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Research Article

Analysis of Batik Industry Wastewater Quality Treated with Activated Charcoal from Coconut Fronds

Ayu Rahmawati Sulistiyaninstyas[1,a*)]; Nesa Fitriani Fahria[2,b)].

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Abstract
The increasing growth and development of population is directly proportional to the increase in activities carried out by humans. Human clothing and lifestyle needs have increased very rapidly which has had an impact on the development of the textile industry, one of which is the batik industry. Many fans of batik production produce waste water which can pollute the waters around residents. This can have a detrimental impact on the environment because there are organic compounds that can cause environmental pollution. The coconut fronds that are often found are not used optimally. Therefore, researchers used coconut fronds made into charcoal as an adsorbent material for processing batik liquid waste. The research will be carried out for 1 month, from June to July 2023. Analysis of the quality of liquid waste will be carried out at the Baristan Laboratory. This type of research is experimental research. The research design uses 25 ml of batik waste treated with 3 grams of activated charcoal, 3.5 grams. , and 4 grams for 40 minutes. Data analysis uses the Effectiveness Formula. Data shows that activated charcoal is effective in reducing oil and fat in batik liquid waste. The higher the weight of activated charcoal for filtration, the higher the reduction in oil and fat levels. However, this does not apply to the COD and pH parameters. Activated charcoal can reduce COD levels with an average effectiveness of 20.32% mg/L, pH with an average of 12% and fatty oils with an average of 66% mg/L.

Keywords: Activated charcoal; COD; Fatty Oils, liquid waste; pH.

INTRODUCTION

The development of the batik industry is one of the sectors experiencing rapid growth over time. As a result, batik received global recognition by UNESCO as a cultural heritage in 2009 [1]. This art form represents a cultural legacy passed down through generations of the Indonesian people. The batik industry in Indonesia operates at various scales, including small, medium, large, and even home-based industries [2].

This industry not only plays a vital role in preserving cultural heritage but also serves as an important economic sector. However, alongside these positive contributions, the batik industry produces substantial amo unts of wastewater, especially from the dyeing and washing processes. This wastewater contains organic compounds that are difficult to degrade, such as synthetic dyes and other harmful chemicals, posing a significant threat to the environment [3], [4], [5]. If not properly treated, this wastewater can cause serious water pollution, affecting aquatic ecosystems and public health in surrounding areas [6].

The wastewater generated from batik production contains key pollutant parameters such as Chemical Oxygen Demand (COD), Biological Oxygen Demand (BOD), pH, and oils and fats. According to previous research, high COD levels in wastewater indicate the presence of large quantities of organic substances that require oxygen to break down. This condition can lead to a reduction in dissolved oxygen levels in water, which in turn threatens aquatic life [7], [8], [9]. Furthermore, heavy metals such as chromium (Cr), lead (Pb), and copper (Cu) present in the wastewater can contaminate soil and water over the long term, causing various health issues for both humans and animals [10], [11], [12].

The environmental conditions polluted by batik wastewater tend to be murky due to the mixing of dyes from the dyeing process. This is because synthetic batik dyes are known for their bright and long-lasting colors on fabric. However, when these synthetic dyes enter the food chain, they can cause various diseases in living organisms [13]. Laboratory tests on batik wastewater have revealed that several parameters exceed the standards set by the 2019 Ministerial Regulation of the Ministry of Environment and Forestry for the textile industry. Key indicators such as Biological Oxygen Demand (BOD5), Chemical Oxygen Demand (COD), Total Suspended Solids (TSS), and harmful substances like phenol, chromium, ammonia, sulfides, and oils surpass the limits. For instance, BOD5 is capped at 60 mg/L with a pollution load of 6 kg/ton, while COD is limited to 150 mg/L and a load of 15 kg/ton. Additionally, pH levels must be between 6.0 and 9.0, with a maximum wastewater discharge of 100 m^3 per ton of textile products, ensuring compliance with environmental standards [14].

Due to the high levels of compounds and suspended solids in batik wastewater that are difficult to break down, treatment is necessary before its release to prevent environmental pollution. This treatment involves using powdered activated charcoal as an adsorbent in the batik wastewater treatment process, allowing the pollutants to be more easily degraded by the environment and preventing further contamination.

Several studies support the effectiveness of activated charcoal in industrial wastewater treatment. For example, Nurhayati et al. reported that activated charcoal could reduce COD and

BOD levels in wastewater by up to 90% [15]. Similarly, Pratama et al. demonstrated that the use of activated charcoal derived from coconut fronds significantly reduced oil and fat levels in batik wastewater [16]. However, further research is still needed to assess the effectiveness of activated charcoal in reducing other parameters such as pH and heavy metal content.

This study aims to evaluate the effectiveness of using activated charcoal from coconut fronds to reduce COD, pH, and oil and fat levels in batik industrial wastewater. By focusing on these parameters, the research seeks to offer a practical and sustainable solution for small-scale batik industries facing challenges in wastewater management. Moreover, the study aims to enhance the understanding of the use of natural and environmentally friendly materials in industrial wastewater treatment, while contributing to the development of sustainable wastewater management technologies in Indonesia [17].

METHODS

This experimental research was conducted from June to July 2023, with samples collected from the Srikandi Batik Tulis Industry in Bandar Lampung. The experiment began with preliminary testing of batik wastewater to assess key pollutant parameters. Samples were then treated using activated charcoal, and subsequent analysis was carried out to determine the effectiveness of pollutant reduction. The wastewater samples, totaling 2 liters, were collected using the SNI 6989.59.2008 grab sampling method, which involves taking a one-time sample from a single location. Follow the figure 1.

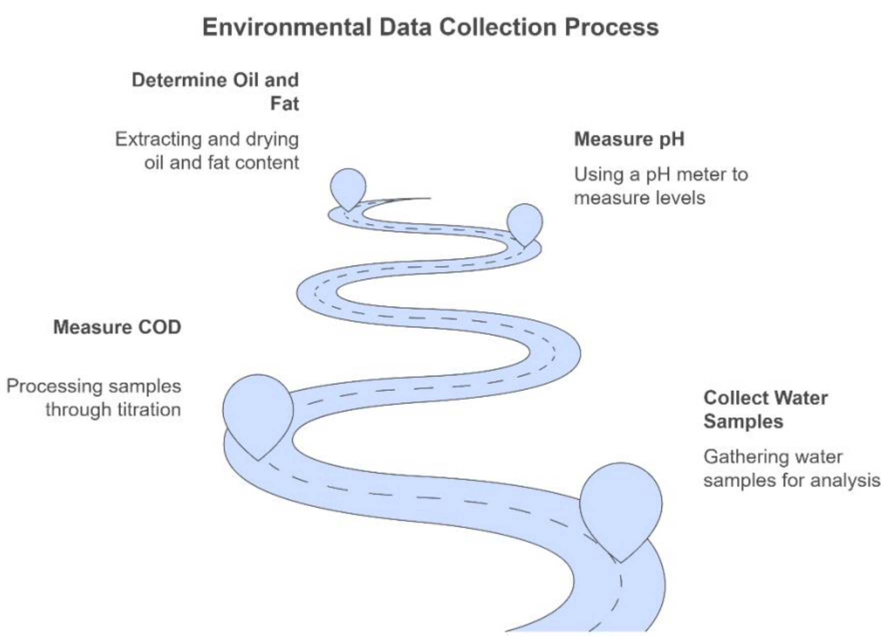

Figure 1. Data Collection Techniques

The data collection techniques in this study involved measuring key parameters such as COD, pH, and oil and fat content in the batik wastewater samples. For COD measurement, 0.04 g of HgSO4, 2 mL of the wastewater sample, 0.5 mL of $K_2Cr_2O_7$ solution, and 0.25 mL of H_2SO_4-Ag_2SO_4 were added to a COD flask. The mixture was gently shaken and gradually supplemented with 2.5 mL of H_2SO_4-Ag_2SO_4 through a condenser. After heating the sample for two hours, it was cooled, diluted, and titrated with FAS to determine the COD levels [18]. The pH of the wastewater was measured using a pH meter, which was immersed directly into the sample [19].. For oil and fat content, a 100 mL beaker was pre-dried in an oven at 200°C for two hours, cooled in a desiccator, and weighed. Then, 1000 mL of the wastewater sample was mixed with methyl orange, acidified with HCl, and extracted using n-hexane. The separated n-hexane layers were filtered using Na_2SO_4, and the resulting filtrate was dried to determine [20] the oil and fat content based on weight changes.

Need Analysis

Data analysis was conducted to calculate the effectiveness of pollutant reduction after treatment with activated charcoal. The formula used to measure the effectiveness is:

$$\text{Effectiveness (\%)} = \frac{A0-An}{A0}\,100\%$$

Where:

A0 : Pollutant concentration befoe treatment

An : Pollutant concentration after treatment [18]

Experimental Design

The experiment used varying amounts of activated charcoal (3 g, 3.5 g, and 4 g) to observe its effect on improving batik wastewater quality. A total of 25 mL of wastewater was treated with different amounts of activated charcoal [7].

Table 1. Experimental Design for Activated Charcoal Treatment on Batik Wastewater

Treatment	Description
P0	Control (no treatment)
P1	25 mL wastewater with 3 g activated charcoal, 40 minutes
P2	25 mL wastewater with 3.5 g activated charcoal, 40 minutes
P3	25 mL wastewater with 4 g activated charcoal, 40 minutes

RESULT AND DISCUSSIONS

Result

This research aimed to investigate the effectiveness of activated charcoal in treating batik wastewater by analyzing three key parameters: COD (Chemical Oxygen Demand), pH, and oil and fat content. The samples were taken from Srikandi Batik Tulis, a home-based batik industry in Bandar Lampung. Initial measurements of the wastewater revealed that all three parameters significantly exceeded the environmental quality standards set by the Ministry of Environment and Forestry [14]. Activated charcoal was used in different doses (3g, 3.5g, and 4g), and the results indicated notable improvements in wastewater quality after treatment.

Table 2. Laboratory Test Results of Batik Wastewater Treated with Activated Charcoal

Parameter	Baku Mutu	Perlakuan			
		P_0	P_1	P_2	P_3
COD	150 mg/L	3500 mg/L	21 mg/L	2670 mg/L	5745 mg/L
pH	6,0-9,0	10,54	8,59	8,28	10,93
Minyak Lemak	3,0 mg/L	60 mg/L	30,80 mg/L	20,80 mg/L	10,30 mg/L

Keterangan :

P_0 Kontrol/tanpa perlakuan
P_1 25 ml air limbah batik, 3 gr karbon aktif, 40 menit
P_2 25 ml air limbah batik, 3,5 gr karbon aktif, 40 menit
P_3 25 ml air limbah batik, 4 gr karbon aktif, 40 menit

Based on Table 4.1, there were differences in the laboratory test results for each parameter before and after treatment with activated charcoal. The COD level before treatment was 3500 mg/L, which decreased to 21 mg/L with P1, 2670 mg/L with P2, and increased to 5745 mg/L with P3. The pH value before treatment was 10.54, which dropped to 8.59 with P1, 8.28 with P2, and increased to 10.93 with P3. For oil and fat content, the initial level was 60 mg/L, decreasing to 30.80 mg/L with P1, 20.80 mg/L with P2, and 10.30 mg/L with P3.

Discussion

COD Reduction

Chemical Oxygen Demand (COD) reflects the quantity of oxygen required to chemically oxidize organic matter in water, which directly correlates to the level of organic pollution. The initial COD measurement of 3500 mg/L in batik wastewater was far above the legal standard of 150 mg/L, indicating a severe level of pollution. After treatment with 3g of activated charcoal, the COD level dramatically decreased to 21 mg/L, representing a 99.4% reduction. This demonstrates the high adsorption capacity of activated charcoal, particularly at the 3g dose. However, when the dose increased to 3.5g and 4g, the COD reduction was significantly less effective, even leading to an unexpected increase in the COD value at 4g. Table 3. Highlights the COD values and their respective reductions.

Table 3. COD Measurements Before and After Treatment

Treatment	COD Before (mg/L)	COD After (mg/L)	Reduction (%)
P1 (3g)	3500	21	99.4%
P2 (3.5g)	3500	2670	25.7%
P3 (4g)	3500	5745	-64.1%

This anomaly can be attributed to the phenomenon of desorption, where the activated charcoal becomes saturated, and previously adsorbed pollutants are released back into the water. Similar findings were reported by Anjani and Sudarja, who highlighted the risk of over-saturation in adsorbents like activated charcoal. These results suggest that while activated charcoal is effective, there is an optimal dosage beyond which its efficiency declines due to saturation [21].

pH Levels

The pH of untreated batik wastewater was highly alkaline (10.54), exceeding the permissible range of 6.0 to 9.0 as established by the Permen LHK. After treatment with 3g and 3.5g of activated charcoal, the pH dropped to 8.59 and 8.28, respectively, falling within the acceptable range for wastewater discharge. The reduction in pH indicates that the activated charcoal was effective in neutralizing the alkalinity of the wastewater. However, with the 4g charcoal treatment, the pH rose again to 10.93, which could be explained by the destabilization of particles that had previously been precipitated. This trend has been observed in studies by Tri Suyanti, which found that exceeding the optimal dose of activated charcoal can cause re-stabilization of previously coagulated particles, thereby increasing the pH [22]. These findings suggest that while activated charcoal can effectively reduce pH, there is a risk of diminishing returns when the dosage is too high, as it can reverse the desired chemical changes. This Data is summarized in the table below.

Table 4. pH Measurements Before and After Treatment

Treatment	pH Before	pH After	Change (%)
P1 (3g)	10.54	8.59	-18.5%
P2 (3.5g)	10.54	8.28	-21.4%
P3 (4g)	10.54	10.93	+3.7%

These results show that lower doses of activated charcoal are more effective in stabilizing the pH to a neutral range, while higher doses can cause adverse effects.

Oil and Fat Reduction

Oil and fat are some of the most difficult pollutants to remove from wastewater due to their low biodegradability and tendency to form films on the water's surface, which limits oxygen transfer and hinders aerobic biological processes. The untreated batik wastewater had an oil and fat content of 60 mg/L, far above the allowable limit of 3 mg/L. The use of activated charcoal led to a gradual reduction in oil and fat content, with the 3g, 3.5g, and 4g treatments reducing levels to 30.80 mg/L, 20.80 mg/L, and 10.30 mg/L, respectively. The 4g treatment showed the highest effectiveness, with an 82.83% reduction in oil and fat content. However, despite this improvement, the levels still did not meet the standard set by the Permen LHK. Table 5 provides the detailed data.

Table 5. Oil and Fat Measurements Before and After Treatment

Treatment	Oil & Fat Before (mg/L)	Oil & Fat After (mg/L)	Reduction (%)
P1 (3g)	60	30.80	49.0%
P2 (3.5g)	60	20.80	65.3%
P3 (4g)	60	10.30	82.8%

Although the 4g charcoal treatment provided the highest reduction, it still did not meet the standard limit. The results suggest that while activated charcoal can significantly reduce oil and fat content, it may not be sufficient as a standalone treatment to meet environmental standards for these pollutants.

This result aligns with research by Iza, et al, who noted that activated charcoal's adsorption capacity is reduced as its pores become blocked by larger organic molecules, such as oils and fats [8]. The high molecular weight of oil and fat makes it challenging for smaller pollutants to be absorbed once the charcoal pores are saturated. The relationship between increased charcoal dosage and adsorption efficiency highlights a trade-off: while more charcoal increases surface area for adsorption, it also increases the likelihood of pore saturation, particularly with large molecules like oil and fat. This is consistent with the findings of Siti Reifa Izarina, who emphasized that the optimal dosage of activated charcoal must be carefully balanced to maximize pollutant removal without oversaturating the adsorbent.

Implications for Future Research and Environmental Management

These results provide valuable insights into the potential of activated charcoal as an affordable and effective treatment method for batik wastewater. However, further research is needed to refine the optimal dosage of charcoal and investigate other complementary methods to address pollutants such as oil and fat more effectively. Activated charcoal remains a promising solution, particularly for small and medium-sized batik producers who face challenges in meeting environmental standards. Future studies should explore the long-term effects of activated charcoal treatment on different types of industrial wastewater and the possibility of recycling or regenerating the charcoal to enhance its sustainability.

CONCLUSION

This study demonstrates that activated charcoal is effective in reducing oil and fat content in batik wastewater, with higher charcoal weights resulting in greater reductions. However, this trend does not hold for COD and pH parameters, where the effectiveness varied. On average, activated charcoal was able to reduce COD by 20.32%, pH by 12%, and oil and fat content by 66%. Further research is recommended to optimize the use of activated charcoal, particularly in achieving compliance with the wastewater standards set by the 2019 Ministry of Environment and Forestry regulations. Additionally, batik industries, especially small-scale producers, are encouraged to adopt activated charcoal filtration in their wastewater management practices.

AUTHORS INFORMATION

Corresponding Authors

Ayu Rahmawati Sulistiyaningtyas– Universitas Muhammadiyah Semarang (Indonesia);
Email: ayurs@unimus.ac.id

Authors

Ayu Rahmawati Sulistiyaningtyas– Universitas Muhammadiyah Semarang (Indonesia);
Email: ayurs@unimus.ac.id
Nesa Fitriani Fahria – Universitas Islam Negeri Raden Intan Lampung (Indonesia).

CONFLICT OF INTEREST

"The authors declare no conflict of interest."

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