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Phytoextraction of Pb and Ni from the Polluted Soil by *Brassica juncea* L.

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Abstract

Phytoremediation is described as 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. Some plants proved to be popular organism for bio-monitoring to determine and identify the sources of heavy metal soil pollution and their detoxification by phytoextraction techniques. In the present work an attempt has been made to remediate Lead (Pb) and Nickel (Ni) from the polluted soil. Soil and plant (luxuriously growing as hyperaccumulator) samples were collected from the polluted sites to find out the extent of Pb and Ni accumulation in them. We found *Saccharum*, *Brassica juncea*, *Tamarix* and *Ricinus* as efficient accumulators of heavy metal from the soil. Accumulation of Pd was higher than Ni in soil samples from all the sites. For greenhouse experiment *B. juncea* was selected for Phytoremediation study. Results of AAS of digested samples of both plants and soils of greenhouse experiments showed that heavy metal content declined in pot soil after plants have been grown and harvested. *B. juncea* reduced 73.15% Pb and 60.13% Ni from their initial concentration in soil thereby proving itself to be a good accumulator of heavy metals and a remedy for controlling heavy metal soil pollution. Most important in phytoremediation is to use wild plants as accumulators in the greenhouse experiment as it minimizes the chances of biomagnification of heavy metals in food chain.

Keywords: Phytoextraction; Heavy metals; AAS; *B. juncea*; Phytoremediation

Introduction

Heavy metals cause a global threat to the environment by creating a serious environmental pollution and are found to be associated with the several health effects. The occurrence of toxic heavy metals in the ecosystem is the result of untreated metal containing agricultural and industrial effluents into water bodies [1-4]. Metal ions interact with cell components such as DNA and nuclear proteins, causing DNA damage and conformational changes that may lead to cell cycle modulation, carcinogenesis or apoptosis [5-7]. Studies revealed that reactive oxygen species (ROS) production and oxidative stress play a significant role in the toxicity and carcinogenicity of metals such as arsenic [8-10], cadmium [11], chromium [12,13], lead [14,15] and mercury [16]. Because of their high degree of toxicity, these five elements rank among the priority metals that are of great public health significance. They are all systemic toxicants that are known to induce multiple organ damage, even at lower levels of exposure.

Lead accumulation in plant cell initiates various morphological, physiological and biochemical changes and induces a range of harmful effects. Lead toxicity causes inhibition of ATP production, lipid peroxidation and DNA damage by over production of reactive oxygen species. In addition, lead strongly inhibits seed germination, root elongation, plant growth, chlorophyll production and negative effects on plants such as hampered electron transport, inhibition of Calvin cycle enzymes, impaired uptake of essential elements, such as Mg and Fe. In human, lead interferes with a variety of metabolic processes and is toxic to many organs and tissues including the heart, bones, intestines, kidney and reproductive systems. It interferes with the development of the nervous system and is therefore particularly toxic to children, causing potentially permanent learning and behavior disorders. On the other hand, Nickel in low concentrations, plays a very crucial role in metabolism for certain enzyme activities, sustain proper cellular redox state and a range of other biochemical and physiological pathways. Therefore, Ni deficiency produces an array of effects on growth and metabolism of plants. However, higher concentration of Ni showed toxic effects at different levels, such as inhibition of mitotic activities, decrease in plant growth and photosynthesis [17], inhibition of enzymatic activities and nitrogen metabolism, initiation of oxidative stress [17]. All of these altered physiological processes ultimately reduce fruit yield and quality. Nickel is a also known as haematotoxic, immunotoxic, neurotoxic, genotoxic, reproductive toxic, pulmonary toxic, nephrotoxic, hepatotoxic and carcinogenic agent for human as well as animals.

Different technologies are used to eliminate these toxic heavy metals from the environment, such as ion exchange [18], membrane technologies [19], reverse osmosis [20], electrochemical treatment [21] and biosorption [22]. These technologies are costly and require high amount of energy [23]. On the contrary Phytoremediation is considered to be sustainable and economically acceptable technology for metal removal from the environment [24-26]. Phytoremediation can be defined as the efficient use of plants to remove, detoxify or immobilize environmental contaminants in a growth matrix, through the natural, biological, chemical or physical activities and processes of the plants.

The objectives of this work were screening of plant that can prove efficient in phytoremediation and beneficial in detoxifying Ni and Pb to control heavy metals soil pollution.

Materials and Methods

Site characterization and sample collection

The soil and plant samples were collected from three of the most polluted sites of Delhi. The sites were chosen for collection and

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sampling was Wazirabad Industrial Area (WB), Ashok Vihar Industrial Area (AV) and Indraprastha Power Station (IP). The plants selected for experimental study from these sites were *B. 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.

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°C for three days. Dried soil was sieved through 0.2 mm size sieves prior to processing for digestion.

Plant and soil digestion

Before digestion to analyze heavy metals, each sample was dried at 60°C for 48 h. The process of digestion was carried out in closed system. 2 g of plant and 0.5 g of soil was weighed for digestion. The samples were treated with concentrated HNO_3 and HCl (6:1, v/v) [27]. Samples were heated up at 300°C for 45 min by microwave to digest samples and evaporate solvent followed by cooling at room temperature (24 ± 2°C). The final volume was made up to 25 ml by diluting the digested samples with Milli-Q water. Samples were filtered through Whatman No. 42 filter paper (GE Healthcare Life Science). These solutions were then used for metal analysis.

Plant and soil analysis

The digested soil and plant samples were then analyzed for Lead (Pb) and Nickel (Ni) content using Atomic Absorption Spectrophotometer (AAS) (Shimadzu AA 7000) [28].

Greenhouse experiment

Seeds of *B. juncea* were sown in labeled pots of all four soil samples in triplicates. The pots were kept in greenhouse and their growth was monitored regularly. 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 heavy metal concentration. To know the level of phytoextraction of heavy metals processing i.e., digestion followed by AAS of seeds, harvested plants and the pot soil was done.

Results and Discussion

Maximum amount of heavy metal, Pb was found in Ashok Vihar Industrial Area site and Ni in Indraprastha Power Station site as analyzed by AAS (Table 1). Different plants have been studied for their phytoextraction capability. Eleven plant species analyzed for metal accumulation by the uptake of Pb and Ni from the soil. We found *Saccharum*, *B. juncea*, *Tamarix* and *Ricinus* as efficient accumulators of heavy metal from the soil (Figure 1). *Saccharum spp*. and *B. juncea* was found to be good accumulator of heavy metal *viz.* Pb and Ni (Table 2). But *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. Greenhouse experiment on DU nursery soil showed 73.15% reduction in Pb and 60.13% reduction in Ni from their initial concentration (Tables 3 and 4) in the polluted soil.

Plants studied for Phytoextraction for various metals, metalloids, non-metals, inorganic and organic contaminants reviewed earlier clearly suggest that remediation of contaminated sites supports the goal of sustainable developments by helping to maintaining the soil as resource and bring back into the beneficial use. Work on Phytoextraction stated that variable distribution of pollutants (Pb, Cu, Cd, and Zn) in the plants used as accumulator was according to their species and plant parts [29].

Pb and Ni accumulation in the plant sample

In the present study, plant species analyzed for metal accumulation showed varied level of heavy metal uptake. Uptake of Pb and Ni by *B. juncea* from the soil of all contaminated sites and greenhouse experiments proved it to be a good hyper accumulator for phytoremediation. *B. juncea* earlier also reported to be the ideal plant and it has all the traits required for phytoremediation [30-32]. In the present study phytoremediation of Pb and Ni metals was observed in

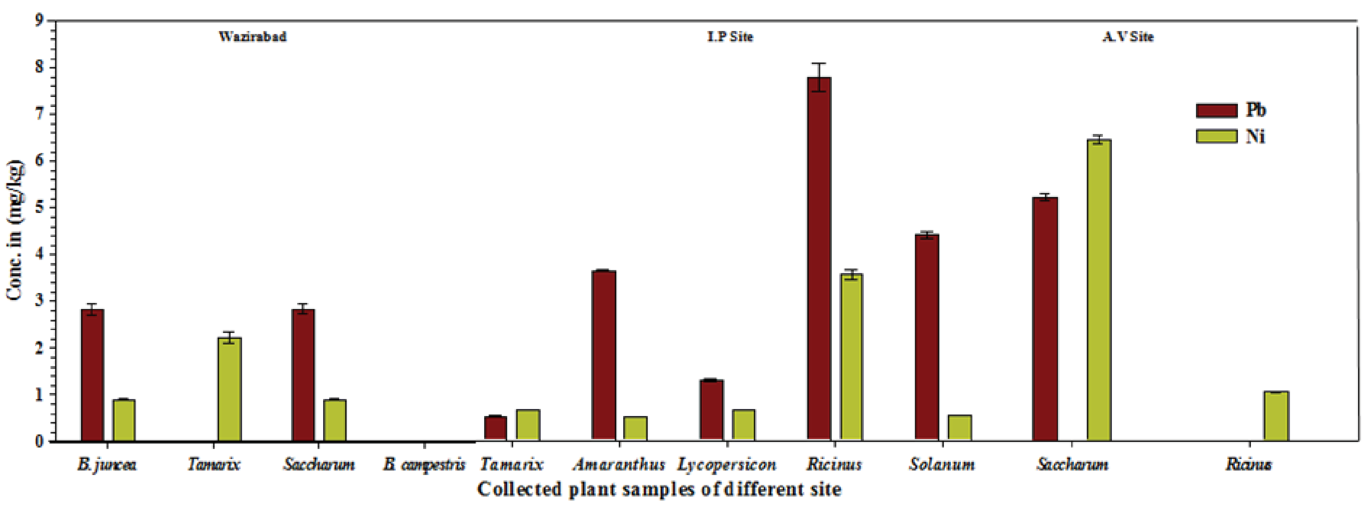

Figure 1: Heavy metal content of different plant samples analyzed by AAS study.

the Delhi University nursery soil (Figure 2). Heavy metals movement was affected by their chemical extraction forms and their combining capacity with inorganic and organic substance. The accumulation and translocation of metals differed with the species of plant, categories of heavy metals, and some environmental conditions [33]. Further the exchangeable fraction of heavy metals is variable in the plants pattern of root development and meteorological conditions.

Phytoextraction of Pb and Ni by *B. juncea*

In the present work also the soluble or available heavy metals were absorbed by roots from the polluted soil and decreased the toxic metal content in the soil to show phytoextraction. The decline in the metal concentration after phytoremediation by *B. juncea* showed various levels of phytoextraction (Figure 3). It could be due to the fact that uptake of heavy metals is not only affected by type of heavy metal but also by the soil type, texture, plant species, exposure duration, temperature and pH [34]. Harvested metal-enriched biomass and seeds are still in our captivity. The possibility would be to reduce the mass by means of a controlled, low-temperature ashing procedure whereby metals would be further concentrated into the ash. Concentrated metals could be used for recovery and recycling [35,36].

Metals	Conc. of heavy metals (mg/kg)			
	Sites			
	Wazirabad	Indraprastha Power Station	Ashok Vihar Industrial Area	DRC Garden
Pb	20.46 ± 0.48	9.375 ± 0.20	20.48 ± 0.51	3.41 ± 0.2
Ni	5.3 ± 0.11	9.645 ± 0.32	7.745 ± 0.18	Nil

Table 1: Heavy metal content analyzed by AAS study in the soil samples collected from the polluted sites.

Plants collected	Conc. of metals (mg/kg)		Site
	Ni	Pb	
B. juncea	0.905 ± 0.04	2.841 ± 0.12	Wazirabad
Tamarix	2.21 ± 0.12	Nil	
Saccharum	0.905 ± 0.038	2.841 ± 0.11	
B. campestris	Nil	Nil	
Tamarix	0.725 ± 0.036	0.568 ± 0.03	Indraprastha Power Station
Amaranthus	0.543 ± 0.04	3.978 ± 0.05	
Lycopersicon	0.725 ± 0.04	1.42 ± 0.05	
Ricinus	3.895 ± 0.11	8.525 ± 0.34	
Solanum	0.588 ± 0.04	4.83 ± 0.21	
Saccharum	1.403 ± 0.04	1.136 ± 0.05	Ashok Vihar Industrial Area
Ricinus	0.227 ± 0.03	Nil	

Table 2: Heavy metal content of collected plant samples from polluted sites analysed by AAS.

Metals	Initial conc. of metals in soil before treatment (mg/kg)	Final conc. of metals in soil after treatment (mg/kg)	Decline in metal content (%)
Pb	179.22 ± 6.11	48.12 ± 2.8	73.15%
Ni	88.01 ± 4.8	35.09 ± 2.4	60.13%

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

Metals	Metal conc. in (mg/kg) in *B. juncea* seeds	Metal conc. in (mg/kg) in harvested plants of pot soil after phytoremediation
Pb	Nil	19.04 ± 1.2
Ni	Nil	Nil

Table 4: Heavy metal content in the seeds and the harvested plants of the seed growing in the pot having polluted soil (DU) (Analysed by AAS).

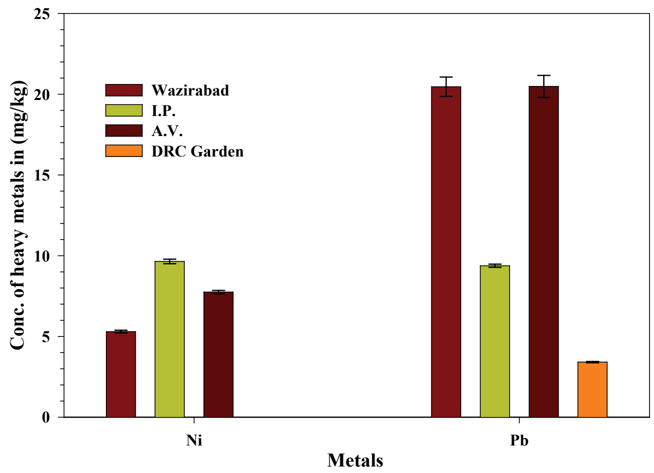

Figure 2: Heavy metals (Pb and Ni) accumulated in soil samples collected from the polluted sites analyzed by AAS.

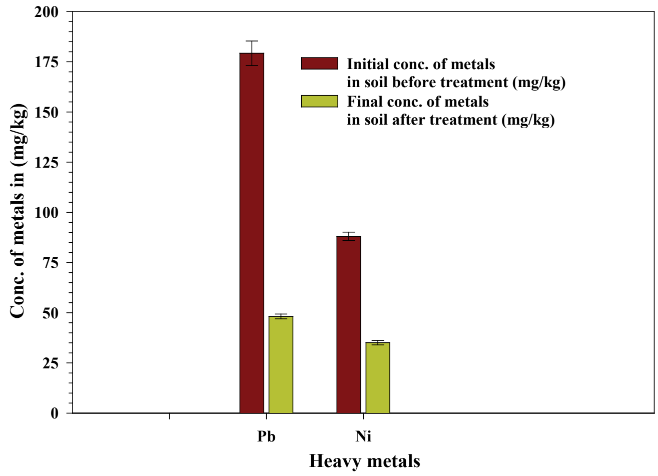

Figure 3: Heavy metal content of DU nursery soil analyzed by AAS study.

Conclusion

From the present study it is concluded that *B. juncea* showed efficient uptake of Pb and Ni from polluted soil and so it act as good hyperaccumulator. Decline in the heavy metal content in the pot soil clearly suggest phytoextraction of toxic metals by *B. juncea* and hence it can minimize the risk of heavy metal soil pollution. The utility of *B. juncea* can also be explored in crop rotation with the food crops to control biomagnification of toxic metals in the food chain.

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