Assessing Phytoremediation Efficacy of Native Wetland Species for Heavy Metal Contamination Mitigation in Urban Areas

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Abstract. Urban environments are increasingly plagued by heavy metal pollution, primarily due to industrial run-off and urbanization, posing significant ecological and health threats. This study employs a combination of field trials and controlled laboratory experiments to evaluate the phytoremediation potential of native wetland plants in mitigating heavy metal concentrations in contaminated soils. Utilizing ICP-OES and statistical analysis tools, a significant reduction in heavy metal concentrations (lead, cadmium, and mercury) was observed, with efficiency rates ranging from 65% to 85% across different species. The findings reveal that Phragmites australis exhibited the highest accumulation capacity, suggesting its viability for urban soil remediation strategies. This research provides actionable insights for urban planners and ecologists seeking sustainable solutions to combat soil contamination.

Keywords: phytoremediation, heavy metals, urban ecology, native species, environmental sustainability, soil contamination, Phragmites australis, Juncus effusus

Introduction

Heavy metal contamination in urban environments has emerged as a pressing global issue, particularly in the context of diminishing green spaces and increasing industrial activities. The World Health Organization (WHO) has identified heavy metals like lead and cadmium

as significant contributors to environmental degradation and public health risks, especially in densely populated areas (WHO, 2024). Heavy metals enter the soil primarily through anthropogenic activities, leading to profound ecological imbalances and posing severe risks to human health through soil-to-food chain transfer. Despite extensive literature documenting the hazards of heavy metals, a critical gap remains in effective remediation strategies, particularly regarding the implementation of native species for phytoremediation. Previous studies have largely focused on conventional methods such as soil washing or chemical treatments (Smith et al., 2023; Jones & Brown, 2022), which are often economically unfeasible and environmentally damaging. Moreover, there is a noticeable lack of research specifically targeting the bioaccumulation capabilities of native wetland flora under urban conditions. The primary research questions guiding this study include: (1) What is the phytoremediation potential of specific native wetland plants in urban contaminated soils? and (2) How do different plant species compare in heavy metal absorption efficiencies? This article is structured as follows: Section 2 outlines the materials and methods, Section 3 presents the results and discussion, followed by conclusions and implications for urban ecological management.

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Methodology

The empirical investigation was conducted through a dual-phase approach involving field sampling and controlled laboratory experiments. Initially, soil samples were collected from five urban sites identified as heavy metal hotspots, and a comprehensive chemical analysis was performed using Inductively Coupled Plasma Optical Emission Spectrometry (ICP-OES, PerkinElmer, Optima 8000). Plant species selection was informed by previous ecological surveys and included Phragmites australis, Typha spp., and Juncus effusus. A split-plot design was employed for the greenhouse experiments, where individual pots (15 cm in diameter) were filled with contaminated soil (heavy metal concentration confirmed via preliminary ICP analysis) and planted with the selected species. Each treatment was replicated thrice, and plants were nurtured under controlled conditions (day/night cycles of 12 hours, temperature maintained at 25 ± 2 °C). Over an 8-week growth period, plant tissue was sampled bi-weekly, and metal accumulation was quantified via ICP-OES analysis of dried plant material. Statistical significance was assessed using ANOVA, with p-values < 0.05 considered significant. All data were analyzed using R (version 4.2.1) and the library 'ggplot2' for visual representation of results.

Results and Discussion

The results of the study indicate significant variations in the phytoremediation efficacy of the tested wetland species. Phragmites australis showed an average heavy metal uptake efficiency of 83%, followed by Typha spp. at 72% and Juncus effusus at 65%. Statistical analysis revealed p-values < 0.01 when comparing the highest and lowest performing

species, indicating robust differences in bioaccumulation capacities. Furthermore, environmental factors, including soil pH and moisture content, were found to significantly influence heavy metal availability, suggesting that optimal growing conditions can enhance remediation outcomes. The implications of these findings are profound for urban ecological management, as they highlight the potential for integrating native species into soil restoration practices. With urban areas facing increasing pressure from environmental pollutants, utilizing native wetland plants offers a sustainable, cost-effective strategy for mitigating heavy metal contamination without resorting to toxic chemical treatments. The comparison with conventional remediation methods further underscores the importance of ecological approaches in urban sustainability initiatives.

Conclusions

In conclusion, this study elucidates the significant role of native wetland species in mitigating heavy metal contamination in urban soils. The findings not only contribute to the existing literature on phytoremediation but also provide practical insights for urban planners and environmental managers seeking sustainable solutions. Future research should explore the long-term effects of community-based phytoremediation efforts and the interactions between different plant species and soil microbes to enhance remediation efficiency.

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Conflict of Interest

The authors declare no conflict of interest.

References

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