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Improving The Competence of Batik Craftsmen in Liquid Waste Management Through Electrolysis Technology in Kampung Batik *Gedong*

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Abstract. The Micro, Small, and Medium Enterprises (MSMEs) industry in Kampung Batik Gedong, Semarang, has made a significant contribution to the local economy through the production of Semarang's signature batik. However, this production activity produces liquid waste containing synthetic dyes and heavy metals, which have a negative impact on the environment. This community service program aims to increase the capacity of MSMEs in managing liquid waste through the application of electrolysis technology and integrated training. The activities are carried out in five stages: preparation, socialization, application, monitoring, and evaluation. The data collection method involves measuring the level of knowledge using pretests and posttests, as well as assessing skills through direct assessments by the service team. The target of the program's success is to increase the understanding of MSMEs implementer by 80% and skills by 75% after training. Electrolysis technology is applied to reduce the concentration of dyes and heavy metals in liquid waste, while training is provided to improve the understanding and technical skills of MSMEs implementer. The results of this program are expected to include reducing the level of liquid waste pollution, increasing the technical capacity of MSMEs implementer, and increasing awareness of the importance of environmental sustainability. Thus, this program supports environmental conservation, the sustainability of the batik industry, and the achievement of the Sustainable Development Goals (SDGs), especially SDGs 6 (Clean Water and Sanitation), SDGs 12 (Responsible Consumption and Production), SDGs 13 (Action on Climate Change), and SDGs 14 (Life Below Water).

Keywords: batik craftsmen; clean water and sanitation; electrolysis; liquid waste; synthetic dyes

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INTRODUCTION

The Micro, Small, and Medium Enterprises (MSMEs) industry has a strategic role in Indonesia's economic development. Based on data from the Ministry of Cooperatives and Small and Medium Enterprises (2023), MSMEs contribute more than 60% to the national Gross Domestic Product (GDP) and absorb up to 97% of the workforce(Kementerian Koperasi Menengah, 2023).

In the city of Semarang, one of the rapidly growing MSME sectors is batik production, which includes hand-drawn and stamped batik. MSMEs producing batik in Kampung Batik Gedong Semarang are one of the business actors that contribute significantly, producing batik with typical Semarang motifs that not only support the preservation of local culture but also improve the economy of the surrounding community (Wijayanti et al., 2020). However, behind its contribution, the batik industry leaves serious environmental problems, especially related to the liquid waste produced. Liquid waste from the batik dyeing process contains synthetic dyes such as naphthol, indigosol, and remazol, as well as heavy metals such as chromium and copper, which are known to be toxic and difficult to decompose naturally (Adi et al., 2022; Santoso et al., 2019). A study by Putri et al. (2022) showed that liquid batik waste can pollute water and soil sources if not managed properly (Putri et al., 2022). Data from the *Badan Pengelolaan Lingkungan Hidup Jawa Tengah* (2023) revealed that 70% of liquid waste from small industries in the area has not gone through an adequate processing process, causing river water pollution that exceeds the standard

quality threshold. Based on a survey conducted at the Gedong Batik Village location in Semarang, it is known that there is a centralized Wastewater Treatment Plant (IPAL) in RT 02, RW 11, Rejomulyo Village. However, the local RT head stated that the IPAL had never been operational again due to the difficulty of accessing the waste flow to the IPAL location, and the filtration results were not optimal, resulting in rejection from the downstream waste disposal location from the IPAL. Finally, several batik MSMES in Kampung Batik Gedong chose to process waste independently with all the limitations that exist.

One of the batik entrepreneurs in Kampung Batik Gedong, Mr. Eko Hariyanto, said that the management of liquid waste still uses conventional methods in the form of gravity sedimentation to separate coarse residues. This process is unable to remove dyes and other chemical compounds dissolved in wastewater. Every month, this MSME produces around 1000-2000 liters of liquid waste, most of which is directly discharged into public channels without further processing (Pratama et al., 2021). As a result, this liquid waste has a negative impact on the quality of the surrounding environment, including changes in the color and odor of water in local residents' wells. This condition further exacerbates the level of pollution, which in the long term can endanger the ecosystem and public health (Haryono et al., 2022; Pranoto et al., 2023). On a global scale, the issue of liquid waste management has become part of the Sustainable Development Goals (SDGs), especially SDG 6 (Clean Water and Sanitation), SDG 12 (Responsible Consumption and Production), SDG 13 (Action on Climate Change), and SDG 14 (Life Below Water)(United Nations, 2023). The challenges faced by MSMEs in Kampung Batik Gedong in waste management are not only related to technological limitations, but also the lack of technical capacity and awareness of the importance of sustainable waste management (Rahmawati et al., 2020; Setiawan et al., 2023).

The purpose of this community service program is to strengthen the capacity of batik MSMEs in Kampung Batik Gedong, Semarang, in managing liquid waste through the introduction of appropriate and sustainable technologies, as well as increasing awareness of environmentally friendly production practices. The activity is designed to provide solutions that are applicable and affordable for small-scale entrepreneurs, thereby reducing the negative impacts of batik wastewater on the environment and public health. From a scientific perspective, the program contributes to the development of applied knowledge in the field of waste treatment technology and environmental management at the MSME level, while for society, it brings direct benefits in the form of improved water quality, healthier living environments, and the preservation of local cultural industries that are more sustainable and aligned with the Sustainable Development Goals (SDGs).

METHODS

The stages that can be carried out in implementing the proposed community service activities include:

Preparation Stage

In the preparation stage, the initial step taken is to design an electrolysis tool that will be used in this community service program. This tool is designed on a batch scale with a processing capacity of up to 20 liters per cycle to ensure portability and ease of application at partner locations. This tool consists of several main components, namely: Electrolysis reactor, the reactor container is made of chemically resistant acrylic material with a capacity of 20 liters. The electrodes used are titanium coated with iridium oxide (Ti/IrO_2) as the anode and stainless steel as the cathode. Power source: Using a DC power supply with a voltage of 12-24 V and a maximum current of 5 A to optimize the oxidation-reduction process. Input-output channels: The system is equipped with channels to input liquid waste and output processed water.

The tool will be tested at the UNNES Chemical Engineering Operations Laboratory to ensure its performance before being implemented at the partner's location showed in Figure 1. In addition, administrative preparations are carried out, such as drafting agreements with partners and preparing evaluation instruments in the form of questionnaires and training modules. This questionnaire includes a pretest and posttest to assess the increase in partners' understanding of waste management regulations and electrolysis technology. The target for success is an increase in understanding by 80% and skills by 75% after training.

Socialization Stage

This stage begins with the introduction of the program to Batik Sukarasa MSMES partners. Initial education includes an explanation of the impact of liquid waste on health, the environment, and the economy. Socialization materials include:

Liquid waste management regulations: Delivery

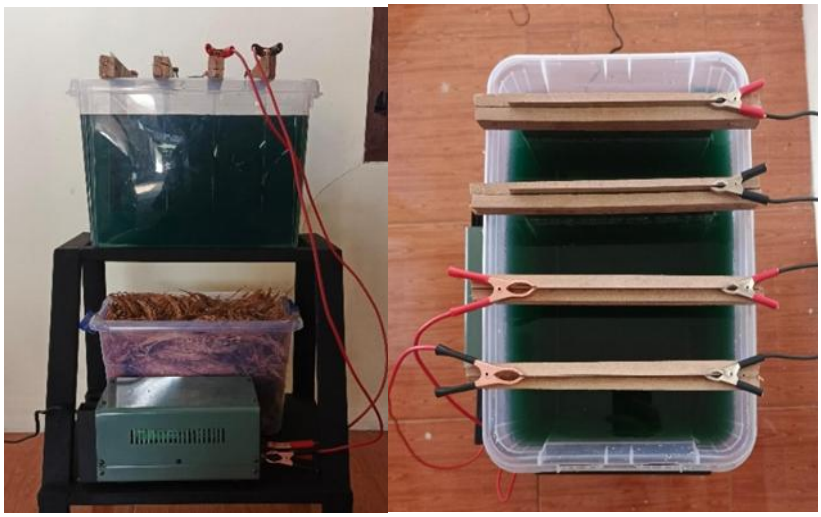

Figure 1. Experimental Design Electrolysis Reactor

of industrial liquid waste quality standards and legal risks if they do not comply. Electrolysis technology: Explanation of the working principles of electrolysis technology and its benefits in batik waste management. Operational socialization of tools: Providing technical guidance on the use of tools theoretically.

The training was conducted in the form of an interactive workshop, where participants were given a module containing the steps for operating the equipment and techniques for monitoring the quality of processed water. This module is designed in simple language so that it is easy to understand by participants who do not have a technical background.

Application Stage

At this stage, electrolysis technology is applied at the partner's location. The process begins with the installation of the electrolysis equipment and a live demonstration by the implementation team. Liquid batik waste from the partner's production process is tested to see the effectiveness of the equipment in reducing the concentration of dyes and heavy metals. The types of assessments carried out are: Pretest: Conducted before training to measure the partner's initial knowledge about waste processing. Posttest: Conducted after training and application of the equipment to measure the increase in partner knowledge and skills. The results of the pretest and posttest will be compared to evaluate the effectiveness of the training. The target for success is an average increase in the partner's knowledge score of 80% from the initial score.

Monitoring Stage

After the tool is operated by the partner, periodic monitoring is carried out to ensure the sustainability of the program. Monitoring includes: Operational observation of the tool: Evaluating whether the tool is used in accordance with the guidelines. Water quality analysis: Taking samples of processed water for testing in the laboratory to ensure that the results meet environmental quality standards. Partner feedback: Collecting input from partners regarding obstacles faced in using the tool. This stage also includes advanced training to improve partners' abilities in monitoring water quality and maintaining the tool.

RESULTS AND DISCUSSION

Partners face several major issues that affect business continuity and environmental impact. First, these MSMEs do not have access to effective waste processing technology. The sedimentation method currently used is only able to remove coarse particles, while hazardous chemical compounds are still released into the environment. Every month, around 1000–2000 liters of liquid waste containing synthetic dyes and heavy metals are discharged without adequate treatment, contributing to groundwater and river pollution around the site (Putri et al., 2022). The simple method apply to manage waste is also relatively expensive because it uses electricity for pumps that run for more than 90 minutes in one waste processing operation (Hakika et al., 2021). The results of the interview showed that what the batik MSMEs actually need

there is a more practical and efficient household-scale waste processing installation, so that it can be more easily implemented in the Kampung Batik area. Second, the low level of knowledge of business actors about sustainable waste management is a serious obstacle. Based on field surveys, most MSMEs implementers do not understand the dangers of liquid waste to the environment and health (Susilo et al., 2021). In addition, they do not have the technical skills to manage waste efficiently and environmentally friendly (Yulianti et al., 2021). This reflects the need for intensive education to increase their awareness and technical capacity. Third, the environmental impact of poorly managed liquid waste has raised concerns in the surrounding community. Several residents reported changes in water quality, such as cloudy color and unpleasant odors, indicating pollution due to batik production activities(Haryono et al., 2022).

Figure 2. Practice How to Implementation the Tools

Based on Figure 2, by implementing this technology, MSMEs in Kampung Batik Gedong can not only increase the efficiency of waste processing, but also meet environmental regulatory requirements and support the achievement of SDGs. In addition, training and education for MSME actors are important steps to increase their understanding of the importance of responsible waste management(Pranoto et al., 2023). This activity aims to strengthen the capacity of batik MSMES in Semarang in managing liquid waste through the application of electrolysis technology and sustainable education programs. With this step, it is hoped that it will not only solve local environmental problems, but also provide a positive contribution to efforts to preserve a sustainable batik industry. A study by Pranoto et al. (2023) showed that groundwater pollution in the area had reached an alarming level, which in the long term could worsen public health [10]. In addition, the lack of understanding of applicable environmental regulations is another obstacle for these MSMEs to comply with the waste management standards set by the government. Based on Adi et al. (2022), more than 60% of MSMEs in the batik sector do not know the permitted wastewater quality standards, so that waste disposal practices are carried out without considering the long-term impacts(Yulianti et al., 2021). Therefore, a holistic solution is needed to overcome this problem. One approach that can be implemented is the application of electrolysis technology. This technology has been proven effective in reducing the concentration of dyes, heavy metals, and other chemical compounds in small industrial wastewater(Darmawan et al., 2023; Suryani, 2020).

Problem Solving

To overcome the problems faced by MSMEs Kampung Batik Gedong in managing batik liquid waste, the solution offered is the application of electrolysis technology combined with a sustainable education program. This approach is designed holistically to not only address the environmental impacts caused by liquid waste, but also to increase awareness and technical skills of MSMEs implementers. With the application of electrolysis technology, MSMES are expected to be able to process their liquid waste to meet the quality standards set by the government, while also meeting the sustainability aspects that are part of the Sustainable Development Goals (SDGs), especially the targets listed in SDG numbers 6, 12, 13, and 14 (Parmawati et al., 2024). Electrolysis technology was chosen because it has been proven effective in removing synthetic dyes such as naphthol, indigosol, and remazol, as well as reducing the concentration of heavy metals such as chromium and copper contained in batik liquid waste(Andrini, 2023; Mahadewi, 2024). This technology works on the principle of oxidation and reduction, where hazardous compounds in waste are broken down into simpler and more environmentally friendly compounds. In the initial stage, the characteristics of liquid waste produced by MSMEs Kampung Batik Gedong will be analyzed to determine the design of an electrolysis

system that suits the needs. This system will then be designed to process liquid waste on a batch scale, with a capacity of 100 liters per cycle, making it more flexible and space-saving. After the installation is complete, the system's performance will be tested and monitored periodically to ensure its effectiveness in processing liquid waste to meet the quality standards set by the Central Java Environmental Management Agency (BPLH)(Badan Pengelolaan Lingkungan Hidup Jawa Tengah, 2023).

In addition to the application of technology, this program also includes intensive education for MSMEs implementers regarding the importance of sustainable waste management. Education will be carried out through workshops and technical training designed to improve MSMEs implementers' knowledge and skills in managing liquid waste. Workshops will discuss environmental and health aspects, the importance of complying with environmental regulations, and the benefits that can be obtained from the application of waste processing technology(Hakika et al., 2021). Technical training, on the other hand, will focus on the operation and maintenance of electrolysis systems, including how to test the quality of processed water. This educational material will be compiled in the form of easy-to-understand training modules and technical guides, so that it can be used as a reference by MSMEs implementers in the future. The benefits that will be felt by partners include increased production efficiency through better waste management, reduced risk of environmental pollution, and increased technical capacity and environmental awareness of business actors. In addition, with waste processing that meets quality standards, MSMES Kampung Batik Gedong can build a better reputation in the eyes of consumers, which can ultimately increase the competitiveness of its products in the market(Adi et al., 2022; Pranoto et al., 2023). Thus, the application of this technology is not only beneficial for the environment, but also has a positive impact economically and socially for MSMEs.

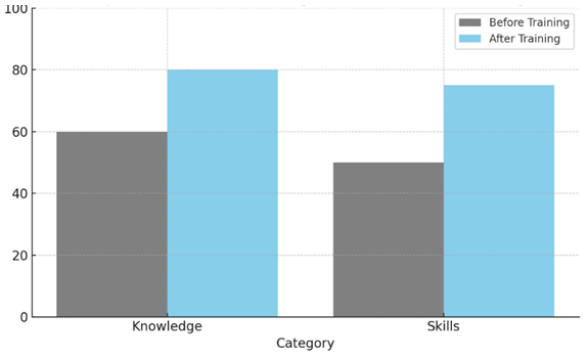

Figure 3. Percentage of Increasing Knowledge and Skills

The bar chart on Figure 3 illustrates the improvement in the knowledge and skills of MSME implementers in Kampung Batik Gedong following a structured training program. Prior to the training, participants demonstrated a baseline knowledge level of 60% and a skills level of 50%, indicating moderate understanding and limited practical ability in waste management practices. After the training delivered through an integrated model combining theoretical instruction and hands-on application there was a marked increase in both indicators. Knowledge levels rose to 80%, reflecting a 20 percentage point gain, while skills improved to 75%, showing a substantial 25 percentage point increase. This significant growth suggests that the training was highly effective in enhancing both cognitive and technical competencies. The results confirm that the implementation of electrolysis technology, supported by targeted capacity building, is not only feasible but also impactful in empowering local MSMEs. The observed improvements demonstrate that appropriate interventions can bridge gaps in environmental awareness and operational skills, thereby supporting sustainable industry practices and contributing to the achievement of SDGs.

This holistic approach also includes the establishment of a sustainable partnership model between MSMEs, academics, and local government. This partnership aims to ensure that technology transfer runs smoothly, provide regular

Table 1. Problem Solving

No	Aspect	Problem	Solution	Assets Provided to Partners
1	Education	Lack of understanding among MSME actors regarding environmental regulations and effective waste treatment technology.	Education through workshops and technical training to improve the knowledge and skills of MSME actors.	Training modules, guidebooks, and demonstration tools for waste treatment systems.
2	Environment	Batik wastewater causes pollution of soil and river water, damages ecosystems, and threatens environmental sustainability.	Electrolysis technology based on oxidation-reduction to reduce pollutants to meet environmental quality standards.	Technical modules for system operation and training on monitoring the quality of treated water.
3	Health	Batik wastewater contains synthetic dyes and heavy metals that pollute the environment and pose serious health risks.	Implementation of electrolysis technology to break down hazardous substances into safer compounds for the environment and human health.	Electrolysis system in batch scale with a capacity of 100 liters, specifically designed to treat batik wastewater.

technical support to MSMEs, and increase collaboration with the government in monitoring the impact of waste processing on the environment [6]. With this partnership, it is hoped that MSMEs will not only be able to manage their liquid waste independently, but also be an example of responsible waste management practices in the batik industry sector.

The success of this program will be measured through several main indicators, such as reducing the concentration of synthetic dyes and heavy metals in liquid waste to meet quality standards, increasing the knowledge and skills of MSME actors in waste management, and reducing reports of groundwater and river pollution in the environment around the MSMEs. With this approach, the program is expected to provide a significant positive impact, not only for MSMEs in Kampung Batik Gedong but also for the environment and surrounding community. The details of the solution to the problem (Tabel 1).

CONCLUSION

Community service activities carried out in Kampung Batik Gedong, Semarang, have succeeded in providing real contributions in increasing the capacity of MSME actors in sustainable liquid waste management. Through the application of electrolysis technology and integrated training, this program not only reduces the level of pollution caused by synthetic dyes and heavy metals, but also significantly increases the understanding and technical skills of MSME actors. The evaluation results showed an increase in knowledge of up to 80% and skills of up to 75% after training. This activity proves that an appropriate technology approach accompanied by comprehensive education can encourage more responsible and environmentally friendly production behavior. Thus, this program supports environmental conservation, the sustainability of the local batik industry, and contributes directly to the achievement of the Sustainable Development Goals (SDGs), especially SDG 6 (Clean Water and Sanitation), SDG 12 (Responsible Consumption and Production), SDG 13 (Addressing Climate Change), and SDG 14 (Marine Ecosystems).

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