# POST-EFFECT OF INCREASING BOTTOM SEDIMENT ADDITIVES TO THE SUBSTRATUM ON LEAD UPTAKE BY PLANTS

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## ABSTRACT

The aim of the studies was to estimate the post-effect of bottom sediment addition to the substratum on lead uptaking by the plants under the conditions of pot experiments. Very acid soil and bottom sediment dredged from Rożnów Reservoir were used for preparation of substrata. Bottom sediment share ranged between 0 and 16% of substratum mass. Tested plants were grown in orders: maize (*Zea mays* L.) and horse bean (*Vicia faba* L., var. *minor*) as well as oat (*Avena sativa* L.) and lupine (*Lupinus angustifolius* L.). The plants were harvested for green mass. The content of Pb in mineralisats obtained from plant material was determined by ICP-AES method. The total quantity of Pb removed with yield of the plants depending on species and part of the plant was compared and changes affected by bottom sediment share in substratum as well as previous plant cultivation were estimated. Under the conditions of substratum contaminated by lead significantly higher amounts of Pb were accumulated in roots than in tops of the plant. In average, the highest Pb contents were determined in lupine roots and horse bean tops, while the lowest data were found in maize roots and tops. Considering total quantity of Pb, the highest amounts were removed with yield of maize, and the lowest with yield of horse bean. The Pb translocation coefficients (TC) (content in the tops *versus* content in the roots) as well as the bioaccumulation coefficients (BC) (content in the tops *versus* content in the soil) for individual plants were calculated. The highest average value of TC was affirmed for horse bean (0.18), and the lowest one for oat (0.09). The mean values of BC for the individual plants decreased as follow: 0.11 – horse bean, 0.08 – lupine, 0.07 – oat, 0.05 – maize. With the increasing share of bottom sediment in substratum decrease of Pb accumulation in the roots of the plant was observed, while an increase of TC values was noted. Similar relation between the sediment dose and Pb content in the tops was not found. In spite of additional Pb load with applied bottom sediment, the increasing of its content in plant tissue was not stated. One possible explanation of this dependence is the decreasing of Pb availability to the plants as a result of sediment ability to the substratum alkalization.

**Key words:** bottom sediment, lead, plants, uptake, translocation and bioaccumulation coefficients.

## INTRODUCTION

Bottom sediment dredged from Rożnów Reservoir is a by-product created as a result of mechanical reclamation of water reservoir [Kloze et al. 2001]. Nowadays there are many attempts of agricultural use of materials like bottom sediments, sewage sludge or incineration ashes. These materials are used as so-called indirect fertilizers and may be consider as a source of organic matter and mineral compounds of calcium, phosphorus and nitrogen or materials containing significant amounts of silt and clay fractions [Kalembasa and Wysokiński 2002, Zhou and Kot 1995]. From ecological point of view natural used of these materials is the most desirable way of their utilization. However it is necessary to pay attention at toxic substances content in those materials. According to Polish legislation the bottom sediments from superficial standing or flowing water reservoirs used in earth works are not counted among waste but they should suit standards of soil and earth quality and should fulfill the criteria of admissible values of toxic substances contents, indicated in the enclosure of Minister of Environment regulation [Dz. U. 165, 2002], for soils occurred in purposed place. Bottom sediment the most often contained increased content of trace metals like: zinc, cooper, nickel, cadmium, chromium, lead and mercury. Trace elements introduced to the soils may cause an increase of their content in cultivated plants and next enter to human food chain [Bojakowska and Sokołowska 1998, Kabata-Pendias and Pendias 1999]. For this reason it is necessary to pay attention on the advantages of agricultural used but on the other hand on great danger related to this way of bottom sediment utilization.

## MATERIAL AND METHODS

A pot experiment was carried out in 2005 in vegetation hall of University of Agriculture in Krakow. The very acid soil and bottom sediment dredged from Rożnów Reservoir were used as components of the substratum. The sediment share in substratum increased following: 0, 1, 2, 4, 6, 8, 10, 12, 14 and 16 % of total mass. The samples (both roots and tops) of plants grown at those mixtures were studied material. Test plants were grown in sequences: maize (*Zea mays* L.) and horse bean (*Vicia faba* L., var. *minor*) as well as oat (*Avena sativa* L.) and lupine (*Lupinus angustifolius* L.). After the vegetation period plants were harvested on green mass, dried and the quantity of biomass of tops and roots was measured. Total content of heavy metals in plant material were determined after dry mineralization and in hot nitric acid solution while in samples of substratum after dry mineralization of organic matter and in a hot mixture of concentrated acids: $HNO_3$ and $HClO_4$ (3:2). Heavy metals content in obtained solutions were assayed by ICP–AES method.

## RESULTS AND DISCUSSION

Soil and sediment bottom applied in experiment contained relativity high amount of lead: 8.53 mg Pb · $kg^{-1}$ and 12.2 mg Pb · $kg^{-1}$ of DM, respectively. With increasing share of bottom sediment in substratum total content of lead were increased as well (tab. 1). In spite of additional Pb load with applied bottom sediment, lead content in all of the test plants roots as well as maize and oats tops were decreased. Bottom sediments from dam reservoirs usually contain significant amount of loam and silt fractions in their granulometric composition and relatively high pH value [Zhou and Kot 1995]. Bottom

sediment additives applied in experiment caused an increase of pH value of substratum and in consequence decreased contents of metals mobile forms and their availability to plants. The lead content in tops of horse bean and lupine did not depend on increasing share of bottom sediment in substratum. Dicotyledonous plants are able to a higher extent to heavy metals absorption, including Pb, from substratum and their accumulation in above-ground parts in comparison with monocotyledonous ones [Jankowska et al. 2007].

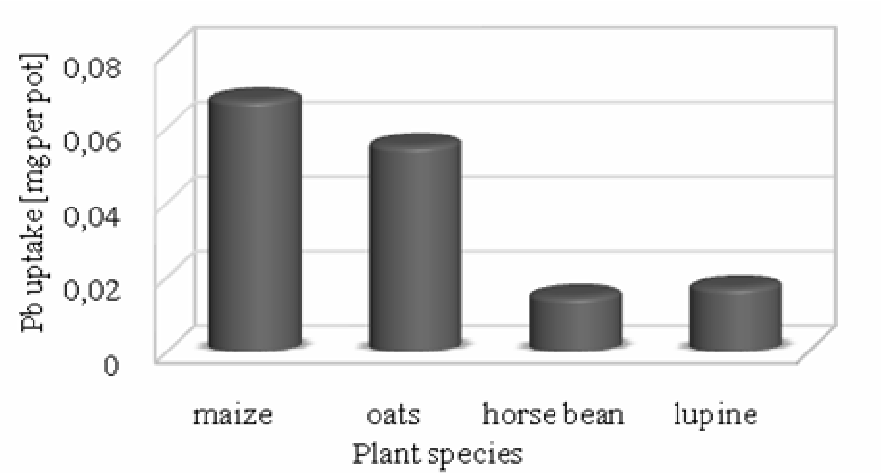
Harmful substances absorption by plants from substratum, inter alia heavy metals, depends on many factors [Gorlach 1995]. In general, under conditions of soils contaminated with trace elements it is substantial to reduce their availability to plant using different methods. Limitation of heavy metals absorption and their entering into plant-animal-human food chain should be an effect of these actions.

*Tab. 1 Mass and share of substratum components and total Pb contents in substratum of individual experimental objects.*

| Substratum mass | Share in substratum | | | | Total Pb content in substratum |
|---|---|---|---|---|---|
| | Soil | Sediment | Soil | Sediment | |
| [kg] | [%] | | [kg] | | [mg·kg$^{-1}$ DM] |
| 4 | 100 | 0 | 4 | 0 | 8.53 |
| 4 | 99 | 1 | 3.96 | 0.04 | 8.57 |
| 4 | 98 | 2 | 3.92 | 0.08 | 8.60 |
| 4 | 96 | 4 | 3.84 | 0.16 | 8.68 |
| 4 | 94 | 6 | 3.76 | 0.24 | 8.75 |
| 4 | 92 | 8 | 3.68 | 0.32 | 8.82 |
| 4 | 90 | 10 | 3.6 | 0.4 | 8.90 |
| 4 | 88 | 12 | 3.52 | 0.48 | 8.97 |
| 4 | 86 | 14 | 3.44 | 0.56 | 9.04 |
| 4 | 84 | 16 | 3.36 | 0.64 | 9.11 |

Total Pb quantity removed with yield of test plant roots was significantly higher than with yield of above-ground biomass in spite of higher tops biomass in comparison with roots yield (fig. 1).

*Fig. 1 The average total amount of Pb removed with yield of test plants*

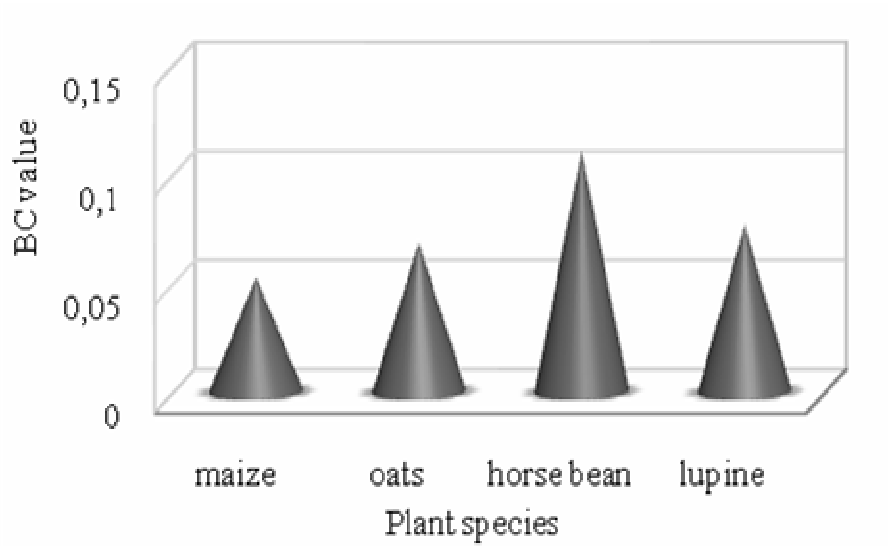


Considerably great quantities of Pb were accumulated in roots, because lead absorption by these parts of plant is a passive process and almost proportional to amount of its soluble forms occurring in substratum [Kabata-Pendias and Pendias 1999]. On average, the most quantities of Pb were removed with yield of maize and the lowest ones with yield of horse bean. It also seems that succession of plants affected amounts of Pb uptake with yield. Significantly smaller amounts of lead were removed with total yield of horse bean and lupine, grown as the second plants in rotation. It is also bound up with generally smaller quantity of biomass produced by dicotyledonous plants in this experiment.

Admissible lead content in fodder plants amounts up to $\leq 10$ mg·kg$^{-1}$ DM [Curyło et al. 1985, Gorlach 1991, Kabata-Pendias et al. 1993]. Considering this criterion, top samples of all the plants contain admisable amount of this metal and they may be allowed as an animal feed.

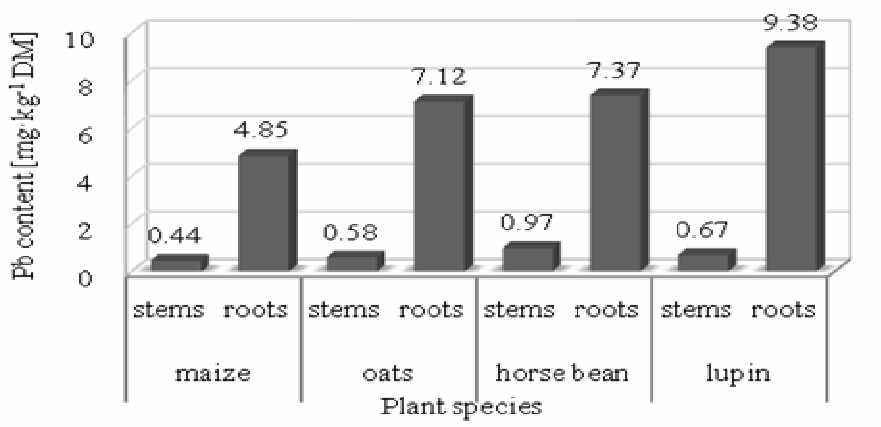
Bioaccumulation coefficient (BC) expresses relation between element content in plant and its content in soil. Analysis of calculated values of Pb BC showed that on average the highest amounts of this metal was accumulated in above-ground parts of horse bean, while the lowest ones in tops of maize (fig. 2).

*Fig. 2 The average BC of Pb in tops of test plants*



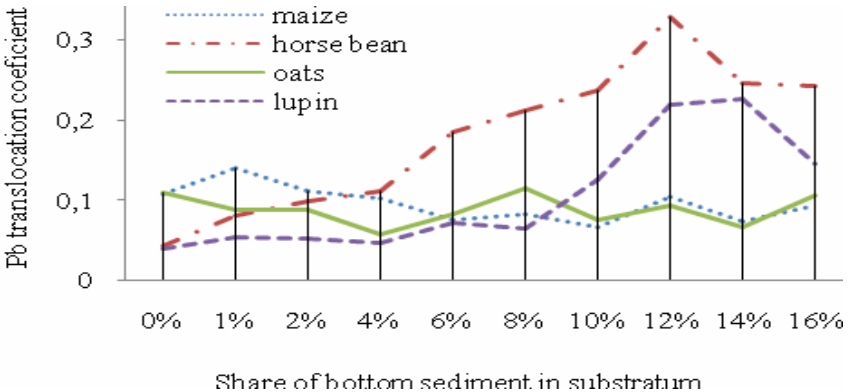

In general, significantly higher values of BC were noted in case of dicotyledonous plants in comparison with monocotyledonous ones. In accordance with the data of other authors [Jankowska et al. 2007] dicotyledonous plants accumulated more Pb than monocotyledonous ones, independently on contamination level of substratum. On average, the highest values of BC were stated in case of plants which above-ground parts accumulated the highest amounts of lead. The lowest average contents of Pb were affirmed both for maize tops and roots, on the other hand the highest average lead contents per 1 kg of dry mass, were stated for horse bean above-ground parts and lupine roots (fig. 3).

*Fig. 3 The average Pb contents in plant tissues*




The translocation coefficient (TC) is a ratio of trace element content in tops *versus* its content in roots. It informs about scale of substances movement from roots to above-grounds parts of plant. There are many plants defense mechanisms, generated by plants cultivated under conditions of contaminated substratum. One of them is reduction or prevention of toxic substances transport to vegetative and generative parts [Baranowska-Morek 2003]. The small values of Pb TC calculated for studied test plants confirm existence of those mechanisms (fig. 4). The highest average translocation coefficient was stated in case of horse bean (0.17), while the lowest one for oat (0.09).

*Fig. 4 Value of Pb translocation coefficient (TC) in tested plants dependent on share of bottom sediment in substratum.*




Relatively low values of TC (fig. 4) are to a large extent caused by dependences between Pb load and its content in plant. It was stated that in parallel with increased content of this metal in substratum after bottom sediment application an increase of Pb content in plants roots was observed [Kabata-Pendias

and Pendias 1999]. Similar dependence between the sediment dose and Pb content in tops was not found. With increasing share of bottom sediment in substratum visible increase of TC values was noted in case of both consecutive plants (lupine and horse bean) grown in experiment and only small changes of TC for maize and oat. One may explain this dependence by decrease of Pb solubility after application of sediment because of its ability to substratum neutralization. Increase of substratum pH value during plants growth period caused decrease of lead availability to plants and in consequence decrease of Pb content in roots what resulted in increase of translocation coefficient value [Gębski 1998]. Bottom sediment dredged from Rożnów Reservoir affected the properties of substratum similarly as liming. According to Sapek [1991], liming is one of the paramount factor which reduce heavy metals mobility, therein Pb, in soil-plant system.

## CONCLUSIONS

1. Under conditions of substratum contaminated by lead significantly higher amounts of Pb were accumulated in roots than in tops of the plant.
2. On average, the highest Pb contents were found in lupine roots and horse bean tops, while the lowest ones in maize both roots and tops.
3. Considering total quantity of Pb uptake the highest its amounts were removed with yield of maize, and the lowest one with yield of horse bean.
4. Considering Pb content, the above-ground parts of test plants suit the criterion of fodder quality.
5. Significantly higher value of Pb bioaccumulation coefficient (BC) was stated for dicotyledonous plants than in case of monocotyledonous ones.
6. With increasing share of bottom sediment in substratum decrease of Pb accumulation in roots of all plants and in tops of maize and oat was observed, while an increase of translocation coefficient (TC) values was noted, especially in lupine and horse bean.
7. Dependence between the sediment dose and Pb content in above-ground parts of horse bean and lupine was not found.
8. Increasing share of bottom sediment in substratum of successive objects caused a decrease of Pb accumulation in plant tissues.
9. In a spite of additional lead load, the bottom sediment applied in experiment did not cause an increase of Pb accumulation in plants because of its ability to substratum neutralization.

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