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Exploring Phytoremediation Potential Of Alternanthera Phyloxeroides (Mart.) Griseb.: A Case Study Using Grey Water Generated In The Miranda House Campus.

Akshita Seth[1], Vibhati Singh Verma[2], Veena Beri[3], Saloni Bahri[4], Somdutta Sinha Roy[5]
[1,2,3,4,5]Department of Botany, Miranda House, University of Delhi. Delhi 110007, India
***Corresponding author**: Somdutta Sinha Roy
somduttasinha.roy@mirandahouse.ac.in

Abstract: *Environmental pollution, including water pollution, is one of the major challenges facing the world today. With fresh water supplies being under strain in many cities and countries around the world, water recycling becomes the only way forward. Bioremediation and especially phytoremediation is an environment friendly solution. This paper explores the phytoremediation potential of Alternanthera philoxeroides in terms of some common water quality parameters like pH, TDS, electrical conductivity, salinity, sulphate, phosphate, chloride and dissolved oxygen (DO). Alternanthera philoxeroides show promising results, with water quality improvement for investigated parameters in laundry water. There was a significant increase in DO levels and decrease in TDS and chlorides in waste water. The results imply that Alternanthera philoxeroides may be a useful agent for improving water quality, offering a sustainable and economical method of treating waste water.*
Key Words: *Phytoremediation; Alternanthera philoxeroides; Greywater treatment; Laundry water; Dissolved Oxygen.*

INTRODUCTION:

Water pollution is one of the most pressing environmental concerns today, and everyday household activities contribute significantly to it (WWAP, 2017). Domestic water used for washing clothes, bathing, dishwashing, or cleaning is known as grey water and black water is generated from toilets carry a mixture of pollutants, including soap residues, detergents, food particles, oils, personal care chemicals, and even trace pharmaceuticals (Eriksson et al., 2002). If discharged untreated into water bodies, this wastewater can cause serious ecological damage by reducing oxygen levels, spreading harmful microbes, and promoting algal blooms (eutrophication) (WHO, 2018). These impacts are particularly severe in densely populated areas lacking proper sewage systems (UN-Habitat, 2020). Over time, such pollution not only degrades aquatic ecosystems but also threatens human health and access to clean water (UNEP, 2016).

Freshwater scarcity is becoming a global crisis, worsened by overuse, contamination, urbanization, industrialization, and climate change (WWAP, 2019). According to Syamlal et al. (2024), global water stress rose from 17% in 2017 to 18% in 2018 (SDG indicator 6.4.2). Freshwater biodiversity has plummeted—showing an 81% decline between 1970 and 2012 (WWF, 2020). Currently, two-thirds of the world's population face water shortages for at least one month each year, and around 500 million people live in areas where water use is double the renewable supply (Mekonnen & Hoekstra, 2016).

Greywater generated by non-toilet activities like bathing, laundry, handwashing, and dishwashing is less polluted than blackwater and contains mainly soap residues, organic matter, detergents, and traces of grease (Li et al., 2009). With low pathogen content, greywater can be treated and reused for non-potable purposes such as toilet flushing, irrigation, and landscaping (Gross et al., 2007). This makes it a valuable component in sustainable water reuse strategies (Al-Jayyousi, 2003).

One promising method for treating wastewater, including greywater, is phytoremediation—a cost-effective and eco-friendly technique that uses plants and their associated microorganisms to remove or degrade pollutants from water, soil, or air (Ali et al., 2013). Through natural processes such as uptake, accumulation, transformation, and rhizosphere interactions, plants can remediate contaminants, including heavy metals, nutrients, pesticides, and organic compounds (Syamlal et al., 2024). Table 1 gives an overview of the plants commonly used for phytoremediation.

Table 1: Plants commonly used for phytoremediation of polluted water.

S.No	Plant Name	Pollutants Removed	Mechanism	Habitat	References
1	Water Hyacinth (Eichhornia	Heavy metals (Pb, Cd, Hg), nutrients (N, P),	Absorbs pollutants	Floating aquatic	Reddy & D'Angelo (1997); Malik (2007); Rai (2008); Rezania et al.(2016); Abbas et

	crassipes)	pesticides, dyes	through roots and shoots; floats on water		al. (2019)
2	Duckweed (Lemna minor, Spirodela spp.)	Nitrogen ,phosphorus, cadmium,zinc, organic waste	Efficient nutrient uptake; forms mats reducing evaporation and algae	Floating aquatic	Zhao et al. (2015); Ziegler et al. (2016); Mohedano et al. (2012); Yan et al. (2013); Appenroth et al. (2010)
3	Cattail (Typha latifolia, T. angustifolia)	Heavy metals, organic pollutants, nutrients	Deep roots absorb contaminants; used in constructed wetlands	Emergent aquatic	Verma & Suthar (2015); Kadlec & Wallace (2009); Marchand et al. (2010); Vymazal (2011); Zhang et al. (2014)
4	Water Lettuce (Pistia stratiotes)	Copper, cadmium, lead, nitrogen, phosphorus	Floating plant with fibrous roots that absorb contaminants	Floating aquatic	Reddy (1984); Lu et al. (2010); Rai (2008); Jayaweera et al. (2007); Sood et al. (2012)
5	Reed Grass (Phragmites australis)	Nutrients, hydrocarbons, metals, organic matter	Used in constructed wetlands	Emergent aquatic	Tanner (2001); Brix (1997); Vymazal(2011); Wang et al. (2014); Scholz (2010)
6	Indian Mustard (Brassica juncea)	Lead, chromium, nickel, zinc	High biomass and metal uptake; used in hydroponic systems	Terrestrial / hydroponic	Salt et al. (1995); Kumar et al. (1995); Blaylock & Huang (2000); Lasat (2002); Srivastava et al. (2005)
7	Vetiver Grass (Chrysopogon zizanioides)	Heavy metals, organic waste, nitrates	Deep roots; flood/drought tolerant	Riparian / wetland borders	Truong & Baker (1998); Roongtanakiat et al. (2007); Danh et al. (2009); Singh et al. (2014); Liu et al. (2020)
8	Alternanthera spp.	Nutrients, dyes, some heavy metals	Varies by species	Wetland / aquatic	Mishra et al. (2010); Brix et al. (2007); Rai (2008); Juwarkar et al. (2009); Shukla et al. (2021)
9	Hydrilla (Hydrilla verticillata)	Nutrients, organics, some metals	Absorbs pollutants; caution due to invasiveness	Submerged aquatic	Chambers et al. (2008); Perna & Burrows (2005); Rai (2008); Sood et al. (2012); Vymazal (2011)
10	Water Spinach (Ipomoea aquatica)	Nitrogen, phosphorus, certain heavy metals	Absorbs pollutants; caution if edible use	Wetland aquatic	Zhou et al. (2007); Qadir et al. (2007); Rai (2008); Sinha et al. (2008); Chan et al. (2006)

Research on the use of Alternanthera species in wastewater treatment has shown a steady rise over the past decade, reflecting increasing global interest in sustainable and cost-effective phytoremediation methods. The most studied species include Alternanthera philoxeroides and Alternanthera bettzickiana, which are known for their fast growth, tolerance to pollutants, and high biomass production.

A review of relevant literature (2014–2024) reveals a surge in publications focusing on the plant's ability to remediate heavy metals (Cd, Pb, Cr) and organic pollutants, including pharmaceutical compounds like acetaminophen and methylparaben. Notable studies include Tauqeer et al. (2016), which demonstrated A. bettzickiana's efficiency in cadmium uptake and detoxification, and Mohammed et al. (2022), who tested Alternanthera spp. in mesocosm-scale constructed wetlands for pharmaceutical contaminant removal. These papers highlight the plant's physiological responses under pollutant stress, including enhanced antioxidant enzyme activity and bioaccumulation capacity.
Alternanthera philoxeroides effectively removes sulfonated textile dyes like Remazol Red. Within 72 hours, up to 70 mg/L concentrations were fully degraded via root- and leaf-specific enzymatic pathways (e.g., azoreductase, laccase). Natural partnerships with plant growth- promoting bacteria (e.g., Klebsiella sp. VITAJ23) raised dye removal to 79 % in 60 days while enhancing plant vitality. In mesocosm-scale constructed wetlands, Alternanthera spp. removed ~87 % of acetaminophen and ~67–82 % of methylparaben over 35 days, significantly outperforming unplanted controls. Alternanthera species—including philoxeroides, sessilis, ficoidea, and bettzickiana—are emerging as robust, multifunctional phytoremediation agents. They tackle a diverse range of pollutants via combined mechanisms: enzymatic breakdown, rhizofiltration, biosorption, and microbial cooperation.
Despite its potential, large-scale field applications remain limited, pointing to a gap between laboratory research and real-world deployment. Emerging trends suggest future research may focus on integrating Alternanthera into engineered constructed wetlands, optimizing microbial interactions, and developing genetically improved strains for higher remediation efficiency.

MATERIALS AND METHODS:

The experimental layout involved collecting plant material, acclimatization in natural pond water before exposure to laundry water from the Miranda House College campus.

Collection of Plant Material

Healthy specimens of Alternanthera philoxeroides were collected from Neela Hauz Biodiversity Park (Latitude: 28.5445° N, Longitude: 77.1984° E), located in New Delhi, India.

Experimental Setup and Plant Stabilization

After collection, the plants were first stabilized in pond water at Miranda House, University of Delhi, to ensure acclimatization. Following stabilization, they were transferred to trays containing untreated laundry wastewater collected from campus washing units. The experiment was conducted over a 8-day period, under natural light and ambient temperature, as typically done in mesocosm studies (Ali et al., 2013). Water samples were collected at two stages: Before treatment (initial sample) and after one week of plant growth (final sample). A corresponding set- up, with distilled water, was maintained as a control (Figure 1). All groups were run in parallel to reduce variability between samples.

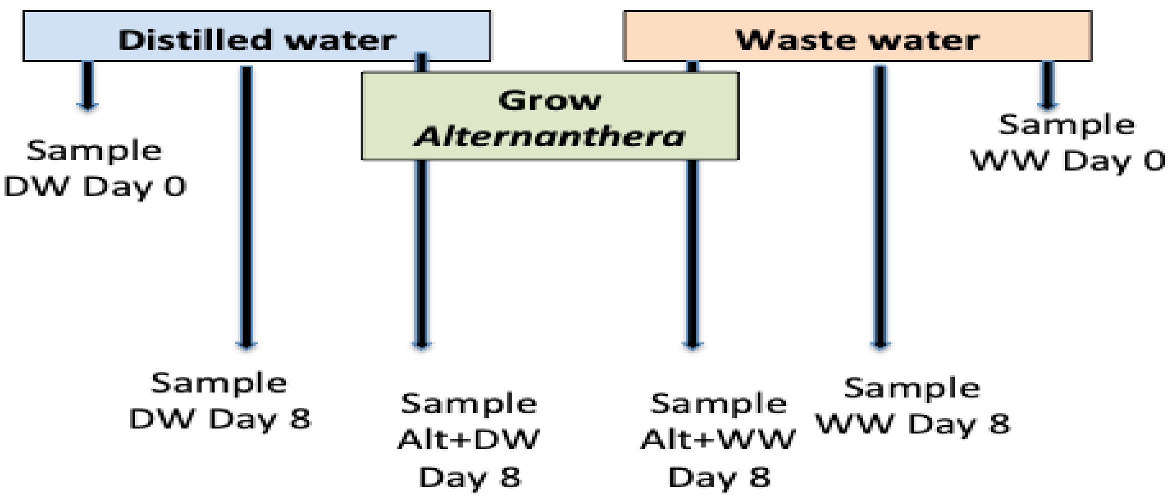

Figure 1: Experimental set up for the study. Water samples were tested on Day 0 before setting up of experiment and on Day 8 with or without Alternanthera.

Analysis of Water Samples

Water samples from the experimental tanks were analyzed to determine changes in the following key physicochemical parameters: pH (digital pH meter M-152-R), Electrical Conductivity (EC meter, M-215-R), Total Dissolved Solids (TDS meter M-M718), and Salinity (salinity meter, M- M813). Dissolved Oxygen (DO), Phosphate (PO_4^{3-}), Sulphate (SO_4^{2-}), Chloride (Cl^-) were estimated using standard protocols for each parameter for all the controls and experimental samples (Kapur, P. and Govil, S. R., 2000).

Data Analysis

All experimental set ups were repeated for 5 times. The results from the water quality tests were subjected to statistical analysis to determine the effectiveness of Alternanthera philoxeroides in phytoremediation of grey water generated from laundry at Miranda House. Data analysis was done on Microsoft Exel and R software.

RESULTS AND DISCUSSION:

The present study evaluates the potential of Alternanthera philoxeroides for in-house treatment of water generated by college laundry. Various studies have shown the phytoremediation potential of Alternanthera, especially with reference to the heavy metals (Sharma et al., 2021; Mazumdar & Das, 2021). Pandey and Gopal (2010) showed the effect of detergent on growth of aquatic plants Azolla and Hydrilla. Harmful environmental effects of surfactants, main component of detergents, have been studied extensively (Villarreal-Reyes et al., 2022). The waste water generated by the laundry can be categorized as grey water, showed higher values for almost all the parameters tested in this study as compared to distilled water (Table 2). As a measure of improvement in water quality, comparative study of water samples with and without Alternanthera philoxeroides carried out in term of its pH, total dissolved solids (TDS), electrical conductivity, salinity was measured every day for 8 days experimental period using electrodes. Chloride, phosphate, sulphate and dissolved oxygen (DO) estimation were done on day 0 and day 8 by colorimetric and titrimetric methods.

pH of the waste water (WW) changed from acidic range to neutral when it was kept for 8 days, with or without Alternanthera. Similar result was obtained for distilled water (DW) set up also. Electrical conductivity (EC) also was reduced when WW was incubated for 8 days with or without Alternanthera. In contrast, EC of the DW increased as a result of 8 day incubation. Chloride and Phosphate didn't show any significant changes. Sulphate showed marginal increase as a result of plant growth in both DW and WW. Dissolved Oxygen shows a significant increase in both DW and WW as a result of plant growth as compared to setup without plant growth (Table 2).

Table 2: Changes in the physico-chemical factors of water as a result of growing Alternanthera philoxeroides.

Parameter / Sample	**pH**	**TDS (in ppt)**	**Electrical Conductivity (in m)**	**Salinity (in ppt)**	**Chloride (in mg/L)**	**Phosphate (in mg/L)**	**Sulphate (mg/L)**	**DO (mg/L)**
DW 0 Day	4.86±0.57	0.08 ±0.01	0.12 ±0.02	0.76 ±0.03	79.88± 8.88	9.21 ±4.29	5.12 ± 2.10	10.83 ± 4.08
DW 8 Day	7.96 ±0.6	1.37± 0.84	5.03 ±3.47	0.36 ±0.12	55.22 ± 19.52	7.70 ±2.91	6.34 ± 0.65	24.24 ± 10.67
Alternanthera+ DW 8 Day	6.61 ±0.56	0.06± 0.02	5.19 ±3.62	0.12 ± 0.04	61.14 ± 21.51	2.18 ±1.76	7.87 ± 0.96	75.0 ± 15.16
WW 0 Day	2.92 ±0.27	8.86 ±0.75	18.20 ±0.67	16.83 ± 0.42	1212.92 ± 88.55	6.85 ±0.86	49.15 ± 4.16	23.0 ± 6.64
WW 8 Day	7.24 ±0.33	4.15± 2.98	6.11 ±1.68	4.57 ±0.97	1049.22 ± 142.60	16.68 ± 15.64	27.56 ± 2.42	41.47 ± 9.98
Alternanthera +WW 8 Day	7.36 ±0.50	4.42± 1.96	6.09 ±1.37	3.75 ±0.40	1214.49 ± 275.26	4.29 ±2.42	86.41 ± 6.25	111.36± 17.59

The violin plots (Figure 2) show the distribution of all the data pooled from different experimental setups. Independent t test was done between different samples for all six samples to assess if the differences observed are real ($p<0.05$). All the parameters, except phosphate, show distinct difference between distilled water and waste water at day 0 (DW_0 vs WW_0, $p< 0.001$). On incubation for 8 days without Alternanthera philoxeroides, parameters like pH, TDS, EC, salinity, chloride and DO showed spontaneous changes due to storage (DW_0 vs DW_8 and WW_0 vs WW_8, $p<0.05$). However, when we compare waste water samples after 8 days without

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and with Alternanthera philoxeroides (WW_8 vs Alt_WW), true extent of the effect of Alternanthera growth for water purification emerges. Alternanthera philoxeroides growth for the period of 8 days increases the DO levels ($p<0.001$), increases sulphate levels ($p<0.001$) and decreases salinity ($p<0.05$).

Principal Component Analysis (PCA) of water parameters under consideration for this study for all 6 groups shows a distinct separation of groups (Figure 3). All the distilled water samples group together (DW_0, DW_8 and Alt_DW) with overlapping of DW_8 and Alt_DW. Waste water samples show distinct separation in the graph, with WW_0, WW_8 and Alt_WW well separated from each other and from the distilled water samples. Our observations from PCA analysis supports the results obtained from t-Test. The changes in the grey water samples obtained from laundry and treated with Alternanthera philoxeroides for 8 days are true.

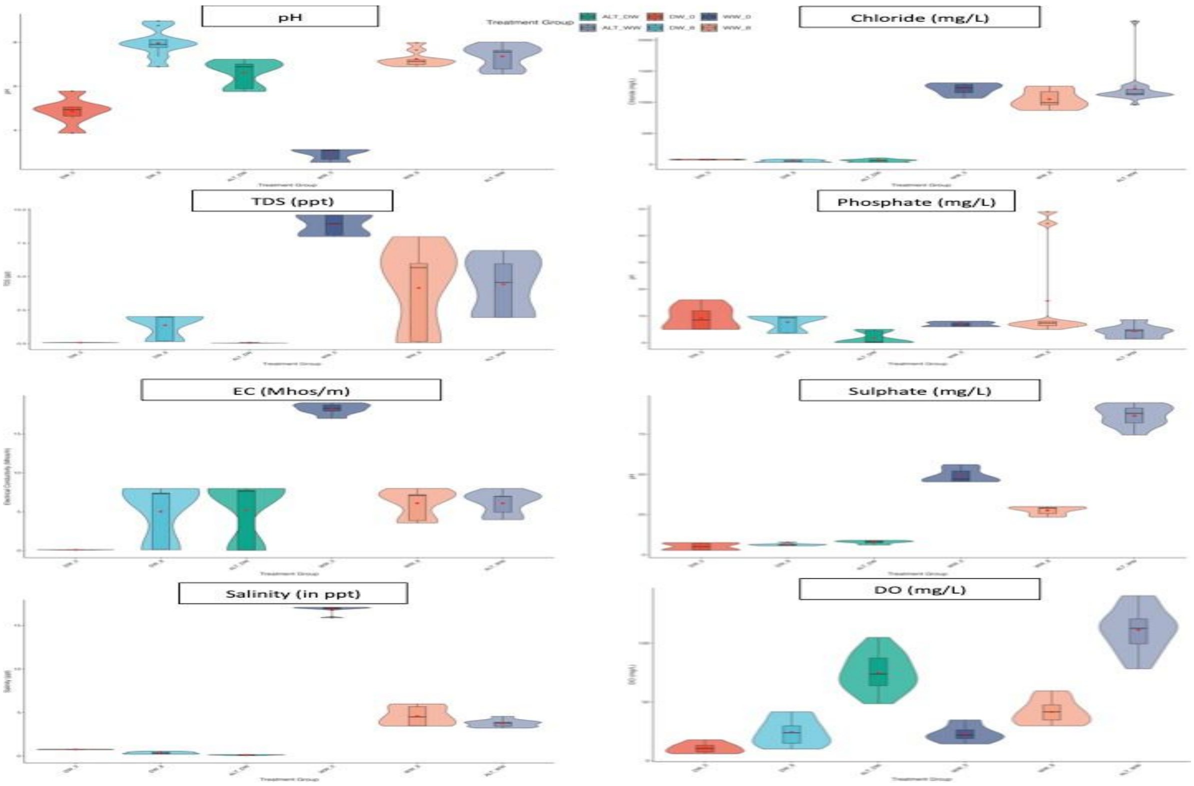

Figure 2: Violin plots showing distribution of all parameters by treatment group. (i) Distilled water day 0 (DW_0,); Distilled water day 8 (DW_8,); Distilled water with Alternanthera philoxeroides growing for 8 days (Alt_DW,); Waste water day 0 (WW_0,); Waste water day 8 (WW_8,); Waste water with Alternanthera philoxeroides growing for 8 days (Alt_WW,)

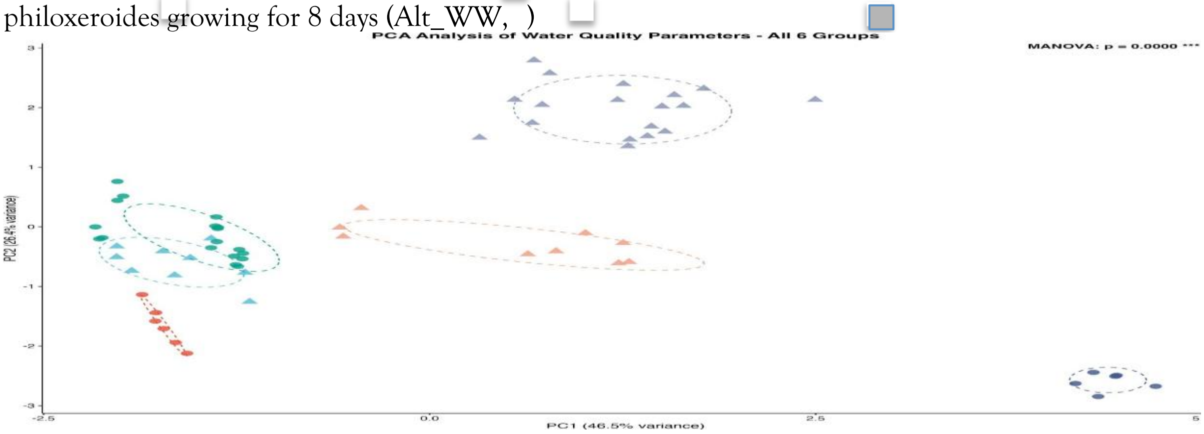

Figure 3: Principal Component Analysis (PCA) of water parameters for all 6 groups. (i) Distilled water day 0 (DW_0, Distilled water day 8 (DW_8, Distilled water with Alternanthera philoxeroides growing for 8 days (Alt_DW, Waste water day 0 (WW_0, ; Waste water day 8 (WW_8); Waste water with Alternanthera philoxeroides growing for 8 days (Alt_WW,)

Our present findings show that Alternanthera philoxeroides is successful in lowering pollutants in all investigated parameters of grey laundry water (WW), there was a notable increase in DO levels and decrease in salinity resulting in water suitable for reuse in other purposes. These results imply that Alternanthera may be a used as a cost effective way for improving water quality, offering a sustainable and economical method of treating wastewater.

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Author's contributions: AS and VSV conducted the experiments and wrote the first draft. VB and SB were involved in devising the methodology, supervising data collection. SSR was responsible for devising the methodology, analysis of data, creating the graphics and manuscript writing, editing and proofreading.

Corresponding Author

Correspondence to Dr Somdutta Sinha Roy

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Availability of Data and Materials

Available on appropriate request to authors.

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