

# Phytoextraction of Heavy Metals from Soil Polluted with Waste Mining by Using Forage Plants in Successive Cultures

Anca Pricop<sup>1</sup>, Benoni Lixandru<sup>1</sup>, Neculai Dragomir<sup>1</sup>, Corneliu Bogatu<sup>2</sup>, Smaranda Mășu<sup>2</sup>, Florica Morariu<sup>1</sup>

<sup>1</sup> Banat University of Agricultural Sciences and Veterinary Medicine, 300645 - Timisoara, Calea Aradului no. 119, Romania

<sup>2</sup> National R & D Institute for Industrial Ecology Branch of Timisoara, 300004 – Timișoara, Regina Maria Street no. 1, Romania

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## Abstract

During two years, was studied the phytoextraction potential of some perennial species (*Medicago sativa* and *Trifolium pratense*, *Festuca arundinacea* and *Lolium perenne*), for Zn, Cd, and Pb from soils polluted with waste mining. The experiment was done on kernoze soil with adding of 20 kg waste mining/m<sup>2</sup> and 8 kg biosolid/m<sup>2</sup>. The results showed that in all experiments, rye-grass is a good extractor for Zn and Cd, and leguminous species for Pb. Both leguminous species, especially *M. sativa*, presented a high tolerance for lead toxicity, even with 3-4 times greater values than maximum allowable level from actual legislation. In all cases, regardless of the experimental variant, raygrass (*Lolium perenne*) is a good accumulator of Zn and Cd, and red clover (*Trifolium pratense*) of Pb. The values of metal bioaccumulation increase gradually with their concentration in soil. Quality of very good extractor of Pb displayed by *Trifolium pratense* species are kept even in case of excessive pollution with Pb, when it exceed 3.4 times the maximum permissible norms. This proves, as *Medicago sativa* species, a good tolerance and resistance to toxicity of this metal. In case of addition of natural zeolite-volcanic tuff there was no increase in the rate of Zn bioaccumulation. Only in case of Cd at *Lolium perenne* and Pb at *Trifolium pratense* appear the favourable effect of metallic ions bioavailability in soil for plants.

**Keywords:** heavy metals, leguminous and gramineous species, phytoextraction, zinc

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## 1. Introduction

It was noted that plants of the species so-called metal-extractors, characterized by a high hyperaccumulator potential, recorded lower rates of growth and development and biomass production per unit area. [3, 4, 7, 9, 10, 13]

Also, plant species with a high production of biomass have a low metal-extractor potential, despite the richness and range of rhizosphere system. [1, 2, 3, 5]

If through geotechnical and biogeochemical activity could be increase soil biodisponibilization function of metal pollutants in accordance with

stimulation of adsorption and absorption processes from soil-rhizosphere symbiotic system, it is estimated that in the case of plant species with a good growth- development rate, the rate of phytoremediation of contaminated soils would increase dramatically. [4-8]

In this sense, have been outlined two directions:

- Use of crop plants, forage or grain, equipped with a good bio-productive potential and
- Use of fertilizing materials (composting) and amendment with positive synergistic effects in translocation of excessive metals.

Results obtained using maize (*Zea mays*), characterized by hefty metabolic and rhizosphere development, and showed that maize is a very good extractor for Zn and Cd, with a phytoextraction efficiency of 52-56% in the first

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\* Corresponding author: Anca Pricop, 0256/277206, anca.pricop@animalsci-tm.ro

year of vegetation, which reaches 66-68% in the second year of vegetation. [9-11,13]

In a sustainable agriculture system, should be avoided soil despoliation by practicing more than two years of the same crops on the same sole. In this sense, phytoremediation process may continue through successive growing of perennial fodder plant species such as alfalfa (*Medicago sativa*), red clover (*Trifolium pratense*), ryegrass (*Lolium perenne*) or mixtures of these species. [9,10,12,13]

## 2. Materials and methods

The study of phytoremediation process was conducted on soils contaminated with metals from three sources: mine tailings, biosolids and artificial pollution. Was also studied the effect of amendment with natural zeolite in type of indigenous volcanic tuff.

Biological material was composed of two species of forage plants: red clover (*Trifolium pratense*) and ryegrass (*Lolium perenne*) sowed in experimental plots of a block with 14 versions.

Composition of the experimental block was as follows:

- 7 variants, of which 6 experimental variants (V1 - V6) + M1 control for *Trifolium pratense*;
- 7 variants, of which 6 experimental variants (V7 - V12) + M2 control for *Lolium perenne*.

Experimental variants were: M1 and M2 – control, V1 and V7 – soil with mine tailings, V2 and V8 - soil with biosolids, V3 and V9 - soil with biosolids and mine tailings, V4 and V10 - soil with biosolids, mine tailings and volcanic tuff, V5 and V11 - soil with biosolids and artificial pollution with Zn, Cd and Pb, V6 and V12 - soil with biosolids and artificial pollution with Zn, Cd and Pb.

Artificial pollution was: 2000 mg Zn / kg soil SU, 4.5 mg Cd / kg soil SU, and 120 mg Pb / kg soil d.m.

Quantities of sterile and biosolids were 20 kg mine tailings / m<sup>2</sup>, respectively, 8 kg biosolids (fermentated sewage sludge) / m<sup>2</sup>, resulting in a sterile-soil ratio of 1:2,5.

Experimental plot area was of 3 m<sup>2</sup> (1.5 x 2 m) with alley between in width of 1 m. The experimental location was situated in the experimental field of discipline of Ecology from Didactical Station of USAMVB Timisoara. The soil in this location is in type of mold leachate, characteristic for low plain of Banat.

Previously, in the same locations and under the same experimental conditions were investigated fitoextractive processes on *Festuca arundinacea* and *Medicago sativa* species. This allowed us to study differential and comparative fitoextraction process in different climatic conditions, using leguminous and gramineous perennial species in two successive years.

At all plants species was used the same technique of sowing: 6 rows / plot, distance between rows of 20 cm and sowing depth of 2 cm. It was used a quantity of seed of 60 kg per ha of *Trifolium pratense* and 120 kg / ha for *Lolium perenne*.

Determination of metal ions was made by atomic absorption spectrometry, and finally, based on the amount of metals accumulated and translocated in plants was calculated the fitoextraction efficiency.

## 3. Results and discussion

Comparative and summative analysis of phytoextraction values of the two experiments (Experiment 1 / 2007 and Experiment 2 / 2008) is presented in Tables 1 and 2.

Table 1 shows the results for phytoextraction efficiency in case of soil mixed with sterile and biosolids compared with variations of soil mixed with sterile, biosolids and volcanic tuff.

It is noted that gramineous have a higher rate of phytoextraction for Zn and Cd, and leguminous for Pb. The addition of volcanic tuff does not stimulate the rate of Zn phytoextraction in both types of forage plants. If on soils with sterile and biosolids, gramineous have a Cd phytoextraction efficiency higher then leguminous, following amendment with tuff, phytoextractive values increase more than 2 times (50.68 mg to 25.23 mg).

Analysis of Pb phytoextraction show a net advantage of the leguminous species, however, in case of amendment with tuff is reduced by about 2 times (17.20 mg to 36.20 mg).

Cumulative Summary of these differences is shown in Figure 1.

Table 2 presents results for phytoextraction efficiency in case of polluted soil fertilized with biosolids in comparison with polluted soil with addition of biosolids and volcanic tuff.

Phytoextraction values from this table come from the variants of soil with the highest degree of pollution (see experimental methodology).

**Table 1** - Comparative and summative values of phytoextraction efficiency of Zn, Cd and Pb in case of cultivation of leguminous and gramineous perennial species on polluted soils with mine tailings and biosolids

Metal pollutants	Phytoextraction efficiency (%)											
	Variants soil + sterile + biosolids						Variants soil + sterile + biosolids+ volcanic tuff					
	L <sub>1</sub>	L <sub>2</sub>	TOTAL	G <sub>1</sub>	G <sub>2</sub>	TOTAL	L <sub>1</sub>	L <sub>2</sub>	TOTAL	G <sub>1</sub>	G <sub>2</sub>	TOTAL
Zn	5.36	60.30	65.66	7.45	80.10	87.55	3.67	62.54	66.21	5.66	67.67	73.33
Cd	4.81	15.44	20.25	10.18	15.05	25.23	-	24.44	24.44	33.88	16.80	50.68
Pb	20.86	15.34	36.20	3.65	1.87	5.52	14.43	2.77	17.20	8.60	1.83	10.43

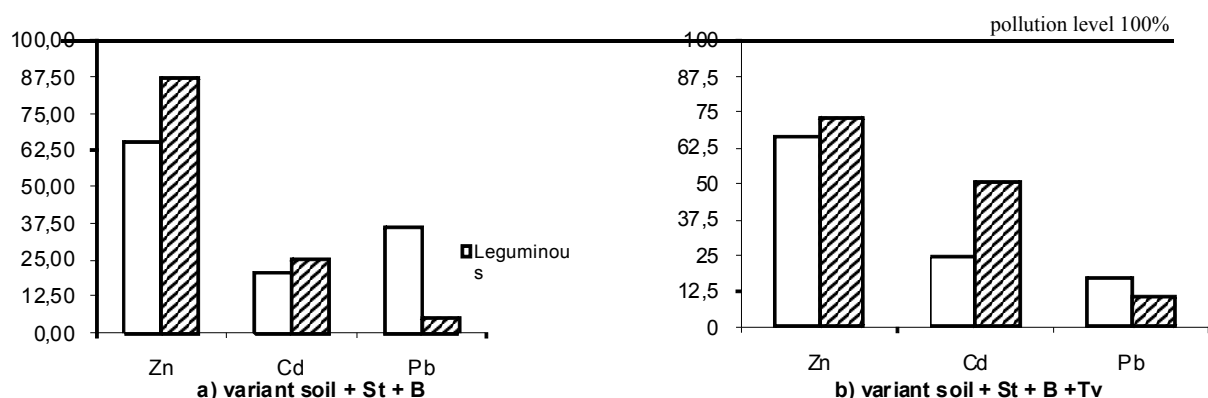
**Legendă:**

L<sub>1</sub> – *Medicago sativa* – Exp. 1 / 2007

L<sub>2</sub> – *Trifolium pratense* – Exp. 2 / 2008

G<sub>1</sub> – *Festuca arundinacea* – Exp. 1 / 2007

G<sub>2</sub> – *Lolium perenne* – Exp. 2 / 2008



**Figure 1** - Summary of the cumulative processes of phytoextraction

**Table 2** - Comparative and summative values of phytoextraction efficiency of Zn, Cd and Pb in case of cultivation of leguminous and gramineous perennial species on artificially polluted soils

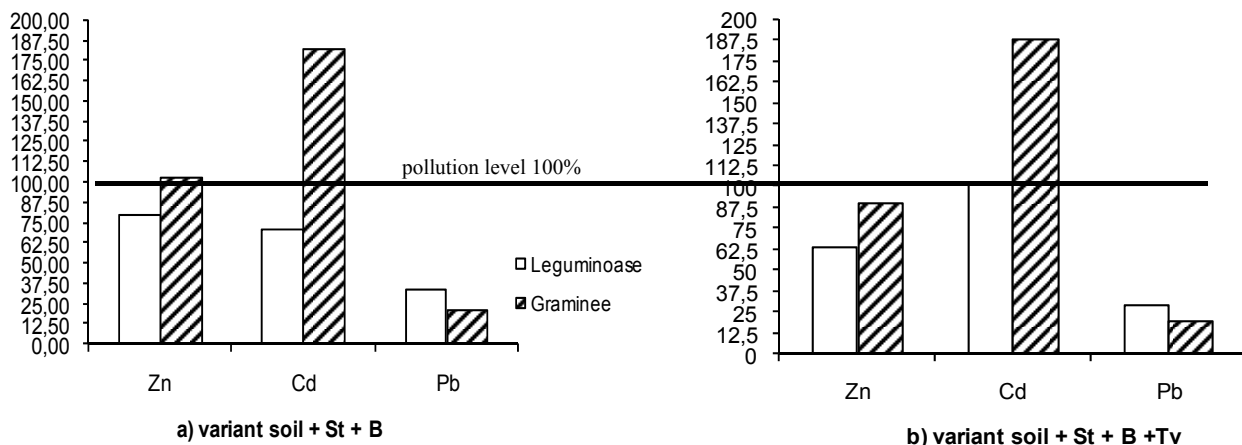
Metal pollutants	Phytoextraction efficiency (%)											
	Variants soil + AP + B						Variante sol + AP + B + T					
	L <sub>1</sub>	L <sub>2</sub>	TOTAL	G <sub>1</sub>	G <sub>2</sub>	TOTAL	L <sub>1</sub>	L <sub>2</sub>	TOTAL	G <sub>1</sub>	G <sub>2</sub>	TOTAL
Zn	2,22	77,84	80,06	2,88	99,98	102,86	1,13	62,45	63,58	1,23	90,09	91,32
Cd	0,97	69,14	70,11	98,05	84,69	182,74	9,44	92,78	102,22	4,72	184,69	189,41
Pb	27,09	5,92	33,11	16,89	4,52	21,41	22,60	7,18	29,78	17,78	2,95	20,73

L<sub>1</sub> – *Medicago sativa* – Exp. 1 / 2007

L<sub>2</sub> – *Trifolium pratense* – Exp. 2 / 2008

G<sub>1</sub> – *Festuca arundinacea* – Exp. 1 / 2007

G<sub>2</sub> – *Lolium perenne* – Exp. 2 / 2008



**Figure 2** – Summary of the cumulative processes of phytoextraction on soils with high pollution level

Data analysis of Table 2 shows similar results to those obtained in case of leguminous and gramineous cultures on soils contaminated from mine tailings. Thus, and this time gramineous are better extractor of Zn and Cd, and leguminous of Pb. Amendment with tuff has the same effect as in the previous case.

The element that differentiates the two versions is that cumulated phytoextraction of Zn and Cd from soils with and without zeolite amendment, as phytoextraction of Cd from soil with zeolite, exceeds 100%.

In Figure 2 are presented these differences.

#### 4. Conclusions

In all cases, regardless of the experimental variant, raygrass (*Lolium perenne*) is a good accumulator of Zn and Cd, and red clover (*Trifolium pratense*) of Pb. The values of metal bioaccumulation increase gradually with their concentration in soil. Quality of very good extractor of Pb displayed by *Trifolium pratense* species are kept even in case of excessive pollution with Pb, when it exceed 3.4 times the maximum permissible norms. This proves, as *Medicago sativa* species, a good tolerance and resistance to toxicity of this metal.

In case of addition of natural zeolite-volcanic tuff there was no increase in the rate of Zn bioaccumulation. Only in case of Cd at *Lolium perenne* and Pb at *Trifolium pratense* appear the favourable effect of metallic ions bioavailability in soil for plants.

Cumulating the results of the two experiments, the best efficiency of Zn phytoextraction was recorded by gramineous species, the values growing in proportion with the concentration of Zn ions in soil.

In the process of phytoremediation of mine tailings mixed with soil in ratio of 2.5 parts sterile to 1 part soil, and administration of 8 kg biosolids / m<sup>2</sup> as organic support for the establishment of grass phytocenosis, recorded a pollution level higher than the norms, in case of Zn, 4.7 times higher and 1.8 times in case of Cd and 3.4 times for Pb.

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