COMPARISON OF PISTIA STRATIOTES AND LEMNA MINOR PLANTS POTENTIALS IN BIOREMEDIATION OF DOMESTIC WASTEWATER

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ABSTRACT

Phytoremediation is an eco-friendly and cost-effective biotechnological method of wastewater treatment that involves the use of plants. In this research work, the potentials of Pistia stratiotes and Lemna minor aquatic plants in the treatment of wastewater were examined. The two plants were cultivated in the wastewater sample for 10 days. Water quality parameters (turbidity, chemical oxygen demand (COD), phosphate, ammoniacal nitrogen and nitrate) tests were conducted on the untreated (influent) and treated water (effluent) samples at a detention time of 24 hours. The outcome of the analysis demonstrates that P. stratiotes effluent achieved a reduction efficiency of up to 91.9%, 68%, 79.6% and 71% for turbidity, phosphate, ammoniacal nitrogen and nitrate, respectively. Whereas for L. minor treated water samples, the highest reduction efficiency for turbidity, COD, phosphate, ammoniacal nitrogen and nitrate was found to be 87.2%, 46%, 48.7%, 83% and 56%, respectively. Hence, the overall outcome obtained indicated that P. stratiotes improved the domestic wastewater quality than L. minor plants.

Keywords: biological wastewater treatment; retention time; nitrate; phosphate; turbidity

1.0 INTRODUCTION

The menace of water pollution has become a global crisis around the world. This is due to increase in population, industrialization, inefficient management of water resources and poor treatment technologies (Shah *et al.,* 2014). One of the environmental issues that impact the lifetime maintenance of water resources in Malaysia is water pollution (Afroz *et al.,* 2014). In Malaysia, freshwater from natural sources contributes 97% of the overall water demand and consumption (Gasim *et al.,* 2009). Unfortunately, there is a high chance that the broadly available sources of natural water endowed in the country cannot guarantee adequate water supply due to water pollution (Afroz *et al.,* 2014). Management of water pollution is one of the most critical aspects of environmental pollution. However, phytoremediation can be used to curb environmental pollution (Raju *et al.,* 2010). Additionally, aquatic plants (free-floating, emergent and submerged macrophytes) and algae have been used to remove nutrients and contaminants from wastewater. Phytoremediation of wastewater using aquatic plant systems has been recognized as an alternative means of wastewater remediation. Aquatic plants such as *Pistia stratiotes, Lemna minor, Azolla filiculoides, Hydrilla verticillata, Azolla caroliniana, Spirodela polyrhiza, Salvinia cucullata, Lemna gibba, Azolla pinnata, Eichhornia crassipes* and *Typha domingensis* has been used as bioaccumulator agents in recovering and recycling of wastewater (Mustafa and Hayder, 2020). Pistia stratiotes is a free, noxious and stoloniferous herb with short stem found floating in stagnant shallow ponds (Pavithra and Kousar, 2016). Similarly, *Pistia stratiotes* aquatic plant was selected as the test plant in this research because it has the ability to enhance microbial activity, absorb nutrients and remove suspended solids (Fonkou *et al.,* 2002). On the other hand, duckweed (*Lemna minor*) belongs to the *Lemnaceae* family. *L. minor* is effective in removal of heavy metals, organic matter, suspended solids and soluble salts from wastewater (El-Kheir *et al.,* 2007; Radic *et al.,* 2010). Furthermore, Hanafiah et al. (2018) reported the effectiveness of *P. stratiotes* and *S. molesta* plants in removal of total suspended solids and ammoniacal nitrogen from wastewater. Hayder and Mustafa (2021) evaluated the performance of three aquatic plants in biofiltration of domestic wastewater. The outcome of the study indicated that the aquatic plants reduced the turbidity, ammonia, phosphorous and nitrate concentration in the wastewater samples. Hence, this study investigated and compared the efficiency of two selected plants; *P. stratiotes* (water lettuce) and *L. minor* (duckweed) in bioremediation of secondary treated domestic wastewater. The novelty of this study included the applications of aquatic weed plants in wastewater treatment. Furthermore, it involved the design and development of a sustainable hydroponic systems for investigating, comparing and ascertaining the potentials of *P. stratiotes* and *L. minor* in bioremediation of wastewater.

2.0 MATERIALS AND METHODS

2.1 Experimental Setup

The experiments were conducted in the premises of the campus and fed with sewage treatment plant (STP) effluent. Two rectangular acrylic tanks connected to an inlet and outlet pipes of known dimensions were used as the wastewater treatment system. The inlet pipe was connected to the exit point of the secondary treated domestic wastewater, which supplies the influent water directly into the constructed treatment tanks. These tanks served as a shallow pond system for the cultivation of the aquatic plant samples and tertiary treatment of the wastewater. Figure 1 illustrates the schematic diagram of the treatment tanks used in this research.

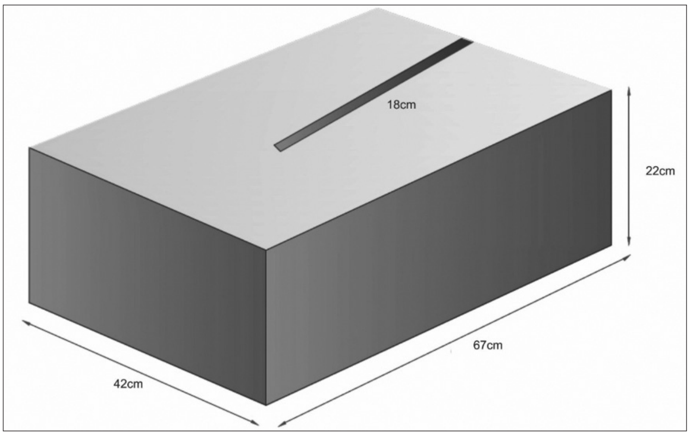

Figure 1: Schematic diagram of the treatment tank

2.2 Collection of the Plant Samples

The selected plant samples (*P. stratiotes* and *L. minor*) were obtained within the vicinity of the campus. Approximately 80g of the plant samples were used for the cultivation process. The plant samples were rinsed and acclimatized for 7 days in plastic bowls before transferring into the constructed treatment tanks filled with the influent water samples.

2.3 Collection and Analysis of the Influent and Effluent Water Samples

The influent water samples were collected at the secondary treated water discharge point in the STP. Whereas, the *P. stratiotes* and *L. minor* treated water samples were regarded as the effluent samples. Physicochemical analysis such as turbidity, chemical oxygen demand (COD), phosphate, ammoniacal nitrogen and nitrate of the influent and effluent water samples were monitored every 2 days at a retention time of 24 hours for 10 days. The turbidity of the water samples was assessed using a HANA HI 93703 turbidimeter with a range of 0-1000 NTU and 890 nm peak. COD level was determined using the reactor digestion method (8000). The phosphate test was analyzed using the ascorbic acid method (HACH method 8084) and the concentration of nitrate was determined using the cadmium reduction method (HACH method 8039). The tests were repeated thrice and the average results obtained were recorded. Furthermore, the percentage reduction efficiency was calculated using equation 1 (Mustafa & Hayder, 2020). Additionally, analysis of variance (ANOVA) was used to assess the significance of difference. The flowchart of the methodology and the summary of the experimental process is presented in Figure 2 and Table 1, respectively.

$$\text{Percentage reduction efficiency } (\%) = \frac{Wi - We}{Wi} \times 100 \qquad (1)$$

Where Wi = influent concentration

We = effluent concentration

The flowchart of the methodology is presented in Figure 2 and Table 1.

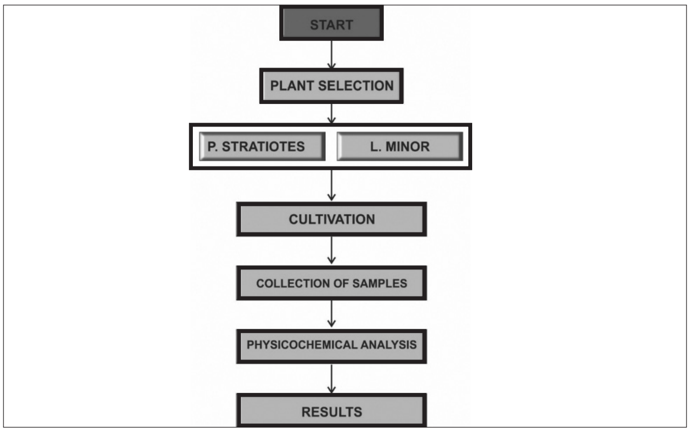

Figure 2: Flowchart of the methodology

Table 1: Summary of the experimental process

Weight of plant	**Type of aquatic plants in the constructed treatment system**	
	a) Pistia stratiotes	***b) Lemna minor***
80 g 0 day of the treatment process	 *Figure 3:* *P. stratiotes samples*	 *Figure 4:* *L. minor plant samples*
10th day of the treatment process	 *Figure 5:* *P. stratiotes on the 10th day of the sampling period*	 *Figure 6:* *Action of duckweed pests in L. minor cultivated treatment system*

3.0 RESULTS AND DISCUSSION

This research work was conducted to investigate the efficiency of *P. stratiotes* and *L. minor* plants in the phytoremediation of domestic wastewater. Water quality parameters such as turbidity, COD, phosphate, ammoniacal nitrogen and nitrate were analyzed according to the methods described above. The results obtained are presented in the graphs below.

3.1 Determination of Turbidity Concentration

The potentials of *P. stratiotes* and *L. minor* aquatic plants in improving the clarity of the influent samples were studied. The outcome of the turbidity analysis are presented in Figure 7.

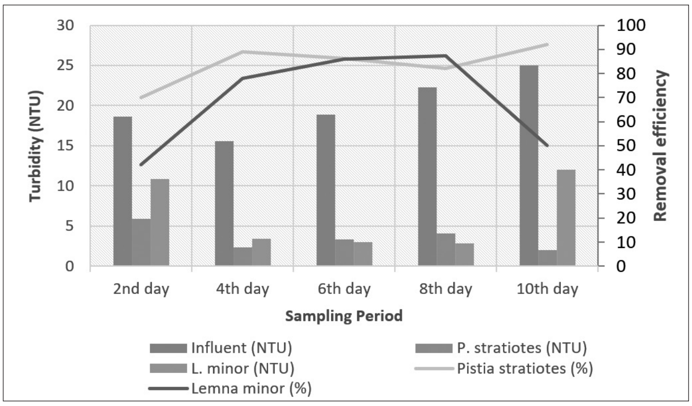

Figure 7: Graph of turbidity reduction against sampling period

From Figure 7, *P. stratiotes* and *L. minor* treated water samples showed a remarkable improvement in polishing the wastewater samples. Additionally, the effluent water samples indicated a constant reduction in the turbidity level when compared to the influent samples from the beginning to the last day of the sampling period. It was observed that on the 2nd day of the experiment, the turbidity level of the influent sample was reduced from 18.6±0.28 NTU to 5.9±1 NTU for *P. stratiotes* and 10.8±1.9 NTU *L. minor* treatment systems. Similarly, the influent samples were improved from 22.3±0.57 NTU to 4 ±0.52 NTU and 2.8±0.95 NTU by *P. stratiotes* and *L. minor*, respectively. The minimum and maximum reduction efficiency of 70% and 90% (*P. stratiotes*) and 42% and 87% *(L. minor*) were achieved. The findings obtained from the study demonstrated that a significant reduction (p< 0.0 5) was observed in the effluent samples. However, *L. minor* aquatic plants showed less effective treatment of the influent samples compared to the results obtained from the *P. stratiotes* plants. The highest reduction efficiency for *L. minor* effluent samples was obtained on the 8th day with a value of 87.2%. These findings indicated that *P. stratiotes* and *L. minor* are efficient in improving the influent water samples to the acceptable water standard of 5 NTU. Also, the results from obtained *P. stratiotes* effluent samples in this study corresponded with the work of (Aswathy, 2017), who reported that *P. stratiotes* significantly improved kitchen wastewater quality with 85.66% reduction in turbidity.

3.2 Determination of COD Concentration

COD is a water quality assessment parameter used for determining the strength of pollutants in wastewater. Figure 8 represents the results obtained from the COD concentration analysis carried out on the influent and effluent wastewater samples.

From the results presented in Figure 8, the trends in the COD concentration analysis demonstrated by the two test plants (*P. stratiotes* and *L. minor*) was almost the same. The COD values for *P. stratiotes* and *L. minor* decreased steadily as the contact time increases. On the 2nd day of the sampling study, *P. stratiotes* and *L. minor* reduced the COD from 152 ±0.5 mg/l to 121 ±0 mg/l and 115 ±0 mg/l , respectively. Additionally, in the overall experiments, the removal efficiency of COD was 49% for *P. stratiotes* and 46% for *L. minor*. The findings obtained from the study demonstrated that a significant reduction (p<0.05) was observed in the wastewater samples, but an insignificant change was observed between the two plants. Similarly, the outcome from the COD concentrated analysis is similar to the results reported by Ng and Chan (2017) in the phytoremediation of palm oil mill effluent wastewater using S. molesta plants. Furthermore, the mechanism by which aquatic plants decrease the concentration of the COD from the wastewater samples can be described in several ways. An increase in COD is caused by the assimilation of solid suspended nutrients attached to the plant roots in the treatment system (Ng and Chan, 2017). In other words, it may intensify the metabolic activity of microorganisms in the wastewater by utilizing available organic matter as a substrate (Mahmood *et al.,* 2005).

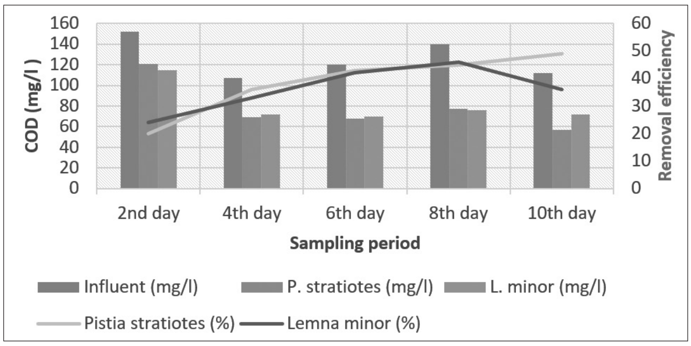

Figure 8: Graph of COD concentration against sampling period

3.3 Determination of Phosphate Concentration

The average phosphate concentration of the influent and effluent water samples are represented in Figure 9.

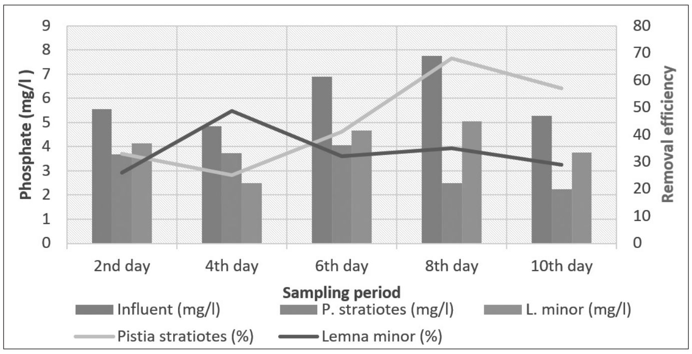

Figure 9: Graph of phosphate concentration against sampling period

From Figure 9, slight inconsistencies were observed based on the outcome of the experiment. The results indicated that the two plants reduced the phosphate level from 4.84 ±0.01 mg/l to 3.72 ±0.05 mg/l (*P. stratiotes*) and 2.48 ±0.01 mg/l (*L. minor*) on the 4th day. The highest reduction efficiency was 68% and 48.7% for *P. stratiotes* and *L. minor*, respectively. Furthermore, the ANOVA indicated a significant difference between the influent and the effluent samples, but an insignificant reduction was demonstrated between the two plants. Additionally, a higher phosphate removal by *P. stratiotes* was recorded in comparison to *L. minor* plants. The short roots of *P. stratiotes* played a significant role in phosphate uptake from the treatment system. Similarly, the built-in variation in macronutrient requirements for physiological processes could have been attributed to the differences observed by the two plants in the absorption of the nutrient. Likewise, an increase in phosphate concentration in wastewater after phytoremediation processes has also been reported (Akinbile *et al.,* 2015). Furthermore, Obek and Hasar (2002) reported a decrease in phosphate concentration from 15 mg/l to 0.5 mg/l in secondary treated effluents using *L. minor* on the 8th day of the treatment period.

3.5 Determination of Ammoniacal Nitrogen Concentration

The results for ammoniacal nitrogen analysis of the influent and effluent water samples are presented in Figure 10.

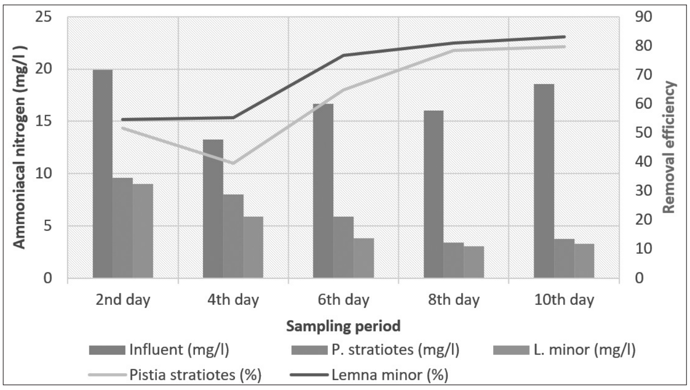

Figure 10: Graph of ammoniacal nitrogen concentration against sampling period

From Figure 10, the treatment system of the two test plants shows an invariable pace of reduction in the average ammoniacal nitrogen concentration of the effluent samples. The test plants reduced the ammoniacal concentration of the influent samples from 19.9±0.05 mg/l , 13.26±0.05 mg/l , 16.7 ±0.02 mg/l , 16.05±0.05 mg/l and 18.58± 0.08 mg/l to 9.6 ±0.1 mg/l , 8.01 ±0.02 mg/l , 5.86±0.05 mg/l , 3.44 ±0.02 mg/l and 3.78±0.17 mg/l (*P. stratiotes*) and 9 ±0 mg/l , 5.9 ±0.1 mg/l , 3.85±0.20 mg/l , 3.04±0.06 mg/l and 3.32±0.14 mg/l (*L. minor*). Similarly, this study indicated up to 79.6% (*P. stratiotes*) and 83% (*L. minor*) ammoniacal nitrogen reduction. Additionally, these findings demonstrated a significant reduction ($p<0.05$) between the influent and effluent water samples. However, the action of duckweed pests on the *L. minor* treatment system did not show a significant effect on the ammoniacal nitrogen concentration on the last day. Patel and Kanungo (2010) reported that the reduction of ammoniacal nitrogen was due to the absorption by *L. minor* plants.

3.6 Determination of Nitrate Concentration

The average nitrate concentration of the influent and effluent samples are represented in Figure 11.

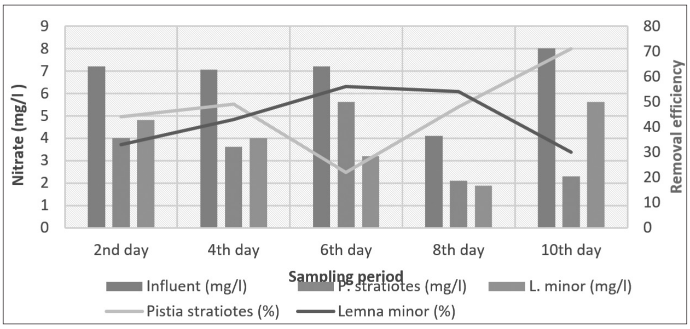

Figure 11: Graph of nitrate concentration against sampling period

From the results presented in Figure 10, it could be deduced that *P. stratiotes* and *L. minor* plants decreased the nitrate concentration of the influent samples within the 10 days sampling period. During the 2-day interval measurements, the nitrate concentration in the influent samples decreased with time, although the reduction was higher in the *P. stratiotes* effluent. Additionally, on the 4th day of the experiment, the test plants reduced the nitrate concentration of the influent samples from 7.04±0.26 mg/l to 3.6±0.1 mg/l (*P. stratiotes*) and 4.0±0 mg/l (*L. minor*). On the 6th day, decrease in the nitrate level of the influent samples from 7.2±0.11 mg/l to 5.6±0 mg/l and 3.2±0.02 mg/l was observed for *P. stratiotes* and *L. minor*, respectively. The slight reduction observed in the *P. stratiotes* effluent sample might be attributed to plant senescence caused by bacterial denitrification. While on the 10th day, a decrease of 2.3±0.17 (*P. stratiotes*) and 5.6±0.26 mg/l (*L. minor*) from 8±0.1 mg/l of the influent samples were observed. Furthermore, the outcomes obtained from this study demonstrated that a significant reduction ($p<0.05$) was observed in the effluent wastewater samples, which varied between 22%-71% for *P. stratiotes* and 30%-56% for *L. minor* plants. The increase in nitrate concentration observed in the *L. minor* effluent samples maybe due to the action of duckweed pests that fed on the *L. minor* plants prior to the final day of the sampling period. The results obtained in the *P. stratiotes* treatment system corroborates with the findings of Wickramasinghe and Jayawardana (2018). This study demonstrated that *P. stratiotes* plants exhibited high efficiency in nitrate uptake than *L. minor* plants. It is probable that the high growth observed by *P. stratiotes* plants enhanced the absorption of nitrate into the roots (Rivers, 2002).

4.0 CONCLUSION

The treated domestic wastewater used in this research work has passed through the preliminary stages of the STP before being subjected to tertiary treatment using *P. stratiotes* and *L. minor* aquatic plants. The outcome of the study indicated that more treatment is required on the secondary treated water samples before discharge into natural water bodies or use for drinking and irrigational purpose. Additionally, it was observed that the two selected plants showed a great tendency in polishing the influent water samples within a short period. Similarly, *P. stratiotes* plants exhibited better performance in comparison to *L. minor* plants. Additionally, *P. stratiotes* recorded reduction efficiency of up to 91.9%, 79.6%, 78% and 68% for turbidity, ammoniacal nitrogen, nitrate, and phosphate, respectively. In contrast, *L. minor* showed a better result than *P. stratiotes* plants in the ammoniacal reduction efficiency with 83%. Although, the constructed treatment system used in this study did not provide a conducive ecosystem for *L. minor* plants as poor growth and the actions of duckweed pests hindered its effectiveness in the tertiary treatment of the water samples. It can be concluded that phytoremediation using aquatic plants in our constructed treatment system is a depurative alternative method for low cost, energy-saving and eco-friendly techniques for tertiary treatment of wastewater.

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CONFLICTS OF INTEREST

The authors declare no conflict of interest. ■

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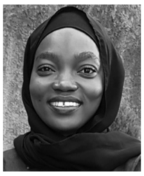
PROFILES



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