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Review Article

Phytoremediation of Heavy Metals from Irrigation Water, Faisalabad, Pakistan

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Abstract: A technique called phytoremediation makes use of a plant's root system to draw contaminants, primarily heavy metals (zn, cr, and ni), from the surrounding rhizosphere. These are the end result of human actions such the use of pesticides, waste byproducts, cosmetics, and pharmaceuticals. This analysis focuses on soil contamination removal since prolonged exposure to heavy metals can cause respiratory illnesses, cardiovascular disorders, cancer of the liver, lungs, and kidneys, among other problems. In order to immobilise metals and change their harmful states into less toxic states, plants use a process called phytoremediation and tactics like phyto(rhizo) stabilisation. Chromium 6 is changed into chromium 3 through phytostabalization, a process in which plants are utilised to change a pollutant's more hazardous form into a less hazardous volatile form that may be transported. Macrophytes, such as Arbidopsis thaliana and Cgara canescens, have been found to use phytofiltration and phytovolatization to remove radioactive and heavy metals. Indian mustard (Brassica juncea) and sun flower (Helianthus annus) are suitable plants for rhizofilteration, which is essential to prevent environmental and health problems. A heavy metal that is widely present in soil is cadmium. Cd can be removed physically in a number of ways, with membrane filtration and adsorption being the most often utilised techniques for doing so. Chemical (in which the addition of barium acetate caused coagulation) and biological (which uses microorganisms such bacteria, yeast species, fungal aspergillus, and green algea chlorel for the Bioremediation of Cd.) approaches are also employed for the removal of cadmium. In essence, phytoremediation uses the already-existing power of plant systems. This approach is more economical and environmentally benign than conventional approaches for cleaning up contaminated soil and ground water. Since drinking water contaminated with heavy metals is thought to be the primary cause of death in Pakistan, getting rid of these pollutants is our top priority.

Keywords: Phytoremediation, Rhizofiltration, Phytostablization, Phytovolatization.

INTRODUCTION

Plants use chemical compounds as a cofactor in different biochemical reactions, as a part of protein structures and macromolecules also involve in electrochemical balance of cellular compartments. Plants require nutrients for their growth (Kohli *et al.*, 2019). The concentration of

nutrients fluctuates because of various factors like precipitation, soil ph. Precipitation, temperature, oxygen content and different organic and inorganic compounds. Heavy metals are widely distributed all over the world (Tak, Ahmad, & Babalola, 2013). They are deriving from metamorphic and volcanic origin. But in recent years, in industrial and agriculture sector, the production of heavy metal is sufficiently increased because of human activity. Some heavy metals are water soluble thus available to plants resulting in disturbance in the different mechanisms in plants. Some heavy metals like Zn Cr, Ni are essential for plant growth but their higher concentration has inhibitory effects on plants different mechanisms. Some heavy metals like Cd, Hb, Ag and Cr are biologically non-essential but show toxicity at even low concentration (DalCorso, 2012). Today most important concerns is alteration in biochemical mechanism because of heavy metals (Sarma, 2011).

With the increase in the scope of industrialization, different type of bioremediation techniques is also coming into practice all over the globe to combat with this new problem of heavy metals. These heavy metals usually persist for a long period of time in nature as compared to petroleum products and pesticides (Zhuang, Chen, Shim, & Bai, 2007). Heavy metals are disastrous for biotic life. The love canal tragedy in Niagara Falls in US explains disastrous effects for heavy metals on humans as wells on animals. Different traditional and chemicals methods were used to combat with the problem of heavy metal but they did not produce significant result (Mani & Kumar, 2014). An ecofriendly technique called phytoremediation is designed to control the pollution of heavy metals. Phytoremediation means utilization of plants to control the concentration of heavy metals. According to Environment protection guide of USA, the word phytoremediation was at first used in 1991.plants have complex mechanism to tolerate heavy metals (Brankovic *et al*., 2011).

Plant mechanism for heavy metal tolerance;

Hemostatic network of plants has different components for the detoxification and metal tolerance include ligands, metallo-chaperons and ion transportos.membrane proteins are involve in the transport of metals ions across different cell membranes (DalCorso, Fasani, Manara, Visioli, & Furini, 2019). These proteins are involving in the trafficking, transport sequestration and efflux of metals across cell membrane, protoplast and chloroplast envelope. Membrane transporters have different families involve in the influx / efflux of different heavy metals. The ZIP family is involve in the up taking and translocation of metals from root to shoot (Podar & Maathuis, 2022). The NRAMPs are known as naturally resistant associated macrophage proteins have a member called NRAMP1 which is involved in the Fe transport and also play a major role in provide high affinity for the uptake of Mn from soil in A.thaliana (Zhang *et al*., 2020). HMA proteins called heavy metals P1B-type ATPase have a member HMA3 involve in the detoxification of Zn, Cd, Pb and Co by regulating sequestration into vacule. HMA4 is a plasma membrane transporter plays role in efflux of Zn from cytoplasm. In response to heavy metal stress, plant regulate different biochemical mechanisms through gene expression and methylation (DalCorso *et al*., 2019) . Plant produce hormones such as jasmonic acid, abscisic acid and as well as molecules like organic acid, phytochelatins and metallothioneins are involve in the chelation of metal ions (Emamverdian, Ding, Mokhberdoran, & Xie, 2015). phytochelation are produce when Cd concentration is high. But metallothioneins are gene codded polypeptides, involve in the intracellular sequestration of metal ions. Chelating agents contribute to heavy metal tolerance through sequestration (Diep, Mahadevan, & Yakunin, 2018).

Phytoremediation:

Large number of metals and metalloids are dispersed in the environment because of different human activities including fertilizers use in agriculture, mining, metallurgy and fossil use (Candeias, Ávila, Coelho, & Teixeira, 2018). To reclaim the contaminated sites there are various conventional approaches like physiochemical techniques including electric field application, excavation of contaminated matrices and soil washing (Rajendran *et al*., 2022). But these approaches have two major disadvantages being expensive and inefficient to remove pollution. Rehabilitation of contaminated sites can be achieve with the technique of phytoremediation which is in situ technique which uses plants and their rhizospores to reduces contamination of water and also from soil (Daniel *et al*., 2022).

Plants use Different ways to remove the contaminants from the environment. Some plants are green livers as they have the ability to degrade many xenobactics and behave as a sink for noxious contaminants. Some plants use solar driven technology to remove contaminants such as heavy metals like Zn, Hg, Pb, Cr,Cu radioactive metals, inorganic compounds like pesticides, tetrachloroethylene tetranitrotoluene (S. Anand, Bharti, Kumar, Barman, & Kumar, 2019). Plants used in the phytoremediation must have certain qualities like rapid fgrwoth, hairy, deep root system, high biomass and high bioaccumulation coefficient. Hyperaccumulation plants have certain abilities to uptake, assimilate, and translocate very high

concentration of heavy metals (Pulford & Watson, 2003). If a plants can accumulate heavy metals in its dry weight more than 0.1% termed as hyper accumulators and can be used in phytoremediation. Hyperaccumulation plants are members of some families like Brassicaceae, Cunouniaceae, Violaceae, Poaceae, Cunouniaceae, Caryophyl, Asteraceae, Euphorbiaceae (Mahajan & Kaushal, 2018).

Strategies of phytoremediation;

Plants deepen their root system into the contaminated soil matrix and establish ecosystem with soil bacteria and fungus.in this way, plants along with microorganisms associated with soil employ different mechanisms to remove heavy metals from the soil and water and for soil reclamation: phytoextraction, phytovolatilization, phyto(rhizo)stabilization, phytodegradation and phytofiltration (Lee, 2013). For phytoremediation, plants must have the ability to take metals and translocate to shoots, ability to tolerate high level of heavy metals and rapidly growing root and shoot system (DalCorso *et al*., 2019). Phytoremediation use different mechanism to remove heavy metals.

Phytoremediation;

Plants have ability to extract essentials (Cu, Mg, Mo, K, Fe, Mn, Ni, P, and Zn) and non-essentials (Se, B, Cd, Co, Cr, Ag, and Hg) metals for the growth of the plant. Non-essential metals are nontoxic when present in a very low concentration but when essential metals exceed their normal concentration they become dangerous for the plant growth.in phytoextraction metals through their roots and then translocate them to their other parts (Agrawal, Singh, Sharma, & Agrawal, 2007). This technique does not work in those areas which are highly populated with heavy metals. Phytoextraction depends on the ability of plants to eradicate metal on fast pace and able to accumulate metals in their maximum parts and are also able to tolerate high concentration of heavy metals. Chenopodium albums and Pteris vittata have the ability of phytoextraction of lead and arsenic (Nascimento & Xing, 2006).

Phytostabalization:

When plants are able to immobilize metals and can transform metallic toxic state to the less toxic state is called phytostabalization. Plant metabolism contribute to the chemical stabilization of metal ions in the vadose zone, mobility, bio availability and limiting leaching (Alloway, 1995). Negotiate charge metal ions usually attract to the plasma membrane and positive charge metal ions bind effectively to the pectin in plant cell wall (Fosso-Kankeu & Mulaba-Bafubiandi, 2014). Those plant species who have the ability to accumulate heavy metals in their below ground parts are best for phytostabalization. In phytostabalization, those plants are needed whose roots can develop into contaminated zone and are also able to immobilize metals in soils through either metal precipitation, complexion or reduction. Through phytostabalization chromium 6 is converted into its less. Toxic form chromium 3. Phytostabalization is more effective in case of high organic matter and and fine soil (Pilz, 2001).

Phytovolatizaion

The eradication of pollutants by using plants be converting more dangerous form to less toxic volatile form along with transportation called Phytovolatizaion (Singh & Kumar, 2018). Some heavy metals like arsenic, selenium and mercury, some organic pollutants get volatize by using plants. Macrophytes like Arbidopsis thaliana and cgara canescens are reported to adopt for Phtovolatizaion. Through Phytovolatizaion, mercury can be eradicated by converting from Hg to hg 2 which is less toxic Brassica juncea show property of volatization of Mercury. Selenium can be volatize in the form of (ch3) 2Se which is 600 times less toxic then elemental Inorganic selenium is converted by plant enzymes into dimethyl selenium by plant enzymes which are involve in sulfur metabolism, assimilation and volatization (N. Anand, 2005) . Dimethyl selenide is dispersed into air as gas which is less toxic than inorganic Se. Arsenic is also categorize as carcinogen and its contamination in the soil is either because of anthropogenic activities or because of natural resources. Arsenic through microbial activity is taken up by plants and some crops such as rice which showed significant properties in mobilizing arsenite through silicon uptake pathway (Allevato, Stazi, Marabottini, & D'Annibale, 2019).

Rhizofilteration:

This approach is used to absorb, concentrate and then precipitate metals into the biomass from contaminated water. Rhizofilteration is known as phytofilteration which have the ability to remove heavy metals along with different radioactive metals. Root systems of plants determines which plants are more suitable for Rhizofilteration because roots act as filter for metals in aqueous environment. Sun flower (helianthus annus) and indian mustard (Brassica juncea) are favorable plants for Rhizofilteration (Govere, 2021).

Improving plants for phytoremediation;

By increasing plant biomass, and by increasing plant tolerance to heavy metals, phytoremediation can be improved. Phytoremediation can be improved by traditional techniques like such as plant hybridization or breeding and also from biotechnological techniques

like genetically modified plants (DalCorso *et al*., 2019). Native plant species residing in melliforous and contaminated sites are able to resistant heavy metals better. Pteris vittata was reported as the most versatile as it has the ability to accumulate heavy metals like V, Ni, Se (Vandana *et al*., 2020).

To improve the efficiency of phytoremediation genetic determinant for accumulation of heavy metals and tolerance linked with wild hyperacculator species can be introduced into plants having significantly higher biomass. Protoplast of Brassica juncea were infused with N. Caerulescens protoplasts to transfer the metal resistance ability to B. Juncea through hybridization (Vandana *et al*., 2020).

Classical breeding and genetic approach provided significant results but molecular engineering enhance plant phytoremediation efficiency. Different recombinant DNA technologies is currently using both nuclear and cytoplasmic genome transferring techniques to allow the transfer if desired determinants into the sexually incompatible plants. Genetic engineering can enhance phytoremediation by introducing metal tolerance genes and also Genes responsible for the uptake, transport and accumulation of heavy metals (Koźmińska, Wiszniewska, Hanus-Fajerska, & Muszyńska, 2018).

New technologies are coming to improve the genome of plants to improve their capacity to uptake and detoxify heavy metals.one of them is CRISPER/Cas9 system which is proven to be successful for the reduction of heavy metals in plants. Phytoremediation can be proven more successful with their association with plant growth promoting rhizobacteria (PGPR).CRISPER/Cas9 technology can be used to improve plants and PGRP, therefore can lead to increasing biomass and increase heavy metal tolerance especially Cadmium, and detoxification (Sami *et al*., 2021).

Cd toxicity and chemistry:

Cadmium is a heavy metal which is widely distributed in the soil and water in the form of toxic metal which has oxidation state ranging from 0 or +2. It occurs in nature in the form of Cd (CO3) and CdSO4. It precipitates in the form of arsenates, chromates, phosphates. The limit of Cd2+in soil and in plants is less than 1mg/L and 0.005-0.02mg/L respectively according to the USEPA. Direct production of cadmium and secondary sources are responsible for the contamination of ecosystem (Mahajan & Kaushal, 2018).

Lighters amount of cadmium has chronic effects on both animals and human health. Human body consumes cadmium through various vegetables. Large amount of cadmium does causes multiple malfunctioning of organs. Cadmium accumulate in the liver and kidney, where it causes liver and renal malfunctioning. Its accumulation in skeleton muscle causes Itai-Itai disease (Rahimzadeh, Rahimzadeh, Kazemi, & Moghadamnia, 2017). The average half-life period of cadmium is 10 years if is calculated in the human body and 18 years in the environment. Cadmium high concentration is also toxic for plants. Cadmium can inhibit nitrogen metabolism and oxidative reactions inside the plant body. Cadmium presence in plants causes leaf cholorosis, necrosis, reduction in plant growth and damage of photosynthetic machinery including PS 1 and PS 2.THUS, removal of toxic metal cadmium become the area of interest for researchers (Shahid *et al*., 2019).

Different technique for the removal of cadmium:

Cd removal can be done by various physical, chemical and biological techniques. These techniques proved to be effective for the removal of toxic nonessential metal cd from contaminated sources.

Physical methods:

Membrane filtration and adsorption are the most commonly used method to remove toxic metal ions through mediation process. Cd is mainly absorbed on different absorbent like activated Carbon, low cost oxides/hydroxides if Al, Mg, and Fe. Specific members were design to absorb Cd like liquid membrane and emulsifying membranes. Ion exchange chromatography is also used for the removal of cadmium (Ganiyu, Van Hullebusch, Cretin, Esposito, & Oturan, 2015).

Chemical Methods:

First method to remove cadmium was demonstrated by Schlage Lock company in which by adding Barium acetate caused coagulation if Cd from electroplating industry effluents. Different solvent extraction techniques can extract cadmium by using various extracts like aqueous Nitrogen donor ligand, Cyanex 301 and phosphorus based extract. Cd +2 can be removed by using different precipitating salts like of NaOH, Mg (OH) 2 and Ca (OH) 2 (Mahajan & Kaushal, 2018).

Biological Methods:

Some species of microorganisms like bacteria, yeast species, fungi aspergillus, green algea chlorella, brown algae Fucus vesiculosus are reported for the Bioremediation of Cd. Remediation of cadmium through microbes provide effective way to remove toxic cadmium but the growth of microbes require optimal climate conditions. In last decades a new technique is emerging which is faster,

cost-effective environment friendly technique and causes the removal of toxic heavy metals from the soil and water. That technique is phytoremediation (Wu *et al*., 2022).

CONCLUSION

In this article we discuss about phytoremediation and their subgroups .Basically the purpose of these techniques to decontaminates the polluted water. These techniques are used for the removal of both organic and inorganic metals. These techniques are cost effectives and environmentally friendly. Some heavy metals such as lead, mercury are harmful for both marine and terriestrial life, by using these techniques we can prevent these hazaradus effects of toxic metals. Nowadays in Pakistan people are drinking polluted water and death ratio increased day by day. An estimated 40 percentage of all deaths in Pakistan are caused by ingesting contaminated water.In future, by using these techniques we can overcome all these problems, therefore we should work on these techniques.

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