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Review Article

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Phytoremediation and Phytotechnologies

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ABSTRACT

Heavy metals are among the most important sorts of contaminant in the environment. Degradation of metals is not possible, so usually their removal is required in clean-up. Most of the technologies for conventional remediation are costly, inhibit soil fertility; and ultimately results in unfavourable impacts on the ecosystem. Currently, phytoremediation is an effective and affordable technological solution used to extract or remove inactive metals andmetal pollutants from contaminated soil and water. This technology is environmental friendly and potentially cost effective. The following review describes the stature of phytoremediation technologies. Natural metal hyperaccumulator phenotype is much more important than high-yield ability when using plants to remove metals from contaminated soils. The hypertolerance of metals is the key plant characteristic required for hyperaccumulation; vacuolar compartmentalization appears to be the source of hypertolerance of natural hyperaccumulator plants. In India, however phytoremediation is yet to become available as a commercial technology. Other initiatives targeted at dissemination, education and training should be activated in order to increase the familiarity and confidence of the public opinion in these new sustainable technologies.

Keywords*: Contaminant, hyperaccumulator,metals, phytoremediation, technology.*

INTRODUCTION

A major environmental concern is the contamination of soil due to human activities which includes dispersal of urban and industrial wastes, spillage, disposal of waste, mining of metal ores, sewage sludge application to name a few of major reasons. This further leads to contamination of our ecosystem caused by organic and inorganic compounds example putrescible and combustible substances, heavy metals, explosives, hazardous wastes[8] and petroleum products, radionuclides, organic compounds like chlorinated solvents, polychlori biphenyls, polycyclic aromatic hydrocarbons, pesticides/insecticides, explosives and surfactants. Heavy metal is one of the major components of inorganic contaminants[1,2]. Organic contaminants can be easily degraded by microorganisms present in soil, while immobilisation or physical removal is required for the degradation of metals. Although metals are essential and important, but these metals at higher concentrations are toxic, because formation of free radicals starts which leads to oxidative stress and many a times due to higher concentration of metals, some of the essential metals can be replaced in enzymes or pigments which further disrupts their function[18].

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Metals therefore makes land unfertile leading to destruction of biodiversity[22]. To minimize and inhibit the release of metal waste in the land, several regulatory steps have been implemented, but for checking the contamination, they are not sufficient[17]. Many physical, chemical and biological techniques can be used for the remediation of metal contaminated soil. Several methods are being used for remediation e.g. chemical, thermal and conventional (excavation and disposal to landfill site. However all these methods suffer from major limitations like generation of large volumetric sludge, need for technical expertise, expensive methodology involved and sub-optimal performance.On the basis of removal and transportation of wastes for treatment there are basically two methods[5].

Ex-situ method

This method leads to the treatment of on and off sites of contaminated soil by the removal of heavy metals, and further after the treatment, returning the soil to the ressite. For the remediation of polluted soils this applied conventional method relies on excavation and physical or chemical destruction and/or detoxification of contaminant, and further the resulted contaminants go through stabilisation, solidification, immobilisation, incineration or destruction. But the ex-situ method shifts the problems related to metal contamination elsewhere[34].

In-situ method

It is a type of remediation method, with no excavation of contaminated site. In-situ remediation method can be defined as transmutation and eradication of the contaminants, immobilisation for the reduction of bioavailability and separation of the toxic contaminant from soil[27]. Advantages of in-situ remediation are low cost and reduced percussion on the environment. However, most of the conventional remediation technologies lead to further perturbation to the already flubbed environment due their pricey utilization[23,3].

PHYTOREMEDIATION

Bioremediation technologies based on plants have been on the whole is described as phytoremediation(Greek prefix phyto means plant and Latin remedium means remedy), which makes reference to the usage of green plants and their affiliated micro biota for the in-situ therapy of contaminated soil and underground water[30]., the very first idea of using metal aggregating plants to get rid of heavy metals and other compounds was introduced[18]. This remedial technology can be practiced with both inorganic and organic pollutants existing in water (liquid substrate), soil (solid substrate), or the air[31], [26]. Under the process of purification essential microbes such as fungi, Cyanobacteria, Rhizobium, Mycorrhiza, as well as fauna which include all biological activities, are removed so for the process of soil remediation[29]and for the growth of plants, the unwanted and useless land is rendered by the physico-chemical techniques[10]. The conventional processes of remediation may rate from $10 to 1000 per cubic meter in comparison to phytoextraction techniques which may be as low as $ 0.05 per cubic meter[12, 13]. Phytoremediation is the direct use of green plants to degrade, contain, or render harmless various environmental contaminants, including recalcitrant organic compounds or heavy metals [21, 4].

Phytoremediation comprises of five main processes[16].

Rhizofiltration

Rhizofiltration involves using the plants (terrestrial or aquatic) to absorb, concentrate, and precipitate low-concentration contaminants from roots. [11],[33]. The advantages of this process are that it can be applied in situ or ex situ, and that species other than hyper accumulators can also be used.

Phytostabilizatio*n*

Phytostabilization is frequently practiced for soil treatment and remediationsludge and sediment[2435] and confide on the capacity of roots to bound the mobility of contaminant and soil bioavailability. It arises through the precipitation, sorption, metal valence reduction or complexation. A compact root system sustains the soil and inhibits erosion. This approach is one of the most effective methods during active immobilisation to retain surface and ground water. But the major drawback is that, the toxic contaminant lasts in soil in their original form, and consequently need proper check[14].

Phytoextraction

Phytoextraction is the finest way to expel contamination from soil[27] and confine it, without disrupting soil structure, richness and productivity[33]. It is best suited for diffusely contaminated areas, where pollutant exists only in comparatively minor concentration. The above approach requires research to explore hyperaccumulator species. Hyperaccumulator species will extract massive concentrations of heavy metals within the roots and further translocate heavy metals to yield considerable bulk of plant biomass[8].

Phytovolatilization

Phytovolatilization is use of plants to pick up contaminants from the soil and further moulding them into erratic form and transpiring them into air. Phytovolatilization take place as plants take up water and contaminants of the inorganic and organic types[24]. Example elimination of mercury with the mercuric ion being altered into less toxic form. The major limitation is that by the process of precipitation, mercury enters back into environment[18].

Phytodegradation

Phytodegradation is disintegration of organic contaminants to simpler forms which are assimilated into plant tissue[11]. Plants contain enzymes which are customarily oxygenases, dehalogenases and reductases[7]. All phytoremediation technologies can be used synchronously, however metal extraction depends on bioaccessible portion in soil.

Table 1: Types of phytoremediation techniques[16]

Process	Mechanism	Contaminant
Rhizofiltration	Rhizosphere accumulation	Organics/Inorganics
Phytostabilization	Complexation	Inorganics
Phytoextraction	Hyper-accumulation	Inorganics
Phytovolatilization	Volatilisation by leaves	Organics/Inorganics
Phytotransformation	Degradation in plant	Organics

PLANTS AS PHYTOREMEDIATORS

The principal application of phytoremediation is for lightly contaminated soils and waters where the material to be treated is at a shallow or medium depth and the area to be treated is large[6]. For both planting and harvesting, phytoremediation makes agronomic techniques economical and applicable[19]. Phytoremediation practices use some of the plants: water hyacinths (*Eichorniacrassipes*); alpinepennycress (*Thlaspicaerulescen)*[28,5]; poplar trees (*Populus* spp.); forage kochia (*Kochia spp*)[25]; *Ipomea alpine*[5]; *Haumaniastrum robertii*[9]; Scirpusspp, coontail (*Ceratophyllum demersum* L.); American pondweed (*Potamogeton nodosus*); and the emergent common ar-rowhead (*Sagittaria latifolia*) amongst others. Mangroves developed unique body features in order to cope up with harsh environment[35]. Different concentrations of each heavy metal from the soils was extracted by Tomato and mustard plants. Different plants have been tested to remove a wide range of contaminants by funding scientific efforts by many Institution and companies.For the phytoremediation of large amount of Pb, Cu, Crand Ni from the soil, the two members of mustard family i.e. *Brassica juncea* and *Brassica olearacea* was favoured by scientists.

Advantagesof phytoremediation

- Aesthetically pleasing
- Less need of equipment
- Cost effective[32]
- Applicable for wide range of contaminants[20]
- Method is environmental friendly
- Less disruptive than techniques
- The plants can be easily monitored as plants can be easily grown.
- The possibility of the recovery and re-use of valuable metals.
- It is the least harmful method
- Preserves natural environment

Disadvantages of phytoremediation

- Time-consuming method
- Enough land is required to grow plants
- Majorly removes only those contaminants which are present around the root zone.
- Soil chemistry
- The contaminant concentration
- Climatic condition
- With plant based systems of remediation, it is not possible to completely prevent the leaching of contaminants into the ground water.
- The survival of the plant is affected by the toxicity of the contaminated land and general conditions of the soil.
- Possible bio accumulations of contaminants which is then passed into the food-chain

CONCLUSION AND FUTURE IMPLICATIONS

The goal of sustainable development is supported by the phytoremediation of contaminated sites by helping to conserve soil as a resource, bring soil back into beneficial use, preventing the spread of pollution to air and water and reducing the pressure for development on green or agricultural field sites. It is amenable to a variety of organic and in organic compounds may be applied either in-situ or ex-situ. A 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 conventionalclean up methods.Further research is required for probing of the bio-path ways involved in contaminant degradation and sequestration and to identifythe specific genes involved in cell signalling path ways that affect the genetic expression plant and microbial enzymes.

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