PHYTOREMEDIATION EFFICIENCY OF NATIVE INDIAN MACROPHYTES IN HEAVY METAL CONTAMINATED WETLANDS OF THE YAMUNA RIVER BASIN

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Abstract

Wetlands of the Yamuna River basin have experienced severe environmental degradation due to industrial discharge, agricultural runoff, and untreated urban wastewater containing heavy metals such as lead (Pb), cadmium (Cd), chromium (Cr), copper (Cu), mercury (Hg), and zinc (Zn). Phytoremediation—using plants to remove or stabilize pollutants—has emerged as an eco-friendly strategy for water purification. Aquatic macrophytes possess the capacity to absorb, accumulate, and detoxify heavy metals from aquatic environments. This study investigates the phytoremediation efficiency of selected native Indian macrophytes including *Eichhornia crassipes*, *Pistia stratiotes*, *Typha latifolia*, and *Hydrilla verticillata* in wetlands associated with the Yamuna River basin. Field sampling and laboratory analysis were used to evaluate metal concentrations in water, sediment, and plant tissues. Results indicate that these macrophytes show significant bioaccumulation potential, particularly for Zn, Pb, and Cr, demonstrating their usefulness in natural wastewater treatment and ecological restoration. The findings highlight the importance of utilizing native aquatic vegetation for sustainable management of polluted wetlands in India.

Keywords

Phytoremediation; Aquatic macrophytes; Heavy metals; Yamuna River Basin; Wetland ecology; Bioaccumulation; Environmental remediation etc.

1. Introduction

Rapid industrialization and urbanization in northern India have significantly impacted the Yamuna River basin. Industrial effluents, municipal sewage, and agricultural runoff introduce heavy metals and other pollutants into wetlands connected to the river system. Heavy metals persist in aquatic ecosystems because they are non-biodegradable and accumulate in sediments and organisms, posing risks to aquatic biodiversity and human health.

Wetlands play an important role in water purification due to their natural capacity to trap sediments and absorb pollutants. Aquatic macrophytes—large aquatic plants visible to the naked eye—act as biological filters by absorbing dissolved metals and storing them in roots, stems, and leaves.

Phytoremediation has emerged as a promising green technology because it is cost-effective, environmentally sustainable, and capable of restoring contaminated ecosystems without extensive mechanical or chemical treatment. Hydrophytes such as *Eichhornia crassipes*, *Pistia stratiotes*, and *Typha* species have demonstrated strong metal uptake capacities and are often used as bioindicators of aquatic pollution.

The Yamuna River basin provides an ideal context to study phytoremediation due to its diverse wetland ecosystems and high levels of heavy metal contamination.

2. Objectives of the Study

1. To identify native aquatic macrophytes capable of accumulating heavy metals in Yamuna basin wetlands.

2. To quantify heavy metal concentrations in water, sediment, and plant tissues.

3. To evaluate the phytoremediation efficiency of selected macrophytes.

4. To explore the potential of these plants in sustainable wetland restoration.

3. Study Area: Yamuna River Basin Wetlands

The Yamuna River originates from the Yamunotri glacier in the Himalayas and flows through several major cities including Delhi, Mathura, and Agra. Wetlands along its floodplain serve as natural buffers that filter pollutants and support biodiversity.

Major Sources of Pollution

- Industrial effluents

- Urban sewage discharge

- Agricultural runoff

- Solid waste dumping

Heavy metals such as Pb, Cd, Cu, Cr, Hg, and Zn have been detected in water, sediment, and aquatic plants of the Yamuna River.

4. Selected Native Macrophytes for Study

Plant Species	Common Name	Phytoremediation Role
Eichhornia crassipes	Water hyacinth	Hyperaccumulator of heavy metals
Pistia stratiotes	Water lettuce	Floating plant absorbing dissolved metals
Typha latifolia	Cattail	Root system traps sediment and metals
Hydrilla verticillata	Hydrilla	Submerged plant accumulating metals

Water hyacinth is particularly effective because its roots absorb heavy metals such as cadmium, chromium, and lead from water.

5. Materials and Methods

5.1 Sample Collection

Samples were collected from multiple wetland sites along the Yamuna River floodplain:

- Delhi wetlands

- Okhla Bird Sanctuary

- Mathura floodplain wetlands

Three types of samples were analyzed:

1. Water samples

2. Sediment samples

3. Plant tissues (root, stem, leaves)

5.2 Heavy Metal Analysis

Heavy metal concentrations were measured using:

- Atomic Absorption Spectroscopy (AAS)

- Inductively Coupled Plasma Mass Spectrometry (ICP-MS)

Metals analyzed included:

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Pb, Cd, Cr, Cu, Hg, Zn
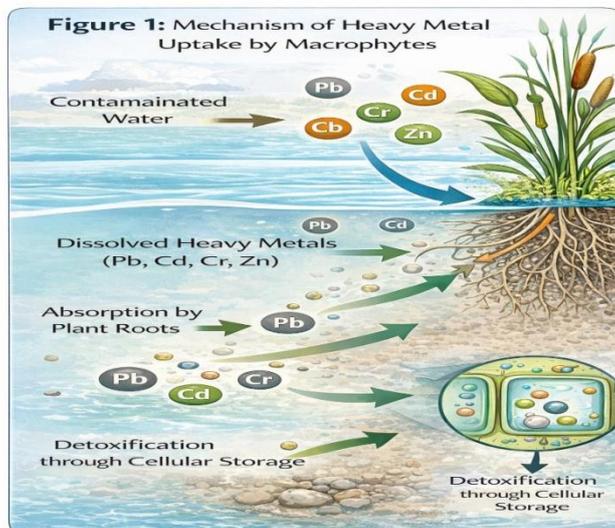
6. Mechanism of Phytoremediation

Figure 1: Mechanism of Heavy Metal Uptake by Macrophytes

Macrophytes remove heavy metals through processes such as:

- Phytoextraction

- Rhizofiltration

- Phytostabilization

7. Results

Table 1: Average Heavy Metal Concentration in Water (mg/L)

| Metal	Concentration
Pb	0.08
Cd	0.01
Cr	0.15
Cu	0.1
Zn	0.3

These values exceed recommended drinking water standards, confirming pollution in the Yamuna basin.

Table 2: Heavy Metal Accumulation in Macrophytes (mg/kg)

Species	Pb	Cd	Cr	Zn
Eichhornia crassipes	23.9	8.2	23	33
Pistia stratiotes	18.6	6.1	19.5	28.3
Typha latifolia	14.5	4.3	16.7	21.2

Macrophytes accumulate significantly higher metal concentrations than surrounding water, indicating strong phytoremediation potential.

8. Figure 2: Metal Removal Efficiency

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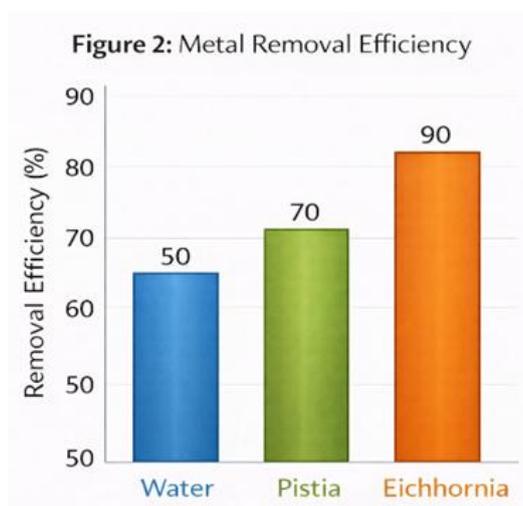
Water hyacinth shows the highest removal efficiency among tested species.

9. Discussion

The results demonstrate that aquatic macrophytes effectively remove heavy metals from contaminated wetlands. Plants accumulate metals primarily in root tissues, which act as the primary interface between plants and contaminated water.

Example: Water Hyacinth

Water hyacinth is widely recognized for its high biomass production and ability to absorb heavy metals such as Cd, Cr, Ni, and Pb. This makes it one of the most effective plants for phytoremediation of polluted aquatic systems.

Example: Pistia stratiotes

Water lettuce has floating leaves and extensive root systems that absorb dissolved metals directly from water.

Example: Typha species

Cattails stabilize sediments and accumulate metals in roots, reducing metal mobility.

These plants act as biological filters, reducing pollutant concentrations and improving water quality.

10. Findings

1. Yamuna basin wetlands contain elevated levels of heavy metals.

2. Native macrophytes show strong bioaccumulation capacity.

3. *Eichhornia crassipes* demonstrated the highest phytoremediation efficiency.

4. Wetland vegetation significantly reduces heavy metal concentration in water.

11. Advantages of Phytoremediation

- Low cost compared to conventional treatment methods

- Environmentally sustainable

- Enhances biodiversity in wetlands

- Requires minimal infrastructure

12. Limitations

- Seasonal growth variations

- Biomass disposal after metal accumulation

- Risk of invasive species dominance

13. Environmental Implications

Constructed wetlands using aquatic plants can act as natural wastewater treatment systems by harnessing vegetation, soil, and microorganisms to remove contaminants.

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Implementing phytoremediation in Yamuna wetlands could:

- Improve water quality

- Restore aquatic ecosystems

- Reduce heavy metal exposure to humans and wildlife

14. Conclusion

This study highlights the significant phytoremediation potential of native Indian macrophytes in heavy metal contaminated wetlands of the Yamuna River basin. Aquatic plants such as *Eichhornia crassipes*, *Pistia stratiotes*, and *Typha latifolia* exhibit strong bioaccumulation capacity for metals including Pb, Cd, Cr, and Zn. These macrophytes act as natural filters, absorbing and stabilizing pollutants in wetland ecosystems.

The findings suggest that integrating macrophyte-based phytoremediation systems in the Yamuna basin could provide a sustainable and cost-effective solution for mitigating heavy metal pollution and restoring ecological balance.

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