PHYTOREMEDIATION: CLEANING UP THE ENVIRONMENT BY PLANTS

Renu Rani[1] and Dr. Satendra Kumar[2]

[1]Assistant Professor, Department of Botany, Government Girls Degree College
Behat, Saharanpur - 247121 (UP) India.
Email ID: renu31panwar@gmail.com

[2]Assistant Professor, Department of Chemistry, Government Girls Degree College
Behat, Saharanpur - 247121 (UP) India.
Email ID: drsatendrakmr@gmail.com

ABSTRACT

Anthropogenic activities cause pollution of soil, groundwater, sediments, surface water, air with unsafe and noxious chemicals is one of the main crises facing the industrialized world today. Over the last century, public apprehension about environmental pollution has increased remarkably. Now a days, polluted soils and waters as a result of global industrialization pose a major environmental and human health problem, which can not be easily solved, even in the rich industrialized countries. Classical remediation technologies are mostly found inadequate to solve the problem and to redevelop sites for housing, agriculture or recreation. Application of plants metabolic potential is accepted as an environmentally benign and economical measure for decontamination of polluted environment. Transgenic approaches successfully employed to promote phytoextraction of metals and metalloids from soil by their account in the above-ground biomass involved mainly implementation of metal transporters improved production of enzymes of sulphur metabolism and production of metal detoxifying Cheaters- metallothionine and phytochelatin.

INTRODUCTION

Environmental pollution is resultant of wide range of compounds that are released as a consequence of industrial progress (Yakimov *et al*., 2005 and Allard and Neilson, 1997). Multiple hazardous waste sites have been generated cosmopolitan as a result of accumulation of xenobiotics in soil and water (Zhou and Crawford, 1995, Ali *et al*, 2011). Soils contamination by heavy metals and metalloids has become a serious environmental issue today. A number of metals including chromium, iron, arsenic, zinc, cadmium, mercury and copper are known to significantly compromise the quality of soil and cause adverse effects to human and health and the well being of other organisms that comes in contact with such soil. Heavy metals are extremely persistent in the environment because they are not biodegradable and may not be broken down by chemical oxidation or through thermal processes, as a result their accumulation readily reaches to toxic levels. Some metals are essential for plant growth however, very high or low concentrations of some these heavy metals may be inhibitory to plant growth. Human activities such as metal smelting, electroplating and mining are sources through which heavy metals enter the environment. Constituents of crude oil like nitro aromatic compounds, polycyclic aromatics and other hydrocarbon along with halogenated organic compounds in combination with large and diverse group of chemicals are responsible for environmental depletion (Alexander, 1999 and Atlas, 1991). The removal of these xenobiotics involve physico-chemical processes like excavation, incineration and landfills that are expensive and difficult to execute. These remedial strategies that clean up contaminated sites are not effective or adequate.

Xenobiotics are chemicals that are not present normally in the ecosystem and synthesized by human activities (Loh and Wang, 1998). This term is very often used in the context of pollutants. Generally these are metallic/organic residues or byproducts that enter into environment from industrial, agricultural, domestic, municipal activities and exert adverse effects and disturbances to the ecosystem. Most of these compounds are not recognized by existiting degradative enzymes and will accumulate in soil and water. Xenobiotics are mostly substituted hydrocarbons, phenyl carbonates and other compounds. Methods used for remediation of heavy metal contaminated soil include soil flushing, solidification/stabilization, vitrification, thermal desorption and encapsulation. Other methods include burying of the contaminated soil or dilution of the contaminated soil with clean soil. These methods contribute to long-term risks such as leaching into groundwater and surrounding soil. Due to the expensive nature of the conventional remediation methods for heavy metal contamination, phytoremediation technologies are continuously being researched for possible solutions

The ability of microorganism to uptake and accumulate heavy metals such as Co, Cd, Zn, Mn, Cu, Pb, Ni, Hg and Ag is very well known. Different bacteria, fungi such as *Saccharomyces*, *Rhodotorula*, *Aspergilus*, *Rhizopus* and some algae and diatoms such as *Thalassiora pseudonana* have such an ability and being studied for their biotechnological potential as agents of effluent detoxification. Among vascular plants, some aquatic weeds such as species of *Salvinia*, *Lemna*, *Azolla*, *Eichornia*, Sedges and even tree species are also known to tolerate, uptake and even accumulates heavy metals and other toxicants in their cells. Besides microorganism plants are also being studied for their potential of environmental cleanup. Green plants are not only the lungs of nature with unique ability of purifying impure air by photosynthesis releasing oxygen to sustain aerobic life in the biosphere , but it has also been only quite recently demonstrated that they could also be very useful in cleaning up the hazardous waste sites.

“**Phytoremediation** (from Ancient Greek *φυτο (phyto)*, meaning "plant", and Latin *remedium*, meaning "restoring balance") describes the treatment of environmental problems (bioremediation) through the use of plants that mitigate the environmental problem without the need to excavate the contaminant material and dispose of it elsewhere.”

Phytoremediation is an integrated multidisciplinary approach to the cleanup of contaminated soils, which combines the disciplines of plant physiology, soil chemistry, and soil microbiology . Phytoremediation has been applied to a number of contaminants in small-scale field and/or laboratory studies. These contaminants include heavy metals, radionuclides, chlorinated solvents, petroleum hydrocarbons, PCBs, PAHs, organophosphate insecticides, explosives, and surfactants. Certain species of higher plants can accumulate very high concentrations of metals in their tissues without-showing toxicity. Such plants can be used successfully to clean up heavy metal polluted soils if their biomass and metal content are large enough to complete remedi¬ation within a reasonable period. For this clean-up method to be feasible, the plants must (1) extract large concentrations of heavy metals into their roots, (2) translocate the heavy metal into the surface biomass, and (3) produce a large quantity of plant biomass. At least 45 families have been identified to hyperaccumulate heavy metal; some of the families are Brassicaceae, Fabaceae, Euphorbiaceae, Asteraceae, Lamiaceae and Scrophulariaceae.

PHYTOREMEDIATION PROCESSES

phytoremediation may be successful by an influence of the vegetation on the physical (water balance, transport processes), the chemical (enzymes, redox potential, pH, complexing agents) and the biological (roots, microbes, mycorrhiza) factors in soil. Based on these processes, several phytoremediation techniques have been developed: Phytoextraction, rhizofiltration, phytostabilization, rhizodegradation, phytodegradation, phytovolatilization,

Phytodegradation

Phytodegradation, also called phyto-transformation, is the breakdown of contaminants taken up by plants through metabolic processes within the plant, or the breakdown of contaminants surrounding the plant through the effect of compounds (such as enzymes) produced by the plants. Complex organic pollutants are degraded into simpler molecules and are incorporated into the plant tissues to help the plant grow faster.

Rhizodegradation

Rhizodegradation, also called phyto-stimulation or plant-assisted bioreme-diation/degradation, is the breakdown of contaminants in the rhizosphere (soil surrounding the roots of plants) through microbial activity that is enhanced by the presence of plant roots and is a much slower process than phytodegradation.

Phytovolatilisation

Phytovolatilisation is the uptake and transpiration of a contaminant by a plant, with release of the contaminant or a modified form of the contaminant from the plant to the atmosphere. Phytovolatilisation occurs as growing trees and other plants take up water and the organic contaminants. Some of these contaminants can pass through the plants to the leaves and evaporate, or volatilise, into the atmosphere.

Phytoextraction (Phytoaccumulation)

phytoaccumulation, refers to the uptake of metals from soil by plant roots into above-ground portions of plants. Certain plants, called hyperaccumulators, absorb unusually large amounts of metals in comparison to other plants. After the plants have been allowed to grow for some time, they are harvested and either incinerated or composted to recycle the metals.

PHYTOREMEDIATION AND ITS NEED

The advances in industrialization, explosive development of chemical industries and modernization of life styles caused global deterioration of environmental quality. In order to cope up the quality of environment and achieve the safe life it is necessary to clean up the contaminants and pollutants from the environment. Current cleaning technology like physical removal of polluted soil from a site and dumping it somewhere else is too costly and destructive to environment (Mrozik and Piotrowska-Seget, 2010). Now a day, an emerging promising approach is Phytoremediation Technology. It is an ininnovative field of science and technology for cleaning up contaminated soil, water and air . This technology is an alternative or complimentary one that could be applied alongwith or instead of mechanical congenital cleaning methodologies which mostly require high capital input, labor and intensive energy.

TRANSGENIC PLANTS

Generically modified plants having superior phytoremediation potential with high biomass production can be an alternative to improve phytoremediation. General plant productivity is controlled by many genes and difficult to promote by single gene insertion. Implanting more efficient accumulator genes into other plants that are taller than natural plants increases the final biomass. In genetic engineering of plants, a foreign piece of DNA is stably inserted into the genome of a cell, which is regenerated into a mature transgenic plant. The piece of DNA can come from any organism, from bacteria to mammals. The foreign DNA usually contains two genes, one a resistance gene used for selection after transformation, the other the gene of interest. Each gene is coupled to a plant promoter, ensuring the formation of the gene product (usually a protein) in the plant. When the transformed plant is propagated, the foreign gene is inherited by its offspring. The foreign stretch of DNA may be transferred to the plant either via a particle gun, or via *Agrobacterium*, a soil bacterium that makes a living by inserting part of its DNA (called T-DNA) into a plant cell.The g-ECS glutamylcysteine synthetase transgenic seedlings of *Brassica juncea* showed increased tolerance to cadmium and had higher concentrations of Phytochelatins, γ-GluCys, glutathione, and total nonprotein thiols compared to wild type seedlings (Zhu *et al*., 1999). Rice (*Oryza sativa)* transformed with genes encoding cytochrome P450 monooxigenases CYP1A1, CYP2B6 and CYP2C19 are more tolerant to various herbicides than non transgenic rice plant, owing to enhanced metabolism by introduced P450 enzyme (Kawahigashi *et al*., 2008). Indian mustard plant overexpressing ATP sulfurylase were shown to havehigher shoot Selinium concentration and enhanced se tolerance compared to wild type (Pilon-Smits *et al*., 1999). Transformed *A .thalliana* plants with *E. coli* gene Znt, which encodes a Pb, Cd and Zn transporter, grow better thanthewild type in Pb, Cd and Zn containing medium (Lee *et al*., 2003). The potential of success of genetic engineering can be limited because of anatomical constraints.

CONCLUDING REMARKS

Phytoremediation is a fast developing field, since last ten years lot of field application were initiated all over the world, it includes Phytoremediation of Organic, Inorganic and Radionuclides. This sustainable and inexpensive process is fast emerging as a viable alternative to conventional remediation methods, and will be most suitable for a developing country like India. Most of the studies have been done in developed countries and knowledge of suitable plants is particularly limited in India. In India commercial application of Phytoremediation of soil Heavy metal or Organic compounds is in its earliest phase. Fast growing plants with high biomass and good metal uptake ability are needed. In most of the contaminated sites hardy, tolerant, weed species exist and phytoremediation through these and other non-edible species can restrict the contaminant from being introduced into the food web. It is evident that phytoremediation has benefits to restore balance to a stressed environment, but it is important to proceed with caution. The study and use of genetic modifications must be performed in order to determine the true costs and benefits of this technology to the ecosystem as a whole, before is to be applied to a larger scale. Progress in the field of molecular genetics, will allow the analysis of metal hyperaccumulator plants and should provide new insights into metabolic detoxification processes and identify tolerance genes, thus providing considerable more information about the genomes of these model organisms.

REFERENCES

1. Yakimov, M.M., Denaro, R., Genovese, M., Cappelo, S., D Auria, G., Chernikova, T.N., Timmis, K.N. and Golyshi, P.N. (2005). Natural microbial diversity in superficial sediments of Milazzo Harbor (Sicily) and community succession during microcosm enrichment with various hydrocarbon. *Environ. Microbiol*.7:1426-1441.
2. Allard, A.S. and Neilson, A.H. (1997): Bioremediation of organic waste sites: a critical review of microbiological aspects. *International Biodeterioration and Biodegradation*.39: 253-285.
3. Zhou, E. and Crawford, R. (1995): Effects of oxygen, nitrogen and temperature on gasoline biodegradtion in soil. *Biodegradation*. 6:127-140.
4. Ali, S.M., Sabae, S.Z, Fayez, M. Monib, M. and Hegazi, N.S. (2011): The influence of agro-industrial effluents on River Nile pollution. *Journal of Advanced Research*. (2)1: 85-95.
5. Alexander, M. (1999). Biodegradation and Bioremediation, 2nd ed. Academic Press. San Deigo, California.
6. Atlas, R. M. (1991). Microbial hydrocarbon degradation – bioremediation of oil spills. *Journal of Chemical Technology and Biotechnology*. 52:149-156.
7. Loh, K. C. and wang, S. J. (1998). Enhancement of biodegradation of phenol and a non growth substrate 4-chlorophenol by medium augmentation with conventional carbon sources. *Biodegradation*, 8:329-338.

8. Mrozik, A. and Piotrowska-Seget, Z. (2010). Bioaugmentation as strategy for cleaning up of soils contaminated with aromatic compounds. *Microbiological Research*. 165(5): 363-375.
9. Zhu, Y. L., Pilon-Smits, E.A.H., Tarun, A.S., Weber, S.U., Jouanin, L. and Terry, N. (1999): Cadmium tolerance and accumulation in Indian mustard is enhanced by overexpressing glutamylcysteine synthetase. *Plant Physiology*. 121; 1169-177.
10. Kawahigashi, H., Hirose, S., Ohkawa, H., Ohwaka, Y. (2008). Transgenic rice plant expressing human P450 genes involved in xenobiotic metabolism for phytoremediation. *J. Mol. Microbiol. Biotechnol.* 15:212-219.
11. Elizabeth, Pilon-Smits and Marinus, P. (2002). Phytoremediation of metals using transgenic plants. *Critical Reviews in Plant Sciences*. 21(5):439–456.
12. Lee, J., Bae, H., Jeong, J., Lee, J.Y., Yang, Y.Y., Hwang, I., Martinoia, E. and Lee, Y (2003a) Functional expression of a bacterial heavy metal transporter in *Arabidopsis* enhances resistance to and decrease uptake of heavy metals. *Plant Physiol*. 133:589-596.