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Weed Plants for Heavy Metal Management

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Abstract—*Researches towards the management of heavy metals (HM) from waste receive much more attention. HM accumulates in the body tissues of living organisms and affects many biochemical pathways and extent of toxicity depends on it's chemically availability. Naturally occurring metal hyper accumulators have gained importance recently due to immense potential of these plants in phytoremediation of heavy metal-contaminated sites. Weed plants are widespread throughout the world and usually have great potential for invasion due to high growth and reproductive rate, efficient dispersal, rapid establishment and stress tolerance. The current research is projected to use weed plants Thalaspi caerulescens, Ageratum conyzoids, Parthenium hysterophorus, Equisetum diffusum, Bidens pilosa, Sedum alfredii for heavy metal management/ detoxification. The detoxification involves the immobilization of metal by complexation/chelation to less toxic form by using natural chelates present in the plants. These plants form phytochelatin complex (PC) with heavy metals and hide their identity. The HM –PC complex formation is depends upon the availability of ligand, kinetics of complex formation, and steric factor.*

Keywords: *Weed plant, heavy metal management, detoxification, complexation, phytochelatin*

1. INTRODUCTION

Environmental pollution by heavy metals has become a serious problem in the world. The mobilization of heavy metals through extraction from ores and subsequent processing for different applications has led to the release of these elements into the environment. The problem of heavy metals pollution is becoming more and more serious with increasing industrialization and disturbance of natural biogeochemical cycles. Heavy metals cannot be destroyed biologically but only transformed from one oxidation state or organic complex to another [1]. Heavy metals adversely effects plant like growth growth, poor yield and aberrations in metabolic function like photosynthesi and respiration [2]. Various chemical and physical methods are employed for the extraction of metals which are costly [3] (Table 1) and require highly sophisticated equipments and skilled labour. The use of synthetic chelates like EDTA cannot be avoided in these methods. Synthetic chelates pollute ground water, negatively affect soil quality and also chelate necessary ions unselectively [4]. So, it is necessary to use environmental friendly, greener and cost effective technique (phytoextraction) for the remediation of heavy metals. Metal hyper accumulating plants have gained increased attention because of their potential to accumulate heavy metals and have application in decontamination of metal polluted soil. Weeds plants are suitable for this purpose because of their inherent resistant capability, fast vegetative and reproductive growth, wide adaptability, stress tolerance and their non-suitability for fodder purpose [5]. They have the intrinsic capacity to accumulate metals into their shoots and roots, have the ability to form phytochelates and formation of stable compound with ions. This behavior of accumulation along with chelate and stable compound formation is utilized as a tool for phytoremediation activity.

Table 1: Cost of different remediation technologies [3]

S. No.	Remediation technology	Approx. Cost [(£)/ tone soil]
1	Biological	5-170
2	Chemical	12-600
3	Physical	20--170
4	Thermal	30-750

2. PHYTOREMEDIATION

Phytoremediation basically refers to the use of plants and to reduce the concentrations or toxic effects of contaminants in the environments [6]. It can be used for removal of heavy metals and radionuclides as well as for organic pollutants (such as, polynuclear aromatic hydrocarbons, polychlorinated biphenyls, and pesticides). It is a novel, cost-effective, efficient, environment- and eco-friendly, in situ applicable, and solar-driven remediation strategy [7-9]. The term ''phytoremediation'' is a combination of two words: Greek phyto (meaning plant) and Latin remedium (meaning to remove an evil). Green plants have an enormous ability to uptake pollutants from the environment and accomplish their detoxification by various mechanisms.

3. CHARACTERISTICS OF WEED PLANTS AS HYPERACCUMULATOR

Hyperaccumulator plant species have revolutionized the phyremediation technology since they have an inherent capacity to uptake metals at levels 50-500 times greater than average plants [10-11]. Metal hyperaccumulators are naturally capable of accumulating HM in their aboveground tissues, without developing any toxicity symptoms. A metal hyperacumulator weed/plant (Table 2) must accumulate atleast 100 mg Kg^{-1} (0.01%dry weight) Cd, As and some othertrace metals,1000 mg Kg^{-1} Co, Cu, Cr, Ni and Pb and1000 mg Kg^{-1} Mn and Ni [12-13]. The bioconcentration factor of soil (BCFs) is defined as the ratio of metal concentration in the shoots to that in the soil [14-16].The BCFw is defined as the ratio of total concentration of element in whole plant to that in the growing solution [17, 16]. The translocation factor which determines the effectiveness of plant in translocation is the ratio of element concentration in the shoots to that in the roots [18, 16].

Table 2: Metal hyperaccumulator weed and their bioaccumulation potential

S. No	Weed plant	Metal	Bioaccumulation	Reference
1	Ageratun conzyoides	Pb	16.86 mg/kg	[37]
2	Ageratun conzyoides	Cd	0.50 mg/kg	[37]
3	Ageratun conzyoides	As	0.12 mg/kg	[37]
4	Solanum photeinocarpum	Cd	158 mg/kg	[38]
5	Bidens pilosa	Cd	303 mg/kg	[39]
6	Thalspi praecox	Cd	>1000 µg/g	[40]
7	Ipomea alpine	Cu	12,300 mg/kg	[41]
8	Echornia crassipes	Cr	6000 mg/kg	[42]
9	Parthenium hysterophorus	Cu	59.3 g/kg	[43]
10	Chenopodium album	Zn	33.5 g/kg	[43]
11	Thlaspi caerulescens	Zn	19410 mg/kg	[44]
12	Thlaspi caerulescens	Cd	80 mg/kg	[44]
13	Phragmites australis	Cr	48225 mg/kg	[45]
14	Sedum alfredii	Zn	13977 mg/kg	[46]
15	Brassica juncea	Ni	3916 mg/kg	[47]
16	Potentilla griffithii	Zn	19600 mg/kg	[48]
17	Rorippa globosa	Cd	218.9 µg/g	[49]

Weed plants posses the following characteristics and can be used for phytoextraction purposes:

- Widely distribution
- More accumulation of the heavy metals
- Bioconcentration (BCF) and translocation (TF) factor>1
- High stress tolerance
- Repulsion to herbivores to avoid food chain contamination
- Protection against pathogens and pests
-Allelopathy

The hyperaccumulating nature of plants depends on the type of species, soil quality, and its inherent control. All the weeds undertaken in the current study are capable of sufficient level of bioaccumulation, and still they are capable of maintaining their growth rates and reproduction levels as compared to controls in studies undertaken.

4. STRESS TOLERANCE MECHANISM IN WEED PLANTS

Weed plants secretes various secondary metabolites under metal stress. Allelopathy is the release of chemicals by weed plants/plants that adversely effects the growth of other plants and enables weed plants to colonize new environment [19-20]. *Parthenium hysterophorus* secretes phenolic acids and sesquiterpenes like parthenin,coronopilin etc. [21] *Lantana camara* secretes both volatile and non-volatile chemicals like lantadenes, aesulin, quercetin,tricin etc. [22, 23].

5. CHELATION AS METHOD OF HEAVY METALS DETOXIFICATION

Chelation of heavy metals with PCs, a primary cellular mechanism for heavy metal detoxification. At the cellular and subcellular levels, the sequestration and storage of non-labile metal-organic complexes in vacuoles are considered as the main detoxification mechanisms [24]. Hardness/Softness characteristics of electron donor and acceptor are not only the determining factor for complex stability but also for chelator's degree of metal selectivity to competing metals and vice versa. In general metal ions and ligands prefer to form complex with partners having similar HS character, but the stability of complex increases with degree softness of both metal and ligand. The stability of complex can be increased with increasing the number of rings formed.

Natural chelators like APCA's (aminopolycarboxylic acid) and NLMWOA (natural low molecular weight organic acids) are produced by many plants and microorganisms which are biodegradable. Natural chelators like EDDS (aminopolycarboxylic acid) are produced naturally by a number of microorganisms [25] such as *Amycolatopsis japonicum* sp. [26]. PC are LMW,metal binding proteins that can form mercaptide bonds with various metals [27] and play a role in their detoxification [28, 29]. PCs are small glutathione derived and enzymatically synthesized peptide that form a family of structures with increasing repetitions of the—Glu-Cys dipeptide units followed by a terminal Gly, (γ-Glu-Cys)n-Gly or (γ–EC)n-Gly, where n generally ranges from 2 to 5, but can be as high as 11 [30]. On the basis of the number of—Glu-Cys units, PCs have been classified as PC2, PC3, PC4, PC5, and PC6 etc. [31]. Polychelatins are the best-characterized heavy metals chelator in plants [30]. The synthesis of polychelatin occurs in cytosol. PCs interact with the metals through thiol (-SH) group of cysteine. However, the degree of polymerization in PCs was observed with increasing intracellular metal concentration indicating increased binding stability of metal–PC_n complexes [32]. The metal–PC complex formation is governed by availability of ligand, kinetics of complex formation, and steric factor. By over expression of natural chelators like PCs, MTs, and organic acids, not only metal ions' entrance into plant cell but also translocation through xylem is facilitated [33].With exposure of metal to the root of the plant, polychelatins coordinate to form ligand complexes with these metals, which are further sequestered into the vacuole. The prominent metal complexation processes are the synthesis of phytochelatin and other metal chelating peptides [34]. Oxalic acid is secreted in rhizosphere of buckwheat (*Fagopyrum esculentum*) due to metal (Al) stress and detoxified Al-oxalate complex is taken up by roots and translocated into leaves [35]. Cd is transported and loaded into the seeds of cadmium hyperaccumulator *Thlaspi praecox* as a Cd-thiolate complex, which is relatively non-toxic because of the strong Cd-S coordination [36].

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