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Bioremediation Potential of *Nymphaea* sp., *Zantedeschia aethiopica*, and *Spirodela polyrhiza* for Laundry Wastewater Treatment

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ABSTRACT

This research aims to assess the efficacy of three distinct types of aquatic plants, namely *Nymphaea sp.*, *Hydrocotyle* sp., and *Spirodela sp.*, in wastewater bioremediation from the laundry industry. The wastewater from the laundry industry contains a range of chemical substances that have the potential to pollute the surrounding environment. These include detergents, fragrances, and other chemicals that can cause pollution of the aquatic environment. The research method entailed the simultaneous planting of the three types of aquatic plants in controlled containers with the tested laundry wastewater. The temperature, pH, total dissolved solids (TDS), and dissolved oxygen (DO) of the laundry water effluent were measured before and after passing through the aquatic plant system. The results demonstrated that all three types of aquatic plants exhibited the capacity to reduce the concentration of TDS in laundry wastewater. The study revealed that there were notable differences in the effectiveness of various aquatic plant species in reducing TDS. Of the three plant species examined, *Spirodela sp.* demonstrated the greatest potential for reducing detergent concentrations, as indicated by a notable decrease in TDS.

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1. INTRODUCTION

In several locations across the country, the processing of household liquid waste remains an unresolved issue. In addition to the considerable financial costs and the challenging standards that are still in place, this is reinforced by the widespread assumption among the general public that the disposal of household waste directly into the environment will not have a significant impact. In such circumstances, the necessity arises for implementing a household waste processing system that is both cost-effective and straightforward to deploy, capable of delivering optimal results in the processing and monitoring of household waste, thus reducing its impact on the environment (Suriawiria, 2003). One potential avenue for exploration is utilizing natural resources that are known to be associated with purifying household waste. In this context, various types of aquatic plants that flourish in ponds or facilitate air circulation (Haryoto, 1999) may offer a promising avenue for investigation.

The role of aquatic plants in liquid waste management is of considerable significance due to their capacity for a range of processes, including rhizofiltration, phytoextraction, phytovolatilization, and phytodegradation/phytotransformation. A variety of aquatic plant species can exhibit these processes. The efficacy of utilizing aquatic plants is contingent upon some factors, including the concentration of pollutants, the duration of the remediation process, and the environmental factors that can impact plant growth and development. Nevertheless, a substantial body of documented evidence attests to the efficacy of phytoremediation as a means of cleansing waterways through the use of aquatic plants (Mustafa & Hayder, 2020).

Phytoremediation represents an effective approach for the treatment of laundry wastewater, with the concentration of dissolved substances in water, represented by Total Dissolved Solids (TDS), serving as a crucial parameter for the evaluation of its efficacy. Research findings indicate that higher concentrations of laundry wastewater correlate with increased TDS levels, suggesting that the presence of organic and inorganic pollutants from detergents contributes to this rise (Sari & Nugroho, 2020). Based on the available evidence, the utilization of aquatic plants in the household waste bioremediation process represents a potential opportunity to reduce the TDS level in laundry wastewater. However, further research is required to obtain more detailed scientific facts. Consequently, research has been conducted in the form of water plant simulations to employ water plants to reduce the levels of water pollution caused by household waste (laundry water waste) and identify the most effective water plants for reducing TDS in water. The research also aimed to assess the efficacy of waste processing from three types of aquatic plants: Kiambang (*Spirodela polyrhiza*), *Nymphaea sp.* (*Nymphaea sp.*), and Arum Lilia (*Zantedeschia aethiopica*).

2. METHODS

The research involved the collection of laundry wastewater samples from two distinct locations, which were subsequently combined within a reactor for experimental purposes. The study utilized three plant species: *Spirodela sp.*, *Nymphaea sp.*, and *Zantedeschia sp.* Prior to their introduction into the reactor containing the laundry wastewater, the plants were meticulously cleaned to ensure experimental consistency.

The parameters subjected to evaluation, both prior to and following the implementation of the plant, encompassed temperature, pH, total dissolved solids (TDS), and dissolved oxygen (DO). The percentage of phytoremediation on TDS in wastewater was calculated using the following formula.

$$phytoremediation = \left(\frac{Remediated\ of\ TDS}{\text{Initial TDS of wastewater}}\right) \times 100 \quad (1)$$

These parameters were measured at four intervals: 24, 48, 72, and 96 hours post-introduction of the plants. The experimental design and data analysis adhered to the Randomized Group Design (RGD) methodology, ensuring robust statistical assessment of the findings.

3. RESULTS AND DISCUSSION

The impact of utilising distinct plant types at the designated time points of 0, 24, 48, 72, and 96 hours on the TDS and DO values of laundry waste can be observed in Tables 1, 2, and 3.

Tabel 1. TDS and DO measurement from phytoremediation by *Spirodela sp.*

Parameter	Plant exposure time (hour)					Phytoremediation (%)
	0	24	48	72	96	
TDS (ppm)	482	447	440	447	460	4.56
DO (ppm)	1	1	1	1	1	0

Tabel 2. TDS and DO measurement from phytoremediation by *Nymphaea sp.*

Parameter	Plant exposure time (hour)					Phytoremediation (%)
	0	24	48	72	96	
TDS (ppm)	482	431	446	453	462	4.15
DO (ppm)	1	1	1	1	1	0

Tabel 3. TDS and DO measurement from phytoremediation by *Zantedeschia aethiopica*.

Parameter	Plant exposure time (hour)					Phytoremediation (%)
	0	24	48	72	96	
TDS (ppm)	482	474	493	482	551	-14.31
DO (ppm)	1	1	1	1	1	0

The application of the three types of plants to wastewater for a period of 96 hours yielded disparate outcomes. In the *Spirodela sp.* and *Nymphaea sp.* species, a reduction in total dissolved solids (TDS) content was observed. This suggests that the phytoremediation process is occurring. However, the TDS levels observed in the *Zantedeschia aethiopica* species. The impact of introducing the three types of water on the plant parameter values is illustrated in **Figures 1, 2, 3** and **4**.

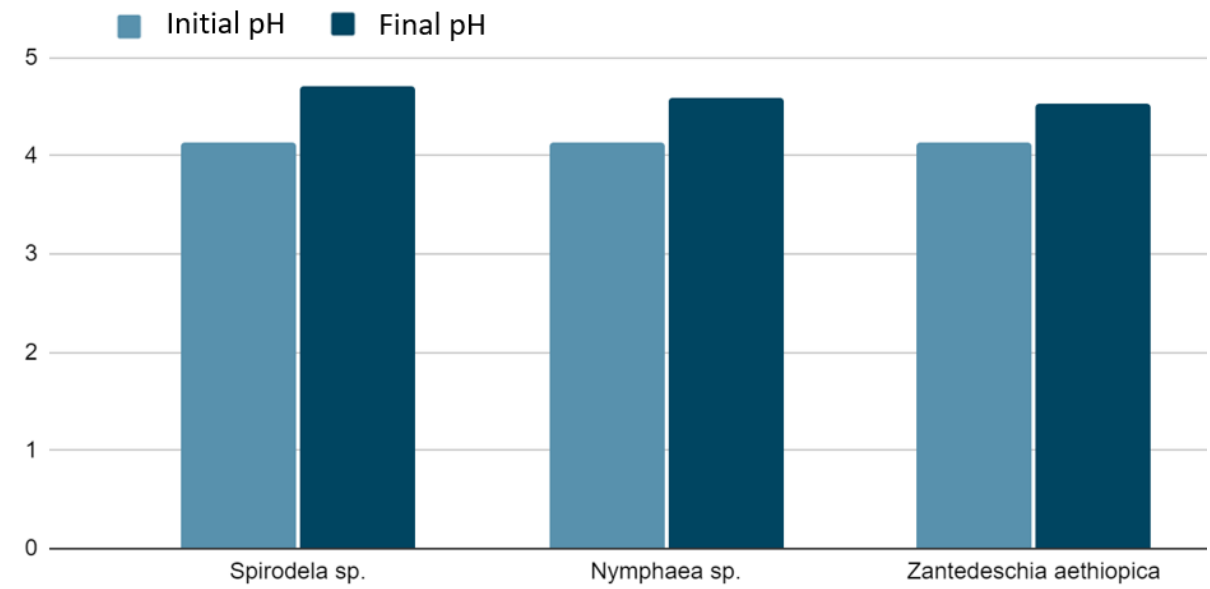

Figure 1. Graph illustrates the pH value after the application of the three plant types

The graph above illustrates that the utilisation of aquatic plants as a phytoremediation medium for household water waste has a discernible impact on the pH of the water. Among the various plants, *Spirodella* sp. exhibits the most pronounced effect, with an increase of 0.14% in pH. In comparison, Nymphaea and Zantedeschia plants were observed to elevate the pH by 0.12% and 0.1%, respectively.

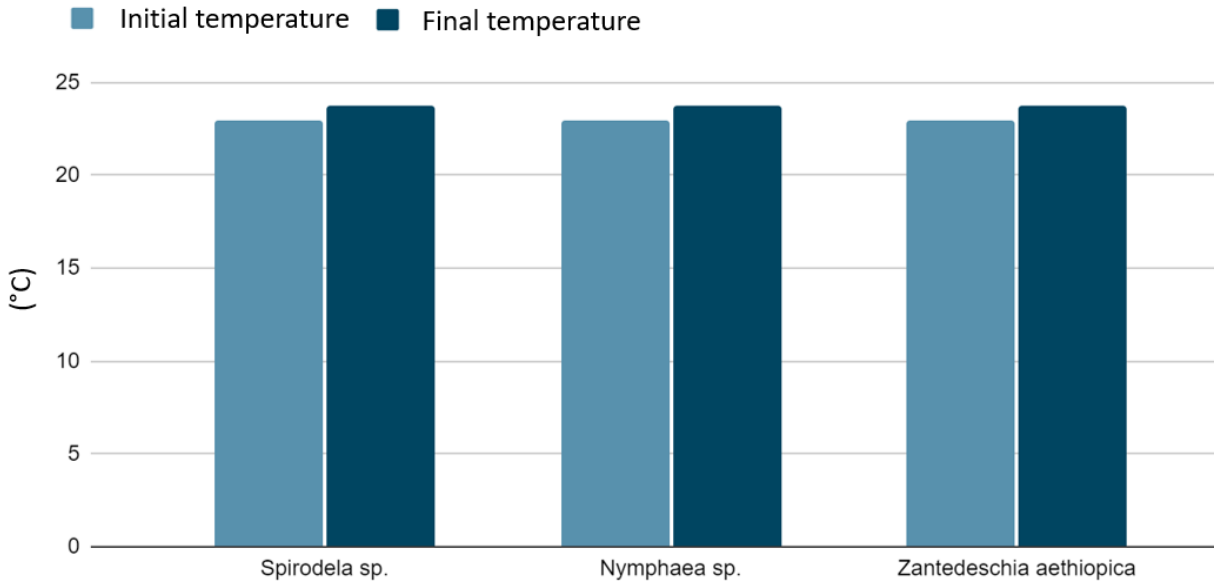

Figure 2. Graph illustrates the temperature value after the application of the three plant types

As illustrated in the graph, the utilisation of aquatic plants for the remediation of laundry wastewater has an effect on alterations in temperature. The temperature of the wastewater increased from 23°C to 23.7°C, representing a rise of 0.7°C.

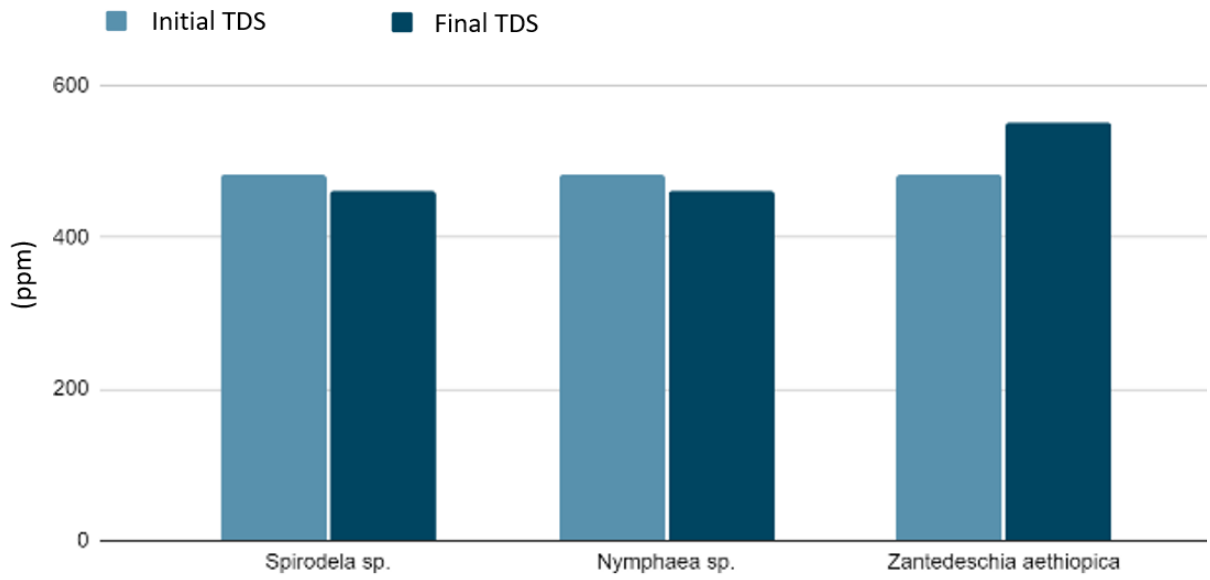

Figure 3. Graph illustrates the TDS value after the application of the three plant types

The utilisation of the aquatic plant *Spirodela sp.* and *Nymphaea sp.* in TDS parameters resulted in a reduction of the TDS level in the wastewater from 482 ppm to 460 ppm in *Spirodela sp.* and to 462 ppm in *Nymphaea sp.* Conversely, the introduction of the *Zantedeschia aethiopica* plant led to an increase in TDS to 551 ppm. No discernible alteration in dissolved oxygen (DO) levels was observed between the initial control and the final day of observation.

The findings of this study demonstrate that *Spirodela sp.* and *Nymphaea sp.* species effectively reduce total dissolved solids (TDS) in laundry wastewater. Conversely, the TDS levels associated with Zantedeschia aethiopica increased, likely due to the leaching of water-soluble root substrates and the accumulation of dust from wastewater stored in open environments. This result emphasizes the importance of selecting appropriate plant species for wastewater treatment. Both *Spirodela sp.* and *Nymphaea sp.* exhibit the ability to absorb various solutes, including organic compounds and nutrients contributing to TDS. Through mechanisms such as phytoextraction and phytodegradation, these plants facilitate the removal of pollutants, leading to a significant reduction in TDS concentrations.

The reduction in TDS observed with Spirodela sp. and Nymphaea sp. aligns with previous research. For example, studies have shown these plants can remove up to 77.5% of chemical oxygen demand (COD), 54.3% of phosphates, and 99.9% of surfactants from laundry wastewater. These findings highlight the promising potential of these species for sustainable phytoremediation. Spirodela, commonly known as duckweed, is particularly effective due to its rapid growth, floating nature, and direct nutrient absorption from the water column. Similarly, Nymphaea (water lilies) possesses extensive root systems that stabilize sediments and enhance nutrient uptake. These traits allow both species to significantly reduce TDS by extracting organic and inorganic pollutants, contributing to improved water quality.

In comparison, other aquatic plants such as Eichhornia crassipes (water hyacinth) and Pistia stratiotes (water lettuce) also exhibit phytoremediation properties. However, Spirodela sp. and Nymphaea sp. offer distinctive advantages, including smaller size for denser planting and adaptability to diverse environmental conditions. These characteristics position them as superior choices for wastewater treatment systems (Banerjee & Roychoudhury, 2022).

Quantitative analysis shows that the wastewater subjected to phytoremediation for 96 hours exhibited a TDS reduction that brought the levels closer to environmental discharge

standards set by the United States Environmental Protection Agency (EPA). The EPA's secondary water quality standard for TDS is 500 mg/L (EPA, 2023). By achieving significant TDS reductions, the use of these aquatic plants can minimize environmental pollution and contribute to the sustainable management of laundry effluent.

The pH of the wastewater increased slightly during phytoremediation, with all three plants showing pH enhancements of 0.4 to 0.6 units. While this indicates progress in reducing acidity, the pH remained below the regulatory range of 6.5–9 required for environmental discharge. *Spirodela sp.* demonstrated a higher pH increase than the other species, though the value still fell within the acidic range. The inability to meet pH standards suggests that phytoremediation alone may be insufficient for wastewater with high acidity levels. Complementary methods, such as adding buffering agents, may be necessary to achieve the desired pH.

The unchanged dissolved oxygen (DO) levels in this study may be attributed to measurement inaccuracies or tool calibration errors. Ideally, aquatic plants should increase DO through photosynthesis, where oxygen is released into the water. This highlights the need for improved calibration and verification of measurement tools in future studies. Despite these limitations, the role of *Spirodela sp.* and *Nymphaea sp.* in enhancing water quality remains significant.

The slight temperature increase (0.3%) observed in the wastewater is within the normal range (22–25°C) for aquatic life (Sugiharto, 2003). This localized heat generation likely stems from microbial activity during organic matter decomposition. While minimal, these changes highlight the role of microorganisms in complementing plant-based wastewater treatment.

In conclusion, Spirodela sp. and Nymphaea sp. offer considerable potential for TDS reduction and overall water quality improvement. However, the findings also reveal limitations, particularly with pH regulation and DO enhancement, suggesting the need for integrating phytoremediation with other techniques. Addressing these challenges could optimize the practical application of aquatic plants in sustainable wastewater management.

4. CONCLUSION

The findings of this study demonstrate that the bioremediation of household laundry wastewater using aquatic plants—namely Spirodela sp., Nymphaea sp., and Zantedeschia aethiopica—holds significant potential for improving wastewater quality by addressing chemical parameters such as pH, temperature, and total dissolved solids (TDS). Among the tested plants, Spirodela sp. was found to be the most effective in increasing water pH levels, although the pH values achieved remained below the acceptable range for safe environmental discharge of liquid waste.

Both Spirodela sp. and Nymphaea sp. effectively reduced TDS concentrations within 96 hours of application, highlighting their superior capacity for removing dissolved solids compared to Zantedeschia aethiopica. However, the study observed no measurable improvement in dissolved oxygen (DO) levels with any of the plants, suggesting that the bioremediation process involving these species may not directly influence oxygenation.

This research underscores the potential of using Spirodela sp. and Nymphaea sp. in wastewater management systems as a sustainable solution to reduce pollutants, particularly TDS. Nonetheless, further studies are needed to address limitations such as suboptimal pH adjustments and to explore complementary strategies to enhance overall wastewater quality, including DO levels.

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6. AUTHORS' NOTE

The authors declare that there is no conflict of interest regarding the publication of this article. Authors confirmed that the paper was free of plagiarism.

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