Advanced and Sustainable Technologies
ASET
E-ISSN 2976-2294
Volume 4, No 2, December 2025 [421-428]

Effect of Rice Husk and Rice Husk Ash in Phytoremediation of Livestock Effluent by *Scirpus grossus*

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Received 28 August 2025, Revised 17 September 2025, Accepted 29 September 2025

ABSTRACT

Livestock wastewater poses a significant environmental challenge due to its high concentrations of chemical oxygen demand (COD), nutrients (nitrogen and phosphorus), suspended solids, and pathogens. If inadequately treated, it can harm both human health and aquatic ecosystems. Phytoremediation, with the use of plants and associated microbes to remove pollutants, offers a low-cost, sustainable alternative to conventional treatment methods. This study investigates the effectiveness of Scirpus grossus (Menerong) in treating livestock effluent, using two agricultural byproducts, rice husk and rice husk ash, as a substrate in phytoremediation treatment. Both media support plant growth and microbial activity while enhancing the removal of contaminants in the wastewater. The system utilizing rice husk achieved removal efficiencies of 78.03% for ammonia (NH_3-N), 33.20% for orthophosphate (PO_4^{3-}), 81.55% for COD, and 49.07% for total suspended solids (TSS). Notably, the rice husk ash substrate outperformed rice husk in several parameters, achieving 75.61% NH_3-N, 33.33% PO_4^{3-}, 96.65% COD, and 68.65% TSS removal. The enhanced performance is attributed to rice husk ash's higher porosity and surface area, which support improved microbial activity and adsorption. These findings demonstrate the potential of Scirpus grossus combined with rice husk ash substrates as an efficient, eco-friendly solution for livestock wastewater treatment. This approach supports sustainable agriculture and waste management practices, making it well-suited for rural application.

Keywords: Phytoremediation, Substrate, Rice husk ash, Rice husk, *Scirpus grossus.*

1. INTRODUCTION

The availability of freshwater in adequate quantity and quality is fundamental to ecological integrity, human well-being, and sustainable development. Recognizing this, the 2030 Agenda for Sustainable Development incorporates a dedicated water quality target within Sustainable Development Goal (SDG) 6, underscoring the global significance of water resource management. The growing prioritization of water pollution control at both national and international levels is expected to exert a substantial influence on future policy frameworks, regulatory approaches, and research agendas aimed at safeguarding water quality and ensuring long-term sustainability [1].

Livestock effluent is a significant contributor to water pollution because of its high concentrations of organic matter and nutrients, which can create severe environmental hazards if not properly managed [2]. The rapid growth of livestock production has further intensified the risk of pollution, largely due to inadequate waste management practices. Traditional treatment methods

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are often insufficient, as they either fail to remove contaminants or prove too costly and environmentally unsustainable.

Phytoremediation, an eco-friendly and sustainable approach utilizing plants to remove, degrade, or immobilize pollutants, has gained increasing attention as a viable treatment option for agricultural wastewater [3]. Phytoremediation is a process that removes contaminants and organic substances from air, soil, and water using living plants. Phytoremediation can be described as the efficient use of plant life to eliminate, detoxify, or immobilize environmental contaminants in a growth matrix (such as soil, water, or sediments) through natural biological, chemical, or physical processes. Plants selected for phytoremediation should exhibit rapid growth, high biomass production, an extensive root system, and strong tolerance to toxic metal compounds, while also being easy to cultivate, manage, and harvest. In this study, *Scirpus grossus* was utilized due to its recognized potential as a hyperaccumulator species. Beyond its ability to tolerate and accumulate pollutants, *S. grossus* can influence water quality by enhancing evapotranspiration processes. Moreover, this species has demonstrated the capacity to effectively remove pollutants even at relatively high concentrations of contaminants in industrial wastewater [4].

Scirpus grossus plants can be a hyperaccumulator due to their fibrous root with white to brown color, a triangular and strong stem, and leaf size of 2 m or greater with 10 mm of thickness. This plant is a perennial aquatic plant with the common name for large bulrush, more club-rush, *rumput menderong* (Malaysia), *mensiang*, and *walingi* (Indonesia). This plant is native to Southeast Asia and is distributed to Australia, Borneo, Bhutan, Cambodia, China, Indonesia, India, Indochina, Laos, Malaysia, Myanmar, Pakistan, the Philippines, Sri Lanka, Thailand, Turkey, and Vietnam. This species is extensively used to deal with domestic wastewater in phytoremediation or wetland generation [5]. This plant can impact water quality through its evapotranspiration mechanisms.

In addition to plant selection, the use of organic and inorganic amendments can significantly enhance the efficiency of phytoremediation systems. Rice husk and rice husk ash, abundant by-products of the rice industry, are particularly effective due to their porous structure, high silica content, and strong adsorption capacity for heavy metals and nutrients [6-7]. When combined with *Scirpus grossus*, these materials not only reduce the mobility and bioavailability of contaminants but also improve substrate aeration, water retention, and root zone conditions. Such improvements may facilitate plant growth, microbial activity, and the uptake of pollutants. The synergistic interaction between *S. grossus* and rice husk or rice husk ash can therefore enhance the potential of pollutant removal efficiencies, demonstrating a sustainable and cost-effective approach for treating contaminated wastewater, especially livestock effluent.

2. MATERIAL AND METHODS

2.1 Experimental Setup

This experimental study was conducted using eight pots, with two replicates established for each treatment system, alongside control pots without plants. All pots were uniform in shape and size and were prepared with a 10 cm layer of gravel (10–20 mm in diameter) at the base, followed by an 8 cm layer of substrate consisting of rice husk and rice husk ash, as shown in Figure 1.

Scirpus grossus plants were acclimatized for 2 weeks before being utilized in the system. The plants were put in the bucket filled with tap water for acclimatization. The livestock effluent was collected from a livestock farm at Alor Pulai, Kedah. The physicochemical parameters of the livestock effluent were measured, including Total Suspended Solids (TSS), Chemical Oxygen Demand (COD), Ammoniacal Nitrogen (NH_3-N), and Orthophosphate. Initially, the effluent was diluted to an appropriate volume of tap water because if the effluent is too acidic, it can harm the plants. In this study, the samples were diluted to a 50% dilution percentage.

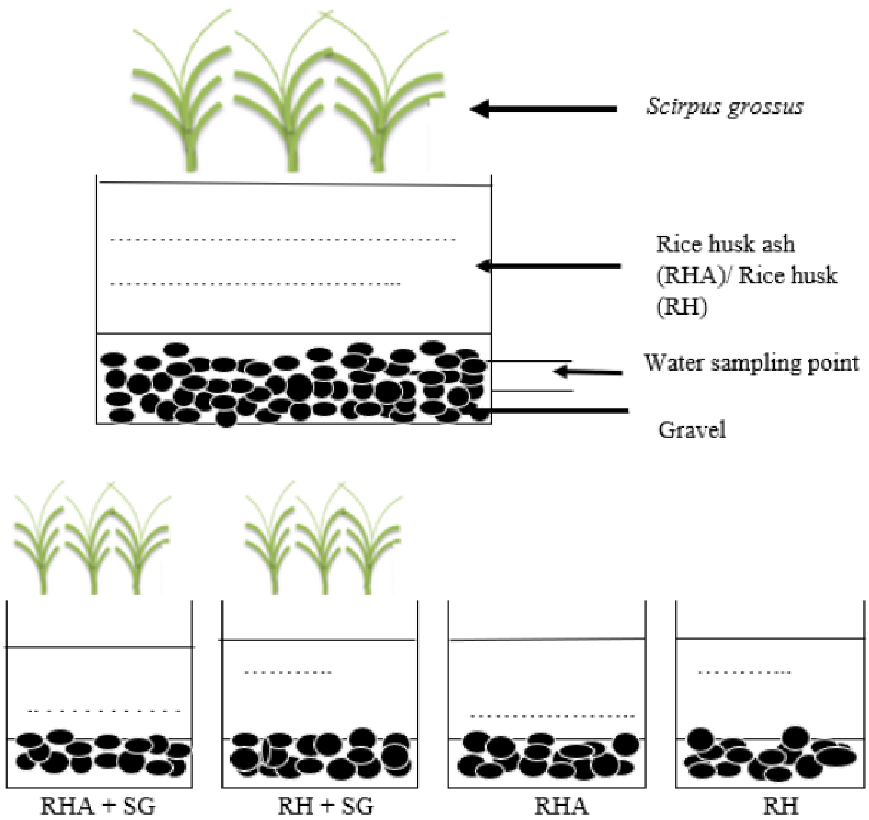


Figure 1: The phytoremediation experimental setup.

2.2 Sampling and Analysis

In each pot, three *Scirpus grossus* plants were cultivated, and 10 L of livestock effluent was added to establish the batch systems. The water level was maintained at the substrate surface, corresponding to a height of 21 cm. To compensate for evaporative losses, particularly on hot days, tap water was added once per week to ensure a consistent wastewater level across all pots. Water quality was monitored by analyzing total suspended solids (TSS), ammoniacal nitrogen (NH_3-N), chemical oxygen demand (COD), and phosphate concentrations in wastewater samples at three-day intervals, beginning on day 0, to assess pollutant removal efficiency and the overall effectiveness of the phytoremediation process.

Physicochemical analyses were conducted following Standard Methods for the Examination of Water and Wastewater (APHA, 2017), ensuring accuracy and reproducibility of results. Removal efficiencies for each parameter were calculated using the formula (1).

$$\text{Removal efficiency (\%)} = \frac{Co-Ct}{Co} \times 100\% \qquad (1)$$

where Co represents the initial concentration and Ct the concentration at a given sampling time. This approach enabled evaluation of both temporal changes in pollutant levels and the overall effectiveness of the phytoremediation system.

The data were statistically analyzed by using the analysis of variance (ANOVA). All data accumulated in this study have been used to determine the significant differences between the systems in removing pollutants and excess nutrients, and all the sample was duplicated. Future studies should incorporate additional replications to enhance statistical reliability and provide stronger evidence for the observed effects.

3. RESULTS AND DISCUSSION

3.1 Livestock Effluent Physicochemical Characterization

Table 1 shows the characteristics of livestock effluent and the concentration of the parameters. The data showed the concentration of livestock effluent in this study, and the Water Quality Index (WQI) was classified in water quality class II for conventional treatment [8].

Table 1. The characteristics of livestock effluent.

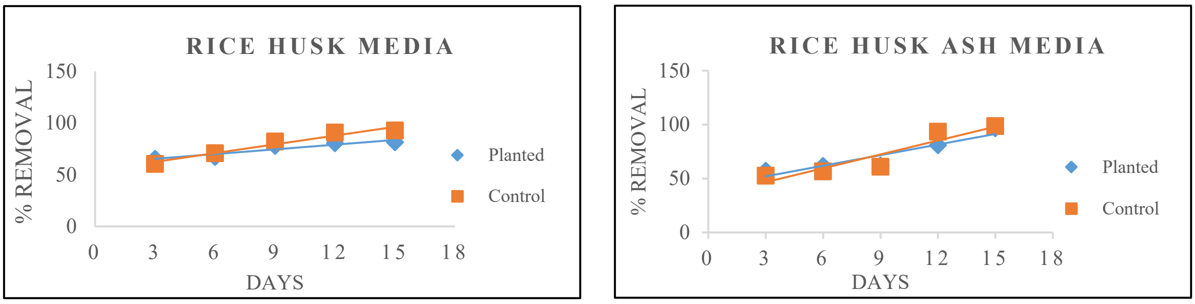
Parameter	Unit	Concentration	Class II
pH	-	5 – 7	6 – 9
Turbidity	NTU	16.00	50
Nitrogen, NH_3-N	mg/L	0.93	0.3
Phosphorus, PO_4^{3-}	mg/L	2.42	0.2
Chemical oxygen demand, COD	mg/L	696.75	25
Total suspended solids, TSS	mg/L	434.50	50

The characterization of livestock effluent revealed substantial deviations from the Class II water quality guidelines. The pH of the effluent falls slightly below the acceptable range, indicating a tendency toward acidic conditions that may hurt aquatic ecosystems. Turbidity was within the permissible limit, suggesting relatively low light attenuation potential from suspended colloids[9]. However, critical exceedances were observed for nutrient and organic parameters. Ammoniacal nitrogen and phosphate concentrations exceeded the guideline values. These elevated nutrient levels pose risks of eutrophication and oxygen depletion in receiving waters [10]. Similarly, COD and TSS greatly exceeded the limits of 25 mg/L and 50 mg/L, reflecting an extremely high organic load and suspended particulate content. Such concentrations indicate that the untreated effluent has the potential to deteriorate water quality severely, disrupt aquatic habitats, and threaten compliance with regulatory standards. These findings confirm that untreated livestock effluent contains excessive organic and nutrient loads, which can deplete dissolved oxygen, impair aquatic ecosystems, and render the water unsuitable for Class II designated uses without prior treatment [11].

3.2 Removal Efficiencies

3.2.1 Chemical Oxygen Demand (COD)

Figure 2 illustrates the COD removal efficiencies in systems containing rice husk and rice husk ash. The results demonstrate that the control systems (without plants) achieved higher removal rates compared to the planted systems. In rice husk media, the planted system achieved a COD removal efficiency of 81.55%, while the control system reached 92.73%. Similarly, in rice husk ash media, the control system attained 98.49% COD removal, which was slightly higher than the 96.65% observed in the planted system. These findings suggest that rice husk and rice husk ash themselves exhibit strong intrinsic adsorptive capacity, effectively reducing COD levels without the contribution of plants. From the ANOVA analysis, there is no significant reduction of COD in both systems because the p-value is larger than 0.05.



(a) (b)

Figure 2. Removal efficiency of COD for both media (a) rice husk and (b) rice husk ash in the constructed wetland system.

This trend aligns with previous studies reporting that lignocellulosic residues, such as rice husk, enhance their capacity to bind and remove organic pollutants from wastewater. Rice husk ash, enriched in amorphous silica, further improves adsorption efficiency by providing a porous structure and larger surface area, which explains the higher removal observed in the ash-based system [6]. While the planted systems showed slightly lower efficiencies, this could be attributed to rhizosphere effects, including microbial competition, oxygen release, and root exudation, which may temporarily alter contaminant dynamics[12].

Nevertheless, the integration of *Scirpus grossus* with rice husk and rice husk ash remains significant. Previous research has highlighted that while adsorptive materials can rapidly remove pollutants in the short term, their efficiency often declines over time due to surface saturation [6]. In contrast, phytoremediation contributes long-term benefits through plant uptake, evapotranspiration, and stimulation of microbial communities, thereby sustaining treatment efficiency [13]. The combination of *Scirpus grossus* with rice husk and rice husk ash may offer a more sustainable and resilient system for agricultural wastewater treatment.

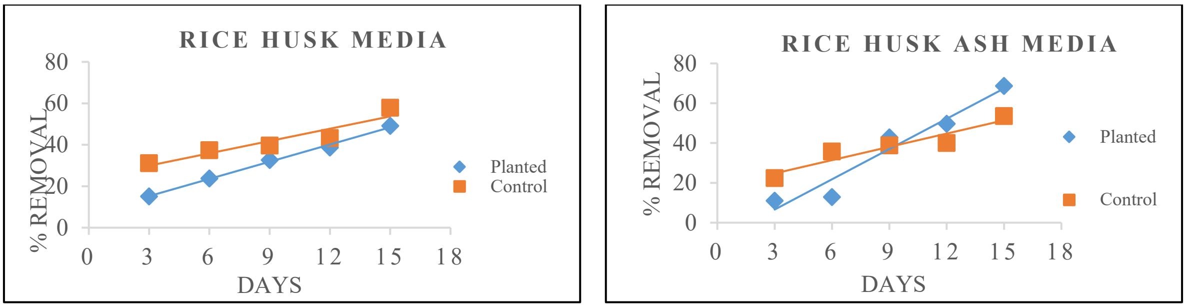
3.2.2 Total Suspended Solid (TSS)

Figure 3 shows the TSS removal efficiencies in both rice husk and rice husk ash. The results showed that the control system in rice husks had greater removal efficiency than the planted system, at 68.65%. However, the planted systems demonstrated a comparatively higher removal efficiency than the controls, using rice husk ash, with 57.82% compared to 49.07% in the control systems. This improvement may be linked to sedimentation processes enhanced by root structures, which act as physical barriers that trap suspended particles[14]. Root exudates can also promote biofilm formation, further facilitating the removal of particulates from the wastewater. Previous studies have similarly reported that wetland macrophytes increase TSS removal by stabilizing substrates and providing surfaces for microbial attachment, thereby complementing sedimentation as a natural removal mechanism [15]. From ANOVA analysis, there is a significant reduction of TSS in the rice husk media because the p-value is ≤ 0.05, but there is no significant reduction in rice husk ash media because the p-value is larger than 0.05.

3.2.3 Nutrient Removal Efficiencies

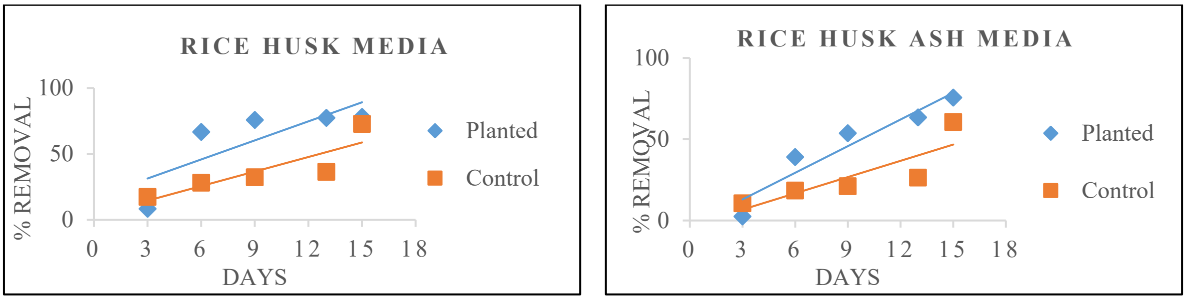
Nutrient removal is mainly achieved by reducing the levels of nitrogen and phosphorus with advanced wastewater technologies, such as an integrated constructed wetland design in the experiment. There are two types of nutrients analysed in this study, that is ammonia nitrogen (NH_3-N) and orthophosphate (PO_4^{3-}). The nutrient removal, distinct trends were observed for both ammonia nitrogen and phosphorus. The concentration of NH_3-N in wastewater can be unpredictable due to the decomposition of organic waste matter and nitrogen fixation processes

[16]. Figure 4 shows the overall performance of ammonia nitrogen (NH_3-N) using *Scirpus grossus* plotted against the days of the treatment, while Figure 5 shows the phosphate removal.



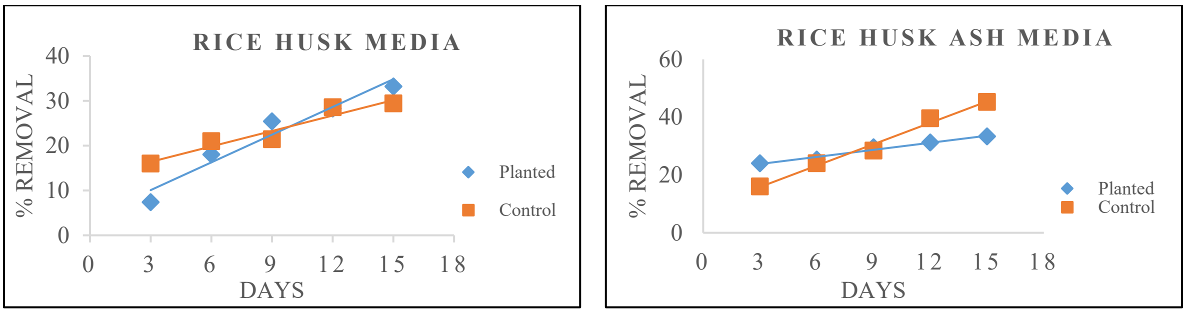
(a) (b)

Figure 3. Removal efficiency of TSS for both media (a) rice husk and (b) rice husk ash in the constructed wetland system



(a) (b)

Figure 4. Removal efficiency of NH_3-N for both media (a) rice husk and (b) rice husk ash in the constructed wetland system.



(a) (b)

Figure 5. Removal efficiency of PO_4^{3-} for both media (a) rice husk and (b) rice husk ash in the constructed wetland system

For ammoniacal nitrogen, the result showed that the planted systems have higher removal efficiency compared to the control system for both media. The planted systems consistently outperformed the control systems, highlighting the critical role of *Scirpus grossus* in nutrient uptake [17]. Ammonia removal in planted systems is likely enhanced through plant assimilation, nitrification-denitrification processes stimulated in the rhizosphere, and oxygen diffusion from roots into the surrounding media [18]. From the ANOVA analysis, there is no significant reduction of NH_3-N in both the rice husk media and rice husk ash because the p-value is larger than 0.05.

The phosphate removal efficiency in rice husks in planted systems was higher than in control systems. In contrast, the phosphate removal efficiencies in rice husk ash were greater in control systems without a *Scirpus grossus* plant. The phosphate reduction is attributed to plant uptake and possible precipitation with cations present in the rhizosphere, in addition to adsorption by rice husk ash [19]. From ANOVA analysis, there is no significant reduction of PO_4^{3-} in the rice husk and in rice husk ash media because the p-value is ≥ 0.05. These findings are consistent with previous research demonstrating that plants not only assimilate nutrients but also enhance microbial processes that contribute to nutrient cycling in constructed wetland systems [20].

4. CONCLUSION

This study evaluated the performance of planted and control systems in treating livestock wastewater by reducing nutrient and organic matter concentrations. The physicochemical parameters analyzed, including pH and turbidity, demonstrated that the presence of plants contributed to pollutant reduction. The results underscore the crucial role of vegetation in improving water quality within phytoremediation systems. Furthermore, the potential of *Scirpus grossus* as a phytoremediation species was confirmed through comparison with control systems. The plant not only survived but also tolerated the livestock effluent over the 15-day experimental period, indicating its adaptability to polluted environments. The findings suggest that *S. grossus* is effective in removing nutrients and metals, thereby demonstrating its capacity to reduce pollutant levels toward regulatory limits. Overall, the study concludes that the integration of *S. grossus* in phytoremediation systems represents a viable and sustainable approach for livestock wastewater treatment. Future studies should consider extending the experimental period more than 15 days to determine the pollutant removal performance by the constructed wetland treatment system, and conducting scaled-up experiments to evaluate its performance under larger or more practical conditions.

ACKNOWLEDGEMENTS

The researchers acknowledge our colleagues at the Faculty of Chemical Engineering & Technology and the Faculty of Civil Engineering & Technology for their technical assistance during the lab work. We are also thankful to our colleagues and the faculty members of the Department of Agrotechnology, Faculty of Mechanical Engineering & Technology, Universiti Malaysia Perlis, for their valuable suggestions and support. Finally, we wish to acknowledge all those who contributed directly or indirectly to the completion of this work.

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Conflict of interest statement: The authors declare no conflict of interest.

Author contributions statement: Conceptualization, Sa'at S.K.M & N.A. Jalil; Methodology and Labworks, N.A. Jalil; Writing & Editing, Sa'at S.K.M & N.A.Jalil; Funding, Jamailudin M.S.