

ASSESSMENT OF LEAD AND CHROMIUM UPTAKE AND PHYTOREMEDIATION EFFICIENCY OF *TARGETES PATULA* L.

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Abstract

Heavy metal pollution is a major global environmental issue that adversely affects the health of plants, animals, and microorganisms. Phytoremediation has emerged as an eco-friendly and cost-effective technique for removing heavy metals from contaminated soils using plants. The present study was conducted to evaluate the phytoremediation potential of *Tagetes patula* for lead (Pb) and chromium (Cr). Soil samples were artificially contaminated with 100, 300, and 500 ppm of each metal, and plant growth and metal uptake were assessed after harvesting. The results demonstrated that all growth parameters, including seed germination, plant height, and fresh and dry biomass, were significantly reduced at increasing concentrations of both Pb and Cr, indicating metal-induced phytotoxicity. Soil analysis after harvest revealed that residual Cr concentrations were higher than those of Pb. Metal accumulation analysis showed contrasting patterns: Pb concentrations in plant tissues decreased as soil Pb levels increased, whereas Cr accumulation in plant tissues increased proportionally with higher soil Cr concentrations. The bioconcentration factor (BCF) and biological accumulation coefficient (BAC) values for Pb were less than one, suggesting limited phytoextraction potential for this metal. In contrast, BCF and BAC values for Cr were greater than one, indicating efficient uptake and accumulation. The translocation factor (TF) for Pb exceeded one, while that for Cr was below one, suggesting greater internal mobility of Pb compared to Cr. The findings indicate that *T. patula* is more suitable for chromium phytoremediation than for lead extraction from contaminated soils.

INTRODUCTION

Pollution can be described as the addition of any substances or the introduction of unwanted changes to the environment which are dangerous for the life of human and other living organisms (Manisalidis *et al.*, 2020). As a result of high rate of industrialization and urbanization, heavy metals are added to soil which affected the health of human and plants adversely (Mahesh *et al.*, 2022). Contamination of soil by the heavy metals is now a days a major environmental problem which is increasing from several years that effect the production of crops. The presence of heavy metals both essential and non-essential in the soil can retard the seed germination, decrease uptake of nutrients and disturb the photosynthesis which leads to the stunt growth and reduction in agriculture yields (Brevik *et al.*, 2020; Ullah *et al.*, 2025; Khan *et al.*, 2025). Although some of the heavy metals are required for normal growth and metabolism of plants but if they are provided in large amounts can adversely affect the absorption and transport of essential elements, disturb the metabolism, and reduce growth and reproduction (Cheng, 2003).

Contamination of environment with heavy metals, especially with cadmium (Cd), chromium (Cr), lead (Pb), nickel (Ni) and mercury (Hg), are creating large issues for environment. Lead and chromium concentration is increasing with the passage of time rapidly in the environment due it high uses in industries related processes. According to Akmal and Jianming, (2009) normal concentrations of lead in soil are extending from 10ppm to 100 ppm, but in the soil where sewage sludge is occurred, have higher than 100ppm. Lead is mainly accumulate in the roots due to its binding with roots and cell wall surface and blockage by casperians strips in endodermis which caused limited translocation of it from roots to aerial parts like stem, leaves and inflorescences (Manousaki and Nicolas, 2009).

Lethality of lead caused stunted growth, imbalance in water, decrease in enzymatic activities, decrease in nutrients uptake such as Mg and Fe and blackening of root systems. It disturbed the photosynthetic rate by changing

the structure of chlorophyll and electron transport chain (Sharma and Dube, 2005). Toxicity of Chromium in plants adversely harms the structures of cell organelles and chlorophyll by declining Hill activity and by disrupting membranes of chloroplast (Wong and Chang, 1991). Cr toxicity caused the nutritional imbalance such as creating zinc and iron deficiency and inhibited the translocation of in nutrients in plants such as Mg, Mn, K, Fe and P. These changes lead to decrease in biomass, decrease in growth and seed production (Moral *et al.*, 2006).

Phytoremediation basically related to the utilization of certain plants accompanying by microorganisms to reduce the harmful causes or amounts of pollutants in the ecosystem (Grepsson, 2011; Khan *et al.*, 2025; Maqbool *et al.*, 2025). To remove soil contaminations, there are many traditional remediation methods but they are expensive and caused further disturbance in ecosystem. To accomplish the global stability and maintaining the balance of environment, heavy metals must be removed (Ji *et al.*, 2001).

Tagetes patula L. belongs to flowering plant and is commonly known as French marigold, included in Asteraceae family (Armitage and Leshaman, 2019). This family is significantly used for the bioremediation of certain heavy metal. Radmila *et al.*, (2021) reported that the species *M. inodora*, *C. setosa* and *A. millefolium* can be used for the extraction of Ca, Mg, Fe, Mn, Cu, Zn and Cr.

The aim of the present study was to investigate the lead (Pb) and chromium (Cr) remediation potential of *Tagetes patula* by determining the concentrations of Pb and Cr in the soil, evaluating the effects of these heavy metals on plant growth parameters, quantifying their accumulation in the vegetative tissues of the plant, and assessing the overall phytoremediation potential of the species for Pb and Cr.

Materials and methods

Research site and Experimental design

The research was carried out in the Green House of the Botanical Garden, Islamia College Peshawar to establish a control

environment. The research was carried in randomized block manner in triplicate forms in groups of four including control. Three groups were contaminated with different concentration of lead and chromium. The seeds were first tested for viability by soaking them for 2 to 3 hours then they were sowed. In order to perform the experiment the solutions were prepared in ppm form by using the formula proposed by skoog *et al.* (2013)

Analysis of growth parameters

The percentage of seed germination was determined through the formula of final germination percent ($FGP = S/T \times 100$). The total number of sowed seeds is represented by T while S represents the number of finally germinated seeds. A meter ruler was used to measure the length of seedling shoot and root at the time of harvest (Ologundudu *et al.*, 2014). To calculate plant fresh and dry weights, a digital balance was used.

Lead and Chromium Analysis in the Soil

A stranded procedure was used to analyze the soil for lead and chromium (Sharidah, 1999). After filtration of solution, the obtained filtrates were used as samples for evaluation of Pb and Cr through AAS (atomic absorption spectrometry), in Central Resource Laboratory (CRL) at University of Peshawar.

Lead and Chromium Analysis in *Tagetes patula* L.

The plant was grinded with pestle and mortar. The powder was digested according to the procedure used by Sajad *et al.* (2019). This filtrate was utilized for the Pb and Cr assessment through Atomic Absorption Spectroscopy, at the University of Peshawar.

Assessment of lead and Chromium Uptake of Plant Sample

Uptake potential of *T. patula* for Pb and Cr was evaluated through calculating the BAC (Bioaccumulation coefficient) by procedure used by Cui *et al.* (2007), Bio concentration factor (Zhuang *et al.*, 2007) and Translocation factor (Adesodun *et al.*, 2007; Padmavathiamma and Li., 2007).

Statistical Analysis

The software Excel, Graph pad Prism 9.0 were used for data analysis

Results

Effect of lead and chromium on growth parameters:

It is clear from the results that seed germination was decreased when the concentrations of both lead and chromium were increased (fig 1). The highest germination rate found in control group while the lowest germination of seed was shown in the 500ppm pots.

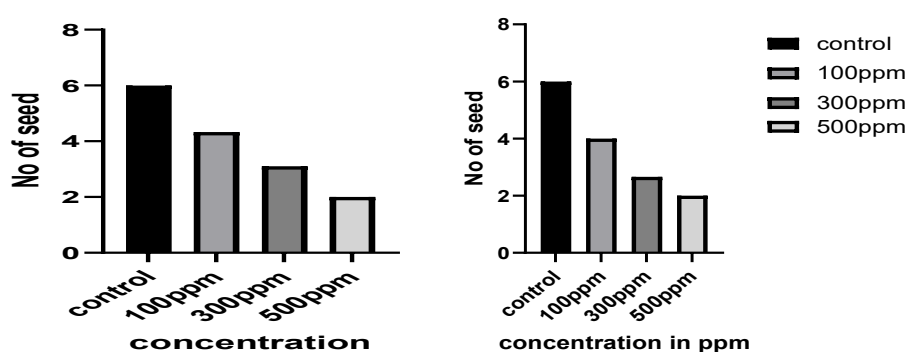


Fig1: Pb and Cr effect on seed germination

Lead effect on plant length

The results revealed that when the concentrations of Pb and Cr were increased, it reduced the height of the plant (fig 2). The

highest value of height was found for the plants grown in control pots while the lowest was shown by the plants in 500ppm pots.

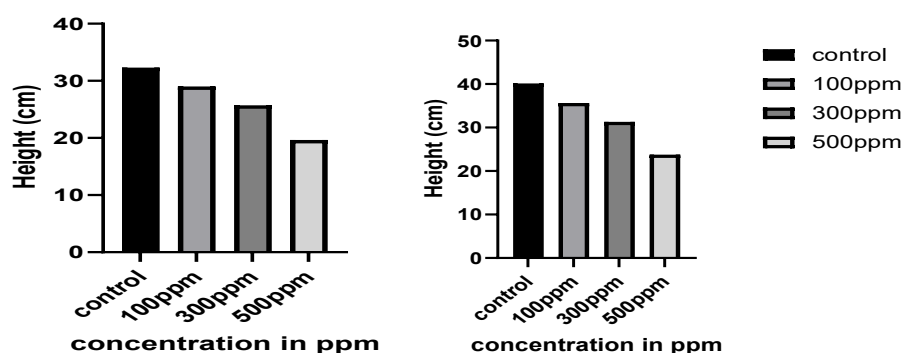


Fig2: Pb and Cr effect on plant height

It can be observed from the figure 3, when the concentrations of lead and chromium treatment were increased it has reduced the

fresh weight of the plant. Control plants have high fresh weight as contrast to the treated plants.

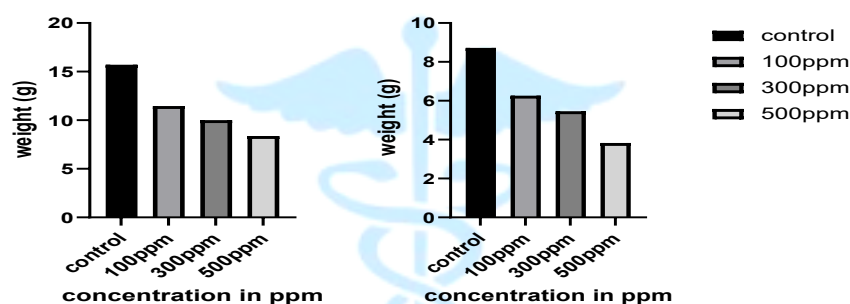


Fig3: Pb and Cr effect on fresh weight

It can be observed in the figure 4, when the concentrations of Pb and Cr were increased from 100ppm to 500ppm, the dry weight of the

plant becomes reduced. So, control plants have shown high dry weight as compared to treated one.

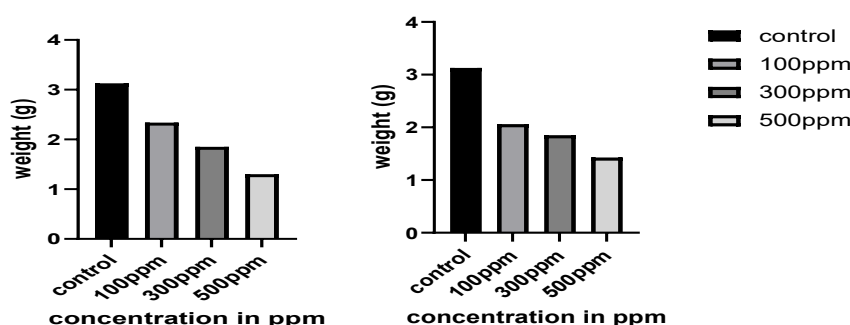


Fig4: Pb and Cr effect on dry weight

Lead and chromium concentration in soil

For the analysis of lead, soil samples were obtained from the Botanical Garden, Islamia College Peshawar. Concentration of Pb in the

soil was detected in range of 0.112 mg/kg. Cr concentration in the soil was found in the range of 1.39 mg/kg respectively.

Pb and Cr concentration in various plant parts

It can be observed from the tables 1 that root; stem and leaves of treated plants have higher concentration of lead and chromium as compared to control plant parts. The highest Pb concentration was noticed in root, stem and leaves of 100ppm (1.70mg/kg, 1.51mg/kg and

1.45 mg/kg) respectively. In case of Cr the highest concentration of was noticed in the root, stem and leaves of 500ppm (6.14 mg/kg, 3.96 mg/kg and 4.05 mg/kg) respectively. It can be observed in the table that leaves have high Cr concentration than the stem in each group.

Table1: Concentration of Pb in various plant parts

Pb and Cr Conct in ppm	Pb Concentration in mg/kg			Cr concentration in mg/kg		
	Root	Stem	Leaves	Root	Stem	Leaves
Control	0.80±0.069	0.588 ±0.35	0.35 ±0.22	1.006±0.098	0.593±0.031	0.746±0.058
100	1.70± 0.50	1.51 ± 0.185	1.45 ± 0.122	2.4 ± 0.71	1.83 ±0.165	1.92 ±0.447
300	1.3± 0.132	1.27 ± 0.082	1.02 ± 0.155	3.66 ±0.351	2.43±0.111	2.88 ±0.115
500	0.63± 0.05	0.253±0.042	0.195±0.049	6.14± 0.484	3.96 ±0.463	4.05 ± 0.168

Bio accumulation coefficient of *Tegetes patula* L. for Pb and Cr

The suitability of the *Tegetes patula* L. for remediation of Pb and Cr was evaluated which can be observed in the Figure. As can be notice

from the figure that except control group (3.1), all groups have BAC less than one for Pb. For Cr the BAC was observed more than one in all groups except control (0.532).

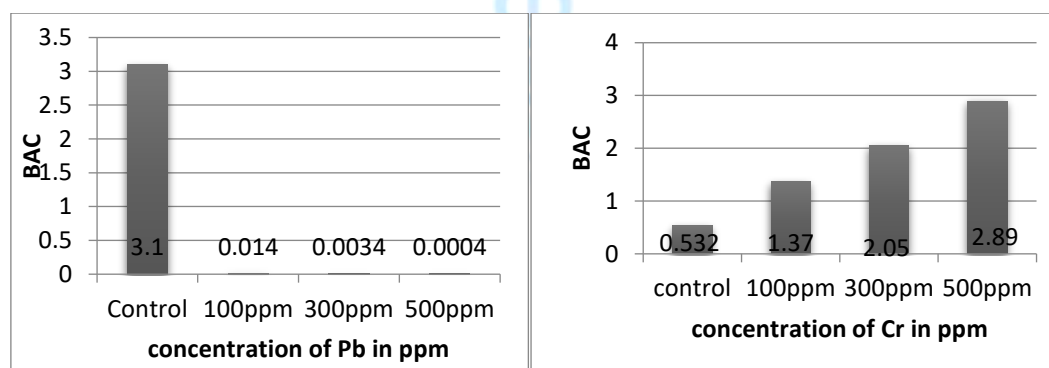


Fig5: Bio accumulation coefficient of *Tegetes patula* L. for Pb and Cr

Bio concentration factor of *Tegetes patula* L. for Pb and Cr

Bio concentration factor (BCF) of *T. patula* for lead and chromium was calculated which can be observed in the Figure 6. The BCF value of

Pb for all treated plants are below the one while for the control it is more than one (7.1). While The BCF value of Cr for all treated plants are above the one while for the control it was less than one (7.1)

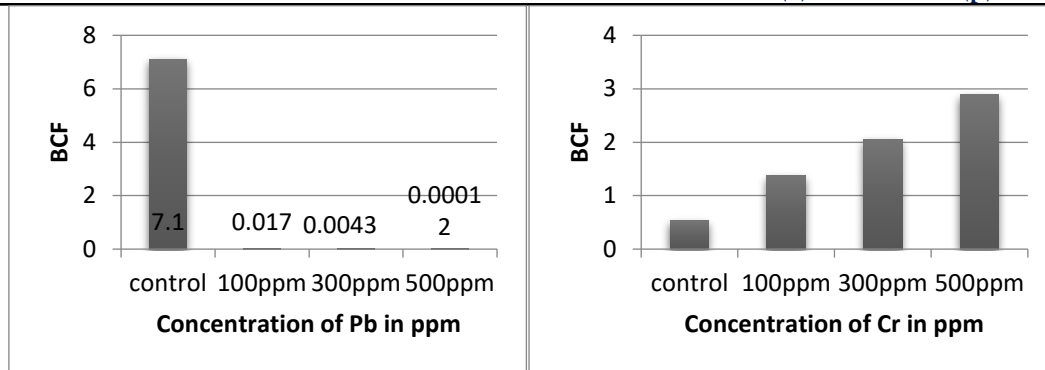


Fig6: Bio concentration factor of *Tegetes patula* L. for Pb and Cr

Translocation factor of *Tegetes patula* L. for Pb and Cr

It is evident from the figure 7, that all the plants have translocation factor value more

than one. The highest value was noticed in the 500ppm while lowest in the 300ppm. While the TF value for Cr treated plants was less than one including control group.

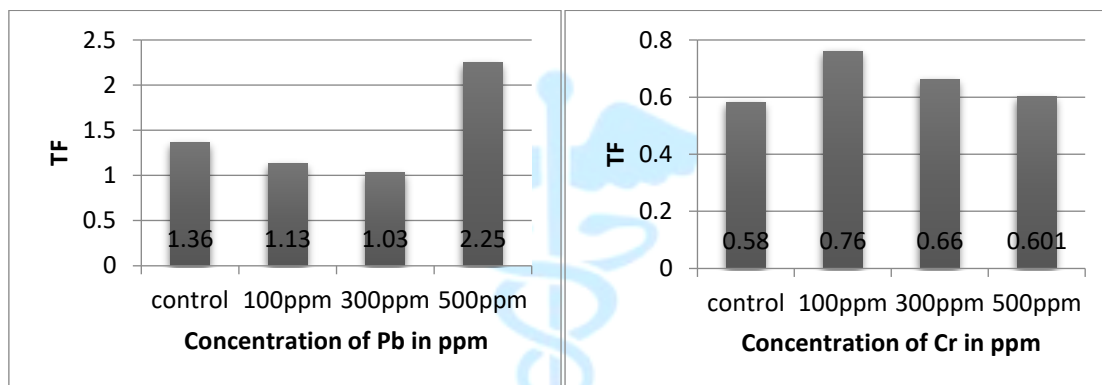


Fig 7: Translocation factor of *Tegetes patula* L. for Pb and Cr

Discussion

The current work assessed the phytoremediation potential of *T. patula* against lead (Pb) and chromium (Cr) contamination in controlled condition of greenhouse. The results evidently confirmed that increasing concentrations of both Pb and Cr employed a substantial inhibitory effect on germination of seed and some vegetative growth parameters comprising of shoot length, fresh and dry weight. This retardation in growth under heavy metal stress is primarily attributed to metal-induced toxicity, impaired nutrient uptake and oxidative stress.

The decline observed in seed germination with increasing Pb and Cr concentrations suggests interference with early physiological processes such as water absorption, enzymatic activation, and embryo development. Analogous to inhibitory effects of Pb and Cr on seed germination have been reported in wheat

(*Triticum aestivum*), and lentil (*Lens esculenta*), supporting the consistency of the present findings with earlier studies (Lamhamdi *et al.*, 2011; Mehboob *et al.*, 2018; Khan *et al.*, 2026). Plant length is also a growth parameter and was measured in centimeter. Plant length was negatively affected by both the metals. Figure 2 showing that when the concentrations of lead and chromium were increased from 100ppm to 500ppm, the plant length was decreased significantly as compared to control plants. Ansari *et al.* (2015) demonstrated that rise in concentration of Cr induced remarkable reduction in plant length and at high chromium concentration minimum length of plant was observed.

Plant Fresh weigh was calculated through digital balance in grams. The Figure 3 is showing that both the metals have negatively affected the fresh weight of treated plants. The figures indicate that when the concentrations



of lead and chromium were increased, they significantly reduce the fresh weight of the plants. Control group have high fresh as compared to treated plants. 500ppm lead and chromium treated plants have shown lowest fresh weights which is maybe due to metals induce water stress, oxidative damage and reduction in nutrients uptake. The same results were observed in the experiments on wheat (*Triticum aestivum*) and mustard (*Brassica juncea*) conducted by Pandey and Sharma, (2003).

Similarly, the dry weight of plants was calculated with digital balance in grams (g). The Figure 4 manifested that both lead and chromium has significantly affected the dry weight of the plants. The results also showed that control plants have high dry weight than the treated plants. The experiments conducted by Ansari *et al.*, 2015 and Peralta-vidua *et al.* (2009) on maize (*Zea mays*), rice (*Oryza sativa*) and wheat (*Triticum aestivum*) concluded that the dry weight of the selected plants were declined. This decline in dry weight was due to oxidative stress and inhibition of the assimilation nutrients etc.

The soil and various plant parts were analysis for the concentration of lead and chromium. The Table 1 is showing the concentration of lead and chromium in different parts of *T. patula*. It can be observed from the soil that it has high concentration of chromium as compared to lead. This high concentration of chromium maybe due to certain factors like bioavailability of metal in soil, plant species, soil PH, forms of metals, chelators and soil microbes (Kabata, 2011, Luo *et al.*, 2016; Khan *et al.*, 2026). The plant parts are also showing high concentration of chromium as compared to lead which makes *T. patula* feasible for the phytoremediation of chromium.

Bio accumulation coefficient (BAC) of *T. patula* was calculated which showed the feasibility of plant for the chromium non suitability for lead phytoremediation. The figure 4 manifested that the BAC of *T. patula* for lead (Pb) was less than one in all treated pots against the controls pots which have BAC value more than one. These results showed that the *T. patula* is not suitable for the remediation of Pb from soil except the control plants. These results have similarity with the experiments done by Zhao *et al.* (2012)

and Gopal and Rizvi, (2008) on rice (*Oryza sativa*) and maize (*Zea mays*) in which the BAC was observed less than one. Mishra *et al.* (2017), and Akinci *et al.* (2010) stated that plants like *Ricinus communis*, *Helianthus annuus* and *Brassica juncea* have BAC more than one which is contrast to the present investigation.

Similarly the Figure 5 showed that all the treated plants have BAC more than one while the control plants less than. These results proved the *T. patula* as feasible plant for the phytoremediation of chromium from the contaminated bodies. The same results were observed in the investigations on *Brassica juncea*, *Berkheya coddii* and *Leersia hexandra* conducted by Sajad *et al.* (2013), Robinson *et al.* (2003) and Zhang *et al.* (2007).

BCF (Bio concentration factor) of *T. patula* for both lead and chromium was calculated. The Figure 3.10 and Figure 6 showing the BAC values for both Pb and Cr. We can notice in the figure 3.10 that all the treated plants have BAC value less than one while control plants have more than one. The similar results were observed by Liu *et al.* (2008), Zhang *et al.* (2007) and Melo *et al.* (2009) in their experiments on *Zea mays*, *Eichhornia crassipes* and *Helianthus annuus* which manifested that BAC value is less than one. Figure 3.12 showed that Cr BCF Value more than one except the control plants. This may be due to high bioavailability of chromium in the soil. Experiments performed by Singh *et al.* (2018) and Meitei and Parsad, (2016) on *Eichhornia crassipes*, *Vetiveria zizanioides* and *Typha latifolia* showed the same results in which the plants have BCF value more than one.

Translocation factor (TF) is the ratio Pb and Cr in plant shoot as to its roots. The figure 7 showed the TF of *T. patula* for lead and chromium. The TF for lead is more than one in all plants while the in the case of Cr it was less than one. An investigation conducted by Cheng *et al.* (2012) for *Brassica rapa* in which it was noticed that the TF value for lead is more than one. Likewise a study was conducted by Sarvestava for the TF value of *Chrysopogon zizanioides* for Cr. The results showed that the TF value is less than one ranging between 0.3 to 0.7.

CONCLUSION

The present study demonstrated that the growth parameters of *T. patula* decreased progressively with increasing concentrations of Pb and Cr (100-500 ppm), indicating dose-dependent metal toxicity. Chromium concentrations in both soil and plant tissues were consistently higher than those of lead. The bioaccumulation coefficient (BAC) and bioconcentration factor (BCF) values for chromium exceeded one, confirming the strong accumulation capacity of *T. patula* and supporting its potential as an effective phytoremediator for chromium-contaminated soils. In contrast, the BAC and BCF values for lead were below one, indicating limited uptake and accumulation, and suggesting poor suitability of this species for lead phytoextraction. Based on these findings, *T. patula* appears to be more suitable for chromium remediation than for lead removal. Future research should focus on long-term field trials, assessment under variable soil conditions, and the exploration of plant-microbe interactions to enhance metal uptake efficiency. Such studies would help validate its practical applicability and improve phytoremediation performance under natural field conditions.

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