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A REVIEW ON PHYTOREMEDIATION BY *ALTERNANTHERA PHILOXEROIDES*

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ABSTRACT

Environmental pollution affects the quality of pedosphere, hydrosphere, atmosphere, lithosphere and biosphere. Great efforts have been made in the last 30 years to reduce pollution sources and remedy the polluted soil and water resources. Phytoremediation, being more cost-effective and fewer side effects than physical and chemical approaches, has gained increasing popularity in both academic and practical circles. More than 400 plant species have been identified to have potential for soil and water remediation. Among them, Alternanthera philoxeroides, Hydrila verticillata, Brassica and Aloe vera species have been mostly studied. It is also expected that recent advances in biotechnology will play a promising role in the development of new hyperaccumulators by transferring metal hyperaccumulating genes from low biomass wild species to the higher biomass producing cultivated species in the times to come. This paper attempted to provide a brief review on recent progresses in research and practical applications of phytoremediation for soil and water resources. Alternanthera philoxeroides plant bears phytoremediation activity which is very helpful in treating wastewater and soil. It absorb heavy metals like Cadmium, Copper, Chromium, Zinc, Lead etc.

Key Words: Alternanthera Philoxeroides, Aloe Vera,Brassica, Heavy Metals, Hydrila Verticillata,

I INTRODUCTION

Phytoremediation is a word formed from the Greek prefix “phyto” meaning plant, and the Latin suffix “remedium” meaning to clean or restore [1].Phytoremediation is the use of living green plants for *in situ* risk reduction or removal of various contaminants from contaminated soil, water, sediments and air. The use of metal accumulating plants to clean soil and water contaminated with toxic metals is the most rapidly developing component of this environmentally friendly and cost effective technology. This technology exploits plant’s innate biological mechanisms for human welfare.

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All of the traditional physiochemical methods to remove heavy metals and pollutants from soil and water have high operational costs and uses of large amount of chemicals and nutrients creating the problem of effluent or sludge treatment. These methods can be advantageous for rapid removal in small areas [2]. The emerging technology called 'Phytoremediation' uses plants to remove pollutants from the environment [3] [4] and is preferred over traditional methods because it offers site restoration, partial decontamination, and maintenance of biological activity and physical structure whilst being potentially cheap, visually unobtrusive and with a possibility of bio-recovery of metals [5] [6]. Because of these advantages phytoremediation is considered as a 'green', sustainable pollution removal process. Advances in science and technology have created growth of industries leading to the unprecedented disturbances in ecological cycles [7].

Accumulation of heavy metals may possess a threat to human health and natural environment.

Phytoremediation is a technology that utilizes plants and associated rhizosphere micro-organisms to remove or to transform toxic chemicals located in water, soils, sediments and even the atmosphere. Phytoremediation is currently used for treating contaminants such as heavy metals including petroleum hydrocarbons, chlorinated solvents, pesticides, explosives and radio-nuclides, and landfill leachates. It is reported that approximately 80% polluted groundwater is within initial 20 metres of ground level. This suggests water pollution removal can carried out using low cost phytoremediation applications [8]. The research in the field of plant technology applied to remediation has increased in the importance [9][10] [11] [12].

When contaminants or in this case heavy metals are in low quantity then phytoremediation may be the most suitable pollution removal technique in terms of cost and effectiveness. This makes phytoremediation a long term and commercially viable solution [13].There are many mechanisms by which live plants can remediate contamination from water and soil. During phytoremediation by live plants, the quality of the process can be affected by physical and chemical properties of the contaminants (water solubility, vapour pressure, molecular weight), environmental characteristics (temperature, pH, organic matter) and plant distinctiveness (type of roots, system, enzymes) [14]. There are many mechanisms by which live plants can facilitate remediation such as phytoextraction phytoaccumulation, phytopumping. phytostabilization, phytotransformation (degradation), phytovolatilization and rhizodegradation .

II PHYTOEXTRACTION

This method of phytoremediation involves the uptake of contaminants through the roots, with the contaminant being translocated to the aerial portions of the plant [15]. After a period of growth the plant is harvested, thereby removing the contaminant from the soil [16]. Plant roots generally contain higher metal concentrations than the shoots despite the translocation mechanisms, but an upper limit to the metal concentration within the root can occur. Root uptake of Pb by hydroponically grown plants reached a maximum concentration and did not increase further as the Pb concentration of the solution increased [17]. Metals are generally unevenly distributed throughout a plant, although in hyper-accumulators the metal content of the leaves is often greater than other portions of the plant; for example,

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the greatest proportion of Ni in *Alyssum heldreichii* was found in the leaves[19]. Calcium and Zn were found in both roots and shoots, although the shoots had higher concentrations of Zn[19].

High concentrations of Zn were found in small hemispherical bodies located on the surface of some leaves of *Thlaspi caerulescens* which is considered to be the best known hyper-accumulator [17]. Site selection that is conducive with phytoextraction is of extreme importance. Phytoextraction is applicable only to sites that contain low to moderate levels of metal pollution, because plant growth is not sustained in heavily polluted soils. Soil metals should also be bioavailable, or subject to absorption by plant roots. The land should be relatively free of obstacles, such as fallen trees or boulders, and have an acceptable topography to allow for normal cultivation practices, which employ the use of agricultural equipment. As a plant-based technology, the success of phytoextraction is inherently dependent upon several plant characteristics. The two most important characters include the ability to accumulate large quantities of biomass rapidly and the ability to accumulate large quantities of environmentally important metals in the shoot tissue [20][18].

In phytoextraction as with the excavation of soil from a contaminated site, the disposal of contaminated material is of great concern. Some researchers suggest that the incineration of harvested plant tissue dramatically reduces the volume of the material requiring disposal[21]. However in some cases valuable metals can be extracted from the metal-rich ash and serve as a source of revenue, thereby offsetting the expense of remediation (Cunningham and Ow, 1996; Comis, 1996)[20][22]. Phytoextraction should be viewed as a long-term remediation effort, requiring many cropping cycles to reduce metal concentrations [21] to acceptable levels. The time required for remediation is dependent on the type and extent of metal contamination, the length of the growing season, and the efficiency of metal removal by plants, but normally ranges from 1 to 20 years. This technology is suitable for the remediation of large areas of land that are contaminated at shallow depths with low to moderate levels of metal- contaminants[21] [23].

[24] reported that *Brassica juncea*, while having one-third the concentration of Zn in its tissue, is more effective at Zn removal from soil than *Thlaspi caerulescens*, a known hyperaccumulator of Zn. This advantage is due primarily to the fact that *Brassica juncea* produces ten-times more biomass than *Thlaspi caerulescens* [24].

Plants being considered for phytoextraction must be tolerant of the targeted metal, or metals, and be efficient at translocating them from roots to the harvestable above-ground portions of the plant[25]. Other desirable plant characteristics include the ability to tolerate difficult soil conditions (*i.e.*, soil pH, salinity, structure, water content), the production of a dense root system, ease of care and establishment, and few disease and insect problems. Although some plants show promise for phytoextraction, there is no plant which possesses all of these desirable traits with the ‘perfect plant’ continuing to be the focus of many plant-breeding and genetic-engineering research efforts.

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III PHYTODEGRADATION

The plant takes up the contaminant through its roots from where the contaminant is translocated to the aerial portions of the plant. The difference between phytoextraction and phytodegradation is that in the latter the contaminant is converted to a less toxic form during translocation to the aerial portions of the plant . Phytodegradation is also known as phytotransformation, and is a contaminant destruction process. Plant-produced enzymes metabolize contaminants which may be released into the rhizosphere, where they can remain active[26] . Plant-formed enzymes have been discovered in plant sediments and soils. These enzymes include dehalogenase, nitroreductase, peroxidase, laccase, and nitrilase [27].

IV PHYTOSTABILISATION

The traditional means by which metal toxicity is reduced is by in-place inactivation, a remediation technique that employs the use of soil amendments to immobilize or fix metals in soil. Although metal migration is minimized, soils are often subject to erosion and still pose an exposure risk to humans and other animals. Phytostabilization, known as phytorestoration, is a plant-based remediation technique that stabilizes wastes and prevents exposure pathways via wind and water erosion [28]. With this method of phytoremediation the plant root system releases chemicals into the surrounding soil which bind to the contaminant making it less bioavailable to the surrounding environment. Phytostabilization is also known as in-place inactivation or phytoimmobilization.

Another study indicated that *Brassica juncea* roots reduced Cr (VI) to Cr (III) [29]. In comparison to other modes of phytoremediation the purpose of phytostabilization is not to remove contaminants from the soil, but merely to stabilize them thus removing the risk to human life and the environment. Although phytostabilization is most effective at sites having fine-textured soils with high organic-matter content, it is also suitable for treating a wide range of sites where large areas of surface contamination exist [30]. Despite this some highly contaminated sites are not always suitable for phytostabilization, because plant growth and survival is not a possibility.

Plants chosen for phytostabilization should be poor translocators of metal contaminants to above ground plant tissues that could be consumed by humans or animals. The lack of appreciable metals in shoot tissue also eliminates the necessity of treating harvested shoot residue as hazardous waste [31]. Selected plants should be easy to establish and care for, grow quickly, have dense canopies and root systems, and be tolerant of metal contaminants and other site conditions which may limit plant growth.

V PHYTOVOLATIZATION

This method relies upon the ability of the plants to absorb contaminants through its roots and convert them into a less toxic form which is released into the atmosphere via transpiration. Phytovolatization is primarily a contaminant removal process, transferring the contaminant from the original medium (ground water or soil water) to the atmosphere. However, metabolic processes within the plant might alter the form of the contaminant, and in some

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cases transform it to less toxic forms. Examples include the reduction of highly toxic mercury species to less toxic elemental mercury, or transformation of toxic selenium (as selenate) to the less toxic dimethyl selenide gas by *Brassica juncea* [32][33]. Mercury and selenium are toxic [34]and there is a doubt as to whether the volatization of these elements into the atmosphere is safe [12] Selenium phytovolatization has been given the most attention to date [35][36] because this element is a serious problem in many parts of the world where there are areas of selenium-rich soil[19].

Although there have been no efforts to genetically engineer plants which volatilize toxic compounds, it is likely that researchers will pursue this possibility in the future. According to [19], the release of volatile selenium compounds from higher plants was first reported by Lewis et al.[36].

VI RHIZOFILTRATION

Rhizofiltration is a phytoremediative technique designed for the removal of metal contaminants from aquatic environments. The process involves the growth of plants in metal polluted waters where the plant absorbs and concentrates the metals in roots and shoots [37][38]. Changes in the rhizosphere pH and root exudates also contribute to the precipitation of metals onto the root surface [28]. As the plant becomes saturated with the metal contaminants either the roots or the whole plants are harvested for disposal. Rhizofiltration is a cost-competitive technology for the treatment of surface water or groundwater containing low, but significant concentrations of heavy metals such as Cr, Pb, and Zn [21]. The commercialization of this technology is driven by economics, applicability to many problem metals, ability to treat high volumes, lesser need for toxic chemicals, reduced volume of secondary waste, possibility of recycling, and the likelihood of regulatory and public acceptance[21][38]. However, the application of this plant-based technology may be more challenging and susceptible to failure than other methods of similar cost.

Alternanthera philoxeroides **(Mart.) Griseb.– The plant:**

*Alternanthera philoxeroides (*Alligator weed) is a perennial herb; 50-120cm long immersed aquatic plant. It originated in South America, but has spread too many parts of the world and it’s considered an invasive species in Australia, China, New Zealand, Thailand and the United States. It is a sprawling herb, usually in water, often in row crops and gardens.*Alternanthera philoxeroides* biomass, a type of freshwater macrophyte, used for the sorptive removal of heavy metals like Ni(II), Zn(II),Pb and Cr(VI) etc. from waste water aqueous solutions [39].

1. The concerns:

Phytoremediation by using metal accumulating plants to clean soil and water contaminated with toxic metals is the most rapidly developing component of this environmental friendly and the cost effective technique, thus

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phytofiltration and phytoextraction are the best developed subsets of phytoremediation nearing commercialization [40]. The contentsof heavy metals in various parts of the paddy plant, namely the grains, husks, leaves, stem, and roots compared to the levels in soil around root zone. Most of the heavy metals studied were found to accumulate in the roots of paddy plants [41].

Phytoremediation potential of Water Hyacinth against dye industry effluent have been reported and was concluded that the water hyacinth can be utilized for treating dye waste water [42].Water Hyacinth root powder was found to be an excellent adsorbent for the methylene blue removal from waste water [43]. Water hyacinth has the tolerance to dye and dye adsorption along with good root development, low maintenance and ready availability in contaminated regions. These characteristics proved its suitability in dyeing industries effluent treatment ponds [44]. A study of several aquatic plants for their uptake, ability and mechanisms and to evaluate their phytoremediation technology was done, Water Hyacinth, Duckweed, Water fern, Hydrilla and Water cresses have been proposed to have a potential for phytoremediation because of its hyper accumulation ability and growth habit [45]. *Alternanthera sessilis* helps in Wastewater treatment since it has ability to uptake chromium, lead and nickel [46].

For reducing the pollution of lakes, harvesting of aquatic plants, which have the ability to withdraw nutrients from the water is done. All aquatic plants can serve this purpose but small plants, like phytoplankton, or submerged plants are more difficult and expensive to harvest than the floating and emergent vascular plants. Four species are considered suitable, *Eichhornia crassipes* (water hyacinth), *Alternanthera philoxeroides*, *Justicia americana* and *Typha latifolia* [47]. Two emergent macrophytes *Alternanthera philoxeroides* and *Hygrophila schulli* were used to remove Pb (lead). Dry biomass of plant and concentration of Pb were measured from different plants parts. Dry biomass of plants was decreased with increase of Pb concentration in soil in which *Alternanthera philoxeroides* was more affected [48]. The removal of Cr (VI) from aqueous solutions using Alligator weed (*Alternanthera philoxeroides*), a freshwater macrophyte, was investigated as a function of initial pH, contact time, reaction temperature and adsorbent concentration in batch studies.

An initial solution pH of 1.0 was most favorable for Cr (VI) removal. Thermodynamic parameters (activation enthalpy change, activation entropy change and activation free energy change) revealed that the adsorption of Cr (VI) onto Alligator weed (*Alternanthera philoxeroides*) is endothermic, non-spontaneous, with a decreased randomness in nature [49].Within root tissue, Cr was present mainly in the vacuoles of parenchyma cells and cell walls of xylem and parenchyma. Alterations in the shape of the chloroplasts and nuclei were detected in *A. philoxeroides* and *B.scabiosoides*, suggesting a possible application of these aquatic plants as biomarkers from Cr contamination [50].

The distribution, mobility and potential risks of Cu, Zn, and Pb were investigated using a sequential extraction procedure. *Alternanthera philoxeroides* had the best ability to accumulate heavy metals among the other *Phragmites communis* , *Aegiceras corniculatum* plant species [51]. The removal of Cr (VI) from aqueous solutions using Alligator weed (*Alternanthera philoxeroides*), a freshwater macrophyte, was investigated in batch studies. The external film diffusion played an important role in the adsorption mechanism. The Alligator weed (*Alternanthera philoxeroides*) could serve as low-cost adsorbent to remove Cr (VI) from aqueous solutions [52]. Accumulation of chromium and copper was also studied in *Alternanthera philoxeroides*[53].

The environmental ramifications of heavy metal releases from natural and anthropogenic activities are well known. Results from various studies indicated that the root metal concentrations were consistently higher than the stem and leaf concentrations in alligator weed (*Alternanthera philoxeroides* (Mart.) Griseb.) indicating the need for complete plant extraction to maximize the metal removal from a contaminated site [54]. The potential of different process and utilization of terrestrial and aquatic plants such as *Alternanthera philoxeroides* in purifying water and wastewater from different sources was reported [24]. Three local perennial plant species, *Alternanthera philoxeroides, Sanvitalia procumbens* and*Portulaca grandiflora*, were examined for their ability to uptake lead from lead contaminated soils *A. philoxeroides* showed significant differences in lead accumulation (29.99%) compared to that from *P. granaiflora* (13.03%) and *S. procumbens* (16.44%). Even though the amount of lead extracted by these three plants was small, the results showed that *A. philoxeroides* had the ability to extract an approximately 1.3-1.8 times greater amount than *P.grandiflora* and *S.procumbens* [55].

VII CONCLUSION

In the present era, large scale pollution of soil and water has imposed demand for adoption ofboth environmentally sustainable as well as costeffective cleanup techniques. Phytoremediation is a low-cost technology which takes advantage of the unique, selective and naturally occurring uptake capabilities of plant root systems, together with the translocation,bioaccumulation and pollutant storage/degradation abilities of the entire plant body.Phytoremediation of contaminated water and soil by hyperaccumulator plants would be a good option in long term. A large number of hyperaccumulative plant species have been tested for the remediation of toxicelements from fresh water systems and soil. *Alternanthera philoxeroides* have shown the ability to accumulate high level of heavy metals from water. A number of studies revealed that phytoremediation of heavy metals like Cadmium, Copper, Chromium, Zinc, Lead etc. using hyperaccumulative plants *Alternanthera philoxeroides*would be a good optionto clean polluted water and soil. The management and disposal ofphytoremediating hyperaccumulative plants is a major concernfor the successful implementation forphytoremediation technology. Despite tremendous promise, hyperaccumulative plants have limited use for large scale applications because they are often slow growing and attain low biomass. However, with the advent of genetic engineering technology, use of transgenic plants can also greatly improve phytoremedial efficiency.

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