PARTICIPATION OF THE INDIGENOUS VS. ALIEN HERBACEOUS SPECIES TO THE CONSTITUTION OF VEGETAL LAYER ON THE BOZANTA MARE TAILING PONDS

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Abstract: This study explored the distribution of different species of native and alien herbaceous species on the tailing pond Bozânta Mare (Maramureş county in NW Romania) and the differences in heavy metal uptake in the roots and shoots relative to: 1. herbaceous species; 2. differential metal uptake and variation within single-species; 3. metal content of soil substrate. In 2007-2009 the contribution of native and alien species to the herbaceous layer forming, were studied on the Bozânta Mare tailing pond, resulted after heavy metal extraction process. The heavy metals found at elevated level in the herbaceous species included for environmental interest are: Pb, Cu, Ni, Zn, Co, Cd, Fe, Cr, Mn, Na, K. Also, the aim of this research is to evaluate the impact of the native vs. alien species presence in the colonization process on the tailing pond.

Keywords: native, alien, herbaceous species, bio-accumulation, heavy metal, tailing pond

INTRODUCTION

Metalliferous mining and processing usually produce the most severe cases of heavy metal pollution [11, 22]. Mine tailings are typical elements in post-mining landscapes which usually have high heavy metal contents and are affected by intensive erosion processes, above all in arid and semiarid areas. The presence of the tailing deposits conduct not only the water pollution but also the air pollution, having as immediate effect the transformation, the degradation or the total destruction of the structures of the biocenosis from the adjacent zones, affecting both the terrestrial and aquatic flora and fauna [15]. Revegetation of these sites is considered a low cost and suitable technology to effect surface stabilization [3]. Plants are considered as monitors of the areas contaminated with heavy metals because of their capacity to act efficiently as interceptors of chemical pollutants [1, 9, 19] and because phyto-remediation is considered to be a friendly technology through which life conditions may be remediated in polluted areas. The selection of such plants plays an important part in developing methods of decontamination, stabilization and reintegration in the landscape of the polluted areas [10].

Owing to the high variety of soil chemistry in metal-contaminated soils and the evolutionary potential of plants to adapt to extreme environments, a number of plant species is able to colonize naturally metal enriched soils and to maintain functional heavy metal ecosystems [8]. The success of phyto-remediation can be ensured when these naturally selected and highly adapted plant species can be used economically. The success will depend on three factors: (1) the degree of metal contamination of the soil; (2) the degree of metal bio-availability (its chemical and physical aspects); (3) the capacity of the higher plants to accumulate the metal.

Phyto-remediation including phyto-stabilisation, in which metal-tolerant plants are used to reduce the mobility of metals, thereby reducing risks of further environmental degradation, by leaching into the ground-water or by airborne spread [18]. A few of the higher plant species have adaptations that enable them to survive and to reproduce in soils heavily contaminated with Zn, Cu, Pb, Cd, Ni, and As [2]. The rehabilitation of tailing ponds is a complex process, depending on many variables whose sharper definition would require interdisciplinary correlations as regards the physical–chemical particularities of the soil, orographycs factors, and especially micro soil factors that impact the changes of micro climatic parameters, systematic studies, physiologic and ecologic studies on the various groups of organisms. In comparison with microbiological parameters, the enzymes are more synthetic indicators of the evolution of technogenic soils because they reflect a) due to their accumulation in form of humic complexes, the past of technogenic soils, and b) due to their catalytic activity, which plays a key role in nutrient cycles, the present biological status of these soils. [4]. In addition, soil properties, such as pH, redox potential, organic matter content, clay mineralogy, cation exchange capacity of solid phase, competition with other metal ions and composition of the soil solution concentrations influence metal exchange with substratum.

The aims of this study were: 1. to evaluate the presence of the different native and alien herbaceous species in the first stage of colonization; 2. to determine the accumulation capacity of different heavy metals in the roots and in the shoots of some species growing on the tailing pond Bozânta Mare in relation to some factors: growth substrate (metal content, acidity, organic matter content), species and ecology, distribution in polluted area.

Site description

The tailing pond in Bozânta Mare, build-up out of the draining waters loaded with waste generated during the flotation proces of non-ferrous minerals, is the focus of our case study. Plants cultivated along repeated re-vegetation attempts that occurred more than 25 years ago on one hand, and the spontaneous growth of selected species as primary succession layer on the other hand, make together a blanket of vegetation covering only in part this tailing pond, today in conservation. The tailing pond has thus become host to an incipient vegetal layer made-up of both "fast - growing" non-native species such as *Pinus nigra*, *Robinia pseudacacia, Prunus serotina, Amorpha fruticosa* etc, perceived as fit in re-vegetation initiatives and planted by purpose in the area, as well as species that belong to the regional flora, such as *Quercus petrea, Salix caprea, Populus tremula, Betula pendula,* spontaneously set-up. Grass species specific to the regional flora such as *Hieracium pilosella, Carex pillosa, Centaurea austriaca, Viola arvensis, Rumex acetosella, Linaria vulgaris, Agrostis capilallaris* etc, as well as adventive breeds such as *Reinouttria japonica, Erigeron canadensis, Setaria glauca* add also up to a vegetation layer still not properly consolidated (the average coverage ratio of the grass layer does not exceed 5-20%). While taking into account the presence on site of these two categories of species, our experiment aims to shed light on the phyto-remediation capacity of native species as compared to the same ability of non-native species. The introduction of native species in polluted sites could be a reserve of plants able to spread toward, and to invade, the neighbouring eco-systems. Within this research we evaluate the resilience against heavy metals in the ground layer, against extreme ecologic circumstances in the area in tandem with the possibility and opportunity to introduce and sustain the native species as part of the re-vegetation plans on degraded soils, while avoiding the plantation of non-native species. As also noticed in other cases in the professional literature in the field [18], our assumption that native species, a valuable natural asset, grow up spontaneously in polluted sites and can be treated as useful species in the ecologic restoration initiatives was fully confirmed.

Soil pH and organic matter

Table 1. Chemical characteristics of tailing pond Bozânta Mare.

Humus %	0.45
N total %	0.037
P_2O_5 total %	0.015
P mobil ppm	0.7
K mobil ppm	8.8
SB mg/100 g sol	6.64
SH mg/100 g sol	8.85
T mg/100 g sol	15.49
V %	42.86
pH	5.75-6.6

Table 2. Heavy metals level in the technogenic soil on the Bozânta Mare tailing pond.

	Cu	Pb	Ni	Zn	Co	Fe	Cr	Mn	Na	K
mg/kg DW	153.2	357.89	0.07	93.64	17.32	15287.5	66.86	517.71	354.26	1243.79

MATERIALS AND METHODS

Sampling

The study was carried out in the Maramureş county (NW Romania), in the proximity of Baia Mare town, in a very polluted areas, named Bozânta Mare. Vegetation sampling for each zone was done by using plots. The samplings were done at the middle of each season from summer 2007 to summer 2009, on the different tailing pond exposition, in correlation with herbaceous layer and trees presences. In the 13 relevées which were analysed, the number of different species was counted and their relative coverage was estimated by using a quadrat method with sub-plots of 1 x 1 m^2. Each relevée consist in 4 m^2, and we considered the number of species and the abundance-dominance index according Braun-Blanquet scale [5, 6]. With the obtained data, the Shannon–Weaver index was calculated in order to estimate the heterogeneity of the plant communities as: $H = - \Sigma p_i \log_2 p_i$ where p_i is the relative frequency of the species “i” in the studied simple and $\Sigma p_i = 1$. Also, the Margalef index [14] that refers to the diversity of the population was calculated as follows: $D = (S-1)/\ln N$ where S is the richness of species and N is the total number of exemplars in the sample. Dominance=1-Simpson index. Ranges from 0 (all taxa are equally present) to 1 (one taxon dominates the community completely). *D=sum((ni/n)2)* where *ni* is number of individuals of taxon *i*. Simpson index=1-dominance. Measures 'evenness' of the community from 0 to 1. Jaccard index - a similarity index for binary data.

Vegetation experiment and analysis

The following data referring to some native and alien herbaceous species on the tailing pond have been taken into consideration: the capacity to absorb heavy metals (Cu, Zn, Pb, Cr, Ni, Co, Mn, Fe, Cd) in the ground layer (expressed in terms of concentration of these metals in the roots and shoots of the plants), the content of Na and K of individual plants of the same species.

Simultaneously with vegetal, soil samples of tailing pond were also collected. Vegetal organs were collected during April-October of 2007-2009, were cleaned and identified by using macro- and micro-morphological characteristics. All samples solutions for vegetal samples, filters and soil were analyzed with AAS. The soil and vegetal samples were taken from every experimental variant, washed with deionized water, dried at 60^0C for 72 hours, brought into the stage of dust. 100 g of dust were taken from each sample subjected to mineralization and then brought into solution. The samples were diluted, filtrated (prepared according to ISO11466) and analyzed from the point of view of heavy metals (Cu, Zn, Mn, Cd, Pb, Co, Fe, Cr and N) through atomic spectrophoto-metry according to AAS800 Analyzer coupled with a computer, and Na and K analyzed through flamphotometry using Flame Photometer 410 Sherwood. A witness sample without vegetal material was also analyzed.

Statistical analysis

Data were analyzed using **Past** Paleontological Statistics Version 1.99 and tested for similarity of plants distribution in different survey, principal coordinates analysis (PCA) for a measure of variance and a distance between different groups of samples. PCA may be used for simple reduction of the data set to only two variables (the two most important components), for plotting purposes. For heavy metal content, three analysis with three repeats were carried out for each species of plant. Principal components analysis (PCA) is a procedure for finding hypothetical variables (components) which account for as much of the variance in your multidimensional data as possible. [14]. These new variables are linear combinations of the original variables. PCA may be used for simple reduction of the data set to only two variables (the two most important components), for plotting purposes. One might also try to hypothesize that the most important components are correlated with some other underlying variables [14].

RESULTS

Spontaneous plant communities that colonize tailings showed different behaviour depending on the pH: in neutral tailings the plant communities were formed by less number of plant species than in acid tailings but they had less seasonal variations, showing a stable development. This spontaneous vegetation, that is adapted to metal toxicity and to drought, allows reducing air borne and water erosion, and may mitigate the spread of the contamination to the nearby areas [7].

The similar situation was recorded in Bozânta Mare tailing pond, an acidic tailing pond. The vegetation diversity on the analysed tailing pond, in different relevées and the abundance-dominance correlated with the exposition and distribution is summarised in Table 3.

Relevées analysed on different zones and at different hights of the waste pond in Bozânta Mare, shows the presence of 17 ligneous species (some present due to the revegetation actions *Robinia pseudacacia, Pinus nigra,* but also due to spontaneous installation: *Salix caprea, Populus tremula, Quercus robur, Quercus petraea,* etc.) and of 31 herbaceous species, the result of spontaneous colonization.

Table 3. The floristic composition in analysed area (+ - 5 – Abundance-Dominance scale according Braun-Blanquet).

Relevée number	1	2	3	4	5	6	7	8	9	10	11	12	13
Exposition and position on tailing pond	SE First terrace	SE First terrace	SE First terrace	SE First terrace	SE On the top of tailing pond	SE On the top of tailing pond	NV NV On the top of tailing pond	SV S On the top of tailing pond	V V On the top of tailing pond	N N Between 1st and 2 terraces	N First terrace	N On the top of tailing pond	N, Bottom of the tailing pond
0	1	2	3	4	5	6	7	8	9	10	11	12	13
Betula pendula	1	+	+ -1	-	1	1-2	+ -1	-	+	+ -1	+	1	+
Robinia pseudoacacia	+ -1	+	+ -1	+ -1	-	-	1-2	2-3	-	+ -1	+		+
Populus tremula	-	-	-	+	3	-	-	-	+	-	-	-	-
Quercus robur	-	-	-	+	+	-	+	+	-	+	+		
Quercus petraea	-	-	-	-	-	-	-	+	-	-	-	+	-
Prunus avium	-	-	-	-	-	-	-	+	-	-	-	-	-
Prunus persica	-	-	-	-	-	-	-	+	+	-	-	-	-
Populus alba	-	-	-	+	-	-	-	-	-	-	-	-	-
Pinus nigra	+	-	-	-	-	-	-	-		+ -1	+		
Salix caprea	-	+	-	-	-	-	-	+	+	+			+
Prunus serotina	-	-	-	-	-	-	+	+	-	+	+	+	-
Rhamnus frangula	-	-	-	-	-	-	-	-	-	+	+	+	-
Rhamnus cathartica	-	-	-	-	-	-	-	+	-	-	-	+	-
Acer negundo	-	-	-	-	-	-	-	-	-	+	-	-	-
Amorpha fruticosa	-	-	-	-	-	-	-	-	-	-	-	+	-
Cornus sanguinea	-	-	-	-	-	-	-	+	-	-	-	-	-
Rubus fructicosus	-	-	+	-	-	-	+	+	-	-	-	+	-
Phragmites communis	+	-	1-2	+	+	1	-	-	-	-	-	-	-
Carex hirta	-	-	-	-	-	-	-	-	+	2	1-2	-	-
Rumex acetosa	+	+	+ -1	+ -1	-	-	+	-	-	-	-	+	-
Reynoutria japonica	-	+	+	+ -1	-	-	-	-	-	-	-	-	-
Poa annua	+	-	+	-	-	+	1-2	-	-	-	-	+	-

0	1	2	3	4	5	6	7	8	9	10	11	12	13
Agrostis capillaris	+	-	+	-	+	+	+	-	+	+	+	+	-
Rumex acetosela	-	-	-	-	+	-	-	+	+	-	-	-	-
Centaurea austriaca	-	-	-	+	-	-	-	+	-	-	-	-	-
Taraxacum officinale	-	-	-	+	-	-	-	-	-	-	-	-	-
Viola arvensis	-	-	-	-	-	-	-	+	+	+	+	+	-
Poa pratensis	-	-	-	-	-	-	+	+	-	-	-	+	-
Ranunculus repens	-	-	-	-	-	-	-	+	-	-	+	-	-
Veronica arvensis	-	-	-	-	-	-	-	+	-	-	-	-	-
Matricaria inodora	-	--	-	-	-	-	-	+	+	-	-	-	-
Sclerantus anuus	-	-	-	-	-	-	-	+	+	-	-	-	-
Holcus lanatus-	-	-	-	-	-	-	-	+	+	-	-	-	-
Erigeron anuus	-	-	-	-	-	-	-	-	+	-	-	-	-
Linaria vulgaris	-	-	-	-	-	-	-	-	-	-	-	+	+
Setaria glauca	-	-	-	-	-	-	+	-	-	-	-	+	-
Hypericum perforatum	-	-	-	-	-	-	-	+	-	-	-	-	-
Achillea millefolium	-	-	-	-	-	-	-	+	-	-	-	-	-
Erigeron canadensis	-	-	-	-	-	-	+	+	-	-	-	-	-
Lamium purpureum	-	-	-	-	-	-	-	+	-	-	-	-	-
Medicago sativa	-	-	-	-	-	-	-	-	+	-	-	-	-
Vicia pannonica	-	-	-	-	-	-	-	-	+	-	-	-	-
Capsella bursa-pastoris	-	-	-	-	-	-	-	+	-	-	-	-	-
Draba verna	-	-	-	-	-	-	-	+	-	-	-	-	-
Rorrippa sylvestris	-	-	-	-	-	-	-	-	-	-	+	-	-
Lysimachia nummularia	-	-	-	-	-	-	-	-	-	+	-	-	-
Ornithogalum umbellatum	-	-	-	-	-	-	-	-	-	+	-	-	-
Hieracium pilosella	-	-	-	-	-	-	-	+	-	-	-	+	-

DISCUSSIONS

The similarity pattern (Fig. 1) based on the Jaccard similarity index, marks out two groups of relevées with a 0.5% similarity 1.3.6 respectively, found on the South Eastern slope comprising a very low number of herbaceous species, respectively 10 and 11 in the Northern slope. The high degree of similarity between these relevées is due to a very low specific diversity. Generally, the similarity pattern emphasizes differences between the specific diversity of the analysed relevées which present loose vegetal strata, in their first stages of colonization, with a variable number of taxa on neighbouring areas, according to the degree of exposure and insolation, the sub layer having similar characteristics.

The relevées were also analysed from the perspective of diversity indices: taxa number, dominant (complementary to the Simpson index), Shannon diversity index and the Margalex floristic diversity one.

According to the determined indices, we distinguish two different relevées groups: those with an under unitary index value: 5, 6, 10, the first two situated on the Eastern slope, close to the top of the pond, where strong insolation prevents vegetation from appearing, and the 10th relevée situated on the slope between the terraces where the proclivity angle of the slope repre-

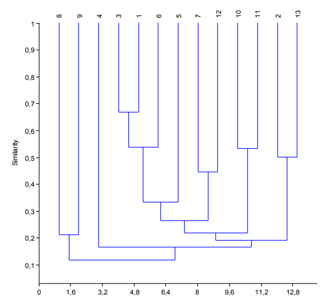
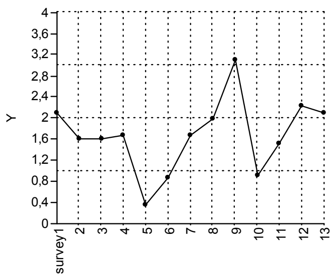
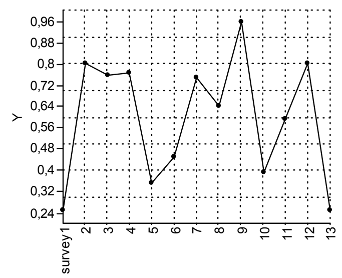


Figure 1. The similarity matrix based on cluster analysis. x – analysed relevées; y- the similarity Jaccard index values.

sents the restrictive factor leading to the fact that a low number of species "dominate" the vegetation; relevées 1, 9, 12, 13 with a value of the Shannon index of over 2, 3 respectively, corresponding to the Simpson index, show a large number of species present, but each with a low number of individuals, thus not accomplishing significant coverage (Fig. 2 - 4).



a.



b.

Figure 2. Variation of diversity indices Shannon (a) and Simpson (b) in analysed relevées: x = analysed relevées y = values of diversity indices.

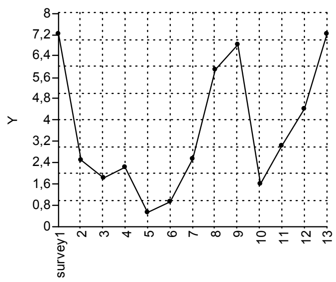


Figure 3. Variation of diversity richness Margalef. x = analysed relevées y = values of diversity indices.

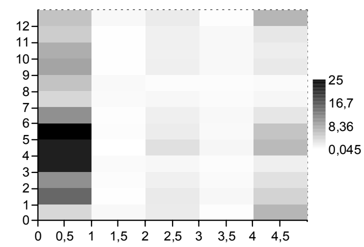
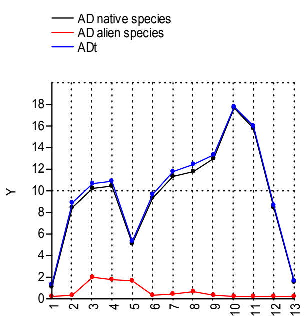


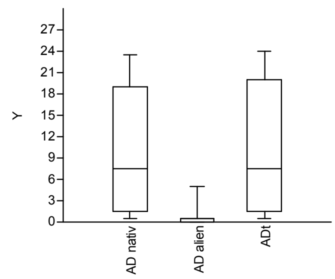
Figure 4. Variation of diversity indices: 1 – no. of taxa; 2 – Dominance; 3 – Shannon diversity index; 4 – Simpson index; 5 – Margalef richness index. x = analysed indices; y = analysed relevées.

The analysis of the above mentioned indices prove undeveloped vegetal communities, in which the general coverage is not enough to establish the antierrosiv function of the vegetal layer.

When it comes to the contribution of the native and alien herbaceous species at forming the vegetal layer in the techno genetic soils of the waste pond in Bozânta Mare, we took into consideration the dominant-abundance index (AD) of each category of species from each analysed relevées. As we can notice in figure 5, the coverage degree of the vegetal layer is low, the average not exceeding 20% of the land, and the contribution of the alien species to the vegetal layer and to the total coverage is insignificant compared to the native species. This comparison proves that even in the situation of highly polluted areas with heavy metals, such as waste ponds, colonisation and vegetal succession operates mainly with native species, belonging to the regional flora, that is why the actions of ecologic reconstruction of bad lands must take into consideration re-vegetating schemes based on using native species.



a.



b.

Figure. 5 a. & b. Abundance - Dominance index for native and alien plant species which form the herbaceous layer. a. plots represent AD-index values for: total/native/alien/plants species; x – no. of relevées and y – AD values; b. Box plot for AD index. (For each plants category, the 25-75 percent quartiles are drawn using a box. The median is shown with a horizontal line inside the box. The minimal and maximal values are shown with short horizontal lines).

The plant response to heavy metals in soil depends on the plant species, the total soil metal concentration, and on the bioavailability of the metal itself depending on physics-chemical properties of soils.

In what concerns the heavy metal bioaccumulation in roots and shoots from plants on Bozânta Mare pond, the differences noticed between the native and the alien species are not fundamentally different. The graph below, representing the main factor analysis applied on all heavy metal concentrations in all the sampled taken for the study, present a segregation of the evidence according to the type of organ studied and not according to the geographical origin of the species. The root samples, especially of the native ones are evidently grouped, indicating a similar behaviour to the heavy metal concentration, while the aerial parts present a more emphasised dispersion, signifying a different mobilisation of heavy metals in the leaves, according to the species.

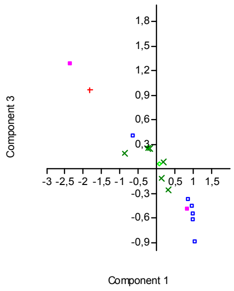


Figure 6. Principal components analysis (PCA). The two most important components between all heavy metals concentration in the analysed species of plants, chosen by the Past programme; (red – soil; blue – native species roots; dark green – native species shoots; pink – alien species rooots; light green – alien species shoots).

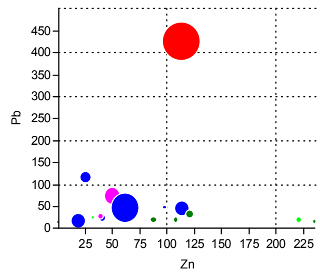


Figure. 7. Pb, Zn, Cu concentrations in analysed plant species.

Figure 7 represents the stocking of Pb, Zn, and Cu of the analysed species. The alien species are mainly predisposed to Zn gathering, and we may also notice the significant differences of Cu concentration (circle diameter) in the roots, while the shoots gather lower values of concentration. The concentration of Cu in substratum is 1.3-33.56 times more than that in plants, no species is bioaccumulator for Cu. Being a low soluble element, lead measures high levels in the roots of both native and allogenous species, at lower or comparable levels with the ones mentioned in professional literature. These do not cite bioaccumulation in spontaneous installed species like the ones we analysed, but in test plants known as hyperaccumulators, such as *Thlaspi rotundifolium* or *Thlaspi caerulescens* with lead concentrations of 2.740 mg/kg-8200 mg/kg and of zinc 10-150-1000 mg/kg [10]. The analysed species do not possess hyperaccumulative properties for these elements, but through their biomass they have the tendency to realize a vegetal layer with a rising coverage from one succession stage to another.

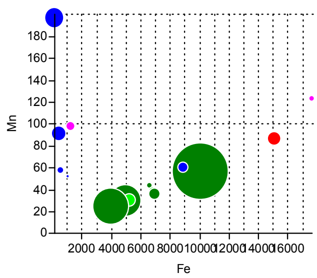


Figure 8. Mn, Fe and Cr concentrations in analysed plant.

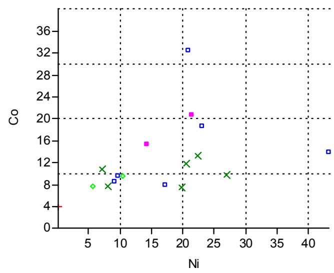


Figure. 9. Co and Ni concentrations in analysed plants.

In Figure 8 the high affinity of native roots for Manganese is very evident, while Chrome gathers in shoots, the highest Chrome concentration being found at *Hieracium pilosella*, above the sublayer value. While Mn is an essential element for plant growth, it is known to be detrimental in excess. Levels required for toxicity and toxicity symptoms however vary widely among plant species and varieties. Between analysed species, according to the results, *Linaria, Rumex acetosella* and *Hieracium pilosella* may be considered Manganese gathering species, while *Setaria glauca* is a Fe gatherer. But in all these species the concentration of Mn was less than the other species presented in the literature [21]

Analysing Figure 9, we notice that all the examined species gather quantities of Co and Ni above their level in the sub layer, not distinguishing high differences between the aliens and the native ones. Ni concentration in roots and shoots of all analysed species are 71.4 – 6171.7 times more than than in substratum. *Linaria vulgaris* roots and *Setaria glauca* shoots are predisposed to Co, while Ni is gathered mainly by *Agrostis capillaries* roots (43.22mg/kg DW). Other studies define plants with Ni^{+2} concentration higher than 1000µg/gDW as ”hyperaccumulator”. This value was not chosen arbitrarily. $Ni^{+2}$is a plant micronutrient and it is found in the vegetative organs of most plants in the range of 1-10 µg/gDW. Toxicity occurs at concentrations higher than 10-50 µg/gDW [2, 13]. Our results revealed greater tolerance of the analysed species to the nickel as compared to other known plant species.

Being a nutritive macro element, Potassium is mainly gathered in shoots, native species gathering higher values, while sodium is stocked especially at root level, the highest values being recorded at *Centaurea* and *Hieracium* (Fig. 10).

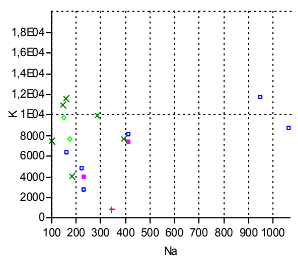


Figure 10. Na and K concentrations in analysed plants.

Other studies gave [16] values of the metal concentration of normal plant with which the uptake in a species could be compared, and showed that the normal compositions of Pb, Cd and Zn in plant are 1, 0.05 and 50 mg/ kg DW, respectively. Pb is non-essential element and can be toxic, chlorophyll synthesis and antioxidase enzymes, while Cd inhibits root growth and cell division [19]. Different metals are differently mobile and, within a plant, Zn are more mobile than Cu and Pb [12]. Zn may be translocated extensively as it is essential to the plant metalloenzymes and photosynthesis. Zn may be translocated chelated to organic acids, while Pb is probably translocated as divalent ion [20]. In this study, *Agrostis capillaris* and *Setaria* collected from Bozanta Mare tailing pond showed abnormal Pb concentration (115.40mg/kgDW), in their roots. The similar situations are recorded for Zn content in: *Rumex acetosella* root (87.26,g/kgDW), *Hieracium pilosella* root and shoot (113.79 mg/kg DW, 120.15 mg/kg DW respectively), *Erigeron canadensis* shoot (220.56 mg/kgDW), *Linaria vulgaris* root and shoot (97.46 mg/kg DW, 235.00 mg/kg DW respectively) and *Centaurea austriaca* root and shoot (61.27 mg/kgDW, 107.94 mg/kg DW respectively).

In this study we demonstrated the possibility of carrying out a vegetal layer by using native species which have ability to tolerate heavy metal and to ensure a wide distribution.

In conclusion, the differences in the concentrations and accumulating capacity to heavy metals between plant species in Bozânta Mare tailing pond exist. The differences are not conspicuous to the origin of plant species, but on the individual accumulation, therefore alien species do not show any additional mechanisms to adapt to contaminated sites or bioaccumulating qualities. Indigenous species, the greater number of individuals and covering more significant that done, is more effective in establishing a vegetable rennet layer.

REFERENCES

[1] Alvarez, E., Ferna´ndez, M.L., Vaamonde, C., Ferna´ndez, M.J., (2003): Heavy metals in the dump of an abandoned mine in Galicia (NW Spain) and in the spontaneously occurring vegetation. The Sience of the Total Environment 313: 185-197.

[2] Assunção, A.G.L., Schat, H., Aarts, M.G.M., (2003): *Thlaspi caerulescens,* an attarctive model species to study heavy metal hyperaccumulation in plants. New Phytologist, 159: 351-360.

[2] Baker, A.J.M., (1987): Ecophysiological aspects of zinc tolerance in *Silene maritime*. New Phytologist, 160: 93-111.

[4] Blidar, C.F., Pop, L., Petrus-Vancea, A., (2009): Enzymological study of the evolution of the technogenic soil submitted to biological recultivation in Bozânta Mare (Maramureş County, North-Western Romania). Analele Universitatii din Oradea, Fascicula Biologie, 16(2): 32-35.

[5] Braun-Blanquet, J., (1964): Pflanzensoziologie. Springer Verlag, Wien-New-York, 3, Aufl, pp. 12-24.

[6] Braun-Blanquet, J., Pavillard, J., (1928): Vocabulaire de Sociologie Végétale, Troisième edition. Imprimérie Lemair-Ardres, pp. 15-18.

[7] Conesa, H.M., Garcıa, G., Faz, A., Arnaldos, R., (2007): Dynamics of metal tolerant plant communities' development in mine tailings from the Cartagena-La Union Mining District (SE Spain) and their interest for further revegetation purposes. Chemosphere 68: 1180–1185.

[8] Ernst, W.H.O., (1990): Mine vegetation in Europe. pp. 21-37. In: Shaw, A.J., (ed.): Heavy Metal Tolerance in Plants: Evolutionary Aspects. CRC Press, Boca Raton.

[9] Ferna´ndez, J.A., Cerballeria, A., (2002): Biomonitoring metal deposition in Galicia (NW Spain) with mosses: factors affecting bioconcentration. Chemosphere, 46: 535-542.

[10] Fischerova, Z., Tlustos, P., Szakova, J., Sichorova, K., (2005): A comparison of phyto-remediation capability of selected plant species for given trace elements. Environmental pollution, 144(1): 93-100.

[11] Freitas, H., Prasad, M.N.V., Pratas, J., (2004): Plant community tolerant to trace elements growing on degraded soils of Sao Domingos mine in the south east of Portugal: environmental implicatios. Environment International, 30 (1): 65-72.

[12] Greger, M., (2004): Metal availability, uptake, transport and accumulation in plants. In Prasad, M.N.V. (Ed.), Heavy Metal Stress in Plants from Biomolecules to Ecosystems, second ed. Springer-Verlag, Berlin, pp.1-27.

[13] Harish, Sundaramoorthy, S., Kumar, D., Vaijapurkar, S.G., (2008): A new chlorophycean nickel hyperaccumulator. Bioresurche Technology, 99: 3930 – 3934.

[14] Harper, D.A.T. (ed.). (1999): Numerical Palaeobiology. John Wiley & Sons, 478 p.

[15] Jelea, M., Jelea, S.G., Kovacs, S.M., Gheţa, D.E., (2007): Research concerning the oxidation degree of the sulphidic tailings from the novăţ tailings storage facility. Carpathian Journal of Earth and Environmental Sciences, 2(2): 45-57.

[16] Markert, B., (1994): Plant as biomonitors-potential advantages and problems. pp. 601-603. In Adriano, D.C., Chen, Z.S., Yang, S.S. (Eds.): Biogeochemistry of Trace Elements. Science Technical Letter, Northwood, NY.

[17] Morris, M.G., Perring, F.H., (1974): The British Oak. Symp. Botanical Society of the British Isles, Faringdon Berks, pp. 56-62.

[18] Salt, D.E., Blaylock, M., Kumar, N.P.B.A., Dushenkov, V., Ensley, D., Chet, I., Raskin, I., (1995): Phytoremediation: a novel strategy for the removal of toxic metals from the environment using plants. Nature biotechnology, 13: 468-474.

[19] Sa´nchez, J., Marino, N., Vaquero, M.C., Ansroren, J., Lego´rburu, I., (1998): Metal pollution by old Lead-Zinc mines in Urumea river valley (Basque country, Spain). Soil, biota and sediment. Water, Air, and Soil Pollution 107: 303-319.

[20] Tanhan, P., Kruatrachue, M., Pokethitiyook, P., Chaiyarat, R., (2007): Uptake and accumulation of cadmium, lead and zinc by Siam weed [*Chromolaena odorata* (L.) King&Robinson], Chemosphere, 68: 323-329.

[21] Vandecasteele, B., Quataert, P., Tack, F.M.G., (2007): Uptake of Cd, Zn and Mn by willow increases during terrestrialisation of initially ponded polluted sediments, Science Of Total Environment, 380: 133 – 143.

[22] Wong, M.H., (2003): Ecological restoration of mine degraded soils, with emphasis on metal contaminated soils, Chemosphere 50: 775-780.

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