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Phytoremediation, a Cheaper and Ecological Alternative in Solving Historical Soil Pollution

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Abstract: Romania, since the pre-accession phase to the European Union, has committed itself to implementing environmental policies in accordance with European legislation. Regarding the stage reached, only a part of these obligations regarding the ecological sanitation of some post-industrial sites were respected, an insignificant part. Many places in Romania are characterized by an emanating, historical pollution. This is the result of decades of inefficient communist economy, with little respect for the environment, high energy consumption and little-added value. To continue solving these problems of historical pollution, enormous funds are needed and the ecological remediation and reconstruction works will be more numerous and increasing. An efficient, environmentally friendly and inexpensive solution is the application of bioremediation methods. These ecological methods are widely observable worldwide, especially in developed countries. Phytoremediation, in turn, is a major method of depollution of contaminated ecosystems, especially those polluted with oil residues from old petrochemical plants or heavy metals from metal mining and processing activities. These economic activities had a wide spread on the Romanian territory during the socialist epoque, and that is why today many polluted areas have remained ecologically unhealthy. Phytoremediation being a much cheaper method than others, which falls within the concept of sustainable development, has great economic and ecological potential in Romania and must be assumed as a variant that should be quickly applied to the situation on the ground. This will be even more necessary in the context in which budgetary allocations for solving environmental problems are in competition with other needs that require the same limited source of funding.

Keywords: phytoremediation; soil pollution; decontaminations; phyto-extraction

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Introduction

The conservation of soils' biodiversity and its improvement in areas that faced negative impact actions (soil pollution with organic contaminants or with heavy metals, physical degradation of the soils with serious implications on the living conditions of the living organisms in the soil etc.) represent major interest themes for scientists and for the whole for specialists, as they have a strong influence on the soils' natural fertility and the ecologic balance of the targeted areas.

These researches got wider due to the awareness of the risks raised by industrialization and its impact on the soil, as a stability factor for the environment, as well as an economic stability factor, generating food for the continuously increasing human population and the demographic pressure generated by it.

The correct approach of an ecological rehabilitation and reconstruction strategy must consider the fact that the ecosystems are living systems, whose components continuously communicate information, both between them, as well as with the environment, in the need to get adapted to the new situation created by pollution.

During the last decades, concerns regarding the heavy metals' contamination has grown, due to their toxicity against animals, plants and microorganisms and due to the fact that they irreversibly become stuck in the soil components or in the ground water (McGrath & Lane, 1989).

The levels of the metal content in the soil depends on the level of emissions, on the transportation of the metal from the source to the place of accumulation and on its remanence, once it reaches the soil. Several metals, such as Zn, Cu, Ni and Cr, are essential or positive micronutrients for plants, animals and microorganisms, while others, such as Cd, Hg and Pb have unknown biological and/or physiological functions. Nevertheless, all these materials can be toxic in relatively low concentrations. Heavy metals that tend to raise most concerns toward human health, agriculture and ecotoxicology are As, Cd, Hg, Pb and U.

The need to use phyto-remedies as decontamination method has imposed due to the increasingly numerous cases of environmental pollution, because of extensive usage, during the last decades, of different chemical substances in various economic fields, in many cases without taking anything in consideration (McCutcheon, 2003).

Describing the Problem

Soil pollution in Romania represents a historical problem, as there were many sites on which industrial objectives functioned during the socialist period, which were polluted with various toxic substances. In fact, not only the soil, but the water and air had the same faith, the contempt for nature and environmental protection being total during that period. The immediate environmental costs or the later ones did not matter for anybody. It was only when Romania adhered to the EU, through its assumed obligations against the environment and the cleansing of these sites with a post-communist soil pollution, the country was forced to find and implement solutions. The costs for them are too high, they assume, in many cases, complex technologies, where access is expensive and the results are not the best ones in many cases. Moreover, sometimes adjacent problems appear, which, to be solved, assume the finding of solutions unfriendly to the environment.

To make a short radiography of the size of contaminated soils' problem, we must present several terrible aspects, presented in many cases even by the central media, which show the gravity of the phenomenon.

In 2015, the Government of Romania adopted the National Strategy for the Management of Contaminated Sites. It signaled the fact that 210 contaminated sites were inventoried, on which more or less complex studies were made; excepting these sites, there were still 1183 location ranked as "potentially contaminated". It is interesting to determine what this "potentially contaminated" concept refers to. According to this document, a potentially contaminated site is represented by and area about which there is credible information that faced polluting activities in the past, but on which no needed studies and text have still been carried on (level II environmental balance or risk evaluation report), to prove the contamination.

Considering this definition, it is logical to think that the number of these polluted soil sites is strongly underestimated, for which pollution has not been yet proved. We can give Germany as example, country in which the initial number of contaminated sites was estimated around 170000 in 1995; by analyzing the Federal Environment Minister for 2020, we can see that today, 26 years later, the number of contaminated sites, at federal level, is 354405, after decontamination activities were already finished in 29808 sites (www.umweltbundesamt.de). We can thus see that soils' pollution was strongly underestimated. There is no reason for us to believe that the situation would be different for Romania. First of all, the first scientific argument might be the fact that polluting agents migrate, very easy in many cases, from the initial area, when they were spilled, to other areas in their proximity.

Second, the underestimation of the numbers regarding the soil-polluted sites in Romania has another cause too, a judicial one. For example, as long as the state issued a functioning authorization for an economic agent on a certain field, or in the case of a person, a construction authorization, if they later discover that the soil in contaminated, whose fault is it? But if, for example, subsequently to the discovery of pollution, the value of the terrain decreases, maybe even to zero and this area was used as a warranty for a credit in the bank?

Let us remind ourselves what happened during the construction of the highway sector by the Bechtel Company. At a certain moment in time, on the surface of the highway, a surface of approximately 12000 square meters was discovered as being polluted with Hg, and also DDT, the Environmental Guard did not know about the existence of these pollutants deposits (https://green-report.ro).

In fact, Expert Cornel Gabrian Florea, author of the strategy, shows that, in Romania, there are more than 900000 hectares of soil polluted with heavy metals. (www.money.ro).

The National Strategy for the Management of Contaminated Sites from 2015 mentions the costs of cleansing the contaminated and potentially contaminated sites as going up to approximately 8.4 billion EUR! Due to the unlimited number of pollutants and their combinations, as well as to the large diversity of classes, types, under-types of soils, of the multiple variants regarding their physical proprieties (especially regarding their structure and texture), and also to the chemical proprieties, there is no generally available method to repair the soils.

Phyto-remediation has the most remediation mechanisms, which include intensified degradation in the rhizosphere (rhizodegradation), phyto-extraction (phytoaccumulation) phytodegradation and phyto-stabilization, or phyto-filtering – the use of hydroponic growth plants to absorb or adsorb the heavy metal ions in underground waters and watery wastes (Yan, 2020). It is more than obvious that the most efficient solutions are found after some enhanced technical and scientific studies, but all must also be compared to the financial resources, which is always limited, so that it would not generate unjustified expenses.

Phyto-remediation can also be used to decontaminate both organic and inorganic pollutants in the soil, water and air, being known that approximately 64% of the polluted sites contain combinations of organic and inorganic substances (Ensley 2000).

The use of traditional methods is much more expensive in most of the cases. These methods, such as scraping, transportation of polluted soil, decontamination and relocation on the old surface lead to very high costs. Even the soil decontamination, when possible, with substances that can “wash” the polluted soil is expensive and the procedure is imperfect, leading to secondary pollution, as residual substances that contain the pollutants must also be managed, decontaminated.

The efficiency of plants as “decontaminants” or “filters” was proved in the decontamination of soils polluted with raw oil, explosives, metals, pesticides, polycyclic aromatic hydrocarbons. Bioremediation is not applicable when the pollutants in the soil cannot be biodegraded or if their bioaccumulation is impossible (bio-sorption) (Shah, 2014).

Bioaccumulation is defined as an absorption phenomenon of pollutants by living organisms, and Biosorption is defined as “ability of biological materials to accumulate heavy metals from wastewater through metabolically mediated or spontaneous physicochemical pathways of uptake, or as a property of certain types of inactive, non-living microbial biomass, which bind and concentrate heavy metals from even very dilute aqueous solutions” (Shamim, 2018).

Phytoremediation is defined to be „a bioremediation process that uses various types of plants to remove, transfer, stabilize, and/or destroy contaminants in the soil and groundwater.” (www.cpeo.org)

Conventionally, hyperaccumulating plants are defined as species capable of bio-accumulating metals at 100 higher levels compared to the levels that are usually found in common plants, the ones that are considered non-accumulating. The tissues of some plant species can accumulate impressive volumes of metals, as it might get profitable to extract those metals from the ashes of those plants.

The success of phyto-remediation, in the case of a certain site, cannot be also attributed to a single method of phyto-remediation, as the combined usage of more procedure is more indicated from the perspective of ecologic, economic efficiency and of the shortening of the time needed for depollution activities.

Species that are able to accumulate large substratum of heavy metals are known from the bryophytes (Ren et. al., 2021; Jiang et. al., 2018; Boyd, 2009; Verbruggen et. al, 2009; Vukojević et al., 2005; Ah-Peng & Rausch De Traubenberg, 2004) and ferns

(Grosjean et. al., 2021; Drăghiceanu et al., 2016; Drăghiceanu & Soare, 2016; Drăghiceanu et al., 2014; Tiwari et. al., 2013). Amongst angiosperms, 400 hyper-accumulators were identified (Parvaiz, 2015; Hemen, 2011), notable families being the Asteraceae, Brassicaceae, Caryophyllaceae, Cyperaceae, Fabaceae, Lamiaceae, Poaceae, Violaceae and the Euphobiaceae. Brassicaceae family includes the largest number of taxa (11 genres and 87 species) with the ability to hyper-accumulate metals (Prasad & Freitas 2003). The list of heavy metals hyper-accumulators includes 145 hyper-accumulators for Ni, 26 for Co, 24 for Cu, 17 for Cd, 14 for Zn, 4 for Pb and 28 for Cr.

Within the phyto-remediation procedures, one may use both grassy and tree species. Depending on the pollutants, one chooses the species, through which its physiology and ecology fits the best to extract, from polluted soil, through bioaccumulation, the pollutant and which can support a high concentration of pollutants.

It is needed to accurately know the biodegrading products subsequently resulted in the metabolism of the involved plants. The question that is raised is not only which those substances are, but also which their mobility in the trophic chains or in the bio-geo-chemical circuit is. For example, the consumption of some parts of plants by the animal is dangerous or not? The accumulation of a vegetal mass volume on the soil and its discomposure leads to contamination of the soil or not or of the underground waters? If some tree species are used for phytoremediation, the wood of those trees can be safely used for burning or in the furniture industry?

At least for heavy metals, the collection and processing of plants that contain a high concentration of such pollutants is difficult (www.cpeo.org). We can though consider that the processing of plants used for phytoremediation, contaminated with a high volume of heavy metals, has a secondary pollution component, if we only consider the needed energy.

The type of used plant must also consider the maximum depth at which the pollutant reached in the soil. The roots of the plant must reach this depth.

If the level is too deep for a species of plants, other species is used, one whose roots go deeper and whose physiology allows the extraction of the pollutant. As trees have deeper roots, they better match the extraction of pollutants at lower levels in the soil.

If the pollutant reached the underground water table, a solution might be represented by pumping the contaminated water toward the surface and watering of the plants used for phytoremediation, so that they would be able to extract the toxic substances in the water.

The phytoremediation procedure is limited by the climate area; in areas with tempered climate or with draught seasons, when the plants significantly reduce their physical processes, the pollutant extraction procedure by the plant does not function in the winter or during the dry season.

We must also consider that, through phytoremediation, one would not reach the transfer of the pollutant from the soil in the air or water, for example, by watering the plantations when they are established (www.cpeo.org).

The decontamination of polluted sites must meet the specific conditions of each location and the type of polluting substance. We must mention that there is no perfect method and the choosing of the remediation method differs from a case to another.

Conclusions

Although phytoremediation cannot be the perfect solution, a panacea for all cases, its usage is preferred, especially when it comes to the soils that were contaminated with dangerous waste, such as the ones polluted with heavy metals or hydrocarbons or other chemical substances that are highly stored in the soil. For large or average areas, where the contamination is superficial or average, phytoremediation is a viable alternative against traditional physical and chemical methods. Compared to traditional technologies, phytoremediation has two major advantages: it is relatively cheap and have a low impact on the environment; moreover, the method is highly accepted by the civil society.

Phytoremediation procedures can be applied "in situ", being way simpler to implement, monitor and quantify the results, with no additional costs regarding the extraction, transportation and relocation of contaminated soil, as costs are lower.

Economic or other kinds of activities in the area are noted interrupted during the implementation period of this procedure and it also leads to lower costs compared to traditional methods.

Considering the large biodiversity loses caused by the intense environmental pollution phenomena at the global level, the benefits of phytoremediation can compensate in a relatively rapid manner, the costs of investments in the application of these methods for the ecologic rehabilitation and reconstructions of ecosystems.

Phytoremediation meets some real requirements, having in mind that one of the most keen components that pollutes the environment behind the legal regeneration limit of natural systems is the accidental pollution phenomenon and the contravention nature, alongside the faulty management of diverse waste and the urgent need to solve some pollution-related issues.

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