Evaluating the Efficacy of Lemongrass (Cymbopogon) and Asian Pigeonwings (Clitoria ternatea) in Biological Wastewater Remediation

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***Abstract* - This study investigates phytoremediation as a sustainable, eco-friendly alternative to conventional wastewater treatment using natural plants for contaminant removal. Literature review and theoretical analysis indicate that biological methods utilizing Lemongrass (Cymbopogon) and Asian Pigeonwings (Clitoria ternatea) effectively reduce BOD/COD levels and heavy metals, offering superior filtration performance. Experimental results demonstrate 94% BOD reduction and 93.6% COD reduction. The research advocates integrating these natural systems for sustainable water management.**

Keywords: Phytoremediation, Wastewater Treatment, BOD, COD, Sustainable Engineering, Phytofiltration, Macrophytes, Environmental Pollution.

I. INTRODUCTION

Wastewater represents one of the most significant environmental challenges in modern civil engineering. Composed of 99.9% water, the remaining 0.1% contains highly hazardous contaminants including organic matter, pathogenic bacteria, viruses, and excessive nutrients. If left untreated, these elements cause oxygen depletion and devastation of aquatic life.

Standard treatment involves mechanical stages such as screening, aeration, and sedimentation, but chemical processes like chlorination often introduce secondary environmental concerns. This research explores phytoremediation as a sustainable, low-cost biological alternative, using specialized plants to absorb, sequester, and detoxify contaminated water through mechanisms including phytofiltration, phytodegradation, and phytoextraction.

Recent studies confirm the efficiency of Lemongrass (Cymbopogon), which removes up to 80% of dissolved solids, and Asian Pigeonwings (Clitoria ternatea), which assists through natural nitrogen fixation. Research by Adonadaga (2020) confirms these grasses meet WHO guidelines for water safety, while achieving over 70% reduction in COD and surfactants.

II. LITERATURE REVIEW

2.1 Key Research Findings

Author & Study	Methodology	Key Conclusion
Rajhi & Bardi (2020)	Microalgae treatment on physiochemic7al quality	Complete heavy metal elimination; significant reduction in mineral salts, phosphorus, and coliform bacteria
Arora & Saraswat (2021)	Earthworms as biofilter for organic matter	Effectively treats municipal sewage; produces high-quality manure
Pandey & Upadhyay (2019)	Field sampling of natural vegetation at Laxmi Taal lake	T. angustifolia and E. crassipes identified as superior bio-accumulators
Adonadaga (2020)	Comparative testing of Lemon Grass, Elephant Grass, Giant Blue Stem	Lemon Grass most efficient: 70–84% TDS removal, meets WHO guidelines
Siswoyo et al. (2019)	Integrated adsorption-phytoremediation system	99.9% surfactant removal and 77.5% COD reduction achieved

2.2 Theoretical Framework

Phytoremediation is the strategic use of green plants to remove, degrade, or contain environmental contaminants through specialized mechanisms:

- Phytofiltration: Absorption of pollutants from water via the root system
- Phytoextraction: Accumulation of heavy metals into harvestable plant tissues
- Phytodegradation: Breaking down organic pollutants through metabolic processes
- Phytovolatilization: Converting pollutants into volatile gases released into the atmosphere

Research (Patil & Shukla, 2019) indicates that natural systems like Duckweed and Water Hyacinth can treat effluent with 100% efficiency over short durations (2 days), offering a viable low-energy alternative to conventional mechanical plants.

III. METHODOLOGY

This study employs a natural, plant-based filtration system to treat wastewater through a dual-layered reed bed design. The treatment process was divided into three primary phases: collection, filtration, and post-treatment analysis. Wastewater was sourced from local domestic and industrial origins containing high levels of organic pollutants such as nitrogen, phosphorus, and surfactants.

3.1 Reed Bed Design and Plant Selection

Two distinct plant species were selected for their nutrient absorption capabilities: Lemon Grass (Cymbopogon) for high TDS removal, and Asian Pigeonwings (Clitoria ternatea) for nitrogen fixation and soil chemistry stabilization. The reed beds were constructed using a multi-layer media stratification approach:

Material	Layer Position	Depth (Bed 1)	Mass (Bed 1)	Mass (Bed 2)
Sand	1 & 6	9–10 cm	55.45 kg	32.5 kg
Charcoal	2–5	3.5–5 cm	8.75 kg	2.5 kg
Aggregate	2–4	5–7 cm	16.9 kg	17.0 kg

3.2 Analytical Testing

Physical tests were performed on filter media to ensure suitability for hydraulic conductivity. Key tests included: Specific Gravity Test (pycnometer method), Impact Value Test, and Moisture Content/Absorption analysis. Plant growth parameters — root length, leaf length, and total plant weight — were monitored over a 75-day period.

IV. RESULTS

4.1 Filter Media Characterization

Test	Parameter	Result
Specific Gravity (Aggregate)	Sample weight: 390 g; Water volume equivalent: 136 g	2.84
Aggregate Impact Value	Initial weight: 0.557 kg; Passing 2.36 mm sieve: 0.445 kg	79.89%
Specific Gravity (Sand)	Highly porous media measured	0.318
Sand Bulking (Peak)	At 30 ml water added	33.33%

4.2 Plant Growth Data

Clitoria ternatea (Reed Bed 1) showed steady leaf growth from 28 cm to 35 cm over 75 days. Lemon Grass demonstrated significantly higher biomass production, with leaf lengths reaching a maximum of 112–113 cm by the end of the observation period, indicating superior nutrient uptake from the wastewater environment.

4.3 Wastewater Treatment Efficiency

Parameter	Raw Sewage (Inlet)	Treated Water (Outlet)	% Change

BOD (3 days, 27°C)	107 mg/l	6.4 mg/l	94.0% Reduction
COD	312 mg/l	20 mg/l	93.6% Reduction
Dissolved Oxygen (DO)	Not Detected	5.7 mg/l	Significant Increase
Alkalinity	368 mg/l	332 mg/l	9.8% Reduction
Nitrate (NO_3)	0.5 mg/l	11.7 mg/l	Increase (Nitrification)

V. DISCUSSION

The system achieved a remarkable 94% BOD and 93.6% COD reduction, attributed to the synergistic effect of the filter media and the root systems of Lemon Grass and Clitoria ternatea. The activated charcoal layer acted as an adsorbent for complex organic molecules, while aerobic zones around plant roots facilitated microbial breakdown of organic matter.

The increase in dissolved oxygen from undetected levels to 5.7 mg/l confirms that plants transport oxygen through aerenchyma tissue to their roots, creating aerobic pockets that support aquatic life in the effluent. The rise in nitrates (0.5 to 11.7 mg/l) indicates successful nitrification — conversion of toxic ammonia into a more stable nitrate form — proving the reed bed is biologically active.

The system performed consistently across seasons. Lemon Grass planted in December/January showed resilience with leaf lengths reaching 113 cm despite cooler temperatures. The low BOD/COD and elevated DO in the outlet make this water suitable for secondary uses including irrigation and aquifer recharge. Harvested biomass can be further repurposed for essential oil extraction, providing an economic incentive aligned with circular economy principles.

VI. CONCLUSION

This study validates that a natural system using Lemon Grass and Clitoria ternatea, supported by structured media of sand, aggregate, and charcoal, can match or outperform small-scale mechanical treatment plants. The phytoremediation approach offers a low-cost, energy-efficient, and ecologically beneficial solution for communities where conventional plants are unaffordable. Integration of these natural systems into sustainable urban planning promotes biodiversity, resource recovery, and alignment with global environmental goals.

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