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Assessment of Heavy Metal Pollution of Medicinal Plants Taraxacum Officinale Web. Growing in the Kuznetsk Basin Areas Affected by Coal Production

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Abstract: We have studied the features of heavy metal accumulation in and have carried out a hygienic assessment of medicinal plants Taraxacum officinale Web. growing in various areas of the microrelief of the Kedrovskii coal mine rock dump. We have revealed a higher variability in the content of Cr, Mn, Zn and Fe mobile forms in the waste embryonic soils and have found that Cu and Zn content was lower than in the case of sufficient soil supply. We have also revealed that in Taraxacum officinale Web. grass and roots, the biophile metals quantitatively predominate in the following sequence: Fe > Mn > Zn > Cu. Irrespective of the dump microrelief, the content of Pb and Cd is higher in grass, while the content of Cu, Zn, Mn and Fe prevails in roots. The maximum biological absorption (Bx) is characteristic for Cu > Zn > Fe. A high degree of translocation of industrial elements (Pb and Cd) from the roots to the grass of Taraxacum officinale Web. in all microreliefs of the dump has been observed. A hygienic assessment of embryonic soil, the roots and grass of Taraxacum officinale Web. has demonstrated the absence of excess of the heavy metal maximum permissible concentrations accepted in the Russian Federation and the maximum permissible concentrations based on the generalized world material and the regional background of the environmentally safe zones of the Kuznetsk Basin.

Key words: Coal mine wastes · Heavy metals · Medicinal plants · Hygienic assessment

INTRODUCTION

The Kuznetsk Basin is the center of coal-mining industry in Western Siberia. It contains about five thousand industrial enterprises, including over fifty mines and coal cuts. As a result of coal mining, the area of the disturbed lands in the Kusnetsk Basin makes up over 100 thousand hectares. In recent years, about 20 thousand hectares have been reclaimed. The rest of the industrial lands are subject to natural overgrowing due to the introduction of seeds from the surrounding areas [1].

The analysis of literature and our own investigations have shown that there are a lot of medicinal plants growing on the coal mine rock dumps of the Kuznetsk Basin, which are used in practical medicine and that the local population collect and store them.

However, the waste products of coal mining (dumps and refuse heaps) can be the source of high content of heavy metals [3, 4].

Heavy metals hold a special place among industrial pollutants due to a widespread occurrence and a high toxicity. They can enter into the biological cycle and accumulate in the human organism. Therefore, we consider topical the study of the resource potential of medicinal plants growing on the Kuznetsk Basin coal mine rock dumps and their safety assessment. The research in this field will allow specialists, on the one hand, to estimate the possibility of introduction and industrial storage of medicinal plant raw material on the coal mine dumps of the Kuznetsk Basin for its use in medical practice and to expand the nomenclature of medicinal plants to be harvested in the region and, on the other hand, to introduce the lands industrially disturbed as a result of coal mining into economic use.

The aim of this work is to estimate the heavy metal pollution of medicinal plant raw material Taraxacum officinale Web. and the adjoining embryonic soils in various parts of the Kedrovskii coal mine rock dump.

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MATERIAL AND METHODS

The Yuzhnyi dump of the Kedrovskii coal mine has a flat and sloping relief with a height of 58 m and an area of 599.3 ha. The rock dump is between 25 and 30 years old. A set of works on its planning was carried out in 2004. The rocks of the dump are presented by sandstone (60%), siltstone (20%), argillites (15%), loams and clays (5%). Coarse aggregates (from 3 to 10 mm and larger) are the predominating fraction. The content of small particles is low. The embryonic soil is characterized by an alkaline reaction (pH of aqueous extract is 7.1–7.7), a middle humus supply (3.5%), a low supply of the mobile forms of phosphorus and nitrogen (1.7–7.0 mg/kg) and the content of exchange potassium being slightly below normal (125 mg/kg).

The research has been carried out in three areas of the Yuzhnyi dump (OSs): OS # 1 is the top, OS # 2 is the slope and OS # 3 is the hollow.

The roots and grass of dandelion Taraxacum officinale Web. and the adjoining embryonic soils selected in 2011–2012 are the objects of the research.

Dandelion Taraxacum officinale Web. is a herbaceous plant of the family Asteraceae. It is the first plant to settle in rock dumps easily adapting to the most unfavorable conditions. In practical medicine they use dandelion roots, which contain polysaccharides (insulin), triterpene compounds, sterols (tarakserols, taraksols, stigmasterol), flavonoids, etc. In folk medicine, the whole plant (flower heads, leaves, grass and roots) is used [5, 6].

The raw material was harvested in summer and autumn in dry and sunny weather according to generally accepted rules. Plants without visible damages were chosen. The samples were selected from areas of 0.25 – 1 m^2 in size. The average sample was prepared by quartering in accordance with Federal Standard 24.027.0-80. The permissible variation in the mass of the average sample did not exceed ±10%. The embryonic soils adjoined with the plants were selected from the root layer (A 0-10 cm) using a generally accepted technique.

Elemental analysis of the samples of embryonic soil and plant raw material was carried out by atomic absorption method using a spectrophotometer AAS-30 (Germany) in the air-acetylene flame on the base of the accredited test center for agrochemical service "Kemerovskii". For the extraction of heavy metals from soil, we used ammonium acetate buffer pH 4.8, with the soil/solution ratio of 1/10 and the extraction time of 24 hours. The sample preparation of plant material was performed by dry ashing followed by the extraction with diluted nitric acid (1:1); the extraction time was 24 hours. The analyses were carried out in three replications; the results were statistically processed using the software Statistica 6.0.

To characterize the availability of chemical elements in plants, we calculated the biological mobility coefficients (Bx), which are the ratios of the concentration of the element in the air-dry weight of the plant organs (mg/kg) to the concentration of the mobile forms of the compounds with the element in soil (mg/kg).

To study the processes of transition of heavy metals from the roots to the aboveground part of the plant, we calculated the transition coefficient (Ct), which is the ratio of the element content in the aboveground phytomass to that in the roots.

RESULTS AND DISCUSSION

The results of the experiment showed the differences in the content of the mobile forms of heavy metals in the embryonic soil of the dump depending on the OS relief (Table 1). Thus, the highest content of Pb, Cu, Ni, Co, Fe was detected on the top (OS # 1) and in the hollow (OS # 3) of the dump as compared to the slope; the maximum differences were observed for Fe (the content is higher than on the slope by 71% and 89% respectively).

The top and the slope of the dump (OS # 1 and # 2) are marked by a higher content of Zn and Mn as compared with the hollow (higher by 151%; 111% and 64%; 87% respectively). The slope and the hollow of the dump are characterized by a higher content of Cr and Cd in comparison with the top and Cr content is higher by 65% and 60% respectively.

The highest variability in the content of the mobile forms of heavy metals in the embryonic soil of the dump was found (mg/kg) for Cr (0.94 ... 1.55), Mn (57.76 ... 145.4), Zn (0.47 ... 0.88) and Fe (11.14 ... 21.10).

The comparison of the content of heavy metals in the embryonic soil of the dump with the hygienic standards did not reveal any excess of its MPC (APC) (Table 1). We found a low content of such biologically active microelements as Cu and Zn, which is lower than the sufficient supply of soils according to N.K. Krupskii and G.N. Alexandrova.

The analysis of the phytomass Taraxacum officinale Web. showed that there are qualitative and quantitative differences in the content of heavy metals in different parts of the plants. In particular, it was ascertained that in all OSs, irrespective of the dump microrelief, the grass of Taraxacum officinale Web. has a higher content of Pb and Cd, while the roots have a higher content of Cu, Zn, Mn and Fe (Table 1). It was also found that in a quantitative

Table 1: The content of heavy metals in embryonic soil and Taraxacum officinale Web. collected from the rock dump of the Kedrovskii coal mine (average data for 2011-2012)

		Elements content, mg/kg						
		Embryonic soils		Plants				
Elements	OS	Mobile form	MPC, APC* [7, 8]	Grass	Root	RB* [9, 10]	MPC for BAA [11]	MPC, generalized [12]
Pb	1	3.42±0.11	6.0	2.40±0.52	1.35±0.07	1.18	6.0	5-10
	2	2.78±0.12		2.50±0.08	1.97±0.13			
	3	3.86±0.07		2.98±0.12	1.93±0.03			
Cd	1	0.21±0.01	APC 1.0	0.34±0.02	0.17±0.01	0.21	1.0	0.05-0.2
	2	0.25±0.02		0.28±0.01	0.10±0.01			
	3	0.23±0.01		0.29±0.02	0.11±0.01			
Cu	1	0.23±0.01	3.0	4.85±0.30	6.11±0.16	6.94	-	5-30
	2	0.18±0.04		3.43±0.15	7.37±0.30			
	3	0.22±0.03		4.65±0.32	5.62±0.17			
Zn	1	0.77±0.02	23.0	6.53±0.50	10.30±0.46	9.96	-	27-150
	2	0.88±0.04		4.70±0.26	5.57±0.16			
	3	0.47±0.03		5.01±0.17	9.52±0,27			
Mn	1	145.4±4.1	140-500	25.23±1.17	29.59±1.23	21.58	-	20-300
	2	122.0±5.2		16.16±0.81	22.03±1.14			
	3	57.76±2.9		32.28±0.17	42.08±2.31			
Ni	1	3.51±0.16	4.0	5.48±0.26	5.52±0.29	1.98	-	-
	2	2.60±0.08		2.32±0.07	3.46±0.15			
	3	3.14±0.15		3.75±0.12	3.55±0.13			
Co	1	0.66±0.03	5.0	2.59±0.09	2.22±0.14	2.15	-	-
	2	0.57±0.02		2.05±0.07	1.65±0.06			
	3	0.76±0.04		0.70±0.03	0.85±0.02			
Fe	1	19.10±0.7	-	159.0±6.61	184.3±6.33	104.51	-	-
	2	11.14±0.7		47.2±1.52	70.87±2.34			
	3	21.10±1.0		141.7±5.03	175.7±4.40			
Cr	1	0.94±0.04	6.0	1.07±0.02	0.92±0.05	4.08	-	-
	2	1.55±0.02		0.60±0.01	0.77±0.01			
	3	1.51±0.01		0.72±0.01	0.68±0.01			

Note: Hereinafter, OS; # 1 - top, # 2 - slope, # 3 - hollow; RB* - regional background (pollution-free zone), APC* - approximate permissible concentration.

respect the biophile metals prevail in the grass and the roots of Taraxacum officinale Web. These metals can be placed in the following order: Fe > Mn > Zn > Cu. The increased need of the plants for the biophile metals is obviously due to their participation in the vital biochemical processes responsible for normal growth and development. The high accumulation capacity of dandelion with respect to heavy metals is mentioned in literature [13–20]. The literature also contains information about the ability of different parts of dandelion to concentrate heavy metals. For example, E.O. Klinskaya and N.K. Khristoforova [21] point out that the concentration of lead in the roadside areas in cities of the Far East is higher in the aboveground part of dandelion. D. Malizia et al. [20] established that dandelion leaves accumulate Cu. B.B. Lind et al. [22] revealed a greater uptake of Cr by the roots of dandelions growing in dross.

Calculations of the biological mobility coefficients showed that both roots and grass of dandelion absorb Cu, Zn and Fe to a greater extent (Bx varies from 40.90 to 4.24). According to the Bx values, these elements can be arranged in the following order: Cu > Zn > Fe. It should be noted that Bx for these elements is higher in the roots than in the grass (Fig. 1). Moreover, the grass was observed to accumulate Cd (Bx > 1).

For Pb and Mn, a suppression of biological absorption (Bx < 1) by the grass and roots of Taraxacum officinale Web. was observed in all OSs irrespective of the microrelief of the dump (Fig. 1). Taking into account the fact that at low values of Bx the grass of Taraxacum officinale Web. accumulates predominantly Pb, we can assume a foliar way of contamination of the grass by this metal. The ability of dandelion to concentrate Cd is mentioned in papers [23–25].

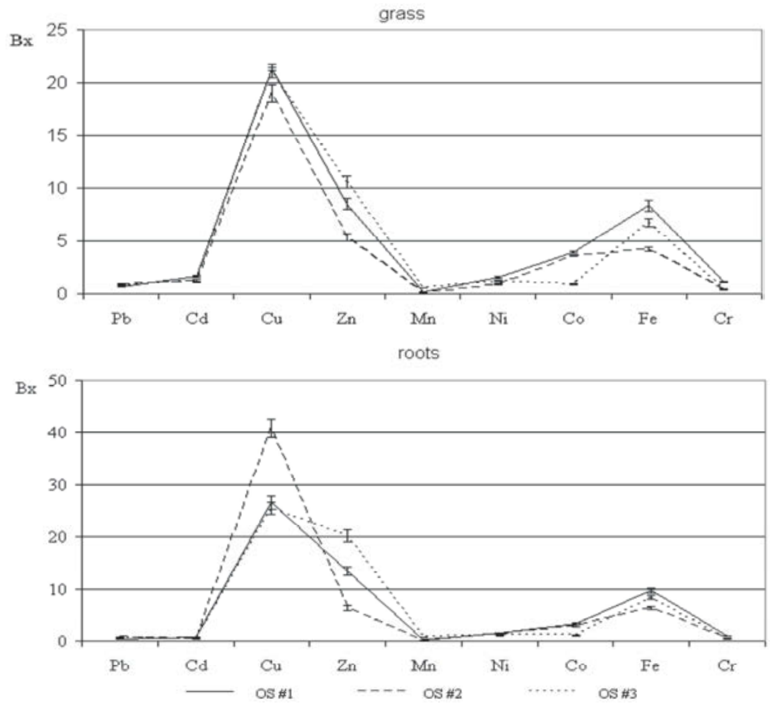

Fig. 1: Biological mobility coefficients (Bx) of Taraxacum officinale Web. growing in the conditions of a rock dump

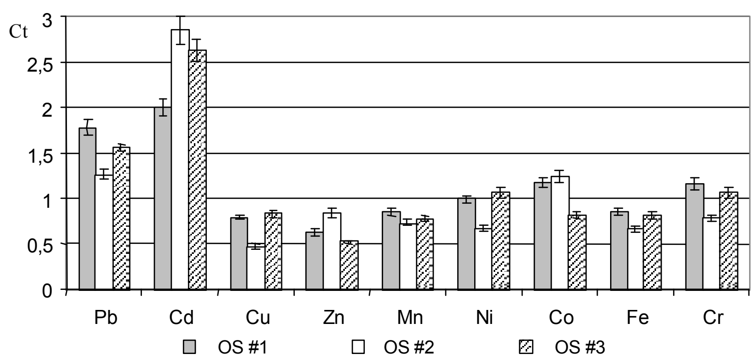

Fig. 2: Coefficients of transition (Ct) of heavy metals from the roots to the grass of Taraxacum officinale Web. in the conditions of a rock dump

An inverse correlation between the content of the mobile forms of biophile heavy metals (Cu, Fe, Zn, Mn) in the embryonic soil and the coefficients of their biological mobility (Bx) was revealed; i.e., higher values of Bx correspond to mainly low values of the mobile forms of heavy metals in the embryonic soil (Table 1, Fig. 1). This confirms the existence of the mechanisms of selective absorption of chemical elements in plants. These mechanisms are quite complicated and are apparently determined by the species characteristics of plants. Obviously, the absorption of metals by Taraxacum officinale Web. depends on many factors of the environment [26].

It was found that the absorption of Cu by the roots and grass of Taraxacum officinale Web. depends on the microrelief of the dump: for the roots, the maximum values of Bx (40.9) were observed on the slope of the dump; for the grass – on the top and in the hollow of the dump (Bx is 21.1 and 21.3 respectively). B. Wiłkomirski *et al*. [27] revealed the peculiarities of accumulation of heavy metals depending on the terrain relief. In particular, they found that at railway junctions, dandelion concentrates Pb, Zn, Hg and Cd and there is more iron on the embankments than in the area of the platform itself.

The analysis of the transition coefficients (Ct) of heavy metals showed a high degree of translocation of industrial elements Pb and Cd from the roots to the grass of Taraxacum officinale Web. in all microreliefs of the dump (Ct is 1.27 ... 1.78 ... 2.86 and 2.0 respectively) (Fig. 2). The minimum degree of transition of heavy metals from the roots into the grass is marked for Cu, Zn, Mn, Fe and Ni (Ct ≤ 1) (Fig. 2).

Modern regulatory documentation does not standardize the content of heavy metals in medicinal plant raw material, so for the analysis of medicinal plants, the following characteristics are often used: MPCs accepted for biologically active additives (BAA) for plant-based food; the content of heavy metals in plant raw material from the control and environmentally safe zones; MACs based on the generalized world data [28].

The hygienic assessment of the roots and grass of Taraxacum officinale Web. showed that there is no excess in MPCs accepted for plant-based BAA and in MPCs based on the generalized world material and the regional background of the environmentally safe zones of the Kuznetsk Basin (Table 1). Therefore, this medicinal plant is not harmful for human health and can be harvested by the population.

CONCLUSIONS

As a result of the research we revealed the peculiarities of accumulation of heavy metals in and carried out a hygienic assessment of embryonic soil and medicinal plant raw material Taraxacum officinale Web. growing in various microrelief elements of the Kedrovskii coal mine rock dump. We established a higher variability in the content of mobile forms of heavy metals in the embryonic soil of the dump for Cr, Mn, Zn and Fe and a lower content of Cu and Zn, which is below the sufficient supply of soils.

We determined how different parts of Taraxacum officinale Web. accumulate heavy metals. Irrespective of the dump microrelief, the grass contained more Pb and Cd and the roots contained more Cu, Zn, Mn and Fe. In a quantitative respect, the biophile metals predominated in the grass and roots of Taraxacum officinale Web. in the following order: Fe > Mn > Zn > Cu.

The analysis of the absorption mechanisms of the mobile forms of heavy metals and their redistribution in Taraxacum officinale Web. showed that the maximum biological absorption coefficients (Bx) are characteristic for Cu > Zn > Fe and it was more typical for the roots than for the grass. The grass was found to accumulate Cd (Bx > 1). For Pb and Mn, we revealed a suppression of biological absorption (Bx < 1) by the grass and roots of Taraxacum officinale Web. in all OSs irrespective of the microrelief of the dump. Taking into account that at low values of Bx the grass of Taraxacum officinale Web. accumulates predominantly Pb, we can assume a foliar way of contamination of the grass by this metal.

It was found that the absorption of Cu by the roots and grass of Taraxacum officinale Web. depends on the microrelief of the dump: for the roots, the maximum values of Bx were observed on the slope of the dump; for the grass – on the top and in the hollow of the dump.

The high degree of translocation of industrial elements Pb and Cd from the roots to the grass of Taraxacum officinale Web. in all microreliefs of the dump was revealed. The minimum degree of transition of heavy metals from the roots into the grass was observed for Cu, Zn, Mn, Fe and Ni (Ct ≤ 1).

The hygienic assessment of the roots and grass of Taraxacum officinale Web. showed that there is no excess of the heavy metals MPCs accepted in the Russian Federation and the MPCs based on the generalized world material and the regional background of the environmentally safe zones of the Kuznetsk Basin (Table 1). Therefore, this medicinal plant is not harmful for human health and can be harvested by the population.

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