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PHYTOREMEDIATION TECHNOLOGY : A REVIEW

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Phytoremediation technology has been reviewed in the present communication. Various processes like phytoextraction, phytodegradation, phytovolatalization, rhizofiltration and phytostabilization etc. were proved to be key to the wonderful lowcost phytoremediation technology.

Keywords : Metallic pollutants; Phytoremediation technology; Pollution.

Man has contributed directly or indirectly for the enrichment of the civilization right from the 'Stone Age' to the recent age of 'Science and technology'. During the process, man has continuously used the so called 'ecosystem', whereby the indiscriminate use of the environment has resulted in many dreadful consequences. Among them 'Soil Pollution' has been a grave concern for the sustainability of man itself. 'Polluted Soils' are enriched with environmentally important non-radioactive metals as, As, Cd, Cr, Pb, Hg, Zn and radioactive metals as Se, U, Cs. Fertilizer, pesticide, insecticide, nuclear tests, industrial effuents provide these metallic pollutants to soil. Various methods are applied to make the soil free from these hazardous metals. Sophisticated technologies are there for the clean-up of contaminated soil but these technologies costs more. So various scientific works have been done to find the alternative and also to minimize the cost. 'Phytoremediation' proved as a low cost technology for clean up of contaminated soil. In phytoremediation technology green plants are used to remove the metallic hazardous pollutants from environement[1]. Complete knowledge of physiology, and internal molecular strategies for phytoremediation, along with biotechnological method are designed together to make this process more efficient. Plants used for removal of polluting metal are able to accumulate heavy metal in their tissues, thus increase in dry weights of plant tissue occur. Interdisciplinary collaboration of experts from the field of molecular biology, plant bicohemistry, plant physiology, soil chemistry and environmental biology makes the plytoremediation technology more productive. Series of scientific works, certifies phytoremediatioin as a best method for accumulation of organic and inorganic pollutants from soil, water also from air. The whole phytoremediation procedure can be divided as phytoextraction, phytodegradation, phytovolatalization, rhizofiltration, phytostabilization, blastofiltration and enhanced rhizosphere biodegradation.

PHYTOEXTRACTION - Plant root absorbs the hazardous metal and organics from soil and translocate them through xylem to shoot and accumulate in the plants tissue.

PHYTODEGRADATION - Plants and soil borne microorganism breaks the accumulated heavy metal and organics, through the metabolic pathway.

PHYTOVOLATALIZATION- Plant take up the heavy metal from soil and volatalize them, and ultimately releases to atmosphere via traspiration.

RHIZOFILTRATION- Some plant roots are able to absorb heavy metal from water and waste streams.

PHYTOSTABILIZATION - Plant immobilize the heavy metal present in soil or ground water and accumulate in the root and precipitate within the root zone.

BLASTOFILTRATION - Young plants (*Brassica juncea)* are able to take up heavy metal and organics from water and accumulate in the shoot.

ENHANCED RHIZOSPHERE BIODEGRADATION- Rhizospheric microorganism sometimes degrade the contaminating heavy metal.

Phyto Extraction : Metals like Pb, Ni, Zn, Cr, Cu, U, Sr, Cs are taken up by roots and transported to shoot. Phytoextraction is mediated by chelating agent, that form compound with heavy metal and also by hyperaccumulating plant that, accumulates the metal at very high rate[2]. The former is known as chelate assisted phyto extraction or *induced phytoextraction* and the latter is known as *longterm phytoextraction*. Lead, Cadmium, Arsenic, radionuclides are removed from soil by chelateassisted phytoextraction. Synthetic cheating agent EDTA (Ethylenediamine tetra acetic acid) when applied to soil enhanced the lead accumulation[3] and accumulation of lead (Pb) in shoot, increases shoot biomass[4].

After attainment of optimal biomass of plant, chelating agents are applied to soil. After metal uptake phase, the metal uptake is estimated by measuring the shoot biomass. Several other metal other than Pb, like Cu, Zn, Ni, Zn can be accumulated in Indian Mustard (*Brassica juncea)* by EDTA mediated phytoextraction chelate metal complexes are transported to shoot from root by xylem via transpiration flow[5]. Pb - EDTA complexes are transported to shoot as it is but in dicot plant takes iron from Fe^{+3}- EDTA complex, as Fe^{+2} after splitting the complex with an enzyme Fe^{+3} chelate reductase from root, Channey[5] has developed a concept regarding phytoextraction, where instead of using chelating agent hyperaccumulating plants are used to accumulate metal at high rate. Hyperaccumulating plants have specialized physiological and genetical modification i.e., specialized gene for accumulation, translocation of metal and also for resistance against high concentration of metal. Naturally occurrring phytoaccumulator, having low biomass, slow growth rate, makes this process less impressive. Till now hyperaccumulators for Pb, Cd, Ar, U etc. not yet found. Recently, one plant of Asteraceae family (*Berkheya caddii)* having high biomass and rapid growth is able to accumulate Ni, and found in North Eastern Transvaal, Africa. Metal accumulation by phytoaccumulator, protects the plants from fungal and insect attack[6,7]. Recently Nickel hyper accumulation, provides protection against fungal and bacterial attack in *Streptanthus polygaloia* and also against insect[8].

Now a days, poplar a woody plant belonging to genus populus, is most widely used in remediating specifically zinc, cadmium, and selenium[9,10]. Transgenic poplars are widely used recently for remediating mercury[11,12]. TCE (Trichloroethylene), a man made chemical, is transformed and degraded by poplars. Ground water is contraminated by TCE in highly developed areas, industrial areas, agricultural areas, and use of poplars proved most impressive in making pollution free soil. Poplars are fast growing, deep rooted and have high water usage, for which, they are most widely used as phytoremediators.

Mechanism for Metal Resistance by Plant : Due to gradual accumulation of metal in plant tissues, plant must adopt some detoxifying mechanism against the accumulated metal. Metals when bind with specific high affinity chelating agent the concentration of free metal ion decreases and thus reduces the phytotoxicity. Metalothionein (MT), which is a low molecular weight gene encoded[13], cystein rich chelating agent show affinity to Cu[14] and helps in detoxifying it in *Arabidopsis thaliana*[15] and phytochelatanin a enzymatically synthesized, cysteine riched low molecular weight chelating agent show affinities to Cd and detoxify it in *A. thaliana*[16] and also to Cu[17]. The Cd phytochelatinin complex was accumulated in vacuole and Cd detoxification occur[18] and Cd transport into vacuole is mediated by Cd antiport and an ATP dependent PC transports[19]. Similarly, Zn accumulation and detoxification in the vacuoles in *Festuca rubra* is established by the observation that the vacuole volume is increased after exposed to Zn[20]. Trichomes also acts as a detoxifying sites for Cd and Pb[21]. Metals are also detoxified by transformation into another form. Se is excluded from the methionine biosynthetic pathway in *Astragalus bisculaters* and provent Se from formation of harmful Selenomethionine, (which replace the methionine residue in protein[22]). Arsenic also incorporate into dimethyl arsenylribosides and certain lipid in marine algae and become less harmful.

Bioavailability of Metal uptake through root and process of accumulation in root : Metal ion shows greater affinity for binding with soil particles, plants can adopt some technique for increasing the soil bioavaibility by producing phytosiderophore (Metal - Chelating compounds). Mugenic acid and arenic acid[23] are such types produced in response to iron[24-26] and Zn[27] deficiencies. After formation the phytosiderophores - metal (Fe, Cu, Zn, etc.) complex is transported via specialized transporter[28]. Root Ferric chelated reductase[29] reduces Fe (III) into soluble Fe (II) and make it easy for root uptake. Plant root secrete some Proton into soil, which makes iron and other metal soil and thus increase the bioavailability. The mechanism of entry of metal into root cell is not yet understood. Recent study shows, some plasmamebrane transporter are responsible for enty of metal into root cell. Genes for Zn transporter[30], Cu-transporter, iron-transpsorter[31] have been isolated from *A. thaliana.* Once the metal enters into the root cell, these are then transported into shoot. Different transport mechanisms are there for different metal. Cd is transported to shoot through xylem vessel by action of transpiration - driven mass flow[32], Cd from non-cationic metal-chelate complexes as Cd citrate, and easily transported to shoot[33]. As cellwall having high cation exchanging capacity, formation of non-cataion metal complexes are necessary for easy transport. Ni-bind with free histidine[34] and transported to shoot through xylem in hyperaccumulator, belonging to genus *Alyssum.* Cu form chelated compound with amino acid like histidine and asparagines[35]. ''Nicotianamine'' a non protenaceous amino acid found in almost all plants having the ability to bind with various divalent metal ion like Cu, Ni, Zn, Fe and Mn[36-37]. Metal ion can also bind with low molecular weight metabolite and protein and transported in the phloem.

Phytovolatalization - Some heavy metals volatalize within the plant cell and thus detoxification occurs. Selenium, a toxic heavy metal, can be released from the selenium accumulator (*Astragalus racemosus)* as dimethyl diselenide[38] and also from non selenium accumulator as dimethyl selenide[39]. Recent work shows that, plants are unable to take inorgaic selenium (Selenate). It was confirmed by the fact that Se uptake inhibition occurs when antibiotic is added hydrophically to Indian Mustard (*Brassica juncea)*[40]. Rhizospheric bacteria plays a great role in reducing and assimilating selenium into organic form. In marine algae, arsenic is also volatalied as dimethyl arsenic. Recently mercuric ion reductase is isolated from bacteria, introduced into *A. thaliana* and this transgenic plants convert Hg^{+2} into elemental mercury (Hg^0) and thus volatalization of mercury occurs[41]. Young seedlings are used as a accumulating tool for heavy metal from water. Young seedlings have the high affinity for ad/absorbing large quantities of toxic metal ions. This phenomenon is termed as *Blastofiltration* (blasto - 'seedling' in Greek). Indian Mustard (*Brassica juncea)* proved as efficient plant for blastofiltration.

Phytoremediation of organic pollutants : Plants are used to remediate soil enriched with organic pollutants[42,43] and ammunition waste like TNT PCB's, TCE (Tetrachloroethylene)[44-46]. Plants can take up organic chemicals from vapour, liquid and solid phase of soil[47]. The more lipophillic organic chemicals are easily taken up by plants as they move across the plant membrane and are soluble in water phase[48]. Other factors like soil pH, texture, organic and water contents plant physiology[49] also determine the uptake of organic pollutants. After accumulation, these organic materials undergo certain changes and then stored in vacuoles and sometimes bind with insoluble cellular structure such as Lignin.

Volatalization also occur in few cases[50]. Plants root exudates, in few cases degrade the harmful organic material in soil[51].

Conclusion : With a growing indiscriminated use of land, water and air along with the unbalanced use of chemicals including fertilizers and other chemicals and nuclear test released the heavy metal, proved as harmful to plants, all soil borne organism, and human being too. Various tests have been conducted to find the possible remedy for these harmful consequences. 'Phytoremediation Technology' now-a-days proved more efficient and low-cost remediating technology. Plants are able to accumulate chelate-metal complexes in their root. Root exudates, i.e., some enzyme can reduce various toxic chemicals and after accumulation, these metals are transported to shoot through xylem and stored in vacuole as less toxic form and sometimes volatalization occur. So phytoextraction, phytodegradation, phytovolatalization rhizofiltration and phytostabilization etc. processes proved to be key to the wonderful lowcost phytoremediation technology which could clean up and leave a green and safe environment for the future.

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