Adverse impacts of Heavy Metals on Human beings and its elimination by Phytoremediation: A Current Perspective

Removal of Heavy Metals By Plant based Approach

Mohd.Faraz Khan
M.Tech Student Department of Environment Science & Engineering
Indian Institute of Technology (Indian School of Mines) Dhanbad
Jharkhand, India

***Abstract*— Heavy metals are frequently cited to as those metals which hold a specific density of more than 5 g/cm3 and adversely alter the environment and living organisms (Järup, 2003). These metals are quintessential to maintain various biochemical and physiological functions in inhabiting organisms when in very low concentrations Current methods for remediation of metal contaminated soils include soil removal and washing, physical stabilization, and/or the use of chemical amendments, all of which are expensive and disruptive, with an average cost of $ 404,700 per ha (Raskin et al., 1997). USEPA (2002) recommended excavation, capping, solidification and stabilization, nitrification, soil washing/acid extraction, soil flushing, phytoremediation, etc. as current remediation technologies for heavy metal contaminated soil.**

Keywords:- Heavy metals; Phytoremediation; Rhizofiltration; PGPR.

I. INTRODUCTION

The term heavy metals have generally been used to describe those metals having an atomic number greater than iron or having a density greater than 5 g/ml. Plants require certain elements for their normal growth, which are called essential elements (micro and macro elements). But there are also some elements which are not vital for plant growth. Such elements are called non-essential elements, which include heavy metals which cause toxicity to plants. Heavy metals like Cr, Cu, Ni, Pb, and Cd are phytotoxic either at all concentrations or above levels. Toxic metals are biologically magnified through the food chain. They infect the environment by affecting the properties of soil like soil fertility, biomass, and crop yields and indirectly it affects the human health.

Table: 1 Clinical Aspects of Chronic Toxicities *(Source: Mahurpawar 2015)*

Metal	Target Organs	Primary Sources	Clinical effects
Arsenic	Pulmonary Nervous System, Skin	Industrial Dusts, Medicinal Uses Of Polluted Water	Perforation of Nasal Septum, Respiratory Cancer, Peripheral Neuropathy: Dermatomes, Skin, Cancer
Cadmium	Renal, Skeletal Pulmonary	Industrial Dust And Fumes And Polluted Water And Food	Proteinuria, Glucosuria, Osteomalacia, Aminoaciduria, Emphysema
Chromium	Pulmonary	Industrial Dust And Fumes And Polluted Food	Ulcer, Perforation of Nasal Septum, Respiratory Cancer
Manganese	Nervous System	Industrial Dust And Fumes	Central And Peripheral Neuropathies

II. REMEDIAL TECHNIQUES

A.BIOREMEDIAION

Bioremediation is a process used to treat contaminated media, including water, soil and subsurface material, by altering environmental conditions to stimulate growth of microorganisms and degrade the target pollutants. In many cases, bioremediation is less expensive and more sustainable than other remediation alternatives. Biological treatment is a similar approach used to treat wastes including wastewater, industrial waste and solid waste.

Aerobic bioremediation

Aerobic bioremediation is the most common form of oxidative bioremediation process where oxygen is provided as the electron acceptor for oxidation of petroleum, polyaromatic hydrocarbons (PAHs), phenols, and other reduced pollutants. Oxygen is generally the preferred electron acceptor because of the higher energy yield and because oxygen is required for some enzyme systems to initiate the degradation process.Numerous laboratory and field studies have shown that microorganisms can degrade a wide variety of hydrocarbons, including components of gasoline, kerosene, diesel, and jet fuel. Under ideal conditions, the biodegradation rates of the low- to moderate-weight aliphatic, alicyclic, and aromatic compounds can be very high. As the molecular weight of the compound increases, so does the resistance to biodegradation.

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 8 Issue 06, June-2019

Anaerobic bioremediation:

Anaerobic bioremediation can be employed to treat a broad range of oxidized contaminants including chlorinated ethenes (PCE, TCE, DCE, VC), chlorinated ethanes (TCA, DCA), chloromethanes (CT, CF), chlorinated cyclic hydrocarbons, various energetics (e.g., perchlorate, RDX, TNT), and nitrate. This process involves the addition of an electron donor to: 1) deplete background electron acceptors including oxygen, nitrate, oxidized iron and manganese and sulfate; and 2) stimulate the biological and/or chemical reduction of the oxidized pollutants. Hexavalent chromium (Cr [VI]) and uranium (U[VI]) can be reduced to less mobile and/or less toxic forms (e.g., Cr [III], U[IV]). Similarly, reduction of sulfate to sulfide (sulfidogenesis) can be used to precipitate certain metals (e.g., zinc, cadmium). The choice of substrate and the method of injection depend on the contaminant type and distribution in the aquifer, hydrogeology, and remediation objectives. Substrate can be added using conventional well installations, by direct-push technology, or by excavation and backfill such as permeable reactive barriers (PRB) or biowalls. Slow-release products composed of edible oils or solid substrates tend to stay in place for an extended treatment period. Soluble substrates or soluble fermentation products of slow-release substrates can potentially migrate via advection and diffusion, providing broader but shorter-lived treatment zones. The added organic substrates are first fermented to hydrogen (H_2) and volatile fatty acids (VFAs). The VFAs, including acetate, lactate, propionate and butyrate, provide carbon and energy for bacterial metabolism.

Natural Bioremediation:

It is also known as natural attenuation or passive bioremediation which is an environmental site management approach that relies on naturally occurring microbial processes for petroleum hydrocarbon removal from groundwater, without the engineered delivery of nutrients, electron acceptors or other stimulants. Main advantage of this method is its cost effectiveness compared to engineered conditions. Disadvantage of this technique is that it takes more time for organic biodegradation.

B.PHYTOREMEDIATION

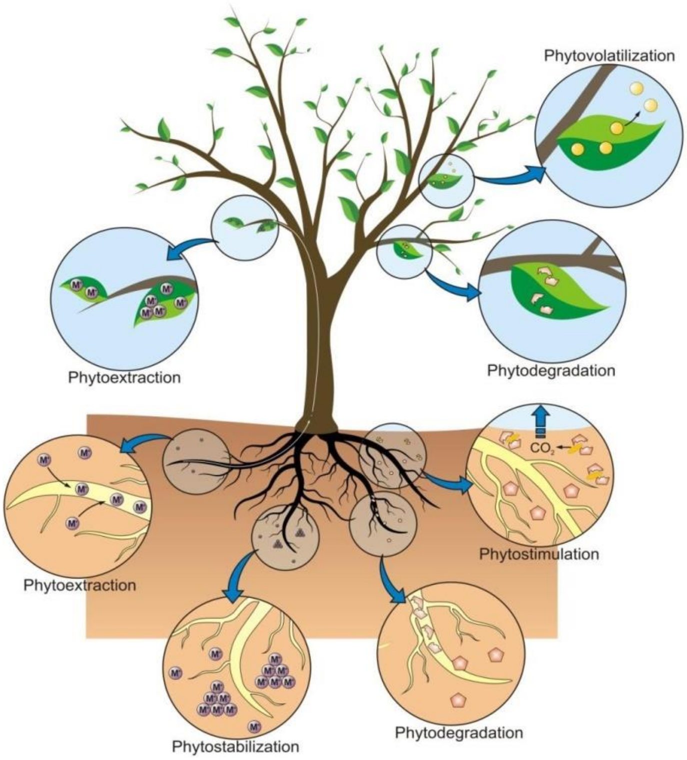
Phytoremediation can be of many types. Phytoextraction is the name given to the process where plant roots uptake metal contaminants from the soil and translocate them to their above tissues. Rhizofiltration is similar in concept to phytoextraction but is concerned with the remediation of contaminated groundwater rather than the remediation of polluted soils. The contaminants are either adsorbed into the root surface or are absorbed by the plant roots. Phytostabilization is the use of certain plants to immobilize soil and water contaminants, which are absorbed and accumulated by the roots, absorbed into the roots or precipitated in the rhizosphere. This reduces or even prevents the mobility of the contaminants stopping their migration into the groundwater and also reduces the bioavailability of the contaminant thus preventing spread through the food chain. Phytodegradation (Phytotransformation) is the degradation or breakdown of organic contaminants by internal and external metabolic processes driven by the plant. Rhizodegradation (also called enhanced rhizosphere biodegradation, phytostimulation and plant assisted bioremediation) is the breakdown of organic contaminants in the soil by soil microbes which is enhanced by the rhizosphere's presence.

Table 2: Techniques/Strategies of Phytoremediation *(Favas et al., 2014)*

Technique	Description
Phytoextraction	Accumulation of pollutants in harvestable biomass i.e., shoots
Phytofiltration	Sequestration of pollutants from contaminated waters by plants
Phytostabilization	Limiting the mobility and bioavailability of pollutants in soil by plant roots
Rhizodegradation	Degradation of organic xenobiotics in the rhizosphere by rhizospheric microorganisms.
Phytovolatilization	Conversion of pollutants to volatile form and their subsequent release to the atmosphere
Phytodegradation	Degradation of organic xenobiotics by plant enzymes within tissues
Phytodesalination	Removal of excess salts from saline soils by halophytes

Fig. 1: Different Process of Phytoremediation

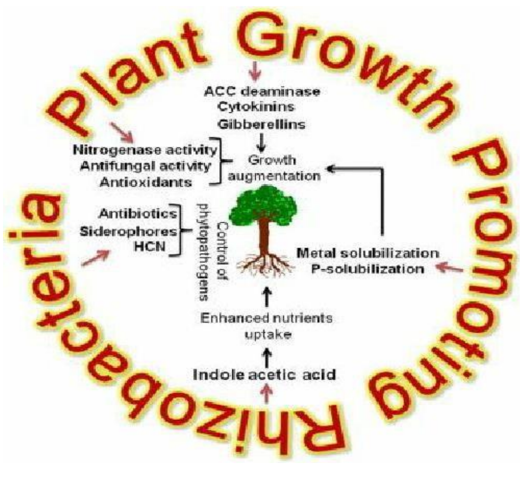
(Favas et al., 2014)



PGPR Metabolic Activities

PGPR are able to produce enzymes, which can affect plant growth under different conditions including stress. For examples, PGPR produces the enzyme 1-aminocyclopropane- 1-carboxylate (ACC)-deaminase, which is able to turn ACC, the prerequisite for the production of the stress hormone ethylene, into a-ketobutyrate and ammonium and hence alleviate the adverse effects of stress on plant growth (Glick et al., 1998). Plant growth promoting rhizobacteria can also produce plant hormones and siderophores, which can significantly affect plant growth by regulating different plant metabolisms and the availability of different soil nutrients including iron, zinc, copper, and manganese. Plant hormones can significantly affect plant growth under different conditions including stress.

Fig 2: Plant Growth Promoting Activities (*Ahemad et al., 2013*)



PGPR and Alleviation of Stress

Plant growth promoting rhizobacteria are able to alleviate the effects of different stresses on plant growth by using the following mechanisms. 1) Interacting with the other soil microbes, 2) production of plant hormones, 3) production of different enzymes such as ACC- deaminase, 4) increasing the solubility of soil nutrients, 5) controlling plant pathogens, 6) affecting heavy metals properties in the soil, and 7) their use for biofertilization. In their seven-stage experiments, Jalili et al. (2009) were able to isolate the strains of *P. fluorescent* and *P. putida* from saline soils to test their stress alleviating abilities. The isolated strains were then used to inoculate canola (*Brassica napus* L.) subjected to salinity stress. Under salinity, 14% of the strains were able to produce ACC- deaminase as the sole N source. The strains differ in their ability able to produce ACC- deaminase, auxin and hydrogen cyanide. Inoculation of canola seeds with *P. fluorescent* resulted in the alleviation of salinity stress on canola seed germination and seedling growth

Under stress, the process of N-fixation may be adversely affected due to the disrupting effects of stress on the production of root products including flavonoids such as genistein. Such root products can activate the bacterial genes resulting in the production of lipochitooligosaccharides and hence some morphological alteration in plant roots, including bulging and curling. It has been indicated that if *Bradyrhizobium* bacteria are preincubated with genistein, before inoculating soybean seeds, the adverse effects of stressors on the process of N-fixation can be alleviated.

Interactions with Other Soil Microbes

Plant growth promoting rhizobacteria may interact with AM fungi through binding to the fungal spore, production of some volatiles by bacteria, injection of some products into the fungal spore and degrading fungal cell wall of the bacteria. Such products can influence fungi performance and hence ecosystem efficiency by affecting the expression of fungal genes .Such interactions can be of significant importance affecting the interactions between the microbes and hence their use for biological fertilization. It is because the selection of the right microbes for the production of bioinoculants can significantly increase their efficiency.

III ADVANTAGES OF PHYTOREMEDIATION

Early research indicates that the phytoremediation technology is a promising cleanup solution for a wide assortment of pollutants and sites. (Chappell 1997). A momentous benefit of phytoremediation is that a variety of organic and inorganic compounds are amenable to the phytoremediation process. Phytoremediation can be used either as an in situ or ex situ application. In situ applications are frequently considered because reduces disturbance of the soil and surrounding environment and minimize the spread of contamination via air and waterborne wastes. An additional advantage of phytoremediation is that it is a green technology and when appropriately implemented is both environmentally friendly and aesthetically pleasing to the public

IV CONCLUSION

Today the soil pollution with heavy metals is a precarious problem for environments. Many techniques used to resolve this problem, but these techniques are a costly and less effective, so the process phytoremediation, it has green process to accumulate heavy metal with the help of plants it has safe and polluted free process. Plants have a power to clean up the environment because they need some metals for its growth so they consumed that metal easily. Phytoremediation is unaffected to people who live and work around the area while it is being cleaned up and is perceived as a more natural solution than large amounts of equipment and noisy machinery. Phytoremediation can be undertaken for less than half the cost of other technologies. Phytoremediation projects need a lesser amount of continuance (Smith 1997). Present study clearly reveals that the ornamental plants are used to clean up the heavy metals from soil by phytoremediation are a polluted frees process and cost effective. Phytoremediations related mechanism play a better role for made polluted free soil water environment. The key problem to almost to any of the methods is of course that of time and inability to handle a diverse and very large amount of contamination. As the technology is better understood and further implemented, however, it will grow in its efficiency and ability and will no doubt grow.

V REFERENCES

[1] Alkorta, I., J. Hernández-Allica, J. Becerril, I. Amezaga, I. Albizu and C. Garbisu (2004). "Recent findings on the phytoremediation of soils contaminated with environmentally toxic heavy metals and metalloids such as zinc, cadmium, lead, and arsenic." Reviews in Environmental Science and Biotechnology 3(1): 71-90.

[2] Chappell, J. 1997. Phytoremediation of TCE using Populus. Status report prepared for the United States Environmental Protection Agency Technology Innovation Office under a National Network of Environmental Management Studies Fellowship, 38 pp.

[3] Chappell, J. (1997) Phytoremediation of TCE Using Populus. Report prepared for U.S. EPA Technology Innovation Office. Washington, D.C., 38 pp. Chappell, J. (1997) Phytoremediation of TCE Using Populus. Report prepared for U.S. EPA Technology Innovation Office. Washington, D.C., 38 pp.

[4] Favas PJC, Pratas J, Prasad MNV. Accumulation of arsenic by aquatic plants in largescale field conditions: Opportunities for Phytoremediation and bioindication. Science of the Total Environment 2012; 433 390-397.

[5] Al-Zahrani, Y. and Abdulrahaman, S.H. 2014. Heavy metals accumulation and Phytoremediation potential of plants from industrial area in Jeddah city, Saudi Arabia. Indian Streams Research Journal 4: 1-9.

[6] Järup L. Hazards of heavy metal contamination. Br Med Bull. 2003; 68(1):167–182.

[7] Jalili F. Isolation and characterization of ACC deaminase-producing Fluorescent pseudomonads, to alleviate salinity stress on canola (Brassica napus L.) growth

[8] Smith, S. (1997). "Phytoremediation: Using Plants to Remediate Soil and Groundwater Contamination."

[9] Raskin, I.; Smith, R.D.; Salt, D.E. Phytoremediation Of Metals: Using Plans To Remove Pollutants From The Environment. Current Opinion On Biotechnology, V.8, P.221-226, 1997.