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Phytoremediation: An Alternative approach for the Restoration of Heavy metal Polluted sites

Tanweer Shumail[1] and Sazada Siddiqui[1]

[1]Department of Biological Sciences. King Khalid University, Abha K. S. A
*Corresponding Author:
Tanweer Shumail, Department of Biological Sciences. King Khalid University, Female Section, Al-samer District, P.O. 3340, ABHA, K.S.A
E-mail : tanweer.shumail@gmail.com.

Abstract

Heavy metal contamination of soil, aqueous streams and groundwater are increasing day by day because of increased industrialization and urbanization. In the present time, it is a major environment and human health problem. The conventional method to remedy problem has their own drawbacks. However, phytoremediation that is an emerging technology for the clean-up of contaminated environment can play a pivotal role in the heavy metal detoxification. This method, which uses plants to extract sequester or detoxification pollutions, is environmentally friendly and visually attractive and the structure of the soil is highly maintained. *Thlaspi caerulescens* and *Viola calaminaria* are plants. Which were first documented for the first time at the end of 19 the century for their high metal accumulating properties in the leaves. There are several other plants like *Brassica*, Sunflower, *Ipomea*, Polycarpia, *Dunaliella*, *Astragalus*, Hydrilla, *Spirodela*, Eichhornia which are able to accumulate heavy metals in their different organs and this list is increasing day by day. In the last decades, extensive researches have been conducted to investigate the biology of metal phytoextraction. Transgenic plants have been prepared for the increased efficiency of phytoremediation. Looking to its significance, a better understanding of the biochemical process involved in plants heavy metal uptake transport, accumulation and resistance is required that will help in system improvement in phytoremediation. Also, there growing need to optimize the organic practices to maximize the clean-up potential of remediative plants. As a chief renewable resource exploited by mankind, plants already give us food, energy, constriction materials, natural fiber and several other things, the use of plants in environmental cleanup assurance to a cleaner and greener world for all of us to live in.

The term phytoremediation is relatively new, coined in 1991. The meaning of phytoremediation is “phyto” mean plant, “remedium” means to clean up or restore. Phytoremediation is an emerging technology that uses plants to remove contaminants from soil and water by Raskin & Ensely[23]. The term phytoremediation is defined in different ways by different scientists. According to. Chang,[5] the use of plants to extract, sequester and /or detoxification various kind of environmental pollutants. According to the Meagher,[17] phytoremediation can be divided into two groups.

1. Elemental pollutions.
2. Organic pollutions.

Element pollutants: Element pollutants contain contaminants such as toxic heavy metals and radionuclides, such as Arsenic, Cadmium, Caesium, Chromium, Lead, Mercury, Strontium, Technetium, Tritium and Uranium reported by Bibey, et al.,[3] & Prieto[21]. Only a few remediation techniques are available for this kind of pollutants and the use of plants to strip heavy metals from the soil is an emerging tool. Remediation of metals contaminants, metal cannot be degraded. Commonly, decontamination of metal contaminated soil requires the removal of toxic metal. Recently, phytoextraction, this is one type of phytoremediation technique, in which the use of plants to extract toxic metal from contaminated soils has emerged as a cost–effective, environmentally friendly clean up.

Phytoremediation techniques can be classified in to five types based on contaminant fate. Each technology has a different mechanism of action for the remediation of the metal polluted soil, sediment or water.

1. Rhizofilteration
2. Phytostabilization
3. Phytovolatilization
4. Phytoextraction
5. Phytotransformation

1. *Rhizofilteration:* It is water remediation technique that involves the uptake of contaminants by plants roots. Rhizofilteration used to reduce contamination in a natural wetland in estuary areas.

2. *Phytostabilization:* It is a technique in which plant reduce the mobility and migration of contaminated soil. Leachable constituents are adsorbed and bond into the plant structure so that they form a stable mass of plant from which the contaminants will not the re-enter the environment. In which heavy metal tolerant plants are used to reduce the mobility of heavy metals, thereby reducing the risk of further environmental degradation by leaching into the groundwater or by airborne spread noticed by Tarek, *et al.*,[27].

3. *Phytodegradiation or Rhizodegradation:* It is a technique in which a breakdown of contaminants through the activity existing in the rhizosphere. This activity is due to the presence of protein and enzymes produced by the plants or by soil organisms such as bacteria, yeast and fungi. Rhizodegradation is a symbiotic relationship that has evolved between plants and microbes. Plants provide nutrients necessary for the microbes to thrive, which microbes provide a healthier soil environment.

4. *Phytovolatilization:* This technique involves the use of plants to extract certain metal from soil and they release them into the atmosphere through volatilization.

5. *Phytoextraction or Phytoaccumulation:* In this process, plants used to accumulate contaminants into the roots and aboveground shoot or leaves. This technique saves tremendous remediation cost by accumulated low levels of contaminants from a widespread area. Unlike degradation mechanisms, this process reduces a mass of plants and contaminants (Usually metals) that can be transported for disposal of recycling. In this case, metal accumulation plants are used to transport and concentrate metals from soil into the harvestable port of roots and above ground shoots noticed by Wanga, *et al.*,[7].

6. *Phytotransformation or phytodegradation:* In this method, plants uptake of organic contaminants from the soil, sediment, or water and subsequently, transformation to more stable less toxic or less mobile form. Metal chromium can be reduced from hexavalent to trivalent chromium, which is less mobile and non-carcinogenic form.

Overview of phytoremediation applications (Table-1)

Table-1. Overview of phytoremediation applications

S.No	Technique	Plant mechanism	Surface medium
1	Phytoextraction	Uptake and concentration of metal via direct uptake into the plant tissue with subsequent removal of the plants.	Soil
2	Phytotransformation	1. Plant uptake and degradation of Organic compound.	Surface water, ground water.
3	Phytostabilization	Root exudates cause metal to precipitate and become less available	Soil and groundwater
4	Phytodegradation	Enhances microbial degradation in rhizosphere	Degradation in rhizosphere rhizosphere
5	Rhizofilteration	Uptake of metals into plant root	Surface water and water pumped.
6	Phytovolatization	Plants evapotranspirated selenium, mercury and volate hydrocarbons	Soil and groundwater
7	Vegetative cap	Rainwater is evapotranspirated by plants to prevent leaching Contaminants and from disposal sites.	Soil

Organic pollutants: The second group of pollutants which can be targeted for phytoremediation is that of the organic a pollutants such as polychlorinated, biphenyls, polycyclic aromatic compounds, nitoaromaties or linear halogenated hydrocarbons. This group of pollutant can be mineralized completely using poplar trees, Willow, Alfa Alfa and different grass verities. Although the knowledge of the degradation of pollutants by plant metabolic system is still limited compound with what is known for bacteria, various reports confirm the importance of phytoremediation as a newly emerging tool. Degradation of compounds such as trichloroethylene (TCE). The explosive 2,4,6 trinitrotoluene (TNT), hexa- hydro-1,2,5, Trinito-1,3,5, Triazine (RDX), Glycerol trinitrate (GTN) and nitroglycerine by Best, *et al.*,[2] using plant enzymes shows the possibility of phytoremediation.

In order to apply phytoremediation efficiency, the limitations of this technique also should be taken into account.

1. The time necessary for acceptable effects.
2. The limited depth of the root system.
3. The slow growth of plants.
4. The problem of being a part of a food chain and, the dependence on changes in the climate and winter dormancy.

In addition to the consumption of transgenic plants, the use of plants which are ecologically well modified, rapid growing and deeply rooting can help to overcome these problems and lead to more effective use to phytoremediation. The importantance of biodiversity (below and above ground) polluted ecosystem is increasingly considered. This subject is emerging commercially significant in the contemporary field of environmental biotechnology. Several microbes including mycorrhizal and non-mycorrhizal fungi agricultural and vegetative crops, ornamentals, and wild metal hyperaccumulating plants are bring listed both in lab and field conditions for decontaminating the metalliferous subtracts in the environment.

Present Status :

As on to date about 400 plants that hyperaccumulate metals are recorded. The dominating families are Asteraceae, Brassicaceae, Carophyllaceae, Cypraceae, Cunoniacae, Fabaceae, Flacaurtiace, Laminaceae. Poaceae, Violaceae and Euphorbiaceae. Brassicaceae has the largest number of species *i.e.* eleven genera and eighty-seven species. Brassicaceae different types are recognized to accumulate metal.

Hyper accumulation of Ni is reported in seven genera and seventy-two species and Zn is reported among three genera and twenty species. *Thalaspi* species is known to hyper accumulate more than one metal *i.e T. caerulescens* hyperaccumulates Cd, Ni, Pb and Zn. *T. goesingenese* hyper accumulate Cd, Zn, and *T. ochroleum,* hyper accumulate, Ni and Zn and *T. rotundifolium* hyper accumulate Ni, Pb and Zn. Hyper accumulating plants have great potential for application in remediation of metals in the environs. Significant progress in phytoremediation has been made with metal radionuclides. This process involves rising of plants hydroponically and transplanted them into metal-polluted water where plant absorb and concentrate metal in their root and shoot. As they become saturated with the metal contaminants, root or whole plants harvested for the disposal. Most researchers believe that the plants for phytoremediation should accumulate metals in the roots. Several aquatic species have the ability to remove heavy metals from water, viz, water hyacianth, *Eichhornia crassipes, Pennyewort* (*Hydrocotyle umbellata*) and duck weed (*Lemna minor*). The root of Indian mustard are effective in the removal of Cd, Cr, Cu, Ni, Pd and Zn and sunflower removal Pb, U, G, and Sr from hydroponic solution. Aquatic plants in freshwater, marine and estuarine system act as a receptacle for several metals. Hyper accumulators accumulate quantities of metals in their tissue regardless of the concentration of metal in soil in, as long as the metal is present.

The primary motivation behind the development of phytoremediation technology is for low cast remediation. Research using semi–aquatic plants for free radionuclide-contaminated waters existed in Russia at the dawn of the nuclear era reported by Salt, *et al*.,[25]. Some plants which grow on metalliferous soils have developed the ability to accumulate a massive amount of the indigenous metals in their tissue without exhibiting symptoms of toxicity studied by Munees[19] and Netty, *et al.*,[20] was the first to suggest the use of these hyper accumulators for the phytoremediation of metal polluted sites. However, Phytoremediators were later believed to have limited potential in this area because of their small size and growth, which limited the speed of metal removal suggested by Kokyo, *et al*.,[12]. According to definition, a hyper accumulator must be accumulated at last 100 mg/g (0.01% dry wt.) Cd, As and some other metals 1000mg/g (0.1 dry wt) Co, Cu. Cr. Ni and Pb and 10,000 mg/g (1% dry wt.) Co, Cu, Cr, Ni and Pb and 10000 mg/g (1% dry wt.) Mn and Ni reported by Reeves & Barker[24].

Bizily,[4] and associates described the use of Arabidopsis thaliana plants transformed with bacterial genes in order to transform detoxify organic mercury and Iimura,[10] and associates described the expression of Mn peroxides gene in transgenic tobacco. Plants that accumulate toxic metal can be grown and harvested economically, having the soil or water with a greatly reduced level of toxic metal contamination investigated by Lombi, *et al*.,[13].

Recently, there has been growing interest in the use of metal–accumulating roots and rhizomes of aquatic or semi-aquatic vascular plants for the removal of heavy metals from contaminated aqueous streams. For example, such as Nasturtium officinale and Lemna minor take up Cu, Co,Mn ,Zn and Pb from contaminated solutions investigated by Kara[28] and Priyadarshini[22]. In a related development, cell suspension cultures of Datura anoxia miller were found to remove a wide Varity of metal ions from solutions suggested by Jackson, *et al*.,[11].

The natural capability to hyper-accumulate metals was found in plants developed on soils which were obviously enriched with heavy metals and this accumulation was thought to be a shield mechanism against herbivores reported by Gleba, *et al*.,[8]. However, the distribution of such plants is limited and the hyperaccumulation ability is contaminant specific.

Future Strategy :

Phytoextraction process involves the use of plants to help the elimination of metal contaminants from a soil matrix. In practice, metal –accumulated plants are seeded or transported into metal –polluted soil and are cultivated using established agricultural practices. If metal accessibility in the soil is not satisfactory for adequate plant uptake. Chalets or acidifying agents would be applied to liberate them into the soil solution. Use of soil amendments such as synthetic (Ammonium thiocyanate) and natural zeolites have yielded promising result synthetics cross-linked polyacrylates, hydrogels have protected plant roots from heavy accumulation, the about prevented the entry of toxic metals into roots. After sufficient plant growth and metal accumulation, the about ground portion of the plant is harvested and removed, resulting the permanent removal of metals from the soil metals should also be bioavailable, or subject to absorption by plant roots. Chemicals that are suggested this purpose include various acidifying agents, fertilizer salts and chelating materials. The retention of metal soil organic matter is also weaker at low PH, resulting is more available metals in the soil solution for root absorption. It is suggested that the phytoextraction process in enhanced when metal availability to plant root facilitated through the addition of acidifying agents to the soil. Chelates are used to boost the phytoextraction of a number of pollutants metal including Cd, Cu, Ni, Pb, and Zn.

Researchers initially applied hyper accumulators to clean metal polluted soils. We have screened fast growing, High- metal accumulating plants, including agronomic crops for their ability to tolerate and accumulate metals in their shoots. Genes responsible for metal hyper accumulation in plant tissues have been identified and cloned glutathione is ubiquitous component cell from bacteria to plants and animals. In phytoremediation of metals in the environment, organic acids play a major role in metal tolerance. Organic acid from complexes with metals, a porous of metal detoxification genetic strategies and transgenic plants and microbe production and field trials with fetch phytoremediation field applications.

Genetic alteration of plants can improve the success of phytoremediation, for example, Phytoextraction can be improved by an increase in the transpiration rate of plants. An Indian mustard cell line with a transpiration rate of 130 % compared with the wild-type plants was able to extract 104 % more iron from soil, whereas the increased resistance of plants to word pollutants also can improve their action during phytoremediation reported by Ying Li, *et al.*, [29]. The introduction and expression of the bacterial gene in plants resulting in enzymes involved in the conversion of xenobiotics when the legislative problem for using such plants are disregarded also a promising tool.

Glutathione and organic acids metabolism play a key role in metal tolerance in plants suggested by Arisi, *et al.*,[1] and Ma, *et al.*,[14]. Molecular genetics and transgenic strategies for phytoremediation. Genetics strategies and transgenic plant and microbe production and field trials will fetch phytoremediation application. Suggested by Sharon[26].

There is a certain limitation to implement phytoremediation with the use of biodiversity reported by Majeti & Helena[15] and Marzena, *et al.*,[16]. To a considerable extent they include, potential contamination of the vegetation and food chain and after extremely different to established and maintain vegetation on contaminated sites, for example, mine tailing with a high level of residual metals. For contaminations, plants show the potential for phytoextraction (uptake and recovery of contaminants into aboveground biomass. Investigated the Garbisu & Alkorta[9] and Evangelou, *et al.*, [6] filtering metal from water onto system (Rhizo-filteration) or stabilizing waste and sites by erosion control and evapotranspiration of large quantities of water (Phytostabilization). After the plants have been allowed to grow for some time, they are harvested and either incineration or composed to recycle the metals. This procedure may be repeated as necessary to bring soil contaminant level down to allowable limits.

If the plants are incinerated, the ash must be disposed of in a hazards waste landfill. Finally, phytoremediation in some countries has limited acceptance by local government takes a long duration of time to mitigate to the contaminant. Metal hyper accumulated are generally slow growing with a small biomass and shallow root system plant biomass must be harvested and removed and followed by proper disposal. Plant experiences stress due to the prevailing high concentration of metals. One of the main advantages of phytoextraction is that the plant biomass containing the extracted contaminated can be a resort for the example: Biomass that contains selenium (Se), an essential nutrient, has been transported to areas that are deficient in "Se" and used for animal feed noticed by Meetu & Shikha[18].

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