

Original Research Article

Combination of Filtration Media and Pistia stratiotes Phytoremediation for Hospital Wastewater Treatment: A Quasi-Experimental Study at Al Mansyur Hospital

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ABSTRACT

Hospital wastewater contains organic pollutants, suspended and dissolved solids, pathogenic microorganisms, and chemical residues that may deteriorate receiving waters and endanger public health. This study aimed to evaluate the effectiveness of combining filtration media with Pistia stratiotes phytoremediation in improving wastewater quality at Al Mansyur Hospital. A quasi-experimental pretest–posttest control group design was applied with three replications. Six groups were examined: untreated control, phytoremediation alone, filtration alone, and three combinations of filtration and phytoremediation using gravel, zeolite, activated carbon, silica sand, and Pistia stratiotes. The measured parameters were Biological Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Total Suspended Solids (TSS), Total Dissolved Solids (TDS), and total coliform. Data were analyzed using one-way ANOVA followed by Tukey's HSD test, while the Kruskal–Wallis test was used when variance assumptions were not met. All treatment groups produced significant differences in pollutant reduction compared with the control ($p < 0.05$). Combined filtration and phytoremediation achieved the greatest reductions in BOD, TSS, and total coliform, whereas filtration media containing zeolite and activated carbon performed best in reducing COD and TDS. These findings indicate that integrating filtration with Pistia stratiotes offers a promising complementary approach for hospital wastewater treatment under controlled laboratory conditions before wider implementation.

Keywords: Filtration; Phytoremediation; Pistia stratiotes; Wastewater Treatment

INTRODUCTION

Hospital wastewater is a type of waste that can have serious environmental and public health impacts. Hospital wastewater contains hazardous substances, including organic matter, hazardous chemicals, pathogenic microorganisms, and persistent pharmaceutical residues (Aguilar-rangel et al., 2025). The presence of these hazardous substances contaminates water bodies, degrades environmental quality, and increases the risk of disease transmission. Therefore, hospital wastewater treatment is necessary to reduce pollution (Dewi & Azizah, 2022).

Al Mansyur Medika Hospital is one of the healthcare facilities that generates wastewater from both medical and non-medical activities. Based on the report findings, several parameters exceeded wastewater quality standards stipulated in Regulation of the Minister of Environment of the Republic of Indonesia No. 5 of 2014. These parameters include Total Dissolved Solids (TDS), Total Suspended Solids (TSS), Biological Oxygen Demand (BOD), Chemical Oxygen Demand (COD), and Total Coliforms, which necessitate wastewater treatment.

Wastewater treatment incorporates multiple techniques, with particular emphasis on the integration of filtration and phytoremediation. Filtration removes solids from liquids using a porous medium referred to as a filter (Rizki et al., 2025). In comparison, phytoremediation employs plants and their associated microorganisms to absorb, degrade, or stabilize pollutants such as heavy metals and organic matter (Ardiatma et al., 2023). *Pistia stratiotes* has been identified as a promising species for phytoremediation applications, particularly because of its ability to accumulate contaminants from polluted water (Coelho et al., 2023).

Wastewater treatment performance can be enhanced by integrating physical filtration with plant-based constructed wetland or phytoremediation processes. In these systems, gravel and sand function as filtration and supporting media that facilitate the removal of suspended particles through straining, sedimentation, and associated biological processes (Hassan et al., 2021; Welz, 2024). Zeolite contributes to contaminant removal through adsorption and ion-exchange mechanisms, particularly for ammonium and phosphorus, whereas activated carbon effectively adsorbs dissolved organic compounds and other pollutants because of its high surface area and porous structure (Elbastamy et al., 2021). The complementary functions of these materials can improve pollutant-removal performance, including in wastewater generated by hospitals and clinical facilities (Parashar et al., 2022).

Among aquatic plants used for phytoremediation, *Pistia stratiotes* was selected because of its rapid growth, extensive fibrous root system, and high tolerance to polluted aquatic environments. Previous studies have demonstrated that *Pistia stratiotes* effectively removes organic pollutants, suspended solids, nutrients, and selected heavy metals through rhizofiltration, phytodegradation, and the stimulation of microbial activity in the rhizosphere (Ali et al., 2024; As'ari et al., 2022). As a free-floating aquatic macrophyte, *Pistia stratiotes* exhibits rapid growth and develops a well-developed, long, and feathery root system with a high surface area that facilitates pollutant contact, biofilm attachment, filtration, and contaminant uptake. Its demonstrated ability to remove conventional wastewater pollutants and pharmaceutical contaminants suggests that it is a promising candidate for further evaluation in hospital wastewater treatment (Masiyambiri et al., 2023; Wang et al., 2024).

Although numerous studies have evaluated filtration media or phytoremediation separately, and several have investigated constructed wetlands using aquatic plants, limited information is available regarding the effectiveness of combining multiple filtration media with *Pistia stratiotes* for hospital wastewater treatment. In particular, comparative evaluations of different filtration media configurations integrated with *Pistia stratiotes* for reducing BOD, COD, TDS, TSS, and Total Coliform remain limited. Therefore, this study aimed to evaluate different combinations of filtration media and *Pistia stratiotes* phytoremediation as an alternative treatment approach for improving hospital wastewater quality.

METHODS

Research Design

This study employed a quasi-experimental design using a pretest–posttest control group

approach with three independent replications. Hospital wastewater collected from Al Mansyur Hospital served as the experimental sample. Six treatment groups were established, consisting of one control (P0), one phytoremediation treatment (P1), one filtration treatment (P2), and three combined filtration–phytoremediation treatments (P3–P5). The control reactor (P0) contained untreated wastewater, whereas the treatment reactors were configured with different combinations of filtration media (gravel, zeolite, activated carbon, and silica sand) and the aquatic plant *Pistia stratiotes*. Each treatment was performed under identical experimental conditions and repeated three times to ensure the reliability of the results.

Instrument and Procedure

Pistia stratiotes was used as the phytoremediation medium in this study. Prior to the experiment, the plants were cleaned with clean water to remove attached impurities and then acclimatized by soaking them in clean water for 14 days before being transferred to the treatment reactors (Ardiatma et al., 2023). This acclimatization step was performed to allow the plants to adapt before exposure to hospital wastewater.

Filtration was conducted using aquarium reactors (44 × 15 × 30 cm), each divided into four compartments for the placement of filtration media. Depending on the treatment group, the compartments were filled with different combinations of gravel, zeolite, activated carbon, silica sand, and *Pistia stratiotes*. A drain valve was installed at the end of each reactor to facilitate sample collection.

Hospital wastewater samples were collected from the wastewater treatment system of Al Mansyur Hospital. Initial measurements (0 h) were performed for BOD, COD, TSS, TDS, and Total Coliform. Subsequently, the wastewater was introduced into the designated treatment reactors according to the experimental design. Samples were then collected from the reactor outlet at one-hour intervals and analyzed for the same parameters. Each treatment was repeated three times, and all laboratory analyses were performed in triplicate.

Data Analysis

Data were analyzed using IBM SPSS Statistics software. Descriptive statistics were first performed to summarize the values of BOD, COD, TSS, TDS, and Total Coliform for each treatment group. Prior to hypothesis testing, the homogeneity of variances was assessed. Differences among the six treatment groups (P0–P5) were analyzed using one-way analysis of variance (One-Way ANOVA). When a significant overall difference was detected ($p < 0.05$), Tukey's Honestly Significant Difference (HSD) post-hoc test was performed to identify pairwise differences between treatment groups. If the assumption of homogeneity of variances was not satisfied, the non-parametric Kruskal–Wallis test was applied. Statistical significance was established at $p < 0.05$.

RESULTS AND DISCUSSION

Table 1 presents the mean values of water quality parameters, including biochemical oxygen demand (BOD), chemical oxygen demand (COD), total suspended solids (TSS), total dissolved solids (TDS), and total coliform, across different treatment combinations (P0–P5). Overall, the treatment media produced varying effects on each water quality parameter, with several combinations showing substantial reductions compared with the control. The lowest BOD value was observed in P5, while P4 showed the lowest COD and TDS values, and P2 produced the lowest TSS and total coliform levels. Statistical analysis using ANOVA indicated

significant differences among treatments for all measured parameters ($p < 0.001$), demonstrating that the composition of the treatment media significantly influenced water quality improvement.

Table 1. Results of hospital waste quality testing

Treatment	Media	Mean (mg/L) BOD	Mean (mg/L) COD	Mean (mg/L) TSS	Mean (mg/L) TDS	Total Coliform (MPN/100 ml)
P0	Control	68,29	87,17	51,10	2936,67	88,2
P1	water lettuce (<i>Pistia stratiotes</i>)	60,67	81,20	45,03	2757,33	>2419,6
P2	Gravel, zeolite, activated carbon, silica sand	28,83	78,70	28,00	1616,33	1
P3	Gravel, water lettuce, activated carbon, silica sand	22,59	80,91	31,60	1827,00	3,1
P4	Gravel, zeolite, activated carbon, water lettuce	28,75	76,87	28,10	1147,33	16,1
P5	Gravel, zeolite, water lettuce, silica sand	21,44	81,58	32,47	2716,67	290,9
	p-value (ANOVA)	0,000*	0,000*	0,000*	0,000*	0,000*

Based on Table 1, the combination of filtration media and phytoremediation significantly reduced wastewater pollutant parameters. The control treatment (P0) still showed relatively high concentrations of BOD, COD, TSS, TDS, and total coliforms, whereas the combined filtration and phytoremediation treatment significantly reduced all parameters. Treatments P3 and P5 showed the highest effectiveness in reducing BOD levels, to 22.59 mg/L and 21.44 mg/L, respectively, indicating that a combination of media such as activated carbon, zeolite, gravel, and silica sand can enhance the adsorption and decomposition of organic matter. The most optimal reduction in TSS and TDS levels was observed in treatments P2 and P4, demonstrating the filtration media's ability to remove suspended solids and dissolved substances through physical filtration and adsorption mechanisms. Additionally, total coliform levels decreased significantly in treatments P2 and P3 compared with the control, indicating that the combined filtration–phytoremediation system can improve the microbiological quality of wastewater.

The ANOVA test results yielded a p-value of 0.000 ($p < 0.05$) for all parameters, indicating significant differences among treatments in the reduction of BOD, COD, TSS, TDS, and total coliforms. These findings demonstrate that *Pistia stratiotes* effectively absorbs organic compounds and reduces pollutant loads through rhizofiltration and the stimulation of microorganisms in the root zone. The effectiveness is further enhanced when *Pistia stratiotes* is combined with adsorbent media such as activated carbon and zeolite, which exhibit high adsorption capacities for organic matter and dissolved contaminants (As'ari et al., 2022).

Table 2. Comparison of BOD, COD, TDS, and TSS concentrations among treatment groups

Treatment	BOD (mg/L)	COD (mg/L)	TDS (mg/L)	TSS (mg/L)
P0	210.3 ± 4.5 ^a	450.2 ± 7.8 ^a	980.1 ± 12.5 ^a	156.3 ± 4.2 ^a
P1	160.4 ± 3.8 ^b	320.4 ± 6.1 ^b	850.5 ± 10.3 ^b	110.2 ± 3.5 ^b
P2	120.3 ± 2.6 ^c	210.5 ± 5.4 ^c	610.7 ± 8.9 ^c	72.5 ± 2.1 ^c
P3	90.4 ± 2.2 ^d	180.6 ± 4.7 ^d	540.8 ± 7.3 ^d	55.4 ± 1.8 ^d
P4	121.5 ± 2.8 ^c	212.3 ± 5.1 ^c	480.4 ± 6.5 ^e	56.2 ± 2.0 ^d
P5	70.8 ± 1.9 ^e	175.3 ± 4.2 ^d	430.6 ± 5.8 ^f	40.1 ± 1.5 ^e
P0	210.3 ± 4.5 ^a	450.2 ± 7.8 ^a	980.1 ± 12.5 ^a	156.3 ± 4.2 ^a

Based on the post hoc test results in Table 2, each treatment combination produced distinct responses in reducing wastewater quality parameters, particularly BOD, COD, TDS, and TSS. For the BOD parameter, the test results indicate that most treatments showed significant differences, but some treatment pairs did not, such as P2 vs. P4 (p -value = 0.9988). This value indicates that both media combinations have relatively similar effectiveness in reducing the content of biodegradable organic matter in the wastewater. This condition suggests that the use of filtration media consisting of gravel, zeolite, activated carbon, silica sand, and a phytoremediation combination using *Pistia stratiotes* can create a mechanism for the removal of organic matter that is nearly identical (Imaniar et al., 2022). The reduction in BOD occurs due to adsorption by activated carbon and zeolite, filtration of organic particles by silica sand and gravel, and the biological activity of water hyacinth, which can absorb dissolved organic compounds through its root system (Ilmannafian et al., 2021). Research by Dewi & Alfiah (2022) indicates that a phytoremediation system using *Pistia stratiotes* is effective in reducing the BOD of liquid waste by increasing rhizosphere microbial activity and plant uptake of organic nutrients.

Analysis of the COD parameter demonstrated that certain treatments did not differ significantly, particularly between P1 and P3 (0.9459), and between P1 and P5 (0.8575). Similarly, the comparison between P3 and P5 showed no significant difference ($p=0.391$). These findings suggest that these treatment combinations are comparable in their effectiveness at reducing both organic and inorganic compounds that require oxygen for chemical oxidation. This similarity is attributed to the predominant roles of activated carbon and zeolite in adsorbing dissolved organic compounds, resulting in nearly equivalent treatment performance (Duran-Ros et al., 2024). Activated carbon provides a high surface area and substantial porosity, facilitating the adsorption of complex organic compounds, while zeolite enables ion exchange and the removal of dissolved pollutants. In contrast, water hyacinth acts as a phytoremediation agent, stabilizing water quality by absorbing nutrients and toxic compounds (Ardiatma et al., 2023).

Analysis of the total dissolved solids (TDS) parameter indicated that all treatment combinations exhibited a significance value of 0.000, demonstrating a highly significant

difference among treatments. The observed reduction in TDS was primarily attributed to the filtration media's capacity to remove fine particles and dissolved ions. Zeolite, with its high cation-exchange capacity, effectively adsorbs dissolved ions, whereas silica sand and gravel function as mechanical filters for small particles that bypass the initial sedimentation stage. Furthermore, the roots of *Pistia stratiotes* absorb dissolved nutrients and minerals from wastewater, thereby enhancing TDS reduction (Nasir & Titah, 2024).

Further analysis of the total suspended solids (TSS) parameter revealed no significant difference between the P3 and P4 treatment pairs (p -value = 0.6326). This finding suggests that both treatments are equally effective at reducing suspended solids in wastewater. The observed reduction in TSS is primarily attributed to physical filtration by gravel, silica sand, and activated carbon layers, which retain small suspended particles and decrease wastewater turbidity (Hammoudani et al., 2024). Moreover, the root system of water hyacinth enhances natural sedimentation by slowing water flow and trapping fine particles that would otherwise remain suspended. The lack of a significant difference between P3 and P4 demonstrates that both media combinations exhibit nearly identical filtration capacities for removing solid particles (Kencana & Radityaningrum, 2022).

Overall, results from further testing across all parameters indicate that the combination of filtration and phytoremediation using *Pistia stratiotes* significantly improves wastewater quality. Differences in effectiveness among treatments suggest that the composition of the filtration medium plays a role in reducing pollutant levels. The combination of filtration and phytoremediation has proven effective in treating wastewater

CONCLUSION

The combination of filtration and phytoremediation significantly improved the quality of hospital wastewater by reducing BOD, COD, TDS, and TSS concentrations under the experimental conditions of this study. The results demonstrated that integrating filtration media with *Pistia stratiotes* enhanced treatment performance compared with individual treatment approaches for several water quality parameters. Pairwise statistical analysis further indicated that some treatment combinations exhibited comparable performance, suggesting that different media configurations may provide similar pollutant removal efficiencies depending on the target parameter. These findings indicate that the combined filtration–phytoremediation system has potential as an alternative or complementary treatment process for hospital wastewater. Further studies under full-scale operating conditions and with longer treatment periods are recommended to evaluate its long-term effectiveness and practical applicability.

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