HEAVY METAL UPTAKE BY PLANTS IN DIFFERENT PHYTOREMEDIATION TREATMENTS

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Abstract: The goal of our research was to develop the phytoremediation technology by testing different treatments under field conditions. The experiment was based on the integrated improvement of physical, chemical and biological conditions of Gyöngyösoroszi spoil. 18 different phytoremediation treatments were tested. The highest chemical risk of Gyöngyösoroszi mine waste was found in case of Pb, Zn, Cd and As. The plots could be successfully vegetated. The biomass production of different treatments was largely different. Multi-level revitalization not only had high impact on the biomass production, but also reduced the heavy metal uptake of plants. The concept of the integrated phytoremediation technology proved to be an efficient tool to stabilize the surface of spoils by plants.

Keywords: heavy metal uptake, phytoremediation technology, multi-level revitalization, rhizosphere soil.

Introduction

Mine wastes represent significant environmental hazards due to their heavy metal content (Komnitsas and Modis, 2006) as well as they are potential Chemical Time Bombs (Murányi, 2000). The uncovered surfaces of spoils are easily transported away by wind erosion. As a consequence of all these, it is important to stabilize the surfaces of mine wastes and to reduce the transport and mobilization of their heavy metal content. Phytostabilization is one of the best available technology to cover the bare spoils with plants (Bíró and Takács, 2007; Farsang et al., 2007).

The goal of our research was to develop phytoremediation technology by testing different treatments and to test them under field conditions.

Materials and methods

The field experiment was carried out on the ground of Gyöngyösoroszi mine. This mine (Pb and Zn mine) has been closed a long time ago, but the problem of mine wastes has not been solved yet. This mine waste was used to develop the phytoremediation technology by integrated improvement of physical, chemical and microbiological conditions. Three large parcels were established.

The oxidation of pyrite content of Gyöngyösoroszi mine waste resulted in pH values about 2.5. No plant can survive such a pH, therefore the mine waste was mixed with fly ash to increase the pH and to improve the physical status of the parcels. Fly ash was supposed to increase the pH up to the range where different plants can exist. One of the three large parcels was also treated with lime to decrease the mobilization of heavy metals and to prevent their plant uptake.

The large parcels were divided into two parts: control part and treated part. On the treated part multi-level revitalization was applied to increase the efficiency of phytoremediation. Multi-level revitalization included nutrient application combined with microbial inoculation. Nutrient application covered inorganic nutrients (NPK fertilizer) as well as organic nutrients (molasses) (Barkóczi et al., 2007). The treated plots were inoculated with a complex inoculant as well (Petrisor et al., 2004).

Three productive plants were selected to stabilize the surface of Gyöngyösoroszi mine waste: grasses (mixture of selected species), sorghum (*Sorghum bicolor* L.) and Sudan grass (*Sorghum sudanense*).
Altogether 18 different phytoremedation treatments were tested. I. parcel: Mine Waste without Fly Ash (FA). Control and untreated plot. 3 test plants. II. Mine Waste (MW) + Fly Ash (FA) without liming. Control and untreated plot. 3 test plants. III. Mine Waste (MW) + Fly Ash (FA) + Liming (L). Control and untreated plot. 3 test plants.

Results and discussion

Chemical risk assessment

On Parcel I (without fly ash mixing) the surface did not vegetate, there was not a single plant, which could germinate. The surface remains totally uncovered, because phytoremediation could not be realized below pH 3.
Phytoremediation on Parcel II and III was successful, the surface could be vegetated. In these parcel we could assess the chemical risks. The chemical risk of heavy metals to enter the food chain was characterized by the heavy metal content of rhizosphere soil samples, analyzed by different methods. Aqua regia digestion characterized the total content, Lakanen-Erviö method characterized the reactive, easily available fraction, acetate extraction simulated the acid rain and distilled water extract corresponded to water soluble fraction of heavy metals.
Total heavy metal content of rhizosphere soil sample indicated As, Cd, Mo, Pb, Zn pollution in each treatment. The reactive, easily available fraction detected Pb pollution in each treatment, and Cd pollution in some treatments. Acetate extract showed Cd, Pb, Zn pollution in each treatment, and As, Ni pollution in some cases. Water soluble fraction identified As, Cd, Pb, Ni, Zn pollution in some cases. Mine waste of Gyöngyösoroszi represents high chemical risks due to its Pb, Zn, Cd and As content.

Biomass production in different treatments

The plants of Parcel II and Parcel III were sampled after harvest and the biomass production was estimated (Figure 1). The treatments resulted in large differences.
The effect of lime application on the yield can be best estimated in case of control plots. Lime increased the yield of each plant. For instance the biomass production of grasses was very little in MW + FA control plot, and very high in MW + FA + L control plot. The deviation is caused by the pH difference of rhizosphere soils. The pH_{KCl} in Parcel II (without liming) was 4.6 (grasses), 3.9 (sorghum), 3.9 (Sudan grass), while in Parcel III (with liming) pH_{KCl} was 7.7 (grasses), 7.7 (sorghum), 7.8 (Sudan grass). Liming was efficient to increase the biomass production in the control parcels.
The effect of multi-level revitalization is clearly demonstrated if the control plot is compared to the corresponding treated plot. In Parcel II (without liming) the biomass production was increased from 2 g m^{-2} to 501 g m^{-2} (grasses), from 45 g m^{-2} to 344g m^{-2} (sorghum), from 44 g m^{-2} to 437 g m^{-2} (Sudan grass). In Parcel III (with liming) the biomass production was increased from 336 g m^{-2} to 728 g m^{-2} (grasses), from 194 g m^{-2} to 270 g m^{-2} (sorghum), from 78 g m^{-2} to 546 g m^{-2} (Sudan grass).

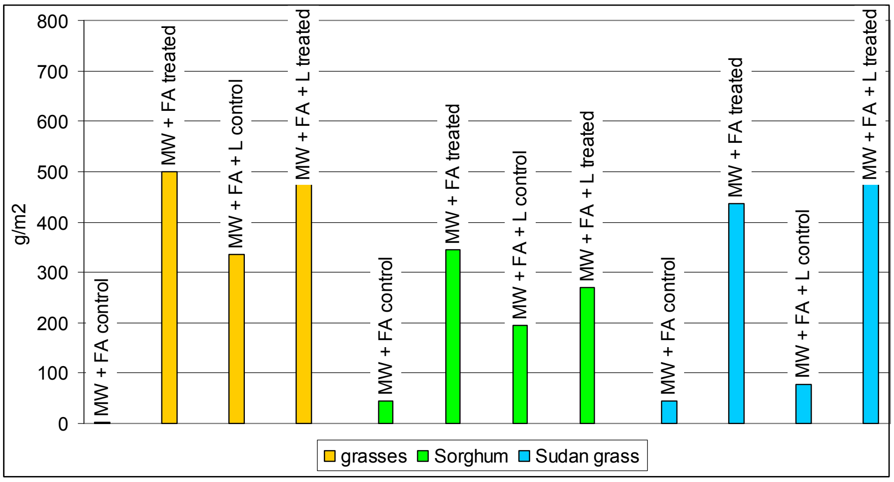

Figure 1. The estimated biomass production of different phytoremediation treatments.

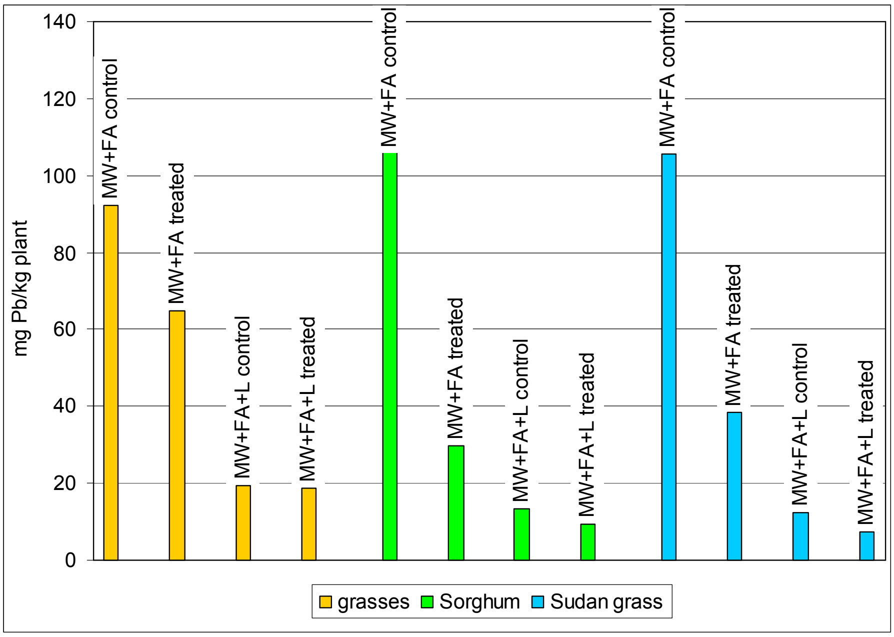

Figure 2. Heavy metal concentration of harvested plants.

Heavy metal uptake of different plants

The heavy metal content of harvested plants were determined and large differences between different treatments were found. Figure 2 shows the lead concentration of plants as a function of phytoremediation treatments.

The highest concentrations were measured in case of control treatments without liming. Mixing fly ash into mine waste did not prevent lead uptake by neither of plants that is Pb content of mine waste was not stabilized from chemical point of view. In the control treatments Pb concentration was 92 mg kg^{-1} in grass, 122 mg kg^{-1} in sorghum, and 106 mg kg^{-1} in Sudan grass. These high concentrations were reduced by applying multi-level revitalization: Pb content decreased to 65 mg kg^{-1} in grasses, to 30 mg kg^{-1} in sorghum and to 38 mg kg^{-1} in Sudan grass.

Low Pb concentrations were measured in Parcel III, where lime was applied. Pb concentration of control parcels could be further decreased when multi-level revitalization was applied, but the effects were much smaller than in Parcel II. Application of lime efficiently reduced the Pb uptake of each plant.

Conclusions

The chemical risks of the Gyöngyösoroszi spoils were assessed. The major contaminants of the waste mine were identified: Pb, Zn, Cd, As.

The concept of the integrated phytoremediation was successfully applied to vegetate Gyöngyösoroszi spoil. The biomass production was different, depending on the technology variant. The highest biomass production was achieved, when multi-level revitalization was also applied.

The integrated phytoremediation treatments not only produced high biomass, but also decreased the heavy metal content in the plants.

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