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Phytoremediation for Heavy Metal Removal from Soils

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Abstract

In the present scenario, phytoremediation has become more widespread subject of interest to researchers and stake holders for remediation of heavy metal contaminated soils. Phytoremediation uses different processes for remediation of pollutants, such as organic pollutants can be degraded in the rhizosphere or they can be taken up by the plant, then degraded, sequestrated or volatilized and inorganic pollutants can be sequestrated or stabilized in harvestable vegetation. Plants selected for phytoremediation must be fast growing and having the ability accumulate large quantities of metal contaminants in their shoot tissue. One of the major advantages of phytoremediation is low cost, however complete and rapid removal of contaminants from the soil is not possible.

Introduction

Heavy metals are the chemical elements having density greater than 5. Some of these elements are a part of our normal diet and are essential for good health and present in human and animal tissues in very low concentration (Sharma *et al.,* 2016). The important essential elements include iron, zinc, cobalt, copper, chromium, manganese, molybdenum *etc*. However, chronic exposure of toxic dose of these metals in human tissues results in various complications in human body. Heavy metals are also reported to cause allergies and repeated long-term contact with some metals or their compounds may even prove carcinogenic. Soils are the ultimate source of food for human beings so that of heavy metals also. Over the years several methods and strategies have been developed for removal of these heavy metal contaminants from soil and water so that entry of these contaminants in food chain can be prevented. There are four soil remediation techniques namely bioremediation, phytoremediation, physical remediation and chemical remediation. One of the effective techniques for heavy metal removal is phytoremediation, the use of green plants to clean up polluted soil and water resources has received much attention in the last few years. Recently, phytoremediation has become more widespread subject of interest to researchers and stake holders.

Phytoremediation

The term "Phytoremediation" is derived from "phyto" (Greek) related to plants and "remedium" (Latin) meaning clean (Vasavi *et al*., 2010). It is an in-situ remediation method in which the ability of plants is used to assimilate or detoxify metal and organic chemicals from water, soil and air (Sharma *et al.,* 2016). Using phytoremediation, organic pollutants can be degraded in the rhizosphere zone or they can be taken up by the plant, then degraded, sequestrated or volatilized. Inorganic pollutants cannot be degraded but can be sequestrated or stabilized in harvestable vegetation, particularly for macronutrient remediation. Phytoremediation offers owners and managers of metal contaminated sites, is an innovative and cost effective option to address recalcitrant environmental contaminants.

Mechanism of Phytoremediation

Plant roots take contaminants from the soil into the plant body. The plant rhizosphere is the site where the action occurs. This soil supports large populations of various microorganisms due to chemicals exuded by plants roots which provide carbon and energy for microbial growth. This combination of plants and microorganisms increase the biodegradation of compounds. Plants use a number of physiological mechanisms (biochemical and morphological) that enable them to tolerate the higher concentrations of heavy metals in soil and adapt to these constraints. It essentially requires the combination of several traits: the accumulation of ions for osmotic adjustment, the synthesis of compatible solutes, the ability to accumulate essential nutrients elements in the presence of high concentrations of other heavy metal ions, the ability to stop or reduce the entry of these ions into the transpiration stream, and the ability to continue to regulate transpiration in the presence of high concentrations heavy metals. Several processes are used to remove heavy metals from contaminated soils by some plants as illustrated in Figure 1.

1. Phytoextraction/ Phytoaccumulation

Phytoextraction involves the uptake and movement of metal pollutants through plant roots into above-ground parts of the plants through the mechanism of hyperaccumulation. These plants take up metals in large quantities from contaminated soils, then transport and accumulate in above ground parts of the plants at concentrations from 100 to 1000 times higher than non-hyperaccumulating species without any phytotoxic effect.

2. Phytostabilization

This involves the use of plant roots to absorb pollutants from the soil and retain them within the rhizosphere, and gets stabilized, rendering them harmless and preventing the pollutants from spreading in the environment.

3. Phytodegradation

Phytodegradation is the breakdown of organic contaminants into non-hazardous forms by plant enzymes. Specific enzymes such as dehalogenases and nitroreductases are used by plants to degrade organic contaminants.

4. Phytovolatilization

This deals with the removal of soil contaminants by plants which are readily changed into vapour and then released into the atmosphere. For example, tobacco plants have the ability to accumulate highly toxic methyl mercury and transform it to the less toxic and volatile elemental Hg that escapes to the atmosphere (Mukhopadhyay and Maiti, 2010).

5. Rhizofiltration

Rhizofiltration involves the elimination of toxic contaminants or pollutants from ground water through filtration by the plant roots. Terrestrial plants are more effective for rhizofiltration compared to aquatic plants because they employ natural solar driven pumps for uptake of particular elements.

6. Phytostimulation

Phytostimulation is the enhancement of microbial activity to degrade organic contaminants in soil by exudates released from plant roots.

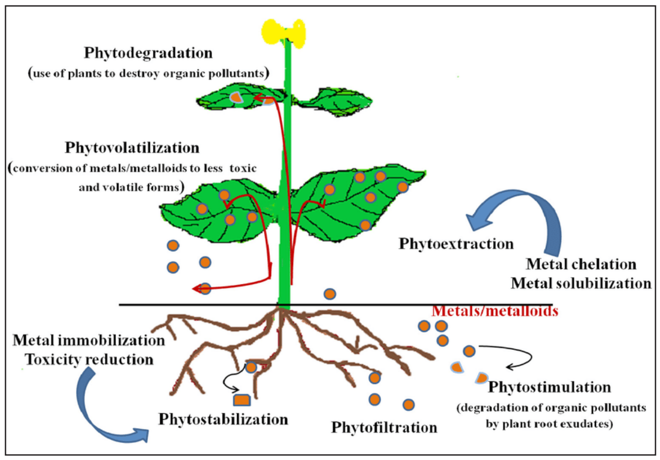

Figure 1: Processes used in phytoremediation of heavy metals (Ojuederie and Babalola, 2017)

Selection of Plant Species for Phytoremediation

As a plant based technology, the success of phytoextraction is depends upon selection of a suitable plant species. Plants must be fast growing and have the ability to uptake and accumulate large quantities of metal contaminants in their shoot tissue. At present, there are nearly 400 known hyper accumulators but majority are not appropriate for phytoextraction, because of their slow growth and small size. Several researches have screened fast-growing, high-biomass-accumulating plants for their ability to accumulate and tolerate metals in their shoots. Some of examples of the plants used in phytoremediation are (Vasavi *et al.*, 2010): Alfalfa, Hybrid Poplar Trees, Blue-green Algae, Duck Weeds, Arrowroot, Sudan Grass, Rye Grass, Bermuda Grass, Alpine Bluegrass, Sunflower, Vetiver grass, Switch Grass, White reddish *etc*.

Advantages of Phytoremediation

• The cost of the phytoremediation is lower than that of conventional methods.

• The plants can be easily monitored.

• The possibility of the recovery and re-use of valuable heavy metals.

• It is the least harmful method, as it uses naturally occurring organisms and maintains the natural state of the environment.

Limitations of Phytoremediation

• Complete removal of the contaminants is not possible.

• Phytoremediation is a very slow process.

• The survival of the plant is affected by the toxicity of the contaminants and conditions of the soil.

• Possible bio accumulations of contaminants which then passed into the food-chain.

Conclusion

The heavy metal contamination in soil is spreading day-by-day due to indiscriminate uses of agricultural chemicals and faulty agricultural practices. Therefore, the removal of metals from soil and environment becomes a subject of paramount importance. Phytoremediation is considered to be an innovative technology and hope fully by increasing our knowledge and understanding of this intricate clean up method, it will provide a cost effective, environment friendly alternative to conventional cleanup methods. The selection of appropriate plant species and modification of cultivated conditions can help in an enhanced removal of contaminants using plants. Biotechnological and genetic engineering interventions can also help in development of new plant species having increased remediation ability.

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