Effectiveness of Salvinia molesta as a Phytoremediator in Reducing pH Levels in Batik Wastewater

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Abstract. *Batik industry wastewater is characterized by deep colors, strong odors, high turbidity, and the presence of hazardous substances such as heavy metals (Zn, Cd, Cu, Cr, Pb), phenols, sulfides, and organic compounds. One solution to address this pollution is through phytoremediation using the water fern (Salvinia molesta). This study aims to evaluate the effectiveness of Salvinia molesta in reducing pH levels in batik wastewater. The treatment with a residence time of 9 days proved to be more effective and efficient in lowering pH compared to the 3rd and 6th days. Linear regression analysis was conducted to assess the effect of time variations on pH effectiveness. The analysis results showed a significance value of 0.091 > 0.05, indicating that the variation in time does not have a significant effect on pH effectiveness.*

Keywords: *phytoremediation, salvinia molesta, ph, effectiveness*

1. Introduction

Industrial wastewater from batik production is characterized by its dark color, pungent odor, high turbidity, and elevated acidity (pH). Additionally, batik wastewater contains synthetic materials that are difficult to dissolve. The substances found in batik wastewater include hazardous metals such as Zn, Cd, Cu, Cr, and Pb, as well as suspended solids or organic matter (Diliarosta, 2018). Not all small and medium-sized enterprises (SMEs) in the batik industry have wastewater treatment installations (WWTPs), resulting in batik wastewater being directly discharged into water bodies through stormwater drains, as observed in initial observations. The presence of wastewater from batik SMEs can be identified by physical pollution indicators, such as a strong odor, which leads to the contamination of water and makes it murky.

The treatment of industrial wastewater, especially in household-scale industries like batik, is still considered expensive. This is due to the higher costs of wastewater treatment compared to production costs, leading small to medium-sized enterprises to often discharge wastewater directly into the ground without treatment. This practice can have fatal impacts on the soil ecosystem, such as soil contamination and a decrease in fertility, and can even lead to groundwater pollution caused by high levels of organic compounds in the wastewater (Idrus et al., 2021). Both natural processes and industrial activities contribute to the production of heavy metals, which subsequently contaminate the environment (air, water, and soil) (Irhamni, 2023).

Phytoremediation is a method of wastewater treatment that utilizes plants to remove and reduce the concentration of metals that exceed quality standards. This approach offers several advantages compared to other remediation methods, including ease of plant care,

accessibility of plant materials, and low operational costs (Prasetyo, 2021).

Water fern (Salvinia molesta) is a phytoremediator (a plant capable of treating waste, including heavy metals, organic, and inorganic substances) with significant potential as an effective hyperaccumulator. Its growth, survival, and effectiveness in reducing pollutant levels in wastewater have been well established (Oktavia and Dewanti, 2016). The choice of water fern (Salvinia molesta) as a phytoremediation plant is also supported by research (Viobeth et al., 2018) indicating that it is a promising hyperaccumulator with robust growth and survival rates. Additionally, water fern can thrive in low-nutrient conditions.

Table 1. Quality standards for batik industry wastewater

Parameter	Quality Standard
pH	6.0 - 9.0
BOD (Biochemical Oxygen Demand)	$\leq$ 50 mg/L
COD (Chemical Oxygen Demand)	$\leq$ 100 mg/L
TSS (Total Suspended Solids)	$\leq$ 50 mg/L
Heavy Metals (e.g., Zn, Cd, Cu, Cr, Pb)	$\leq$ specific limits
Odor	Non-offensive
Color	Colorless or clear

2. Method

The objects of this research are batik wastewater and water fern (Salvinia molesta). Approximately 30 liters of batik wastewater were collected from the EcoPrint batik SME located in Bineh Krueng village, Tangan-Tangan subdistrict, ABDYA Regency. Batik wastewater originating from the EcoPrint production facility. The reactor performance is evaluated solely based on the reduction of pH parameter values.
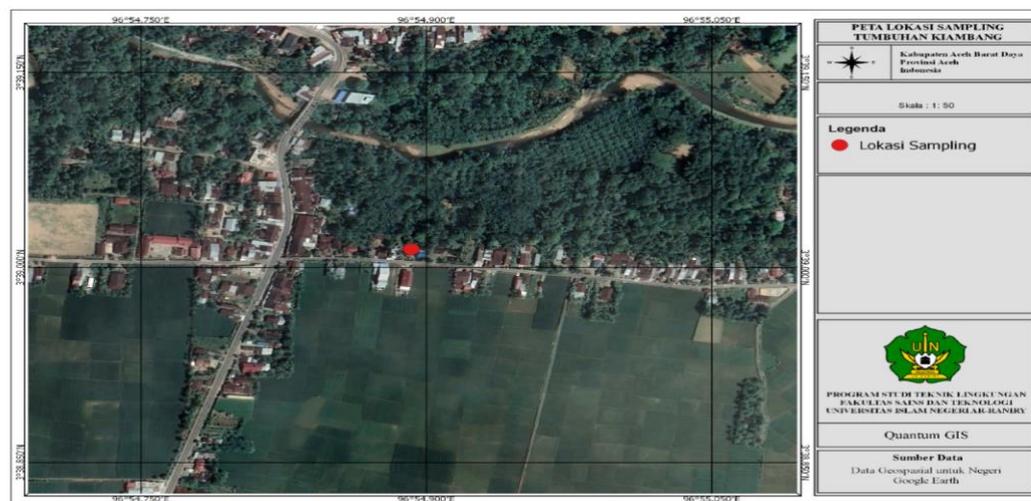

Figure 1. Map of batik wastewater sampling locations (LCB)

The acclimatization/maintenance stages of the research plants, which were taken from their habitat located in Pulau Kayu village, specifically from the drainage behind residential areas, were conducted by first placing the plants in plastic containers filled with 50% or approximately 20 liters of wastewater obtained from the collection site. Acclimatization was carried out to help the plants adjust to their new environment and lasted for 7 days before the research procedures were initiated.

a. Preparation of the wetland basin and control basin using plastic containers measuring 30 cm × 15 cm × 15 cm.
b. Wastewater is introduced into the wetland reactor that already contains gravel and sand media, along with the plants that have been acclimatized for 7 days.
c. The wastewater is allowed to settle in the wetland reactor for 9 days.
d. Phytoremediation is carried out by observing variations in the number of plants, using 3 reactor basins. The first basin serves as the control, the second basin (BR2) contains 8 plants, and the third basin (BR3) contains 16 plants. Sampling is conducted on days 3, 6, and 9.
e. Laboratory analysis is performed to assess the reduction of wastewater parameters, specifically Cr and pH. Testing is conducted at the Standardization and Industrial Service Center (BPSJI) laboratory in Banda Aceh.
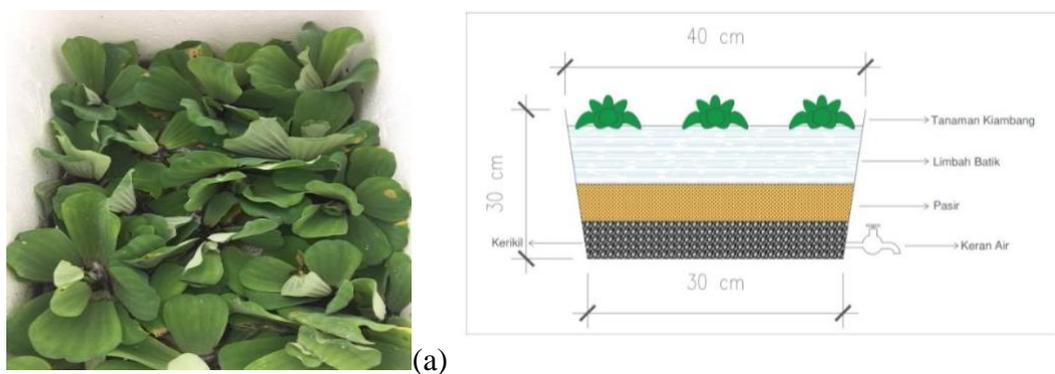

(a)   (b)

Figure 2. (a) Water fern (Salvinia molesta) during the acclimatization process; (b) Design of the culture basin for water fern (Salvinia molesta)

The Procedure for Measuring pH is Explained in Detail as Follows: (SNI 06-6989.11-2019).
a. Rinse the electrode with deionized water, then dry it with a soft tissue paper.
b. Immerse the electrode into the test sample until the pH meter displays a stable reading.
c. Record the reading from the scale or display on the pH meter.
d. Note the temperature at the time of pH measurement and report the results.

The effectiveness of plants in degrading pollutants in batik wastewater is calculated using the formula for wastewater effectiveness and compared against the established quality standards. The formula for effectiveness is as follows:

$$\text{Effectiveness (\%)} = \frac{a-b}{a} \times 100 \text{ \%}$$

Linearity of the data can be assessed using the test of linearity with a significance level of 5%. If the significance value for linearity is greater than 0.05, the data is considered linear; if it is below 0.05, the data is considered non-linear (Nabila and Isroah, 2019).

3. Results and Discussions

Based on Figure 3, the morphology of the water fern (Salvinia molesta) before the phytoremediation process shows no physical changes; the plants remain healthy, with leaves that have not yet yellowed and roots that are still intact. This indicates that there has not yet been any absorption of heavy metals from the batik wastewater.
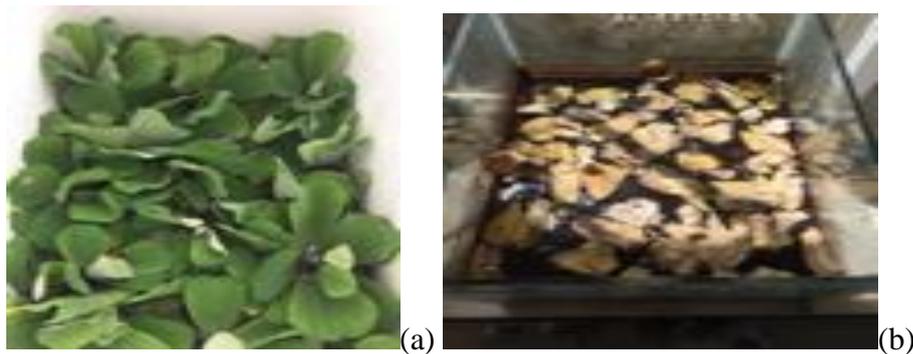
Figure 3. (a) Plant morphology before treatment; (b) Condition of water fern (salvinia molesta) on day 9

After 9 days of treatment, each water fern in the experimental basin showed symptoms such as the appearance of yellow spots due to chlorosis. In severe cases, leaves even fell off the stems. Additionally, a small portion of the fibrous roots experienced shedding.

Figure 4. (a) Phytoremediation testing process; (b) Condition of water fern on day 6; and (c) Wastewater sample

Water fern (Salvinia molesta) has the ability to absorb, extract, and remove pollutants from batik wastewater by taking them up through its roots, which then spread throughout the plant via the vascular system (Aminatun et al., 2024). pH Levels After Treatment.
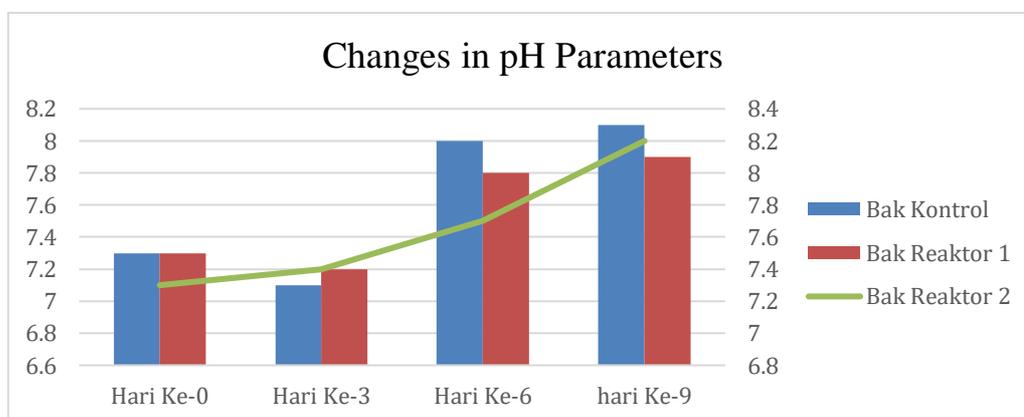

**Figure 5.** Graph of changes in ph parameters

Table 2. pH Parameters

Parameter	Variation		After Treatment
pH	Control Basin	Day 0	7,3
		Day 3	7,1
		Day 6	8,0
		Day 9	8,1
	Basin 1 (8 Plant)	Day 0	7,3
		Day 3	7,2
		Day 6	7,8
		Day 9	7,9
	Basin 2 (16 Plant)	Day 0	7,3
		Day 3	7,4
		Day 6	7,7
		Day 9	8,2

Based on Table and Figure at above, the pH parameter values indicate that temperature affects the absorption rate, as temperature is related to plant metabolism and photosynthesis. The higher the ambient temperature, the greater the plant's ability to absorb ions. A temperature range of 25°-30°C is considered the optimum for the phytoremediation process. In addition to affecting the transpiration rate, temperature also influences the oxygen levels in water. Figure: shows the graph of the average temperature measurements in each reactor during the phytoremediation process."

An increase in temperature will affect the absorption rate, as temperature is related to plant metabolism and photosynthesis. The higher the ambient temperature, the greater the plant's ability to absorb ions. According to, the absorption of metal ions is not entirely accumulated by plants, as metal ions can transfer from water through evaporation by binding with oxygen and forming new ions. A temperature of 25-30°C (mesophilic temperature) is ideal for the phytoremediation process of aquatic plants. The temperature measurements during the phytoremediation process in this study, which ranged from 25°C to 30°C in each reactor, represent favorable conditions for the growth and development of water hyacinth.

The pH value was obtained by measuring the pH of the liquid waste in each control and experimental reactor with water hyacinth using a pH meter every three days. The initial pH measurement yielded a value of 7.3, which can be considered neutral. The pH level can influence plant growth during the phytoremediation process. The optimal pH conditions for plants range from 6.0 to 8.0. Based on the initial pH measurements, it shows that the liquid waste from batik production still meets the quality standards according to the Ministry of Environment Regulation No. 16 of 2019.

The pH levels of each reactor tend to increase. During photosynthesis, water hyacinth absorbs a significant amount of CO_2, which is then converted into glucose and oxygen with the help of sunlight. As a result, the concentration of CO_2 in the liquid waste from batik production decreases, leading to an increase in pH. The following is the reaction that occurs during the photosynthesis process of the plants:

$$6H_2O + 6CO_2 \xrightarrow[Cahaya\ Matahari]{klorofil} C_6H_{12}O_6 + 6O_2$$
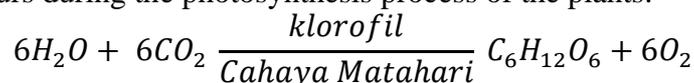
The significant decrease in pH observed on day 3 may be attributed to the continuous absorption of nutrients or metals by the plants. According as cited in Hapsari (2018), this process can create conditions where an increase in the absorption of positive

ions (H+) leads to a rise in pH, while an increase in the absorption of negative ions (OH) results in a decrease in pH.

Based on the graph showing the relationship between the average pH of batik liquid waste and water hyacinth (Salvinia molesta) during the phytoremediation process, the pH value from the treatment on the final day, which is day 9, was found to be in the range of 8.1 to 8.2. This pH meets the quality standards according to the Ministry of Environment Regulation No. 16 of 2019, which stipulates a range of 6.0 to 9.0. A pH that meets these quality standards indicates that the waste is safe to be disposed of into the environment.

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	-32.242	17.693		-1.822	.320
	pH	4.945	2.284	.908	2.165	.275

a. Dependent Variable: Bak Kontrol

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	-51.061	8.244		-6.194	.102
	pH	7.347	1.060	.990	6.928	.091

a. Dependent Variable: Bak 2

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	-49.919	23.079		-2.163	.276
	pH	7.326	3.021	.924	2.425	.249

a. Dependent Variable: Bak 1

Figure 6. The results of the linear regression test

The results of the linear regression test to determine the effect of time variations on the pH effectiveness in tank 1 can be seen in the appendix. The analysis shows a significance value of $0.249 > 0.05$, indicating that the time variations do not have a significant effect on the pH effectiveness.

The results of the linear regression test to determine the effect of time variations on the pH effectiveness in tank 2 can also be found in the appendix. The analysis indicates a significance value of $0.091 > 0.05$, leading to the conclusion that the time variations do not have a significant effect on the pH effectiveness.

4. Conclusions

The treatment duration of 9 days was able to reduce the pH more effectively and efficiently compared to day 3 and day 6. The results of the linear regression test to determine the effect of time variations on the pH effectiveness in tank 2 can be found in the appendix. The analysis shows a significance value of $0.091 > 0.05$, indicating that the time variations do not have a significant effect on the pH effectiveness. However, the treatment with Salvinia molesta resulted in a significant decrease in pH compared to the control group without treatment.

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