

## Technology-based Waste Management in Batik Production

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### ABSTRACT

The environmental challenges faced by Batik Bujang and Batik Candafa, two Riau-based SMEs, stem primarily from the production process, which generates substantial wastewater containing harmful chemicals. The improper disposal of these by-products poses serious risks to water bodies and surrounding ecosystems. This research aims to design a waste management system using eco-friendly technologies capable of processing up to 40 liters of wastewater, thereby minimizing environmental harm. A mixed-method approach was adopted, combining quantitative analysis of waste volume and chemical composition with qualitative insights from SME owners. The findings indicate a significant reduction in chemical pollutants post-treatment, aligning with eco-sustainability goals. This study fills the research gap by providing a technological solution specifically tailored to the needs of small-scale batik producers, emphasizing sustainability and environmental responsibility.

**Keywords:** Batik Production; Waste Management; Eco-friendly Technology; SMES; Sustainability

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**SDGs:** Quality Education (4); Decent Work and Economic Growth (8); Responsible Consumption and production (12); Climate Action (13); Peace, Justice and Strong Institutions (16)

### INTRODUCTION

Batik, a centuries-old textile tradition in Indonesia, is highly revered not only for its artistic and cultural significance but also for its economic contribution, especially in the small and medium enterprise (SME) sector. In Riau, two notable batik brands—Batik Bujang and Batik Candafa—are leading examples of SMEs striving to preserve and innovate within the traditional art of batik production. However, with the increasing demand for batik products, the environmental impact of the batik production process has become a significant concern.

The environmental challenges associated with batik production primarily revolve around the extensive use of water and chemicals, particularly synthetic dyes, which are often discharged into local water bodies without proper treatment (Sudrajat, 2020). This issue is particularly pressing in the case of SMEs like Batik Bujang and Batik Candafa, where limited financial and technological resources hinder the adoption of sustainable practices (Hidayat et al., 2019). Studies have highlighted the detrimental effects of untreated batik wastewater, which contains heavy metals, toxic dyes, and other pollutants that contribute to water contamination and ecosystem degradation (Setyaningsih & Prasetyo, 2021; Nugroho & Rahmawati, 2022).

Batik production is a water-intensive process, particularly during the dyeing and waxing stages, where large volumes of water are required to rinse and fix the colors (Yuliani et al., 2020). In regions like Riau, where the availability of clean water is increasingly limited due to industrialization and climate change, the waste generated by batik production poses an additional strain on local water resources (Agustina et al., 2020). The improper disposal of wastewater from batik production also exacerbates the environmental challenges faced by local communities, contributing to water pollution and health risks (Sulistiani, 2021).

Despite the growing recognition of these environmental issues, there remains a significant gap in research on sustainable waste management practices in SMEs engaged in batik production. Most studies have focused on large-scale batik industries in central Java, while the environmental practices of smaller batik enterprises, particularly in regions like Riau, remain underexplored (Firmansyah et al., 2019; Pratiwi & Mulyadi, 2022). Moreover, while several technological advancements in eco-friendly dyes and wastewater treatment have been proposed, their adoption among smaller batik producers has been limited by a lack of awareness, infrastructure, and financial support (Widiastuti et al., 2021; Purnama & Santoso, 2020).

This research aims to address this gap by examining the environmental challenges faced by Batik Bujang and Batik Candafa in Riau. It will explore the current waste management practices of these SMEs and evaluate the potential for technology-driven solutions to improve sustainability. The study will also contribute to the broader discourse on the role of SMEs in promoting environmentally responsible practices in traditional industries.

The existing literature highlights the environmental impact of batik production, with a particular focus on large-scale operations in Java. However, there is limited research on smaller enterprises in regions like Riau, where environmental challenges are compounded by limited access to sustainable technologies and resources (Haryanto & Susanti, 2018; Maharani et al., 2021). Furthermore, while some studies have proposed innovative waste management techniques, their practical application and feasibility within SMEs remain underexplored (Widodo et al., 2022). This research will fill the gap by investigating the specific challenges and opportunities for Batik Bujang and Batik Candafa in adopting environmentally sustainable practices.

## LITERATURE REVIEW

### Environmental Challenges in Batik Production

Batik production involves multiple stages that contribute to environmental degradation, particularly through water pollution. The dyeing process, which requires significant amounts of water and chemicals, is the primary source of waste, leading to the discharge of untreated wastewater into rivers and other water bodies (Sudrajat, 2020). Studies show that the wastewater generated by batik production often contains hazardous chemicals, including heavy metals and synthetic dyes, which are harmful to both aquatic ecosystems and human health (Nugroho & Rahmawati, 2022; Setyaningsih & Prasetyo, 2021).

In Riau, where Batik Bujang and Batik Candafa operate, environmental challenges are further exacerbated by the region's limited access to clean water and the lack of waste treatment infrastructure. Agustina et al. (2020) found that batik producers in Riau are contributing to water scarcity issues, particularly as industrial activities and population growth increase demand for water resources. This situation has created an urgent need for sustainable water management practices to mitigate the environmental impact of batik production.

### Sustainable Waste Management Practices

Research on sustainable waste management in the batik industry emphasizes the importance of wastewater treatment, eco-friendly dyes, and waste recycling. Proper wastewater management is critical in reducing pollution. Setyaningsih and Prasetyo (2021) advocate for the adoption of filtration and chemical neutralization systems that can treat wastewater before it is released into the environment. These technologies, however, are often inaccessible to smaller enterprises like Batik Bujang and Batik Candafa due to high costs and a lack of technical expertise (Firmansyah et al., 2019).

Eco-friendly dye alternatives have been widely recommended as a sustainable solution to reduce the environmental footprint of batik production (Yuliani et al., 2020). Organic dyes, for instance, can be sourced from natural ingredients, making them less harmful and more biodegradable. However, Purnama and Santoso (2020) note that SMEs face challenges in switching to these alternatives, as organic dyes are often more expensive and require different production processes. The transition to eco-friendly materials in SMEs remains slow, particularly in Riau, where awareness and financial resources are limited (Sulistiani, 2021).

Waste recycling has also been proposed as a method for reducing environmental impact. By recycling production waste into reusable materials, batik producers can minimize their ecological footprint while simultaneously cutting down on costs (Widodo et al., 2022). For example, residual sludge from dye waste can be repurposed into construction materials like bricks, contributing to a circular economy in batik production (Widiastuti et al., 2021). However, such innovations are rarely applied in smaller enterprises, where infrastructure and technical know-how are limited (Pratiwi & Mulyadi, 2022).

### Role of Technology in Reducing Environmental Impact

Technological advancements in waste management have the potential to transform the sustainability of batik production, particularly in SMEs. Digital monitoring systems, for example, can help batik producers track resource use and waste output in real-time, enabling them to optimize processes and reduce waste (Hidayat et al., 2019). Technologies like solar-powered dyeing machines and energy-efficient equipment can also lower the

environmental impact of batik production (Firmansyah et al., 2019). However, despite the potential of these technologies, their adoption remains limited in SMEs like Batik Bujang and Batik Candafa.

The main barrier to adopting such innovations is cost. Small batik producers often operate with limited financial resources, which makes investing in sustainable technologies challenging (Maharani et al., 2021). Additionally, a lack of awareness and technical expertise prevents many SMEs from implementing eco-friendly solutions, even when they are available (Widiastuti et al., 2021). Sulistian (2021) emphasizes the need for greater support from the government and non-governmental organizations to help SMEs access the resources and training required to adopt sustainable practices.

## METHODOLOGY

This study employs a **quantitative experimental approach** to design and test the effectiveness of a batik production waste treatment machine with a 40-liter capacity. The machine is specifically designed to address the waste issues produced by Batik Bujang and Batik Candafa, two SMEs located in Riau. The research methodology comprises several stages, including literature review, machine design, prototype development, testing, data collection, and result analysis.

The first stage is a **literature review**, which investigates relevant waste treatment technologies, particularly those suitable for batik waste that contains dyes and chemicals. Furthermore, existing environmental standards in Indonesia are examined to ensure that the designed machine meets regulatory requirements.

The next stage involves the **design of the waste treatment machine**. The machine is designed to process 40 liters of waste per cycle, corresponding to the daily volume of waste generated by Batik Bujang and Batik Candafa. The machine's design incorporates key components such as a filtration system to filter solid particles, a sedimentation unit to separate heavy chemicals, and a decolorization unit utilizing activated carbon to reduce the dye content in the waste. The design is created using mechanical design software (CAD) to visualize and ensure that all components function optimally.

Once the design is completed, the **prototype of the machine** is built based on the specified design. The prototype is tested using actual batik waste from the production processes of Batik Bujang and Batik Candafa. The tests aim to measure the machine's effectiveness in treating waste, utilizing a 40-liter processing cycle.

**Data collection** is conducted during the testing phase, including measurements of the processed waste volume and the chemical content of the water before and after treatment. The collected data include levels of heavy metals, Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), and the reduction of dye in the waste. These measurements are then analyzed to determine how effectively the machine reduces pollutants and improves the quality of the treated water.

Following data collection, a **result analysis** is performed using statistical methods to assess the machine's efficiency. The test results are compared to applicable environmental standards and traditional waste treatment methods that may have been previously used by these SMEs. In addition to technical analysis, the research includes an **economic analysis** aimed at calculating the costs of constructing and operating the machine, as well as the potential long-term cost savings it could offer.

This research also considers the sustainability aspect. The machine is expected to provide a long-term solution that is both environmentally friendly and economically feasible, making it implementable by other SMEs in the Riau region and beyond. The machine will be validated through several test cycles to ensure consistent results. If successful, this method can be promoted as a practical solution for batik waste management at the SME level.

## RESULT

The results of this study present the outcomes of designing, developing, and testing the batik waste treatment machine with a 40-liter capacity. The testing was conducted at Batik Bujang and Batik Candafa, focusing on measuring the effectiveness of the machine in reducing harmful pollutants from the batik production waste. Below are the key findings:

### Machine Performance

The machine was tested in multiple cycles, each processing 40 liters of waste produced during batik production. The following performance indicators were observed:

- **Filtration Efficiency:** The filtration system successfully separated solid particles such as wax residues and other suspended materials from the wastewater. This initial step reduced the overall turbidity of the waste by approximately 85%, making the subsequent chemical treatments more effective.
- **Sedimentation Unit Efficiency:** The sedimentation unit showed effectiveness in separating heavy metals and chemical compounds present in the wastewater. Analysis revealed a reduction of heavy metal content (including zinc and copper from the dyes) by around 70% after each treatment cycle.
- **Decolorization Process:** The decolorization unit, which utilized activated carbon, achieved significant reduction in dye concentration. Spectrophotometric analysis indicated that the machine removed approximately 80-90% of dye color from the wastewater. This finding was consistent across multiple cycles.

### Water Quality Improvement

Water samples were collected both before and after the treatment process and analyzed for key environmental parameters:

- **Biochemical Oxygen Demand (BOD):** The initial BOD levels of the untreated wastewater averaged around 300 mg/L, which is considerably higher than the acceptable environmental standard for industrial discharge. After treatment, BOD levels dropped to approximately 60 mg/L, indicating a substantial improvement in the biodegradability of the wastewater.
- **Chemical Oxygen Demand (COD):** Similarly, COD levels decreased from an initial average of 700 mg/L to around 100 mg/L after treatment. This shows that the machine effectively removed a significant portion of organic pollutants, which contribute to the overall chemical contamination of water.
- **Heavy Metal Concentration:** The treatment reduced concentrations of hazardous metals such as copper and zinc by more than 70%, as verified through atomic absorption spectrometry. These reductions align with the environmental standards for wastewater discharge set by the Indonesian government.
- **Dye Concentration:** The level of dye in the water was significantly reduced, with color removal efficiency reaching 80-90%. This suggests that the machine is highly effective in tackling the specific challenges posed by batik dye pollution.

### Economic Feasibility

An economic analysis was conducted to determine the cost-effectiveness of the machine compared to traditional methods. The analysis focused on two primary cost factors:

- **Operational Costs:** The cost of running the machine, including electricity and maintenance, was relatively low, making it suitable for small and medium-sized enterprises (SMEs) like Batik Bujang and Batik Candafa. Over the long term, the machine's ability to reduce waste treatment costs makes it an affordable solution.
- **Reduction in Environmental Penalties:** The use of this machine can potentially lower costs associated with environmental fines and compliance with government regulations. By improving water quality, the SMEs are less likely to face penalties for releasing untreated wastewater.

### Sustainability and Environmental Impact

The implementation of the waste treatment machine demonstrated substantial environmental benefits. By reducing harmful chemicals, heavy metals, and dyes in the wastewater, the machine helps minimize the negative environmental impact of batik production. The treated water meets local environmental standards and can safely be released into local water bodies, reducing the ecological footprint of the SMEs.

Additionally, the machine's design emphasizes sustainability through:

- **Low Energy Consumption:** The machine operates on a low-power system, making it energy-efficient and reducing operational costs.
- **Reusability of Treated Water:** The water treated by the machine can be reused in some stages of the batik production process, reducing water usage and contributing to water conservation efforts.

### Machine Reliability and Scalability

Throughout the testing period, the machine proved reliable, with minimal mechanical issues. The design allows for scalability, meaning that the machine can be modified to handle larger volumes of wastewater for bigger production units. Its modular structure also makes it easier to maintain and repair, further supporting its use by other batik SMEs in the region.



**Figure 1. Machine for Batik Waste Management**

### DISCUSSION

The management of waste in batik production, particularly among SMEs like Batik Bujang and Batik Candafa in Riau, poses significant environmental challenges. The dyeing process often involves the use of synthetic chemicals, which can lead to harmful waste that, if improperly disposed of, may contaminate soil and water resources. According to Wulandari et al. (2020), the use of synthetic dyes in textile manufacturing generates hazardous waste, which can severely affect local ecosystems if not managed appropriately.

Moreover, research by Sari and Prasetyo (2019) indicates that unsustainable production practices can degrade soil quality and reduce biodiversity in the surrounding areas. This highlights the urgent need for sustainable waste management practices to mitigate the adverse effects of batik production on the environment.

To address these issues, some SMEs have begun adopting more environmentally friendly methods. For example, Batik Bujang and Batik Candafa have started utilizing natural dyes derived from plants, which not only minimizes pollution but also enhances the market appeal of their products in a growing eco-conscious consumer base. Halimah (2021) emphasizes the importance of transitioning to natural materials in the textile industry to lessen negative environmental impacts.

Another potential solution involves providing training and education for batik artisans on sustainable production practices. Santoso and Anwar (2022) suggest that such training can raise environmental awareness among artisans and equip them with the necessary skills to implement better practices, thereby contributing to more sustainable waste management.

## CONCLUSION

The research demonstrates that the 40-liter waste treatment machine effectively reduces the harmful pollutants found in batik production wastewater. It significantly improves water quality by removing dyes, reducing chemical and heavy metal concentrations, and lowering BOD and COD levels. The machine provides a cost-effective and environmentally sustainable solution that can be implemented by SMEs like Batik Bujang and Batik Candafa. With minimal energy consumption and potential for scalability, the machine has the potential to be adopted widely within the batik production industry.

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