INNOVATIVE GREEN TECHNOLOGY FOR FIXING AND DEWAXING IN BATIK PROCESSING

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ABSTRACT: This paper explores the application of green technology in the fixing and dewaxing stages of batik processing, aiming to create a more environmentally friendly approach. A prototype of a machine that involved both fixing and dewaxing was designed and fabricated adhere with the concept of traditional methods. The prototype includes a steel drum that agitates batik fabric, thereby facilitating the activation of sodium silicate alongside synthetic dyes applied to the fabric. A heater was added to warm the water for the dewaxing process. Additionally, an Internet of Things (IoT) system was developed to operate and monitor the wastewater produced during the process, with a sensor installed in a wastewater container. The system detects pollution levels based on parameters such as Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), pH, and turbidity, in accordance with regulations from the Department of Environment. It determines which wastewater should be stored for treatment and which can be safely discharged for drainage. Consequently, this prototype harnesses green technology in batik fabric processing while preserving traditional methods and contributing to environmental protection. The research establishes a solid framework for the integration of green technology with IoT in batik manufacturing to support future experiments along with quantitative performance evaluation.

KEYWORDS: *Batik Processing; Batik Green Technology; Batik Processing Machine; Sustainable Process.*

1.0 INTRODUCTION

Batik is a well-known traditional textile art form predominantly produced in Malaysia and Indonesia, representing a vital creative industry in Southeast Asia. The term *batik* is believed to have originated from the Malay and Javanese words, Amba (to write) and *titik (*to decorate) [1]. Batik fabric is produced using two primary methods: hand-drawn and block-stamped techniques, both employing wax as a resist material. Most batik products include clothing, handicrafts, scarves, and framed artwork. However, it is notable that batik craftsmanship has largely been preserved as similar tools and techniques are persistently being used until today in both countries [2].

Traditionally, the production of batik fabric involves several stages, as illustrated in Figure 1. The first step in creating hand-drawn batik is to sketch the design on white fabric using a pencil. Hand-drawn batik employs a *canting* tool to apply hot liquid wax across the design. This process serves to resist the dye, preventing it from penetrating the fabric and allowing the original colour to remain when it is dyed. Batik stamping, also known as block-printed batik, utilizes a stamp tool dipped in liquid wax, which is then stamped on the fabric repeatedly. Batik stamping is faster and more suitable for mass production compared to *canting*. The next stage is the dyeing process, during which producers currently use two types of dyes: natural dyes and synthetic dyes. The most common synthetic dyes used are reactive dyes, which are suitable for batik fabrics such as cotton, rayon, and silk. Following the dyeing, there is a fixation process that involves the use of sodium silicate or soda ash. This step alters the pH to activate the dye and form a strong bond with the fibres in the batik fabric. After rinsing with water, the fabric undergoes a dewaxing process, where it is soaked in hot water to melt away the wax. Subsequently, the fabric is cleaned, and finally, it is left to dry.

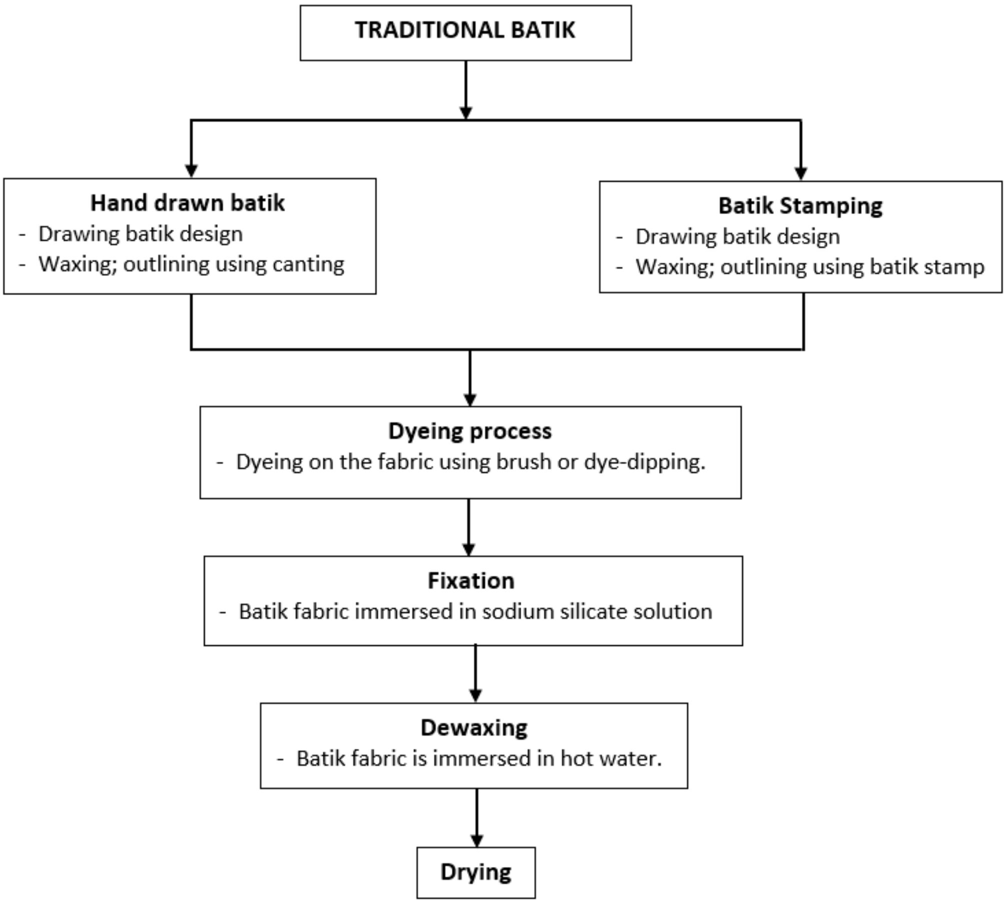


Figure 1: A flow chart of hand drawn batik and batik stamping process.

However, as a result of the process, most of the wastewater generated is released into the drainage system. Such waste contributes to pollution, primarily due to the use of soda ash, sodium silicate, and other contaminants in the batik-making process [3]. It has also been stated that the batik industry is one of the main sources of water pollution, with the industry's compliance rate being the lowest, as reported by the Malaysian Department of Environment (DOE) [4]. For instance, reports from researchers indicate a high concentration of chemical oxygen demand (COD) in wastewater discharged from five batik factories in Kota Bahru, Kelantan [5]. Furthermore, many workers in the batik industry encounter problems with occupational health services. Small staff numbers expose workers to potential dangers associated with ergonomic and chemical hazards. Typically, they experience prolonged standing and manual handling. Workers who stand continuously while performing their tasks are more likely to suffer from pain and discomfort in their extremities and lower back [6]. Meanwhile, the most common chemical hazard is skin diseases, which arise from the minimal use of Personal Protective Equipment (PPE). The batik-making process exposes workers to various physical and chemical hazards, including skin irritants and contact allergens, potentially leading to the development of skin disorders [7].

According to [8], in developing batik industry and pertaining to the environment, it must involve premise housekeeping such as detached wet and dry areas, space for batik styling, fabric dyeing space, colour stabilization space, dewaxing and rinsing and immersion space. Next, comfortable workspace for employees and a proper waste management that include the establishment of drainage system and compliance with occupational health and safety. Therefore, a sustainable process using green technology should be implemented towards batik producers. This been support by [9], that innovative green technology is one of the eco-friendly actions that can be taken by small and medium sized enterprises (SMEs) and can be used to improve SMEs environmental performance. When it is implemented towards Batik industry it can offers products and processes that contributes to the prevention on environmental damages [10]. Therefore, due to the environmental issues, healthcare workers and time consuming in batik industry, it is necessary to developed new method involving green technology.

2.0 PREVIOUS WORK

The traditional process for batik usually needs to be processed from sketching into batik fabric around two to three days. There is evolution in batik manufacturing with the existence of innovative tools and machine. However, the process of batik fabric production is still carried out separately where it only focuses on part of the process, such as chanting tools, dyeing and fixation process. In view of this, the part that gets the most attention is the chanting works by applying Computer Numerical Control (CNC). This computerized operation of machining tools was developed either to do chanting job or to colour the batik fabric. In articles by [1,11,12] has mentioned how they developed batik pen chanting tool being control using CNC machine. Meanwhile, most of the development using CNC machine is focusing on colouring the batik fabric as reported by [13,14]. Both innovations are focusing on increasing the batik production and reducing the production time.

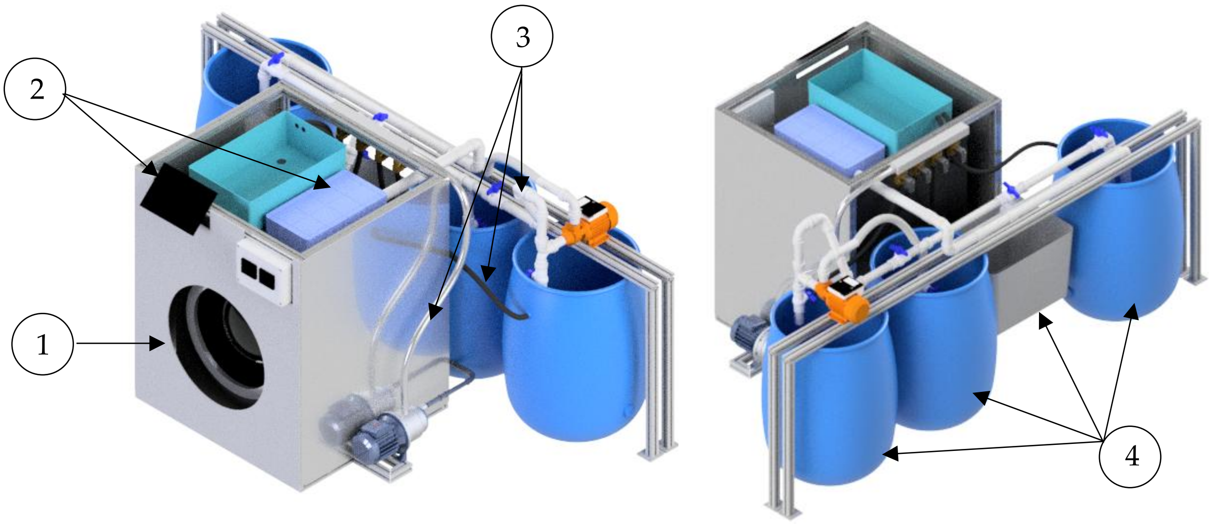
According to [15], improving the technology and the orientation of the equipment for each batik production process can influenced the production in Batik SMEs. The improvement technology which being developed are ergonomic drawing table, electric canting, a tub with roller fixation padder and a copper plate kenceng for dewaxing. The application of modern orientation technology has been proven effectively enhancing the production performance of batik SMEs. A technology approach on the batik design is also being developed using digitalization technology to create traditional Batik designs. In other hands, maintaining separation tools may increased the production but in tackling the environmental issues and healthcare workers still unclear.

An approach of green energy source is also being attempt in improving environmental pollution for batik industry. [16], has changed the usage of kerosene stove to electrical stove using solar power in home scale batik production. The result shows an increment of production and gross profit, stable energy power and preserve the environment. This is also being mention by [17] in applying solar power for home scale batik industry. The difference in this method, it used a reflectors of mirror glass and aluminium foil. The result shows that the mirror glass system can produced 15% output power more than using a system without reflector.

Previous studies have conducted various techniques to increase batik production using greener and more sustainable methods. It is not only good for batik production but also for the health and safety of workers and more environmentally friendly. Therefore, in this study integration of fixing and dewaxing traditional process in one machine has been developed. An IoT system also being used as a monitoring system to ensure the suitability of waste water from batik processing to be released or not.

3.0 THE ECO-FRIENDLY BATIK PROCESSING MACHINE

The eco-friendly batik processing machine, as illustrated in Figure 2, has been designed based on the concept of a front-load automatic washing machine. The design was completed using Autodesk Inventor software. The entire system is operated and monitored through an Internet of Things (IoT). This machine consists of several essential components, including the main machine, an IoT system, a piping system, and containers.



1. Machine
2. IoT System
3. Piping System
4. Containers

Figure 2: Isometric view of eco-friendly batik processing machine

The main machine features a steel drum with a front-loading door located at the centre of a holding frame that is connected to a heating element for temperature regulation. The speed of the steel drum is controlled by a motor equipped with a belt drive. The drum pulley is connected to the motor pulley. The machine is held stable by a suspension system and a range of balance blocks. It also has several sensors and valves to simplify the whole process. The automated machine is an extremely effective system which utilizes the ESP32 microcontroller to automate the process communicating with the STM32 microcontroller in the machine. The system is also controlled through wireless operation and data logging applications by the ESP32 microcontroller. All collected data is stored in a cloud. Efficient running of the process requires a proper piping system. It ensures that fluids are brought to the proper places and prevents contamination of different fluids needing recycling. So, pumps and pipes must be selected as per their target use cases. This study requires four containers because of the diverse processes involved, which ultimately promote recycling and reduce pollution.

The machine processing flowchart is outlined in Figure 3. The literature review shows that an eco-friendly approach in the batik industry consists of designing machines and premises that are friendly to both the environment and workers. The figure illustrates how the development of machines concentrates on batik that has already undergone dyeing. The machine handles the entire process, which includes batik fixing, rinsing, dewaxing, and a final rinsing. The flowchart shows that after batik fabric is prepared which includes sketching, waxing and dyeing, it will go through the fixing process as the first process, and it will continuously be processed until the end of the process inside the machine. The machine is filled with a certain volume of sodium silicate inside the steel drum and running for a certain speed and time. When the process is finished, the sodium silicate is pumped into a container and can be used again for the next batch.

When the fixing process finished, the batik fabric was still inside the steel drum, and it was filled with tap water at room temperature for the rinsing process. The process is done three times to ensure that sodium silicate is removed from the batik fabric. This step is crucial to ensure the fabric is clean and to prevent any issues in the next process. This is including agitation movement towards the water. When the process is finished, the wastewater is pumped into a wastewater container, and using the sensor operated and monitored by IoT system, it examines the biological oxygen demand (BOD), the chemical oxygen demand (COD), and the power of hydrogen (pH). Through the reading, the wastewater will be categorized as needing treatment or good for release. The reading of wastewater at high level is pumped into a treatment container, and wastewater at low level will be discharged into a drainage system.

The next process is dewaxing, in which the batik fabric, which is inside the steel drum, is filled with tap water at a designated temperature for wax removal from the batik fabric. The warm water is combined with soda ash to cleanse and facilitate the wax to dissolve and drop out of the batik surface. The wastewater is then pumped into a dewaxing wastewater container, monitored for pollution level once the process is finished. The wastewater is left until all the wax freezes and floats to the surface, before being tested, so it becomes simple to remove the wax and re-consume it. The left wastewater was examined and if high level polluted water was present, it would be pumped into the treatment container and if low pollution, would be discharged into the drainage system.

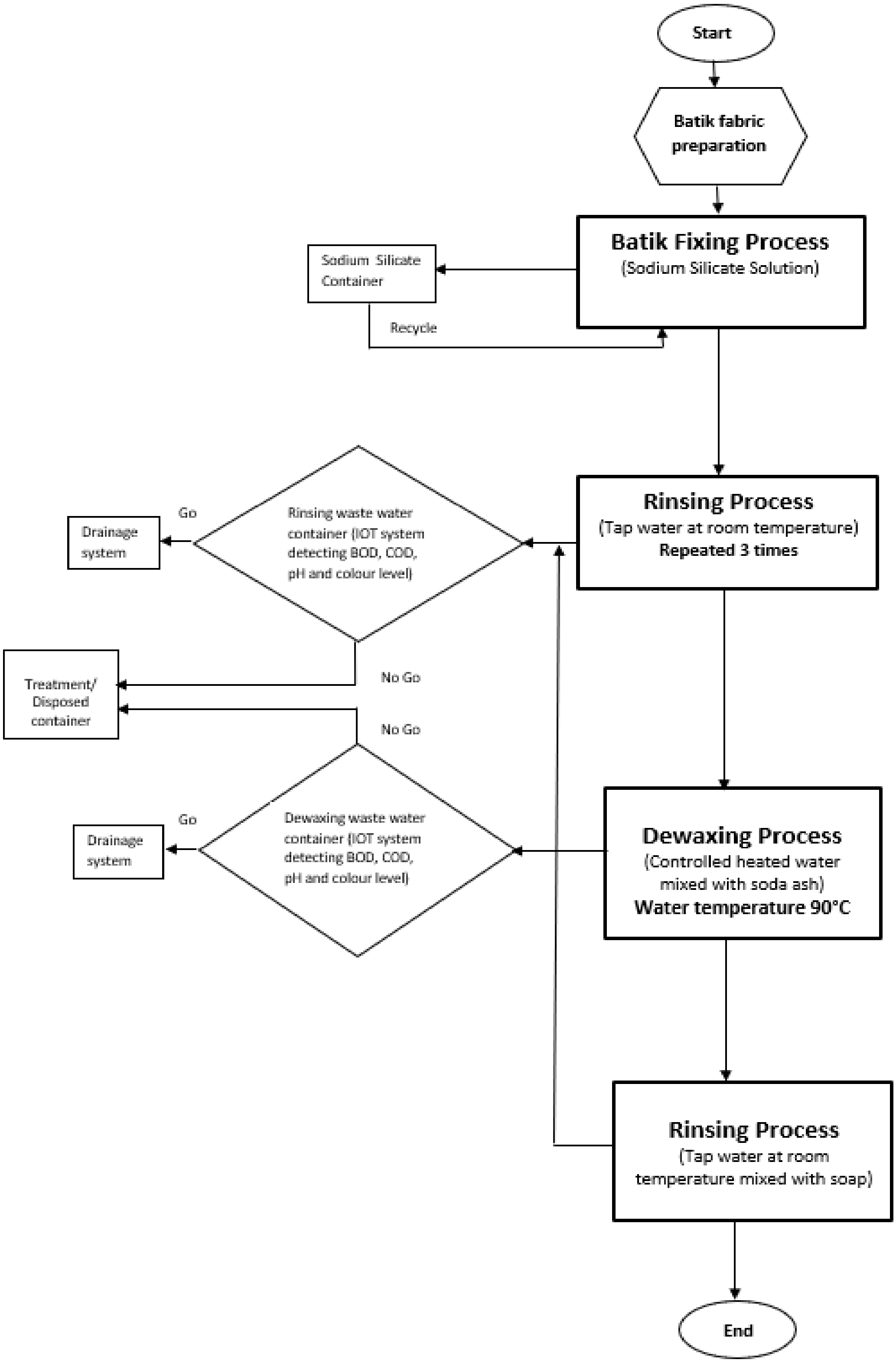


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Figure 3: A flowchart of system in the batik machining process

Lastly, the batik fabric will go through the rinsing process again, and this time the tap water is at room temperature and mixed with soap, and some producers will mix it with softener. After it finishes, the wastewater will be pumped into a rising wastewater container and will be checked as in the previous procedure. When the process is done, the batik fabric will be taken out and sent for drying. Through this process, the premises do not require a large space and are definitely friendlier towards the environment and workers as shown in Figure 4.

Figure 4: Final prototype of eco-friendly batik processing machine

4.0 THE OPERATIONAL PARAMETER OF ECO-FRIENDLY BATIK FIXING AND DEWAXING MACHINE

4.1 Fixing Process

The process of fixing colour with sodium silicate based on an agitation of washing machine concept is to create friction between a fabric and the agitator itself. The action forces the water and chemical through the yarns and fibres. Sodium silicate serves as a dye fixative in batik fixing keeping pH up as an alkaline buffer for reactive dyes and its reaction on cotton fabric fibres that resists fading to bind permanently. The agitator swivels throughout the fixing process with swinging motion, which forces the sodium silicate through the yarns and fibres of batik fabric. In the action of changing its colour, sodium silicate is very alkaline, this high alkaline bond in the fabric is needed to retain the dye and bind the dye to the fabric making sure that the effect is beneficial for colour fixing. The agitation speed and duration facilitate an even distribution of sodium silicate across yarns and fibres and is therefore more likely to be directed into fibre pores. This process also enhances the reactivity of the dye to attach and interact with the fabric fibres that enhances the colours to be stronger, more stable, and to also be resistant against fading.

4.2 Rinsing Process

The rinsing process is performed to wash away any unfixed dye molecules and excess sodium silicate left on the fabric surface through agitation using clean water at room temperature.

4.3 Dewaxing Process

The dewaxing involves the removal of the wax that serves as a resist material in traditional batik design. The machine is equipped with a heater to heat the water until it can reach 90°C. The fabric is immersed into a water in steel drum with a temperature of 90°C, to melt and separate the wax from the fibres. Soda ash is added to facilitate the cleaning process. Dewaxing shows the complex batik type of pattern and highlights the contrast between coloured and non-coloured parts. When performed after proper fixation and rinsing, the colours remain stable and do not fade. Wax collected from the process, too, can be recycled, helping to make the batik produced sustainable. A special pump that can run with hot temperature is needed to push the wastewater into the container.

4.4 Rinsing with Soap Process

Soap rinsing ensures that all remaining traces of wax, alkali, and unfixed dye are removed. In addition, the fabric is rinsed in a gentle detergent or soap solution at around 40°C, then rinsed through clean water. This rinsing enhances the softness and brightness while simultaneously improving its tactile quality and aesthetic attributes. It also improves wash and rub fastness by removing any residual chemicals that could otherwise cause degradation over time. The sample of product are shown in Figure 5.

Before After

Figure 5: Sample of batik after completing the whole process

5.0 THE IoT SYSTEM

The Internet of Things (IoT) system integrated into the eco-friendly batik processing machine plays a crucial role in ensuring that the entire operation runs efficiently, safely, and sustainably as shown in Figure 6. The system is designed to monitor, control, and analyze various parameters throughout the fixing, rinsing, dewaxing, and final rinsing processes. It utilizes sensors and microcontrollers to collect real-time data related to the machine's operation and wastewater quality as shown in Figure 7.

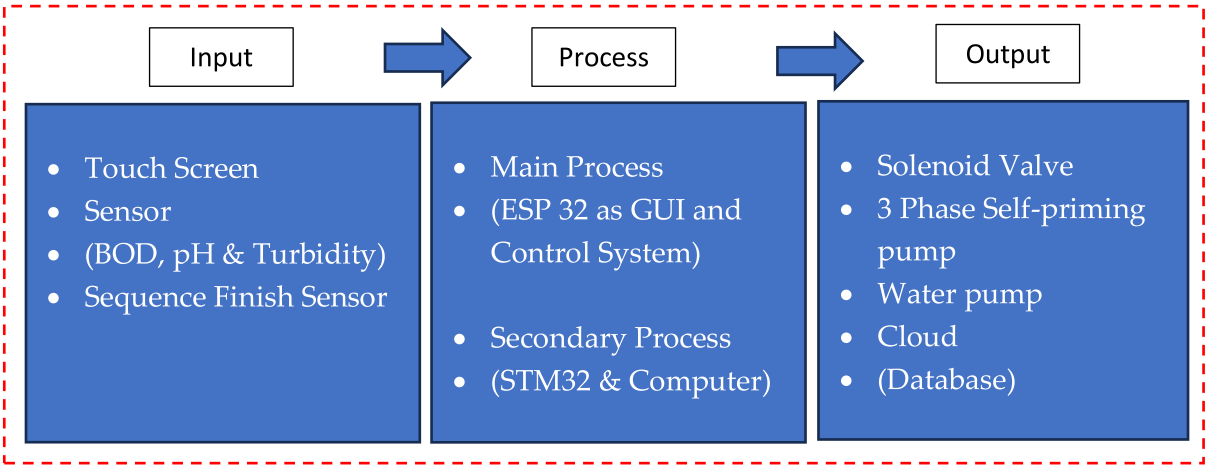

Figure 6: Input-output block diagram

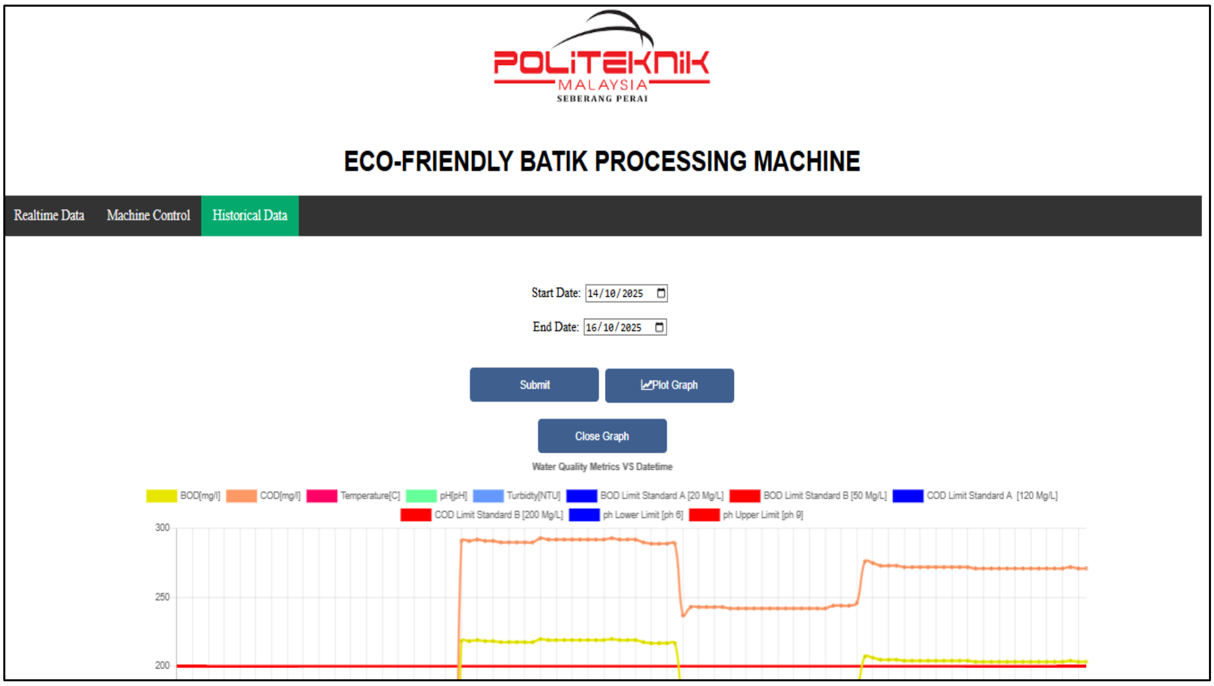

Figure 7: An example of a view of data on the screen of Windows

The ESP32 microcontroller is one of the central components in the system, and it wirelessly communicates with the STM32 controller to provide the mechanical functions for the machine. ESP32 communicates the control command (RPM, operating time & water temperature) remotely to STM32 controller via the internet or local environment. ESP32 also sends out the current selected mode for the machine to the cloud. With this setup, the users can observe process conditions with a connected device like a smartphone or computer.

The IoT system is also responsible for monitoring wastewater conditions in accordance the Department of Environment (DOE) standards based on Environmental Quality Act 1974. The sensors installed in the wastewater containers are used to record important environmental parameters such as Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), pH, and turbidity. The collected information determines whether the wastewater will be safely discharged into the drainage system or should be treated further. If the readings exceed the safe limit, the wastewater is automatically directed to a treatment container where it can be purified before the waste product is discharged.

Apart from environmental monitoring, the IoT platform significantly improves automation and operational safety. Automation enables pumps, valves, and heaters to be controlled in accordance with the process requirements and avoid human intervention, which in turn can also minimize the exposure of end users to the heat or chemicals present in a process. Alerts and notifications can also be set to alert the operator about system faults, excessive temperatures, or abnormal water quality levels.

In essence, the IoT system integrated into this innovative batik processing machine turns a classical craft into a smart, data-driven, and eco-conscious process. The ability of this method to keep batik manufacturing eco-friendly (which reduces environmental pollution) allows producers as well to meet existing environmental regulations, thus, not sacrificing quality or sustainability.

6.0 CONCLUSION

This research developed an innovative eco-friendly batik processing machine that integrating the fixing and dewaxing into a single automated system equipped with IoT based monitoring. As opposed to earlier works that only had isolated batik production steps or simply increasing productivity, the method of this research considers the process integration, green technology principles, and intelligent wastewater monitoring all in one equipment. Controlled mechanical agitation along with regulated heating and automated chemical handling creates a continuous and efficient method for dye fixation and wax removal without the need for manual handling or operator skill. Furthermore, the embedded IoT framework develops a structured approach for monitoring vital wastewater parameters including BOD, COD, pH, and turbidity, which meets the Department of Environment (DOE) requirements, facilitating the decision-making process in wastewater re-use, treatment, or discharge. Although complete experimental verification and comparative performance metrics are not published to date, this work, and its concepts, provides a complete design framework and operational concept that helps fill a significant gap in existing batik processing technologies, considering environmental sustainability and occupational safety. The designed system paves the way for the feasibility of quantitative performance evaluation, regulatory compliance verification, and ergonomic assessment and other future projects. This study, then, shows how automation, as combined with smart monitoring, represents a potential path in bringing traditional batik manufacturing into the modern age without losing its historical and cultural importance, and sustainable industrial practice.

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