Effectiveness of phytoremediation method using water hyacint plants in reducing bod and TDS content in batik industry liquid waste

Siti Jamilatun[1*], and *Nurmustaqimah*[1]

[1]Chemical Engineering, Faculty of Industrial Technology, Universitas Ahmad Dahlan, Yogyakarta, Daerah Istimewa Yogyakarta, Indonesia

Abstract. The textile industry, especially Indonesia, has made significant contributions to economic progress; yet, its production process frequently causes harm to the environment. An issue that occurs is the presence of wastewater generated during batik manufacturing, which has elevated concentrations of pollutants such as COD (Chemical Oxygen Demand) and BOD (Biochemical Oxygen Demand). This study investigates the utilization of water hyacinth plants for phytoremediation as a viable approach to manage batik liquid waste. The investigation was conducted using time intervals of 0, 3, 6, 9, and 12 days. The investigation encompasses the reduction in Biochemical Oxygen Demand (BOD), Total Dissolved Solids (TDS), and the impact of pH. The study findings demonstrate that the most significant reduction in BOD was observed on the sixth day, with a value of 25.52 mg/L achieved from an initial concentration of 86.38 mg/L. The TDS decrease achieved a level of 526 ppm. This research demonstrates the high efficacy of the phytoremediation approach in absorbing wastewater.

1 Introduction

The textile sector has made a significant contribution to the economic growth of numerous countries [1]. Indonesia is a country where there has been a substantial surge in textile development. Batik is a textile product that has experienced significant growth due to its alignment with current fashion trends [2]. Nevertheless, the industrial method frequently causes detrimental effects on the environment [3], [4]. The wastewater generated during batik production has elevated amounts of chemical oxygen demand (COD) and biological oxygen demand (BOD), posing a threat to water quality and the survival of aquatic organisms [5].

One potential solution to address this issue is to utilize the phytoremediation approach. Phytoremediation is a method of waste treatment that use plants to absorb, break down, or diminish environmental pollutants, such as wastewater [6]. Phytoremediation has demonstrated more potential and economic benefits compared to alternative treatment approaches for textile wastewater treatment. The concept is environmentally conscious, promoting sustainability and simplicity. Phytoremediation refers to the utilization of green

* Corresponding author: sitijamilatun@che.uad.ac.id

plants for the purpose of extracting contaminants from waste materials. The textile industry is a vast and intricate network within the manufacturing sector [7].

Water hyacinth (Eichornia crassipes) is a commonly utilized plant in phytoremediation, a process in which it absorbs and accumulates toxins from water [8], as stated in [9]. Water hyacinth plants have the ability to decrease the amount of nutrients present. In the treatment of phytoremediation using water hyacinth, the plants effectively lower pollutant levels of BOD by 68.86%, COD by 66.86%, and phosphate by 77.5%. Water hyacinth roots can efficiently eliminate these pollutants, providing a sustainable method for treating wastewater in both industrial and domestic settings. The roots of water hyacinth foster the growth of aerobic bacteria, which aid in the elimination of several pollutants from water [10].

The objective of this study is to assess the efficacy of phytoremediation and the potential of water hyacinth plants in reducing the levels of BOD (Biochemical Oxygen Demand) and TDS (Total Dissolved Solids) in liquid waste from the batik industry. Analysis is conducted to examine the reduction in Biological Oxygen Demand (BOD) and Total Dissolved Solids (TDS) levels, and how this affects the pH of liquid waste.

2 Material and Methods

This section should provide a clear description of the experimental procedure. The method section for the research paper may contain the design of steps (experimental setup) or procedures carried out in data collection (data collection techniques) and analysis used to obtain results (statistical testing).

2.1 Location

The study used untreated liquid waste obtained directly from CV Banyu Sebring Yogyakarta as the sample. The sampling approach is conducted meticulously to assure the sample's representativeness and accuracy in later analysis. The test method adheres to the Indonesian national standards.

2.2 Material

The research utilizes batik liquid waste obtained from CV Banyu Sebrang Yogyakarta as the primary material. The chemicals utilized comprise of distilled water, Manganese (II) Sulfate (MnSO4), Sulfuric Acid (H2SO4), 0.025 N Sodium Thiosulfate (Na2S2O3), 1% Amylum Indicator, and a dilution solution in the form of distilled water. Distilled water is utilized as a solvent and mixing medium for the purpose of diluting the solution. Manganese (II) Sulfate is utilized for the purpose of detecting and quantifying the concentration of dissolved oxygen in batik waste samples, particularly in the context of redox studies. Sulfuric acid is employed as an acidifier to precisely regulate the pH of the solution, facilitate redox processes, and aid in the separation and purification of specific components in the effluent samples. Sodium thiosulfate serves as a reducing agent in iodometric titration, which is employed to measure the concentration of oxidizing substances in effluent samples. The iodometric titration indicator, amylum 1%, is employed to accurately determine the end point of the reaction between sodium thiosulfate and oxidizing chemicals in waste samples. Water hyacinth plants serve as agents for organic waste treatment.

2.3 Tools

The study utilized many instruments including jerry cans, plastic containers with a volume of 10 liters, Styrofoam, net pot, aerator, hose, aerator stone, Winkler bottle, stative and clamps, burette, pro pipette, measuring pipette, measuring flask, and Erlenmeyer flask. The equipment used in the research consists of a jerrican, a plastic container (with a volume of 10 liters), Styrofoam, Netpot, Aerator, Hose, Aerator stone, Winkler bottle, Stand and clamp, Burette, Pipette, Measuring pipette, Measuring flask, Erlenmeyer flask.

2.4 Methods

Samples of the batik effluent purification are initially collected from the CV waste disposal process. Prior to the implementation of the treatment process, Banyu Sebring Yogyakarta utilized 7-liter jerry cans to depict the waste's composition in the absence of treatment. The effluent was then (1) diluted with a diluent solution in a 90:10% ratio in order to decrease its concentration and render it less hazardous for plants to process. (2) The diluted effluent was introduced into a reactor that was furnished with aerators and aerator stones. These components not only facilitated the air circulation but also supplied supplementary oxygen to support the proliferation of microorganisms and plants engaged in the phytoremediation process. Subsequently, vegetation was incorporated into the reactor as a means of absorbing and treating the effluent contaminants. (4) Periodically, on the zeroth, third, sixth, ninth, and twelfth days, effluent samples were collected in order to assess the efficacy of phytoremediation in reducing the concentration of contaminants in the effluent as time progressed.

2.4.1 Analysis of pH

The pH analysis was performed utilizing the electrometric technique of a pH meter. Prior to usage, the pH meter underwent calibration by employing three buffer solutions with pH values of 5, 7, and 9 in order to guarantee precise measurement. Once the calibration process is complete, the pH meter electrode is placed into the effluent sample to measure its pH. The pH meter records the pH value of the measured effluent after it has stabilized, indicating its level of acidity or basicity (Yulfizar, 2011). Assessing the pH of effluent is crucial for evaluating its environmental state and determining the necessity for treatment processes or additional treatment.

2.4.2 Analysis of BOD (Biochemical Oxygen Demand)

The significance of Biochemical Oxygen Demand (BOD) in establishing criteria for wastewater quality is widely acknowledged. When BOD readings surpass the established limitations, it suggests the presence of organic contamination in Wastewater [11]. The Winkler technique is employed to determine BOD, and it involves the following phases in the BOD analysis process. (1) Initially, a measuring flask mixes wastewater samples with a diluent solution. (2) Subsequently, the sample was placed inside a Winkler bottle, and 1 ml of MnSO4 and 1 ml of AIA were added. The mixture was then left undisturbed for approximately 10 minutes. Subsequently, 1 ml of concentrated H2SO4 was introduced into the mixture and agitated until the precipitate was fully dissolved. Subsequently, the mixture was left undisturbed for approximately 10 minutes. (3) Subsequently, a volume of 25 ml of the combination was extracted and transferred into an Erlenmeyer flask in order to perform a titration with a 0.025 N Na2S2O3 standard solution until a faint yellow coloration became visible. (4) Subsequently, 1 ml of a 1% amylum indicator was introduced into the solution to signal the conclusion of the titration, and the titration process was continued until the black color vanished. The calculation was performed using the subsequent computation:

1. Factor calculation

$$F = \frac{Bottle\ volume}{(botol\ vol - Vol.MnSO4 - Vol.Alkali\ Iodida\ Azida)} \quad (1)$$

2. DO calculation

$$DO_{(mg/L)} = \frac{V \times N \times 8000 \times F}{(Volume\ uji)} \quad (2)$$

The quantity of sodium thiosulfate (V), measured in milliliters (ml), is utilized in computations to ascertain the quantity of substance that undergoes oxidation in a titration reaction. The concentration of oxidizing chemicals in the examined sample can be determined by considering the normality of sodium thiosulfate (N) in solution and the factor (F) value.

2.4.3 BOD calculation

The BOD (Biochemical Oxygen Demand) value, expressed in milligrams per liter (mg/L), quantifies the oxygen consumption by microbes during the decomposition of organic substances in water samples. A1 and A2 represent the concentrations of dissolved oxygen (DO) in the samples before and after the five-day incubation period. B1 and B2 denote the dissolved oxygen (DO) levels of the blank solution before and after incubation. The BOD calculation takes into consideration the degree of dilution, or the ratio of sample volume (V1) to total volume (V2), represented by P. This is done to factor in the impact of sample dilution on the test results.

$$BOD_{(mg/L)} = \frac{(A1 - A2) - (B1 - B2) \times (1 - P)}{P} \quad (3)$$

3 Results and Discussion

3.1 Decrease in BOD value in batik liquid waste with a concentration ratio of 90:10%

The efficacy of water hyacinth in lowering BOD levels in batik liquid waste from CV. BANYU SABRANG was studied over a period of 12 days, with measurements taken at intervals of 0, 3, 6, 9, and 12 days. Fig. 1 illustrates the outcomes of the reduction in BOD (Biochemical Oxygen Demand) value of batik liquid waste.

The analysis results presented in Fig. 2 indicate that the BOD value exhibited a decline beginning on day three, when it reached 41.22. Subsequently, on day six, the BOD value decreased to 25.52. On days nine and twelve, however, the BOD value increased substantially, peaking at 56.93 and 66.74, respectively. The efficacy of the BOD reduction procedure was achieved on day six, owing to the synergistic interaction between microorganisms and water hyacinth roots. The capacity of water hyacinth roots to assimilate organic contaminants is a critical ecological function in phytoremediation; this capability is intricately linked to the extent of their root system. The proliferation of microorganisms within the root system of water hyacinth substantially contributes to the reduction of biochemical oxygen demand (BOD) values, as it enables enhanced environmental adaptation. Consistent with prior investigations, this discovery demonstrates that the application of water

 https://doi.org/10.1051/bioconf/202414802001

hyacinth in organic waste phytoremediation substantially diminished biochemical oxygen demand (BOD) levels within a specified timeframe, with the most substantial reduction taking place on the sixth day of treatment. However, the observed rise in biochemical oxygen demand (BOD) values on days nine and twelve can be attributed to the excessive adherence of colloids to plant roots, resulting in root loss and an escalation in wastewater organic matter content [12].

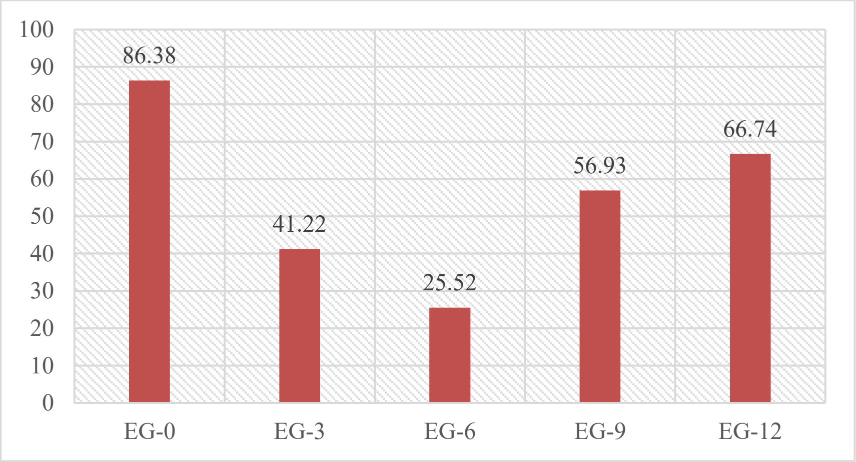

Fig. 1. Graph of the decrease in BOD value of batik liquid waste.

3.2 Decrease in TDS value in batik wastewater concentrations of 90; 10% and pH

The findings of this research demonstrate a reduction in the Total Dissolved Solids (TDS) concentration in batik waste that underwent phytoremediation with water hyacinth, as illustrated in Fig. 2.

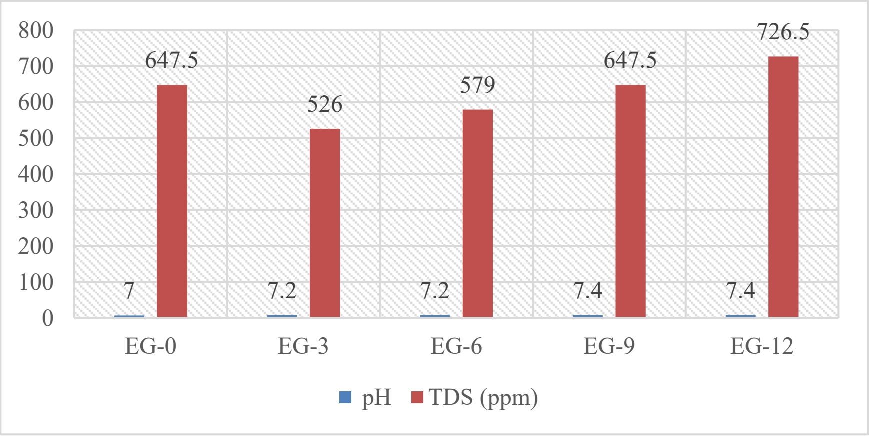

Fig. 2. Graph of the decrease in TDS and pH values in batik liquid waste.

As illustrated in Fig. 2, the efficacy of the phytoremediation treatment in reducing TDS concentration was demonstrated by a decrease in TDS to 526 on the third day, followed by an increase to 726.5 on day twelve. There are multiple potential causes for this phenomenon.

One such factor is the desorption process facilitated by water hyacinth, which allows for the absorption of various solutes from the refuse. However, it is worth noting that during phytoremediation, some of these substances may be released back into the solution. Additionally, the TDS concentration in the effluent can be influenced by environmental factors including temperature, pH, and nutrient availability. This is consistent with the observed increase in TDS value in sample EG-12 subsequent to the phytoremediation treatment. This may be the result of excess toxic ions dissolved in water, including potassium, chloride, sodium, and other substances [13].

After conducting pH and Total Dissolved Solids (TDS) measurements on batik waste samples, it was observed that the pH values of certain samples (EG-3, EG-6, and EG-12) increased following the phytoremediation treatment involving water hyacinth plants. The rise in pH levels seen in these samples suggests that the water hyacinth plant environment can cause an alkaline shift in batik waste. The interplay between plants and chemical constituents in the effluent can alter the pH level of the water. Furthermore, the elevation in pH level can also be attributed to the photosynthetic process conducted by the water hyacinth plant. During this process, the plant utilizes CO2 and releases OH- ions into the water, resulting in an augmentation of the pH value. This process also entails the plant's uptake of H+ ions from the water, resulting in a reduction in the concentration of H+ ions and ultimately leading to an increase in the pH value. The decrease in pH can also be attributed to the generation of H+ ions resulting from the decomposition of plant matter and the creation of sulfates through oxidation [14].

4 Conclusion

The utilization of water hyacinth plants in effluent treatment via phytoremediation effectively decreases the Biochemical Oxygen Demand (BOD) for a period of 12 days at a rate of 25.52 mg/day. Notably, the BOD value decreased significantly on day six, which provides further evidence of the efficacy of the phytoremediation process in mitigating organic pollution in wastewater. It should be noted, however, that on days nine and twelve, BOD levels increased, which was likely due to the excessive attachment of colloids to the roots resulting in the loss of plant roots. Furthermore, it was observed that the Total Dissolved Solids (TDS) value exhibited a reduction of 526 percent on day three subsequent to the phytoremediation treatment. However, this decline was followed by a rise on day twelve, potentially attributable to environmental influences including temperature, pH, and nutrient accessibility, as well as the desorption mechanism operating within water hyacinth. However, the observed rise in pH levels in the batik effluent samples subsequent to phytoremediation treatment indicates a promising prospect for enhancing the effluent's quality. This finding aligns with governmental guidelines that specify the optimal pH range for liquid waste as 6 to 9. Hence, the utilization of water hyacinth plants in phytoremediation may present a compelling alternative for mitigating the effluent pollution issue prevalent in the batik industry.

I would like to extend my gratitude to the lecturers who served as my advisors and offered assistance throughout the course of this research endeavor. Under her guidance and support, this research endeavor was successfully concluded.

References

1. Md. N. Pervez, Md. I. H. Mondal, Y. Cai, Y. Zhao, and V. Naddeo, Textile waste management and environmental concerns. Fundamentals of Natural Fibres and Textiles, Elsevier. 719–739 (2021). doi: 10.1016/B978-0-12-821483-1.00002-4

2. B. Suharto, R. Wirosoedarmo, and R. H. Sulanda, Pengolahan limbah batik tulis dengan fitoremediasi menggunakan tanaman eceng gondok (Eichornia Crassipes). Jurnal Sumberdaya Alam dan Lingkungan. **3**, 1, 14–19 (2018)
3. F. A. Phang et al., Environmental Awareness in Batik Making Process. Sustainability. **94**, 12, 1–14 (2022)
4. S. Lestari, S. D. Tandjung, and S. J. Santoso, Effect of Batik Waste Water on Kali Wangan Water Quality in Different Seasons. E3S Web of Conferences. **31**, 2–5 (2018)
5. S. J. Erwindo, Karakterisasi Air Limbah Batik Di Kota Yogyakarta Dan Kabupaten Bantul Dengan Parameter BOD, COD, DAN TSS (2019)
6. A. Kafle, A. Timilsina, A. Gautam, K. Adhikari, A. Bhattarai, and N. Aryal, Phytoremediation: Mechanisms, plant selection and enhancement by natural and synthetic agents. Environmental Advances. **8**, 100203 (2022). doi: https://doi.org/10.1016/j.envadv.2022.100203.
7. S. B. Gavi, Y. A. Bankar, D. B. Jadhav, and M. S. Lawand, Use of Phytoremediation Technology to Upgrade Domestic Wastewater Quality: An Experimental Investigation. International Journal for Scientific Research & Development. **4**, 3 (2016)
8. G. Aghni, B. Sukono, F. R. Hikmawan, and D. Satriawan, Mekanisme Fitoremediasi: Review. Jurnal Pengendalian Pencemaran Lingkungan (JPPL). **2**, 2 (2020)
9. F. Akhsanul Hafidhin, R. Ratnawati, J. Sutrisno, I. Nurhayati, A. Nur Febrianti, and M. Al Kholif, Penerapan Teknologi Fitoremediasi Menggunakan Tanaman Eceng Gondok untuk Mengolah Air Limbah Laundry (2023). [Online]. Available: https://journal.unhas.ac.id/index.php/jai2
10. N. Bindal and S. Ramesh, Treatment of Wastewater with Phytoremediation Using Water Hyacinth—A Review. 249–261 (2024). doi: 10.1007/978-981-99-6229-7_21.
11. W. Atima, BOD dan COD sebagai parameter pencemaran air dan baku mutu air limbah. BIOSEL (Biology Science and Education): Jurnal Penelitian Science dan Pendidikan. **4**, 1, 83–93 (2015)
12. W. A. Wirawan, R. Wirosoedarmo, and L. D. Susanawati, Pengolahan limbah cair domestik menggunakan tanaman kayu apu (Pistia stratiotes L.) dengan teknik tanam hidroponik sistem DFT (deep flow technique). Jurnal Sumberdaya Alam dan Lingkungan. **1**, 2, 63–70 (2014)
13. N. I. Ilyas, W. D. Nugraha, and S. Sumiyati, Penurunan kadar TDS pada limbah tahu dengan teknologi biofilm menggunakan media biofilter kerikil hasil letusan gunung merapi dalam bentuk random. Jurnal Teknik Lingkungan. **2**, 3, 1–10 (2013)
14. R. Rahadian, Efisiensi penurunan cod dan tss dengan fitoremediasi menggunakan tanaman kayu apu. Jurnal Teknik Lingkungan. **6**, 3 (2017)