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Original Article

Screening of Native Plants Growing Around an Industrial Area of Mangalore, Karnataka: Perspectives for Phytoremediation

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ABSTRACT

Aim: To identify native plant species with high tolerance and remediation potential for specific pollutants present in the industrial area, aiming to develop effective and sustainable phytoremediation strategies for environmental cleanup. **Materials and Methods:** The study conducted field investigations around an industrial area to screen plants for heavy metal accumulation. Soil and plant samples were analyzed for heavy metals using the acid extraction method, and five plant species were identified, with *I. globosa* showing potential for metal accumulation. **Results:** The soils around the industrial area of Mangalore, Karnataka, were severely contaminated with heavy metals. This contamination had a significant impact on the plants growing in the area. Among the identified plant species, *I. globosa* from the Poaceae family demonstrated the potential for accumulating and translocating heavy metals. The study confirmed the efficacy of plants growing around industrial areas in absorbing and accumulating heavy metals, indicating their potential for phytoremediation applications.

Keywords: Bioaccumulation, Heavy metals, Native plants, Phytoremediation, Pollution.

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INTRODUCTION

Industries in recent years have caused a massive increase in the deposition of heavy metals in the environment, and humans are the primary targets for exposure to heavy metals.[1] Heavy metal pollution occurs naturally due to volcanic eruptions, weathering, and mining and remains in the environment as pollutants.[2] Anthropogenic activities will increase the concentration of heavy metals in the environment. 40-73% of Cd, Zn, and Pb anthropogenic emissions are related to smelting activities.[3] Heavy metals in air, water, and soil concern many scientists because these metals accumulate in the natural vegetation and enter the food chain.

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There are several technologies for the remediation of heavy metals from a contaminated region. It can be physical or chemical treatment, but most of these techniques are expensive and alter the soil's properties, or it will lead to secondary contamination; to avoid secondary contamination, we choose an eco-friendly and cost-effective technology called Phytoremediation. 'Phyto' Use of Plants for remediation of heavy metal contaminated environment. This technology suits all types of pollutants in different mediums, like organic and inorganic pollutants in soil and liquid substrates like water and air.[4] Phytoremediation is divided into Phytoextraction, Phytostabilization, Phytodegradation, Rhizofiltration, and Phytovolatilization.[5,6] Phytoremediation technology offers several benefits over conventional remediation techniques, including maintaining the structure of the surface soils, enhancing soil nutrition, and reducing the concentration of metal contaminants. In mining sites, both pollutions clean up and ecological restoration can be done simultaneously using this technology.[7] Continuous studies are conducted to explore suitable plant species for enhancing remediation efficiency.

The screening of random plants of native species from the contaminated area is the study interest. Therefore, industries near Mangalore and Surathkal are considered for the study area, known for many industries and possible pollution in the surrounding area. Overexposure to these pollutants leads to accumulation in soil, water, and in native flora. The study objective is the Screening of native plants growing in a contaminated area and; Identification of the tolerant species for phytoremediation strategy.

MATERIALS AND METHODS

Site characterization and Sample collection

Soil and plant samples were collected from Permude, Surathkal, (13°00 '21.2 "N 74°52 '44.4 "E) 15.4-20 km away from Mangalore, Karnataka. Petrochemical, fertilizer, thermal power plants, pharmaceutical, and many other industries surround the site. Soil and plant samples were collected in August 2019. Five different regional flora (Figure 1) were collected according to the standard method of.[8] Soil samples from the plant's root zone (15-20 cm depth) were collected from different places of the study site.

Soil and Sample Analysis

Soil and plant samples were air-dried followed by oven dry at 50±5°C, powdered and sieved through a 2mm sieve, and stored for analysis. The percentage organic content of the soil was determined by the Walkley-Black titration method.[9] Soil pH was determined according to Matter method.[10,11] 5:1 ratio of water soil mixture was stirred for 15 min. The pH was determined on the supernatant using Eutech instrument pH 700, Thermo Scientific pH meter.

For heavy metal analysis, the dried samples (plant and soil) were weighed and moistened with water, and 2:2:5 ratios of HNO_3, $HClO_4$, and H_2SO_4 were added; the mixture was placed on a hot plate at 95±5°C for extraction of heavy metals.[12] After the extraction, the samples were cooled and diluted to 50 mL, filtered through Whatman No. 1 filter paper. The Cd, Cr, Pb, and Hg concentration was analyzed in Atomic Absorption Spectrophotometer AA8000 Labindia.

Soil pollution index

The soil pollution index is calculated by dividing the metal concentration in the soil by the background metal concentration.[6,13]

$$PI = ([Cd]_{soil}/3 + [Cr]_{soil}/75 + [Pb]_{soil})/100$$

Bioconcentration Factor, Translocation factor, and Bioaccumulation Factor Coefficient

Bioconcentration Factor (BCF): the metal concentration ratio of plant roots to soil is known as the bioconcentration factor, calculated using the formula.[14]

$$BCF = \text{Metal in root/metal in soil}$$

Translocation Factor (TF): It is the shoot-root quotient. The translocation of metals from roots through shoots is called the translocation factor.[3]

$$TF = \text{Metal in Shoot/ Metal in root}$$

Bioaccumulation Factor Coefficient (BAC): BAC has been computed using the formula based on the ratio of heavy metals in the soil and plant root.[15]

$$BAC = \text{Metal in Shoot/ Metal in Soil}$$

Data Analysis

The statistical analysis of the data was performed using ANOVA in GraphPad Prism. All the data are triplicate values and presented as the Mean ± Standard error.

RESULTS

Site Description

Many petrochemicals, fertilizer, thermal power plants, steel, paint, and automobiles surround the study area Permude Surathkal (Site 1). Many villages surround this place, and the neighborhood has a massive accumulation of hazardous waste. These wastes from the industries mound at villagers' lands; during the rainy season or floods, water carries these wastes, leading to significant contamination of grounds and water sources.

Soil properties and metal concentrations

The soil sample collected from the industrial area has an acidic pH value of 4.12 - 4.45. If the samples are collected from agricultural habitats pH may be high due to the addition of lime for agricultural production.[16] Strongly acidic soils result in poor plant growth and metal toxicity in the soil. Our study showed acidic soil, and the selected plant species are thriving in the studied area. The soil sample collected from the study area contains less organic matter, 0.192%. Low organic matter means fewer biological activities and affects plant growth. Our study revealed low organic matter, but there is no hindered plant growth, but the plants were showing discoloration; this may be due to heavy metal stress.

Heavy metal concentrations in Permude are presented in Figure 2(a-b). The soils from this area have a maximum concentration of Cd in site 2 (27.628±0.017 ppm) and less concentration in site 1. Whereas 19.778±0.007 ppm of Pb in site 5, 10.72±0.007 ppm of Cr concentration in site 1 was analyzed. According to the report, the area has high Cd and Pb levels. Soils from this area can be considered contaminated, and the pollution index of the soil ranged from 5.8 to 9.3. This shows that the area is moderately polluted.

Screening of native plant species around the study area

A total of five Species were identified and classified as five families. Dr. K.G Bhat, Poornaprajna College Udupi, has authenticated the selected plant species. The samples were collected from 1000m away from the industrial area and identified as *Pycreus polystachyos, Isachne globose, Chromolaena odorata, Plycarpon prostratum, Pityrogramma calomelanos* belongs to five different family (Table 1). The plant species selected were divided into perennial and annual herbs and sedges.[17] These plants can grow in contaminated and non-contaminated soil.

Heavy metal concentration in plants and soil samples

Heavy metal concentration in plants

The Cr metal content in the root and shoot of selected plants are significantly different; the concentration of Cr [Figure 3 (a)] in the shoot of *P. calomelanos* was comparatively more (4.392±0.010 mg/L) than *I. globosa* 0.265±0.002 mg/L in the shoots and *C. odorata* 0.580±0.002 mg/L. This result indicates that the metals present in the soil translocate through roots to shoots and accumulate in the shoots. Whereas plants (*P. polystachyos, P. prostratum, P. calomelanos*) were tried to grow in a hydroponic system, they could not acclimatize and show any positive response to the accumulation of heavy metals, *I. globosa* and *C. odorata* showed good accumulation property in the hydroponic study.

The Pb metal content in the shoot of all five selected plants was more than the roots. *P. prostratum* was comparatively more; however, it was not able to survive in the hydroponic study. 9.114±0.002mg/L concentration was noted in *C. odorata* and 8.675±0.003mg/L in *I. globosa*, 4.682±0.002 mg/L of Pb was accumulated in the root of *I. globosa* [Figure 3 (b)]; this shows the plant can transport metals from roots to shoots and store them in the shoot. In contrast, continued studies expressed the same results in hydroponic systems. Hydroponic study reports were not disclosed.

Cd metal content in all selected plants showed accumulation in the root than shoots; the maximum absorption was noticed in [Figure 3 (c)] *P. polystachyos* 9.527±0.002 mg/L, *P. calomelanos* 9.405±0.003 mg/L, *C. odorata* 9.342±0.003 mg/L. Least metal

Table 1: List of species collected from the study area.

Sl. No	Species	Family	Growth habitat
1	Pycreus polystachyos	Cyperaceae	Grass-like Sedge
2	Isachne globose	Poaceae	Grass
3	Chromolaena odorata	Asteraceae	Shrub
4	Plycarpon prostratum	Caryophyllaceae	Herb
5	Pityrogramma calomelanos	Pteridoceae	Fern

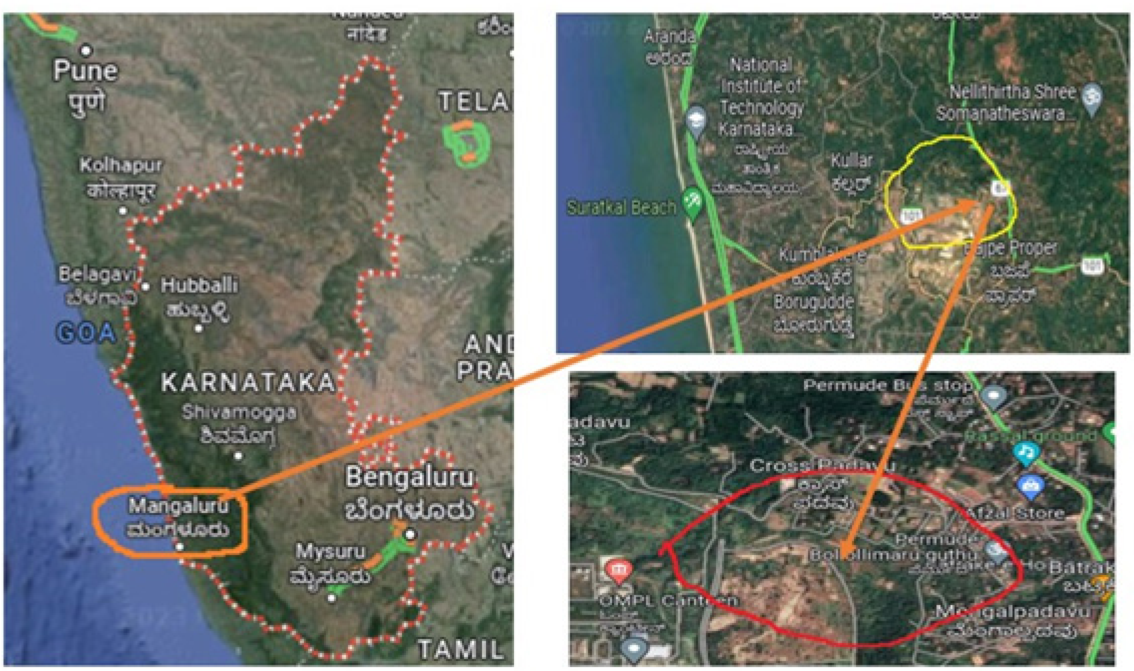

Figure 1: Map showing the Plant and Soil Sampling area collected for phytoremediation study.

absorption was noticed in *I. globosa* 8.923±0.003mg/L in the root and 4.995±0.005mg/L in the shoot. Here the plants are absorbing the metal, but they are not transferring to above-ground parts, so they are not suitable metal transporters. Though *C. odorata* and *I. globosa* showed less absorption than other species, they are moderate bio accumulators.

According to USEPA, and WHO guidelines, the permissible level of heavy metals in a plant for Pb is 2mg/kg, Cd is 0.02mg/kg, and Cr is 0.03mg/kg. The results of heavy metal present in the study site samples are more than permissible. The selected plants can quickly grow, and undergo photosynthetic activity, in the presence of heavy metal as its micro or macronutrient, are seen from the BCF, BAC, and Translocation Factor.[18]

The BCF, BAC, and TF of the selected plants are displayed in Table 2.

To evaluate the ability of plants to translocate the selected metals from roots to aerial parts of the plant, the TF was calculated; in Table 2, it was confirmed that all five plants are potential

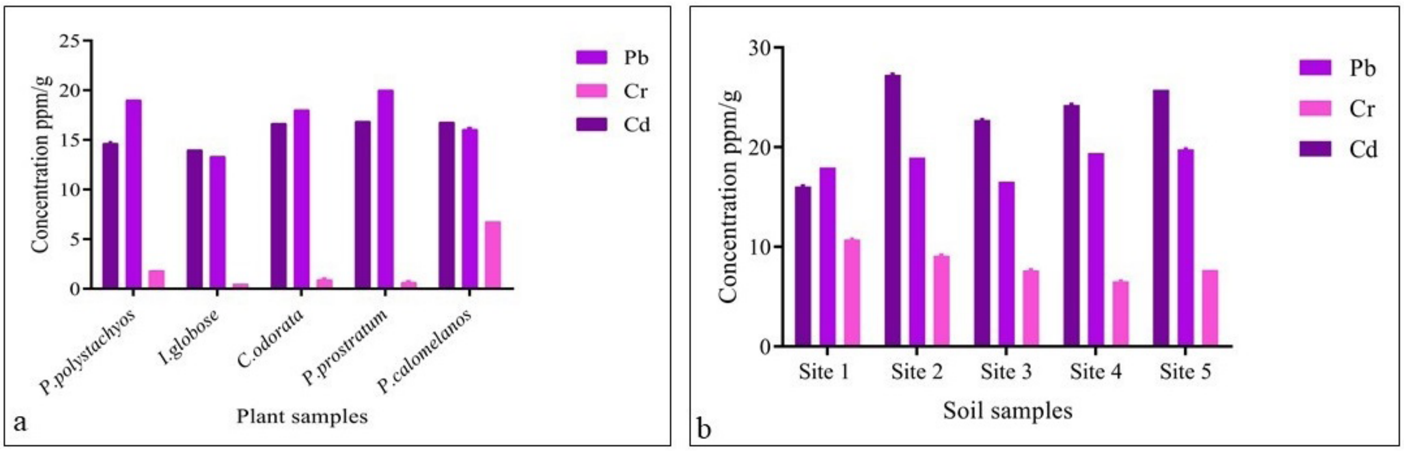

Figure 2: Heavy metals extracted from Study site a) Plant samples, b) soil samples. The data represented in Mean±SD, Significant difference at $p<0.05$

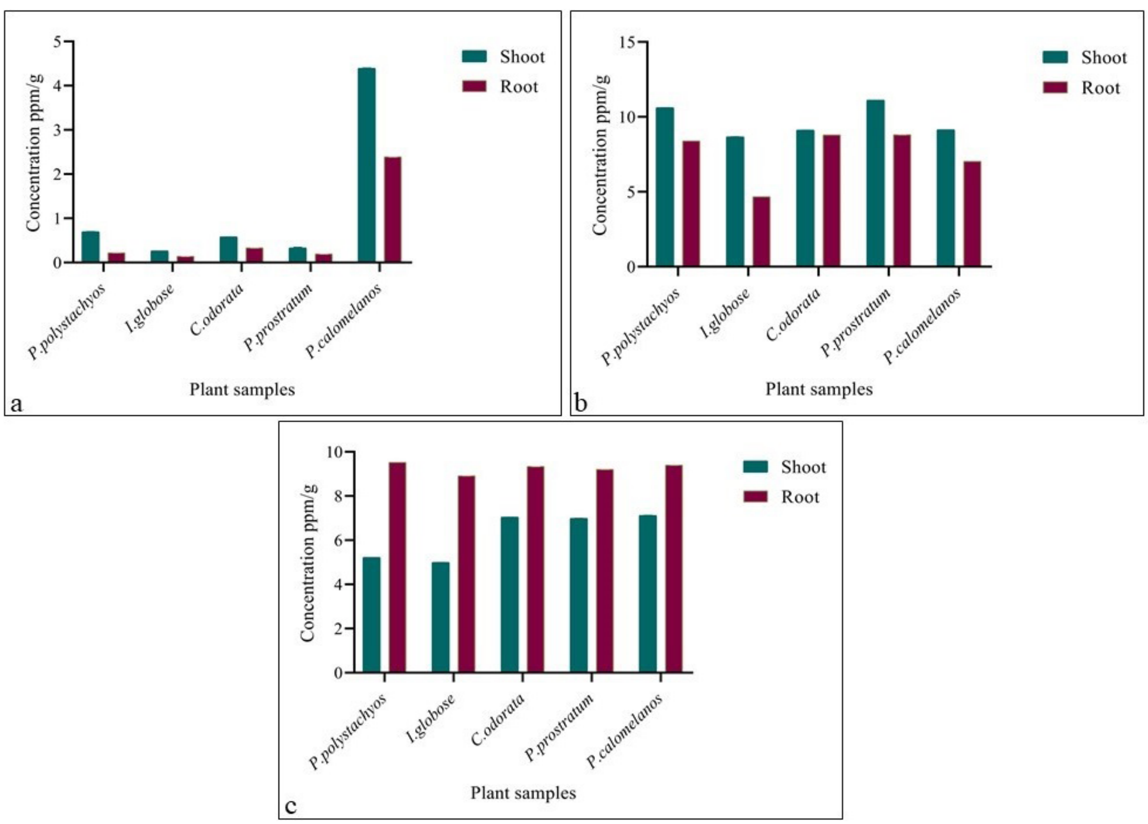

Figure 3: Heavy metal concentration a) Cr metal Concentration in shoot and root, b) Pb metal concentration in shoot and root, c) Cd metal concentration in shoot and root. The data represented in Mean±SD, Significant difference at $p<0.05$.

Table 2: Bioconcentration Factor, Bioaccumulation Factor Coefficient and Translocation factor for the selected plants.

Plants	TF			BCF			BAC		
	Cr	Pb	Cd	Cr	Pb	Cd	Cr	Pb	Cd
P. polystachyos	1.58	1.44	0.17	0.06	0.432	0.774	0.106	0.626	0.138
I. globosa	2.60	6.36	0.13	0.033	0.129	0.536	0.087	0.822	0.074
C. odorata	2.03	4.67	0.28	0.036	0.144	0.478	0.070	0.674	0.138
P. prostratum	2.12	2.50	0.58	0.037	0.294	0.441	0.079	0.736	0.257
P. calomelanos	4.39	2.07	0.59	0.159	0.264	0.405	0.70	0.54	0.241

transporters of Cr and Pb, whereas Cd will store in the roots of the plants. The translocation of metals from roots to shoots was confirmed by the TF value greater than one; *I. globosa* and *C. odorata* showed the highest TF value for Pb metal. However, the same was confirmed by a hydroponic study with these two plants (data to be published). The BCF value of all selected plant species was less than one, indicating the metals are transferred to the plants; the highest BCF value was 0.77 in *P. polystachyos* for Cd metal to consider as moderate accumulators. However, the same does not reflected in the hydroponic system. *I. globosa* and *C. odorata* also displayed an increase in bioaccumulation factor to be considered potential phytoremediation.

According to studies BAC range, the plants with 1.0-10 are classified as hyperaccumulators, 0.1-1.0 as a moderate accumulator, and 0.01-0.1 as low accumulator plants.[19,20] Less than 0.01 is not an accumulator plant. According to this classification, the screened plants for Hg, Cd, and Pb show moderate and Cr-low accumulators. The translocation factor should be more than 1 to consider it a bio-accumulators.[14]

Plant selection for phytoremediation

Phytoremediation is a cost-effective, eco-friendly technology that uses plants to remove/reduce contamination. In contrast, using native plants in the contaminated site reduces screening, harvesting, and replanting time. Many factors support the selection criteria of plants for the phytoremediation perspective, which are Soil pH, organic matter, Bioconcentration Factor (BCF), Translocation Factor (TF), and Bioaccumulation Coefficient (BAC) (Table 2).[21]

The selected plants can be used for phytoremediation of different metals. However, further studies have proven that *I. globosa* can be efficiently used as a phytoremediator of Cr and Pb-contaminated areas, which showed the maximum translocation factor. *I. globosa* is a perennial plant and can grow in any climatic conditions; high survival and tolerance to extreme soil conditions and toxic metals, strong proliferation potential, fast growth rate, it does not have many reports for phytoremediation properties, but our study showed maximum accumulation of chromium and lead. These plants could suit Cr, Pb, Cd, and Hg Phytoremediation.

C. odorata is also a good candidate for phytoremediation study; the TF factor was maximum Pb metal than other; this indicates that plants can efficiently translocate metals from roots to shoots and accumulates in the shoots. These plants are perennial shrub forms dense, tangled bushes that can grow in any climatic conditions, belongs to the Asteraceae family, and is commonly known as Siam weed; Since the metals accumulate in the shoots while harvesting, only shoots can be harvested, and further plants can grow and accumulate metals. *C. odorata* has already been known as phytoremediator species in many areas.[22]

DISCUSSION

The study site is surrounded by various industrial activities, these industries contribute to the accumulation of hazardous waste, which often ends up contaminating the land and water sources, especially during rainy seasons or floods. The presence of these contaminants has a significant impact on the environment and poses risks to the surrounding communities.

The soil properties in the industrial area were assessed, and it was found that the soil had an acidic pH. Soil pH plays a crucial role in the accumulation and availability of metals for plants.[23] Acidic soil conditions can solubilize metals, making them more bioavailable to plants.[6,24] The organic matter content in the soil was found to be low. The organic matter of normal soil varies from 3% to 6%. Generally, organic matter contains 58% of organic carbon. Low organic matter affects biological activities in the soil and can impact plant growth. Despite the acidic soil and low organic matter, the selected plant species were observed to thrive in the studied area, although they showed signs of discoloration, potentially due to heavy metal stress. Many studies have proven that toxic heavy metals like Cd, Pb, Hg, and Zn in the soil lead to accumulation in plant parts and decrease crop productivity.[25] Studies showed that the presence of Zn in soil influences the microorganisms for the breakdown of organic matter.[26] With our findings, the area is contaminated with Cd, Cr, and Pb.

Bioconcentration Factor (BCF), Bio-Accumulation Coefficient (BAC), and Translocation Factor (TF) parameters confirm the phytoremediation potential of the plants.[27] A BCF and TF value more than one value higher than one indicates plants are hyperaccumulators showed that BCF and TF value <1 is a good accumulator and efficient metal transporter, BAC is the accumulation factor the ratio of metals in the shoots to that in the soil.[28-30]

A study showed around twenty-three plants were screened for Hg accumulation in the Hg mining site.[29] Similarly, five plants were screened and checked for phytoremediation aspects in our study. The selected plants demonstrated varying abilities to absorb and accumulate heavy metals. The Bioconcentration Factor (BCF), Bioaccumulation Coefficient (BAC), and Translocation Factor (TF) were calculated to evaluate the phytoremediation potential of the plants. *I. globosa* and *C. odorata* exhibited promising results, with high TF values for Pb, indicating their ability to transport metals from roots to shoots.

CONCLUSION

The deposition of heavy metals and subsequent contamination in the region surrounding Mangalore, Karnataka, due to industrial activities, is a significant environmental issue that needs to be remediated. The area's characterization and evaluation of soils have revealed the presence of metals such as Pb, Cd, and Cr, indicating a severe contamination problem. However, native plant species in these contaminated regions have exhibited a remarkable ability to accumulate heavy metals and thrive in such harsh environments. Among the five species studied, *I. globosa* and *C. odorata* has demonstrated exceptional potential in accumulating Pb, Cd, and Cr, suggesting their suitability for phytoremediation purposes. These findings provide a promising foundation for developing targeted phytoremediation strategies to address heavy metal contamination in the affected area. By leveraging the metal-accumulating capabilities of these plant species, it may be possible to mitigate the environmental impact and reduce the concentrations of contaminants in the soil. Further investigation is necessary to understand the underlying factors that contribute to the accumulation properties of these plants. Future research should focus on unraveling the physiological and biochemical mechanisms involved in the metal accumulation process of *I. globosa* and *C. odorata.* This knowledge can then be utilized to optimize phytoremediation strategies and enhance their effectiveness.

Though industries have waste management systems, metals can still enter the environment through natural systems like rainwater, flood, wind, accidental spills, and atmospheric emissions. Nevertheless, it is crucial to regulate the contaminants; implementing phytoremediation can be a preventive measure for good environmental health, affected region can be safeguarded and restored.

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CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

ABBREVIATIONS

Cd: Cadmium; **Pb:** Lead; **Cr:** Chromium; **HNO_3:** Nitric acid; **$HClO_4$:** Perchloric acid; **H_2SO_4:** Sulphuric acid.

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