©gopalax -International Journal of Technology And Engineering System(IJTES): Jan –March 2011- Vol.2.No.3.

Ability of *Cicer arietinum* (L.) for Bioremoval of Lead and Chromium from Soil

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Abstract---**Intensive industrial activity has resulted in contamination of soils with high concentrations of heavy metals and toxic elements, potentially bioaccumulated in crop and causing serious health and socio-economic problems. Soil pollution not only leads to pollution of water resources but also restricts the use of a site or can lead to soil degeneration. The present study is considered to take the advantage of bioaccumulative nature of heavy metals for soil remediation. The experimentation involves the usage of Chickpea [Cicer arietinum (L.)] for the phytoextraction of Pb and Cr. The seeds were sown in artificially contaminated soil separately with 25, 50, 75, 100 and 150 mg/Kg Cr and 50, 100, 200, 400 and 600 mg/Kg Pb. The plants were allowed to grow for a period of 30 days and bioaccumulation was analyzed at interval of 10 days. Higher bioaccumulation was observed for higher heavy metal concentration and longer growth periods. An attempt has been made in the present paper to compare the extent of soil cleanup with time.**

Index Terms--- **soil contamination, heavy metals, phytoremediation**

I. INTRODUCTION

Soil nurtures various life forms and plays an integral part as a life sustaining medium for human beings. However, various anthropogenic activities lead to its contamination, which directly or indirectly affects all living forms. Thus, soil remediation has been attracting considerable researchers' attention over the last few decades. Among all contaminants, heavy metals have been focused because of their bioaccumulative nature and shows further harmful health effects on prolonged exposure. Unlike organic contaminants, heavy metals are non biodegradable, and therefore can remain in environmental segments and somatic cells for a longer time. Shaw et al.

(2004) outlined four general criteria explaining the groups of heavy metal: 1) Relatively abundant in the earth's crust; 2) reasonable extraction and usage; 3) having direct contact with people; and 4) toxic to humans [1]. Successful remediation of soils contaminated with heavy metals involves translocation from one matrix to another as these metals are environmentally non-biodegrable. Present physical and chemical remediation techniques are expensive, time consuming and environmentally destructive. Soil microorganisms can degrade organic contaminants, while metals need immobilization or physical removal. Phytoremediation circompasses all the flaws and proves to be an efficient technique for heavy metal removal Phytoremediation is the use of plants to remove pollutants from soil or water. This natural and environmental friendly technology is cost-effective, aesthetic, soil microorganism friendly, diversity enhancer, energy derivation from sunlight, [2], [3] and [4], and basically, it is efficient in retaining the fertility of soil even after the removal of heavy metals [5].

Among heavy metals, lead is one of the major contaminants found in soil, sediments, air and water. Total annual emission of lead by motor vehicles & industrial plants alone throughout the world amounts more than half a million ton. Lead can persist in the environment for 150-5000 years [8].

Cr and its corresponding compounds have multifarious industrial uses. They are extensively used in leather processing and finishing [8], in the production of refractory steel, drilling muds, electroplating cleaning agents, catalytic manufacture and in the production of chromic acid and specialty chemicals. Hexavalent chromium compounds are used in industry for metal plating, cooling tower water treatment, hide tanning and, until recently, wood preservation. These anthropogenic activities have led to an increase in the level of chromium contamination in the biosphere.

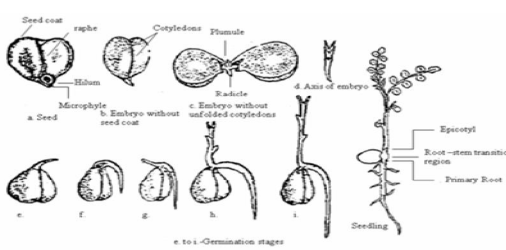

Figure 1. Chickpea seed and its germination stages [7].

Chickpea [*Cicer arietinum* (L.)] belongs to genus *Cicer*, tribe Cicereae, family Fabaceae, and subfamily Papilionaceae. It originated in southeastern Turkey. The name *Cicer* is of Latin origin, derived from the Greek word 'kikus' meaning force or strength. Chickpea is an herbaceous annual plant which branches from the base. It is almost a small bush with diffused, spreading branches. The plant is mostly covered with glandular or nonglandular hairs but some genotypes do not possess hair.

II. MATERIAL AND METHODS

A. Plant Material

Seeds of [*Cicer arietinum* (L.)] were taken from the VIT University nursery and were surface-sterilized in 70% ethanol for 30 s. The seeds were rinsed 3 times with sterile water. The seeds were pretreated with 2% sodium chloride solution and then soaked in a moist muslin cloth for 24 hours till it germinated.

B. Experimental set-up

Plastic pots of 20 cm diameter and 16 cm height were chosen for the experimentation purpose. The pots were sealed from the bottom in order to avoid leaching of heavy metal from soil. Red soil was taken for the experimental set-up from VIT University nursery and characterized for various parameters. 2 Kg of soil was filled in each pot reaching upto a height of 6.3 cm and diameter of 14 cm.

C. Metal treatments

Seeds were submitted to metal stress by adding $Pb(NO_3)_2$ in the concentration range of 50, 100, 200, 400 and 600 mg/Kg Pb ; and $K_2Cr_2O_7$ in the concentration range of 25, 50, 75, 100 and 150 mg/Kg Cr and making up to a volume of 300 mL. The pre germinated seeds were selected on the basis of size, color and shape and 10 identical seeds/pot sown into the soil at a depth of 5 cm into the soil. Control pots were prepared without the addition of metals. All the pots were set up in duplicates and plants were allowed to grow for fixed interval of time. The seeds were daily watered.

D. Metal accumulation

Plants were harvested and uprooted slowly form pot after 10, 20 and 30 days, causing minimum damage to the roots. Roots, stems and leaves were washed thoroughly with running deionized water (the roots were rinsed three times in 500 ml of deionized water), and dried. Different plant parts were separated in Stems and Leaves (S+L); and roots (R). They were, manually cut in small pieces, dried in filter papers and the fresh weight (FW) of different these organ were measured. The various organs were then heated at 80 ◦C for three days to determine dry weight (DW) of each organ, before crushing and storage in small flasks for the extraction of lead and chromium.

The metal content was determined using Atomic Absorption Spectrometer (Varian Spectra 240; Acetylene). To this effect, 1 g of dried plant material was digested by a mixture of HNO_3, HCl and H_2O_2 (EPA 3050b method). The results were expressed in mg Kg^{-1} DW.

III. RESULTS AND DISCUSSIONS

A. Soil characterization

Soil was characterized for various parameters such as pH (1:10 soil/water), total organic carbon (Walkley Black Titration method) and moisture content.

TABLE I. CHARACTERIZATION OF SOIL

S.NO.	Regular	Result
1	pH	8.78
2	Moisture Content	4.5%
3	Total Organic Content	1.5%

B. Seed Germination

Lead and chromium considerably affected germination of Chickpea (*C. arietinum L.*) seeds. The number of germinated seedlings decreased with increase in concentration of heavy metal in soil. This characteristic of effect of Ni and Co stress on chickpea seeds was shown by Khan et al (2010) [9]. The germination rate was highly affected under chromium stress. Chromium stress inhibited formation of plantlets for two highest concentrations of chromium in soil. Lead toxicity also affected seed germination adversely.

C. Biomass Production

Visible decrease in plant biomass with increase in the concentration of heavy metals in the soil was observed [10]. There was a visible decrease in the biomass production of the plant with respect to time due to metal stress. . There was a notable decrease in the dry weight of the plants with increase in time interval due to following two reasons:

a. Longer period of exposure to contamination.
b. Restriction of external addition of nutrients.

D. Bioaccumulation analysis

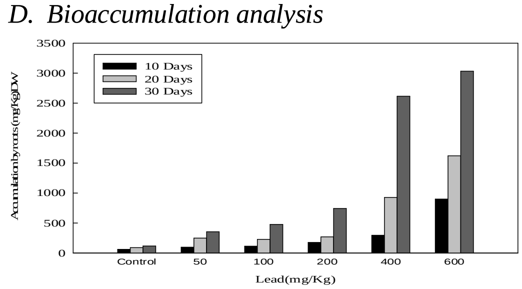

Figure 2. Variation in bioaccumulative property of lead by roots of *C. arietinum L.* with different concentration of lead and time of exposure.

Figure 2 explains bioaccumulation characteristics of lead by roots of chickpea. Roots are the most vital part of a plant and are exposed to the highest concentration of any form of contamination in the soil. So, root-soil interaction is an important parameter affecting the bioaccumulative property of a plant species.

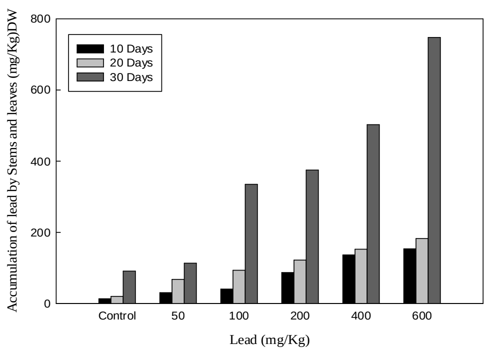

Figure 3. Effect of time and varying level of lead concentration in soil on its bioaccumulation by stems and leaves of *C. arietinum L.*

Figure 3 explains the bioaccumulation of lead by stems and leaves. Translocation of heavy metal to stems and leaves depends upon various environmental and biological factors. Concentration of contaminant in stems and leaves is lesser as compared to roots.

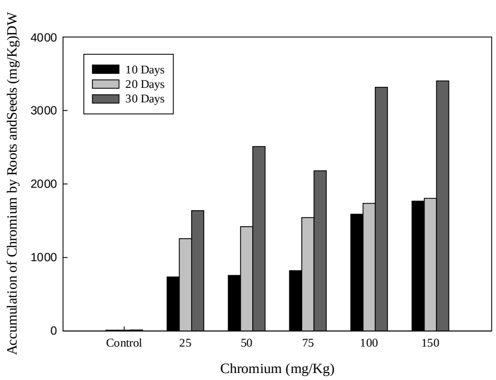

Figure 4. Ability of roots and seeds of *C. arietinum L.* for bioaccumulation of chromium with varying chromium concentration and duration of exposure.

Figure 4 clearly depicts the uptake of chromium by the roots and seeds (for two highest concentrations). Chromium toxicity in plants resisted not only root formation for all concentrations but also shoot formation for two highest concentrations.

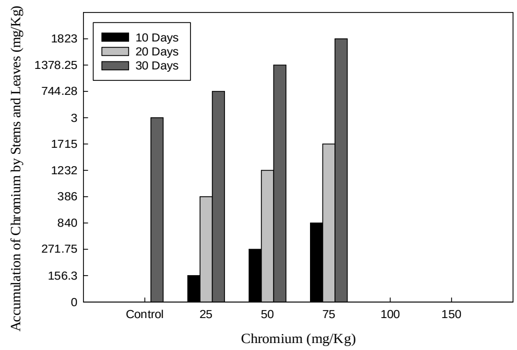

Figure 5. Bioaccumulative property of stems and leaves of C. *arietinum L.* for varying concentration of chromium in soil and different exposure time.

With the increase in concentration of the heavy metal exposure to the plant, bioaccumulation by the plants also increases

Lead accumulation by the plants increased with increase in the concentration of lead in soil.

CONCLUSIONS

This study was conducted to determine Chickpea's potential for metal accumulation. The results obtained in this study brought out the variable behavior of Chickpea seeds in reaction to metallic stress. The nature of the response to stress of each cultivar depended on the metal. $Pb(NO_3)_2$ and $K_2Cr_2O_7$ led to a variation of the biomass and growth. When compared to control, there was a greater accumulation of lead and chromium in the roots as compared to the aerial parts of the plant. Moreover, to better understand the mechanisms that Chickpea seed may develop in response to metallic stress of Pb and Cr more research is needed on the behavior of the same cultivars *in vitro* and their ability to accumulate heavy metals under sterile and controlled conditions. The study also pointed towards the use of external nutrient additives for better growth and sustainability of the plants.

ACKNOWLEDGMENT

The authors would like to thank Environmental Engineering Laboratory of VIT University for providing facilities and extending all possible supports.

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