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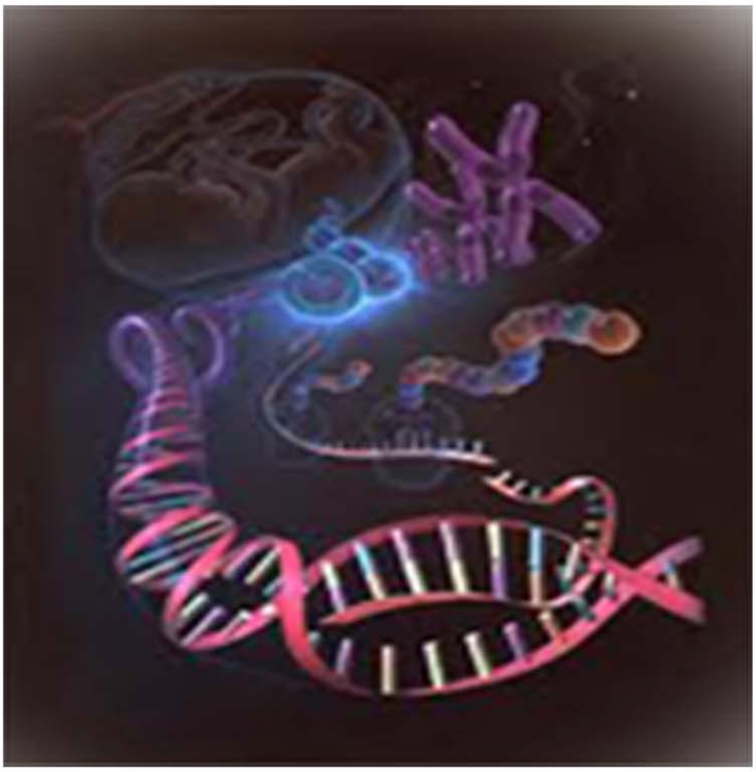

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Review Article

ROLE OF VESICULAR ARBUSCULAR MYCORRHIZA IN THE MYCOREMEDIATION OF HEAVY TOXIC METALS FROM SOIL

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Mycoremediation results in the removal of pollutants from environment by fungi. As a result of industrialization or pollution, the soil and drinking water are contaminated with large amount of toxic heavy metals like Cd, Pb, Cr, Zn, Ni, As and Al. High concentration of these metals produce detrimental effect on ecosystem as a result of which food chain is also affected causing risk to human health. These metals affect the growth, physiology and germination of plant as they cause diseases like chlorosis, yellowing, reddening, wilting, and shortening of roots. From the literature survey, it was found that VAM fungi provide an appropriate and efficient system for environmental cleanup through the process of chelation. Therefore VAM and plant symbiotic relationship have the immense potential to extract heavy metals from soil. The process of chelation is different in both plant cells as well as VAM fungi. Basically hyper-accumulators have the ability to perform the process of mycoremediation. Hyper-accumulators perform the process of extraction of heavy metals through phytoextraction, phytostabilisation, phytovolatilisation, phytorhizofiltration. This review details the application of VAM in phytoremediation of heavy toxic metals from soil.

Keywords: Mycoremediation, Phytoremediation, VAM, Heavy Toxic Metals

INTRODUCTION

Phytoremediation meaning "plant restoring balance" describes the treatment of environmental problems through the use of plants that mitigate the environmental problems. It is the ability of certain plants called Hyper-accumulators to bioaccumulate, degrade and render harmless contaminants in soil, water or air. Contaminants such as toxic metals, pesticides, etc., have been mitigated in Phytoremediation projects. Examples of plants that have successfully gone through the process of Phytoremediation are Mustard plant, Hemp, Alpine and Pigweed. Contamination of soil is the major environmental concern because of the excess of industrial and urban wastes generated by vivid activities of living beings. Wide

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variety of organic well as inorganic compound produce contamination, including, heavy toxic metals, putriscible and combustible substances and petroleum products .Heavy metals confer a different problem than organic compounds. Organic contaminants are degraded by soil microorganisms but metals need to be immobilized or physically removed. Due to oxidative stress by formation of free radicals and their capability to replace essential metals the high concentration of heavy metals is detrimental.

As a result of this the land become unsuitable for plant growth and disturbs biodiversity (Gosh and Singh, 2005). Phytoremediation is steadily accepted both at the academics and industrial level as it is one of the most recognized and more researched technologies. According to the study it was analyzed that till today various methods are investigated to remediate the heavy metals from soil. Conventional methods like *ex situ*-excavation, detoxification, and remediation of soil by physico-chemical treatment (Zhou and Song, 2004, Gosh and Singh, 2005, Dahn *et al.,* 2009, Upma *et al.,* 2012) are very expensive, tedious and time consuming methods. The most important side effects of conventional methods are that they degrade the biotic figure of the soil. Because of their disadvantage of conventional methods a new technology came into being and is known as Phytoremediation. It is also known as green technology because it is eco-friendly as wide variety of microorganisms is used in this technology to degrade the toxic metal pollutants (Ahmadopur *et al*., 2012). As conventional methods are not economically and technically efficient (Baccio *et al.,* 2003), so Phytoremediation can be used as a natural source to remove toxic components like heavy metals from contaminated soil (Gabrisu and Alkorta, 2001, Mangkoedihardijo and Surahmadia, 2008) as plants represents efficient system to metabolize substances.

This novel green technology is a gifted power of the plant to remove heavy metals from contaminated environment by establishing relationship with mycorrhizae (Ahmadopur *et.al.,* 2012). This method is economical, ecofriendly and efficiently remove pollutants like metals, hydrocarbons, chlorinated solvents from soil (Susarla *et al*., 2012, Jadia and Fulekar, 2008; Zhang *et al*., 2010). This technology has been proved to be efficient since 3000 years according to the survey conducted by (Lasat, 2000). As the study conducted by (Gosh and Singh, 2005, Brunett *et al.*, 2008). The vivid plants that are used in this process are provided with the name known as accumulators. At high concentration ($\geq$ 100) of metals these accumulators aggregate the heavy metal without showing any effects on tissue (Barcilo and Poschenriedu, 2003). From the past studies performed by various scientists the various types of plants have been enlisted, that perform Phytoremediation process efficiently .It includes *Jatropha curcas* (*Euphorbiaceae*), *Dodonea viscoae* (*Sapindaceae*) *and Cassia auriculata* (*Fabeaceae*) (Nagaraju and Karimulla, 2000). From the study it was found that the work of Phytoremediation has been performed on sludge amended soil (Aziz, Radwan and Dahdoh, 1997) and plants like sunflower, maize to remove metal like Cd, Pb, Zn, etc. (Poniedziatek, 2010).

SOIL CONTAMINATION BY HEAVY METALS

Our ecosystem consists of various forms of contaminants like atoms, molecules, compounds, metals, non metals etc. The excess of any components in the ecosystem lead to the contamination of it as a result of which the whole ecosystem gets imbalance and polluted. Presently our environment is contaminated by organic as well as inorganic pollutants. The three very essential parts of ecosystem air, water and soil is degraded or contaminated by the unmanageable activities of various sector of the country like industrial sector and agricultural sector. Cd, Cr, Ni, Zn, Cu, Pb, are the major pollutants of environment (Ahmadopur *et al.,* 2012). The foremost cause of the toxicity of heavy metals is that they take place of essential metals in pigments or enzymes and hence cause problem in their proper functioning i.e. they are not efficient for the plant growth system and affects plants biodiversity (Gosh and Singh, 2005).The soil is contaminated by heavy metals through two different ways natural and artificial (anthropogenic). The atomic no. of heavy metals is greater than 20. Their characteristics are same as that of metals such as density, stability of cation and conductive nature (Raskin *et al.*, 1994). Heavy metals are 53 elements aggregate in one category with particular weight greater than 5 g/ cm^3 (Holleman and Wiberg, 1985, Weast, 1984). Cu, Fe, Mn, Zn, is essential in vivid type of redox and enzyme catalyzed reaction in electron transport and in DNA and RNA metabolism (Zenk, 1996). Each and every compound is essential in a specific amount but if the concentration of these elements increases beyond that particular level it will become a problem for the ecosystem .Plant maintain homeostasis in concentration of heavy metals. Plant take up the essential heavy metals by particular uptake systems at the increased concentration enters the tissues via non specific transporters. Non essential metals like Cd, Pb, and Hg and as get entry via. Passive diffusion into the roots (Mertz, 1981, Williams, 2003).

As heavy metals have the tendency to replace a vital element by renovating protein structure or by interfering with the enzymatic activities creating deficiency symptoms, so as a result of this tendency the plasma membrane permeability is affected by the replacement of important intrinsic proteins such as Hz-ATPases (Hall, 2002). Another effect of increased heavy metal level is the oxidative damage of the tissue by the formation of reactive oxygen species (Schutzendubel and Polle, 2002). As a result of which plant produce mechanism under stress condition to maintain ion equilibrium (Clemens, 2001, Hall, 2002). Consequently, heavy metals thus form the category of pollutant. Heavy metal becomes the part of the environment through three pathways: Accumulation in environment, disposal of industrial metals in sludge and metal mining process. Heavy metal deposition occurs via three processes: Dry deposition, Wet Deposition and Occult Deposition. Dry deposition depends on the size of the particles; the range of particle size varies from 0.001 μm to 50 μm and it include different processes like Gravitational settling, impaction, tubular transfer and Brownian movement. Deposition process of heavy metals depends on the type of surface on which the heavy metals is going to be deposited. Once the metal get entered inside the plant the basic site of heavy metal deposition is cell wall and intracellular membrane. The heavy metal analysis is done through Atomic Absorption Spectroscopy (AAS). The principle of AAS is that it is used to measure the amount of light absorbed at the resonant wavelength. As the no. of atoms increases the amount of light absorbed increases and then by measuring the amount of light absorbed, one can predict the quantitative resolve of the analyte under study. Judicious selection of particular light supply and cautious choice of wavelength allows the specific quantitative determination of individual elements under study in the presence of other elements

EFFECT OF VARIOUS HEAVY TOXIC HEAVY METALS ON PLANTS

I. Zinc: The presence of zinc in soil is affected by the pH because both Mn and Zn struggle for hydronium ion Hz and aluminum ion Alz^3. In soil solution Mn and Zn solubility increases Zn toxicity (Fergus, 1954, Shuman, 1975, Bar-Tal *et al*., 1988, Castilho *et al*, 1993, Grath *et al*., 1988, Turner, 1994). Zn toxicity produces chlorosis which leads to reddening of leaves. Reddening takes place due to formation of anthocyanin pigment .The plants which grows under zinc toxicity develops smaller and perpendicularly tilted leaves as compared to the other plant. In severe cases, wounded lesions may also be produced and leads to death of the plant. Zinc toxicity affect the growth of roots also, as a result of which short lateral roots are produced and even shortening leads to yellowing .Because of zinc toxicity the initial symptoms i.e. chlorosis is allied with diminution of iron mobilization with enhancing amount of zinc in the soil (Harmans *et al*., 1993, Ren *et al*., 1993, Fontes and Cox, 1995). Even when the phosphorus quantity in the tissue remains normal, the plants sensitive to zinc toxicity produces phosphorus deficiency (Boawn and Rasmussen, 1971).

II. Copper: The initial symptom of copper toxicity is chlorosis at the intervenial region and then further this chlorosis will take the form of cream or white lesions (Taylor and Foy, 1985, Zhu and Alwa, 1993, Lee *et al*., 1996). During acute conditions the leaves may also get wilted and this wilting may further even leads to purpling of foliage (Yau *et al*., 1991). Copper toxicity also shows its effect on root growth. In dicot seeds the toxicity of copper produce short and blunted radicles with fungal colonization which exhibit dark black color on the tips of radicles. Even some plants are not able to produce root hairs which are grown in soil with high amount of copper (Patterson and Olson, 1983, Zhu and Alwa, 1993). Copper may also exhibit its effects on the mobilization of other toxic heavy metals like zinc (Zn) and iron (Fe) .The high amount of copper produce negative impact on the mobilization of zinc but not on the mobilization of manganese (Mn) through phloem tissues. It may also effect the mobilization of iron (Fe) and induced zinc (Zn) deficiency as reported earlier (Lexmond and Van Der Vorm, 1981, Yau *et al*., 1991, Ouzocenidou, 1995, Daveis, 1993, Ren *et al*., 1993; Lee *et al*., 1996).

III. Manganese: The mobilization of Mn depends upon its current amount in the plant species (Welch, 1995, Pearson *et al*., 1996). When the precise supply of Mn is given to plants, only some amount of Mn is mobilized through the phloem tissues. But during excessive supply of Mn the process of transportation through the phloem tissues gets affected and it may even slow down the transportation (Pearson *et al*., 1996, Herren and Feller, 1997). Plants which are grown in Mn toxic environment, they exhibit symptom like brown spots on leaves. Initially this brown spot appears at the lower leaf level and slowly or gradually it proceeds toward upper leaves (Horst and Marschens, 1978, Elamin and Wilcox, 1986, Horiguchi, 1988). This brown spotting after some time will lead to necrotic lesion formation which ultimately leads to death of leaves. Another symptom like "Crinkle-leaf" which is also related to browning conditions appears on novel leaf, petiole and stem (Horst and Marschner, 1978, Miller, 1995). According to some previous studies the browning may first occurred on older leaves then on the young leaves. The induced deficiency symptoms of Mn include reduction in iron uptake. This type of condition arises when the Fe: Mn fall between 18 (Lee, 1972). It may also exhibit negative impact on magnesium mobilization as high amount of Mn induces Mg deficiency.

IV. Cadmium: Cadmium is one of the most portable elements in nature as it gets deposited in plants very easily .In an experiment conducted on soya bean it is reported that cadmium gets deposited in larger amounts in roots, then in the stem followed by leaves (Chen *et al.*, 2003). Because of this nature of cadmium the deposition of cadmium occurs more at the root level which leads to decrease nodulation and deterioration of roots. Phytoremediation of cadmium is a very crucial process. According to some previous studies performed by scientists the tolerance of cadmium is maintained by the homeostasis route .From the studies conducted on some cereals like wheat and maize, maize was found to have better efficacy to phytoremediate Cd then wheat (Wang *et al.*, 2002). Other metals concentration is also affected like iron deficiency is the hint of Cadmium stress.

V. Nickel: Like all other metals Phytoremediation of nickel also has been done since years before by various workers. It was initially extracted from the ore kupfernickel according to which its nomenclature was done. Sulfide and silicate oxide ores are the basic source of metallic nickel. It is used in stainless steel, electroplating as well as used in alloy form too. Basic characteristics of nickel include its electrical conductivity, its strength, corrosion; resistance, etc., 2+ oxidation state of nickel is the most prevalent state in ecosystem. (ASTDR, 2005). Its toxicity causes contact dermatitis, Nickel carbonyl poisoning, carcinogenicity, epigenetic effects in human. In plants the high concentration of nickel will cause decrease in iron uptake. High concentration of nickel, i.e., above 60 ppm will result into inappropriate increase in dry matter (Latif *et al.*, 1988). In some other studies conducted on toxicity of nickel it was found that in some plants it causes reduction/ decrease in fresh and dry weight (Eleiwa and Naguib, 1987) while in some other plants its toxicity may lead to increase in level of ascorbic acid, enzymes and rate of photosynthesis (Dobrolyubskii, 1958). Nickel is accumulated in large amount in shoots with respect to increase in its concentration in soil. With increase in the level of nickel in plant, Fe and Ni concentration in shoot increases but Mn and Zn amount decreases (Eleiwa and Nauguib, 1987).

VI. Lead: The basic characteristics of lead are it is malleable, ductile and easy to smelt, and since ancient years it is used with arsenic and antimony. Metallic lead is Pb□ and it has the ability to avert corrosion as well as has the capability to form alloy. Lead is a non-recyclable compound and is responsible for environmental toxicity which is increasing day by day because of urbanization (Francisco *et al.*, 2003). Lead is present in hand pack grenades, soldering, paints, glass, crafts, polish, jewelry and even herbal medicine can be the impending source or its revelation (Patrick, 2006). It causes various neurological, neurotoxic, cardiovascular, carcinogenic detrimental effects in human. The amount of lead in plants is depicted in a respective order, i.e., roots > leaves> stem> inflorescence> seeds. This order may change according to various varieties of plants under study (Antosiewiez, 1992). They can affect the plant physiologically, ultra structurally and biochemically. The initial symptom of lead toxicity includes inhibition of root development, stunted height of plant and chlorosis (Burton *et al.*, 1984). It may even inhibit various enzymatic reactions, causes disproportion of water, change the membrane porosity, distort the nutrition uptake, as well as alter the hormonal class and at the end its toxicity may even lead to death at its high concentration. (Ernst, 1998, Seregen and Ivanov, 2001). It may even cause differences in germination index and percentage, dry mass of root as well as shoot, tolerance index, etc. (Mishra and Choudhary, 1998). The effect of lead on roots growth is very quick as the growth rate of roots gets reduced and branching pattern also changes. Photosynthesis is also influenced by lead toxicity which cause decrease in the pace of photosynthesis which may in turn affect chlorophyll synthesis, carbon di oxide fixation, Calvin cycle, pentose phosphate pathway, nitrogen incorporation, protein hydrolysis, antioxidative metabolism, etc. (Valle and Ulmer, 1972, Prassad and Prassad, 1987, Moustakas *et al.*, 1994, Verma and Dubey, 2003).

MECHANISM OF THE MYCORRHIZAL EXTRACTION OF HEAVY METALS FROM SOIL

Mycorrhiza is a versatile beneficial relationship. The most popular root-fungus association is Vesicular Arbuscular mycorrhizal association also known as glomeromycotan association (Read, 1997, Burdett, 2002). Mycorrhiza term was first used by Frank (1885), who claimed that plant-fungus relationship is essential for survival of both and absorption of substance from soil takes place, through this relationship (Harley and Smith, 1983). Because of this intimate relationship plant and fungal association is very different from other associations (Nehls *et al.*, 2001, Pfeffer and Bago *et al.*, 2001). The VAM fungi is benefited from this association as they get the nutrients and in turn they increase the phosphorus and trace metal uptake by plants (Burgus *et al.*, 1983, Jasper *et al.*, 1988) by Electrochemical potential gradient (–120 and –180 mV). The amount of spare metals in the soil is considered as bio-available fraction of metal. To understand the process of metal uptake through the plant the studies were carried out on the process of uptake of iron. In these experiments two processes were identified: in first process iron chelates Fez^3 were formed which were reduced to Fez^2 by the reductant (Chaney *et al.*, 1972, Brown and Ambler, 1973, Olsen and Brown, 1980, Welch *et al.*, 1983). In second process some acids such as mugeneic acids and avenic acids were used as reluctant which are known as phytometallophores (Kochian, 1993, Fan *et al.*, 1997). The release of phytometallophore is generally related to deficiency as compared to sufficiency.

Commonly VAM fungi occur in rhizosphere but some may also be present in stem and thallus (Smith and Read, 1997, Read *et al.*, 2000). As Arbuscular mycorrhiza increases the nutritional status of the host, in the same way fungal hyphae absorbs heavy metals, and transfer it to the plant. Therefore on one hand mycorrhizal plant express increased heavy metal uptake and on other hand VAM fungi helps in immobilization of heavy metals in soil. Therefore the cleanup of the ecosystem depends on the Heavy Metals- Plant- Mycorrhizal relationship through the removal of heavy metal from the soil. During stress condition i.e. increased concentration of toxic heavy metals plants employs various mechanisms to maintain the metal-ion equilibrium internally as well as in their surrounding environment (Clemens, 2001, Hall, 2002). In this mechanism various types of genes are also involved which helps in accomplishing the mechanism of remediation of heavy toxic metals which in turn helps in detoxification of heavy metals from contaminated soil (Thomine *et al.*, 2000, Hirayame *et al.*, 1999 Gravot *et al.*, 2004, Himelblau and Amasino, 2000). The main purpose of detoxification is: chelation of toxic heavy metals by root exudates and rejection of the uptake of toxic heavy metals by immobilizing them in the cell wall of roots.

PROCESS OF DETOXIFICATION IN PLANT CELL

Initially chelating agents like histidine and organic acids are excreted by the plants that bind in the soil followed by the process of binding of heavy metals to the plant cells. As the plasma membrane is the selective barrier in the plant cell, active as well as passive transport takes place by the specific and non specific metal transporters and also from the pores of the plasma membrane. Intracellularly the cells of the plants secrets chelating agents like phytochelatins and metallothionein which have high affinity for heavy metals. Along with this they also secrets organic acids, amino acids and specific metal chaperons, followed by formation of a complex which is exported from cytoplasm to tonoplast and then finally to vacuole. According to the previous studies storage takes place not only in vacuole but also inside endoplasmic reticulum and chloroplast (Briat and Lobreause, 1997). Arbuscular mycorrhizal fungi by absorbing phosphorus, essential nutrients and water from soil helps the host plant to improve their nutritional status. In the similar manner VAM fungi also absorbs heavy metals from the soil and transport it to the plant results in the process of phytostabilisation and phytoextraction. From the previous studies it is now known that fungi from strain Glomeromycota are found easily in the soil, and even in the absence of host plant, normally VAM spores and hyphae show response towards heavy metals. There is a threshold value of heavy metals that affects the germination and growth of hyphae known as EC50 value which vary according to the strains (Shalaby, 2003).

PROCESS OF DETOXIFICATION IN VAM CELL

In the case of fungal cell wall a different protein called glomalin is secreted by the cells of fungi to form a complex with heavy toxic metals which helps in its binding to plant cell wall. In fungal cells plasma membrane is the selective barrier as a result of which active as well as passive transport takes place by the specific and non specific metal transporters and also from the pores of the plasma membrane. After seizure of heavy metals in the fungal cell wall, the heavy metals are transported in the hyphae of the fungus. Intracellularly the cells of the plants secreting chelating agents like phytochelatins and metallothinein have high affinity for heavy metals. They also secrete organic acids, amino acids and specific metal chaperons.

CONCEPT OF HYPER-ACCUMULATORS

The idea of using this Green Technology was first came forward in 1983 which arose from the discovery of plants which are able to accumulate or mineralize high concentration of toxic heavy metals in their shrubbery (foliage). These plants are known as hyper accumulators. (Baker and Brook, 1989, Ruskin *et al*., 1997, Brooks, 1998). The basic feature of hyper-accumulators is (Gabrisu *et al*., 2002): high metal tolerance, capacity to accumulate high concentration of metals, high escalation rate, large biomass producers and bountiful/ prolific root system. Hyper-accumulators accumulate heavy toxic metals in the aerial part of the plant in the metal rich soil. These incredible characteristics of the plants arose the interest of researchers to understand the evolution of hyper-accumulators (Poschenrieder *et al*., 2006, Boyd, 2007, Vesk *et al*., 2009). They illustrate the defense hypothesis as the hyper-accumulators have the capacity to protect the plants against herbivores and pathogens. The study was conducted on 450 plant species. (Verbruggen *et al*., 2009, Brooks, 1998, Reeves, 2000). In the studies of hyper-accumulators, via *, Thalpsi caeruscelescens* was most prominently studied as naturally this plant is able to accumulate different heavy toxic metals like Zinc, cadmium, nickel (Baker *et al*., 1994, Reeves *et al*., 2001, Roosens *et al*., 2003, Assuncao, 2003, Cobbett, 2003, Peer, 2006). In another experiment conducted on *T.caerulescens* it was find out that the pathogen Psm *Pseudomonas syringae* will built their path in apoplastic cells of *T. caerulescens* and cause leaf spot, so when Zn metal concentration increases in the apoplastic cell it does not allow the pathogen to grow, so it is concluded from this study that heavy metals protects the plants from diseases (Debener *et al*., 1991, Kupper *et al*., 1999, Kupper *et al*., 2004, Cosio, 2005). The most important feature of hyper-accumulators is that they express > 1 shoot to root metal concentration, whereas on the other hand non hyper accumulators root have high metal concentration than shoot (Baker *et al*., 1981, Gabbrielli *et al*.,1990, Homer *et al*., 1991, Brown *et al*., 1995, Kramer *et al*., 1996, Shen *et al*., 1997, Zhao *et al*., 2000, Grath *et al*., 2002).

From the previous studies done, many workers (Chaney *et al*., 1997, Garisbu and Alkarta, 2001, Grath *et al*., 2002, Lasat, 2002, Ernst, 2005, Ahmadopur *et al*., 2012) have reported following major process of Phytoremediation: phytoextraction, phytorhizofiltration, phytovolatilisation and phytostabilisation.

PHYTOEXTRACTION

Phytoextraction is a removal process in which the uptake of contaminants by plant roots and movement of contaminant from root to the aboveground part of the plant occurs. Most of the work for root uptake is carried out for N, P, S, Fe, K and even Cl except for carbon. (Marschner *et al.*, 1995). This concept of Phytoremediation arise from wild plants varieties as they have the ability to amass large amount of toxic heavy metals (Marschner *et al.*, 1995, Baker and Brooks, 1989) and the degree of accumulation may range from 1-5%. Initially the secretion of chelating agents occurs which helps to bound chelated soil bound metals. Compounds like phytosidereophores (Mugenic acid in barley and deoxymugenic acid in oats), metallothioneins and phytochelatin. As a result of iron deficiency phytosiderophores becomes free, which in turn move some other heavy metals like Zinc, Copper, and Manganese (Kinnersely, 1993). After this, the process of reduction takes place in which reductase reduces soil bound metal ions and they become easily available in soil (Welch *et al.*, 1993). It was found that the microbes present in the rhizospheric zone of the plant increases the availability of metals like Zn, Cd, Fe, and Mn for plant uptake. Metals of mobile nature get easy entry inside plant like Ca²z and Mg²z and do not require active mobilization, but other metals require an energy dependent process to enter inside the roots through transmembrane carriers. To get entry inside the root heavy metals struggle with Ca and Mg to capture the transmembrane carriers but if Ca and Mg are present in large amount they does not allow the toxic heavy metals to capture the transmembrane carrier. The studies conducted on Cadmium accumulator showed that in the rhizosphere it is present as CdS_4 complex, in the stem it forms complex with ligand of oxygen and nitrogen and in leaf it gets deposited in trichomes (Salt *et al.*, 1995).

PHYTOSTABILISATION

It is the process of immobilization of contaminants in soil which is accomplished through absorption, accumulation and also precipitation within the root zone. It is completely dependent on the ability of root to immobilize or absorb metal. It prevents the spreading of toxic metals to the other areas and also does not allowed soil attrition to take place. The major negative impact is that the toxic metal will remains in the soil so continuous inspection is essential (Ghosh and Singh, 2005).

PHYTORHIZOFILTRATION

Like phytostabilisation, the phytorhizofiltration is also used to immobilize the toxic heavy metals. In this technique both aquatic and terrestrial plants are used on partially treated soil, contaminated from various toxic metals like lead, copper zinc etc. (Chaudhary *et al.*, 1998; United States Protection Agency, 2000). From the previous studies it is find out that Sunflower and *B.juncea* are the best plants for phytorhizofiltration. The characteristic of plants that is suitable for phytofiltration is that they should have good growth vigour (Kumar PBAN, 1995). In *B.juncea* lead is found in the forms of precipitate in cell walls and in corn roots it is found in the form of electron intense deposits within and outside the cell wall and May even bind to the anionic binding sites of the cell wall. (Broyer *et al.*, 1972, Malone *et al.*, 1974).

PHYTOVOLATILISATION

In this technique plant firstly take up the toxic metal, convert them into unstable (gaseous) form and then finally transpire them. It is initially used for the volatilization of mercury, arsenic and selenium. Hyper-accumulators convert the organic form of these compounds into the volatile form and release this volatile form into the atmosphere. This process is known as phytovolatilisation. Mercury and selenium are toxic and causes pollution in various parts of world (Wilber, 1980, Suszcynsky and Shann, 1995, Brooks 1998). Phytovolatilisation is the best process for the Phytoremediation of Se contaminated environment (Lewis *et al*., 1966, Terry *et al*., 1992, Banuelos *et al*., 1993a b, Grath, 1998).

CONCLUSION

Till today numerous researches have been performed by various researchers on mycoremediation. As it is a Green Technology so because of its eco-friendly behavior it is used at large extent to remove toxic heavy metals from the soil. Soil contamination occurs due to various harmful discharges of industrial, agricultural and medicinal activities. From the various categories of phytoremediation like phytoextraction, phytostabilisation, phytorhizofiltration, phytovolatilisation, phytoextraction is found the most efficient and successful process. It was shown from time to time by the different experiments performed for phosphorus toxicity on white clover (*Trifolium repens.L, Triticum aestivum.L) by* (Turk *et al*., 2006), for aluminum toxicity on (*Leucanea luecocephala*) by(Melo *et al.,* 1987) for cadmium toxicity on (*Pinus silvestris*) by (Colpaert and Assche, 1993), for copper toxicity on (*Ponicrius trifoliata* and *Citrus sinensis*) by (Graham,Timmen *et al*., 1986), for zinc toxicity on (*Pinus sylvestris*) by (Bucking and Heyser, 1994).

From the present review of literature on the role of VAM in removal of Heavy toxic metals from soil, we can state that the arbuscular mycorrhizal fungi are incredibly effective in accomplishing this process of Phytoremediation. Metals like zinc, cadmium, mercury, arsenic, lead have been reported at various sites by the researchers (Munoz, 2004, Biller, 1994, Silva *et al*., 2003, Bech *et al*., 2002) and they successfully conducted studies to remediate these heavy toxic metals by the process of Phytoremediation.

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