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Phytoremediation as a program for decontamination of heavy-metal polluted environment

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ABSTRACT The aim of the project is to develop a biotechnology which is able to detect and eliminate pollutant heavy metals from the environment. Elements of the system include introduction of heavy metal accumulating plants (endemic or foreign) in the target areas (polluted soil, refuse dumps, slurry); increasing the uptake of heavy metals with local stress resistant bacteria and fungi species in the plant rhizosphere; monitoring the actual metal load with transgenic cyanobacteria functioning as biosensors. The expected result is a technology ready for application, involving special combinations of soil- and heavy metal-specific plant and microbial species, and the technical details of application and related know-how including detoxification of the final product. Application of the technology decreases the rate of pollution under limiting values. The advantage of phytoremedial methods include reduced expenses and the natural restoration of nature.
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KEY WORDS

heavy metal pollution
phyto(bio)remediation
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In these recent years, one of the most important global problems is the pollution of the environment by our industrial, economic or social activities. In 1999, according to the European Environmental Agency, 1.5 million contaminated localities were counted alone in the (then) 13 states of the EU (EEA-ETC/S, 1999). Heavy metals are considered toxic compounds as their targets are essential metalloenzymes. Metal-accumulating plant species can concentrate heavy metals like Cd, Zn, Co, Mn, Ni, Pb up to 100 or 1000 times those taken up by non-accumulator (excluder) plants. The phytotechnology using plants for clean-up of contaminated sites, soil or water is known as phytoremediation. In most cases, microorganisms bacteria and fungi, living in the rhizosphere with close association with plants, may contribute to mobilize metal ions, increasing the bioavailable fraction [phyto(bio)remediation]. Their role in eliminating organic contaminants is even more significant than in case of inorganic compounds.

Phytoremediation technologies, depending on the type and speciation of the pollutant, are based on the applicable characteristics of the plant species (Salt et al. 1998):

-phytoextraction; absorption of contaminants in the roots and translocation into shoots that can be harvested and burned gaining energy and recycling the metal from the ash;

-phytostabilisation; that is immobilization of organic or inorganic pollutants preventing their migration in soil, as well as their movement by erosion and deflation. Hydraulic control is part of this technique by using phreatophyte trees (*Salix, Populus*) which intensively transpire;

-phytodegradation and phytotransformation are applied for removal of organic contaminants;

-rhizofiltration, by constructed wetland for cleaning up communal wastewater;

-phytovolatilization, uptake and release into the atmosphere.

These technologies usually include reduced expenses and the natural restoration of nature compared to chemical and physical remediation techniques. The main obstacles for large-scale application are the long time required for the remediation and the limits of plant tolerance towards toxic compounds (Schwitzguébel et al. 2002). In Europe, phytotechnologies aiming at the remediation of contaminated environment and protect food safety are co-ordinated by COST Actions (COST action 837, 1999-2003, COST Action 859, 2004-2009).

The aim of this project is to work out different methods to stabilize and extract toxic metal elements from contaminated soils, warps and other industrial or mining waste materials by different plant species in order to reduce the danger for getting these elements into the environment. We are going to focus on phytostabilization and phytoextraction technologies.

Main elements and participants of the project

The project includes basic research (20%), applied research (60%) and technical development (20%) properly distributed among the members of the participating institutions.

Monitoring and application of special, endemic or introduced, species to hyperaccumulate heavy metals on the contaminated area (Department of Plant Physiology, University of Szeged, Szeged, Hungary);

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Soil monitoring on the contaminated areas: changes in element content, pH, moisture and other physical and chemical parameters under different plant cover (Department of Physical Geography and Geoinformatics, University of Szeged, Szeged, Hungary);

Stimulation of heavy metal uptake in plant roots by bacteria and fungi species living in the rhizosphere (Institute for Biotechnology of Bay Zoltán Foundation for Applied Research, Szeged, Hungary);

Monitoring of the environmental metal loading with biosensors as by cyanobacteria transformed for this purpose (Institute of Plant Biology, Biological Research Center, Hungarian Academy of Sciences, Szeged, Hungary);

The contaminated areas and materials as well as infrastructural and technological background are presented by Aquadukt Ltd. (Szekszárd, Hungary) and Hologén Ltd. (Szeged, Hungary).

Elimination of the end product: the contaminated biomass coming from the field plots get into special burner with possibility to recycle metal content from the ash (phytomining). (Hologén Ltd, Szeged, Hungary).

Monitoring and analysis of plant species and soil samples from two target localities, Mártély (South Hungary) and Almásfüzitő (North-West Hungary) are being carried out. At Mártély, a slurry deposite (16 000 m^3) and at Almásfüzitő, „red sludge" from alum earth factory and other, presumably heavy metal-contaminated areas are the study sites.

Our first results are related to the slurry removed from the oxbow lake at Mártély (used to be a bend in Tisza river) which contained Zn, Pb and Cr above the environmental limit value (ethylenediamine tetraacetic acid extraction). The level of contamination, however, was still well tolerated *in situ* by *Salix sp*., *Phragmites australis* and some other species. In November 2004, a large number of species were found on and at the shores of the slurry (Vashegyi et al. 2005). In further experiments, heavy metal load on *Salix* clones rooted and grown hydroponically under greenhouse conditions proved that Zn was taken up by roots and relatively large proportion of it was translocated to the leaves, while Pb and Cr were retained in the roots (Vashegyi et al. 2005). In our further plans, therefore, we are going to continue physiological experiments for heavy metal accumulation capability of different species, to carry out field trials on experimental slurry plots constructed for this purpose at Mártély and to establish *Salix* cultures on the pilot-sized slurry beds.

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