Phytoremediation: A Promising Solar Driven Green Technology for Remediation of Contaminated Soil, Ground Water & Waste Water

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Abstract- *Phytoremediation is an interdisciplinary technology can benefit from many different approaches that used aquatic/ ornamental plants are suitable for wastewater/soil treatment because they have tremendous capacity of absorbing nutrients and removes heavy metals from wastewater/Soil and hence bring the pollution load down. This review showed that aquatic plants such as pistia, duckweed, water hyacinth and hydrilla can have remediatry effects on lead removal from wastewater and some phytoremidiator may be useful in remediating soil media. Therefore, aquatic/ornamental plants uptakes on heavy metals are varied based on their species to species as well as metal to metal.*

Keywords- Heavy metal, Phytoremidiator, Waste Water Pollution, Hyper accumulator

I. INTRODUCTION

Phytoremediation is a concept for clean-up of environment or polluted media that involves the use of plants to clean contaminated environments. Despite all of today's present technology, it seems that foliage plants and trees may be the best means of improving water, air and soil quality. Duckweed appear to be better alternative and have been recommended for wastewater treatment because it has capability of rapid growth on wide range of pH and cold tolerable to grow throughout the year but aquatic plants, such as water hyacinth, can only grow in summer. Duckweed produces biomass faster than any other aquatic plant and has clear potential as an alternative for accumulation of heavy metals. This study revealed that the aquatic / ornamental plants showed a better pollutants removal from polluted water and may be helpful in research studies and phytoremedial approaches. Phytoremediation involves growing plants in a contaminated soil and waste water, for a required growth period, to remove contaminants from the targeted soil & water, or facilitate binding/containment or detoxification of the pollutants. The plants can be subsequently harvested, processed and disposed.

II. PHYTOREMEDIATION

Phytoremediation offers a cost-effective, non-intrusive, and safe alternative to conventional cleanup techniques. In this research work at Kota, as well ornamental plants some aquatic hydrophytes plants from natural wetlands from the native place have been used to treat industrial wastewater and contaminated soil. Most ornamental hydrophytes adapted to the wastewater well, and were fairly efficient in scavenging BOD_5 (biological oxygen demand 5d), COD (chemical oxygen demand), TN (total nitrogen), TP (total phosphorus) and heavy metals (Cr, Pb, Cd) in the wastewater. However, the efficiency varied a lot for various species to different contaminants, Iris pseudacorus L. and Acorusgramineus Soland were good choices for treatment of composite-polluted urban industrial wastewater. Some variation in the change of membrane peroxidation and endogenous protective system in responses to wastewater was found among six hydrophytes, which have a correlation with the efficiency of wastewater treatment.

2.1 ADVANTAGES/ LIMITATIONS OF PHYTOREMEDIATION

Advantages:

- Environmentally friendly, cost-effective, and aesthetically pleasing.
- Metals absorbed by the plants may be extracted from harvested plant biomass.
- May reduce the entry of contaminants into the environment by preventing their leakage into the groundwater systems.
- It is potentially the least harmful method because it uses naturally occurring organisms and preserves the environment in a more natural state.
- Low cost solar driven method for cleanup of environmental pollution.

Limitations:

- Required a large area for treatment purpose as, treatment of larger volume of pollutants accompanied by a large area of land.

- Slow growth and low biomass require a long term commitment.
- With plant-based system of remediation, it is not possible to completely prevent the leaching of contaminants into the groundwater.
- The survival of the plants is affected by the toxicity of the contaminated land and the general condition of the soil.

Table**- 1-** Specific Metal Hyper-Accumulators for Removal of Specific Metals

Plant species	**Metal**	**References**
Ipomea alpine	Cu	Baker (1990)
Sebertia acuminate	Ni	Jaffre (1976)
Thlaspicaerulescens	Zn, Cd	Reves& Brooks (1983)
Astragalusracemosus	Se	Beath et al.(2002)
Haumaniastrumroberti	Co	Brooks (1977)
Arabidopsis thaliana	Zn, Pb	Lasat (2002)
Thlaspigoesingens	Ni	Kramer et al. (2000)
Brassica oleracea	Cd	Salt et al. (1995b)
Arabidopsis halleri	Zn, Cd	Cosio et al. (2004)
Sonchusasper	Pb, Zn	Yanqun et al. (2005)
Corydalis pterygopeta	Zn, cd	Yanqun et al. (2005)
Alyssum bertolonii	Ni	Chaney et al. (2000)
Stackhousiatryonii	Ni	Bhatia et al. (2005)
Hemidesmusindicus	Pb	C. Sekhar et al. (2005)
Salsola kali	Cd	la Rosa et al. (2004)
Helianthus anus	Cd,Cr,Ni	Turgut et al. (2004)
Pterisvittata	As	Tu& Ma (2005)
Sedum alfredii	Pb, Zn	Li et al. (2005)

III. FACTORS AFFECTING PHYTOREMEDIATION

The success of phytoremediation as an environmental clean-up technology depends on several factors including bioavailability of metals in soil, plant's ability to uptake, translocate and accumulate metals in shoots and plant-microbe interactions. Plants capability to uptake pollutants depends upon the survival of plants in local condition

3.1- Metal bioavailability: For plants and their associated microbes to remediate pollutants, they must be in contact with them and able to act on them. Therefore, the bioavailability of a pollutant is important for its remediation. Pollutant bioavailability depends on the chemical properties of the pollutant, soil properties, environmental conditions and biological activity. Soils with small particle size (clay) hold more water than sandy soils, and have more binding sites for ions, especially cations (CEC) (Taiz and Zeiger, 2002). The concentration of humus in soil is also positively correlated Understanding the process affecting pollutant bioavailability can help optimize phytoremediation efficiency. Aged soils are more difficult to phytoremediate as pollutants in aged polluted soils tend to be less bioavailable and more recalcitrant than pollutants in soil that is newly contaminated. In such cases, amendments may be added to soil that make metal cations more bioavailable for plant uptake.

3.2- Plant uptake and translocation: Access of heavy metals to bare roots is confined to the first few millimeters of the root tip. Uptake and transport across root cellular membrane is an important process which initiates metal absorption into plant tissues. Two different uptake routes have been reported:

(a) Passive uptake driven only by the concentration gradient across the membrane, and
(b) Inducible substrate-specific and energy dependent uptake mediated by membrane protein with transport functions (Nies, 1999; Williams et al., 2000).

Either through passive or active uptake, root cells capture metals from soil that remain bound by their cell wall and then transported across the membrane. But the electrical charge on metal ions prevents their diffusion freely across the lipophilic cellular membranes into the cytosol. Therefore, metal transport into cells is also driven by ATP dependent protein pumps that catalize H+ extrusion across the membrane.

3.3- Plant Microbe interactions: The limited bioavailability of various metallic ions, due to their low solubility in water and strong binding to soil particles, restricts their uptake/accumulation by plants. However, root colonizing bacteria and mycorrhiza can significantly increase the bioavailability of various heavy metal ions for uptake. Some bacteria are known to release biosurfactants (e.g. rhamnolipids) that make hydrophobic pollutants more water soluble (Volkering et al., 1998). Soil microorganism's organic exudates stimulate bioavailability and facilitate root absorption of a variety of metal ions including Fe^{2+} (Crowley et al., 1991; Burkal et al., 2000), Mn^{2+} (Barber and Lee, 1974) and Possibly Cd^{2+} (Salt et al., 1995a). Root exudates which feed the microorganisms by providing carbohydrates, also contain lipophilic compounds and natural chelating agents (citric, acetic and other organic acids) that increase ion mobility in soil or promote biosurfactantproducing microbial populations.

3.4- Role of Metal Chelators: the complex root secretions from plants contain natural chelating agents that affect pollutant solubility and uptake. Inside plant tissues such chelator compounds also play a role in tolerance, sequestration and transport (Ross, 1994). Phytosiderophores are chelators that facilitate uptake of Fe and perhaps other metals in grasses (Higuchi et al., 1999).

IV. MECHANISM OR PROCESSES BEHIND THE TECHNOLOGY

There are several processes in which plants or aquatic macrophytes can be used to clean up, or remediate, contaminated soil and waste water. To remove pollutants from soil, sediment and/or waste water, plants can break down, or degrade organic pollutants or contain and stabilize metal contaminants by acting as filters or traps. There are a number of different types or mechanism of phytoremediation, Defining these mechanism is useful to clarify and understand the different processes that can occur due to vegetation, what happens to a contaminant, where the contaminant remediation occurs, and what should be done for effective phytoremediation. The different forms of phytoremediation may apply to specific types of contaminants or contaminated media, and may require different types of plants (the terms 'plant' and 'vegetation' will be used interchangeably to indicate all plant life, whether trees, grasses, shrubs, or other forms).The uptake of toxic elements in plants or aquatic macrophytes occurs primarily through the root system, in which the principal mechanisms for preventing contaminant toxicity are found.

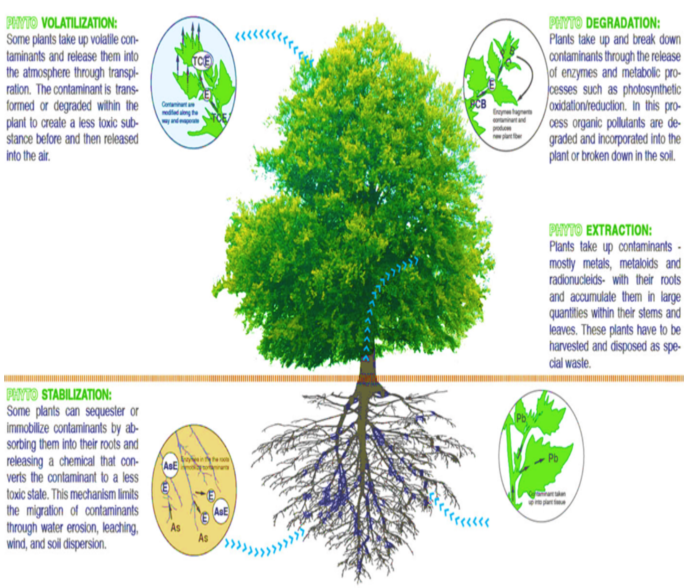

Fig.1-Mechanism of phytoremediation

The root system provides an enormous surface area that absorbs and accumulates the water and nutrients essential for growth, as well as other non-essential contaminants. The use of trees (rather than smaller plants) is effective in treating deeper contamination because tree roots penetrate more deeply into the ground. In addition, deep-lying contaminated ground water can be treated by pumping the water out of the ground and using plants to treat the contamination.

4.1- Phytoextraction-Phytoextraction is pollutant uptake by roots with subsequent accumulation in the above ground portion of a plant, generally to be followed by harvest and ultimate disposal of the plant biomass. It is a toxic element removal process.

4.2-Phytostabilization- Phytostabilization is the use of vegetation to remove soil contaminants in situ, through modification of the chemical, biological, and physical conditions in the soil. Contaminant transport in soil, complexation, or metal valence reduction in soil within the root zone; or binding into humic (organic) matter through the process of humification.

4.3- Rhizofiltration- Rhizofiltration (also known as phytofiltration) is the removal by plant roots of contaminants in surface water, waste water, or extracted ground water, through adsorption or precipitation onto phytoimmobilization. inrhizofiltration this accumulation can occur in the roots or in the portion of the plant above water, whereas for effective phytoextraction the accumulation occurs aboveground, not in the roots, rhizofiltration differs from phytoextraction in that the contaminant is initially in water, rather than in soil.

4.4-Rhizo-degradation- Rhizodegradation is the enhancement of naturally-occurring biodegradation in soil through the influence of plant roots, and ideally will lead to destruction or detoxification of an organic contaminant.

4.5-Phytodegradation- Phytodegradation is the uptake, metabolizing, and degradation of contaminants within the plant, or the degradation of contaminants in the soil, sediments, sludge's, ground water, or surface water by enzymes produced and released by the plant.

4.6- Phytovolatilization- it is the uptake of a contaminant by a plant, and the subsequent release of a volatile contaminant, a volatile degradation product of a contaminant, or a volatile form of an initially non-volatile contaminant. Phytovolatilization 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 cases transform it to less toxic forms.

V. EXPERTS REVIEWS ON PHYTOREMEDIATION OF WASTE WATER

A. K. Hegazy, N. T. Abdel Ghani et al. studied Typha for phytoremediation of industrial waste water in Egypt and observed Rhizo-filtration to be the best mechanism to explain TyphaDomingensis phytoremediation capability. The concentrations of Al^{3+}, Fe^{3+}, Zn^{2+} and Pb^{2+} in wastewater ponds exceeded the upper limits indicated by the Egyptian environmental regulations. The native aquatic plant species T. domingensis accumulates high concentrations of Al^{3+}, Fe^{3+}, Zn^{2+} and Pb^{2+} in their roots. There were significantly positive relationships between the concentrations of Al^{3+}, Fe^{3+}, Zn^{2+} and Pb^{2+} in the T. Domingensis roots and those in water. T. domingensis has the potential to be used in phytoremediation purpose to remove metal pollutants from contaminated wastewaters.

In a research work by Anil Giri in NIT Rourkela on assessing the phytoremediation potential of the aquatic plant Eichhorniacrassipes for arsenic (III) and chromium (VI) from water. The accumulation, relative growth and bio-concentration factor of plant on treatment with different concentrations of arsenic(III) and chromium(VI) solution significantly increased ($P<0.05$) with the passage of time. Plants treated with 0.100 mg/L arsenic (III) accumulated the highest concentration of arsenite in roots (7.20 mg kg-1, dry weight) and shoots (32.1 mg kg-1, dry weight); while those treated with 4.0 mg/L of chromium (VI) accumulated the highest concentration of hexavalent chromium in roots (1320 mg/kg, dry weight) and shoots (260 mg/kg, dry weight) after 15 days. The plant biomass was characterized by SEM, EDX, FTIR and XRD techniques.

In 2012, an experimental study was carried out by Amin Mojiri, University of Science, Malaysia on treatment of municipal waste water. Work was carried out to investigate the phytoremediation of heavy metals from municipal wastewater by Typhadomingensis. Typhadomingensis was planted in pots containing 7 litre of municipal wastewater and aeration was done. After 24 and 48 hours, the samples were taken for testing. The concentrations in the root and shoot tissues were found in the order of Fe>Mn>Zn>Ni>Cd. The evidences provided by this experiment indicated that the Typhadomingensis was capable to remove heavy metals from urban wastewater.

Treatment of dairy waste waterusing phytoremediation technique was studied by Bhavsar Swati, Pujari Veda-vati et al. of West Bengal.Dairy industry is considered to be largest source of food processing wastewater in many countries. Huge amount of water is used during processing of milk, that generate high volume of effluent containing dissolved sugars, proteins, and fats etc. which are mainly organic in nature.

5.1 EXPERTS VIEWS ON PHYTOREMEDIATION OF CONTAMINATED SOIL

Scott D. Cunningham, William R. Berti, et al. worked on phytoremediation of contaminated soil & observed Plant-based remediation techniques having increasing promise for use in soils contaminated with organic and inorganic pollutants. Two contrasting approaches to remediation are being pursued: pollutant-stabilization and containment, where soil conditions and vegetative cover are manipulated to reduce the environmental hazard; and decontamination, where plants and their associated microflora are used to eliminate the contaminant from the soil.

Figure-2 Phytoremediation of Contaminated sites using plants.

Degraded soils of mines usually have low concentrations of important nutrients, like N, P and K. Toxic metals can also adversely affect the number, diversity and activity of soil organisms, inhibiting soil organic matter decomposition and N mineralization processes.

Metal toxicity issues do not generally arise in the case of native flora, considering that native plants become adapted over time to the locally elevated metal levels. Native plants may be better phytoremediators for contaminated lands than the known metal hyper accumulators because these are generally slow growing with shallow root systems and low biomass. Plants tolerant to toxic metals and low nutrient status with a high rate of growth and biomass are the ideal species to remediate degraded soils and habitats like those around mines. The native flora displayed its ability to withstand high concentrations of heavy metals in the soil. Some species also displayed variable accumulation patterns for metals at different soil concentrations. This variation was also observed in different parts of the same plant suggesting that full consideration of plant–soil interactions should be taken into account when choosing plant species for developing and utilizing methods such as phytoremediation.

The existing natural plant cover at abandoned mining sites can be increased manifold by wide-scale planting and maintenance of native species with higher metal accumulation potential for some years. Even dispersal of seeds obtained from plants on site is to be encouraged. Adding organic amendment is essential to facilitate the establishment and colonization of these “pioneer plants”. They can eventually modify the man-made habitat and render it more suitable for subsequent plant communities. Allowing native species to remediate soils is an attractive proposition since native wild species do not require frequent irrigation, fertilization, and pesticide treatments, while simultaneously a plant community comparable to that existing in the vicinity can be established.

VI. SUMMARY & CONCLUSION

Environmental pollution is increasing tremendously on account of an unabated or uncontrolled increment in population, industrialization, urbanization, anthropogenic activities as well as depletion of natural sources. The metal/metalloids pollution due to industries is of great concerns now days, as these hazardous pollutants are accumulated in through crop in living organisms or grazing animals are responsible for many metabolic and physiological disorders. Advancement in science and technologies parallel to industrial revolution has opened new vistas to exploit the inherent traits of natural resources including green plants to overcome the damage to the environment by pollutants.

This paper is an attempt to review the green technology which based on plants and may be used for pilot project work in future on the basis of past reviews obtained from various studies.so it is concluded from the reviews that the Phytoremediation technique is relatively new method for abetment of hazardous pollutant from contaminated soil, waste water, ground water or effluents. Many research organization and academic institution are actively involved in this field. However a huge scope is there to explore for future development.

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