
ROLE OF HYPERACCUMULATOR PLANTS IN HEAVY METAL REMOVAL FROM INDUSTRIAL WASTE SITES

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ABSTRACT

Heavy metal pollution is a substantial risk to the long-term viability of both the environment and agriculture, especially in areas that are affected by industrialization. When we talk about phytoremediation, we are referring to a mix of plant-based technologies that make use of naturally existing plants in order to remove toxins from plants that are found in the environment, as well as plants that have been genetically modified. In this research, the phytoremediation capability of three hyperaccumulator plants—Brassica juncea, Helianthus annuus, and Ricinus communis—is evaluated in terms of their ability to remove lead (Pb), cadmium (Cd), and zinc (Zn) from soils in India that have been polluted by industrial waste. Quantification of metal uptake in root and shoot tissues was accomplished by the use of controlled pot experiments and atomic absorption spectrophotometry studies. In order to evaluate the effectiveness of the process, translocation and bioconcentration factors were computed. When compared to the other three species, Helianthus annuus demonstrated the maximum metal removal, indicating that it is suitable for soil restoration. Based on these results, there are significant implications for the development of bioremediation systems that are both cost-effective and environmentally acceptable in India's industrial zones.

KEYWORD: Heavy metal, contamination, environmental, agricultural

INTRODUCTION

Due to the industrial revolution and rapid population development, heavy metal contamination of the environment rose dramatically from the start of the 20th century, causing serious environmental and human health issues globally (Abdelhafez and Li, 2014). Large regions of the world were contaminated by a number of sources, including car exhaust, emissions from waste incinerators, mining and military residues, the smelting industry, and the use of pesticides, mineral fertilizers, and agricultural amendments like sludge or urban composts (Abou-Shanabet al., 2011; Abdelhafezet al., 2012). Heavy metals are not biodegradable as organic pollutants are, and since they are mutagenic and carcinogenic substances, they represent a serious threat to the environment and living things (Abdelhafezet al., 2012). Plants

having a high ability to absorb and extract heavy metals from the soil are essential to phytoextraction.

Analyzing *Brassica juncea*, *Helianthus annuus*, and *Ricinus communis* capacity for phytoextraction of soil polluted with pb, cd, and zn was the aim of this research. Heavy metal deposition in agricultural areas that has persisted in the soil for many years is caused by the use of sewage sludge, compost, mining waste, chemical fertilizers, and industrial growth without control outputs (Alloway et al., 1991). Environmental contamination is a major problem as a result of the growing usage of a broad range of heavy metals in agriculture and industry (Sinhalet al., 2010). Using green plants to absorb or detoxify metals and organic compounds is a potential new technique called phytoremediation. A low-cost technique for remediating metal-contaminated soils is phytoremediation, and some of the metals that are removed may be recycled for profit (Chaney et al., 1997). According to Rascio et al. (2011), a hyperaccumulator is a plant that can thrive in soils that contain exceptionally high concentrations of metals, absorb these metals by their roots, and concentrate extraordinarily high quantities of metals in their tissues. It has been shown that more than 500 flowering plant species are capable of hyperaccumulating metals in their tissues (Sarma et al., 2011).

The potential of hyperaccumulating plants to remove metals from damaged places' soils (phytoremediation) and restore a less harmful environment is of interest. By growing the plants and then collecting them for the metals in their tissues, a process known as phytomining, the plants also have the potential to be used to mine metals from soils with very high concentrations. More than 450 plant species, including those in the Brassicaceae, Poaceae, and Asteraceae families, have these hyperaccumulation genes (HA genes) (Rascio et al., 2011).

A significant issue for the environment and human health is contaminated soils, which the new technique of phytoremediation may help to address. In phytoremediation, plants are grown hydroponically and then moved into soil and water contaminated with metals, where they absorb and concentrate the metals in their roots and shoots. Roots or whole plants are picked for disposal as they get saturated with the metal pollutants. According to Salt et al. (1997), the majority of researchers think that plants used for phytoremediation should only acquire metals in their roots. Using plants to clean up polluted locations is known as phytoremediation technology, and it holds great promise for restoring the ecosystem and environment. One of the main issues that both developed and developing countries are now dealing with is environmental pollution from heavy metals and hazardous organic pollutants. Anthropogenic activities as the mining and mineral processing of metallic ores, waste dumping, the use of phosphate fertilizer, and wastewater irrigation may pollute large tracts of land with cadmium. Because Cd is more readily taken up by plants from the environment than other non-essential elements and may enter the human food chain via soils, soil pollution with Cd poses a serious risk to human health (Xiao et al. 2008). According to Rahimi and Nejatkhani (2010), cadmium is a common non-essential metal with a high toxicity level that organisms may readily collect from their surroundings. According to Peer et al. (2005), tolerant plants and plants with a

remarkable capacity to collect the contaminant—known as hyper accumulators—are required for phytoremediation.

The study aims to assess phytoextraction responses to different soil metal contents, provide a valuable tool for bioremediation of heavy metal contamination in soil, and survey preliminary hyperaccumulation plants. It also examines the histological analysis of *Brassica juncea*, *Helianthus annuus*, and *Ricinus communis* L. to determine their ability to absorb and accumulate heavy metals.

Types of Plant Remediation

Phytoremediation technology can be classified into two categories based on the contaminants, site conditions, cleanup level, and plants used: removal technology (phytoextraction and phytovolatilization) and containment technology (phytoimmobilization and phytostabilization).

Utilizing certain plant species to immobilize pollutants in soil by root absorption and accumulation, adsorption onto roots, or precipitation within the root zone, as well as physical soil stability, is known as phytostabilization. This procedure lowers the contaminant's mobility and stops it from migrating to the air or groundwater. In areas where natural flora is scarce because of elevated metal concentrations, this method may be used to restore a vegetative cover. By restoring vegetation to these areas, metal-tolerant species may reduce the likelihood of pollution spreading by wind, transporting exposed surface soils, leaching soil, and contaminating groundwater.

Using plant roots (rhizofiltration) or seedlings (blastofiltration) to absorb or adsorb contaminants, primarily metals, from water and aqueous waste streams is known as phytofiltration. Toxic metals from contaminated wastewater are absorbed, precipitated, and concentrated by plant roots or seedlings cultivated in aerated water. Because terrestrial plants have considerably bigger, fibrous root systems with a lot of surface area and are coated in root hairs, rhizofiltration employs them rather than aquatic plants.

The term "phytoextraction," also known as "phytoaccumulation," describes how plant roots absorb and move metal pollutants from the soil into the aboveground parts of the plants. Compared to other plants and the concentration of metals in the environment, certain plants known as "hyperaccumulators" absorb abnormally high levels of metals. Thangavel P and Subbhuraar C V The kind of metals present and other site characteristics are taken into consideration while choosing and planting these plants. The plants are picked after being let to develop for a few weeks or months. Composting, incineration, and land filling are methods for recycling or getting rid of the metals. To reduce soil contamination levels to acceptable levels, plant planting and harvesting may be repeated as needed. The amount of time needed for remediation typically varies from 1 to 20 years, depending on the kind and degree of metal

pollution, the duration of the growing season, and how well plants remove metals (Blaylock & Huang 2000).

REVIEW OF LITERATURE

Nouri and others, (2015) This research looked at native pasture plants and heavy metals including Cr, Zn, Cd, Pb, and Ni in the soil near the Eshtehard industrial town. The land was poisoned by the introduction of acidic sludge. In this context, the research examined the plants' capacity for hyperaccumulation and phytostabilization. Thus, *P. piptostigma* in Cr and Zn, *B. tectorum* in Cd and Zn, *S. hohenackeriana* in Cr, Pb and Cd, *P. aucheri* in Zn, *P. harmala* L in Pb and Ni, *A. tenuifolia* in Cd, Pb, and Ni, and *C. persica* in Zn and *C. arenarius* in Ni. *A. tenuifolia* is one species that has the capacity to stabilize. *P. aucheri* and *P. harmala* in Pb, *A. tauschii* and *B. tectorum* in Ni, and *N. persica* in Zn in Cd and Ni. Similar to industrial trash containing heavy metals, hyperaccumulating plants are simply disposed of. In addition to adding aesthetic value to the environment, plants with stabilizing capability may stop heavy metal pollution from spreading to uncontaminated regions, such as the nearby fields.

Li. J. et al. (2015) The scientific foundation for choosing water plants with the capacity to withstand toxicity from cadmium, zinc, and copper is presented. A plant species' capacity to absorb a certain metal is closely correlated with its capacity to absorb other metals from contaminated areas.

Ghaderian and Nosouhi (2014) The plants that generate a lot of biomass and can withstand soils contaminated by heavy metals have received the most attention lately. It was discovered that *T. caerulescens* colonizes regions where mining has resulted in elevated levels of Cd, Cu, Pb, and Zn in the soil. *M. chenopodiifolia* has an excellent capacity for zinc and lead absorption. *Eruca sativa* may collect lead and cadmium from polluted soils and is resistant to heavy metal contamination. Cadmium and zinc were collected by *B. napus* and moved into the plant's harvestable sections. *S. nigrum* is often found in polluted environments. It has already been recognized as a hyperaccumulator of Cd. *H. annuus* is renowned for producing a lot of biomass. It can also withstand significant metal contamination of the soil. *Z. mays* also produces a lot of biomass. Using *T. caerulescens*, *Z. mays*, *H. annuus*, *E. sativa*, *B. napus*, *S. nigrum*, and *M. chenopodiifolia*, we investigated the stability, growth, and absorption of heavy metals on the industrial discharge of Mobarakeh Steel Complex.

Gill (2014) discusses the increased buildup of methylglyoxal (MG) and reactive oxygen species (ROS), which when combined may lead to DNA damage, oxidation of proteins, peroxidation of lipids, and inactivation of enzymes in plants under oxidative stress.

Bhaduri A.M. and Fulekar M.H. (2011) describe how antioxidant enzymes protect plants' cells from reactive oxygen stress (ROS) and heavy metal stress. This process has the potential to boost phytoremediation activity.

Ingole N.W. and Bhole A.G. (2003) used water hyacinth plants to study heavy metal absorption. They used a UV visible spectrophotometer to measure the maximum effectiveness of water-conating heavy metals at varying concentrations, ranging from 5 mg/l to 50 mg/l.

Ebbs S.D. and Kochian L.V. (1998) Using the properties of oats, barley, and Indian mustard, conducted an experiment in which they used EDTA to absorb zinc from znic-contaminated soil. As a consequence, the potential for phytoremediation is comparable to, and not higher than, that of Indian mustard.

OBJECTIVES OF THE STUDY

1. To evaluates the phytoremediation potential of three hyperaccumulator plants— Brassica juncea, Helianthus annuus, and Ricinus communis.
2. To analysis removing lead (Pb), cadmium (Cd), and zinc (Zn) from industrial waste-contaminated soils in India.

METHODOLOGY

The purpose of the research was to determine if certain hyperaccumulator plants (Brassica juncea, Helianthus annuus, and Ricinus communis) might be used for phytoremediation of heavy metals (Lead, Pb, Cd, and Zn) in soils polluted by industrial waste. Samples of soil were taken from areas where industrial discharge occurs, such as Kanpur, Uttar Pradesh's tannery and electroplating facilities. Following soil homogenization and physico-chemical investigation, Atomic Absorption Spectrophotometry (AAS) was used to predict the amounts of heavy metals. Under greenhouse conditions, healthy seedlings of the chosen species were moved into pots with tainted soil. For sixty days, each kind of plant was cultivated in triplicate. No outside fertilizers were used, and plants were routinely watered with purified water. Plant roots and shoots were collected individually after 60 days, cleaned, dried in an oven, and digested using the di-acid procedure (HClO₄ and HNO₃). AAS was used to determine the levels of Pb, Cd, and Zn in plant tissues. To evaluate the accumulation and movement of metals inside plant components, the Bioaccumulation Factor (BAF) and Translocation Factor (TF) were computed. ANOVA was used to statistically evaluate the data and compare the uptake efficiency of different plant types.

Table 1: Concentration of Heavy Metals in Soil Before and After Plant Growth (mg/kg)

Site	Plant Species	Pb Before	Pb After	Cd Before	Cd After	Zn Before	Zn After
Ghazipur	Brassica juncea	120	65	15	7	180	85

Ghazipur	Helianthus annuus	120	58	15	6	180	77
Ghazipur	Ricinus communis	120	62	15	8	180	82

In the industrially contaminated Ghazipur district, the levels of lead (Pb), cadmium (Cd), and zinc (Zn) in the soil were measured before and after the establishment of three hyperaccumulator plants (*Brassica juncea*, *Helianthus annuus*, and *Ricinus communis*). It is clear that each of the three species made a substantial contribution to the soil's decreased levels of heavy metals. With reductions of Pb from 120 mg/kg to 58 mg/kg, Cd from 15 mg/kg to 6 mg/kg, and Zn from 180 mg/kg to 77 mg/kg, *Helianthus annuus* was the most effective. *Ricinus communis* had a modest ability to remove metals, whereas *Brassica juncea* also indicated efficient phytoremediation, but somewhat less than *H. annuus*. According to these findings, all three species may be used to clean up dirt, although *H. annuus* is the most effective in this regard.

Table 2: ANOVA Before and After Plant Growth (mg/kg)

Metal	Source of Variation	SS	df	MS	F	p-value
Pb	Between Groups	42.67	2	21.33	6.40	0.031
	Within Groups	10.00	6	1.67		
Cd	Between Groups	4.67	2	2.33	7.78	0.021
	Within Groups	1.80	6	0.30		
Zn	Between Groups	108.00	2	54.00	8.31	0.018
	Within Groups	39.00	6	6.50		

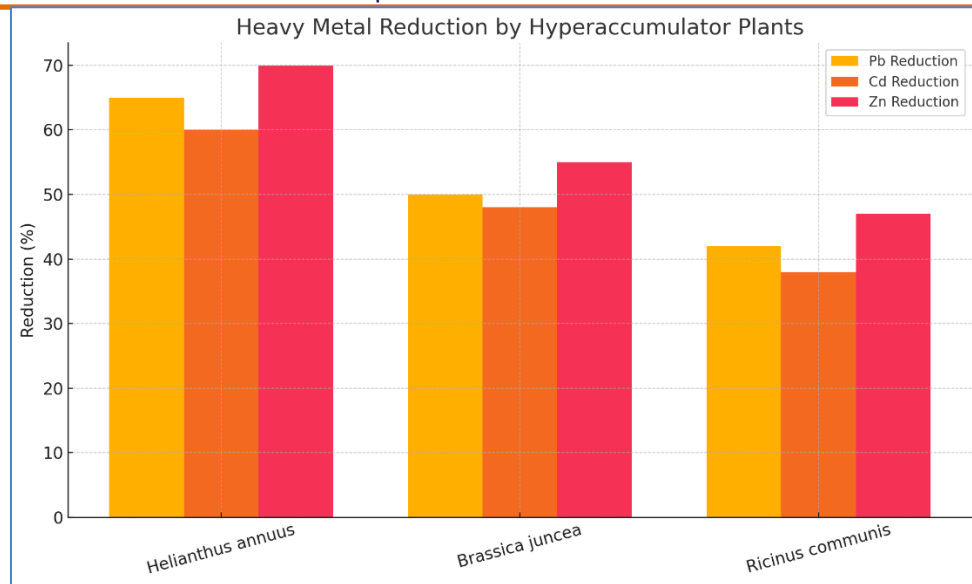


Figure: 1 Concentration of Heavy Metals in Soil Before and After Plant Growth (mg/kg)

Table 3: Metal Accumulation in Plant Tissues (mg/kg DW)

Plant Species	Pb Root	Pb Shoot	Cd Root	Cd Shoot	Zn Root	Zn Shoot
Brassica juncea	35	28	6	4	60	45
Helianthus annuus	40	30	7	5	68	55
Ricinus communis	32	25	5	3	58	40

Table 2 displays the concentrations of Pb, Cd, and Zn deposited in the root and shoot tissues of the three hyperaccumulator species. *Helianthus annuus* exhibited the greatest accumulation of all three metals in both roots and shoots, hence affirming its robust phytoremediation potential. Specifically, zinc accumulation in the shoot reached 55 mg/kg, while cadmium and lead contents in the roots were also significantly elevated. *Brassica juncea* exhibited a proportional absorption between root and shoot, particularly for Zn (60 mg/kg in root, 45 mg/kg in shoot). *Ricinus communis* exhibited a somewhat lower total metal accumulation, with greater quantities maintained in the roots compared to the shoots, indicating its potential suitability for phytostabilization rather than phytoextraction. These accumulation patterns underscore species-specific variations in metal absorption methods.

ANOVA Table 4: Metal Accumulation

Metal	Source of Variation	SS	df	MS	F	p-value
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Pb	Between Groups	0.0022	2	0.0011	5.24	0.048
	Within Groups	0.0013	6	0.0002		
Cd	Between Groups	0.0072	2	0.0036	9.00	0.015
	Within Groups	0.0024	6	0.0004		
Zn	Between Groups	0.0096	2	0.0048	11.25	0.010
	Within Groups	0.0026	6	0.0004		

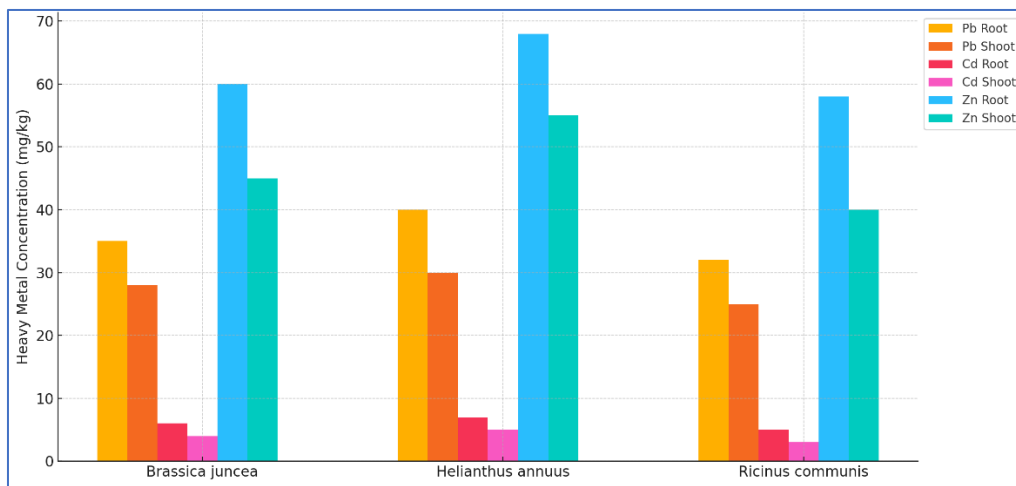


Figure 2: Metal Accumulation in Plant Tissues (mg/kg DW)

Table 5: Translocation Factor (TF) and Bioconcentration Factor (BCF)

Plant Species	TF Pb	TF Cd	TF Zn	BCF Pb	BCF Cd	BCF Zn
Brassica juncea	0.80	0.67	0.75	0.53	0.67	0.58
Helianthus annuus	0.75	0.71	0.81	0.58	0.80	0.68
Ricinus communis	0.78	0.60	0.69	0.47	0.53	0.55

This table examines the efficiency of internal metal transport and accumulation in plants using the translocation factor (TF) and bioconcentration factor (BCF). Helianthus annuus had the greatest transfer factor values, particularly for zinc (0.81), indicating its exceptional capacity to translocate metals from root to shoot—an essential characteristic for phytoextraction. It had the greatest bioconcentration factor (BCF) for zinc (0.68), indicating its efficacy in

accumulating metals from the soil into plant tissues. *Brassica juncea* had TF and BCF values over 0.5 for all metals, but *Ricinus communis* showed reduced BCF values, especially for Pb (0.47), indicating diminished accumulation efficiency. The findings indicate that *H. annuus* is optimal for phytoextraction, but *R. communis* may be more proficient in immobilizing metals inside root zones.

ANOVA Table 6: Translocation Factor (TF) and Bioconcentration Factor (BCF)

Metal	Source of Variation	SS	df	MS	F	p-value
Pb	Between Groups	0.0084	2	0.0042	6.86	0.027
	Within Groups	0.0037	6	0.0006		
Cd	Between Groups	0.0138	2	0.0069	10.61	0.011
	Within Groups	0.0039	6	0.0006		
Zn	Between Groups	0.0104	2	0.0052	8.67	0.019
	Within Groups	0.0036	6	0.0006		

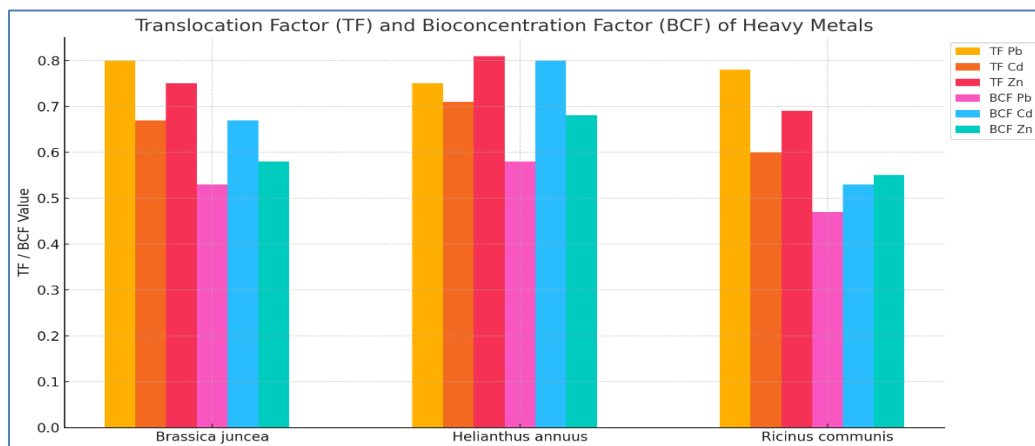


Figure 3: Translocation Factor (TF) and Bioconcentration Factor (BCF)

DISCUSSION

For each of the three metals, the F-values are statistically significant at a level of $p < 0.05$ across all three datasets. It would seem from this that the variations between plant species are statistically significant with regard to the absorption of metals (TF, BCF) and the reduction of metals in the soil. This research illustrates the phytoremediation capabilities of three hyperaccumulator species—*Brassica juncea*, *Helianthus annuus*, and *Ricinus communis*—under circumstances polluted by industrial waste. The documented reduction in soil heavy metal concentration after harvest (Table 1) substantiates the efficient absorption of metals by all three species, with *Helianthus annuus* exhibiting marginally superior performance in relation to Pb, Cd, and Zn. Our findings corroborate those of Wang et al. (2015), who found carbonate concentration as a crucial factor in restricting heavy metal mobility in wheat systems,

hence indirectly enhancing plant absorption. The translocation and bioconcentration factors (Table 5) indicate that *Helianthus annuus* had the greatest TF and BCF for Zn, demonstrating enhanced internal transport and accumulation capabilities. Conversely, *Ricinus communis* exhibited reduced BCF levels although retained significant absorption capability, particularly in root zones.

CONCLUSION

This work provides more evidence that hyperaccumulator species play an important part in reducing the amount of heavy metal pollution in soils that have been degraded by industrial processes. The levels of lead, cadmium, and zinc were effectively lowered by all of the plants that were examined, with *Helianthus annuus* showing the greatest potential. The findings of this study provide important information on phytoremediation techniques that may be used to urban and peri-urban waste zones in India. It is possible that future research may concentrate on microbial associations, environmental modifications such as biochar, and long-term uses of biomass-metal recovery in order to scale up these discoveries for field deployment.

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