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A Review: Phytoextraction, an Effective Application to Remove Pollution and Heavy Metals from Water

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Abstract: Heavy metals concentration is increasing day by day due to the activities of the human. Due to this increment heavy metals create serious problems to the survival of the organism on the earth. So this is a need of the environment to protect or conserve it from different problems by using different techniques. Phytoextraction is the widely use application of plant in Environmental Biology. This technique was getting more attention for the hyper accumulation of heavy metals in the plants. Plants were good source for the removal of heavy metals from the soil. In this review the use of plant, some important plants which were used in Phytoextraction, pollution of soil causes by heavy metals, effects of heavy metals specially Cadmium and Lead and the mechanism of uptake and adsorption of heavy metals by the plants was studied. Further studies are required in this field to find out other techniques and also the fixation of the plant which are used in this process. Because the organic contaminants, cannot be degraded easily.

Key words: Phytoextraction · Cadmium (Cd) · Lead (Pb) · Pollution in Soil · Heavy Metals Effect · UOG

INTRODUCTION

In Phytoextraction some specific plants were used to remove heavy metals from soil. Than these plants were harvested and removed from the contaminated soil and in this way the amount of heavy metals was decrease in the soil [1]. Now a days soil removing, soil filling or soil washing were also used to removed heavy metals and these were done by physical and chemical methods however these chemical and physical methods were expensive and depends heavy metals and soil conditions and on environments [2]. Heavy metals pollution in soil is extensively serious problem, due to quick growth of industry and by the modern agriculture process. These heavy metals remain in soil for a long time and affect the plant growth because they are not simply decomposed by soil microorganisms and for that reason, can easily be absorbed by plants [3]. Only lead (Pb) remain about 150-500 years in the soil and it was reported that by the industry contaminations it will remain for 150 years in the soil [4]. Cadmium (Cd) which is a noxious metalhas about 18 years of half life [5]. Many pollutants released by modern human activities including pesticides, poisonous gasses and heavy metals, has endangered the healthy survival of living organisms [6]. Many human activities cause pollution in different areas of world such as Japan, Indonesia and China mostly such as Cd, Cu and Zn [7]. The soils near any industry contain high levels of heavy metals due to discharge by the industry [8-9]. Raskin *et al*. [10] and Blaylock and Huang [11] also reported that the presence of heavy metals in soil was due to smelting of metalliferous ore, electroplating, gas exhaust, energy and fuel production, the application of fertilizers and municipal sludges to land and industrial manufacturing. Heavy metals constitute a very diverse group of elements widely varied in their chemical properties and biological functions [12]. Heavy metals absorbed by the plants directly affect the plant growth and many other processes including photosynthesis, respiration etc and also they can affect human health by their presence in food crops [13]. In this Era use of metal-accumulating roots and rhizomes of aquatic or semi aquatic vascular plants for the removal of heavy metals from contaminated aqueous streams is studied very

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Table 1: Important Plant Used for Phytoextraction of Heavy Metals

Contaminant	Plant	Medium	References
Lead (Pb)	*Chenopodiumalbum* L.	Soil	[17]
Cadimum (Cd)	*Thlaspicaerulescens*	Nutrient solution	[18]
Mercury (Hg)	*Arabidopsis thaliana*	Soil	[19]
Copper (Cu)	*Haumaniastrum*species	Soil	[20]
Cobalt	*Haumaniastrum*species	Soil	[20]
Boron	*Gypophilasphaerocephala*	Soil	[21]
Zinc	Corn	Soil	[22]
Nickel	*Thlaspigoesingense*	Soil	[23]
Uranium	*Loliumperenne* L.	Soil	[24]

seriously and many plants are use for this purpose. For example; water hyacinth (*Eichorniacrassipes*) [14], watercress (*Nasturtium officinale*) [15], duckweed (*Lemna minor* L.) [16] take up Pb, Cu, Fe, Cd and Ni from contaminated solutions.

Pollution in the Soil: In 21st century pollution due to the sewage cause a serious problem in land, rivers and streams, also the fast growing development of urbanization and industrialization led to the rising use of sewage foragricultural land irrigation and water pollution. Sewage provides water and valuable plant nutrients; it leads tothe potential accumulation of heavy metals in agricultural soils [25]. The sewage sludge is use as fertilizer for agriculture and also the reformation of soil because sludge contains a lot amount of organic contents which benefits the soil [26]. The composition of sewage is mainly excrement, excreta, wastewater from clothwashing machines and waste from kitchen dishes, bathing water, paper fiber, food particles, vomit and garbage. Different types of dissolved oxygen were also present which includes Biochemical Oxygen Demand (BOD), ChemicalOxygen Demand (COD), Oxygen Demand Index (ODI), Total Oxygen Carbon (TOC), nutrients and heavymetals. Domestic water also contain huge amount of phosphorus and nitrogen [27]. Many geochemical forms of the heavy metals arepresent in the environment, these forms are: exchangeable, water soluble, Fe-Mn oxide-associated, water soluble, organic-associated and residual forms [28]. In microorganism heavy metals can be bounded intracellular accumulation, extracellular precipitation and chemical transformationscatalyzed by these microorganisms, such as oxidation, reduction, methylation, dimethylation. The toxicity and the mobility of heavy metals in soils depend not only on the total concentration, but also ontheir specific chemical form, binding state, metal properties environmental factors and soil properties like pH,organic matter content [29]. Heavy metals can make bonds with sulfur containing ligands and can easily enter in to the cell and stop working of many enzymes and disturb the metabolic processes by reacting with SH-groups of ligands[30].

Heavy Metals Removed by Phytoextraction and Their Effects to Human and Plants: Heavy metals can be classified into four majorgroups on their health importance.

Essential: Cu, Zn, CO, Cr, Mn and Fe. These metalsalso called micronutrients [31]and were toxic when taken in excess of requirements [32].

Non essential:Ba, Al, Li and Zr
Less toxic: Sn and Al
Highly toxic: Hg, Cd and Cd.
Cadmium (Cd)

Cadmium (Cd) is one of the most deleterious trace heavy metals both to plants and animals. With the development of modern industry and agriculture, Cd has become one of the most harmful and widespread pollutants in agricultural soils,and soil-plant-environment system mainly due toindustrial emission, the application of Cd containing sewage sludge and phosphate fertilizers and municipal waste disposal [33].In humans, Cd accumulates mainly in the kidney with a biological half life about 20 years and leads to pulmonary emphysema and renal tubular damage [34].Extreme cases of chronic Cd toxicity can result in osteomalacia and bone fractures, as characterized by the disease called Itai-Itai in Japan in the 1950s and 1960s, where local populations were exposed to Cd contaminatedfood crops, principally rice. According to recent soil survey done in China, at least 13330 ha of farmland in 11 provinces were contaminated by varying degrees of Cd [35].Under Cd stress, tolerant species and

genotypes in plant kingdom could reduce Cd activity to alleviate or eliminate its toxicity through regulating the physiological and biochemical metabolism. In order to survive, plants have to develop efficientand specific heavy metal detoxification mechanism in different plant species [36]. It has been demonstrated that some plants can actively or passively change H^+ excretion under heavy metal stress. Such rootinduced changes of rhizosphere pH play a major role in the bioavailability of many pH dependent nutrients, but also potentially toxic metals and a range of trace metals[37].Hassan *et al.* [38]also found that the toxic effect of Cd on rice varied withthe form of nitrogen fertilizer and application of $(NH_4)_2SO_4$ to Cd stressed rice plants, compared to NH_4NO_3 or $Ca(NO_3)_2$, would be beneficial to mitigate detrimental effect of Cd and to reduce Cd accumulation in plants. The maximum amount of cadmium present in different countries soil is 1-20 mg/kg [39-40].

Lead (Pb): Lead is the industrial metal which is extensively present in the air, water, soil and food. It is easily soluble in the water and transported through atmosphere. It behaves like calcium in body and accumulates in bone, liver, kidney and other tissues.It is a cumulative tissue poison and gets stored in different parts of the body especially in bones, liver, kidney and brain [41]. In these days lead consider as an effective soil and environment pollutants. The cultivated soils near to industrial and urban area have been large amount of lead (Pb) contents where it becomesto accumulate in the surfaceground layer[42].According to Schütz *et al,* [43] lead (Pb) is the most dangerous metal for human health and it seriously affect the central nervous system, responsible for anemia, gastrointestinal damage and leads to cause change in the genetic expression. The presence of lead in the soil was caused by direct contamination during the processing of the food, by the soil, air or by the pesticides and fertilizer in the fields. Contaminated soil and water were also responsible for the introduction of the lead in the food. During the casual transportation, storage and industrial processing lead is also polluting the food.[44].The major source of vegetables contamination with toxic elements are irrigation with water from streams contaminated by industries, the cultivation on former industrial landcontaminated by spilled oil and industrial wastes, the pollution of crops by heavy traffic,and the application of contaminated fertilizer [45]. The maximum amount of lead present in different countries soil is 50-300 mg/kg [39 - 40].

Mechanism for the Uptake and Adsorption of Cd and Pb by Plants: The uptake of heavy metals also helps us to enable to examine the tolerance of plants to heavy metals [46]. Cd and Pb is uptake by the root system of the on the root surface, Cd^{2+} and Pb^{2+} make bond with the carboxy-groups of mucilage uronic acids. These Mucilage binding stops the entering of the heavy metals and protect the root system. But some of the metals which were bounded are released whenmucilage biodegradation occurs [47]. In the slighterdegree Cd and Pb enter into plants through the leaves and this absorption of heavy metals depends upon leaf morphology: the downy leaves, they absorb the heavy metals from the atmosphere efficiently then others [48].Yang *et al*. [49] studied that the lowest rate of uptake of Cd was in ryegrass and the highest uptake and transport rate in the Ladino clover plants. Two mechanisms are responsible for metal transport from the bulk soil to plant roots: (i)convection or mass flow and (ii) diffusion [50].The sensitivity of plants to heavy metals depends on an interconnectedsystem ofphysiological and molecular mechanisms such as (i) uptake and accumulation of metalsthrough binding to extracellular exudates and cell wall constituents; (ii) efflux of heavymetals from cytoplasm to extranuclear compartments including vacuoles; (iii) complexationof heavy metal ions inside the cell by various substances, for example, organic acids, aminoacids, phytochelatins and metallothioneins; (iv) accumulation of osmolytes andosmoprotectants and induction of antioxidative enzymes (v) activation or modification ofplant metabolism to allow adequate functioning of metabolic pathways and rapid repair ofdamaged cell structures [51].The uptake rate of heavy metals depends on the pH value of the soil solution, the organic matter content in the soil and the concentrations of other ions. At higher pH values, the solubility of Cd salts in the soil solution declines due to the formation of lowsoluble compounds; as a result, the biological availability of soil Cd decreases [52]. Other metals also affect the uptake of Cd and Pb, Ca^{2+}effect is most obvious though somewhat unclear: Ca^{2+} considerably inhibited Cd^{2+} uptake by roots of diverse plant species[53].Emongor *et al*. [54] found that heavy metals took up by vegetables grown with wastewater tend to remain in roots. Only a fraction of heavy metals are translocated to the shoots and even a small fraction reaches the fruit [55].

Conclusion and Future Studies: It was concluded that plants were good source to remove heavy metals especially Cadmium and Lead. It has wide applications in

the polluted environment. And the heavy metals have a lot of serious affects on human and animal health and also on plant growth. Phytoremediation is yet to become a commercial technology.Progress in the field is prohibited by limited knowledge of basic plant remedial mechanisms. Further studies requires to tell about the more use of plants for Phytoextraction and also the study about how to fix the plant debris, because after the uptake of heavy metals from the soil the questions arises that, In which form the heavy metals were up taken, or the heavy metals are converted in to any other soluble nutrients are any other chelated form? How to fix the debris or litter of plant? Because it may happened that if one place was cleaned by the Phytoextraction process may pollute the other place on which the plant litter was transported. So further research required in this field.

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