Heavy Metals (Cr, Cd, Cu, Pb and Zn) Uptake by *Cirsium arvense* and *Agropyron repens*

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The purpose of this study was to monitor the heavy metal soil contamination and also to accomplish a comparative study on Cirsium arvense and Agropyron repens heavy metals uptake. The samples were collected from seven different sites situated at various distances from the polluted area Tarnaveni, Romania. Near the chemical wastes spontaneous vegetation is predominant. In this vegetation formed on fallow land, Agropyron repens (monocotyledonate perennial weed) and Cirsium arvense (dicotyledonate perennial weed) are dominant species. The metal (Cr, Cd, Cu, Pb and Zn) concentrations were determined by flame atomic absorption spectrophotometry. The data were statistically analyzed using Main Component Analysis and Generalized Linear Model. Based on our research, we can conclude that Cirsium arvense is accumulating more chromium compared to Agropyron repens and is recommended to be used as an indicator for chromium contamination. The present study highlights that animals consuming spontaneous vegetation grown in this area ingest significant amounts of chromium and zinc.

Keywords: bioaccumulation, plant leaves, potential health risk

Metals and metalloids due to their extensive use represent an important fraction of the pollutants released in the air, soil and water. They really seem to be ubiquitous [14]. The researchers observed that the comparative mobility of heavy metals followed the order: Cu > Pb > Zn > Cr [9].

Different plants vary in their capacity to accumulate chromium. Soil pH is influencing the accumulation of chromium in plants, the reduction of Cr (VI) to Cr (III) by organic matter takes place more rapidly in acid than in alkaline soils [3]. Plants have a low capacity to translocate and absorb chromium who is mainly accumulated in roots [1,18].

Due to the high solubility and mobility of cadmium in soils compared to other heavy metals (mercury, zinc, chromium or lead) its environmental occurrence at high levels represents a serious hazard for terrestrial ecosystems [16]. Plants can accumulate high quantities of this element, although the cadmium level in the soil is low [10].

The copper content in plants is proportional to its concentration in the soil [8].

Lead and cadmium are cited as primary contaminants, but zinc and copper can be toxic to plants if their concentration in the growth environment is high [7].

Worldwide, an increased metal uptake by vegetations grown on such contaminated soils is observed [12, 22].

Near the chemical wastes, spontaneous vegetation is predominant. In this vegetation formed on fallow land, *Cirsium arvense* (dicotyledonate perennial weed) and *Agropyron repens* (monocotyledonate perennial weed) are dominant species. These plants were selected based on their accumulation features, described by Tamas J. and Kovacs E., 2015 [21], as metal tolerant plants, able to accumulate heavy metals in significant amounts.

The purpose of this study was to monitor the heavy metal soil contamination and also to analyze Cr, Cd, Cu, Pb and Zn accumulations in *Cirsium arvense* and *Agropyron repens* edible parts (leaves), grown at various distances from the polluted area Tarnaveni, Romania, in order to evaluate the potential health risk for animals.

Recent studies suggest that pollution may also adversely affect the integrity of the central nervous system and adds to neuro-degeneration through different mechanisms [5].

Experimental part

Material and methods

Tarnaveni is known for its chemical industry centre till 2002 when the chemical platform was closed [20]. Soil and plant samples (*Cirsium arvense* and *Agropyron repens)* were collected from seven locations (table 1), situated at various distances from the polluted area Tarnaveni (figure 1a).

The samples locations were selected randomly based on the fact that contaminated wind-roses are not always easy to predict [19] and that the waste resulting from the activity of the chemical platform was stored in three ponds behind the factory, at a distance of a few hundred meters

Fig. 1a. The study area

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Fig. 1b. Chemical waste-Tarnaveni area, Romania
(Photo: Alda Simion)

of the Tirnava River (fig. 1 b). The dispersion of fine particles by wind has caused accumulation of pollutants in soils and plants in the adjacent area.

The soil structure in the area has medium or reduced pollution vulnerability, which permits to obtain accurate information regarding long-term soil pollution [2]. The soil samples were collected from a 0-40 cm depth. The *p*H determinations were made in water suspension.

The soil and plant samples collection and preparation and the metal analysis were undertaken using the procedures described by Harmanescu M.[12].

The heavy metals contents were determined at the University of Environmental Research Laboratory by flame atomic absorption spectrometry (FAAS) by air/acetylene flame, using an Analytic-Jena device.

All the analysis were made in triplicate and the mean values were calculated. The results were reported as ppm (mg/kg dry weight).

Statistical analysis

The data were statistically analyzed using Main Component Analysis and Generalized Linear Model, both recommended to interpret the data [4].

The statistical package used were Microsoft Excel and Past Version 2.17c [11].

The soil samples are similar to the soil structure described by Suciu I. et al, 2008 *brown and black earth, pseudoredzinic soils, and hayfield black earth, regosoils, clay soils and alluvial soils* with a soil *p*H that ranged from 7.63 to 8.01.

Table 2 presents the results regarding the heavy metals concentrations (total forms) in plants and corresponding soils.

As presented in table 2, the highest values of heavy metal registered in plants are the following:

- chromium in *Cirsium arvense* - 9.36 ppm,
- cadmium in *Agropyron repens*- 0.19 ppm,
- copper in *Agropyron repens* - 26.76 ppm,
- zinc in *Agropyron repens* - 314.1 ppm,
- lead in *Agropyron repens*- 1.05 ppm.

Comparative with other studies, our results show that the maximum value of chromium, cadmium, copper and zinc registered in the studied plants are high, especially for chromium and zinc [15,17].

The maximum heavy metals total contents in soils take up to 1.03 times (for zinc), 1.08 times (for cadmium), 1.44 times (for lead), 4.33 times (for chromium) the Alert threshold values for Romania [24].

The highest level of chromium registered in soil was 432.9 ppm, a value that exceeds even the Intervention threshold value for Romania [24].

The logarithmic data of total heavy metals contents (mean values) in plants and corresponding soils are presented in figure 3.

Table 1
SAMPLING SITES GEOGRAPHICAL COORDINATES

Sampling sites	North	East	Altitude
L1	46.31927	24.27191	281
L2	46.32141	24.27620	275
L3	46.33148	24.27211	369
L4	46.31251	24.28137	293
L5	46.31009	24.23339	280
L6	46.27626	24.19909	303
L7	46.24027	24.12058	267

Legend: L_1-L_7 = sampling sites

According to figure 3, the highest content of chromium was registered by the samples collected from location 1 for both plants as well as for the soil (*Cirsium arvense* is accumulating more chromium compared to *Agropyron repens*).

The Main Component Analysis (PCA) method simplifies the interpretation of data, using the var-covar matrix and Joliffe cut-off of 0.074265.

Based on the PCA % variance and Broken stick imagine are selected the first three PC axis: PC1 (51.371% variance); PC2 (28.176 % variance); PC3 (11.337 % variance), because they have the highest percent of variance.

Table 2
TOTAL HEAVY METALS CONTENTS (PPM) IN PLANTS LEAVES AND CORRESPONDING SOILS

Heavy metals	Vegetation	Range (ppm)	Heavy metals total contents in soil (ppm)			
			Range	NC*	ATV**	ITV***
Cu	*Cirsium arvense*	2.47 - 15.44	20.22 - 63.06	20	100	200
	Agropyron repens	0.89 - 26.76				
Zn	*Cirsium arvense*	10.34 - 44.49	127.18 - 309.94	100	300	600
	Agropyron repens	75.9 - 314.10				
Cd	*Cirsium arvense*	0.09 - 0.13	1.27 - 3.26	1	3	5
	Agropyron repens	0.08 - 0.19				
Pb	*Cirsium arvense*	0.24 - 0.69	30.91 - 72.47	20	50	100
	Agropyron repens	0.19 - 1.05				
Cr	*Cirsium arvense*	0.66 - 9.36	17.19 - 432.9	30	100	300
	Agropyron repens	0.15 - 3.89				

**Normal contents in soil, for Romania; **Alert threshold values for Romania ; ***Intervention threshold values for Romania [24].*

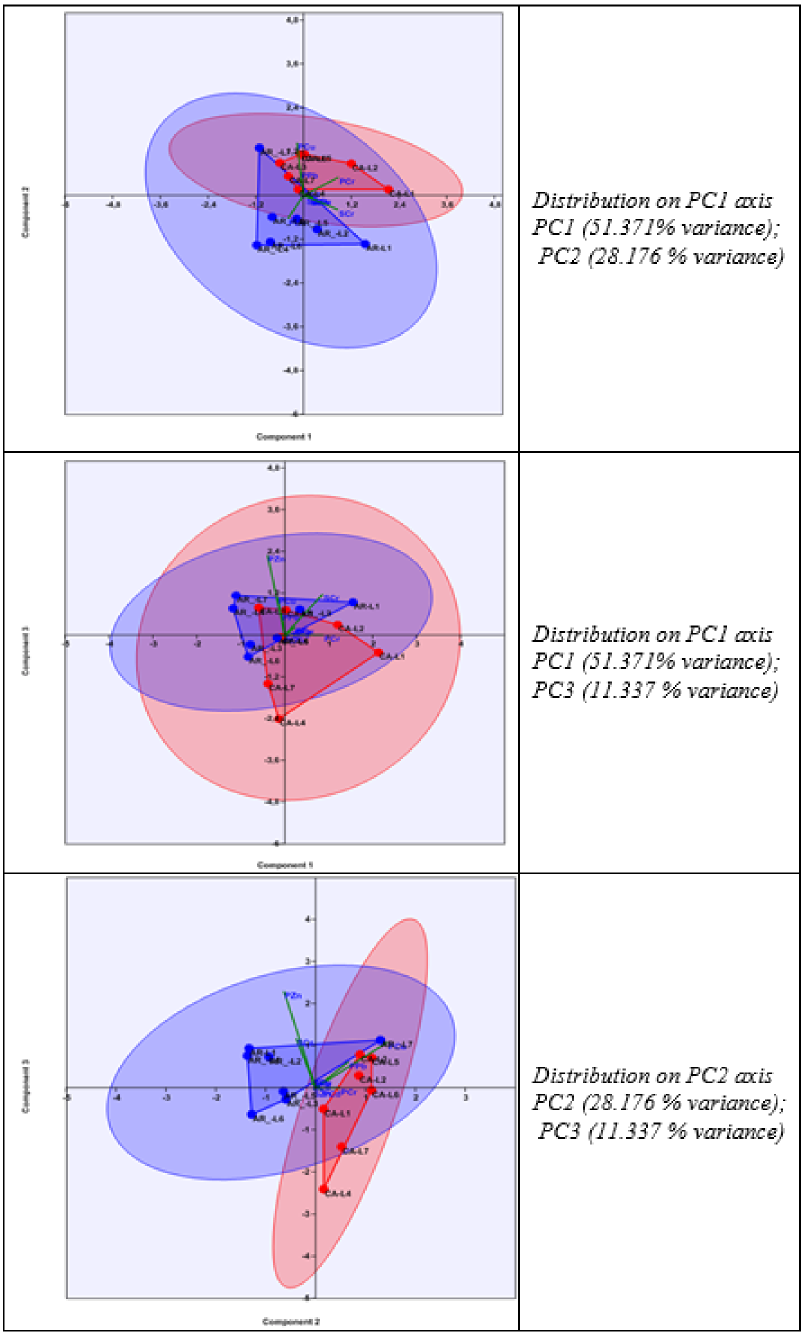

Fig. 2. Main Component Analysis representation of heavy metals data using 95% Ellipses and Eigenvalue scale

Legend: CA= Cirsium arvense, AR=Agropyron repens, L1-L7 = sampling sites; Red colour Ellipses -representation of heavy metals concentrations data in Cirsium arvense plants and corresponding soil samples; Blue colour Ellipses - representation of heavy metals concentrations data in Agropyron repens and corresponding soil samples

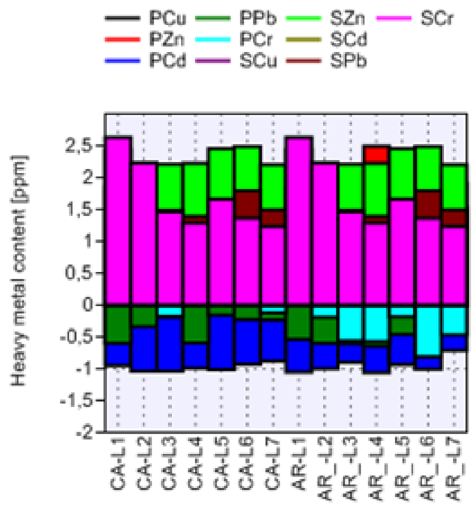

Fig. 3. Logarithmic representation of heavy metal content in soil and plant samples

Legend: CA= Cirsium arvense, AR= Agropyron repens, L1-L7 = sampling sites

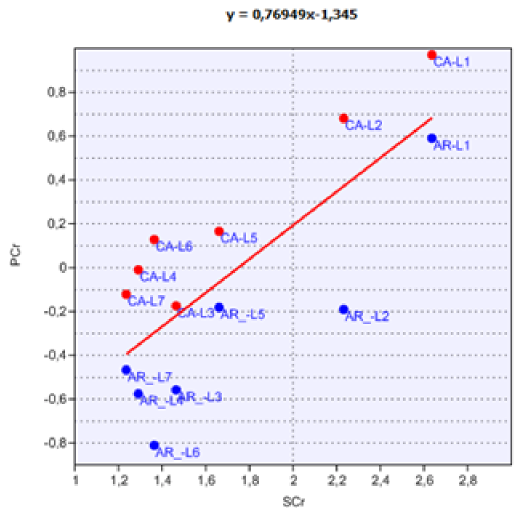

Fig. 4. Generalised Linear Model for chromium content in soil and plants

Legend: CA= Cirsium arvense; AR=Agropyron repens; L1-L7= sampling sites; red colour dots - representation of heavy metals concentrations data in Cirsium arvense plants; blue colour dots - representation of heavy metals concentrations data in Agropyron repens plants

The area data shows that *Cirsium arvense* presents more pollution risk due to the higher bioaccumulation of heavy metals.

The Generalized Linear Model presented in figure 4 exhibits the correlation between soil samples metal concentrations and plants.

The equation (1) permits to calculate the possible chromium plant samples concentration if we know the soil samples concentration.

$$y = 0.76949 \cdot x - 1.345 \quad (1)$$

where:

y = plants chromium concentration [ppm];

x = soil chromium concentration [ppm]

The Generalised Linear Model for chromium content in soil and plants confirm that *Cirsium arvense* is accumulating more chromium compared to *Agropyron repens*.

Conclusions

Heavy metals (Cr, Cd, Pb and Zn) total content in soil from the studied area exceeds the Alert threshold values for Romania.

The highest level of chromium registered in soil even exceeds the Intervention threshold value for Romania.

Our results are in accordance with Suciu et al., 2008 who found similar values of chromium and copper total contents in the soil samples from Tarnaveni area, which confirms that the pollution continues to be high in that area.

The results show that the levels of heavy metals found in studied plants are high, especially for chromium and zinc.

Based on our statistical analysis, we can conclude that *Cirsium arvense* is accumulating more chromium compared to *Agropyron repens* and is recommended to be used as an indicator for chromium contamination.

The present study highlights that animals consuming *Cirsium arvense* and *Agropyron repens* grown in this area ingest significant amounts of Cr and Zn.

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