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SOIL REMEDIATION – AN ALTERNATIVE TO ABATE HUMAN EXPOSURE TO HEAVY METALS

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Abstract. This paper addresses the issue of soil pollution in the context of historical background, and its implications for the human exposure to heavy metals. The importance of metal bioavailability is also stressed. Various approaches to the problem are described, including administrative and technical preventive measures.

Key words:
Soil pollution, Land use, Human exposure, Heavy metals, Metal uptake, Soil cleaning

Due to the existence of geological deposits of useful minerals such as coal and metal ores, some areas in Europe have a long history of industries such as power production, metallurgy and chemical manufacturing. In Central Europe of the 19th century, medieval silver and zinc industries began polluting the environment with substances released to air, water and soil. The Industrial Revolution which took place in the late 18th and early 19th centuries, created a high demand for manpower, which resulted in an enormous increase in the population density in the industrial areas. Owners of industrial enterprises were mainly interested in short-term profit, without showing much consideration for the worker's health and environment. The adverse effects of man-made substances on humans and other living organisms were either unknown or ignored. During the last few decades, the world has become more environmentally responsible, however, the quality and quantity of emitted pollutants has become more complex and difficult to manage.

Many industrialized countries around the world followed a similar pattern of the development. Applying various approaches, the USA and the European Union, have overcome many significant environmental problems. Central and Eastern European countries are in a transitional phase in their socioeconomic development as they move from centrally-planned to free market economies. Nowadays, some of these countries must face the challenge of joining the European Community and address the difficult issues of harmonization. Frequently, uneasy choices have to be made between satisfying urgent basic needs and undertaking long-term actions needed to ensure appropriate quality of life.

It should be emphasized that financial constraints are the major factor that limits the range of remediation activities regardless of an approach adopted. Therefore, the future land use should be analyzed carefully before the clean-up process begins to avoid unnecessary expenditures. A simplified method of land categorization may serve the purpose. The land use categories may be based on the sensitivity of different lands to environmental contamination.

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The following land use categories may be distringuished:

1. Very sensitive
- kindergartens
- playgrounds
- garden allotments
- farming areas
- household gardens

2. Moderately sensitive
- houses
- resthomes

3. Sensitive
- offices
- shops
- industrial facilities

4. Less sensitive
- roads
- parking lots.

Considering biodegradable pollutants, the process of natural attenuation may be regarded as environmental self-cleaning. In many situations, natural systems are capable of degrading organic contaminants to less- or non-toxic by-products. Unfortunately, natural attenuation is not applicable to heavy metals, which are persistent pollutants and remain in soil indefinitely. Soil contaminated with heavy metals may contribute to human exposure by (a) inhalation (through respiratory uptake) of suspended metal-containing dust; (b) digestion (digestive tract uptake) from contaminated food or drinking water; and (c) involuntary ingestion by children (e.g. *pica).*

In the vicinity of industrial enterprises, metal content in plants, resulting from soil pollution is high enough to prohibit from consuming them by humans or animals [1]. Soil pollution is not only a concern for small scale, backyard gardens and large-scale commercial agriculture, but also kindergartens, playgrounds, public recreation and residential areas. In the environment, the chemical form in which a metal occurs (i.e. speciation) is important. The uptake of metal by a living organism is a function of bioavailability which, in turn, depends on the solubility of the compound in water and bioliquids. Bioavailable metal concentrations in soils may be sufficiently high as to impair plant growth or conversely, metals may be present at extremely high concentrations, but not in bioavailable forms, resulting in low risk to living organisms.

Over the last decade, an increasing number of research groups have explored solutions for the reclamation of contaminated areas.

Fig. 1 shows the decision-making process associated with the land reclamation activities. The first step is an **environmental impact assessment** to determine the present impact of contaminated soil on the following factors: land users, remediation workers, non-human receptors (ecological impacts) and remedial goals.

When approaching the problem of contaminated land, technical or administrative methods may be used. However, the administrative methods are generally preferred, as the cost factor is much lower than that for any technical methods. The system of land categorization used in the Upper Silesia Industrial Region of Poland [2] serves as an example of an administrative control. A three-category scale of land suitability was constructed to advise farmers, local agricultural administrators, and land planners on the risks associated with various uses of a given site. The category scale is based on the degree of contamination in a particular area and considers the status of the local environment.

There are three categories:

Category A – safe zone – all agricultural crops can be planted without danger to consumers.

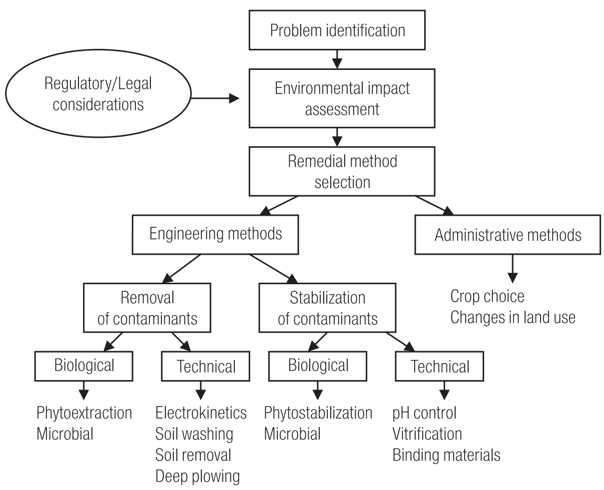

Fig. 1. Decision-making process in soil remediation.

Table 1. Estimated costs of various methods of soil cleaning obtained from various sources

Type of treatment	Cost/m^3 in US $	Time required (months)
Fixation	90–200	6–9
Landfilling	100–400	6–9
Soil extraction, leaching	250–500	8–12
Phytoextraction	15–40	19–60

Category B – intermediate zone – limited agricultural activity (low-cumulating species consumed in small quantities can be grown).

Category C – unsafe zone – growth of edible and pasture plants is not recommended.

This type of categorization serves as a guide and contains many simplifications. Therefore, a more detailed analysis of each area of contaminated soil is required before a final decision on the plant species selection.

For the lands of category C, decisions must be made to remediate the soils or restrict land use. If technical methods are used for soil remediation, the site characterization data should be collected in order to provide the necessary information as to what method of remediation, removal or stabilization, is applicable. This should be followed by a **feasibility study** to determine the cost/performance of the proposed remedial project. Table 1 shows cost estimates for the most frequently used soil cleaning methods. The costs of technical soil cleaning methods for metals are extremely high even for countries with strong economies. Therefore, research efforts have been directed towards biological approaches, which are more economically feasible and environmentally friendly. **Phytoextraction,** the use of plants to remove metals from contaminated soils [3,4] is a promising biotechnology.

The multi-criteria and multi-perspective analyses of contaminated land management [5] are useful in selecting the most appropriate remediation method in a given situation. This analytical tool allows to assess technical, economic and social aspects of land management.

In the developing countries, soil remediation is often limited to the stabilization of metals due to economic constraints. Among the various methods of stabilization the most promising is a combination of chemical and biological methods. The pollutants are first bound chemically, to form insoluble compounds in soil. This prevents metals from entering the soil solution. Such an arrangement reduces metal bioavailability to plants growing on the soil surface and protects groundwater from contamination. Another step in the combined method is planting a biological cover on the surface of the remediated area. The preferred species would be an indigenous grass, whose growth is supported by the target soil. The majority of grass species do not accumulate metals in above-ground parts, thus retain the contaminants below ground. Grass forms a dense root mat, which is not permeable to rainwater, and prevents potential solubilization of soil metals. This root mat also prevents windblown resuspension of metal-containing dust. The stabilization technology is not a final solution, but it may serve for diminishing the problem. In many situations isolation may be the only immediate, affordable way of reducing exposure to metals in soil.

References

1. Gzyl J. *Ecological impact and remediation of contaminated sites around lead smelters in Poland*. J Geochem Expl 1995; 52: 251–8.
2. Kucharski R, Marchwińska E, Gzyl J. *Agricultural policy in polluted areas.* Ecol Eng 1994; 3: 299–312.
3. Kucharski R, Sas-Nowosielska A, Dushenkow S, Kuperberg JM, Pogrzeba M, Małkowski E. *Technology of phytoextraction of lead and cadmium in Poland. Problems and achievements.* Proceedings of the 4th International Symposium and Exhibition on Environmental Contamination in Central and Eastern Europe, Warsaw, Poland. Contribution 435 (CD-ROM); 1998.
4. Sas-Nowosielska A, Kucharski R, Nowosielski O. *The use of zinc-tolerant plant species for soil pre-treatment before lead and cadmium phytoextraction*. Proceedings of the 4th International Conference "Soil Monitoring", Czech Republic, Brno; 1999. p. 20–23.
5. Janikowski R, Kucharski R, Sas-Nowosielska A. *Multi-criteria and multi-perspective analysis of contaminated land management methods.* Environ Monitoring Assessment 2000; 60: 89–102.

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