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Training on Environmentally Friendly Technology for Processing Tofu Waste for MSMEs in Yogyakarta

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ABSTRACT

Micro, Small, and Medium Enterprises (MSMEs) producing tofu play an important role in the national economy, but most of them have not properly managed their production waste, which has the potential to cause environmental pollution. This community service activity aims to implement a simple, effective, and sustainable tofu liquid waste treatment technology, as well as to enhance the human resource capacity of MSME partners in Yogyakarta to manage waste independently. The methods used include observation, in-depth interviews, questionnaires, and the implementation of four outreach sub-activities: (1) the hazards of tofu waste content, (2) wastewater quality standards, (3) wastewater treatment methods, and (4) Internet of Things (IoT)-based waste treatment technology. The results of the activity show that more than 80% of the partners have been educated about the dangers of waste, understand the correct treatment methods, and are able to use IoT technology to monitor waste parameters in real-time via smartphones. The impact of this community service is an increase in partners' awareness of environmental responsibility and their readiness to implement sustainable waste treatment technology.

Keywords: IoT; tofu waste; community service; wastewater treatment; MSMEs

INTRODUCTION

MSMEs provide comprehensive economic services to local communities and play an important role in facilitating and increasing community income, driving economic growth, and achieving national stability. This is evident in the context of the economic crises that twice threatened Indonesia, namely in 1998 and 2008-2009. It was found that nearly 96% of MSMEs were able to withstand the crisis shocks (Isworo et al., 2022; Laksono Putro et al., 2021; Zalfain et al., 2024). In fact, it is micro, small, and medium enterprises that quickly recovered Indonesia's economy after being hit by the economic crisis. MSMEs not only play an important role in the national economy but also contribute significantly to the creation of new jobs by the state/government. MSMEs also create many new labor units and employ new workers, which can support household income and welfare. The tofu subsector is one of the MSME subsectors that contributes to the national economy and is able to absorb a large workforce, making it reliable in efforts to improve the national economy (Feng et al., 2023; Hardyanti et al., 2024; Hartini et al., 2021; Pramesti et al., 2019; Wang et al., 2022). Currently, there are many MSMEs handling tofu production in Yogyakarta. Among the many tofu MSMEs, the quality of waste disposal needs to be improved to see how great the impact is on clean water quality and sanitation. In this community partnership program, we partnered with one of the MSME sectors, namely a Tofu Factory Owner in Yogyakarta.

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More than 50% of partners do not dispose of industrial waste properly. Similarly, regarding the application of technology in the waste treatment process, more than 50% of the community have never used technology to support their waste treatment process. It can be concluded that on average, tofu MSMEs have not properly and correctly disposed of the waste they generate, thus potentially polluting the environment. Tofu production typically has a very high Chemical Oxygen Demand (COD) value, indicating significant organic pollution. In some locations, COD values can reach between 5000–8500 mg/L (Hardyanti et al., 2023; Ropiudin & Syska, 2023; Yang et al., 2022). This high level of organic matter not only pollutes water sources but can also disturb aquatic ecosystems and public health. Therefore, tofu wastewater treatment is very important to prevent negative impacts on the environment (Amelia et al., 2021, 2024; Hernanda et al., 2024; Maryudi et al., 2022). Hence, we need to support our partners in educating the community about tofu industrial waste disposal so that the waste generated does not pollute the environment.

The agreed-upon priority problem to be solved is the lack of knowledge regarding the latest technology, including environmentally friendly production waste management and the utilization of production waste that can provide added economic value. This is partly due to limited business facilities and infrastructure, especially related to technological equipment. Most MSMEs still use simple production technology and production waste treatment technology. Furthermore, MSMEs also have limited knowledge regarding the dangers posed by the waste they generate, so there is a need for education on the impacts and treatment of such waste. Additionally, there is no application of technology. Currently, technology can be a solution to assist human work by combining required needs. The technology that can be used is applying the Internet of Things (IoT) to waste treatment technology. In this case, the waste treatment process can be carried out automatically. This can impact time efficiency in work. This Community Service Program has the main objectives of creating and implementing a simple, effective, and sustainable tofu liquid waste treatment technology at the MSME level, as well as increasing the capacity of partner human resources in managing their waste independently.

MATERIALS AND METHODS

The priority problems agreed upon between the Team and the Partners include: (1) production-related issues, namely tofu industrial waste treatment, which will be assisted by the team leader from the field of Chemical Engineering; (b) technology utilization issues, namely the utilization of Internet of Things (IoT) technology, which will be assisted by a team member from Electrical Engineering; and (c) the lack of education regarding the dangers of tofu wastewater content, which will be assisted by a team member from Chemical Engineering. Therefore, before carrying out community service activities as an implementation of the solutions to the problems faced by the partners, a program formulation or stages of problem-solving is required.

During the planning stage, the Team collects information and data related to the conditions and constraints faced by the Tofu Factory as the Community Service Partner. Data and information collection methods include direct observation at the partner's location, in-depth interviews, and distributing survey forms to identify the problems faced and their expectations regarding the community service program to be implemented. From the direct observation activities, in-depth interviews, and survey distribution, the following information was obtained. Based on the above constraints, a relationship between partner problems, solutions, and outcomes was then compiled, as presented in Table 1 and Table 2.

Table 1. Relationship Between Partner Problems, Solutions, and Outcomes

No	Problem	Solution	Outcome
1.	Partners are not yet aware of the dangers of tofu wastewater content	Provide education to partners regarding the dangers of tofu wastewater content	More than 80% of partners have been educated
2.	Partners do not yet know waste treatment methods, therefore they have not carried out industrial waste treatment processes	Provide education to partners regarding correct waste treatment methods. The educational stages include: introduction to the chemicals used in the tofu production process, various waste treatment methods, and education on the health and environmental hazards of waste if discharged directly into rivers/water bodies.	More than 80% of partners have been educated
3.	Lack of technology utilization	Proposed solution in the form of waste treatment technology integrated with IoT technology. The reactor is equipped with a camera that can display images in real-time via a smartphone. The advantage of this prototype is that it can periodically monitor the tofu waste treatment process and can be monitored through a smartphone. This can increase the effectiveness of tofu production and improve environmental health.	More than 80% of partners are able to use the waste treatment technology integrated with IoT technology

Table 3. Detailed Design of Program Implementation Methods

No	Program	Sub-Activity	Implementation Date
1.	Partners do not yet know waste treatment methods, therefore they have not carried out industrial waste treatment processes	Socialization on wastewater treatment methods	April 4, 2026
2.	Lack of technology utilization	Socialization on Waste Treatment Technology	April 11, 2025

RESULTS AND DISCUSSION

Based on Table 3 regarding the Detailed Design of Program Implementation Methods, there are four sub-activities designed to address partner problems related to tofu industrial waste treatment. These four sub-activities are arranged sequentially and are interconnected, starting from providing an understanding of wastewater quality standards, introducing treatment methods, socializing waste treatment technology, to explaining the dangers of tofu waste content.

Socialization on wastewater treatment methods (April 4, 2026)

After understanding the quality standards, the next step was to introduce various wastewater treatment methods that are simple, inexpensive, and suitable for the partners' industrial scale. In this socialization session, physical methods (such as filtration and sedimentation), chemical methods (coagulation-flocculation), and biological methods (such as biofilters and activated sludge) were

explained. Partners were provided with an overview of the advantages and disadvantages of each method, including estimated operational and maintenance costs.

Through an active question-and-answer session, the partners admitted that this was the first time they had received systematic information about waste treatment techniques. They began to be able to imagine which method would be most feasible to implement at their production sites. This socialization also encouraged partners to engage in internal discussions regarding the possibility of land allocation and budgeting. At the end of the activity, the partners agreed to proceed to the next stage of introducing more applicable technology.

Figure 1. Socialization of wastewater treatment methods

Socialization of Waste Treatment Technology (April 11, 2026)

In this sub-activity, partners were introduced to the application of Internet of Things (IoT) technology in tofu wastewater treatment systems. IoT technology enables real-time monitoring of important wastewater parameters such as pH levels, temperature, and turbidity through sensors connected to a digital platform. Data from the sensors is transmitted wirelessly to the manager's smartphone or computer, allowing partners to monitor waste conditions remotely without having to go to the treatment facility location. In this socialization, the main components of the IoT system were also explained, including microcontrollers (e.g., ESP32 or Arduino), water quality sensors, and a simple dashboard for displaying data.

Partners were given examples of how the IoT system can send automatic alerts (notifications) if any parameter exceeds the quality standard threshold, enabling immediate corrective action. Furthermore, this technology also helps record periodic data histories, which are useful for reporting to authorities and evaluating treatment equipment performance. Although it sounds advanced, the socialization emphasized that IoT systems for small-scale industries can be designed at an affordable cost using components widely available on the market. The partners appeared enthusiastic and began to show interest in exploring IoT implementation as a more modern, efficient, and transparent waste treatment solution.

Figure 2. Socialization of Waste Treatment Technology

From these two activities, the session concluded with the distribution of questionnaires or evaluation forms to determine the participants' level of understanding after attending the counseling sessions, in order to assess the impact gained by the community from the implementation of this community service activity. The themes of the questionnaire questions are shown in Table 3, and the assessment results are presented in Figures 5-7.

Table 4. Statements in the pretest and posttest

Socialization on Wastewater Treatment Methods	
Question No.	Question
1	You understand the dangers of tofu waste
2	You understand the importance of treating tofu waste before disposal
3	You can identify the types of hazardous components in tofu waste
4	You can process tofu waste independently
5	You understand the types of tofu waste treatment methods
6	You know the method of treating tofu waste using Heterogeneous Fenton
7	You understand the tools and materials for treating tofu waste using Heterogeneous Fenton

Socialization on Waste Treatment Technology	
Question No.	Question
1	What does IoT stand for?
2	What is the purpose of using IoT?
3	What components are used in IoT?
4	What are the benefits of IoT?
5	How does the IoT system work?
6	Can it be monitored remotely?
7	How satisfied are you with this entire event?
8	How relevant was the material presented to your needs?

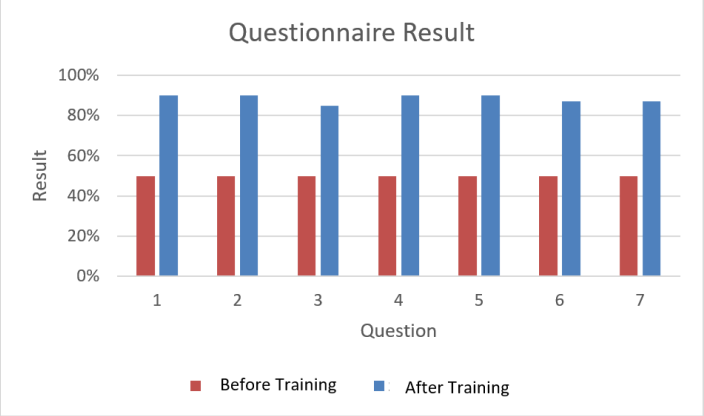

Figure 5. Assessment of Questionnaire Results for the Socialization on Wastewater Treatment Methods

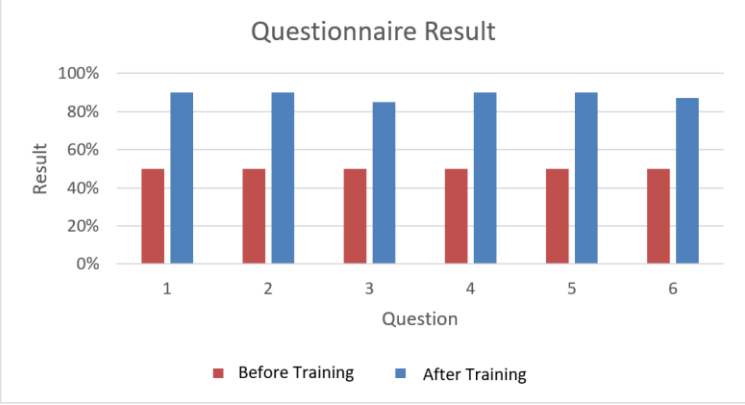

Figure 6. Assessment of Questionnaire Results for the Socialization on Waste Treatment Technology

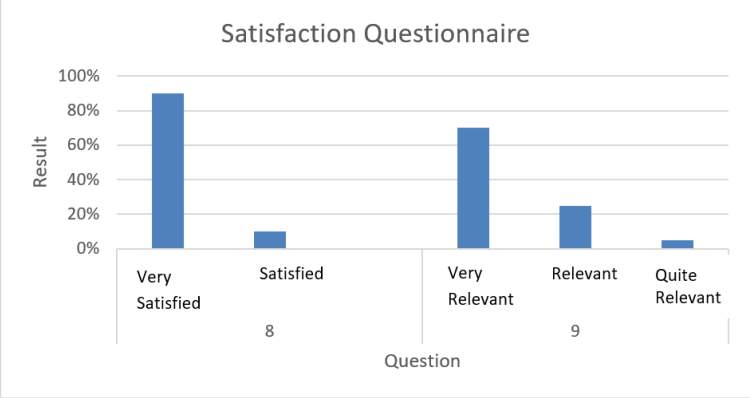

Figure 7. Partner Satisfaction Questionnaire

CONCLUSION

The community service activities that were carried out successfully achieved the established goals. Through a series of socialization sessions covering the understanding of the dangers of tofu waste content, wastewater quality standards, wastewater treatment methods, and the introduction of Internet of Things (IoT) technology for waste treatment, there was a significant increase in the knowledge capacity and awareness of the partners. The evaluation results showed that more than 80% of partners had been educated on the dangers of waste, proper treatment methods, and were able to use waste treatment technology integrated with IoT. Thus, this program has succeeded in creating and implementing a simple, effective, and sustainable tofu liquid waste treatment technology at the MSME level, while also enhancing the capacity of partner human resources in managing their waste independently.

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Conflict of Interests

The authors declared that no potential conflicts of interest with respect to the authorship and publication of this article.

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