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# THE METAL UPTAKE OF PLANTS ON THE LANDFILL SITES IN BEREG COUNTY

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**Abstract:** Our time is characterized by active struggle against various environmental pollutants. The soil factor is determinative and most informative for demonstration and detection of the dumps' possible impact on the environment. We investigated the total copper, zinc, lead of the soil in landfills, as well as the corresponding metal contents in the plants growing there in Bereg County. Metal content of the contaminated soils Cu 47.9-34.8 mg/kg, Pb 67.18-43.7 mg/kg, Zn 237.5-228.2 mg/kg, and on the control: Cu 19.5 mg/kg, Pb 15.39 mg/kg, Zn 23.2 mg/kg. The contents of heavy metal in the plants growing within the landfill sites Cu 15.16-15.26 mg/kg, Pb 1.87-2.79 mg/kg, Zn 33,38-33,89 mg/kg and on the control: Cu 12,55 mg/kg, Pb 0.89 mg/kg, Zn 26,55 mg/kg. Numerous adventive plants (Urtica spp., Artemisia spp., Stenactis annua (L.) Nul, Polygonum sachalinense Fr. Schmidt, etc.) that force out autochthonous species are bioindicators of the polluted areas.
**Keywords:** plants, contaminated soil, heavy metal.

## INTRODUCTION

Our time is characterized by active struggle against various environmental pollutants. It is no secret that in previous decades, due to unreasonable human industrial, agricultural activity and owing to household waste products, the soil's surface strata have become a sort of depots of huge amounts of heavy metal and other pollutants. The latter, due to their cumulative and prolonged activity, ability to become involved into the trophyc chains constitute a real menace for the environment and for human beings. The soil factor is determinative and most informative for demonstration and detection of the dumps' possible impact on the environment, for it regulates the ecology of all other environmental objects. The dumps' impact on the soils was evaluated in comparison with the control sites. Plants absorb numerous elements from soil. Some of the absorbed elements are referred to as essentials because they are required for plants to complete their life cycle (Arnon and Stout, 1939). Certain essential transition elements such as iron, manganese, molybdenum, copper, zinc, and nickel are known as micronutrients because they are required by plants in minute quantity (Arnon and Stout, 1939). Other transition metals such as silver, gold and cobalt (Gomez, 2002; Taiz and Zeiger, 1998) and non-transition elements like aluminum (Ghanati et al., 2005) have proven to have a stimulatory effect on plant growth, but are not considered essential.

Moreover, it has been documented elsewhere that plants also absorb elements which have no known biological function and are even known to be toxic at low concentrations. Among these are arsenic, cadmium, chromium, mercury, and lead. However, even micronutrients become toxic for plants when absorbed above certain threshold values. Plants take up essential and non-essential elements from soils in response to concentration gradients induced by selective uptake of ions by roots, or by diffusion of elements in the soil. The level of accumulation of elements differs between and within species (Huang and Cunningham, 1996; McGrath et al., 2002). Phytoremediation can provide a cost-effective, long-lasting and aesthetic solution for remediation of contaminated sites (Ma et al., 2001). More than four hundreds plants are known as hyperaccumulators of metals, which can accumulate high concentration of metals into their aboveground biomass. These plants include trees, vegetable crops, grasses and weeds. It is important to use native plants for phytoremediation because these plants are often better in terms of survival, growth and reproduction under environmental stress than plants introduced from other environment. There has been a continuing interest in searching for native plants that are tolerant to heavy metals; however, few studies have evaluated the phytoremediation potential of native plants under field conditions (Shu et al., 2002; Mcgrath and Zhao, 2003).

We investigated the total copper, zinc, lead, cadmium of the soil in landfills, as well as the corresponding metal contents in the plants growing there in Bereg County. We located the landfills near small settlements in the Bereg region (Hungary) served as the sampling areas: Beregsurány (Bd), Gelénes (G), Beregdaróc (Bd) and Beregdaróc forest (as control).

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## MATERIALS AND METHODS

### Sampling

In case of dumps, soil and plant samples were collected from three sampling sites. Six sampling points was marked out on each sampling sites. Samples were taken from three places of a given sampling site, within a square of 10 x 10 m. The three samples which were taken from the same place were mixed with each other.

### Methods

Total heavy metal content as well as the content of available heavy metals in soil samples and total heavy metal content in plant samples was determined by analysis of Cu, Pb and Zn after acid digestion, using inductively coupled plasma mass spectrometry (ICP-AES). Total organic carbon in soils was analysed with TOC, using a Shimadzu TOC-5000A analyser.

### Statistical analysis

For each parameter data were submitted to a two-factor analysis of variance (ANOVA). SPSS statistical package version 14.0 programs for Windows 98.

### Sampling Sites

Our sampling sites were legal and abandoned but illegally used dump sites, on the periphery of Gelénes, Beregdaróc and Beregsurány, which are small settlements in Szabolcs-Szatmár-Bereg County. The dump site of Bs is situated southeast of the settlement and was formed by filling of an abandoned riverbed. Formerly, the dump site of Bd had been a clay-pit, which has been filled with communal wastes. The control area was marked out southeast of Beregdaróc, along the Ukrainian-Hungarian frontier. It is the only part of the oak-hornbeam forest (Querceto robori-Carpinetum Soó and Pócs 1957 em. Soó 1980), which more or less remained in its original stage.

### Illegal dumpsite of Beregsurány (Bs)

This illegal dumpsite was created by infilling of a deserted riverbed with communal wastes of the settlement. Additionally, draining of fecal wastewater as contaminating material arises as a serious problem on the area. Formerly deposited wastes have been overgrown with several plant species, such as common nettle (Urtica dioica L.), burdock (Arctium lappa L.), spiny sowthistle (Sonchus asper L.), celandine (Cheildonium majus L.), creeping buttercup (Ranunculus repens L.), common waterplantain (Alisma plantago-aquatica L.) and broadleaf cattail (Typha latifolia L.). Dominant species of the 1-1.5 meter high coat of green is Calamagrostis arundinacea L. Among the several grass species situated Polygonum sachalinense L., Polygonatum multiflorum L. All.

### Legal dumpsite of Gelénes (G)

This is an expertly built regional dumpsite where wastes of the neighboring settlements are deposited. Deposited waste is lined with mainly grass and weed species such as common nettle (Urtica dioica L.), burdock (Arctium lappa L), cleavers (Gallium aparine L.) and spiny sowthistle (Sonchus asper L.). Grass cover is continuous and covers 100 per cent of the area. Dominant species of the 0.6-1.5m high grass cover is Bromus arvensis L.

### Dumpsite of Beregdaroc (Bd)

The soil of the site is covered by ruderal plants. During the creation of this dumpsite, clay-pits were filled in with communal wastes. As the dumpsite has not been used for a long time, succession is at an advanced stage. In the plant cover, wastes (mainly plastics) can be observed only in some places. Ruderal plants are dominant on the site, and height of the grass cover is 1-1.5 m. The dominant species Urtica dioica L., Stenactis annua L., Arctium lappa L., Sonchus aspe L., Tanacetum vulgare L., Polygonum sachalinense L.) disperse nearly equally in the mosaic-like grass cover.

### Forest of Beregdaroc (Control site)

On the Great Hungarian Plain, forest of Beregdaroc is the only part of hornbeam-oak grown forests (Querceto robori-carpinetum Soó and Pócs 1957 em. Soó 1980) which remained in its original state. Grass covers 50% of the area, however, this cover is not continuous. Geranium robertianum L. and Galium aparine L. are the dominant grass species among the trees, while more opened areas are dominated by Urtica dioica L. Grass cover is as high as 1m. Besides other plant species, Ajuga reptans L., Alliaria petiolata M.B, Arctium lappa L., Asperula odorata L., Convallaria majalis L., Dryopteris filix-mas L., Galium aparine L., Poa nemoralis L., Sonchus asper L. can be found on the area as well. Table 1. contains selected properties of the soils of sampling sites.


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Table 1. Physico-chemical properties of the soils of sampling sites

| Samples | pH (KCL) | TOC% | WHC% | CEC% | $CACO_3$% |
|---|---|---|---|---|---|
| 1. Gelénes | 4.33 | 25.8±0.3 | 22±0.1 | 27±0.2 | 0.00 |
| 2. Beregsurány | 4.81 | 24.2±0.4 | 25±0.4 | 26±0.3 | 0.00 |
| 3. Beregdaróc | 4.52 | 23.4±0.2 | 24±0.3 | 27±0.2 | 0.00 |
| 4. Control | 5.22 | 19.6±0.4 | 24±0.2 | 41±0.3 | 0.00 |

**RESULTS AND DISSCUSIONS**

Significant differences could be measured in the heavy metal contents of soils (Table 2.). The copper content of dump sites (Beregdaróc 34.8 mg/kg, Beregsurány 43.2 mg/kg, Gelénes 47.9 mg/kg) exceeds the copper content of the control area (19.5 mg/kg). The dump sites of Gelénes (234.8 mg/kg), Beregsurány (237.5 mg/kg) and Beregdaróc (228.2 mg/kg), zinc content is significantly more than the control area (23.2 mg/kg). Tendencies of lead content are similar to that of copper and zinc content. Dump soils (Beregsurány 46.1 mg/kg, Beregdaróc 43.7 mg/kg, Gelénes 67.18 mg/kg) contain significantly more lead than the control area (15.39 mg/kg).

Table 2. Gross contents of heavy metals in soils

| Samples | Σ (Cu) mg/kg | Σ (Zn) mg/kg | Σ (Pb) mg/kg |
|---|---|---|---|
| 1. Gelénes | 47.9±0.3c | 234.8±0.3b | 67.18±0.3c |
| 2. Beregsurány | 43.2±0.3c | 237.5±0.4b | 46.1±0.2b |
| 3. Beregdaróc | 34.8±0.2b | 228.2±0.2b | 43.7±0.4b |
| 4. Control | 25.5±0.3a | 23.2±0.4a | 15.39±0.5a |

Note: ANOVA: Tukey's B-test (n=13). The values in the rows with identical letter indices do not significantly differ from each other (P< 0.05).

Metal contents in plants vary with plant species (Alloway et al., 1990). Plant uptake of heavy metals from soil occurs either passively with the mass flow of water into the roots, or through active transport crosses the plasma membrane of root epidermal cells. Under normal growing conditions, plants can potentially accumulate certain metal ions an order of magnitude greater than the surrounding medium (Kim et al., 2003). Baker (1981) suggested that plants could be classified into three categories: (1) excluders: those that grow in metal-contaminated soil and maintain the shoot concentration at low level up to a critical soil value above which relatively unrestricted root-to-shoot transport results, (2) accumulators: those that concentrate metals in the aerial part, and (3) indicators: where uptake and transport of metals to the shoot are regulated so that internal concentration reflects external levels, at least until toxicity occurs. Those plants with better ability to adjust to the toxicity effects are able to survive in heavy metal/metalloid impacted sites and are better candidates for phytoremediation purposes. Plants that accumulate high concentrations of metals in their fronds are called hyperaccumulators. This term was coined by Baker and Brooks (1989) to define plants that contained greater than 1000_gg−1 of nickel in dry leaves. Plants that accumulate more than 100mg Cd kg−1 (0.01%) or more than 500mg Cr kg−1 (0.05%) in dry leaf tissue can be considered hyperaccumulators (Baker et al., 2000).

Metal concentrations in plants growing in uncontaminated soils were 0.3–18.8, 1.1–33.1, and 6–126mg kg−1 for Pb, Cu and Zn, respectively, whereas the highest metal concentrations in plants growing in contaminated soils were 1506, 1123 and 710mg kg−1 for Pb, Cu and Zn, respectively (Kabata- Pendias and Pendias, 1992). The combination of elevated soil pH and high organic matter in the study site may have played a role in the limited plant availability of heavy metals in the soil, resulting in low plant uptake of these metals (Jung and Thornton, 1996, Rosselli et al., 2003). However, no significant correlations were found between metal concentrations and soil pH (data not shown).

**Table 3. Lead concentrations in soil and plant samples (mg/kg) from sampling sites**

| Scientific name | Sampling | Roots | Shoots | Soil |
|---|---|---|---|---|
| Arctium lappa | G | 27.98±0.1c | 22.62±0.3b | 67.18±0.2c |
| | Bs | 20.68±0.4b | 18.48±0.4b | 46.12±0.3b |
| | Bd | 17.01±0.2b | 16.48±0.2b | 43.79±0.1b |
| | Control | 10.07±0.2a | 9.28±0.4a | 15.39±0.4a |
| Urtica dioica | G | 26.34±0.4b | 13.47±0.1b | 67.18±0.3c |
| | Bs | 21.42±0.3b | 12.67±0.2b | 46.15±0.4b |
| | Bd | 19.94±0.2b | 12.34±0.4b | 43.76±0.2b |
| | Control | 4.93±0.1a | 5.56±0.3a | 15.39±0.3a |
| Sonchus asper | G | 23.21±0.3b | 18.81±0.4b | 67.18±0.1c |
| | Bs | 22.52±0.3b | 10.79±0.3b | 46.14±0.2b |
| | Bd | 18.38±0.4b | 12.58±0.4b | 43.75±0.4b |
| | Control | 10.34±0.2a | 9.87±0.2a | 15.39±0.4a |

Note: ANOVA: Tukey's B-test (n=13). The values in the rows with identical letter indices do not significantly differ from each other ($P < 0.05$).

The contents of heavy metal in the plants growing within the dumps were significantly higher than those in the plants from the control site. In this study the concentrations of Pb, Cu and Zn in soils and plant biomass are provided in Tables 3, 4 and 5. Total Pb concentrations in the plants ranged from 27.98 to 5.56 mg kg−1, with the maximum being in the roots of Arctium lappa from site Gelénes (Table 3). In addition, the roots of Sonchus asper, Urtica dioica and the shoots of Arctium lappa, Sonchus asper from site Gelénes also contained significant amounts of Pb (26.34-18.81 mg kg−1) to the control site. None of the plant species accumulated Pb above 1000mg kg−1 in the shoots, the criteria for a hyperaccumulator (Baker and Brooks, 1989). In 90% of the plant samples, the root Pb concentrations were much greater than those of the shoot Pb contents, indicating low mobility of Pb from the roots to the shoots and immobilization of heavy metals in roots. Analyzing Pb concentrations in plants collected from a dump site, Pitchtel et al. (2000) showed Pb concentrations (non-detectable to 1800mg kg−1). Stoltz and Greger (2002) reported a range of 3.4 to 920mg kg−1 of Pb concentrations in different wetland plant species collected from mine tailings. Joonki et al. (2006) collected and analyzed for total metal concentrations of native plants and the associated soil samples on a contaminated site. According to their opinion in the roots of Sonhus asper the lead concentration was 146 mg/kg whit 2405 mg/kg soil lead concentration. As opposed to this Yanqun et al. (2005) find that the Sonhus asper's lead accumulation in the roots was more higher (4560.8 mg/kg) whit 2880.2 mg/kg soil lead concentration.

Copper concentrations in the plants varied from 6.21 to 29.61 mg kg−1 (Table 4). Like Pb, the maximum value was found in the roots of Arctium lappa from site Gelénes and no plant species accumulated Cu above 1000mg kg−1. In addition to Arctium lappa the roots of Urtica dioica and Sonchus asper from site Gelénes also contained significant amounts of Cu (27.74-25.43 mg kg− 1) to the control site. The Cu concentrations in the roots were greater in all samples than in the shoots. Copper concentrations of 6.4–160mg kg− 1 in the plant biomass were reported by Stoltz and Greger (2002), which were higher than those in our research. Shu et al. (2002) reported Cu concentrations of 7–198mg kg−1 in plant biomass of Paspalum distichum and C. dactylon. According to Joonki et al. (2006) opinion in the roots of Sonhus asper the cooper concentration was 46 mg/kg whit 746 mg/kg soil copper concentration.


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**Table 4. Copper concentrations in soil and plant samples (mg/kg) from sampling sites**

| Scientific name | Sampling | Roots | Shoots | Soil |
|---|---|---|---|---|
| Arctium lappa | G | 29.61±0.3b | 25.42±0.3b | 47.91±0.2c |
| | Bs | 28.35±0.2b | 27.52±0.4b | 43.25±0.3c |
| | Bd | 26.42±0.3b | 25.31±0.2b | 34.83±0.1b |
| | Control | 21.52±0.4a | 19.50±0.1a | 25.55±0.3a |
| Urtica dioica | G | 27.74±0.2b | 23.61±0.2b | 47.97±0.2b |
| | Bs | 31.31±0.2b | 29.32±0.3b | 43.28±0.2b |
| | Bd | 25.43±0.3b | 21.31±0.3b | 34.82±0.3b |
| | Control | 10.21±0.4a | 9.11±0.2a | 25.58±0.4a |
| Sonchus asper | G | 21.45±0.1b | 15.26±0.1a | 47.91±0.3c |
| | Bs | 20.34±0.4b | 15.16±0.2a | 43.27±0.4c |
| | Bd | 22.72±0.3b | 15.92±0.3a | 34.89±0.2b |
| | Control | 14.19±0.2a | 11.55±0.1a | 25.52±0.4a |

Note: ANOVA: Tukey's B-test (n=13). The values in the rows with identical letter indices do not significantly differ from each other (P< 0.05).

The Zn contents in the plants ranged from 12.41 to 52.31mg kg−1 (Table 5). Like Pb and Cu, the maximum values were again found in the roots of Arctium lappa and Urtica dioica from Gelénes and no plant species accumulated Zn above 1000mg kg−1. Similar to Pb and Cu, Zn concentrations were greater in the roots than the shoots. Research conducted by Stoltz and Greger (2002) showed Zn concentrations of 68–1630mg kg−1 in plant biomass while those by Shu et al. (2002) showed 66–7607mg kg−1 in plant biomass.

**Table 5. Zinc concentrations in soil and plant samples (mg/kg) from sampling sites**

| Scientific name | Sampling | Roots | Shoots | Soil |
|---|---|---|---|---|
| Arctium lappa | G | 48.41±0.4b | 39.63±0.4b | 234.82±0.4b |
| | Bs | 51.38±0.3b | 48.42±0.3b | 237.53±0.2b |
| | Bd | 53.29±0.1b | 47.34±0.4b | 228.21±0.3b |
| | Control | 34.21±0.4a | 28.52±0.3a | 23.28±0.4a |
| Urtica dioica | G | 52.31±0.3b | 37.53±0.2b | 234.83±0.4b |
| | Bs | 41.75±0.2b | 39.26±0.3b | 237.56±0.3b |
| | Bd | 47.51±0.4b | 41.28±0.4b | 228.23±0.4b |
| | Control | 17.35±0.3a | 12.41±0.4a | 23.28±0.1a |
| Sonchus asper | G | 35.65±0.1b | 33.89±0.1b | 234.82±0.1b |
| | Bs | 35.43±0.4b | 33.38±0.4b | 237.54±0.4b |
| | Bd | 38.10±0.2b | 33.81±0.3b | 228.26±0.4b |
| | Control | 28.31±0.4a | 26.55±0.4a | 23.2±0.2a |

Note: ANOVA: Tukey's B-test (n=13). The values in the rows with identical letter indices do not significantly differ from each other (P< 0.05).

According to Joonki et al. (2006) opinion in the roots of Sonhus asper the zinc concentration was 134 mg/kg whit 1000 mg/kg soil zinc concentration. As opposed to this Yanqun et al. (2005) find that the Sonhus asper's zinc accumulation in the roots was more higher (7893.9 mg/kg) whit 13,231.2 mg/kg soil zinc concentration. Though metal concentrations in the soil were correlated (r=0.72–90), metal concentrations in the plants were poorly correlated with metal concentrations in the soil, which is expected since total metal concentrations have been considered poor indicators of metal availability to plants (Kabata-Pendias and Pendias, 1992).

The use of trees and bushes for the phytoremediation of land contaminated by heavy metal does seem to have considerable potential (Pulford and Watson, 2003). Although trees and bushes had longer development stages than herbaceous, the relative biomass of trees and bushes were lower than herbaceous in the same space and time. And herbaceous were easy for culture and plant, and had stronger ability to adapt stress environment. In another study, the tolerant ability of herbaceous to heavy metals was higher than bush and tree (Landberg and Greger, 1996). So, herbaceous were important as hyperaccumulators.In situ remediation techniques, such as phytoremediation the attenuation of pollution through the use of plants, which impose minimal environmental disturbance, offer economic, agronomic, and societal benefits to all countries. Up to the present time phytoremediation of soilborne heavy metals and of organic contaminants has been pursued as two distinct disciplines. This compartmentalized approach applies to fundamental studies of the mechanisms of action, as well as to the development of remediation technologies.

## CONCLUSIONS

A direct linear dependence between the concentrations of heavy metal in overground parts of the plants was revealed to be taking place under poly-element contamination of natural ecosystems. Among the analyzed plant species growing at dumps, no heavy metal hyper-accumulator was found. Numerous adventive plants were (Arctium lappa Urtica spp., Artemisia spp., Stenactis annua (L.) Nul, Polygonum sachalinense Fr. Schmidt, etc.) that force out autochthonous species and frequently are mono- or subdominants of plant groupings, are bioindicators of the polluted areas.

The gross and moveable metals contents in the soils of dumps and respective control sites shows that their concentration in the forest soils is significantly higher than in the similar samples of the soils contaminated by household waste. That is why, dumps provide for accelerated washing of heavy metals compounds of the soils, their migration into the underground and surface waters, and further accumulation in plant tissues.

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