GeoScience Engineering

BIOMONITORING OF POST-MINE ENVIRONMENT USING RUDERAL PLANTS

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ABSTRACT

Ruderal plants that remove toxic metals by accumulating in their tissues are called accumulators. Such accumulators can be used for phytoremediation or phytomining. The use of plants for biomonitoring environmental pollution by a non-invasive monitoring method correlates the effects of anthropogenic factors and living organisms. The advantage is the early detection of changes in the environment, thanks to the rapid response of bioindicators, responding to changes in the habitat, for example, by creating deformations. At present, biomonitoring is one of the indispensable parts of nature and environmental protection. The following species were selected for research - *Aster amellus* L., *Rosa canina* L. and *Paraleucobryum longifolium*; the area of interest was the post-mining area. The aim of the study was to verify the hyperaccumulation activity of ruderal plants on the thermally active dump pile Ema, in the district of Ostrava-Karviná, Czech Republic. The plant samples were taken in the places with the thermal activity and were compared as for the capacity of bioaccumulation of hazardous metals – Co, Mo, Cd, Pb, Cr, As, Ba, Sr in the plant tissues from different parts of the plants (root, stem, leaf, fruit). The results were compared with the collection of metals at sampling points. The highest ability to bioaccumulate was demonstrated by plants from the *Bryophyta* division.

Keywords: Bioavailability; Ema dump pile; Hyperaccumulation; Plants; Toxic metals.

1 INTRODUCTION

Ruderal plants play a very important role in ecosystems (primary producers, water retention, soil protection against erosion, cosmopolitan occurrence – they are geographically widespread, grow in various conditions, including heavily industrialized areas and create a suitable environment for microorganisms). They have been shown to be very sensitive to anthropogenic influences, especially to the occurrence of toxic substances in the environment. In addition, environmental elements can accumulate to a much greater extent than is essential for their physiological functions and can therefore also significantly accumulate hazardous metals and semi-metals from the environment, which may be present in the environment in very low concentrations (due to absence of vascular bundle have limited transport of these elements). Plants that can remove toxic metals from the environment by the process of an accumulation the toxic metals in their tissues are collectively referred to as hyperaccumulators.

Among the first hyperaccumulation plants were plants that demonstrably increase the concentrations of metal ions in their above-ground parts without external signs of damage to their tissues. In particular, nickel, copper, cobalt and lead ions, in amounts up to 100 times higher than in common plants [1]. Examples of such plants were, for example, *Viola lutea*, *Thlaspi arvense* and *Aurinia saxatilis*, which were the first hyperaccumulators plants described [2, 3]. Towards the end of the 20th century, with the development of analytical methods for the determination of metal ion residues in plant biomass, the process of identification of hyperaccumulator plants was faster. The most researched and best-known hyperaccumulator became *Thlaspi caerulescens* [4].

Vol. 68 (2022), No. 1
pp. 99–104, ISSN 1802-5420
DOI 10.35180/gse-2022-0073

Currently, approximately 450 species of hyperaccumulator plants are known. These are plants from more than 45 families. Although it is a heterogeneous and very diverse group of plants, in general, hyperaccumulators can be characterized as endemic species whose growth activity and other physiological abilities are significantly dependent on the geochemical values of the environment [5, 6].

From a phylogenetic point of view, the process of hyperaccumulation can be considered as an ecophysiological adaptation of the plant to a high content of metals contained in the environment. From this point of view, hyperaccumulators can be considered as indicators of metal contamination in the environment, especially in increased concentrations of metals in the soil. The current hypothesis indicates that hyperaccumulation is a defence mechanism against pathogens is also interesting [7].

The ability of plants to accumulate depends not only on external propositions of the environment, but above all, on their genetic makeup, which is reflected in the different abilities of plants to tolerate different concentrations of metals in the environment. Based on the study of the mechanisms of plant adaptation to high levels of metals, plants can be divided into two types. The first type – the accumulators that can actively receive metals and transport them to the above-ground parts. The second type are plants that limit metal transport, maintain low metal concentrations in the above-ground parts and excrete metals by root system [8].

2 METHODS

2.1 Description of the locality of interest

Ema dump is a well-known landmark of the city of Ostrava of anthropogenic origin, which covers an area of 32 ha with an estimated volume of 8 million m^3 and a height of 315 m. It is an old dump complex of three, now already closed coal mines called Ema, Trojice and Petr Bezruč with significant thermal activity.

The primary material of the Ema dump is carbon tailings, which is the main, but not the only product of mining activity; its accompanying rocks have different petrographic compositions. Characteristic is the presence of fine-grained flammable particles, which contribute to the self-ignition of the dump. The manifestations of self-ignition can be observed in the form of vents with the outputs of hot gases accompanied by a characteristic odour of sulfur (Fig. 1). The ongoing internal thermal activity of the dump is also reflected on its surface; in many places it is possible to measure the temperature range 12 °C – 82 °C (depending on the measuring point).

Figure 1. *Manifestations of thermal activity on the Ema dump (left), measured temperature at the sampling point (right) [Kučová, 2020]*

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2.2 Sampling

Sampling was performed on the southwest slope of the Ema dump; during sampling, the temperature was measured with a probe at the same time (Fig. 1). Soil samples were further prepared in the laboratory by quaternization and homogenization to the required grain size for analysis. The plant samples were first cleaned of impurities (roots from soil residues), then homogenized, dried and then ground to the required grain size. Soil samples were analyzed by atomic absorption spectrometry (AAS) and X-ray fluorescence spectrometry (XRF). The values of the content of risk elements were measured by the AAS method – *Rosa canina* L. and *Aster amellus* L. were divided into the root part, the stem and from *Rosa canina* L. was further removed the fruit, from *Aster amellus* L. was removed the leaf; division *Bryophyta* was divided into rhizoids and cauloid (Fig. 2).

Figure 2. *Sampling preparation – drying and homogenization [Kučová, 2020]*

3 RESULTS AND DISCUSSION

Regulation of the Ministry of the Environment No. 294/2005 Coll. on the conditions for depositing waste in landfills and their use on the surface defines the limit values of selected elements – As, Cd, Cr, Hg, Ni, Pb and V. Measured values of selected elements in soil samples (Table 1) exceed the limits only in two cases: for arsenic, the highest measured value is 97 μg/g and for barium, the highest measured value is 632 μg/g.

The measured values also correspond to the content of the metals in the monitored plants – *Rosa canina* L., *Aster amellus* L. and the representative of the division *Bryophyta*, when the highest accumulation was observed in barium (Ba). Of these plants, the highest values of accumulation of Ba were achieved in the representative of the division *Bryophyta*, whose accumulation values reached average values in the case of cauloid 188 μg/g, in the case of rhizoids even 205 μg/g. Significant values were also observed in the accumulation of Pb, Cr, As and Sr (Fig. 3,4,5).

Table 1. *Metal content at the sampling points*

Metals	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	CZ no. 294/2005
Co (μg/g)	3.35	8.8	16	10	14	30
Mo (μg/g)	0.925	0.2	0.66	0.66	0.33	*
Cd (μg/g)	0.2	0.2	0.66	0.66	0.33	2.5
Pb (μg/g)	19	34	79	29	58	100
Tl (μg/g)	0.2	0.33	0.5	0.66	1.2	*
Cr (μg/g)	13.5	33	49	32	36	200
As (μg/g)	97	8.2	17	16	14	30
Ba (μg/g)	113.5	325	632	250	22	600
Sr (μg/g)	55	115	65	58	75	*

** the Regulation does not state the value*

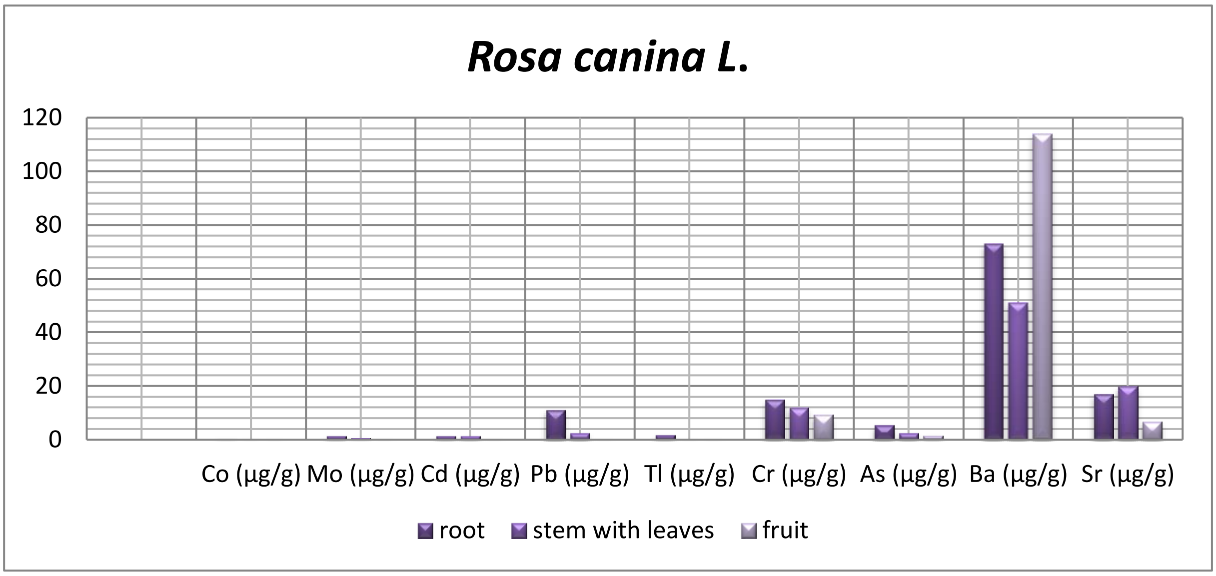

Figure 3. *Results of bioaccumulation of metals in the plant Rosa canina L.*

Rosa canina L. shows a different ability to bioaccumulate in different parts of the plant (Fig. 3). The highest measured value of Ba was found in fruits – the value of 114 µg/g was approximately 42.5 % of the average input concentration of metal contained in the soil at the point of plant collection. The metals Sr, Cr, Pb and As were the most bioaccumulated by the roots of the plant.

The plant *Aster amellus* L. (Fig. 4), in contrast, showed the highest ability to accumulate metals in the above-ground part, specifically in the stem, while in the leaves there were clear differences in the measured values of the analysed elements. Ba was accumulated up to 83 µg/g.

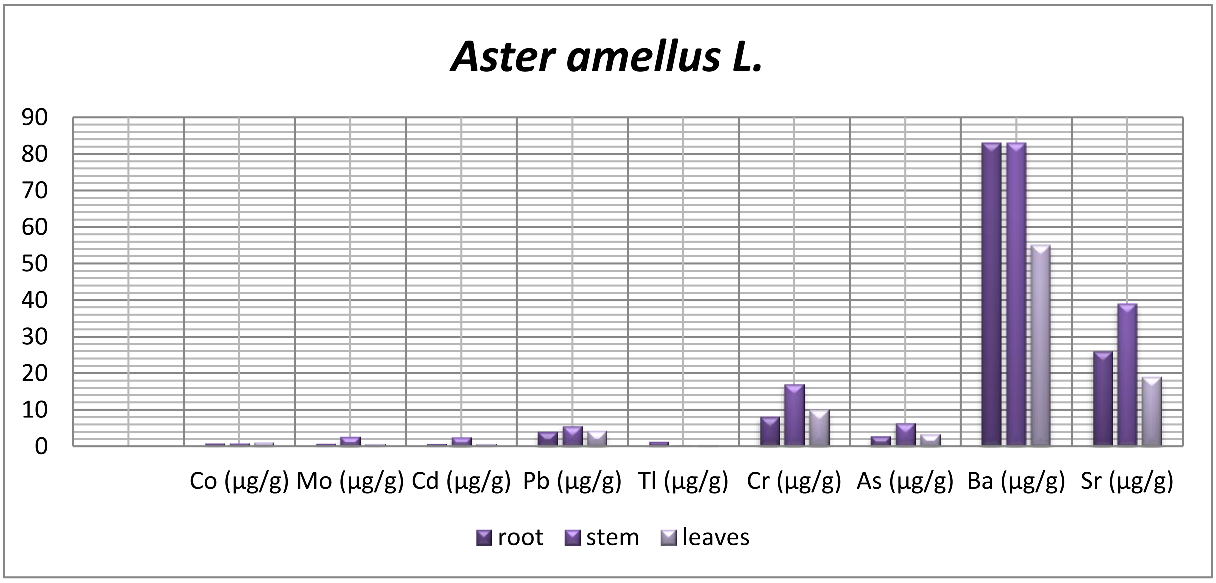

Figure 4. *Results of bioaccumulation of metals in the plant Aster amellus L.*

Representatives of the taxonomic division *Bryophyta*, proved to be the most successful plants in bioaccumulation (Fig. 5). All measured values of metals in tissues were high, both for rhizoids and cauloids. Hyperaccumulative ability was confirmed for Pb, Cr, As, Ba, Sr. The growth of moss as a pioneer plant is pointed out by a number of works dealing with the biological diversity of anthropogenically polluted places, especially after the mining and processing of ores [9–12]. The results are significant in terms of studying the adaptation of living organisms to anthropogenic influences, mainly due to bioremediation of soils [13–15].

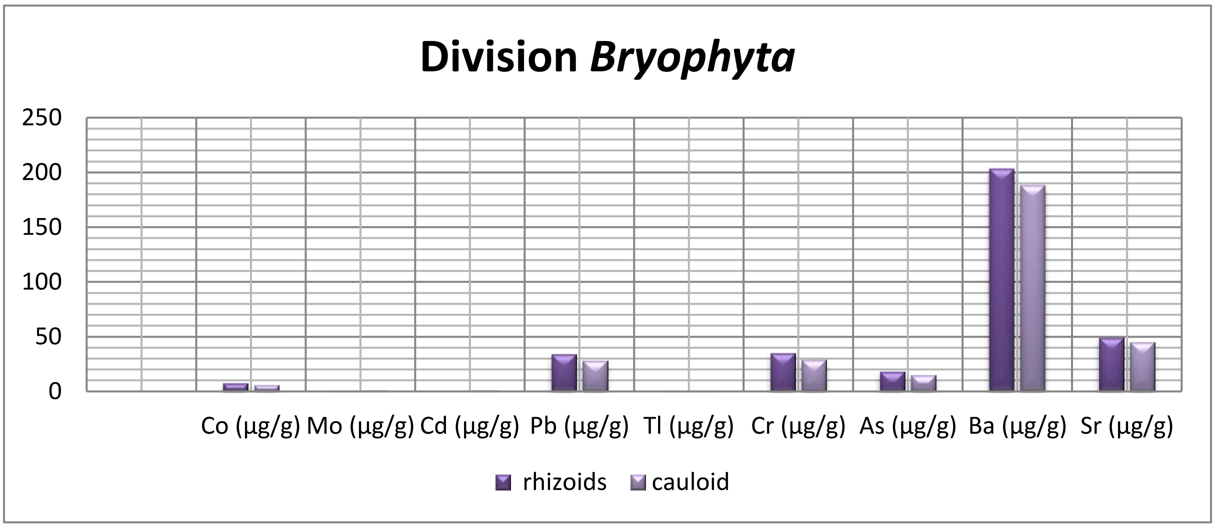

Figure 5. *Results of bioaccumulation of metals in the division Bryophyta*

4 CONCLUSION

The results of the research indicate a possible hyperaccumulation ability of *Bryophytes*. Representatives of *Bryophyta* demonstrated the highest accumulated amounts of monitored metals at the survey site. The remaining monitored plants – *Aster amellus* L. and *Rosa canina* L. did not show a high ability of bioaccumulation in plant tissues in the monitored metals and no deformity formation was observed in them either. From a practical point of view, it is possible to classify *Bryophyta* as a suitable hyperaccumulator and the growth of this plant on anthropogenically contaminated areas can be considered desirable due to the active processes of bioremediation of contaminated soil.

ACKNOWLEDGEMENT

This work was supported by the Project for Specific University Research (SGS) No. SP2021/11 and SP2022/8 from the Faculty of Mining and Geology of VŠB – Technical University of Ostrava & Ministry of Education, Youth and Sports of the Czech Republic.

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Vol. 68 (2022), No. 1
pp. 99–104, ISSN 1802-5420
DOI 10.35180/gse-2022-0073