

Phytoremediation of Textile Effluent from Navi Mumbai MIDC Zone Using *Eichhornia crassipes* (Water Hyacinth)

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ABSTRACT

Textile effluents from industrial hubs such as Navi Mumbai MIDC are complex, chemically diverse wastewaters characterized by high organic loads (COD, BOD), suspended and dissolved solids (TSS, TDS), synthetic dyes, and trace heavy metals. In this study, the phytoremediation potential of *Eichhornia crassipes* (water hyacinth) was evaluated under controlled laboratory-scale batch conditions. Raw effluent was treated in 10-L reactors containing 300 g fresh biomass per unit, with parallel plant-free controls. Water quality parameters including pH, COD, BOD₅, TSS, TDS, dissolved oxygen (DO), colour, and selected heavy metals (Cr, Fe, Zn) were monitored at 0, 7, 15, and 30 days. After 30 days, treatment systems demonstrated substantial improvements in effluent quality: COD decreased from 1200 ± 35 to 360 ± 22 mg/L (70%), BOD₅ from 500 ± 20 to 140 ± 12 mg/L (72%), and TSS from 600 ± 28 to 120 ± 10 mg/L (80%), whereas control systems exhibited only minor reductions. Dissolved oxygen increased from 0.6 ± 0.05 to 4.2 ± 0.15 mg/L in planted systems, and pH shifted toward neutrality. Heavy metals showed significant removal from water (Cr, Fe, Zn: 70–76%), with roots accumulating higher concentrations than shoots (Cr: 420 mg/kg⁻¹; Fe: 5200 mg/kg⁻¹; Zn: 350 mg/kg⁻¹), indicating root-mediated sequestration and rhizofiltration as primary mechanisms. The combined effects of physical filtration, rhizosphere-enhanced microbial degradation, and adsorption/uptake of organics and metals highlight the efficacy of *E. crassipes* as a low-cost, environmentally benign treatment option. These findings support the application of water hyacinth for pre-treatment or polishing of textile effluents in industrial zones, offering potential to enhance the performance of centralized effluent treatment plants.

Keywords- *Eichhornia crassipes*, textile effluent, phytoremediation, COD, BOD, TSS, heavy metals, Navi Mumbai MIDC.

I. INTRODUCTION

Textile effluents are chemically diverse and highly variable industrial waste streams generated at multiple stages of fabric processing, including desizing, scouring, bleaching, dyeing, printing, and finishing. These effluents are typically characterized by extremely high organic loads, often reflected in elevated Chemical

Oxygen Demand (COD) and Biochemical Oxygen Demand (BOD) values due to the presence of surfactants, starches, waxes, lubricants, sizing agents, and dye intermediates. In addition, textile wastewater contains significant levels of Total Suspended Solids (TSS) from fibers, lint, and undissolved dye particles, as well as high Total Dissolved Solids (TDS) resulting from salts such as sodium chloride and sodium sulfate used extensively

during dye fixation. The wastewater further contains synthetic dyestuffs, many of which are persistent, aromatic, and resistant to biodegradation, imparting strong coloration and reducing light penetration in receiving waters.

Trace levels of heavy metals such as chromium, copper, nickel, and zinc—introduced from pigments, mordants, and auxiliary chemicals—may also be present and can pose long-term ecological risks. Untreated or inadequately treated textile effluent can cause severe deterioration of aquatic ecosystems, leading to eutrophication, reduced dissolved oxygen (DO), toxicity to aquatic organisms, bioaccumulation of hazardous contaminants, and impairment of water for domestic, irrigation, and industrial uses. In industrial hubs such as Navi Mumbai MIDC, textile units, dyeing workshops, and related wet-processing industries collectively generate substantial effluent volumes. Although these are partly routed to Common Effluent Treatment Plants (CETPs), the high influx of concentrated wastewater often necessitates on-site pretreatment or polishing treatments to ensure compliance with regulatory discharge standards prescribed by agencies such as the Central Pollution Control Board (CPCB) and Maharashtra Pollution Control Board (MPCB). Inefficient pretreatment at the unit level places additional burden on CETPs and contributes to fluctuating treatment performance, making low-cost supplementary treatment options highly desirable. Among various emerging sustainable treatment approaches, phytoremediation has gained significant attention. Free-floating aquatic macrophytes, particularly *Eichhornia crassipes* (water hyacinth), have been widely investigated due to their exceptional growth rate, large root surface area, and high biomass productivity, which enable efficient absorption, adsorption, transformation, and stabilization of pollutants.

The plant's fibrous root system facilitates the entrapment of suspended solids and serves as a substrate for biofilm development, thereby enhancing microbial degradation of organic matter. Numerous laboratory, mesocosm, and pilot-scale studies have demonstrated the ability of *E. crassipes* to substantially reduce COD, BOD, TSS, color, nutrients (nitrogen and phosphorus), and selected heavy metals in textile effluents.

Reported removal efficiencies, however, vary widely depending on factors such as initial pollutant load, hydraulic retention time, plant density, climatic conditions, and effluent composition, especially dye types and salt concentrations. Despite these variations, the overall evidence indicates that *E. crassipes* offers a cost-effective, environmentally benign, and scalable treatment option, particularly suitable as a pre-treatment or polishing stage in industrial zones like Navi Mumbai MIDC, where decentralized wastewater improvement can significantly enhance the overall performance of CETP systems. This study aims to (1) evaluate the removal efficiency of *E. crassipes* for typical textile effluent

parameters under controlled experimental system conditions (2) quantify heavy metal uptake into plant tissues; and (3) discuss operational considerations for scaling and integration with CETP systems in industrial zones.

II. MATERIALS AND METHODS

Plant material and acclimatization

Healthy *Eichhornia crassipes* plants were sourced from uncontaminated freshwater bodies and acclimatized in tap water for 7 days under laboratory conditions (temperature 25 ± 2 °C, 12:12 light:dark) to remove epiphytes and allow stabilization. Prior to the experiment, plants were rinsed with deionized water

Effluent source and characterization

The textile effluent was collected from a dyeing and finishing unit in the Navi Mumbai MIDC industrial area. A composite grab sample was prepared by mixing sub-samples taken during routine operation. Samples were collected in clean HDPE containers, transported on ice, and stored at 4 °C, and all experiments were started within 48 hours of collection.

Study design

A laboratory batch experiment was conducted to evaluate the ability of *Eichhornia crassipes* to treat raw textile effluent collected from the Navi Mumbai MIDC area. A batch setup was used to monitor water quality changes under static conditions, with two groups prepared: a Treatment group containing effluent with *E. crassipes* and a Control group containing effluent without plants, each with three replicates ($n = 3$). Experiments were performed in 10-L HDPE reactors filled with 8 L of effluent. Plants were acclimatized in clean water for seven days, and a uniform biomass of 300 g fresh weight was added to each Treatment reactor. All reactors were maintained at 27 ± 2 °C under a natural 12 h light–12 h dark cycle with gentle aeration. Water samples were collected at 0, 7, 15, and 30 days and analyzed for pH, EC, TDS, TSS, COD, BOD₅, colour, and selected heavy metals using APHA Standard Methods (2017). This setup provided a controlled system for comparing pollutant removal in the presence and absence of *E. crassipes*.

Data analysis

Removal efficiency (%) for each parameter was calculated as:

$$\text{Removal (\%)} = (C_0 - C_t) / C_0 \times 100$$

Where C_0 is initial concentration (day 0) and C_t is concentration at time t (e.g., day 30). Comparison between planted and control experimental systems was done descriptively (mean of triplicates).

III. RESULTS AND DISCUSSION

Physico-chemical parameters:

Table 1. Mean concentrations and removal efficiencies (treatment vs control) after 30 days.

Parameter	Initial (day 0)	Treatment (day 30)	Removal (%) Treatment	Control (day 30)	Removal (%) Control
pH	9.0 ± 0.10	7.8 ± 0.12	shift toward neutrality	8.8 ± 0.08	minor shift
COD (mg/L)	1200 ± 35	360 ± 22	70.0%	980 ± 40	18.3%
BOD ₅ (mg/L)	500 ± 20	140 ± 12	72.0%	420 ± 18	16.0%
TSS (mg/L)	600 ± 28	120 ± 10	80.0%	520 ± 24	13.3%
TDS (mg/L)	2500 ± 60	1600 ± 50	36.0%	2350 ± 55	6.0%
DO (mg/L)	0.6 ± 0.05	4.2 ± 0.15	increase (oxygenation)	1.0 ± 0.06	slight increase
Colour (ADMI/Abs.)	high (no SD)	marked reduction (qualitative)	—	slight reduction (qualitative)	—

(All values represent triplicate means ± standard deviation)

pH: Initial pH was strongly alkaline (9.0 ± 0.10). In the treatment system it shifted toward near-neutral levels (7.8 ± 0.12), indicating buffering by rhizosphere processes. The control remained alkaline (8.8 ± 0.08) with only a minor shift.

Chemical Oxygen Demand: The initial COD of 1200 ± 35 mg/L decreased to 360 ± 22 mg/L (70% removal). This reduction reflects enhanced microbial degradation supported by root surfaces and oxygen transfer. In contrast, the control system achieved only an 18.3% reduction (to 980 ± 40 mg/L).

Biological Oxygen Demand: BOD declined from 500 ± 20 mg/L to 140 ± 12 mg/L (72% removal), demonstrating strong biological oxygen-demand reduction via plant-microbe interactions. Control reduction was minimal (16%).

Total Suspended Solid: TSS dropped from 600 ± 28 mg/L to 120 ± 10 mg/L (80% removal), the highest among

all parameters, attributed to sedimentation and filtration beneath the plant mat. The control showed only 13.3% removal.

Total Dissolve Solid: A moderate reduction was recorded: 2500 ± 60 mg/L to 1600 ± 50 mg/L (36%). Controls showed negligible change (6%), reflecting reduced capacity for dissolved solids removal without plants.

Dissolved Oxygen: DO in untreated wastewater was very low (0.6 ± 0.05 mg/L). The treatment system increased DO to 4.2 ± 0.15 mg/L through photosynthetic oxygenation, whereas the control increased only slightly (1.0 ± 0.06 mg/L).

Colour: Colour intensity exhibited a marked qualitative reduction in the treatment system, whereas the control showed only slight visible improvement.

Heavy metal accumulation in plant:

Table 2. Heavy metal concentrations in water and percent removal after 30 days (treatment).

Metal	Initial (mg/L)	Final water (mg/L)	Removal (%) water	Plant tissue concentration (mg/kg ⁻¹ dry weight) — roots	Shoots
Cr	Chromium	3.0 ± 0.12	0.9 ± 0.05	70.0%	420 ± 18
Fe	Iron	15.0 ± 0.45	4.5 ± 0.22	70.0%	5200 ± 210
Zn	Zinc	2.5 ± 0.10	0.6 ± 0.03	76.0%	350 ± 14

Metal concentrations in water and plant tissues after 30 days are presented in Table 2. All initial and final water concentrations are triplicate means ± SD. Substantial removal of chromium, iron, and zinc from the effluent was observed in the treatment system, accompanied by pronounced accumulation in root tissues.

Chromium (Cr): Water concentration decreased from 3.0 ± 0.12 mg/L to 0.9 ± 0.05 mg/L (70% removal). Root tissues accumulated 420 ± 18 mg/kg⁻¹, considerably higher than shoots (110 ± SD previously provided), indicating strong root retention.

Iron (Fe): Initial concentration of 15.0 ± 0.45 mg/L reduced to 4.5 ± 0.22 mg/L (70%). Roots accumulated the highest metal load among all parameters (5200 ± 210 mg/kg⁻¹), highlighting Fe's strong affinity for root sorption sites.

Zinc (Zn): Zn decreased from 2.5 ± 0.10 mg/L to 0.6 ± 0.03 mg/L (76%), the highest removal among the metals. Roots accumulated 350 ± 14 mg/kg⁻¹, confirming efficient uptake and binding.

Overall, roots accumulated significantly higher metal concentrations than shoots, consistent with adsorption to root surfaces, rhizosphere precipitation, and restricted translocation to aerial tissues

IV. CONCLUSION

The results of the laboratory experimental system clearly showed that *Eichhornia crassipes* is effective in reducing the organic and particulate pollutant load of raw textile effluent. Substantial decreases in COD,

BOD, and TSS were recorded over the 30-day treatment period, with overall removal efficiencies of approximately 70% for COD, 72% for BOD, and 80% for TSS. These values fall well within the ranges reported in earlier studies where water hyacinth has been applied for the treatment of dyeing wastewater, mixed textile effluent, or industrial wastewater with high organic content. The observed reductions indicate that the plant contributes to multiple removal pathways, including physical filtration, whereby the dense root system traps suspended particles and enhances settling beneath the plant canopy; rhizosphere-enhanced microbial degradation, in which microbial consortia attached to the roots metabolize organic compounds, leading to decreased COD and BOD; and adsorption or uptake of soluble organic constituents by plant tissues. Together, these processes create a synergistic treatment environment that markedly improves water quality compared to abiotic controls. Significant improvements were also observed in heavy metal concentrations, with Cr, Fe, and Zn showing reductions in the range of 70–76% in the treated systems. Such declines are consistent with known phytoremediation mechanisms of *E. crassipes* and can be attributed to a combination of biological and physicochemical processes. First, the extensive fibrous root network provides a large surface area for metal adsorption, facilitated by negatively charged functional groups, lignocellulosic structure, and the presence of root exudates that promote metal complexation. Second, metal uptake and sequestration into plant tissues particularly roots was confirmed by the elevated metal concentrations measured in harvested biomass, indicating that root accumulation serves as a primary sink. This pattern aligns with phytostabilization and rhizofiltration dynamics commonly reported for *E. crassipes*. Third, metals may be removed through co-precipitation with bioflocs, formed within the rhizosphere as microbial activity alters pH, redox conditions, and dissolved organic matter, promoting the formation of insoluble metal complexes. These mechanisms closely correspond with those documented in previous research on water hyacinth-based treatment of textile, dyeing, tannery, and mixed industrial effluents. The consistency of removal efficiencies and mechanistic pathways across studies reinforces the suitability of *E. crassipes* as a low-cost, efficient phytoremediation species for organic and inorganic contaminants typical of textile wastewater.

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