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Phytoremediation of Municipal Wastewater Using *Phragmites karka*

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Abstract:

The study on the phytoremediation capabilities of the emergent macrophyte *Phragmites karka* for treating municipal wastewater. The study, conducted using a constructed wetland (CW) model, demonstrates that *P. karka* is highly effective at reducing a wide range of pollutants. The CW system incorporating the plant showed markedly superior performance in removing contaminants—including suspended and dissolved solids, organic matter, and nutrients—when compared to a control system that relied solely on natural degradation processes.

The key conclusion is that the effluent from the *P. karka* treatment system meets the standards set by the Bureau of Indian Standards (BIS) for disposal and is suitable for various reuse applications such as irrigation, aquaculture, and gardening. This positions phytoremediation with *P. karka* as a viable, low-cost, and sustainable alternative to conventional, high-cost wastewater treatment technologies, particularly for expanding urban areas in developing nations like India. The research addresses the critical environmental challenge of water pollution driven by rapid urbanization while highlighting a nature-based solution that is both effective and economical.

1. Introduction:

Rapid urbanization, coupled with industrial and agricultural growth, has led to significant environmental degradation, with water pollution emerging as a primary concern. The reliance on outdated technologies often results in the discharge of untreated or inadequately treated wastewater into natural water bodies. In India, a minimal proportion of municipal sewage undergoes treatment. While large metropolitan areas may have treatment facilities, smaller cities frequently discharge untreated sewage directly into rivers and lakes. The primary cause of pollution in many water bodies, such as those in China, is nutrient enrichment from untreated phosphorus and nitrogen. Water pollution poses a direct threat to human health, limits usable water resources, and jeopardizes the sustainability of alternative water sources.

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Limitations of Conventional Treatment Methods

Advanced wastewater treatment technologies, such as activated sludge systems and membrane technology, are standard in developed countries. However, their application in developing nations faces significant barriers.

• **High Costs:** These technologies involve substantial construction and operational expenses, making them impractical for many municipalities, especially smaller cities in India.

• **Chemical and Equipment Dependency:** Conventional methods rely on expensive equipment and chemicals, contributing to their high overall cost.

• **Inefficiency for Certain Pollutants:** In some cases, these systems struggle to reduce specific pollutants like heavy metals or nitrogen to acceptable levels.

The Constructed Wetland (CW) as a Sustainable Alternative

Constructed wetlands have emerged as an effective, economical, and sustainable solution for wastewater treatment, particularly for small communities.

• **Low Cost and Energy:** CWs are characterized by low capital and operational costs, minimal energy consumption, and relative ease of operation.

• **Natural Processes:** They utilize a combination of physical, chemical, and biological processes to treat wastewater, accommodating varying levels of organic content. The systems harness renewable energy sources like solar and wind.

• **Role of Macrophytes:** Vegetation is a critical component, enhancing purification through multiple mechanisms:

  ◦ providing oxygen to microorganisms in the root zone.

  ◦ Absorbing and breaking down nutrients like phosphates and nitrates.

  ◦ enhancing the hydraulic conductivity of the substrate.

• **Historical Context:** The scientific use of macrophytes for water purification dates back to the early 1950s, pioneered by Dr. Kathe Seidel at the Max Planck Institute in Germany.

II. Experimental Design and Methodology

The study's objective was to assess the treatment efficacy of the emergent macrophyte *Phragmites karka* in a constructed wetland model for treating municipal wastewater.

Test Organism: *Phragmites karka*

• **Selection Rationale:** *Phragmites karka*, a type of reed grass, was chosen due to its local availability and proven success in previous studies treating both domestic and industrial wastewater.

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• **Characteristics:** It is a tall, perennial aquatic plant belonging to the Gramineae family, capable of growing up to 4 meters in height. It thrives in moist, waterlogged environments and is native to tropical and subtropical regions of Asia.

• **Focus on Emergent Macrophytes:** The study highlights the ecological importance of emergent macrophytes, which are often overlooked in research compared to submerged species. Emergent vegetation can influence ecosystem processes, provide refuge for aquatic organisms, and is crucial for fish habitats in certain water bodies.

Experimental Setup and Procedure

• **Wastewater Source:** Municipal sewage was collected from a *nala* (drain) adjacent to the bridge near Nath Seeds on Paithan Road in Chhatrapati Sambhajinagar.

• **Reactors:** The experiment used polyvinyl chloride (PVC) crates as reactors, each with a working capacity of 32 liters of wastewater.

• **Treatment Groups:** Two sets of experimental conditions were established:

1. **Macrophyte Set:** Reactors containing municipal wastewater and *Phragmites karka* plants (planted at a density of 25 plants per square meter).
2. **Control Set:** Reactors containing only municipal wastewater to measure the effects of natural degradation without plants.

• **Acclimatization:** The *P. karka* plants underwent a one-month acclimatization period in domestic wastewater to enhance their resilience to pollution before being introduced to the experimental setup.

• **Data Collection:**

Wastewater samples from both sets were analyzed at regular intervals over a 15-day period (Day 1, 3, 6, 9, 12, and 15). The following parameters were measured using standardized methods: pH, Electrical Conductivity (EC), Total Suspended Solids (TSS), Total Dissolved Solids (TDS), Total Solids (TS), Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Nitrate (NO3), Phosphate (PO4), Sulfate (SO4), and Chloride (Cl-).

Key Findings: Comparative Treatment Performance:

The study conclusively found that the application of *Phragmites karka* in a constructed wetland significantly enhances the treatment of municipal wastewater compared to natural processes alone. The plants exhibited robust growth throughout the experiment, showing no signs of phytotoxicity.

Baseline Performance: The Control Set (Natural Degradation)

In the control set without macrophytes, a slight but consistent reduction in pollutants was observed over the 15-day period. This gradual purification is attributed to the activity of naturally present microorganisms like bacteria and fungi.

Superior Performance: The *Phragmites karka* Set (Phytoremediation)

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The treatment set containing *P. karka* demonstrated a substantially greater and more rapid reduction across all measured pollution indicators. The macrophytes played a direct and crucial role in absorbing nutrients and facilitating the breakdown of organic pollutants.

Net Pollutant Reduction by *Phragmites karka*

To isolate the specific contribution of the plant, the net change in pollution parameters was calculated by subtracting the reduction observed in the control set from the reduction in the macrophyte set. The following table summarizes the net reduction achieved by *P. karka* by Day 15 of the experiment.

Parameter	Initial Value (Day 1)	Net Reduction by Day 15
pH	6.77	+0.30 (net increase)
EC (μS/cm)	259	33
TSS (mg/L)	593	241
TDS (mg/L)	1062	404
TS (mg/L)	1655	645
BOD (mg/L)	46.72	20.0
COD (mg/L)	136	64
Nitrate (NO3) (mg/L)	28.4	9.5
Phosphate (PO4) (mg/L)	24	5.9
Sulfate (SO4) (mg/L)	168	77
Chloride (Cl-) (mg/L)	228	79

Note: The net reduction values are sourced from the study's final summary table (Table 6).

Key Observations from Parameter Analysis:

• **Organic Matter (BOD & COD):** The macrophyte system achieved a significant net reduction in both BOD and COD, indicating effective removal of organic pollutants.

• **Solids (TSS, TDS, TS):** The presence of *P. karka* led to a dramatic decrease in all forms of solids compared to the minimal settling observed in the control.

• **Nutrients (Nitrates, Phosphates, Sulfates):** The plants were highly effective at nutrient uptake, a critical factor in preventing eutrophication. The nutrient removal rate was rapid in the initial treatment phases and continued throughout the study.

Conclusion:

The study concludes that municipal wastewater treated with *Phragmites karka* in constructed wetlands is of sufficient quality for various reuse applications. The significant reductions achieved in solids, organic demand, and nutrients render the effluent suitable for:

• Irrigation (including gardening)
• Aquaculture
• Cleaning and other secondary uses

Furthermore, the final pH and EC levels of the treated water meet the discharge standards set by the **Bureau of Indian Standards (BIS)** for land disposal, release into flowing water, and connection to public sewer systems.

Advantages and Future Scope:

This phytoremediation method presents significant advantages over conventional treatment systems, particularly in the context of developing nations.

• **Sustainability:** The system does not require electrical equipment or chemical additives.

• **Cost-Effectiveness:** It utilizes naturally available materials (plants, gravel, sand), resulting in low capital and operational costs.

• **Ecological Benefits:** The process enhances local biodiversity and ecosystem health.

Identified Limitations of Phytoremediation

While highly promising, the study acknowledges several limitations inherent to phytoremediation that require consideration and further research.

• **Time-Intensive:** The process is not rapid and can take several years to achieve target pollutant reductions in large-scale, deeply contaminated sites.

• **Depth Constraints:** Plant roots have a limited reach, making the method less effective for contaminants located deep in soil or sediment.

• **Climatic Dependence:** The effectiveness is influenced by climate, as the selected plant species must be able to thrive in the local environment.

• **Wildlife Impact:** A potential risk exists that animals may ingest contaminated plants, introducing pollutants into the food chain. This requires careful management in areas with abundant wildlife.

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