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Phytoremediation of Heavy Metals Contaminated Soils by *Catharanthus roseus*

V. Subhashini[1], A.V.V.S. Swamy[2]

Department of Environmental Sciences, Acharya Nagarjuna University, Nagarjuna Nagar, Guntur, Andhra Pradesh, PIN CODE-522 510

Abstract: ***In the present study Catharanthus roseus (Apocynaceae family) an herbaceous ornamental plant was used for the Phytoremediation of lead, nickel, zinc, cadmium and chromium contaminated soils. Heavy metals total accumulations in root, stem and leaf was calculated and Bioconcentration factor, Translocation factor values was also calculated. Finally, the result shows that the plant species was good accumulator of these heavy metals.***

Keywords: Heavy metals, Phytoremediation, Bioconcentration factor, Translocation factor, *Catharanthus roseus*

1. Introduction

An extensive area of the world is contaminated with organic and inorganic pollutants including heavy metal pollutants (Ensley, 2000). Organic pollutants include solvents like trichloroethylene (TCE) (Newman *et al.,* 1997), herbicides, atrazine (Burken and Schnoor, 1997). Inorganic pollutants include plant macronutrients such as nitrates and phosphates, micro nutrients, Cr, Cu, Fe, Mn, Mo, Ni, Zn and nonessential elements. As, Cd, Co, F, Hg, Se, Pb, V and radionuclides, 238U, 137Cs and 90Sr (Dushenkov, 2003). Heavy metals that are hazardous viz. lead, mercury, cadmium, nickel, arsenic, copper, zinc and chromium. Such metals are found naturally in soils in trace amounts. Metals like Cadmium (Cd), Lead (Pb), Zinc (Zn) and Chromium (Cr) when present in high concentrations in soil exert potential toxic effects on overall growth and metabolism of plants (Agrawal and Sharma, 2006) and bioaccumulation of such toxic metals in the plant poses a risk to human and animal health.

Increased concentrations due to anthropogenic activities in certain areas pose serious threat to all living organisms. Metal ions are commonly removed from dilute aqueous streams through chemical precipitation, reverse osmosis and solvent extraction. These techniques have disadvantages such as incomplete metal removal, high reagent and energy requirements, generation of toxic sludge or other waste products that again require disposal. The search for alternate and innovative treatment techniques has focused attention on the use of biological materials for heavy metal removal and recovery technologies and has proved efficient in the removal of heavy metals and economically viable compared to conventional treatment. Metal accumulative bioprocesses generally are divided into two categories, biosorptive uptake by non-living biomass and bioaccumulation by living cells.

The term Phytoremediation refers to a diverse collection of plant-based technologies that use either naturally occurring, or genetically engineered plants to clean contaminated environments (Flathman and Lanza, 1998). Phytoremediation is clean, simple, cost effective, non-environmentally disruptive (Wei *et al*., 2004) green technology and most importantly, its byproducts can find a range of other uses (Truong, 1999, 2003). Phytoremediation is a technology that exploits a plant's ability to remove contaminants from the environment or render toxic compounds harmless. Phytoremediation has been attracting attention as a rapidly developing, inexpensive plant-based remediation technology (Carbisu and Alkorta, 2001). This technology exploits the natural ability of a green plant to accumulate a variety of chemical elements and transport them from the substrate to above ground parts. The ability to accumulate heavy metals to high levels and to tolerate elevated levels of toxic metals has been reported in a number of plants (Baker and Brooks, 1989). A plant with an abnormally high level of metal accumulation is called a hyperaccumulator (Jaffre, *et al.,* 1976). A large number of hyper accumulators are seen in to the Brassicaceae family (Reeves and Baker, 2000).

The plants used for Phytoremediation must be fast growing and have the ability to accumulate large quantities of metal contaminants in their shoot tissue. Barley (*Hordeum vulgare* L.) and oat (*Avena sativa* L.) are the highly tolerant species of metals such as Cu, Cd, and Zn, and accumulate moderate to high amounts of these metals in their tissues. Many herbaceous species also accumulate moderate amounts of various metals in their shoots. Several studies were available on many fast growing Brassicas for their ability to tolerate and accumulate metals, including Indian mustard *(B. juncea),* black mustard *(Brassica nigra* Koch), turnip *(Brassica campestris* L.), rape *(Brassica napus* L.), and kale *(Brassica oleracea* L.). The aquatic or semi-aquatic vascular plants such as, water hyacinth *(Eichhornia crassipes),* pennyworth *(Hydrocotyle umbeliata),* duckweed *(Lemna minor),* and water velvet *(Azolla pinnata),* can take up Pb, Cu, Cd, Fe and Hg from contaminated solutions existed for a long time (Prasad *et al.,* 2001). A number of species are members of Brassicaceae, including a species of Arabidopsis, *A. halieri,* which can hyperaccumulate Zn in its shoots (Reeves and Baker, 2000). Recently, *Sonchus asper* and *Corydalis pterygopetata* grown on lead and zinc mining area in China have been identified as heavy metal hyper accumulators (Yanqun *et al.,* 2005). Phytoremediation presents many advantages, as compared to other remediation techniques, it is applicable to a broad range of contaminants, including many metals with limited alternative options. It is cost-effective for large volumes of water having low concentrations of contaminants; plant uptake of contaminated groundwater can prevent off-site migration of toxic substances (Schwitzguebel, 2000).

2. Material and Methods

The heavy metal contamination of soils increased with increasing industrialization as well as through ruthless application of weedicides, pesticides, etc., in agriculture. *Catharanthus roseus,* plant species has been selected for the present study to examine the potential to absorb the heavy metals from the soil and accumulate them in the above ground and below ground biomass.

A brief description of the plants selected for the present study

Figure 1: *Catharanthus roseus* Plant and Roots

Catharanthus roseus (Periwinkle) is a species of Apocynaceae family. Synonyms include *Vinca rosea, Ammocallis rosea,* and *Lochnera rosea;* other English names occasionally used include Cape Periwinkle, Rose Periwinkle; Rosy Periwinkle, and "Old-maid". It is also widely cultivated and is naturalized in subtropical and tropical areas of the world. It is an evergreen sub-shrub or herbaceous plant. The species has long been cultivated for herbal medicine and as an ornamental plant. In traditional Chinese medicine, extracts from it have been used to treat numerous diseases, including diabetes, malaria, and Hodgkin's disease. The substances vinblastine and vincristine extracted from the plant are used in the treatment of leukemia. It is noted for its long flowering period, throughout the year in tropical conditions (Gamble, 2008: *).

The experimental plant seedlings were maintained in earthen garden pots. Species were grown in pots and were irrigated with known heavy metal solutions (Pb, Ni, Zn, Cd and Cr) were added to the pots alternate days for 60 days. In controls normal water was used. The plants were grown for a period of two months (60 days). The initial soil heavy metal concentration was analyzed. Every 20 days the plant samples from each pot were collected and washed thoroughly under running tap water and distilled water. The collected samples were washed with distilled water remove dust particles. The samples were then cut to separate the roots, stems and leaves. The different parts (roots, stems and leaves) were air dried and then placed in a dehydrator for 2-3 days and then dried in an oven at 100°C. The dried samples of the plant were powdered and stored in polyethylene bags. The powdered samples were subjected to acid digestion. 1 gm of the powdered plant material were weighed in separate digestion flasks and digested with HNO_3 and HCl in the ratio of 3:1. After cooling, the solution was filtered with Whatman No.42 filter paper the filtrate was analyzed for the metal contents in AAS.

Calculation of Bioconcentration factor (BCF) and translocation factor (TF)

Heavy metals are currently of much environmental concern. They are harmful to humans, animals and tend to bioaccumulate in the food chain. Metal concentrations in plants vary with plant species. The concentration, transfer and accumulation of metals from soil to roots and shoots was evaluated in terms of Biological Concentration Factor (BCF), Translocation Factor (TF). Biological Concentration Factor (BCF) was calculated as metal concentration ratio of plant roots to soil (Yoon *et al.,* 2006). The Bioconcentration Factor (BCF) of metals was used to determine the quantity of heavy metal absorbed by the plant from the soil. This is an index of the ability of the plant to accumulate a particular metal with respect to its concentration in the soil (Ghosh and Singh, 2005a). Translocation Factor (TF) was described as ratio of heavy metals in plant shoot to that in plant root given in equation (Cui *et al.,* 2007; Li *et al.,* 2007). To evaluate the potential of this species for Phytoextraction, the Translocation Factor (TF) was calculated. This ratio is an indication of the ability of the plant to translocate metals from the roots to the aerial parts of the plant. Metals that are accumulated by plants and largely stored in the roots of plants are indicated by TF values <1, with values greater indicating translocation to the aerial part of the plant (Yoon *et al.,* 2006).

3. Result and Discussion

3.1 Accumulation of metals in *Catharanthus roseus:*

Catharanthus roseus absorbed Lead through root system in high quantities by 20th day itself and the lead was translocated in a slow manner throughout the remaining period of experimentation. As a result by the 60th day only 50% of the lead that was absorbed was translocated to stem and leaves. There was lowest accumulation in leaves (0.92 mg/kg) and highest accumulation was recorded in roots (67.33 mg/kg) with a total accumulation of lead (77.05 mg/kg) in the whole plant. The results of lead accumulation in *Catharanthus roseus* during the experimental period revealed that the rate of translocation were meagre. Nickel accumulation in *Catharanthus roseus* was initially higher in stem followed by roots. The Nickel accumulation was consistent in leaves from the beginning of the experiment. However, the 60th day the accumulation in roots increased by manifold and reached highest followed by stem and leaves in that order. Out of the 47.75 mg/kg of Nickel accumulated in plants 20.63 mg/kg was retained in the roots, 16.63 mg/kg of Nickel was accumulated in stem and 10.49 mg/kg in leaves. Two thirds of the Nickel remained in roots and stem. The results revealed that *Catharanthus roseus* is a good accumulator of Nickel. The initial concentration of Zinc was maximum in stem compared to roots and leaves. The increase of accumulation in roots and stem was consistent throughout the experimental period. However, from 40-60 day interval, the concentration of Zinc increased to 88.44 mg/kg (from 46.99 mg/kg) in leaves. The accumulation in stem also increased from 81.66 to 94.68 mg/kg in stem. On the whole, the leaves recorded highest accumulation of zinc followed by roots and stem. The highest accumulation of zinc in leaves leaving low quantities of zinc in stem and roots reveal that maximum quantity of

Zinc is translocated up to leaves. Out of the total 67.60 mg/kg of Zinc absorbed 9.93 mg/kg was translocated to root and 9.85 mg/kg to stem and 47.82 mg/kg to leaves. The results revealed that *Catharanthus rose us* is a good accumulator of Zinc.

The concentrations of Cadmium were very low in the initial stage. The accumulation of Cadmium was highest in the stem (13.17 mg/kg) followed by leaves (11.03 mg/kg) and lowest in roots (3.25 mg/kg). The overall rate of accumulation in leaves, stem and roots increased consistently up to 40th day and there was a sudden increase from 40-60th day. The results revealed that as the plant continued to grow the absorption of Cadmium also increased but the Cadmium absorbed by roots was completely translocated to stem and leaves. Out of the total accumulated 27.45 mg/kg of Cadmium roots retained only 3.25 mg/kg and the remaining was translocated to stem (13.17 mg/kg) and leaves (11.03 mg/kg). *Catharanthus roseus* is a good accumulator of Chromium. From the experiments conducted it is recorded that the roots have accumulated highest chromium content (6.7 to 36.73 mg/kg) and then the absorption of chromium was consistent throughout. The accumulation in stem was very less compared to leaves and roots, finally resulting in highest accumulation of chromium in leaves followed by roots and stem.

Catharanthus roseus showed a differential tendency of accumulation of different metals. The leaves have accumulated lowest quantities of lead, nickel and cadmium, while zinc accumulated in highest quantities (47.82 mg/kg) in leaves. The leaves showed a vide variation in effinity of accumulation i.e. from 0.92 mg/kg of lead to 47.82 mg/kg of zinc. The total accumulation of metals showed a moderate range, the lowest being cadmium (27.44 mg/kg) followed by nickel (47.75 mg/kg), zinc(67.61 mg/kg), chromium (69.31 mg/kg) and lead (77.05 mg/kg) in that ascending order. Among the three plant parts roots showed highest accumulation of lead and chromium, while stem accumulated highest quantities of nickel and cadmium and no other metal accumulated in highest quantity in stem compared with leaves and roots. Highest accumulation of chromium was observed in leaves followed by root and stem. The strong root system and considerable biomass of the root system are favoring the accumulation of metals.

Table 1: Accumulation of Pb, Ni, Zn, Cd and Cr in *Catharanthus roseus* during the experimental period

Metal	Leaf	Stem	Root	Total accumulation	BCF	TF
Lead	0.92	8.79	67.33	77.05	8.13	0.15
Nickel	10.49	16.63	20.63	47.75	5.66	1.31
Zinc	47.82	9.85	9.93	67.60	5.17	5.8
Cadmium	11.03	13.17	3.25	27.45	74.99	7.43
Chromium	31.72	6.7	30.89	69.31	5.1	1.24

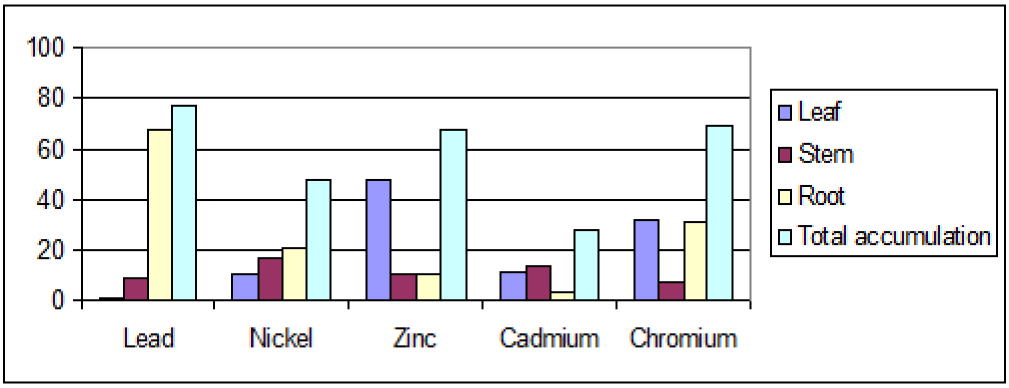

Figure 1: Accumulation of Pb, Ni, Zn, Cd and Cr in *Catharanthus roseus* during the experimental period

4. Conclusion

Phytoremediation is method which green plants for clean up contaminated hazardous waste sites. Phytoremediation is applied *ex situ* and *in situ*, continually and inducted to clean up contaminated terrains of toxic metals. In the present study, the results shows that the experimental plant species was good accumulator of lead, nickel, zinc, cadmium and chromium contaminated soils.

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