ABSTRACT

Pollution has become a major concern these days with rapid rise in hazardous chemicals being dumped into land and water. Traditional clean up techniques have now failed to completely remediate pollutants. Plants can concentrate considerable amounts of xenobiotics in their roots, shoots and leaves and thus can be an attractive way of pollution control. Phytoremediation is one such ecologically sound, cost effective, sustainable and novel technique that employs plants to completely remove toxic contaminants.

Key Words: Phytoremediation, Pollution, Xenobiotics, Plant, Transgenic

INTRODUCTION

The reckless exploitation and wanton misuse of natural resources along with industrialization has resulted in large scale pollution. Traditional physical and chemical pollution control efforts have now become inefficient and expensive. Current engineering methods to remove these pollutants are expensive and intensive, annually costing billions of dollars worldwide. The social and economic costs of environmental damage caused by the prevailing industrial growth in India have been estimated to be much higher than the required expenditure of 0.5-1.0% of GNP for pollution control. Thus, the need for the hour is adoption of technologies that are environmentally sustainable and more cost-effective. Phytoremediation is such a sustainable, cost effective, innovative technology that uses biological systems for treatment of contaminants.

Plant-assisted bioremediation or phytoremediation

The use of green plants for remediation of polluted soil is an attractive way of sustainable development. Plants can concentrate considerable amounts of xenobiotics in their roots, shoots and leaves. Xenobiotics (Xenos-foreign) are chemicals made by synthetic organic chemists which are strangers to the biosphere. These are also broadly defined as any compounds or substances that are released in any compartment of environment by action of man and thereby occur in concentrations higher than natural. Heavy metals and many synthetic pesticides fall under such category of xenobiotics. In India, in the past few decades, soil and ground water has been contaminated with metal, mainly due to industrial activities and petroleum hydrocarbons, which leaked from underground storage tanks. Besides, pesticides and herbicides have added to the pollution burden of water and soil. Phytoremediation aims to address such pollutants. Pollutants like Cd, Pb, Zn, As, petroleum, hydrocarbons and radionuclides can be extracted by plants like Viola baoshanensis, Sedum alfredii, Rumex crispus, Helianthus annuus, Medicago sativa, Populas sp, Juniperus communis, Festuca pratensis, Brassica juncea, Brassica oleracea1. Pollutants like Cu, Cd, Cr, Ni, Pb, Zn can be phytostabilized by Anthyllis vulneraria, Festuca
arvernensis, Koeleria vallesiana, Armeria arenaria, Lupinus albus\(^2\) while, arrowroot (Canna) plant can render substances non toxic by acting as “green liver”\(^3\). This process of breakdown of chemicals is analogous to human liver and hence the name. Indian mustard, sunflower, water hyacinth, Azolla, duckweed, cattail and poplar are popular species for phytoremediation because of their fast growth, high biomass, high tolerance and accumulative property.

**Phytoremediation of metals**

At least 45 plant families are known to contain metal-accumulating species. Such plants can accumulate metals up to levels that are 100 to 1,000 times of those normally accumulated by plants grown under the same conditions\(^4\). Metals that can be phytoremediated include Cd, Co, Fe, Hg, Se, Pb, V, W, Cr, Cu, Fe, Mn, Mo, Zn and radioactive isotopes such as \(^{238}\)U, \(^{137}\)Cs and \(^{90}\)Sr. Some metal hyperaccumulative plants identified are Arabidopsis halleri (Zn, Cd)\(^5\), Sonchus asper (Pb, Zn), Corydalis pterygopetala (Zn, Cd)\(^6\), Astragalus bisulcatus (Se)\(^7\), Stackhousia tryonii (Ni)\(^8\), Hemidesmus indicus (Pb)\(^9\), Salsola kali (Cd)\(^10\), Sedum alfredii (Pb, Zn)\(^11\), Pteris vittata (As)\(^12\), Helianthus annus (Cd, Cr, Ni)\(^13\).

**Phytoremediation of hydrocarbons and persistent organic pollutants**

Petroleum fuels, alcohols, esters, nitrobenzenes, ethers, polycyclic aromatic hydrocarbon (PAHs) and highly chlorinated compounds like PCBs and chlorinated solvents do not appreciably degrade aerobically. Petroleum, hydrocarbons are efficiently removed by Viola baoshanensis, Sedum alfredii, Rumex crispus, Helianthus annus, Alfalfa (Medicago sativa), poplar, juniper, fescue and Indian mustard (Brassica oleracea)\(^1\).

Common osier (Salix viminalis) and Pine (Pinus radiata, Pinus ponderosa) can accumulate petroleum hydrocarbons, organic solvents, MTBE, TCE and by-products\(^14\). In a study, Cynodon dactylon and Festuca arundinacea showed mean petroleum reduction by 68 % after 1 year\(^15\). Benzene can be effectively removed by Chlorophyta comosum, Ficus elastic, Kalanchoe blossfeldiana, and Pelargonium domesticum while Fluoranthene can be removed by Cyclotella caspia\(^17\). DDT, explosives, waste and nitrates can be removed by Elodea canadensis, Pueraria thunbergiana, Duckweed, parrotfeather and hybrid poplar\(^18\). Certain cell suspension cultures of Petroseminium hortense and Glycine max are able to degrade \(^{14}\)C DDT\(^19\). Pumpkin, zucchini, and squash also are found to be successful when used for phytoremediation of DDT, DDE, and DDD\(^20\). In addition, a study showed that hairy root cultures (Cichorium intybus) are promising in the degradation of DDT\(^19\). Leaves and fruits of zucchini can concentrate dioxins and furans while pumpkin, sedge, tall fescue, zucchini, bark of black walnut and tulip poplar trees can concentrate PCB. Poplar trees (Populus) can address Atrazine and has been extensively studied in recent years as well\(^18\).

**Role of chelators in phytoremediation**

Understanding the process affecting pollutant bioavailability can help optimize efficiency of phytoremediation. For instance, organic acids enhance Ni remediation in Stackhousia tryonii\(^8\) and the synthetic metal chelator EDTA increases the efficiency of Cu phytoextraction by Elsholtzia splendens in polluted soils\(^21\). EDTA and citric acid\(^13\) combination can also enhance Cd, Cr and Ni uptake in Helianthus annus.

**Transgenic plants in phytoremediation**

Other than naturally occurring hyperaccumulative species, use of genetically engineered plants are greatly emphasised now a days. Such plants have one or more genes being incorporated from other species, thus improving their phytoremediation capacity. Some workers suggested that transgenic plants might be able to contribute to the wider and safer application of phytoremediation. A recent publication describes the development of transgenic poplars (Populus tremula x Populus alba) over expressing mammalian cytochrome P450 2E1 (CYP2E1). Cytochrome P450 is a family of enzymes commonly involved in the metabolism of toxic compounds. The engineered plants showed enhanced performance about the metabolism of trichloroethylene and the removal of a range of other toxic volatile organic pollutants, including vinyl chloride, carbon tetrachloride, chloroform and benzene\(^21\). Similarly, introduction of a mammalian CYP2E1 gene into tobacco plants
resulted in plants with increased metabolism of TCE. Transgenic wetland species, such as *Spartina* sp, reeds, and *Typha* sp also showed tremendous phytoremedial promise. In a separate study, over expression of two key enzymes, cystathionine-gamma-synthase and selenocysteine methyltransferase, was shown to promote the conversion of selenocysteine to volatile selenium. In *Brassica juncea*, APs gene from *Arabidopsis thaliana* imparted Se remedial property. Likewise, by introducing bacterial genes involved in the metabolism of TNT and RDX, the tolerance and uptake of these pollutants by transgenic plants were considerably improved. In addition, phytoremediation of herbicides has been enhanced by using transgenic plants expressing GST or cytochrome P450 genes. Such transgenic plants produced for metabolizing herbicides and long-persisting pollutants can be used for phytoremediation of foreign chemicals in contaminated soil and water. Development of transgenic plants for enhanced phytoremediation of metals has also been successful, including plants that have been developed to detoxify and remove lead, cadmium and selenium from polluted soils.

Thus, the phytoremedial efficiency can be improved many fold by the use of transgenic plants. But, it is not yet clear how applicable these transgenic are for environmental cleanup, since no field studies have been reported (except one using transgenic Indian mustard plant for Se), yet the concept seems promising.

**CONCLUSION**

In the present era, large scale pollution of soil and water has imposed demand for adoption of both environmentally sustainable as well as cost-effective cleanup techniques. Phytoremediation takes advantage of the unique, selective and naturally occurring uptake capabilities of plant root systems, together with the translocation, bioaccumulation and pollutant storage/degredation abilities of the entire plant body. 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.

**REFERENCES**

9. Chandra Sekhar K., Kamala C.T., Chary N.S., Balaram V. and Garcia G., Potential of


