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REVIEW ARTICLE **OPEN ACCESS**

Phytoremediation: An Alternate Way to Treat Cadmium in Soil

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ABSTRACT

Despite the major efforts that have been made over recent years to clean up the environment, pollution remains a major problem and poses continuing risks to health. The problems are undoubtedly greatest in the developing world, where traditional sources of pollution such as industrial emissions, poor sanitation, inadequate waste management, contaminated water supplies, and exposure to indoor air pollution from biomass fuels affect many people. Heavy metals pollution has become a major problem throughout the world. The utilization of heavy metals through extraction from ores and subsequent processing for different applications has led to the release of these elements in the environment. Among these pollutants, Cd is most toxic heavy metal that cause environmental problems and as well as health problems due to its high mobility in the soil-plant system. The present paper will give an insight into the importance of bioremediation to remove the Cd with the application of microorganisms like Aspergillus niger, Pleurotus ostreatus, Spergilus versicolor, Fomitopsis pinicola etc. Cadmium (Cd), from contaminated soil is expected to reduce the concentration of metals in the soil and minimize the associated environmental hazard.

Key Words: *Phytoremediation, Cadmium, Pollutants, Heavy Metal, Bioaugmentation*

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INTRODUCTION

In recent years, urbanization, industrialization of our environment has increased at a very fast pace, due to this, the occurrence of contaminants in our surrounding has also increased, which is concerns all over the world [1, 2].These heavy metals are metallic as well as chemical element that shows properties like high in densities and high atomic weights and atomic numbers. Heavy metal contaminations in soil have been enhanced through various natural activities and through manmade or industrial activities (see Table 2). Heavy metals are non-biodegradable and they also have tendency to enter in the food chain by these crop plants, and same time they stored in the living beings body through the process of Biomagnification.
On the basis of function of these heavy metals in our environment, these are of two types- Essential and Non-essential. Essential heavy metals like Copper (Cu), Iron (Fe), Manganese (Mn), Nickel (Ni), and Zinc(Zn) are important for plant growth and physiological and biochemical processes [3].; sometimes these essential heavy metals play toxic role when present in huge amount. Non-essential heavy metals are those which do not play any role in plant life cycle like cadmium, lead, arsenic etc [4] and they are the reason for environmental pollution and drastically influence a large number of bio-physiological processes in plants and also reduce the agriculture productivity [3].Cadmium and Lead both are non-essential trace elements and potentially highly toxic. As a non-essential metal, Cd disturbs various physiological processes in plants, such as restriction of photosynthesis, induction of oxidative stress, and destruction of micro-and macro-elements balance [5-9]. Heavy metals get stored in the living beings body through biomagnification via the food chain because they enter into the food web or chain by crop plants and when these crops are utilized by human beings they cause so many diseases in humans and plants (Table-1) [10-11]. The phenomenon of using metal accumulating plants to remove or reduce heavy metals and other toxic compounds from environment was first introduced in 1983,but the concept has actually been executed for the past 300 years. In spite of this potential, phytoremediation is yet to become a commercially available technology in India. Our life on earth is dependent on its environment but presently the quality of environment is very bad. These all is due to anthropogenic activity and as well natural processes. Bioremediation is a technique in which we use microbes for the reduction of contaminants from the contaminated site however in phytoremediation process there is use of plant for the reduction of contaminants from environment like air, soil, and water contaminated with hazardous

contaminants. In it we use green plants and the microorganisms that help in the process. There are two important seasonal crop plants which are very common in phytoremediation *Brassica juncea, Sorghumvulgare.*

Description of plants

Brassica juncea- It is commonly known as brown mustard, Chinese mustard, Indian mustard, oriental mustard and vegetable mustard. The leaves are ovate or obovate shape which is simple and petioled. The flowers have raceme inflorescences and bisexual with four free sepals and four yellow petals, along with two longer and two shorter stamens. Brassica *juncea* is particularly effective at removing cadmium from soil. In India B*. juncea* is grown in winter as rabi crop.

Sorghum vulgare - Sorghum vulgare is popularly known as Jowar. It is used as food and fodder crop of dry land agriculture. The cereal crop is perennial in nature with corn like leaves, bearing the grain in a compact cluster. Sorghum, is the fifth important cereal crop in the whole world after wheat, rice, maize and barley. Jowar is the major staple food grain crops in India. Out of the total area under jowar cultivation in India, 50% is cultivated in Maharashtra. The advantage of this crop is that it can be grown in both Kharif and Rabiseason.

Harmful Effects of Cadmium on Human Health and Plant –

The biological half-life of cadmium (Cd) is about 18 years [12]. Phytoremediation efficiency is mainly dependent on biomass and the heavy metal concentration in the harvestable materials.

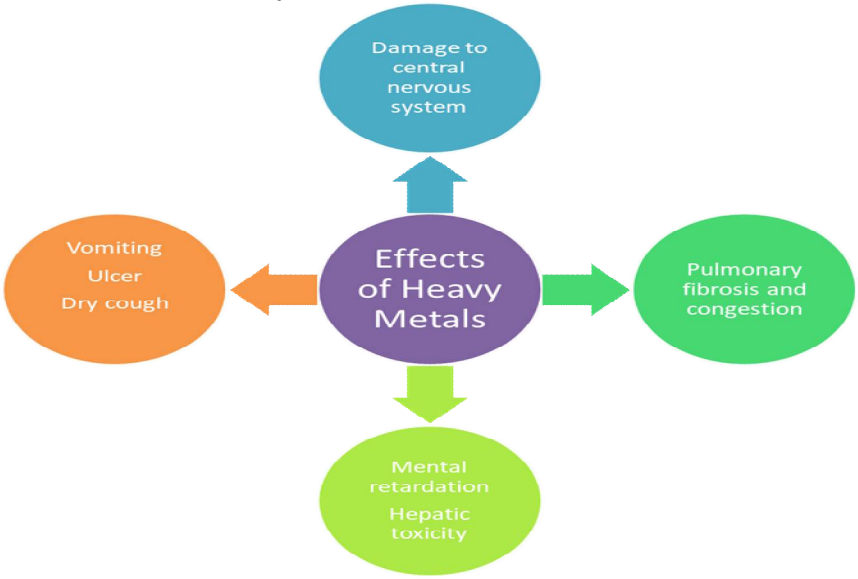

Fig. 1- showing effects of cadmium on human health

Phytoremediation -Phytoremediation word comes from the Greek word phyto means plant, and the word remedium (Latin) means restoring balance or remediation. In the phytoremediation process there is use of plant for the reduction of contaminants from contaminated soil, water and air contaminated with hazardous contaminants. In it, we use green plants or microorganisms that help in this process. This process takes advantage of the unique and selective uptake capabilities of plant root systems, and applies these natural processes alongside the translocation, bioaccumulation, and contaminant degradation abilities of the entire plant. [13]. In this process we used plants and their extract to reduce environmental pollution or decreases their bioavailability in contaminated environment [14]. Any substance, which causes undesirable effects in the environment, damage the health of the environment and ultimately diminishes the quality of life, is called a pollutant.

Table 1: Anthropogenic Sources of Non- Essential Heavy Metals in Atmosphere

Heavy metal	Sources
As	Pesticides and wood preservatives
Cd	Paints and pigments, plastic stabilizers, electroplating of cadmium containing plastics, phosphate fertilizer.
Cr	Tanneries, steel industries, fly ash
Cu	Pesticides, fertilizers
Hg	Release from Au-Ag mining and coal combustion, medical waste.
Ni	Industrial effluents, kitchen appliances, surgical instruments, steel alloys, automobile batteries
Pb	Aerial emission from combustion of lead petrol, battery manufacture, herbicides and insecticides

Strategies of Phytoremediation –
Phytoremediation process includes-

- **Phytostabilization**-In it plants reduce or stabilize contaminants or heavy metal bioavailability in soil.
- **Phytoextraction**–Plants are used to extract and reduce contaminants from soil and stored in root and shoot.
- **Phytovolatilization** –Plants absorb heavy metals or contaminants from contaminated soil and release these contaminated compounds into the our surroundings as volatile compounds.
- **Phytofiltration** –Using hydroponically grow plants to absorb heavy metal ions from ground water [14, 15, 16]. Other phytoremediation strategies include phytodegradation and rhizofiltration.

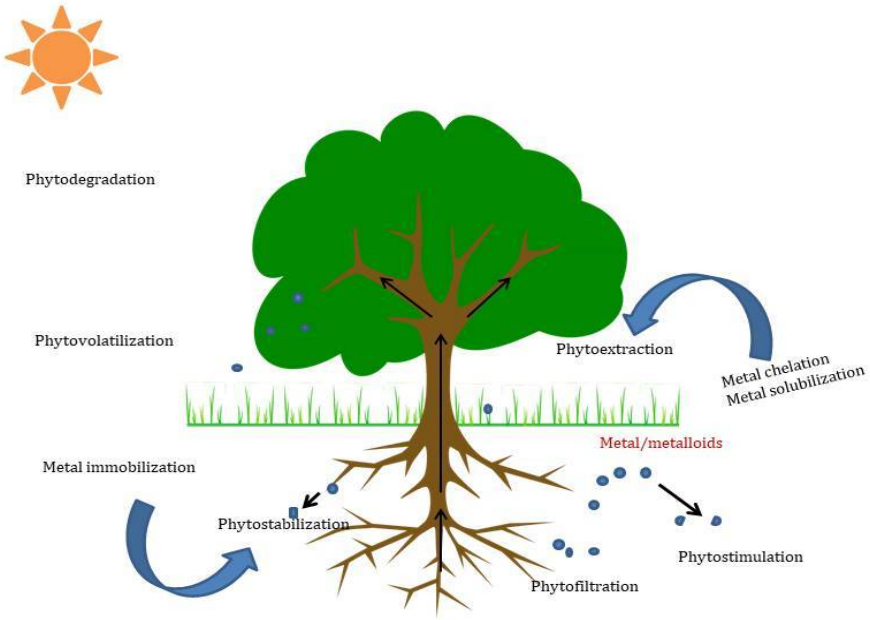

Fig. Showing different strategies of Phytoremediation

Phytostabilization - In phytostabilization process we use plants of metal tolerant species to immobilize toxic heavy metals by roots below the ground part and also decrease their bioavailability [17, 18]. This occurs by absorption by roots, precipitation, complexation or metal valency reduction in the rhizosphere.
Phytoextraction- In phytoextraction process plants uptake contaminants from contaminated soil and water through roots of plants, then translocate and accumulate these contaminants mainly heavy metals in different parts of the plants which is shoot [19, 20].This technique is the main and most useful phytoremediation technique for removal of toxic metals from polluted soil, sediments or water, although its efficiency depends on many factors, such as metal bioavailability, soil properties, metal speciation and plant species and, mainly, on shoot metal concentration and biomass [21, 22].
Phytovolatilization - Phytovolatilization is a process in which we use plants to take pollutants from polluted soil and change these toxic elements into less toxic volatile form by plant transpiration process via the leaves or foliage system of plant and they release these toxic volatile compound into the atmosphere. This strategy of phytoremediation process is use for decontamination or detoxification of heavy metals that have high volatility characteristics like Selenium (Se), Mercury (Hg), Arsenic (As) and group of organic pollutants [23].
Phytofiltration – In it we use plant roots called rhizofiltration, when we use shoots called caulofiltration and when we use seedlings called blastofiltration to reduce heavy metals from polluted surface of waters and waste waters [24]. In **rhizofiltration** process contaminants are either absorbed by the plant roots in various aquatic environments rather than soil or adsorbed on to the root surface. In **Blastofiltration** the sudden increases in surface to volume ratio that occurs after germination and the fact that many seedlings are able to adsorb or absorb large amounts of heavy metals, making them uniquely suitable for water remediation (Krishna et al., 2012). Castor, okra, melon and moringa seeds are used because they have blastofiltration potential. Castor and Okra seeds are the most efficient, while Moringa seeds removed 100% of Cd from the contaminated-water recent studies in **caulofiltration**, have also indicated great potential in this regard for metal removal from contaminated water bodies. For example, a study

conducted with *Ipomoea* aquatic exposed to Pb concentrations over 20 mg L1 demonstrated that significant sequestration of excess metal occurred in stem tissue.

Phytotransformation - Phytotransformation also known as phytodegradation, is the capture of pollutants and heavy metals from the water, soil [23, 24], Occurs in the roots (rhizodegradation) as well as shoots [25]. Plants and their enzymes are used to metabolize toxic compound and transform them into less toxic compounds[26]. Some plants have the ability to convert metal species into their more stable forms, as in the case of Cr, which is converted from Cr6þ to Cr3þ, in order to reduce the effects of phytotoxicity, Cr3þ is less mobile and less toxic than Cr6þ [27, 28]

Factors that influence Phytoremediation process – there are several factors that affects this processes and its efficiency, which may be –plant species, soil pH, carbon content in soil, plant microorganisms interaction, environmental conditions [29] Usually, only a small amount of the heavy metals occur in soil is available for uptake through plants roots, since metal many times bind strongly to soil particles or precipitation causes many metals to become insoluble [30, 31].

Nanoparticles used in this process - Nanoparticles are atomic or molecular aggregates, size varies between 1 and 100 nm classified as – natural (volcanic eruption or lunar dust or mineral composites), incidental (originating from the anthropogenic that is man-made and engineered [32]. Anthropogenic or man-made and engineered nanoparticle concentrations present in our surrounding at very high level and their concentration increasing day by day and there are currently extensive discussions on the risks of these compounds to plants and human health. Many NPs are metallic in nature, such as AgNP, AuNP, as well as TiO2, ZnO and Al2O3 [33]. Some reports on higher (vascular) plants are available. CuNP were shown to be toxic to *Phaseolus radiatus* (mung bean) and *Triticum aestivum* (wheat) [34]. However, many studies have reported that there is low or no significant effects of the presence of NP to higher plants, indicating potential for the phytoremediation of these compounds in the environment, than it is termed as "nanoremediation".

Genetic engineering or genetically modified plants- The recently coined term genoremediation is used in this context (Mani and Kumar, 2014). Genetic engineering is a most promising biotechnology for increases the phytoremediation power of plants to degrade the pollution caused by heavy metals. In genetically modify plants, a foreign particle of gene from an organism, which may be a plant species or bacteria or animals is transferred and inserted into the genome of a plant. After DNA recombination and ligation, the foreign particle of gene is inherited and confers specific characters to the target plants. This technology has many advantages to modify plant's desirable characters for phytoremediation in comparison to the traditional method of breeding in a very short time period [35, 36].

Micro-organisms help to improve plant performance-In this process use of plant-associated microorganisms sometimes also known as rhizosperic microorganisms is another approach to increase plant growth and its performance phytoremediation. Microorganisms are found in rhizosphere zone which may be directly increases proliferation of root and thus help in plant growth, also increases heavy metal tolerance mechanism and plant health [37, 38, 29]. Now it has been proved that Plant Growth Promoting Rhizobacteria have tendency to increases phytoremediation process. PGPR can increases plant growth and its fitness, and also protects plants from pathogens, increases plant tolerance mechanism, and increases plant nutrient uptake mechanism, heavy metal uptake mechanism and metal translocation [39].

CONCLUSION

In present day urbanization and industrialization of our environment have been increases at a very fast pace. So, it is very important to develop techniques, policies and strategies to reduce heavy metal pollution because heavy metal creates major problems in human as well as in environment. This review paperdefines the importance of plants in our life without plants there is no life. Phytoremediation is a process in which plant usedto remediate, reduce or detoxify contaminants or heavy metals mainly Cadmium from polluted water and soil. In this review paper we discuss about phytoremediation processes its strategies and different factors that affect the phytoremediation process.

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