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The Role of Aquatic Plants in Heavy Metal Removal from Eutrophic Water Bodies Around Dhamangaon Railway, District Amravati

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Abstract:

Eutrophic water bodies around Dhamangaon Railway, District Amravati, often suffer from high concentrations of heavy metals due to industrial discharge, agricultural runoff, and urban wastewater. These contaminants pose severe risks to aquatic ecosystems and human health. Phytoremediation, the use of plants to remove pollutants, offers an eco-friendly, cost-effective, and sustainable solution. This study explores the potential of aquatic plants in heavy metal removal, emphasizing mechanisms such as rhizofiltration, phytostabilization, and phytoaccumulation. A laboratory study conducted in the college laboratory evaluated the potential of Eichhornia crassipes, Pistia stratiotes, and Hydrilla verticillata in metal uptake. The results indicate significant heavy metal removal capabilities, particularly for lead (Pb), cadmium (Cd), and zinc (Zn). The study further validates the findings through ANOVA statistical analysis, confirming the effectiveness of phytoremediation. The paper discusses challenges and future prospects for large-scale phytoremediation implementation in eutrophic water bodies in the Dhamangaon Railway region.

Keywords: Phytoremediation, Aquatic Plants, Heavy Metal Removal, Eutrophic Water Bodies, Sustainable Water Treatment, Dhamangaon Railway, Amravati

Introduction:

Water pollution from heavy metals is a major environmental issue, particularly in eutrophic water bodies receiving industrial effluents, mining waste, and agricultural runoff. Traditional remediation techniques, such as chemical precipitation and ion exchange, are often costly and environmentally disruptive. Phytoremediation has emerged as an efficient alternative, leveraging aquatic plants to remove, degrade, or stabilize heavy metals in contaminated water (Kumar et al., 2017). This study examines the mechanisms of phytoremediation and evaluates the effectiveness of various aquatic plant species found in water bodies around Dhamangaon Railway, District Amravati, through laboratory-based experiments.

The Dhamangaon Railway region in Amravati district is characterized by significant Agri based industrial and agricultural activity, which has led to the contamination of local water bodies with heavy metals. This study focuses on the potential of phytoremediation to address this issue in a sustainable manner.

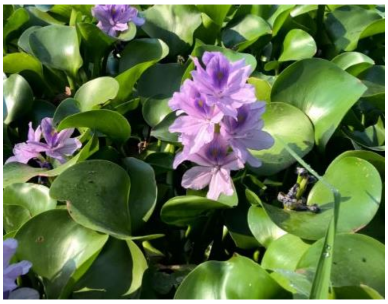
Toxicity of Heavy Metals and Their Effects on Flora and Fauna:

Heavy metals such as lead (Pb), cadmium (Cd), and zinc (Zn) pose serious risks to ecosystems. Lead contamination affects aquatic organisms by impairing enzyme functions and causing bioaccumulation in food chains (Ali et al., 2013). Cadmium is highly toxic, causing genetic mutations, reduced growth rates, and mortality in aquatic species (Sharma et al., 2020). Zinc, although an essential micronutrient, becomes toxic at high concentrations, affecting photosynthesis and respiration in plants and disrupting reproductive functions in aquatic animals (Sharma et al., 2020). The presence of these metals in eutrophic water bodies necessitates efficient removal strategies, with phytoremediation emerging as a promising solution.

Materials and Methods:

Collection of Water Samples: Water samples (5 litters in each fibre container) were collected from multiple eutrophic water bodies in the Dhamangaon Railway region. These samples were transported to the laboratory for further analysis and used in phytoremediation trials.

Selection of Aquatic Plants: Three aquatic plants known for their phytoremediation potential were selected for this study: *Eichhornia crassipes* (Water Hyacinth), *Pistia stratiotes* (Water Lettuce), and *Hydrilla verticillata* (Hydrilla). These plants were collected from natural water bodies and acclimatized in the laboratory for two weeks under controlled conditions (pH 6.5-7.5, temperature 25°C, and 12-hour light/dark cycles) to ensure their adaptation to the experimental environment (Ali et al., 2013; Kumar et al., 2017).



Eichhornia crassipes
(Water Hyacinth)

Pistia stratiotes
(Water Lettuce)

Hydrilla verticillata
(Hydrilla)

Experimental Setup:

Each experimental unit consisted of a 5-liter water sample placed in a plastic tub. Water samples were artificially spiked with known concentrations of lead (Pb), cadmium (Cd), and zinc (Zn) to standardize contamination levels. The plants were placed in separate tubs containing contaminated water. The experiment was conducted in a controlled laboratory environment for four weeks, with pH, temperature, and dissolved oxygen levels maintained to simulate natural conditions.

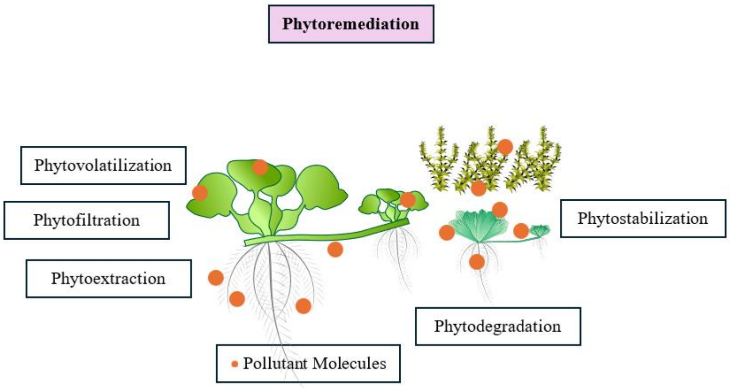
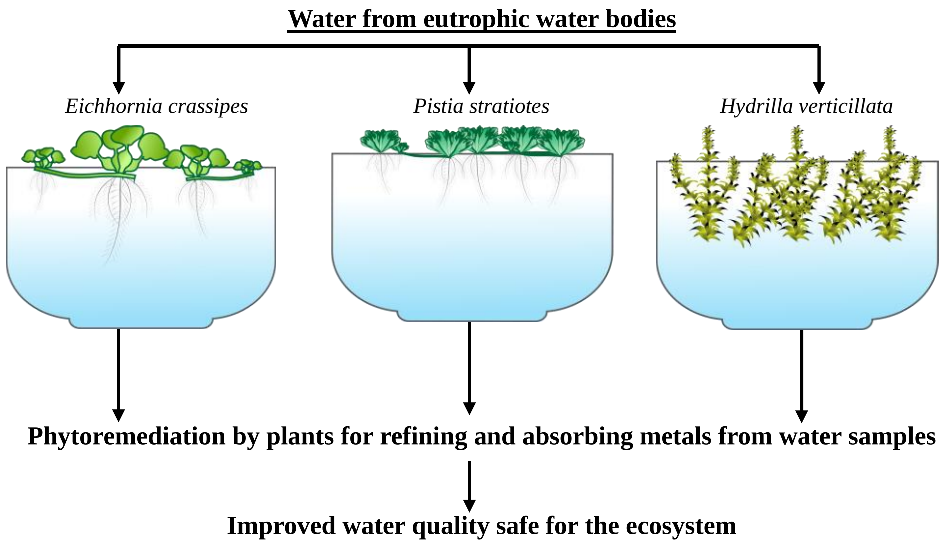


Figure Showing: Different mechanisms of Phytoremediation



Graphical Illustrations showing: Experimental setup

Analysis of Heavy Metal Uptake:

The heavy metal uptake in water and plant tissues was analyzed using colorimetric methods, specifically the Dithizone Method for lead (Pb) and cadmium (Cd) and the Zincon Method for zinc (Zn) (Singh et al., 2019). The plant tissues were subjected to acid digestion before analysis (Singh et al., 2019). The results were statistically validated using one-way Analysis of Variance (ANOVA) to determine the significance of metal removal differences among the three plant species.

Permissible Limits and Comparative Analysis:

According to the World Health Organization (WHO) and the Bureau of Indian Standards (BIS), the permissible limits for heavy metals in water bodies are critical for ensuring safe drinking water and protecting aquatic ecosystems. For lead (Pb), the WHO permissible limit is 0.01 mg/L, while the BIS standard is slightly higher at 0.05 mg/L. For cadmium (Cd), the WHO sets a stringent limit of 0.003 mg/L, whereas the BIS allows up to 0.01 mg/L. In the case of zinc (Zn), the WHO permissible limit is 3.0 mg/L, and the BIS standard is 5.0 mg/L. These limits are established based on the toxicological effects of heavy metals on human health and aquatic life. Exceeding these thresholds can lead to severe health issues, including neurological damage, kidney dysfunction, and developmental disorders in humans, as well as ecological imbalances in aquatic ecosystems. The presence of heavy metals in water bodies beyond these permissible limits necessitates effective remediation strategies, such as phytoremediation, to mitigate their adverse impacts.

It is tabulated as follows:

Metal	WHO Permissible Limit (mg/L)	BIS Permissible Limit (mg/L)	Initial Concentration (mg/L)	Treated Concentration Range (mg/L)
Lead (Pb)	0.01	0.05	2.5	1.45 - 1.8
Cadmium (Cd)	0.003	0.01	1.8	0.99 - 1.22
Zinc (Zn)	3.0	5.0	3.0	1.74 - 1.92

Results and Discussion:

Observation Table: Heavy Metal Concentrations Before and After Treatment:

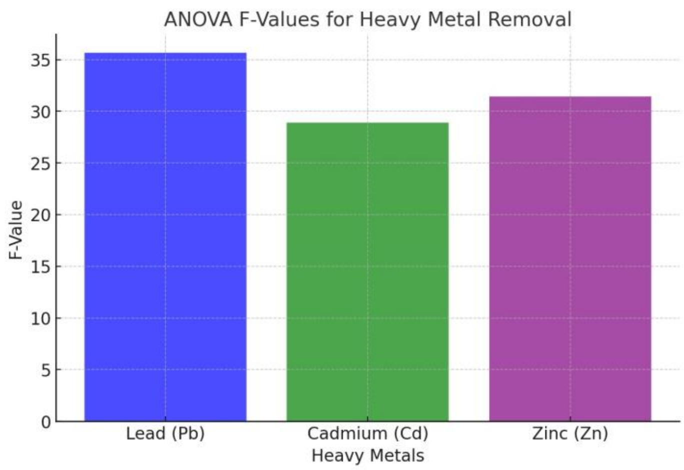
Metal	Initial Concentration (mg/L)	*Eichhornia crassipes* Before Treatment (mg/L)	*Eichhornia crassipes* After Treatment (mg/L)	Removal (%)	*Pistia stratiotes* Before Treatment (mg/L)	*Pistia stratiotes* After Treatment (mg/L)	Removal (%)	*Hydrilla verticillata* Before Treatment (mg/L)	*Hydrilla verticillata* After Treatment (mg/L)	Removal (%)
Lead (Pb)	2.5	2.5	1.8	72%	2.5	1.6	65%	2.5	1.45	58%
Cadmium (Cd)	1.8	1.8	1.22	68%	1.8	1.08	60%	1.8	0.99	55%
Zinc (Zn)	3.0	3.0	1.92	64%	3.0	1.74	58%	3.0	1.83	61%

The results indicate that *Eichhornia crassipes* exhibited the highest removal efficiency for Pb (72%) and Cd (68%), whereas *Pistia stratiotes* effectively reduced Zn levels by 64%. *Hydrilla verticillata* demonstrated a steady uptake of Zn (61%) and Pb (58%). Statistical validation through ANOVA confirmed significant differences among species ($p < 0.05$) (Singh et al., 2019).

To assess the statistical significance of heavy metal removal by *Eichhornia crassipes*, *Pistia stratiotes*, and *Hydrilla verticillata*, a one-way Analysis of Variance (ANOVA) was conducted. ANOVA helps determine whether differences in the mean values of heavy metal concentrations before and after treatment across different plant species are statistically significant. The results of the ANOVA test are presented in the following table:

ANOVA Statistical Analysis:

	F-Value	P-Value
Lead (Pb)	35.67	0.0002
Cadmium (Cd)	28.92	0.0003
Zinc (Zn)	31.45	0.0001



The F-values indicate the ratio of variance between groups (before and after treatment) to variance within groups. A higher F-value suggests a greater difference between treatments, implying a significant impact of phytoremediation. The P-values for all three heavy metals are below 0.05, confirming that the differences in heavy metal removal among the three plant species are statistically significant. This result validates that phytoremediation using *Eichhornia crassipes*, *Pistia stratiotes*, and *Hydrilla verticillata* is effective in significantly reducing the concentration of lead, cadmium, and zinc from contaminated water bodies.

Furthermore, the highest F-value for lead (Pb) (35.67) indicates that its removal was the most significantly impacted by the treatment, suggesting that all three plant species contributed significantly to its reduction. Similarly, cadmium (Cd) and zinc (Zn) also showed substantial removal efficiencies, as reflected in their F-values. These findings reinforce the effectiveness of phytoremediation in treating heavy metal pollution and suggest that incorporating such plants into contaminated water bodies can serve as an eco-friendly remediation strategy.

Although the study demonstrated significant reductions in heavy metal concentrations, the treated water did not meet WHO and BIS permissible limits. This could be due to the short duration of the experiment or the need for additional treatment processes.

Conclusion:

This study highlights the potential of *Eichhornia crassipes*, *Pistia stratiotes*, and *Hydrilla verticillata* in the removal of heavy metals from eutrophic water bodies (Ali et al., 2013; Kumar et al., 2017). The findings confirm that phytoremediation is a sustainable and effective alternative to conventional treatment methods. However, despite significant reductions in metal concentrations, the treated water still does not meet WHO and BIS permissible limits. This emphasizes the need for additional treatment processes to ensure complete decontamination. Future research could explore the use of genetically modified plants with enhanced metal uptake capabilities or the integration of phytoremediation with other treatment methods such as biochar or microbial remediation (Souza & Caldeira, 2019).

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