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Phytoremediation–A Greener and Sustainable Technology for Controlling Toxicity of Copper in Soil

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Abstract—*The amount of heavy metals released to the environment has been increasing significantly as a result of technology development, anthropogenic and industrial activities. It poses environmental disposal problems due to their non degradable and persistence nature. These metals are toxic to organisms and have tendency to bioaccumulate in living tissues and cause disruptive integration of biochemical processes. Therefore, there is an urgent need to remediate the heavy metals from the environment. On the contrary, Phytoremediation is considered to be a "green revolution" in the field of innovative clean up technologies. It describes the treatment of environmental problems through the use of plants that mitigate the same without the need to excavate the contaminated material and dispose it elsewhere. In this technique, some plants proved to act as hyperaccumulators of heavy metals. These plants accumulate toxic metals in different parts of the plant at varied rate. Therefore, an attempt has been made to control Copper content in the polluted soil. Although Copper (Cu) is an essential element required in a small amount for proper growth but at elevated concentration, it could cause liver, kidney damage and neurological disorders. In the present study, soil and plant samples were collected from the different locations containing industrial wastes. Samples were digested and analyzed for the Cu content using Atomic Absorption Spectrophotometry (AAS). We found Saccharum sp., Solanum sp., Brassica juncea and Lycopersicon species as efficient accumulators of Cu from the soil. For greenhouse experiment, Brassica juncea was selected as accumulator plant. Seeds were grown in the pots containing polluted soil of all sites. Prior to sowing, they were analyzed for AAS study. AAS Results of greenhouse experiments showed the decline in Cu content in pot soil after treatment. Further, higher concentration of Cu content in the harvested plant as compared to the seeds, confirms the Cu uptake and phytoextraction. Therefore, it was concluded that Brassica juncea acted as good accumulator and proved to be a remedy for controlling Cu pollution. The present investigation can be helpful in controlling the biomagnification of heavy metals in the food chain and reduces the risk of heavy metal soil pollution.*

Keywords*: Heavy Metals, Phytoremediation, Hyperaccumulators, Brassica juncea, Biomagnification*

1. INTRODUCTION

Heavy metal toxicity and the danger of their bioaccumulation in the food chain represent one of the major environmental and health problems of our modern society. The primary sources of heavy metal pollution are mining, energy production and agricultural activities including pesticides [1]. This can lead to accumulation by living organisms [2]. Each source of contamination has its own damaging effects to plants, animals and ultimately to human health, but those that add heavy metals to soils and waters are of serious concern due to their persistence in the environment and carcinogenicity to human beings. Therefore, heavy metal pollution poses a great potential threat to the environment and human health.

Although some of the heavy metals at low concentrations are essential for plants, but at higher concentrations, may cause metabolic disorder and growth inhabitation for most of the plant species [3]. The most common heavy metal contaminants are Cadmium (Cd), Chromium (Cr), Copper (Cu), Mercury (Hg), Lead (Pb), Nickel (Ni) and Zinc (Zn) [4]. Heavy metal toxicity causes inhibition of photosynthetic carbon reduction cycle enzymes, nitrate reductase enzymes and spore germination. These metals can cause DNA damage and their carcinogenic effects in animals and humans are probably caused by their mutagenic ability. Excess of Cu can cause liver, kidney damage and many neurological disorders such as Alzheimer disease, Huntington disease, Wilson disease.

Newer technologies were developed time to time in order to control the toxicity level in soil and water. Currently several processes used to remediate metal contamination from soil are engineering-based such as soil excavation and soil treatment systems. They are not fully acceptable as they not only destroy the biotic components, but are technically difficult and expensive to implement. Therefore, scientists and engineers have started to generate cost effective technologies which includes use of microorganisms/ biomass/ live plants for cleaning of polluted areas [5]. Phytoremediation is considered to be a "green revolution" in the field of innovative clean up technologies. It describes the treatment of environmental problems through the use of plants that mitigate the same without the need to excavate the contaminated material and dispose it elsewhere. In this technique, some plants proved to act as hyperaccumulators of heavy metals. These plants accumulate toxic metals in different parts of the plant at varied rate. Therefore, an attempt has been made to control Cu content in the polluted soil by the use of this eco friendly cost effective technology.

2. MATERIAL AND METHODS

2.1. Site characterization and sample collection

The soil and plant samples were collected from three most polluted sites of Delhi. Sampling was done at Wazirabad Industrial Area (WB), Ashok Vihar Industrial Area (AV) and Indraprastha Power Station (IP). The plants selected for experimental study from these sites were *Brassica juncea, Tamarix, Saccharum, Brassica campestris* (from WB), *Tamarix*, *Amaranthus, Lycopersicon, Ricinus, Solanum* (from AV), *Saccharum* and *Ricinus* (from IP). Soil samples from Daulat Ram College Botanical Garden (DRC) and Delhi University (DU) were also collected for comparative study. Soil and plants efficiently growing in contaminated sites (WB, AV, IP, DU and DRC) were collected.

2.2. Preliminary sample treatment

Collected plants were rinsed thoroughly in water before kept for drying in blotting sheets. Both plant and soil samples were dried in the oven at 60^0C for three days. Dried soil was sieved through 0.2 mm size sieves prior to processing for digestion.

2.3. Plant and soil digestion

The process of digestion was carried out in closed system. 2g of plant and 0.5g of soil was weighed for digestion. The samples were treated with concentrated HNO_3 and HCl (6:1, v/v) [6], heated up at 300^0C for 45 min by microwave to digest samples and evaporate solvent followed by cooling at room temperature (24 ± 2^0C). The final volume was made up to 25ml by diluting the digested samples with Milli-Q water.

2.4. Plant and soil analysis

The digested soil and plant samples were then analyzed to find Cu content using Atomic Absorption Spectrophotometer (AAS) [7].

2.5. Greenhouse experiment

Seeds of *B. juncea* were sown in labelled pots of soil samples in triplicates. The pots were kept in greenhouse and their growth was monitored regularly (Fig. 1). After about 8 weeks, when the plants reached a height of approximately 12-15 cm, they were uprooted intact. Small amount of pot soil was also taken to analyze the amount of Cu concentration. Atomic absorption spectrophotometric analysis was done in seeds, harvested plants and the pot soil to know the level of phytoextraction.

Fig. 1: ***Brassica juncea*** **in pots under green house conditions.**

3. RESULTS AND DISCUSSION

The Cu content was found to be maximum in A.V site, followed by I. P. site (Table 1; Fig. 2). Among different plant species, *Saccharum*, *B. juncea*, *Lycopersicon*, *Tamarix* and *Ricinus* were found to be efficient accumulators of Cu from the soil (Table 2; Fig. 3). *B. juncea* was found to be good accumulator of Cu. In greenhouse experiment on DU nursery soil, a significant reduction was observed in the Cu content (when compared to initial concentration) after phytoremediation treatment by *B. juncea* in pots (Table 3; Fig. 4). More than threefold increase in Cu uptake was found in harvested plants of *B. juncea,* in comparison to seeds (Table 4; Fig. 5).

Table 1: Analysis of Cu content in the soil samples collected from the polluted sites.

Cu Concentration (mg/kg)				
Metal	**Sites**			
	Wazirabad	**I.P**	**A.V**	**DRC Garden**
Cu	5.545±0.1	8.805±0.12	10.96±0.14	0.44±0.01

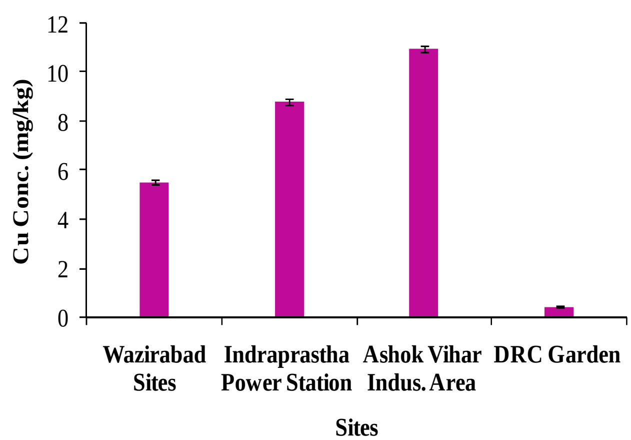

Fig. 2: Copper accumulation in soil samples collected from the different polluted sites.

Table 2: Concentration of Cu in plant samples collected from polluted sites.

Plants collected	Cu Concentration (mg/kg)	Site
B. juncea	2.493±0.11	Wazirabad
Tamarix	1.598±0.018	
Saccharum	1.305±0.011	
B. campestris	0.103±0.001	
Tamarix	1.61±0.03	I.P
Amaranthus	0.925±0.002	
Lycopersicon	2.42±0.011	
Ricinus	1.64±0.01	
Solanum	2.73±0.011	
Saccharum	3.45±0.015	A.V
Ricinus	1.86±0.002	

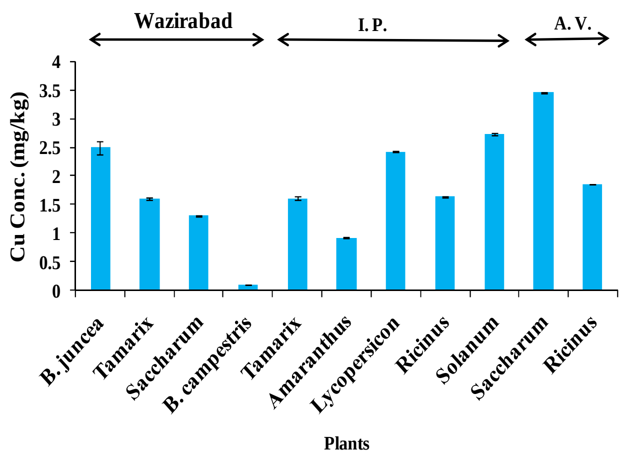

Fig. 3: Copper content in different plant samples collected from different sites.

Table 3: Copper content of DU nursery soil before and after treatment (phytoremediation by *B. juncea*) in pots.

Metal	Before Treatment	After Treatment
	Initial conc. of Cu in soil (mg/kg)	Final conc. of Cu in soil (mg/kg)
Cu	542.73±7.22	516.58±5.82

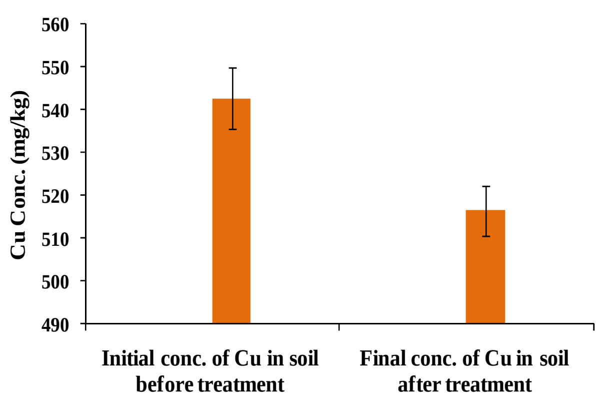

Fig. 4: Comparison of Copper concentration in DU nursery soil (Before and after treatment).

Table 4: Copper content in seeds and the harvested plants of the seed growing in the pot having polluted soil (DU).

Metal	Cu conc. (mg/kg) in B. juncea seeds	Cu conc. (mg/kg) in harvested plants of pot soil after phytoremediation
Cu	11.12±0.022	38.11±1.8

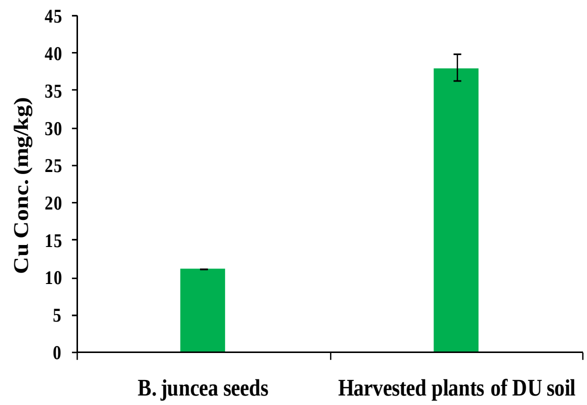

Fig. 5: Copper concentration in seeds and harvested plants of *B. juncea* grown in DU nursery soil.

Plants studied for Phytoextraction of various metals, metalloids, non-metals, inorganic and organic contaminants reviewed earlier [8-9]. Use of plants of economic value such as biofuel crops have been suggested for utilization and remediation of the contaminated sites [8]. As they can both remediate contaminated soils and produce valuable biomass, which could bring income for the owner of the contaminated site. In the present study, the variable accumulation of Cu in soil collected from the different sites were similar to the results of [9], according to which, the accumulation of different metals in plant depends on the type of waste deposited on the polluted sites. According to [10], the accumulation and translocation of metals differ with the species of plant, categories of heavy metals, and some environmental conditions. In the present study, plant species analyzed for Cu accumulation showed variation in the level of metal uptake. For greenhouse experiment, *Brassica juncea* was selected as accumulator plant. It showed higher accumulation of Cu in comparison to other plants. *B. juncea* was found better suited for this purpose as it can tolerate and accumulate the metals intended to be extracted preferable in the above ground parts. It showed high tolerance to metal concentrate in soils, fast growth, high accumulating biomass, easily grown and fully harvestable. Similar results were earlier reported for phytoextraction of heavy metals [11].

In the present study, the available heavy metal Cu was absorbed by roots from the polluted soil, resulting decline in the toxic level of Cu in the pot soil to show phytoextraction. The decline in the Cu concentration in pot soil after phytoremediation by *B. juncea* could be due to the fact that uptake is not only affected by type of heavy metal but also by the soil type, texture, plant species, exposure duration, temperature and pH [12]. An increase in the Cu uptake in harvested *B. juncea* plants of DU nursery soil, in comparison to seeds confirms the phytoextraction process. Recently, [13] reported high potential of *Brachiaria decumbens* in phytoextraction and phytostabilization of Cu in a vineyard soils and Cu mining waste by entire plant.

4. CONCLUSION

From the present study, it was concluded that *Brassica juncea* showed efficient uptake of Cu from polluted soil. Therefore, it can act as a hyperaccumulator. Decline in the Cu content in the pot soil clearly suggest the phytoextraction of toxic metal by *B. juncea*. From the present study, it is also suggested that phytoremediation can minimize the chances of biomagnification of heavy metal in food chain. Its use in mixed cropping in the field of food crops can reduce the risk of health hazards due to heavy metal toxicity.

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