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SPEKTA

Innovative Internet of Things-based Integrated Liquid Waste Monitoring for Sustainable Batik Industry

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ABSTRACT

Background: Batik, a UNESCO-recognized art form, experiences rising production demands. However, traditional waste disposal methods pollute waterways and degrade soil. This study addresses this concern.

Contribution: We implemented an Internet of Things (IoT)-based liquid waste monitoring system in CV Smart Batik Indonesia to promote a green economy and sustainable practices. The system monitors critical waste parameters (temperature, pH, TDS, DO, turbidity) in real-time.

Method: We integrated sensors to collect waste data, which is then transmitted through an internet network for monitoring.

Results: The system offers automated monitoring with notifications via a website or mobile application while ensuring data confidentiality through Wireguard protection.

Conclusion: This community service activity demonstrates the effectiveness of IoT-based monitoring systems in promoting sustainable batik production by ensuring compliance with environmental standards and reducing human workload in waste monitoring.

1. Introduction

Water is the most important natural resource that has been given to mankind. However, currently these water resources are deteriorating due to very rapid industrial development and various other human activities. This causes a decrease in the carrying capacity of the environment, especially water, as a result of low human awareness of the importance of managing water resources [1][2]. One that affects water quality is industrial liquid waste which is the remaining waste produced from a production process in an industry in liquid form, one of which is the batik industry [3].

Indonesia is an archipelagic country rich in resources and various cultural heritages. The wealth of resources and various kinds of cultural heritage in Indonesia are the basis for the country's development. One of Indonesia's cultural heritages is batik. Batik is a work of art that has high value [4]. Batik was recognized by UNESCO in 2009 as a world cultural heritage. This is very influential on the level of demand for batik production which is increasing sharply [5]. However, the increase in the batik industry also resulted in negative impacts, namely environmental problems. One of the dominant environmental problems currently is liquid waste originating from the activities of the batik-making process. It is estimated that the use of water in the process of making batik on average is approximately 25 – 50 m2 per meter of batik cloth. Industry ministry data in 2017 showed that batik production in Indonesia averaged 500 million meters per year, meaning 25 million m3 of water per year. The water supply for the batik industry per year is equivalent to providing clean water for 2,500 households [6].

Nearly 85 percent of the clean water supply becomes batik liquid waste with a large volume, thick color, and strong odor. In addition, batik liquid waste has temperature, acidity level (pH), Total Dissolve Solid (TDS) Dissolve Oxygen (DO) dan turbidity. characteristics [7]. High temperatures will result in decreased dissolved oxygen content in water which will kill organisms and organic waste will increase nitrogen levels into nitrate compounds which cause foul odors [8]. The batik process is carried out through several stages, namely the preparation stage, patterning stage, immersion, then dyeing, polishing or removing batik wax and finally finishing. The batik process produces waste in the form of liquid as shown in Figure 1. Waste in liquid form produced by the batik industry already exists from the stages of fabric processing, dyeing to shedding [9][10].

In addition, the coloring process of batik uses synthetic dyes. The craftsmen prefer to use synthetic dyes compared to natural dyes because of the advantages possessed by synthetic dyes, namely the color produced from synthetic dyes is more stable when compared to using natural dyes besides that its use is more practical and easier to obtain [11]. The stable nature of these synthetic dyes makes it more difficult and takes longer for these dyes to decompose in the environment so they can become pollutants because they contain dangerous chemical compounds, namely heavy metals. Heavy metal compounds found in the waste of the printed batik industry are suspected to be chromium (Cr), Lead (Pb), Nickel (Ni), copper (Cu), and manganese (Mn) [12]. The batik industry, like many others, faces challenges in managing its liquid waste. Traditional methods of waste disposal often led to pollution of water bodies and soil degradation. By implementing an IoT-based monitoring system, the study contributes to environmental sustainability by enabling real-time tracking and management of liquid waste. This can help in reducing pollution and minimizing the environmental footprint of the batik industry.

Figure 1. Coloring Process in Batik

Improving environmental governance, technology and infrastructure development is very important [13]. Environmentally friendly and sustainable waste management can contribute to a green economy [14]. Green economy is a development concept that prioritizes the efficient use of resources, reducing greenhouse gas emissions, and utilizing renewable energy to create sustainable economic growth. One of the efforts in managing liquid waste in the batik industry that is environmentally friendly is to use a water recycling system by conducting regular monitoring [15]. By applying the principles of a green economy, the batik industry can become more efficient in the use of resources, reduce waste and increase energy efficiency.

CV Smart Batik Indonesia is one of the original Yogyakarta MSMEs that produces and markets handmade (non-printing) batik products. These MSMEs provide anti-mainstream batik, such as education, health, music, science, information technology, machinery, electronics, history, culture, economy, geography, sports, and other unique motifs. The company has been trusted by various agencies in Indonesia to provide employee uniforms with custom designs. In producing its batik, CV Smart Batik Indonesia collaborates with MSME partners for batik craftsmen in the area around the Special Region of Yogyakarta and Surakarta, Central Java, these batik craftsmen partners are home industries that have not been touched by technology in monitoring the waste of used batik dyes. CV Smart Batik Indonesia has a high social responsibility towards the environment by becoming a partner in this community service. One of the most important priority issues in this community service is environmental problems. Batik industry produces liquid waste which can pollute the environment if it is not managed properly. During the time, batik liquid waste in CV Smart Batik Indonesia has been collected in storage tanks and allowed to seep into the ground without further processing.

The purpose of this community service activity is to develop an Internet of Things (IoT)- based integrated liquid waste monitoring system that is protected by Wireguard to support a sustainability in the batik industry. The integration of IoT technology into liquid waste monitoring represents a novel approach to addressing environmental challenges in the batik industry. This innovation can serve as a model for other industries facing similar issues, showcasing the potential of technology-driven solutions in promoting sustainability and efficiency. This system will be able to measure and monitor the quality of liquid waste produced by the company in real- time. The resulting devices from this service are sensors, meters, and other types of monitoring equipment that are connected to the network, enabling real-time monitoring and analysis of water-related data [16]. Furthermore, by elucidating the design rationale and technical specifications of the proposed system, this research offers valuable insights for practitioners, policymakers, and researchers alike seeking to enhance sustainability within the batik industry. Ultimately, the findings of this study are expected to not only advance our understanding of environmental monitoring in the context of batik production but also pave the way for broader applications of IoT technology in industrial waste management.

2. Method

The method of implementing this community service can be conducted with the following steps as shown in Figure 2

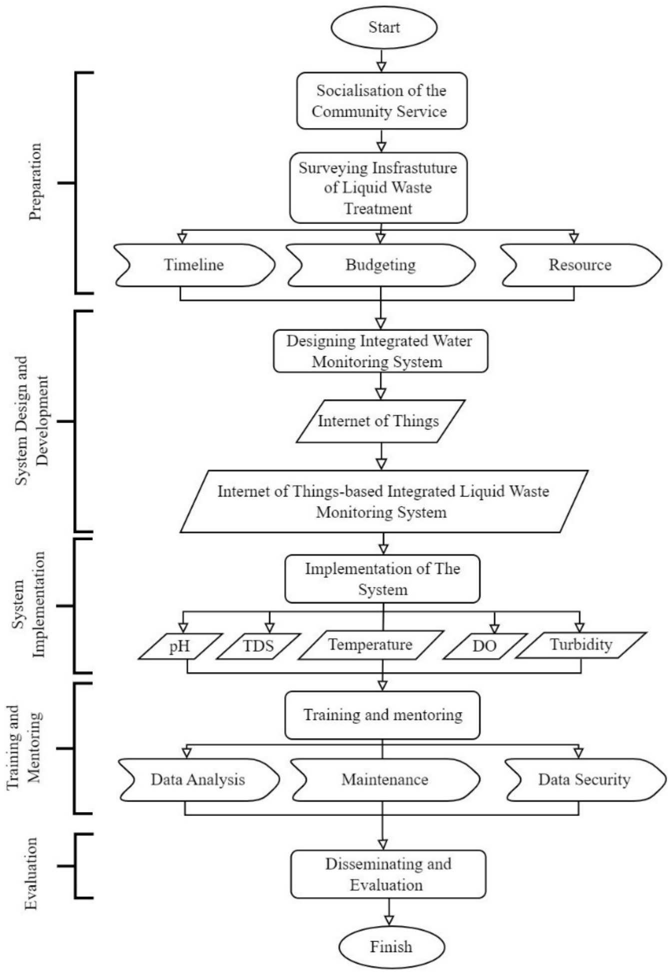

Figure 2. Study Flow

2.1. Preparation

In this preparation, the assessment is conducted in CV Smart Batik Indonesia. This activity will involve understanding the current liquid waste management practices with socialisation and surveying the infrastructure of liquid waste treatment and also how an

Internet of Thing-based liquid waste monitoring system can be implemented in CV Smart Batik Indonesia. Furthermore, a detailed project plan is developed that includes a timeline, budget, and resource allocation. Determine the scope of the community service, the technology required for the liquid waste monitoring system, and the expected outcomes.

2.2. System design and development.

The design and development of an IoT-based integrated liquid waste monitoring system is carried out in term of temperature, acidity level (pH), Total Dissolve Solid (TDS), Dissolve Oxygen (DO) and turbidity as shown in Figure 3. LCD is employed to show the value of 5 sensors mentioned. Meanwhile, this system is connected to the Internet network to monitor liquid waste quality by using smartphone or browser and ensure that the liquid waste produced meets predetermined standards set by Government Regulation [17].

Table 1. Liquid Waste Quality Standards for Batik Industry Activities [17]

Parameter	Wet Process		Dry Process	
	Most Content (mg/ L)	Most Pollution Burden (Kg/Ton)	Most Content (mg/ L)	Most Pollution Burden (Kg/Ton)
BOD	85	5.1	85	1.275
COD	250	15	250	375
TDS	2000	120	2000	30
TSS	60	36	80	12
Phenol	0,5	0 03	1	0,015
Chromium (Cr)	1	0.06	2	003
Ammonia Total (NH_3 as N)	3	0.18	3	0.045
Sulfide (S)	0,3	0.018	0,3	0.0045
Oil and Total Fat	5	0.3	5	0.075
Temperature	± 3°C to air temperature			
pH	6,0 - 9,0			
Most waste discharge (m^3/Ton Batik Product)	60		15	

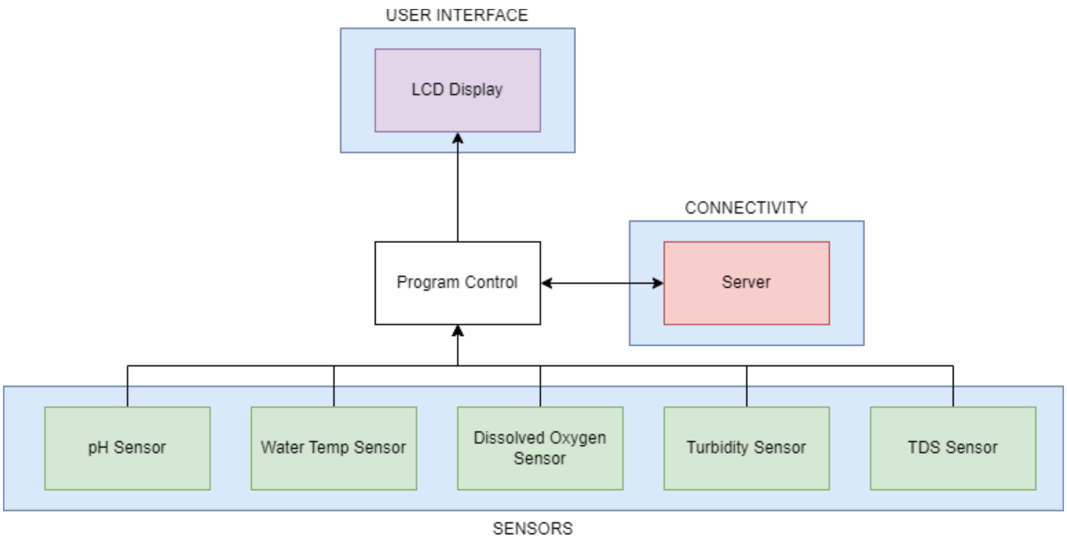

Figure 3. Architceture of waste monitoring system

To enhance the performance of sensing, the implemented system employed industrial grade sensor. Industrial grade sensors were chosen because of its realibility and the resolution of sensing. The system works in harsh condition with contaminated water flowing simultaneously. Regular maintenance needed to keep the performance of sensor in good condition as instructed in manual book of sensors. Table 2. shows the specification of sensors that implemented on system

Table 2. Sensors Specification Implemented in Waste Monitoring System

pH	Seed Studio Industrial pH Meter	**Function**
eC	Gravity Analog Electrical Conductivity	Measuring pH in Waste liquid
Dissolved Oxygen	Gravity Analog Dissolved Oxygen	Measuring electrical conductivity in liquid corelatedwith TDS
Temperature	DFRobot DS18B20	Measuring the amount of oxygen that diffuses through the membrane into sensor
Turbidity	DF Robot Non-Contact Turbidity	Measuring the temperature of liquid
pH	Seed Studio Industrial pH Meter	Measure the amount of light that is scattered by the suspended solids in water

2.3. System implementation

Implementation is carried out by adjusting the existing field conditions at CV Smart Batik Indonesia and the next step is to implement the system in the batik industry CV Smart Batik Indonesia. During this process, Installing the necessary hardware, software, and infrastructure components as per the system design. Ensure that all hardware is set up correctly, and software is installed on appropriate servers or devices meets the needs of users in CV Smart Batik Indonesia. In addition, testing of the system is conducted to identify and rectify any issues or bugs. This includes unit testing, integration testing, and user acceptance testing. Address all identified defects before moving forward.

2.4. Training and mentoring

After the system is implemented, training and assistance is carried out for system users, namely employees of CV Smart Batik Indonesia. This training aims to increase their understanding of how to use the system and ensure that the system is used properly to monitor liquid waste. By implementing a comprehensive training and mentoring program, the IoT-based Integrated Liquid Waste Monitoring System in CV Smart Batik Indonesia continues to operate effectively, meets its objectives, and contributes to improved liquid waste management in the community over the long term

2.5. Evaluation

An evaluation is carried out to ensure the success of an IoT-based integrated wastewater monitoring system that is protected by Wire guard in supporting the sustainable in the batik industry CV Smart Batik Indonesia. In addition, the results of this community service can be disseminated through social media, online media and YouTube video to expand its influence and encourage the adoption of similar technology in other batik industries.

3. Results and Discussion

3.1. Preparation

This community service program is carried out in collaboration with CV Smart Batik Indonesia's partners, more precisely at one of the CV Smart Batik Indonesia workshops in Laweyan Solo, Central Java, which is one of the batik production SMEs. From the survey process that has been carried out, CV Smart Batik Indonesia is one type of business that produces hazardous waste. This waste is quite polluting the surrounding environment, especially in the river around the workshop. The waste produced is waste that comes from the batik production process. One of the wastes that can damage the environment is the remaining dye waste which falls and pollutes the water. This will cause the water to become polluted and can affect deep waters if it seeps into the ground.

The activities in this stage were begun by reviewing any existing infrastructure related to liquid waste treatments in CV Smart Batik Indonesia. This may include sewage systems and liquid waste treatment facilities as shown in Figure 4. In addition, the availability and quality of internet connectivity was evaluated in the locations. A reliable internet connection is essential for real-time data transmission and liquid waste monitoring system based on Internet of Things.

Figure 4. Liquid waste treatments in CV Smart Batik Indonesia

3.2. System design and development.

The Internet of Things (IoT) Based Liquid Waste Monitoring System with Wireguard protection is a current technological design that makes it possible to make a practical solution for monitoring waste systems, integrated sensors will send data for monitoring via the internet network in the factory environment protected liquid waste. This system uses ESP32 as a microcontroller to read the quality of the liquid waste in the factory using sensors (Figure 5).

The reading results will then be processed in ESP32 and a comparison will be made whether it exceeds the threshold set by the user. If the reading results when the TDS and/or pH meter exceeds a predetermined threshold, then the ESP32 system will give a warning in the form of a buzzer sound [18][19]. Furthermore, all information regarding the results of sensors readings will be sent to the user's smartphone, so that the user can monitor the quality of the liquid waste in real time. In order for the ESP32 system to send TDS, DO, pH, temperature, turbidity reading data to the user's smartphone, we will use the MQTT server as a data terminal and broker between the ESP32 system and the user's smartphone. This system will monitor the liquid waste generated by the batik industry and transmit data in real-time to a digital platform as shown in Figure 6.

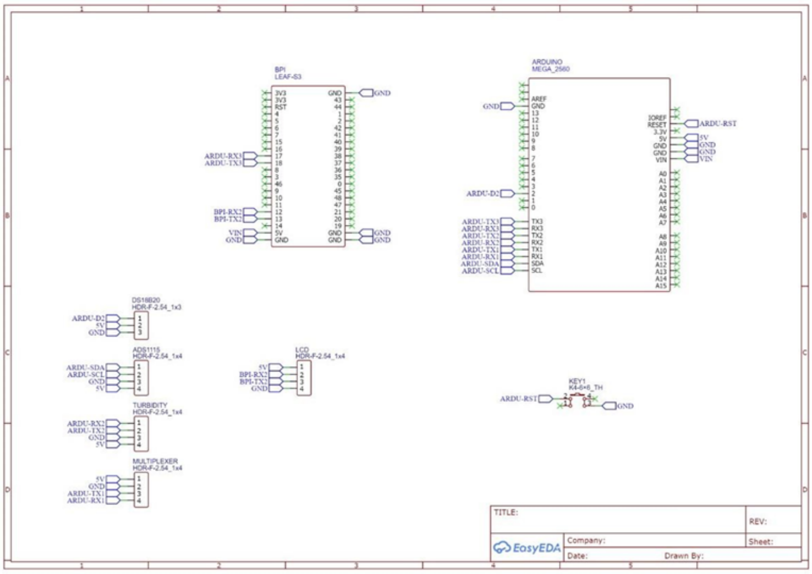

Figure 5. Schematic the liquid waste monitoring system

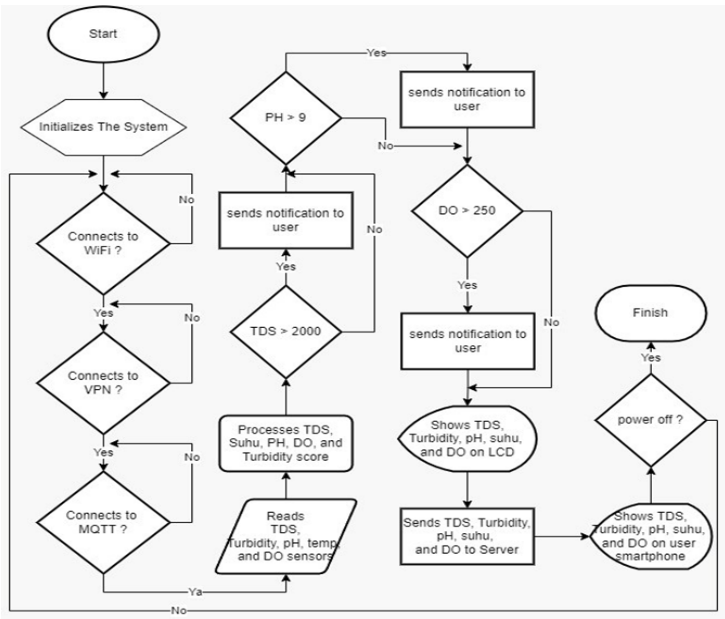

Figure 6. Workflow of the liquid waste monitoring system

The tool is designed a programming flow for monitoring liquid waste at CV. Smart Batik Indonesia. The system we build will take readings from sensors installed in the liquid waste. When the TDS value in the liquid waste exceeds 2000 ppm and/or the pH value is less than 6 and more than 9, the system will sound a warning buzzer and send a warning to the operator via his smartphone. Sending warnings to the operator's smartphone must go through the MQTT server which acts as a terminal and data link between the TDS monitoring system and the operator's smartphone. The system built because it is based on IoT allows operators to monitor the quality of the TDS, DO, pH, temperature, and turbidity of liquid waste anywhere and anytime. The operator will receive information in real time as long as it is connected to the internet network.

3.3. System implementation

The implementation of the IoT-based waste monitoring system presents promising implications for the batik industry and environmental management. The real-time data collection allows for quick detection of anomalies, enabling timely interventions to prevent potential environmental hazards [20]. The fluctuation in pH levels indicates the need for consistent monitoring to maintain proper waste treatment processes. Additionally, the instances of chemical composition surpassing limits underscore the importance of refining production practices to minimize such occurrences [21].

In this study, The Integrated liquid waste monitoring system based on Internet of Things (IoT) was implemented in CV Smart Batik Indonesia as shown in Figure 7. The system consisted of sensors placed at key points in the waste discharge process, continuously collecting data on parameters of TDS, DO, pH, temperature, turbidity. Furthermore, the integration of IoT technology streamlines data collection and reduces the reliance on manual measurements, potentially leading to increased operational efficiency and cost savings. However, potential areas for improvement, such as data security, user interface, cost-effectiveness, and scalability, should be addressed to ensure the system's success in the Sustainable Batik Industry.

The unique feature of this study is the integration of Wireguard for secure communication, which is not a common feature in previous studies. Wireguard provides a secure and efficient VPN solution that can protect the data transmitted between the sensors and the user's smartphone. This feature is particularly important in industrial settings where the security of data transmission is paramount.

Figure 7. Implementation the Liquid Waste Monitoring System

3.4. Training and mentoring

In this stage, the performance of liquid waste monitoring system based on Internet of things is continuously monitored and the stakeholders in CV Smart Batik Indonesia were trained as shown in Figure 8. The effectiveness of the training and mentorship program will be conducted periodic evaluations. The content of the training cover:

- Liquid waste monitoring system operation and data collection procedures.
- Data analysis and interpretation.
- Troubleshooting and basic maintenance tasks.
- Data security and privacy best practices.

Figure 8. Training the liquid waste monitoring system for stakeholder

The study explores how the findings can inform policy-making within the batik industry and broader environmental regulations. This could involve advocating for stricter liquid waste quality standards, the licensing of waste management facilities, and the enforcement of regulations against improper waste disposal [22][23]. The study could also discuss the need for increased public awareness and education on the importance of proper waste management practices among batik industry entrepreneurs and the community at large.

3.5. Evaluation.

An evaluation is carried out to ensure the success of an IoT-based integrated liquid waste monitoring system protected by Wireguard in supporting the sustainability in the batik industry CV Smart Batik Indonesia (Figure 9). Community service team always maintain open lines of communication with CV Batik Indonesia to address concerns, share updates, and gather feedback on system performance. Stakeholders keep thorough records of the challenges, and achievements. The community service was evaluated against the predefined goals and make any necessary improvements.

This community service program is disseminated through interesting and informative content via YouTube videos (Figure 10) and online media by highlighting the main aspects and benefits of an IoT-based Integrated Liquid Waste Monitoring System. The types of content distributed include:

- o Sharing the success stories and case studies of community service program in CV Smart Batik Indonesia.
- o Demonstrating the system's operation and impact.
- o Explaining the technology and its benefits in Infographics.
- o Testimonials from CV Smart Batik Indonesia stakeholders
- o Posting about the project's journey and results.

Figure 9. Integrated the liquid waste monitoring system based on internet of things tools

Figure 10. Disseminating the system in YouTube [24] and online media [25]

4. Conclusion

` The IoT-based integrated liquid waste monitoring system showcases its potential to enhance environmental sustainability and support the realization of a sustainable industry in CV Smart Batik Indonesia. By providing real-time insights and facilitating informed decision-making, this technology contributes to better waste management practices and underscores the industry's commitment to responsible production. Future research could focus on incorporating advanced analytics techniques such as machine learning and predictive modeling into the monitoring system. This would enable proactive decision-making and optimization of waste management processes. Furthermore, The IoT-based monitoring framework developed for the batik industry could serve as a blueprint for similar applications in other textile industries or manufacturing sectors facing liquid waste management challenges. Collaboration between academia, industry, and government agencies facilitated by IoT-based monitoring systems can accelerate the adoption of sustainable practices across various sectors. The limitation of this study is constrained by factors such as connectivity issues, sensor reliability, and data security concerns, which should be addressed in future iterations of the system.

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