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Batik Wastewater Treatment by Using Mono and Polyculture Phytoremediation Utilized Giant Salvinia (*Salvinia molesta*) and Water Spinach (*Ipomoea aquatica*)

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ABSTRACT. Phytoremediation with mono and polyculture systems of giant salvinia (*Salvinia molesta*) and water spinach (*Ipomoea aquatica*) plants for the treatment of batik wastewater has been carried out. This research aims to study the effect of giant salvinia and water spinach plants in reducing pollutant levels in batik wastewater, determine the order kinetics of Cu, TDS, and BOD reduction in monoculture and polyculture systems, and determine the effectiveness of Cu, TDS, and BOD reduction in monoculture against polyculture system. The research methodology included two main treatments, namely phytoremediation and data analysis. Phytoremediation was carried out by varying the combination of water spinach and giant salvinia plants with ratio of 0:100, 50:50, and 100:0 with a total plant mass of 100 gr. Analysis was conducted based on spectrophotometric and gravimetric principles. The results of the analysis were tested for significance by ANOVA test. Research data showed that polyculture of giant salvinia (*Salvinia molesta*) and water spinach (*Ipomoea aquatica*) could increase the effectiveness of reducing Cu metal by 91%, dye by 90%, and TDS by 36%. While polyculture system has better effectiveness in reducing Cu metal, TDS and dyes concentration than monoculture system, but the difference in effectiveness is not statistically significant.

Keywords: Batik wastewater, *Ipomoea aquatica*, mono and polyculture, phytoremediation, *Salvinia molesta*.

INTRODUCTION

Recent days, improving society and an intention to boost economic growth through increased production of goods and services culminating in the acceleration of activity and industrialization. The more industrial activities raising, the more waste is produced. The waste generated by industry is harmful to the environment because it contains pollutants. Therefore, it is necessary to make serious efforts to overcome pollution to maintain good and sustainable environmental quality (Latumahina et al., 2024).

Batik is one type of textile industry that is widely found in Yogyakarta. On the one hand, the batik industry supports the community's economy, but the liquid waste produced can be risky for the environment (Astari et al., 2024). Most of the batik industries are small, so the amount of waste produced is not large but is spread out and randomly enter the water bodies. The batik industry is a producer of environmental pollutants such as high conductivity, biochemical oxygen demand (BOD), chemical oxygen demand (COD), total dissolved solids (TDS), oil, and pH and temperature levels that are not suitable for the environment. Most of these polluting components are non-biodegradable. Dyeing process produces liquid waste that contains chemicals that have the potential to increase the value of COD and dyes in wastewater, also dyeing activity contributes to increasing the BOD (Apriyani, 2013). The entire batik industrial process uses chemicals that contain heavy metals so that the waste produced also contains heavy metals. Copper metal (Cu) is widely used in the production process of an industry either as a raw material, catalyst, or main ingredient. Apart from dyes, the batik making process also uses several other chemicals such as starch, oil, wax, caustic soda (NaOH), detergent and so on. This results in batik waste burdening the environment with quite high pH, temperature, conductivity, BOD, COD, TSS, TDS and oil values (Budiyanto et al., 2018).

One alternative for wastewater treatment released from Batik industries is phytoremediation. Phytoremediation is the use of plants to remove, move, stabilize, or destroy pollutants, both organic and inorganic compounds (Setiyono, 2017). Two types of plants that can be used to reduce contaminants in waste are giant salvinia and water spinach (**Figure 1**). Giant salvinia and water spinach are excellent remediator plants because they have high hyperaccumulator properties and can proliferate massively (Hisam et al., 2022). The selection of remediator plants is based on the consideration that these plants can grow in low-nutrient environments and can multiply quickly (Oubohssaine and Dahmani, 2024). The combination of several plants as bio-accumulator so called polyculture phytoremediation (Ng et al., 2021) in comparison of monocultural system is interesting for the studied in further.

EXPERIMENTAL SECTION

Materials

The materials used are giant salvinia plants, water spinach plants, batik wastewater, distilled water. Some chemicals from Sigma-Aldrich are nitric acid 65% (HNO_3) solution, hydrochloric acid (HCl) solution, potassium dihydrogen phosphate (KH_2PO_4) solids, dicalcium hydrogen phosphate (K_2HPO_4) solids, sodium hydrogen phosphate heptahydrate ($Na_2HPO_4·7H_2O$), ammonium chloride (NH_4Cl) solids, sodium hydroxide (NaOH) solids, magnesium sulfate heptahydrate ($MgSO_4·7H_2O$), calcium chloride solids ($CaCl_2$), ferric chloride solids ($FeCl_3$), microbial seed suspension solution, glucose-glutamic acid solution (GGA), sulfuric acid solution (H_2SO_4), glacial acetic acid solution (CH_3COOH), sodium thiosulfate solution ($Na_2S_2O_3$), allylthiourea nitrification inhibitor solid (ATU). In addition, potassium hexachloroplatinate solid (K_2PtCl_6), cobalt chloride solid ($CoCl_2·6H_2O$), Cu standard solution, amylum indicator, and filter paper were purchased from Merck-Germany.

Instrumentations

The apparatuses in this research are an analytical balance (Mettler Toledo AB54-S), a Muffle furnace (Fischer model 184), DO meter (Lutron DO5509), pH meter (Mettler Toledo), hot plate stirrer (Thermolyne Cimarec 1), Atomic Absorption Spectrophotometer (PerkinElmer 3310), and UV-Visible Spectrophotometer (HANNA Iris Spectrophotometer H1801).

Methods

Acclimatization

Plants that had been obtained were acclimatized to adapt them to a different environment. The plants were placed in a tub containing clean water without pollutants for 14 days. Plants in good condition were selected for use in the RFT and phytoremediation tests.

Range Find Test (RFT)

Range Find Test (RFT) is conducted to determine the concentration of waste to be used in phytoremediation. Based on the provisions of US-EPA Guidelines Parts 850.4500, the RFT includes 5 concentrations following a geometric sequence: 5%, 10%, 15%, 20%, and 25%. The RFT process is carried out for 4 days or 96 hours, but if there is no change in the plants, the time is extended by 24 hours. After the RFT process is complete, the plants are cleaned and adjusted by cutting the leaves that have withered or perforated.

Phytoremediation

The phytoremediation process was carried out with 5 L of 20% effluent concentration. Phytoremediation lasted for 8 days. Variations in the ratio of water spinach and giant salvinia plant combinations used were 50:50, 100:0, and 0:100. These variations were made with a total mass of 100 grams.

Sample Testing

Samples of 100 mL each were taken with a measuring cup every 2 days. Samples were taken from the center point of the tub. The samples were stored in a sample holder and closed. Samples were kept at room temperature and analyzed immediately.

Metal Content Analysis

Metal content analysis process uses the SNI 6989.6: 2009 method. A total of 100 mL of the wastewater sample was shaken until homogeneous, then 5 mL of nitric acid (HNO_3) was added. The solution was heated on an electric heater until almost dry. Then, 50 mL of distilled water was added into a volumetric flask through filter paper, and distilled water was added up to the limit mark. Metal standard solutions were prepared according to the variation of metal concentrations. Wastewater samples and standard solutions were analyzed by Atomic Absorption Spectrophotometer.

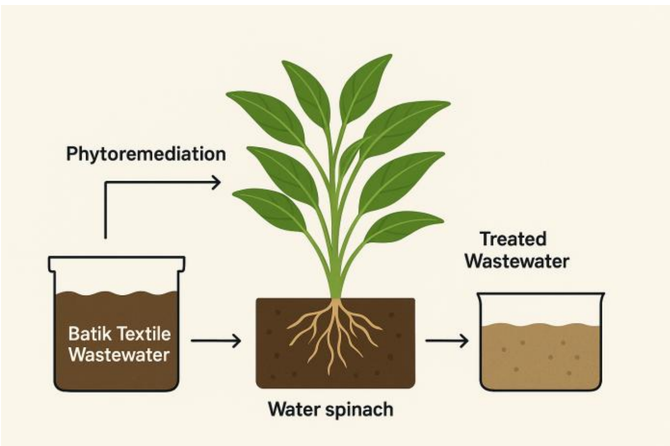

Figure 1. Schematic of phytoremediation system (source: chatgpt.com)

pH Content Analysis

The pH meter was dipped in several areas of the waste container. The pH values on the pH meter were recorded. The pH value used as the final value is a constant pH value and the mode pH value.

Analysis of DO Levels

DO meters were dipped in several areas of the waste container. The values on the DO meter were recorded. The DO value used as the final value is the constant value and the mode value.

Analysis of TDS Content

The analysis of TDS content was conducted using the SNI 6989.27-2019 method. The weight of the evaporation cup was recorded. Next, the waste sample was shaken until homogeneous and placed into a 50 mL evaporation cup. The test sample was evaporated until dried using a water bath. The dried evaporation cup was then placed in an oven at 103-105°C for 1 hour. The evaporation cup was transferred to a desiccator and weighed.

Analysis of BOD Content

The analysis of BOD levels was conducted using the SNI 6989.72-2009 method. The test sample was conditioned at 20°C with a pH of 6 to 8. The test sample was placed into two DO bottles (A_1 and A_2). DO_0 and DO_5 values were measured by iodometric titration, which involved adding 0.33 mL of $MnSO_4$ and 0.33 mL of alkali iodide azide with a micropipette just above the surface of the solution. After settling, 1 mL of concentrated H_2SO_4 was added. An amylum indicator was then added, and titrated until the solution became colorless.

Dyestuff Analysis

Dyestuff analysis was carried out using the SNI 6989.80-2011 method. The test sample's pH was adjusted to 7 with HCl. The sample was filtered, and 50 mL of filtrate was collected. A standard solution was prepared by dissolving 1.246 g of potassium hexachloroplatinate (K_2PtCl_6) and 1 g of cobalt chloride ($CoCl_2 \cdot 6H_2O$) in 100 mL of concentrated HCl in a 1000 mL volumetric flask. Standard and sample solutions were tested with UV-Visible Spectrophotometer.

ANOVA Test

ANOVA test compared the control sample with samples A, B, and C and compared sample A with samples B and C, and sample B with sample C. ANOVA testing was conducted at a confidence level of 95% or a p-value of 0.05.

Determination of the Order of Decrease

The determination of the order of decrease was carried out on the control, A, B, and C samples. Samples were tested against rate models of order 0, 1, and 2.

RESULTS AND DISCUSSION

Samples of batik waste were analyzed for initial concentrations of metals, TDS, BOD, dyes, DO, and pH. The results of the analysis were compared with the quality standards of industrial wastewater based on the Yogyakarta Special Region Government Regulation number 7 of 2016 to see the quality of the waste samples qualitatively.

Based on **Table 1**, the BOD, TDS, and pH values in the batik effluent from Giriloyo Batik Village are above the threshold. The high BOD and TDS values are caused by using synthetic dyes, which result in high levels of turbidity in the batik waste. The heavy metals results show that the dominant metal found in Batik effluent is copper (Cu). All heavy metal concentrations are still below the quality standard because the batik process uses naphthol dyes, which are a type of azo dye that does not contain heavy metals in its main components.

The phytoremediation process was carried out for 8 days and tested every 2 days. Metal, TDS, BOD, dye, DO, and pH parameters were observed for changes. Changes in metal parameters before and after phytoremediation can be seen in **Table 2**.

The determination of effectiveness was based on the ability of the control, A, B, and C samples to reduce the concentration of contaminants over 8 days. The decrease in concentration is presented as a percentage so that the change in the value of each parameter can be understood both qualitatively and quantitatively.

Table 1. Profile of chemical parameters in batik wastewater

Parameter	Concentration	Quality Standard
TDS	5,840 mg/L	2,000 mg/L
BOD	540 mg/L	60 mg/L
Dyestuff	1638 TCU	-
pH	10.55	6.0 – 9.0
DO	2.7 mg/L	-
Cu	0.2730 mg/L	2 mg/L
Fe	0.0860 mg/L	5 mg/L
Pb	0.0099 mg/L	0.1 mg/L
Cr	0.0095 mg/L	1.0 mg/L
Cd	0.0018 mg/L	0.05 mg/L

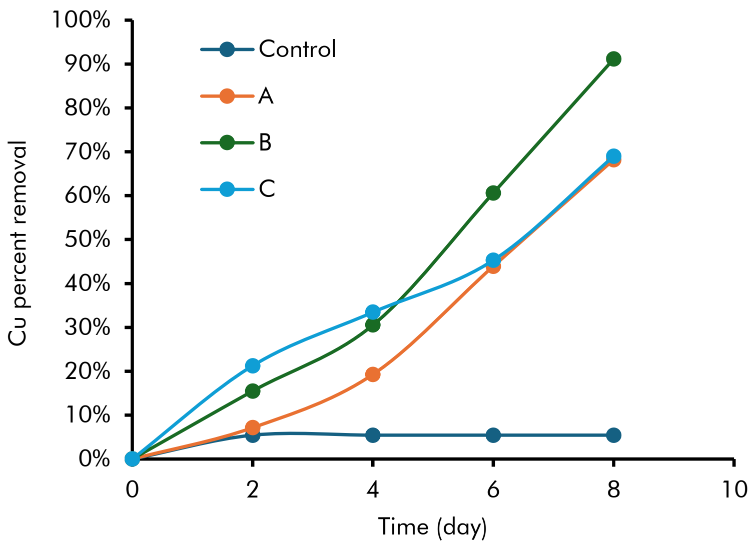

Figure 2. Percent removal of Cu

Based on **Figure 2**, the control sample showed almost no decrease, while samples A, B, and C showed a decrease, although it was not significant. Sample B, which is a polyculture system, experienced the highest decrease. Giant salvinia and water spinach monoculture systems were less effective in reducing Cu levels in the waste. This is due to the synergistic effect in the polyculture system that enhances metal absorption in plant roots. Metal content analysis was performed spectrophotometrically. Sample preparation used strong acid (HNO_3) as a destructor. The reaction that occurs the destruction process is:

$$Cu(CH_2O)_{x(s)} + HNO_{3(aq)} \rightarrow Cu(NO_3)_{2(aq)} + CO_{2(g)} + NO_{(g)} + H_2O_{(l)}$$

The difference in significance is known with the ANOVA test to see the difference in the effectiveness of the copper reduction. The ANOVA process was conducted with a 95% confidence level or an α value of 0.05 ($\alpha > 0.05$).

Table 2 showed that the control sample does not have a significant difference to samples A and C. Therefore, phytoremediation of batik waste samples is only effective and significant with the giant salvinia and water spinach polyculture system in reducing Cu metal levels. Furthermore, the difference in reduction between the remediated samples was not significant. Monoculture and polyculture systems have no difference in the effectiveness of Cu metal reduction although the resulting values are different.

Samples A and B follow as shown in **Table 3** indicated the reaction kinetics equation of order 0. The regression values for samples A and B are 0.9478 and 0.9421, respectively. The kinetic equation for sample C follows order 1 with a value of 0.9439. The regression value for the control sample is the same value of 0.5 at order 0, 1, and 2. This is because there is no suitable kinetic order for the reduction of Cu metal levels in the control sample.

The initial value of the TDS parameter in batik waste is 5,840 ppm, which is far above the established quality standards. High TDS levels indicate poor water quality or high levels of pollution. The decrease in the value of the TDS parameter is presented in **Figure 3**. Based on **Figure 3**, the TDS value in the control sample has the highest value and the least significant decrease. The decrease in sample B shows a better percent decrease, indicating that the giant salvinia and water spinach polyculture system is more effective in reducing TDS levels than the monoculture system. High level of TDS is due to the large content of organic and inorganic compounds that dissolve in water (Butler and Ford, 2018).

Table 2. ANOVA test of Cu for control and remediated samples.

Sample	ANOVA Parameter		
	Fcount	p-value	Fcrit
Control to A	0.5502	0.4794	5.3176
Control to B	7.9393	0.0225	5.3176
Control to C	2.3014	0.1677	5.3176
A to B	2.1394	0.1816	5.3176
B to C	0.5805	0.4679	5.3176
A to C	0.3916	0.5484	5.3176

Table 3. Kinetics of metal Cu reduction

Sample	Parameter			
	R^2	Equation	k	Order
Control	0.5000	y = -0.0056x – 1.4537	-0.0056	1
A	0.8795	y = -0.1398x – 1.1162	-0.1398	1
B	0.7984	y = -0.2709x – 1.2208	-0.2709	1
C	0.9439	y = -0.1637x – 1.2303	-0.1637	1
Control	0.5000	y = 0.0241x + 4.2804	0.0241	2
A	0.7868	y = 0.8926x + 2.3191	0.8926	2
B	0.6156	y = 4.8008x - 3.5235	4.8008	2
C	0.9109	y = 1.1157x + 2.8872	1.1157	2
Control	0.5000	y = -0.0013x + 0.2338	-0.0013	0
A	0.9478	y = -0.0243 + 0.2904	-0.0243	0
B	0.9421	y = -0.024x + 0.2258	-0.0240	0
C	0.9433	y = -0.0267x + 0.2762	-0.0267	0

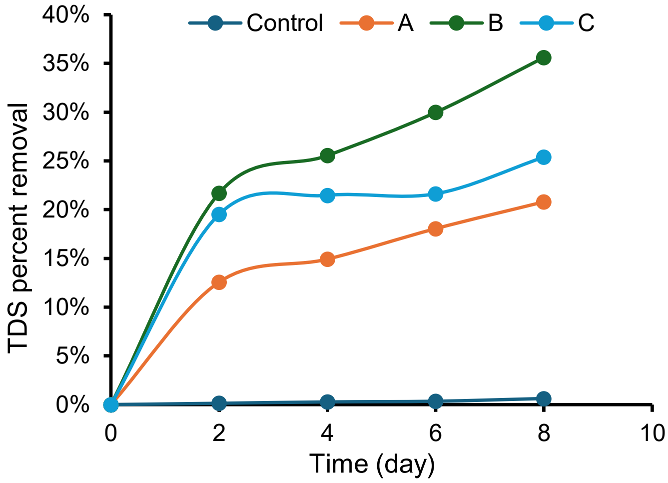

Figure 3. Total dissolved solid reduction values

Table 4. ANOVA test of TDS for control and remediated samples

Sample	ANOVA Parameter		
	Fcount	p-value	Fcrit
Control to A	18.8463	0.0024	5.3176
Control to B	16.9560	0.0035	5.3176
Control to C	19.2171	0.0023	5.3176
A to B	1.7014	0.2283	5.3176
B to C	0.5188	0.4918	5.3176
A to C	0.4488	0.5217	5.3176

Table 4 showed the ANOVA test for TDS condition of the control and remediated samples as shown below. Based on **Table 4**, it can be concluded that the control sample has a significant difference from samples A, B and C. Therefore, phytoremediation of batik waste samples has a significant TDS reduction effectiveness value compared to waste samples that do not undergo a phytoremediation process. Moreover, the effectiveness value of reducing the TDS parameter between the remediated samples does not have a significant difference. This could be due to water spinach and kiambang plants having similar effectiveness in the process of remediating pollutants in wastewater.

Table 5 showed that the control sample followed the kinetic order 0 equation while samples A, B, and C followed the kinetic order 2 equation. The control sample follows order kinetics 0 with a regression of 0.9587. This indicates that the reaction rate of the control sample is independent of the concentration of the reactants. Samples A, B, and C follow order kinetics 2 with regression values of 0.8887; 0.9254; 0.5477, respectively.

The BOD parameter in the waste before treatment is 540 mg/L. This value is still very high and dangerous for the environment. When phytoremediation is carried out, there is a decrease in BOD values, as presented in **Figure 4**.

Table 5. Kinetics of TDS reduction

Sample	Parameter			
	R^2	Equation	k	Order
Control	0.9584	y = -0.0007x + 8.6567	0.0007	1
A	0.8870	y = -0.0032x + 8.6267	0.0032	1
B	0.8904	y = -0.0496x + 8.5624	0.0496	1
C	0.5428	y = -0.232x + 8.5474	0.2320	1
Control	0.9581	$y = 1 \times 10^{-7}x + 0.0002$	0.0000001	2
A	0.8887	$y = 6 \times 10^{-7}x + 0.0002$	0.0000006	2
B	0.9254	$y = 1 \times 10^{-5}x + 0.0002$	0.00001	2
C	0.5477	$y = 5 \times 10^{-6}x + 0.0002$	0.000005	2
Control	0.9587	y = -4.2x + 5748.8	4.2	0
A	0.8852	y = -17.8x + 5578.4	1.8	0
B	0.8496	y = -222.8x + 5230.4	22.8	0
C	0.5383	y = -116.4x + 5180.8	116.4	0

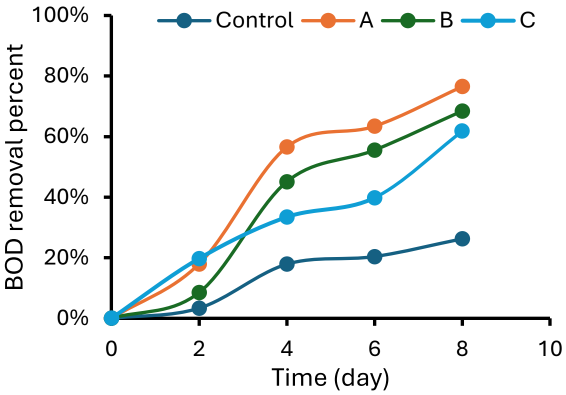

Figure 4. Biological Oxygen Demand (BOD) decreasing values over the time

Based on above **Figure 4**, BOD values decreased in all samples. The control sample experienced a slower decrease compared to the phyto-remediated sample. This is because phytoremediator plants have a good root biomass, which creates a better microclimate for the life of aquatic biota, algae, and degrading bacteria (Kafle et al., 2022).

Table 6 revealed that control sample has significant effectiveness as indicated by the Fcount > Fcrit value and p value <0.05. Therefore, wastewater that undergoes a phytoremediation process has a better reduction effectiveness compared to systems that are not phytoremediated and the effectiveness is significant. In other hand, the difference between the remediated samples is not significant. This low significance is based on the p value which is higher than 0.05 and the Fcount that is lower than the Fcrit values.

Based on **Table 7**, the control sample follows the kinetics equation of order 2, samples A and B follow the kinetics equation of order 1, and sample C follows the kinetics equation of order 0. Therefore, samples A and B the reaction rate depends on one of the reactants.

The dye parameter value before treatment is 1638 TCU. The color of batik waste is caused by residual dyes in the dyeing process. During the phytoremediation process there was a decrease in dye intensity shown in **Figure 5**.

Table 6. ANOVA test of BOD in control and remediated samples

Sample	ANOVA Parameter		
	Fcount	p-value	Fcrit
Control to A	8.8295	0.0178	5.3176
Control to B	6.2798	0.0366	5.3176
Control to C	6.2393	0.0370	5.3176
A to B	0.6625	0.4392	5.3176
B to C	0.1400	0.7180	5.3176
A to C	0.7464	0.4127	5.3176

Table 7. Kinetics of BOD reduction

Sample	Parameter			
	R^2	Equation	k	Order
Control	0.9473	y = -0.0402x + 5.8884	-0.0402	1
A	0.9710	y = -0.1853x + 5.741	-0.1853	1
B	0.9678	y = -0.1515x + 5.799	-0.1515	1
C	0.9443	y = -0.1106x + 5.7724	-0.1106	1
Control	0.9527	y = 0.0001x + 0.0028	0.0001	2
A	0.9374	y = 0.0013x + 0.0023	0.0013	2
B	0.9450	y = 0.0009x + 0.0025	0.0009	2
C	0.8690	y = 0.0006x + 0.0028	0.0006	2
Control	0.9401	y = -12.45x + 359.2	-12.45	0
A	0.9381	y = -29.575x + 288.5	-29.575	0
B	0.9481	y = -28.15x + 309.9	-28.15	0
C	0.9736	y = -22.5x + 307	-22.5	0

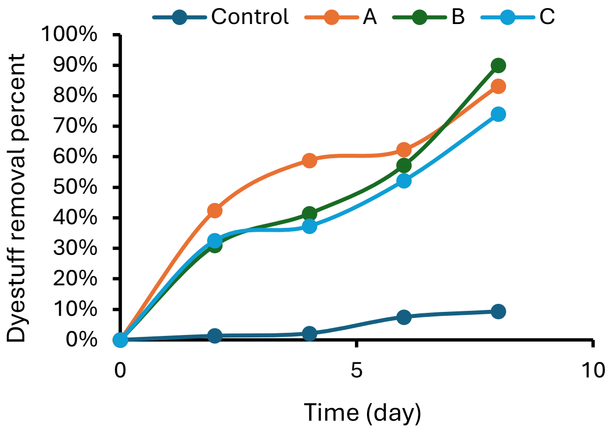

Figure 5. Decreased Dyestuff Values

Table 8. ANOVA test of control dye and remediated samples.

Sample	ANOVA Parameter		
	Fcount	p-value	Fcrit
Control to A	23.0204	0.0013	5.3176
Control to B	15.5679	0.0042	5.3176
Control to C	9.8806	0.0013	5.3176
A to B	0.1139	0.7443	5.3176
B to C	0.4905	0.5035	5.3176
A to C	1.1650	0.3118	5.3176

Based on **Table 8**, the dye value in the samples decreased after phytoremediation. The highest decrease was observed in sample B, indicating that the polyculture system of water spinach and giant salvinia plants effectively reduces the dye compared to the monoculture system.

The control sample has a significant difference in value to samples A, B and C. It can be concluded that wastewater that undergoes phytoremediation has a better effectiveness in reducing dyes compared to those that do not undergo phytoremediation, and the effectiveness of the reduction is significantly different. Also, the significance generated based on the ANOVA method is low. Monoculture and polyculture systems do not have significant differences in effectiveness for reducing dye concentration. The low significance due to the p value which is higher than 0.05 and the Fcount value which is lower than the Fcrit values (**Table 8**).

From **Table 9**, the control, B, and C samples followed the reaction kinetics equation of order 0. The reaction rate in the control, B, and C samples is not affected by the concentration of reactants. The kinetics equation for sample A follows order 1. Determination of the kinetics order is necessary to determine the optimal conditions of a phytoremediation system. Practically, kinetics data helps to predict how fast a pollutant is removed from a waste.

Table 9. Kinetics of dye reduction

Sample	Parameter			
	R^2	Equation	k	Order
Control	0.9144	y = -0.013x + 7.3789	-0.013	1
A	0.9374	y = -0.1996x + 7.1169	-0.1996	1
B	0.8190	y = -0.2541x + 7.3908	-0.2541	1
C	0.9261	y = -0.1518x + 7.3506	-0.1518	1
Control	0.9115	y = $9x10^{-6}$x + 0.0006	0.000009	2
A	0.8105	y = 0.0004x + 0.0005	0.0004	2
B	0.6250	y = 0.0007x - 0.0004	0.0007	2
C	0.8193	y = 0.0002x + 0.0005	0.0002	2
Control	0.9172	y = -19.7x + 1600.4	-19.7	0
A	0.8929	y = -119.7x + 1129.6	-119.7	0
B	0.9659	y = -136.1x + 1284.8	-136.1	0
C	0.9479	y = -128.1x + 1442	-128.1	0

Table 10. pH Values

Days	pH Values in Samples			
	Control	A	B	C
0	9.83	9.58	9.76	9.64
2	9.78	9.30	9.65	9.60
4	9.70	9.24	9.50	9.34
6	9.67	8.96	9.00	8.72
8	9.50	8.60	8.43	8.34

Table 11. Dissolved Oxygen Values

Days	pH Values in Samples			
	Control	A	B	C
0	2.50	2.50	2.50	2.50
2	2.70	4.70	4.30	3.70
4	4.00	5.30	5.00	5.90
6	4.30	6.90	6.70	5.50
8	4.50	8.00	7.50	6.30

The phytoremediation process produces O_2 and CO_2, which will affect the pH and DO quality in water. Carbon dioxide produced by plants dissolves in water to form H_2CO_3, affecting the pH value. Oxygen produced by plants is carried by air and dissolves in water. During the phytoremediation process, there was a change in pH value as shown in **Table 10**.

The pH value is determined by the biological activity of microbes in the plant roots. The increase in water pH is due to the respiration process by phytoplankton in the water. Plants and phytoplankton absorb HCO_3^- as nutrients needed for growth, thereby reducing the number of H^+ ions. The decrease in water pH is caused by the process of CO_2 production in plants, which then dissolves in water. The mechanism of H_2CO_3 formation in water is shown in the following equation.

$$CO_2 + H_2O \rightarrow H_2CO_3 \leftrightarrow H^+ \; HCO_3^- \leftrightarrow CO_3^{2-} + H^+$$

Water dissolved oxygen is used to oxidize organic and inorganic compounds, causing long chain breaks to occur. A higher value of dissolved oxygen in water decreases the value of chemical demand. The DO parameter values during the phytoremediation process are shown in **Table 11**.

Other data in **Table 11** mentioned that sample which does not undergo the phytoremediation process will experience a slower increase in DO values. The DO value in sample A is quite low compared to other phytoremediated samples. This is due to the morphology of water spinach plants, which have wide leaves that cover the water surface. The wide leaves slow down the process of water contact with free air, making it difficult for oxygen to dissolve in the wastewater.

CONCLUSIONS

The polyculture of kiambang (*Salvinia molesta*) and water spinach (*Ipomoea aquatica*) can increase the effectiveness of reducing Cu metal 91%, dye 90%, and TDS 36%. In addition, the polyculture system had better effectiveness in reducing Cu metal, TDS, and dye than the monoculture system, but the difference in the performances were not significant.

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REFERENCES

Apriyani, N., 2013, The chemical content of batik wastewater, *Journal of Chemical Information and Modeling*, *53*, 1689–1699.

Astari, S.A., Mudasir, M., and Suherman, S., 2024, Soil toxicity around the textile industry in Bantul using spinach seeds (*Amaranthus gangeticus*) and bean sprouts (*Phaseolus aureus*), *Molekul*, *19*(1), 1–7.

Budiyanto, S., Anis, A., Purnaweni, H., and Sunoko, H.R., 2018, Environmental analysis of the impact of batik wastewater pollution on the quality of duh well water in the batik industrial center of Jenggot Pekalongan city, *E3S Web of Conferencesl*, *31*,09008.

Butler, B.A., Ford, R.G., 2018, Evaluating relationships between total dissolved solids (TDS) and total suspended solids (TSS) in a mining-influenced watershed, *Mine Water and the Environment*, 37(1):18–30.

Hisam, N.I.B., Zakaria, M.Z., Azid, A., Bakar, M.F.A., Samsudin, M.S., 2022, Phytoremediation process of water spinach (*Ipomoea aquatica*) in absorbing heavy metal concentration in wastewater, *Journal of Agricultural Biotechnology*, *13*(1S): 131-144.

Kafle, A., Timilsina, A., Gautam, A., Adhikari, K., Bhattarai, Aryal, N., Wulandari, C.D.R., 2022, Phytoremediation: Mechanisms, plant selection and enhancement by natural and synthetic agents, *Environmental Advances* , *8*, 100203.

Latumahina, L.J., Tanzil, Y., Suyanta, S., Suherman, S., 2024, Toxicity test of zinc on contaminated soil by petroleum products (fuel oil) around Pertamina Rewulu-Cilacap Pipeline Bantul, Yogyakarta by using mung bean (Vigna radiata) and water spinach (Ipomoea aquatica), *Indonesian Journal of Chemistry*, *24*(4), 951-961.

Ng, Y.S. and Chan, D.J.C., 2021, The role and effectiveness of monoculture and polyculture phytoremediation systems in fish farm wastewater, *RSC Advances*, *11*, 13853–13866.

Oubahssaine, M., Dahmani, I., 2024, Phytoremediation: Harnessing plant power an innovative technologies for effective soil remediation, *Plant Stress*, *14*, 100578.

USEPA, 2012, Ecological Effects Test Guidelines OCSPP 850.4500: Algal Toxicity, *U. S. Environmental Protection Agency*, 26.