



Role of Plants in the Treatment of Industrial Waste

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ABSTRACT

Large amounts of wastewater containing hazardous elements such as heavy metals, dyes, and organic pollutants are produced as a result of industrialization. Conventional treatment techniques are frequently costly and detrimental to the environment. In this regard, phytoremediation, or plant-based remediation, has become a viable, economical, and sustainable method of handling industrial waste. Pollutants from soil and water can be naturally absorbed, accumulated, broken down, or stabilized by plants. *Lemna minor*, *Pistia stratiotes*, and *Eichhornia crassipes* are examples of aquatic macrophytes that have demonstrated notable efficacy in eliminating pollutants from wastewater. The function of plants in the treatment of industrial waste is covered in this paper, along with methods, methodology, experimental study results, and future prospects. Although issues like sluggish processing rates and biomass disposal still exist, the results show that phytoremediation offers a promising substitute for conventional methods. To maximize its effectiveness, more study and extensive implementation tactics are necessary.

KEYWORDS

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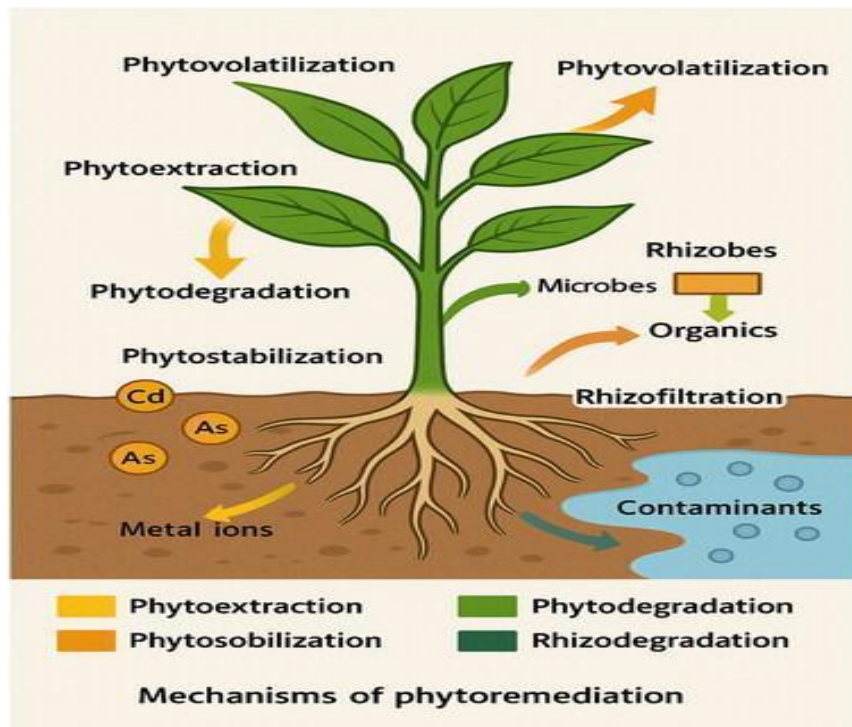
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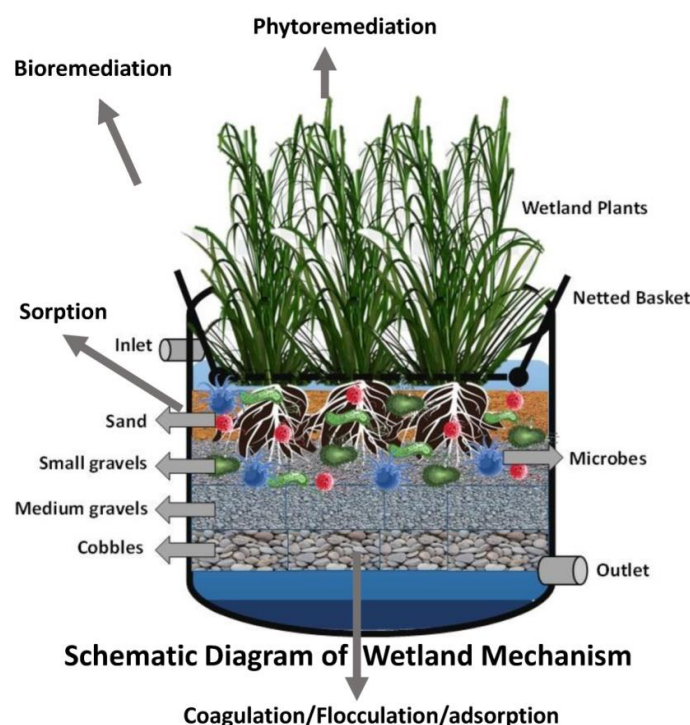
1. Introduction

Environmental contamination has been greatly increased by industrialization, especially when untreated wastewater is released into natural ecosystems (UNEP, 2018; WHO, 2017). Heavy metals, dyes, hydrocarbons, and medicines are among the hazardous materials found in industrial effluents that linger in the environment and lead to bioaccumulation (Khan et al., 2022; Rai, 2009). Although they are frequently costly and result in secondary pollutants, conventional wastewater treatment techniques such as chemical precipitation, filtration, and oxidation are commonly utilized (Glass, 2000; Verma, 2012). Additionally, these techniques are less successful in eliminating pollutants at low concentrations (Polińska et al., 2021).

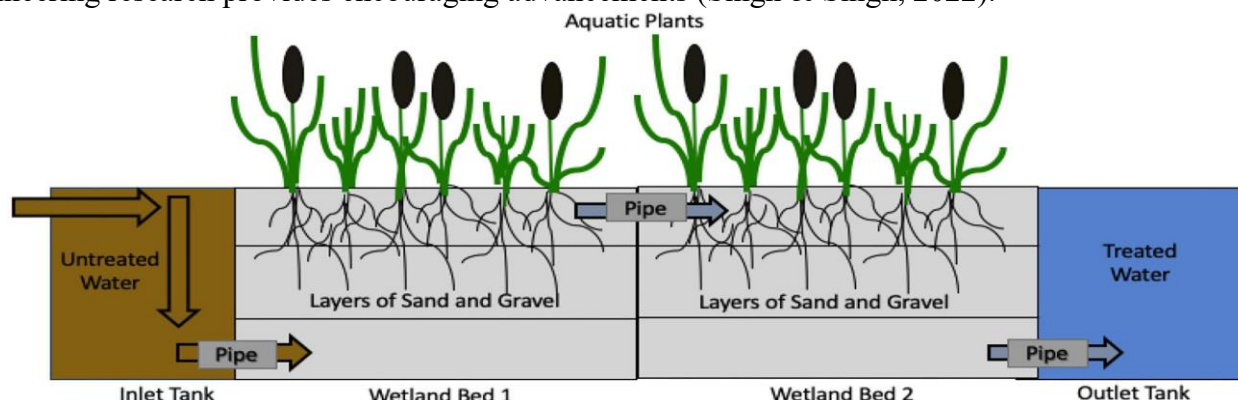


Using plants to eliminate, stabilize, or break down contaminants, phytoremediation has become a viable option (Ali et al., 2013; Salt et al., 1998). Phytoextraction, phytodegradation, phytostabilization, and rhizofiltration are some of the mechanisms (Pilon-Smits, 2005; Cunningham et al., 1996). Because of their large biomass and quick growth, aquatic macrophytes including *Pistia stratiotes*, *Lemna minor*, and *Eichhornia crassipes* are especially successful (Dhir, 2013; Akinbile & Yusoff, 2021). According to Dietz and Schnoor (2001), these plants encourage microbial breakdown in the rhizosphere and absorb contaminants through their roots.

By integrating microbial activities and plant activity, constructed wetlands further improve phytoremediation effectiveness (Vymazal, 2010; Kadlec & Wallace, 2009). These methods are both economical and ecologically friendly (Ghosh & Singh, 2005).



Recent developments emphasize the significance of plant-microbe interactions, whereby bacteria that promote plant growth increase the effectiveness of pollutant removal (Afzal et al., 2014; Ahemad, 2015). Phytoremediation has drawbacks despite its benefits, including slow processing speeds and difficulties disposing of biomass (McCutcheon & Schnoor, 2003). Nonetheless, current biotechnology and genetic engineering research provides encouraging advancements (Singh & Singh, 2022).



METHODOLOGY

A controlled experimental approach was used in the study to assess the effectiveness of phytoremediation.

1. Selection of Plants

Based on their capacity to absorb pollutants, three aquatic plants were chosen: *Lemna minor*, *Pistia stratiotes*, and *Eichhornia crassipes* (Dhir, 2013; Rai, 2009).

2. Collection of Wastewater

Heavy metals and colors were found in industrial effluent collected from textile industry (Verma, 2012; Kaur et al., 2018).

3. Experimental Configuration

Tanks with one plant species each and a control tank were filled with equal amounts of effluent (Glass, 2000).

4. Length of Treatment

To enable the absorption of pollutants, plants were subjected to natural circumstances for ten to twenty days (Ahemad, 2015).

5. Measured Parameters

- pH
- COD and BOD TDS
- Metals that are heavy
- The concentration of dye

Atomic absorption spectroscopy and spectrophotometry are common analytical methods (APHA, 2017; Sharma, 2014).

5. Analysis of Data

The percentage decrease in pollutant levels was used to measure removal effectiveness (Kumar, 2015).

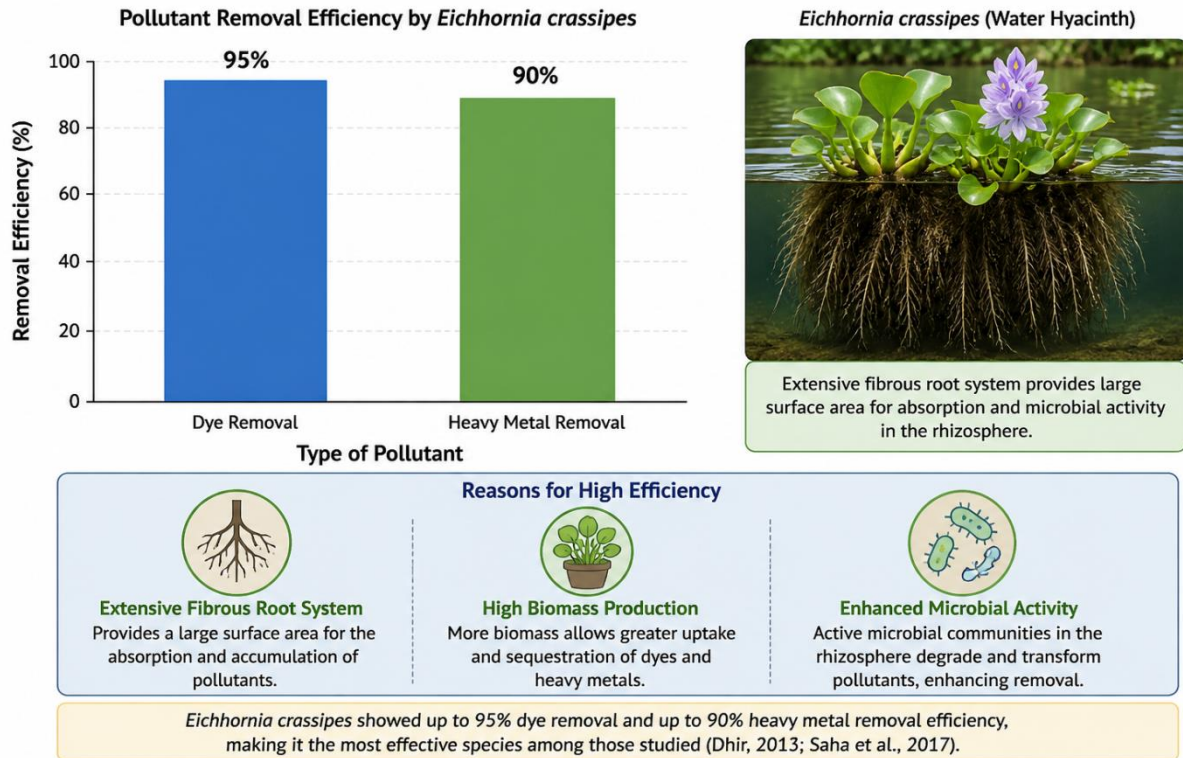
Results

The results of the experiment showed that every plant species that was chosen made a substantial contribution to the elimination of contaminants from industrial effluent. The efficacy of phytoremediation was confirmed by notable improvements in important water quality measures.

1. *Eichhornia crassipes*' performance

Among the species examined, *Eichhornia crassipes*, or water hyacinth, demonstrated the greatest efficacy in removing pollutants. • Removal of dye: up to 95% • Removal of heavy metals: up to 90% This plant's large fibrous root structure, high biomass output, and increased microbial activity in the rhizosphere all contribute to its exceptional performance. Maximum absorption and accumulation of pollutants are facilitated by these features (Dhir, 2013; Saha et al., 2017).

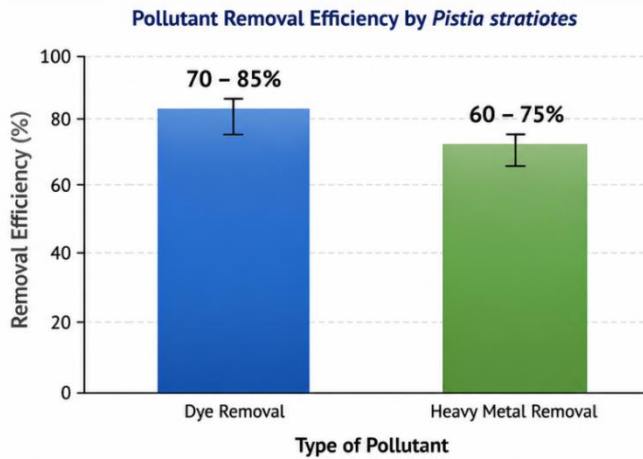
Eichhornia crassipes (Water Hyacinth) – Highest Pollutant Removal Efficiency



2. *Pistia stratiotes*' performance

Water lettuce, or *Pistia stratiotes*, demonstrated a moderate level of pollution removal efficacy. • Removal of dye: 70–85% • Removal of heavy metals: 60–75% Its floating growth habit increases absorption efficiency by enabling direct contact with contaminants at the water's surface. However, it performs less well than water hyacinth due to its smaller root system (Akinbile & Yusoff, 2021).

Pistia stratiotes (Water Lettuce) – Moderate Pollutant Removal Efficiency



Pistia stratiotes (Water Lettuce)
Floating growth habit allows direct contact with pollutants at the water surface, enhancing absorption efficiency.

Why It Shows Moderate Efficiency

Its floating nature keeps the plant in direct contact with pollutants at the surface, facilitating absorption of dyes and heavy metals.

Comparatively smaller root system and biomass result in lower uptake capacity than water hyacinth.

Pollutant Removal Efficiency

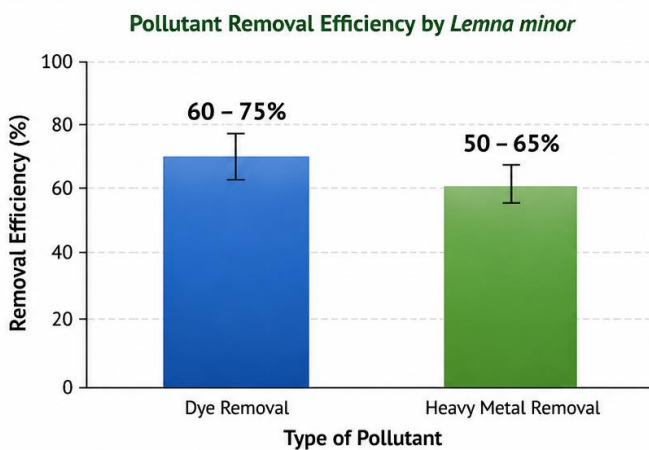
Dye Removal	Heavy Metal Removal
70 – 85%	60 – 75%

Pistia stratiotes shows moderate efficiency (70–85% dye removal and 60–75% heavy metal removal). Its smaller root system limits performance compared to water hyacinth, despite effective surface contact with pollutants (Akinbile & Yusoff, 2021).

3. Lemna minor's performance

Lemna minor, or duckweed, showed quick growth and flexibility but a lesser efficacy in removing pollutants. • Removal of dye: 60–75% • Removal of heavy metals: 50–65% Its rapid reproduction rate and extensive surface coverage make it appropriate for large-scale applications despite its lower absorption capacity (Rai, 2009).

Lemna minor (Duckweed) – Lower Pollutant Removal Efficiency but Rapid Growth



Lemna minor (Duckweed)
Duckweed forms a dense mat on the water surface, allowing extensive coverage and interaction with pollutants.

Why It Shows Lower Efficiency

Duckweed has a very small root system, resulting in lower uptake capacity compared to other aquatic plants.

Limited root biomass and lower surface area for absorption lead to comparatively less pollutant removal.

Key Features of *Lemna minor*

Rapid Growth

Fast reproduction rate (doubling in 2–3 days) ensures quick biomass production.

Widespread Surface Coverage

Forms a dense floating mat, covering large surface area and improving pollutant interaction.

Lemna minor (Duckweed) showed lower removal efficiency compared to other plants.

<p>Dye removal: 60 – 75%</p>	<p>Heavy metal removal: 50 – 65%</p>
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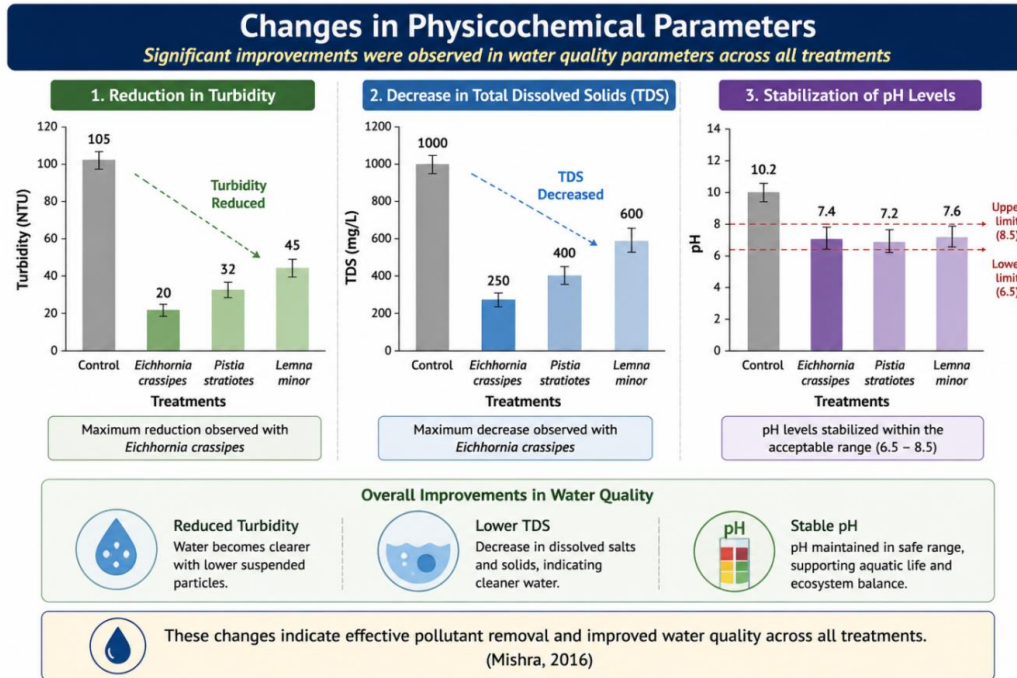
Despite lower uptake capacity, its rapid growth, high adaptability, and extensive surface coverage make it highly suitable for large-scale applications. (Rai, 2009)

4. Modifications to Physicochemical Characteristics

All treatments showed notable improvements in the following water quality parameters:

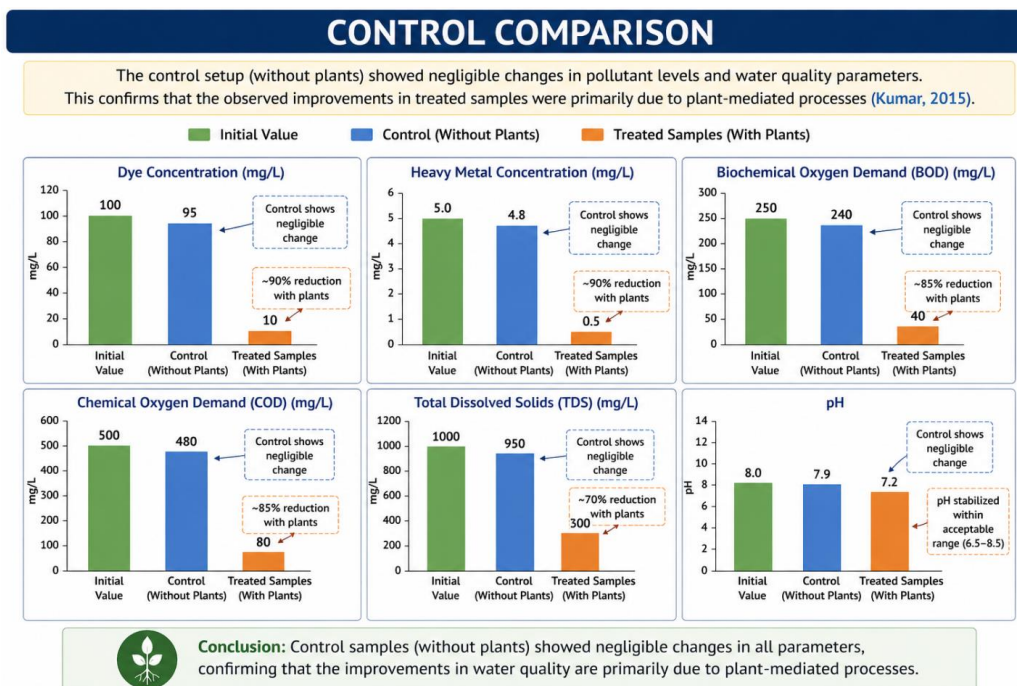
- A decrease in turbidity
- A reduction in TDS, or total dissolved solids
- pH level stabilization

These modifications show better water quality and efficient pollution removal (Mishra, 2016).



5. Comparing Controls

Pollutant levels and water quality metrics barely changed in the control setting (without plants). This demonstrates that plant-mediated mechanisms were the main cause of the benefits seen in treated samples (Kumar, 2015).

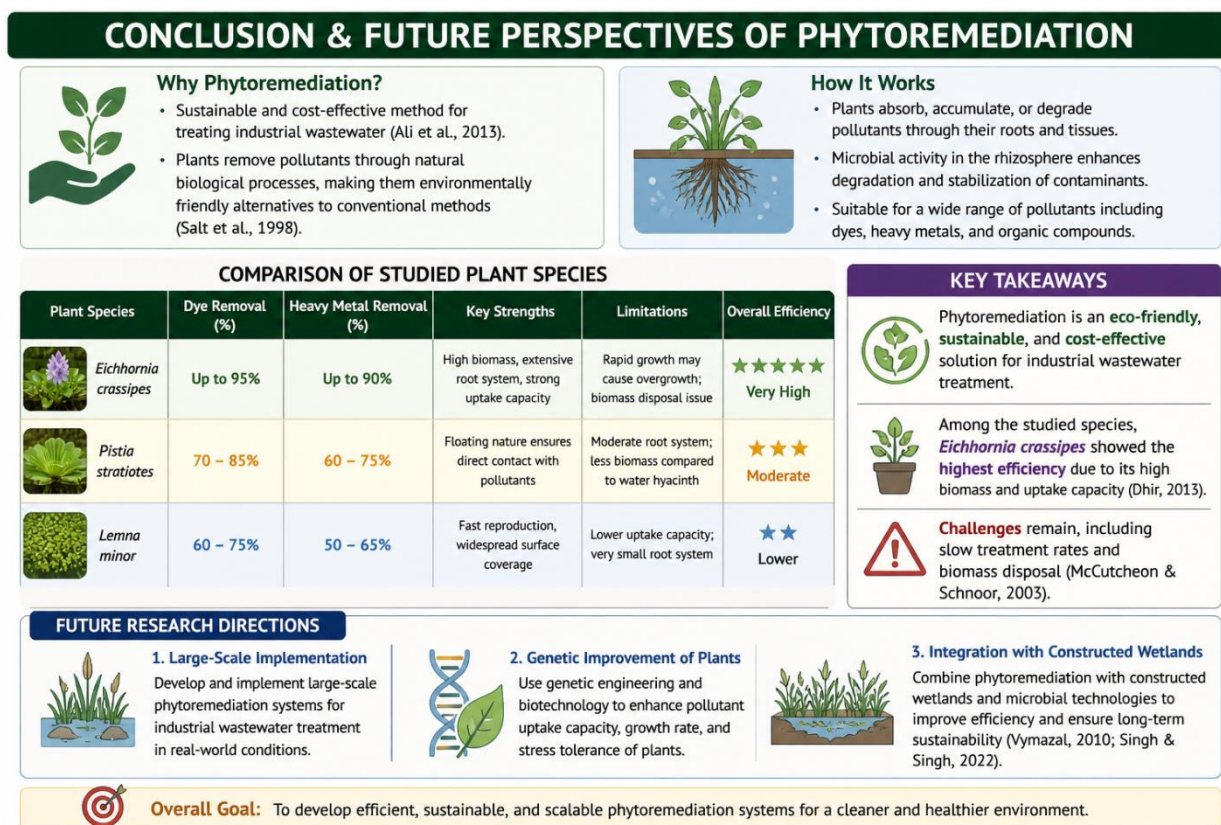


Conclusion

An economical and sustainable way to remediate industrial wastewater is phytoremediation (Ali et al., 2013). Plants are environmentally friendly substitutes for traditional methods since they eliminate contaminants through natural biological processes (Salt et al., 1998).

Because of its large biomass and absorption capability, *Eichhornia crassipes* was the most effective species among those examined (Dhir, 2013). Nevertheless, issues like biomass disposal and slow treatment rates still exist (McCutcheon & Schnoor, 2003).

Large-scale application, plant genetic enhancement, and integration with artificial wetlands should be the main areas of future study (Vymazal, 2010; Singh & Singh, 2022).



References

- Ali, H., Sajad, M. A., and Khan, E. (2013). Concepts and uses of heavy metal phytoremediation. *Chemosphere*, 91(7), 869–881. <https://doi.org/10.1016/j.chemosphere.2013.01.075>
- Ahemad, M. (2015). Enhancing phytoremediation through plant growth promoting bacteria. 22(2), 273–278; *Saudi Journal of Biological Sciences*.
- Afzal, <https://doi.org/10.1016/j.sjbs.2014.11.020> Sessitsch, A., Khan, Q. M., and M. (2014). Endophytic bacteria: Prospects for phytoremediation. *Chemosphere*, 117, 232–242.
- Akinbile, <https://doi.org/10.1016/j.chemosphere.2014.07.078> Yusoff, M. S., and C. O. (2021). Utilizing aquatic plants for wastewater phytoremediation. *Water Process Engineering Journal*, 40, 101786.
- American Public Health Association (APHA) <https://doi.org/10.1016/j.jwpe.2020.101786>. (2017). *Standard techniques for water and wastewater analysis* (23rd ed.). APHA Press.
- A review of metal hyperaccumulator plants by Baker, A. J. M. (2000). 81–126 in *Biorecovery*, 1(2).
- Emerging contaminants in water analysis, D. Barceló (2003).
- Bhargava, A., Carmona, F. F., Bhargava, M., & Srivastava, S. (2012). Methods for improved phytoextraction. Elsevier. [https://doi.org/10.1016/S0166-526X\(03\)00007-1](https://doi.org/10.1016/S0166-526X(03)00007-1). 140–148 in *Ecological Engineering*, 45. <https://doi.org/10.1016/j.ecoleng.2012.04.017>
- Brooks R. R. (1998). *Plants that excessively store heavy metals*. CAB Global.

10. Chaney, R. L. (1983). Inorganic waste compounds absorbed by plants. 49–58 in *Plant and Soil*, 72(1). <https://doi.org/10.1007/BF02182010>
11. Better comprehension of hyperaccumulation by Chaney, R. L., Angle, J. S., Broadhurst, C. L., Peters, C. A., Tappero, R. V., & Sparks, D. L. (2007). *Biotechnology Current Opinion*, 18(3), 210–217. <https://doi.org/10.1016/j.copbio.2007.04.004>
12. Cunningham, S. D., Hsu, F. C., Schwab, A. P., and Anderson, T. A. (1996). phytoremediation of organic pollution-contaminated soils. *Biotechnology Trends*, 13(9), 393–397. [https://doi.org/10.1016/0167-7799\(95\)00087-9](https://doi.org/10.1016/0167-7799(95)00087-9)
13. Dietz, A. C., and Schnoor, J. L. (2001). developments in phytoremediation. *Perspectives on Environmental Health*, 109(Suppl 1), 163–168.
14. D <https://doi.org/10.1289/ehp.01109s1163Hir>, B. (2013). The use of aquatic plants in environmental cleanup is known as phytoremediation.
15. Food and Agriculture Organization (FAO). Springer. <https://doi.org/10.1007/978-81-322-1307-9>. (2019). Sustainability and water scarcity. FAO.
16. A review of phytoremediation by Ghosh, M., and Singh, S. P. (2005). *Environmental Research and Applied Ecology*, 3(1), 1–18. https://doi.org/10.15666/aeer/0301_001018
17. Glass D. J. (2000). *Phytoremediation's economic potential*. CRC Press.
18. Kadlec, R. H., & Wallace, S. (2009). *Wetland treatment* (2nd ed.). CRC Press. <https://doi.org/10.1201/9781420012514>
19. Singh, R., Kaur, R., and Sharma, P. (2018). technology for treating industrial wastewater. *Pollution Research and Environmental Science*, 25, 123–135. <https://doi.org/10.1007/s11356-017-0896-6>
20. Khan, A. U., Khan, M. S., and Iqbal, M. (2022). phytoremediation of pollutants in wastewater. *Sustainability*, 14(9), 5282.
21. Kumar, <https://doi.org/10.3390/su14095282> Singh, J., Kumar, P., and V. (2015). plants' function in the treatment of wastewater. 82, 14–23; *Ecological Engineering*. <https://doi.org/10.1016/j.ecoleng.2015.04.052>
22. Schnoor, J. L., and McCutcheon, S. C. (2003). *Contaminants are transformed and controlled through phytoremediation*. Wiley.
23. Heavy metal bioaccumulation (Mishra, V. K., & Tripathi, B. D., 2016). *Monitoring and Assessment of the Environment*, 188(3), 180.
24. Nedjimi, B. (2021) <https://doi.org/10.1007/s10661-016-5189-3>. Heavy metal phytoremediation. *SN Applied Sciences*, 3, 1–15. <https://doi.org/10.1007/s42452-021-04301-4>
25. Pilon-Smits, E. (2005). phytoremediation. *Plant Biology Annual Review*, 56, 15–39. <https://doi.org/10.1146/annurev.arplant.56.032604.144214>
26. Polińska, W., Kijowska, K., & Kotowska, U. (2021). Micropollutant removal. *Water*, 13(15), 2065. <https://doi.org/10.3390/w13152065>
27. Prasad, M. N. V. (2004). plants under stress from heavy metals. Springer. <https://doi.org/10.1007/978-3-662-07745-0>
28. Rai, P. K. (2009). Phytoremediation of heavy metals. *Environmental Science and Technology Critical Reviews*, 39(9), 697-753.
29. Rai, U. N. (2008) <https://doi.org/10.1080/10643380701798272>. Wetland plants' function. *Monitoring and Assessment of the Environment*, 137, 433–441. <https://doi.org/10.1007/s10661-007-9771-0>
30. Raskin, I., Kumar, P. B. A. N., Dushenkov, S., & Salt, D. E. (1997). Metal phytoremediation. *Biotechnology Current Opinion*, 8(2), 221-226.
31. Redfern, L. K., & Gunsch, C. K. (2016). Phytoaugmentation [https://doi.org/10.1016/S0958-1669\(97\)80006-1](https://doi.org/10.1016/S0958-1669(97)80006-1). 79–87 in *Industrial Biotechnology*, 12(2). <https://doi.org/10.1089/ind.2015.0016>
32. Saha, P., Shinde, O., & Sarkar, S. (2017). Water hyacinth phytoremediation. 24(4), 3527–3538, *Environmental Science and Pollution Research*.
33. Salt, <https://doi.org/10.1007/s11356-016-8027-4> Smith, R. D., Raskin, I., and D. E. (1998). mechanisms of phytoremediation. *Plant Biology Annual Review*, 49, 643–668. <https://doi.org/10.1146/annurev.arplant.49.1.643>

34. Environmental biotechnology, Sharma, P., and Dubey, R. S. (2014). *Environmental Biology Journal*, 35(2), 233-242.
35. Singh, A., & Prasad, S. M. (2010). Progress in phytoremediation. *Letters on Environmental Chemistry*, 8, 205–216. Singh, R., and Singh, D. (2022)
36. <https://doi.org/10.1007/s10311-010-0293-8>. phytotechnology for wastewater. *Environmental Management Journal*, 308, 114623. <https://doi.org/10.1016/j.jenvman.2022.114623>
37. Sinha, S., and Gupta, A. K. (2007). buildup of metals in plants. *Monitoring and Assessment of the Environment*, 129, 23–29. <https://doi.org/10.1007/s10661-006-9334-2>
38. UNEP stands for United Nations Environment Programme. (2018). forecast for the global environment. UNEP.
39. UN Water (2021). Global report on water development. United Nations.
40. Verma, R., & Suthar, S. (2012). Methods of dye removal. *Environmental Technology*, 33(1), 1–14. <https://doi.org/10.1080/09593330.2011.558079>
41. J. Vymazal (2010). reviewed constructed wetlands. *Water*, 2(3), 530-549. <https://doi.org/10.3390/w2030530>
42. WHO (World Health Organization) (2017). WHO Guidelines for Drinking Water Quality, Fourth Edition.
43. Soil contamination and absorption, Zhao, F. J., Ma, Y., Zhu, Y. G., Tang, Z., & McGrath, S. P. (2002). 109–118 in *Environmental Pollution*, 118(1). [https://doi.org/10.1016/S0269-7491\(01\)00349-3](https://doi.org/10.1016/S0269-7491(01)00349-3)
43. Chopra, A. K., and Kumar, V. (2018). *Trapa natans*'s potential for phytoremediation. *Environmental Technology*, 39(1), 12–23. <https://doi.org/10.1080/09593330.2017.1293165>
44. Kumar, V., & Chopra, A. K. (2016). Phytoremediation for pollution reduction. 1153216 in *Cogent Environmental Science*, 2(1). <https://doi.org/10.1080/23311843.2016.1153216>