Analele Universităţii din Craiova, seria Agricultură – Montanologie – Cadastru (Annals of the University of Craiova - Agriculture, Montanology, Cadastre Series) Vol. XLIV 2014

PHYTOREMEDIATION USING MEDICINAL PLANTS - A REVIEW

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Keywords: contaminants, hyperaccumulation, medicinal plants, phytoremediation, poluted sites.

ABSTRACT

Intensification of industrial activities and the demographic explosion resulted in severe environmental pollution, with dramatic consequences on the atmosphere, water and soil. The pace of production and dispersion of the pollutant exceededat present the natural processes of of biodegradation, the release of toxic substances into the terrestrial ecosystem representing a major problem. In search of technological remedies of the environmental pollution, phytoremediation, that uses directly green plants, provides important perspectives. Although at present this therapy technique is poorly implemented, it presents certain advantages including the reduced environmental impact. Therefore, this paper is a synthesis that aims to highlight the use of medicinal plants, specially selected for the greening of polluted areas.

INTRODUCTION

Phytoremediation is an emerging technology appeared in the last decade of the twentieth century. Its denomination comes from the Greek word *phyto* = plant and the Latin word *remedium* = to correct, removing of something harmful. This technology uses different plant species, having the ability to degrade, extract, accumulate, immobilize and remove the pollutants from soil, water or air [6].

So the process of phytoremediation consists in the use of the green plants to remove the pollutants from the environment or to reduce their toxicity. The pollutants which can be removed by using the techniques of phytoremediation are represented by heavy metals (Cd, Co, Pb, Cu, Ni, Se, Zn and others), radionuclides (Cs, Sr, U, Ra and others), chlorinated solvents (TCE, PCE), petroleum hydrocarbons (BTEX), different nutrients (nitrates, ammonia, phosphates,) and others [6].

Phytoremediation is an effective technology for the removal of a number of inorganic and organic pollutants. Some plant species present both the capacity to mineralise and transfer in the root toxic organic compounds, and the accumulation and concentration of some inorganic compounds in the aerial part of the plant [30]. The inorganic pollutants appear as natural elements of the earth's crust or atmosphere and from the human activities such as: mining, industry, auto road traffic, agriculture, which favors their release into the environment, leading to toxicity. The inorganic pollutants do not degrade, but their toxic effect can be phytoremediated by stabilizing or by blocking them in the harvested plant tissues [7].

Phytoremediation has become popular in the last 10 years. This is on the one hand due to the low cost of implementation and, on the other hand, due to the limited cost available for the environment cleaning. Currently, the US are spent 6 to 8,000,000 dollars for the environmental cleaning and 25 to 50,000,000 dollars per year in the world [11].

In Europe there is not a significant commercial use of the phyto-remediation, but this ecological technique can be developed in the following years [7].

In Romania the universities and research institutes have a greater importance in the preparation, education, analysis, implementation and long-term monitoring of the environmental protection activities [5].

The applicability of phyto-remediation for the rehabilitation of contaminated sites has been proven by numerous scientific projects implemented also in Romania: FITORISC [32], ECORES [31], SEDI.PORT.SIL [30] etc

Plants are not only source of food, fuel, fiber, but also environmental counterbalances to industrial and agriculture pollution. The plants and their abilities are [1]:
- living plants can be compared to solar driven pumps which can extract and concentrate several elements;
- plants absorb a high number of elements from soil and water;
- they also have the ability to remove, contain, inactivate or degrade harmful environmental contaminants, such as: Cd, Hg, Pb, St;
- heavy metal accumulation in edible plants must alert the public on potential risks of toxicity effects, because chemical composition of plants reflects the elemental composition of the soil;
- practically, chemical composition of any plant depends upon the local geographical conditions, type of soil and its composition;
- plants have the ability both to tolerate elevated levels of heavy metals and accumulate them in very high concentration.

MATERIAL AND METHOD

At least 400 species distributed in 45 botanical families are considered metal hyperaccumulators. By definition, hyperaccumulators are herbaceous or woody plants that accumulate and tolerate without visible symptoms a hundred times or greater metal concentrations in shoots than those usually found in non-accumulators [1].

The plants hyper-accumulators are able to accumulate metals into the overground tissues without the occurrence of the symptoms of toxicity, reaching tissue concentrations higher than in the contaminated soil. The phytoextraction process is used for the purpose of the decontamination of the substrate on which the plants are growing, thus making possible to reuse the extracted metals or their export from the polluted area [19].

Trhe aromatic plants are cultivated for the production of essential oils and food processing. The essential oil of aromatic plants is being used in soaps, detergents, insect repellents, cosmetic, perfumes and food processing industries. These plants are non edible and are not being consumed directly by humans or animal like the cereals, pulses or vegetables. The essential oil from aromatic plants is free from the risk of heavy metals accumulation from plant biomass. The heavy metals do not enter the food chain through phytoremediation by aromatic plants. The wild animals do not damage/eat the aromatic crops due to its essence. In fact, aromatic plant resources are very abundant, and they can be used on large scale. These plants offer a novel option for their use in the phytoremedation of the heavy metal contaminated sites [12].

The studies conducted in the phyto-remediation field showed that this type of treatment presents a significant potential, applicable for the elimination of: heavy metals, radionuclides, chlorinated solvents, chlorinated pesticides, organic phosphorous pesticides, explosives, nutrients, surfactant agents [30].

The rehabilitation and ecological reconstruction of the contaminated soils and waters from the municipal and industrial landfills is done using both physical and chemical methods, as well as biological methods. Of the biological methods, the most common are [31]:

- bioremediation by means of micro-organisms [31] and of the biostimulants beneficial for the contaminants decomposition and their transformation into non-hazardous secondary products [21];
- the phytoremediation, consisting in the use of the vegetation for the in situ treatment of the soil, sediments and the contaminated waters. The method is based primarily on the

ability of plants to store the extracted metal into roots and / or into the aerial parts, or to release it into the atmosphere through the process of transpiration [32]. The plants have shown the ability to resist to relatively high concentrations of organic pollutants without the occurrence of toxic effects, being able to absorb and transform them quickly in metabolites with a toxicity significantly reduced [31].

Though several regulatory steps have been implemented to reduce or restrict the release of pollutants in the soil, they are not sufficient for checking the contamination. Metal contaminated soil can be remediated by chemical, physical and biological techniques. These can be grouped into two categories [9].

Ex-situ method

It requires removal of contaminated soil for treatment on or of site, and returning the treated soil to the resorted site. The conventional ex-situ methods applied for remediating the polluted soils relies on excavation, detoxification and/or destruction of contaminant physically or chemically, as a result the contaminant undergo stabilisation, solidification, immobilisation, incineration or destruction.

In-situ method

It is remediation without excavation of contaminated site. In-situ remediation technologies as destruction or transformation of the contaminant, immobilisation to reduce bioavailability and separation of the contaminant from the bulk soil. In-situ techniques are favoured over the ex-situ techniques due to their low cost and reduced impact on the ecosystem. Conventionally, the ex-situ technique is to excavate soil contaminated with heavy metal and their burial in landfill site. But the offsite burial is not an appropriate option because it merely shifts the contamination problem elsewhere and also because of hazards associated with the transport of contaminated soil. Diluting the heavy metal content to safe level by importing the clean soil and mixing with the contaminated soil can be an alternative of on-site management. On-site containment and barriers provide an alternative, it involves covering the soil with inert material. Immobilization of inorganic contaminant can be used as a remedial method for heavy metal contaminated soils. This can be achieved by complexing the contaminants, or through increasing the soil pH by liming. Increased pH decreases the solubility of heavy metals like Cd, Cu, Ni and Zn in soil. Although the risk of potential exposure to plants is reduced, their concentration remains unchanged. Most of these conventional remediation technologies are costly to implement and cause further disturbance to the already damaged environment[9].

Plant based bioremediation technologies have been collectively termed as phytoremediation, this refers to the use of green plants and their associated micro biota for the in-situ treatment of contaminated soil and ground water [9].

Heavy metal uptake by plant through phytoremediation technologies is using these mechanisms of phytoextraction, phytostabilisation, rhizofiltration, and phytovolatilization as shown in figure 1 [2].

4.1. Phytoextraction is the uptake/absorption and translocation of contaminants by plant roots into the above ground portions of the plants (shoots) that can be harvested and burned gaining energy and recycling the metal from the ash.

4.2. Phytostabilisation is the use of certain plant species to immobilize the contaminants in the soil and groundwater through absorption and accumulation in plant tissues, adsorption onto roots, or precipitation within the root zone preventing their migration in soil, as well as their movement by erosion and deflation.

4.3. Rhizofiltration is the adsorption or precipitation onto plant roots or absorption into and sequesterization in the roots of contaminants that are in solution surrounding the root zone by constructed wetland for cleaning up communal wastewater.

4.4. Phytovolatilization is the uptake and transpiration of a contaminant by a plant, with release of the contaminant or a modified form of the contaminant to the atmosphere from the plant. Phytovolatilization occurs as growing trees and other plants take up water along with the contaminants. Some of these contaminants can pass through the plants to the leaves and volatilize into the atmosphere at comparatively low concentrations.

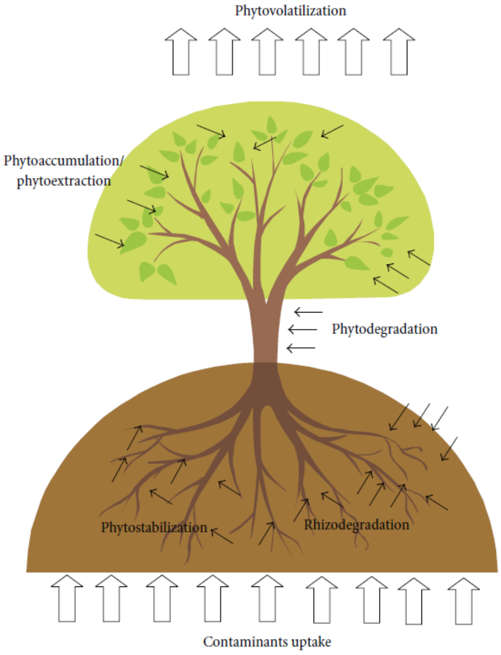

Figure 2 - The mechanisms of heavy metals uptake by plant through phytoremediation technology [2]

Plants also performan important secondary role in physically stabilizing the soil with their root system, preventing erosion, protecting the soil surface, and reducing the impact of rain. At the same time, plant roots release nutrients that sustain a rich microbial community in the rhizosphere. Bacterial community composition in the rhizosphere is affected by complex interactions between soil type, plant species, and root zone location. Microbial populations are generally higher in the rhizosphere than in the root-free soil. This is due to a symbiotic relationship between soil microorganisms and plants. This symbiotic relationship can enhance some bioremediation processes. Plant roots also may provide surfaces for sorption or precipitation of metal contaminants.

In phytoremediation, the root zone is of special interest. The contaminants can be absorbed by the root to be subsequently stored or metabolised by the plant. Degradation of contaminants in the soil by plant enzymes exuded from the roots is another phytoremediation mechanism.

For many contaminants, passive uptake viamicropores in the root cell walls may be a major route into the root, where degradation can take place [2].

RESULTS AND DISCUSSIONS

Some medicinal plants with storage capacity for various toxic substances are given in Table 1.

Table 1

Species of medicinal plants accumulators

Species	The accumulated toxic substance	The accumulator vegetative organ	Extracted contaminant/substrate	Refe rences
Thalspi caerulescens	Zn, Cd	shoots	heavy metals, mining wastes	[29], [26]
Catharanthus roseus	Cr	roots, leaves	chromium, sludges derived from tanneries	[25]
Brassica	Se, Zn,Cu,Pb	roots , shoots,	heavy metals	[16]

juncea (indian mustard)		leaves		
	Atrazin	roots	pesticides	[14]
	Cd	roots, shoots	cadmiumm	[26]
Hypericum perforatum	Cu, Cd	roots, shoots, leaves	heavy metals	[17]
Matricaria recutita	Cd, Zn	roots, shoots, leaves	heavy metals	[17]
Bacopa mannieri	Hg, Cd	roots, shoots	sewerage wastes, chlorosodical industrial wastes	[13]
Achillea millefolium	Cu	roots	heavy metals, mining wastes	[4]
Salvia officinalis	Cd	shoots	cadmium	[17]
Centaurea cyanus	Zn	roots	heavy metals, mining wastes	[4]
Echinophora platyloba				
Ocimum basilicum	Cd	roots, shoots, leaves	Organic and inorganic additives	[18]
Artemisia vulgaris	Zn, Cu, Pb, Cd, Ni	roots, shoots, leaves	sludges, compost, waste paper and from retteries	[20]
Alyssum bertolonii	Ni	roots	mining wastes	[23]
Mentha spicata	Cr, Cu	roots, shoots, leaves	heavy metals arising from exploitation and burning of fossil fuels	[28]
Hippophae rhamnoides	Fe, Zn, Mn, Cu	leaves, fruits	mining wastes	[3]
Rinorea niccolifera	Ni	leaves	heavy metals	[8]
Aloe vera	Cd, Cr, Pb, Co, Ag, Se, Hg	leaves	heavy metals	[22]
Cannabis sativa	Pb, Cu, Zn, Cd, Ni	shoots, roots, leaves	heavy metals	[10]
Urtica dioica	Cr	shoots, roots, leaves	chromium	[27]
Taraxacum officinale	Cd, Cu, Zn	leaves		[24]
Astragalus racemosus	Se	shoots, roots	naturally seleni ferous soil	[15]

Advantages and disadvantages of phytoremediation are presented in Table 2.

Table 2

Advantages and disadvantages of phytoremediation [9]

Advantages	Disadvantages / Limitations
Amendable to a variety of organic and inorganic compounds.	Restricted to sites with shallow contamination within rooting zone of remediative plants.
In Situ / *Ex Situ* Application possible with effluent/soil substrate respectively.	May take up to several years to remediate a contaminated site.
In Situ applications decrease the amount of soil disturbance compared to conventional methods.	Restricted to sites with low contaminant concentrations.
Reduces the amount of waste to be landfilled (up to 95%), can be further utilized as bio-ore of heavy metals.	Harvested plant biomass from phytoextraction may be classified as a hazardous waste hence disposal should be proper.
In Situ applications decrease spread of contaminant via air and water.	Climatic conditions are a limiting factor.
Does not require expensive equipment or highly specialized personnel.	Introduction of nonnative species may affect biodiversity.

In large scale applications the potential energy stored can be utilized to generate thermal energy.	Consumption/utilization of contaminated plant biomass is a cause of concern.

Specific problems when using medicinal plants used in phytoremediation:
a) economic impact: possibility of cost recuperation through valorization of bio-mass; enhance the economic feasibility of phytoremediation; low cost techniques relevant for diffuse moderate pollution in large areas;
b) cultivation and use of medicinal plants have to respect the potential hazard connected with environmental contaminants, such as toxic metals or pesticides;
c) needs for better exploit the metabolic diversity of the plants, but also understand the complex interactions between soil, plant roots, and micro-organisms (bacteria and mycorrhiza) in the rhizosphere;
d) for medicinal purpose, cultivation in alkaline soil/water and for phytoremediation purpose cultivation in acidic soils/water is recommended.

CONCLUSIONS

▪ This technology can be applied "in situ" to remediate shallow soil, ground water and surface water bodies.
▪ Phytoremediation has been perceived to be a more environmentally-friendly "green" and low-tech alternative to more active and intrusive remedial methods.
▪ Phytoremediation is a new cleanup concept that involves the use of plants to clean or stabilize contaminated environments. The high cost of existing cleanup technologies led to the search for new cleanup strategies that have the potential to be low-cost, low-impact, visually benign, and environmentally sound.
▪ By phytoremediation, the physical structure and the biological properties of the soil are maintained, and the fertility and biodiversity can be improved.
▪ The hyperaccumulating nature of plants depends on the type of species, soil quality, and its inherent control.
▪ All the medicinal plants undertaken in the current study are capable of sufficient level of bioaccumulation, and still they are capable of maintaining their growth rates and reproduction levels.
▪ Studies on phytoremediation using medicinal plants should be planned by researchers for carrying out more analysis for finding out the capability of these weeds, so as to remove the metallic component in industrial and municipal level waste waters.

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