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Research Paper

Automation of Palm Oil Industry Wastewater Quality Control System Using Microcontroller-Based Poly Aluminium Chloride (PAC) Integrated with Google Spreadsheet

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ABSTRACT

The development of microcontroller technology has been widely utilized in various fields, including in the treatment of industrial wastewater. One type of wastewater that requires special handling is palm oil mill effluent (POME), which contains high levels of pollutants such as water turbidity, fluctuating pH values, and high total dissolved solids (TDS). This research has developed an automated wastewater quality control system based on a microcontroller integrated with Google Spreadsheet. The system is designed to read real-time data from three key water quality parameters: turbidity, pH, and TDS. The next step is for the system to automatically determine the appropriate dosage of Poly Aluminium Chloride (PAC) through an actuator in the form of a peristaltic pump. The main components of the system include an Arduino Mega 2560, turbidity sensor, pH sensor, TDS sensor, and an internet connection module for data transmission. Monitoring data is sent and recorded automatically to Google Spreadsheet, enabling remote access and analysis. System testing results show that the system has successfully met the quality standards for POME wastewater, specifically turbidity (≤150 NTU), pH (6–9), and TDS (≤500 ppm). Component testing also demonstrates high measurement accuracy, reaching 98.680% for the turbidity sensor, 98.890% for the pH sensor, and 98.676% for the TDS sensor.

Keywords: Microcontroller, Poly Aluminium Chloride (PAC), Google Spreadsheet, Palm Oil Mill Effluent (POME)

INTRODUCTION

The palm oil industry is one of the leading sectors in Indonesia that contributes significantly to the national economy. Behind its economic potential, this industry also produces large amounts of liquid waste that can pollute the environment or better known as Palm Oil Mill Effluent (POME) [1][2][3]. Most palm oil mills manage POME through a series of aerobic and anaerobic ponds until it reaches the quality standards set by the government before being discharged into water bodies [4][5]. Based on government regulations, the quality of POME effluent that can be discharged to water bodies includes turbidity ≤150 NTU, pH (6-9), and Total

Dissolved Solids (TDS) (≤500 mg/L) [6]. Coagulants are often used as a solution to help remove contaminants from water.

One method commonly used in wastewater treatment palm oil industry is the coagulation-flocculation process using chemicals such as Poly Aluminium Chloride (PAC) [7][8]. This method aims to agglomerate suspended particles so that they easily settle and separate from wastewater. The use of PAC can reduce turbidity values by up to 89.02% [9]. Conventional use of PAC is usually done manually with the dose determined based on estimates without real-time measurement of water parameters. This process is often inefficient due to the mismatch between the dose of PAC given and the actual conditions of the waste [10].

Along with technological developments, wastewater treatment systems can now be improved by using microcontrollers as a control center capable of processing sensor data automatically [11][12][13]. In this study, an automated palm oil industry wastewater quality control system was developed that uses a microcontroller to read important parameters such as turbidity, pH, and TDS in real-time. The data obtained is used to determine the correct PAC dosage by automatically setting the working time of the peristaltic pump. This system is also connected to Google Sheets which functions as a data recording medium so that data can be monitored, stored, and analyzed from anywhere [14].

There is one research that has been conducted by Ilham regarding the liquid waste monitoring system at the palm oil mill, namely one of the inputs used does not experience significant changes until the end of monitoring and there is no method of dealing with liquid waste that will be disposed of in the river body [15]. With this automation system, the palm oil industry wastewater treatment process becomes more efficient, accurate, and easy to monitor. The system is able to adjust the dosing of PAC based on the actual condition of the wastewater so that the use of PAC becomes more efficient and the treatment results are more consistent. Data recording integrated with Google Spreadsheet provides ease of documentation, remote monitoring, and minimizes the risk of recording errors.

MATERIALS & METHODS

Data

The materials used are palm oil liquid waste (POME) from PTPN VII Bekri, Lampung and Poly Aluminium Chloride (PAC) coagulant with a concentration of 20%.

Sensor and Data Acquisition

This device consists of Arduino Atmega, 16x2 I2C LCD, HC-SR04 ultrasonic sensor, ph sensor, turbidity sensor, and total dissolved solids sensor. Arduino Atmega functions as a sensor data control center whose programming uses Arduino IDE. HC-SR04 ultrasonic sensor to measure the height in the container, ph sensor to measure the acidity or basicity of wastewater, turbidity sensor to measure the turbidity level of wastewater, and TDS sensor to measure the total amount of dissolved solids in wastewater. The measurement results will be displayed on the 16x2 I2C LCD which looks like turbidity (NTU), pH, TDS (ppm), dosage (mL), and water quality. The electronic circuit of this system is made using the fritzing application, as shown in Fig 1.

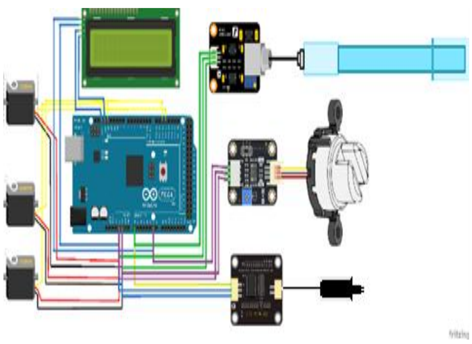

Figure 1. Electronics circuit system

System Procedures

This system is designed to automate the monitoring process and determination of coagulant dosage in palm oil industry wastewater treatment. The process begins with the sampling of wastewater that will be tested using several sensors, namely the HC-SR04 Ultrasonic Sensor, pH sensor, turbidity sensor, and TDS sensor. These sensors detect wastewater quality parameters that will be used as the basis in determining the appropriate coagulant dosage. The data obtained from the sensors is sent to the Arduino Mega 2560 which functions as the control center of the system. The Arduino Mega 2560 then processes the data and determines the appropriate response based on the embedded program.

The Arduino Mega 2560 controls the actuators consisting of Pump 1, Pump 2, and Mixer. Pump 1 is activated to drain wastewater from the initial container into the treatment container where the coagulant addition process is carried out. After the wastewater enters the treatment container, Pump 2 operates to drain the PAC coagulant with a predetermined dose based on the sensor analysis results.

The determination of the PAC dosage is based on the level of turbidity and the amount of solute in the water, so that the volume supplied can be adjusted automatically.

This process ensures that the coagulant is applied in an amount sufficient to bind the dirt particles in the wastewater without causing chemical wastage. Once the PAC coagulant is added, the system activates the Mixer to mix the solution evenly. This stirring aims to accelerate the reaction between the coagulant and the dirt particles in the water so that flocs are formed which are easier to settle and separate from the water. During this process, sensors continuously monitor changes in water parameters to ensure that the coagulation process is running properly.

The system is equipped with an LCD display that shows wastewater parameters as well as information on the coagulant dosage. In addition, data is also automatically sent to a Google Spreadsheet via a wireless connection so that operators can access and analyze the data in real-time or in the long term. With this automatic recording, evaluation of the effectiveness of the system can be done more easily, and can be used as a reference for further optimization in the treatment of palm oil industry wastewater.

Realization Device

The front view of this tool is divided into two parts, the first part is for waste before dosing coagulant, the second part is for processing coagulant dosing. there are also three sensors placed in the second container facing down, and three coagulant containers that function for giving to the sample. A 16x2 I2C LCD is used to read the results of the optimization treatment, as shown in Fig. 2.

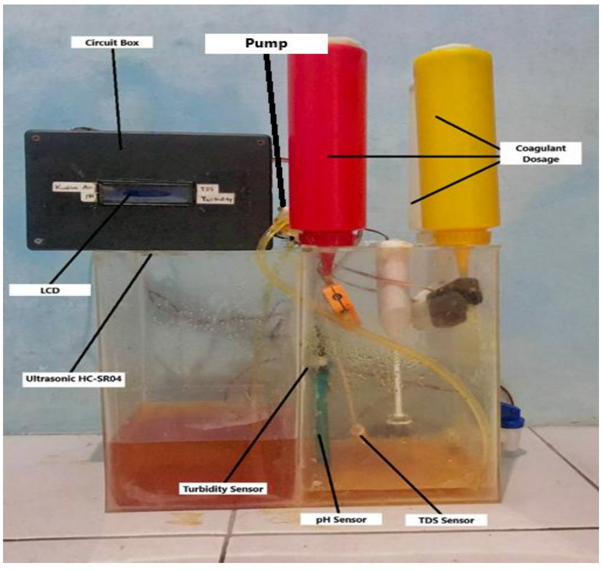

Figure 2. View of the device

RESULT

The optimization system was successfully designed by utilizing four main components: turbidity sensor, pH sensor, TDS sensor, and servo to control the PAC dosage. The system is designed so that all components can work in an integrated manner using an Arduino Mega 2560 microcontroller. The turbidity sensor detects the level of water turbidity, while the pH sensor is used to measure the acidity or basicity of wastewater. In addition, the TDS sensor measures the total dissolved solids in the water. The data from these three sensors is then processed by the fuzzy logic algorithm embedded in the Arduino. Based on the processing results, the servo controls the opening of the PAC reservoir to deliver the appropriate dose of coagulant. With this integration, the system is able to provide an efficient and reliable solution in the management of palm oil industry wastewater. Research was conducted to obtain automation of palm oil industry wastewater treatment tools based on the use of PAC with integrated google spreadsheet. Data collection was carried out for 12 minutes. Data in the form of turbidity (NTU), pH, and TDS (ppm) values which are then used as data during palm oil industry wastewater treatment.

The treated POME samples consistently met the wastewater discharge standards set by the Indonesian Ministry of Environment and Forestry [6], with turbidity values below 150 NTU, pH maintained within the range of 6 to 9, and TDS levels below 500 ppm. Significant improvements were observed in water clarity, dissolved solids reduction, and pH stabilization after the PAC was administered. The system's capability to adjust chemical dosage dynamically according to actual water conditions enhanced efficiency, minimized chemical waste, and ensured compliance with environmental regulations. Furthermore, the automated data logging into Google Spreadsheet provided a practical solution for documentation and long-term analysis of system performance.

Table 1 shows the changes in the initial and final conditions of palm oil industrial waste. Changes occurred in turbidity, pH, and TDS after the addition of coagulants.

Table 1 System Test Results

Time (minutes)	Turbidity (NTU)	pH	TDS (ppm)
1	160	4.1	80.92
2	160	4.1	80.92
3	160	4.1	80.92
4	151	4.61	80.92
5	143	4.61	230.18
6	143	4.61	230.18
7	143	4.61	230.18
8	143	4.61	230.18
9	138	4.61	330.28
10	138	4.61	330.28
11	138	4.61	330.28
12	138	4.61	330.28

Based on Table 1, changes in turbidity, pH, and TDS parameters during liquid waste treatment with coagulants. The initial turbidity value of 160 NTU remained constant until the third minute, then began to gradually decrease to 151 NTU in the fourth minute, 143 NTU in the fifth minute, and finally reached 138 NTU between the ninth and twelfth minutes. This decrease indicates the effectiveness of the coagulation process in reducing wastewater turbidity, showing that suspended particles begin to settle over time. To present the data in a more visual and easily understandable format, a graph is included to illustrate changes in turbidity, pH, and TDS parameters during the wastewater treatment process, as shown in Fig 3.

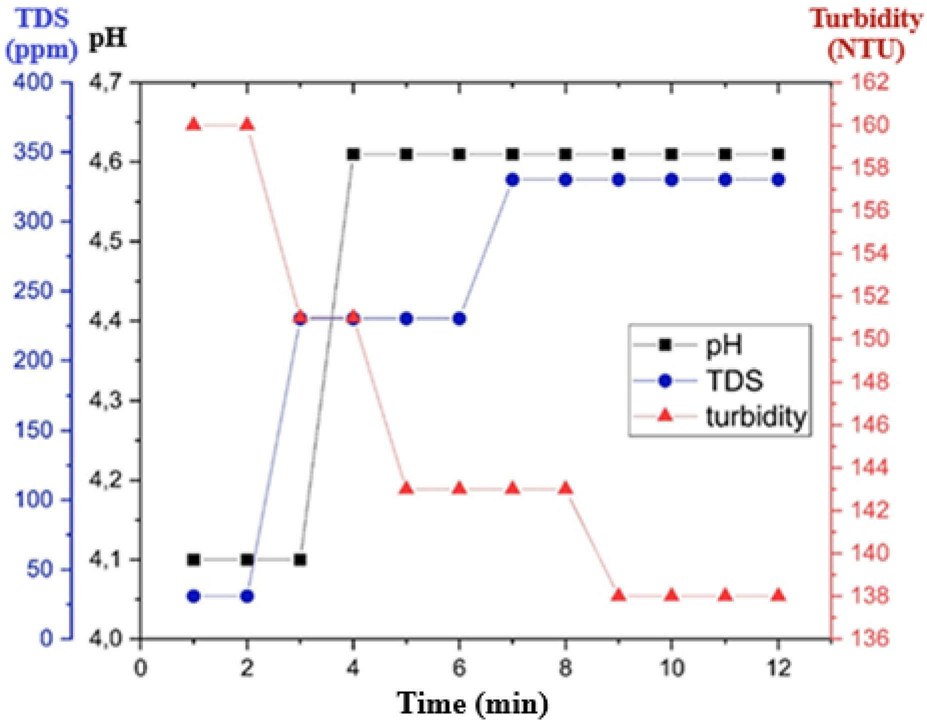

Fig 3. Changes in Turbidity, pH, and TDS during wastewater treatment

Based on the data in Table 1, the data is presented in graph form for each variable, namely turbidity, pH, and TDS.

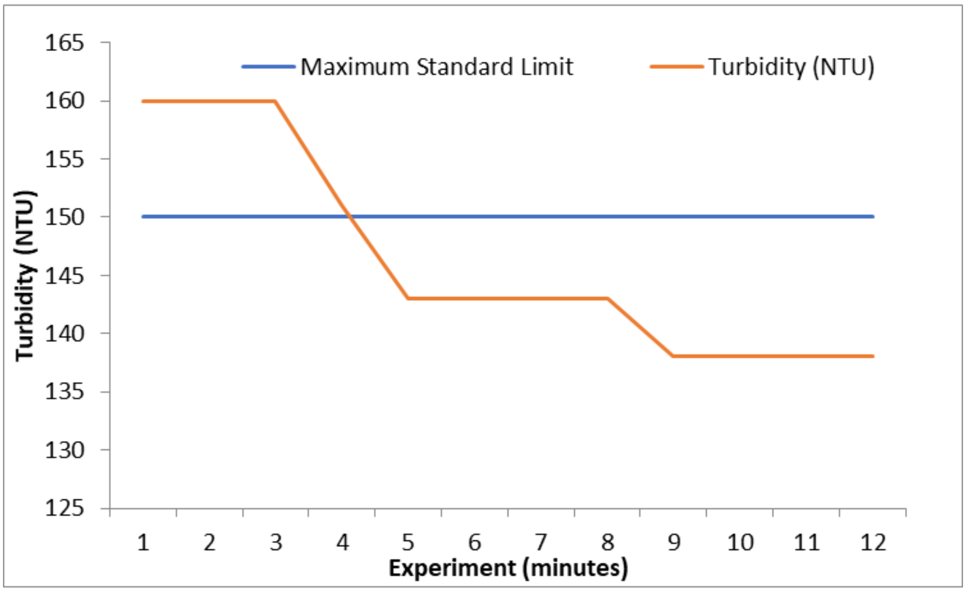

Fig 4. Graph of Turbidity Test Results with Standard Maximum Limits

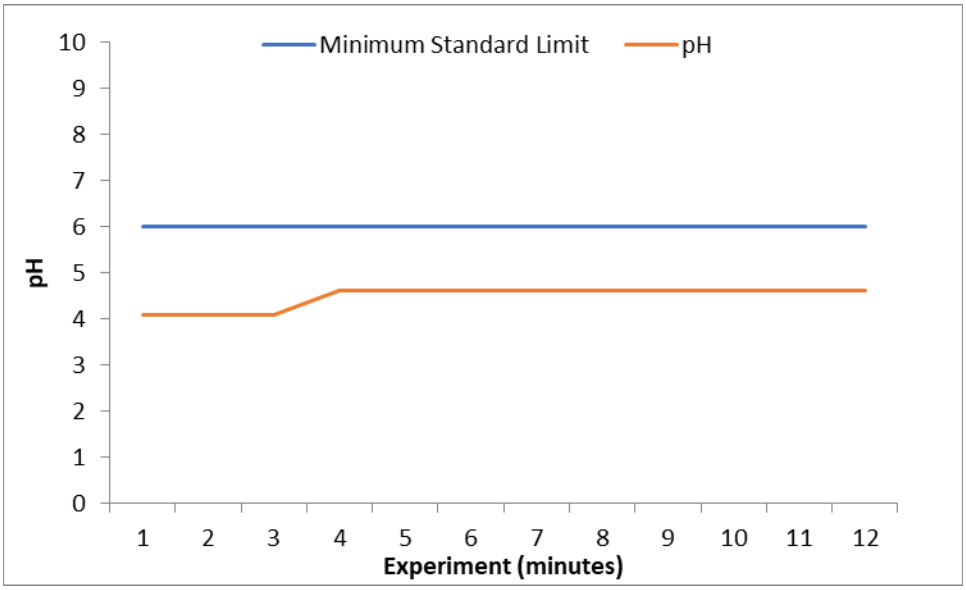

Fig 5. Graph of pH Test Results with Minimum Standard Limits

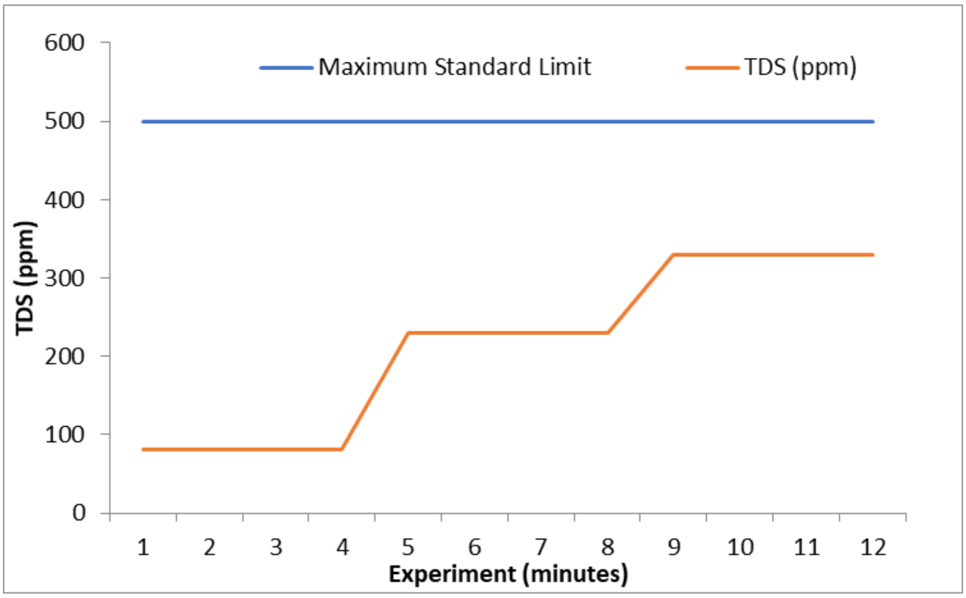

Fig 6 Graph of TDS Test Results with Standard Maximum Limits

Figure 4. shows the results of turbidity testing on treated palm oil industrial wastewater compared to the maximum standard limit. The graph shows that the initial turbidity value was 160 NTU, then gradually decreased to 138 NTU at the 9th minute and remained stable until the 12th minute. This decrease indicates that the treatment process successfully reduced the turbidity level of the wastewater below the DLH standard limit of 150 NTU. These results indicate that the treatment system is capable of reducing the suspended particle content in the wastewater, making it clearer and meeting the applicable environmental standards.

Figure 5. shows the results of pH testing on treated palm oil industrial wastewater compared to the minimum standard limit. The graph shows that the initial pH value was 4.1 and increased slightly to 4.61 at 4 minutes, then remained stable until 12 minutes. Although there was an increase in pH during the treatment process, the resulting value remained below the DLH's minimum standard of 6. This indicates that the treated wastewater is still acidic and requires further neutralization to meet environmental standards before being

discharged into water bodies. The primary cause of the low pH is that the palm oil industrial wastewater has not undergone treatment in aerobic and anaerobic ponds. This process is crucial because aerobic and anaerobic ponds help stabilize wastewater pH by breaking down organic matter and increasing alkalinity, thereby bringing the pH closer to or within the standard range.

Figure 6. shows the results of Total Dissolved Solids (TDS) testing on treated palm oil industrial wastewater and compares them with the maximum standard limit. The graph shows that the initial TDS value was 80.92 ppm and gradually increased to 330.28 ppm at the 9th minute. After that, the TDS value remained constant until the end of the test. Despite the increase, the TDS value after treatment remains below the maximum limit set by the Environmental Agency (DLH), which is 500 ppm. This result indicates that the tested wastewater treatment system does not cause a surge in TDS values exceeding the threshold, thereby ensuring that the treated wastewater still meets applicable environmental standards.

The effectiveness of the system was measured based on the ability to optimize wastewater quality after PAC dosing. The treatment results show that after the application of PAC dosage, the turbidity level of wastewater is reduced to below the limit of wastewater quality standard requirements. In addition, the amount of total dissolved solids also decreased to meet the wastewater quality standard requirements. However, the pH of the wastewater after being dosed with coagulant could not rise drastically to the water quality standard requirements because no further treatment process was carried out in the aerobic and anaerobic ponds.

CONCLUSION

The results of the study show that an automated quality control system for industrial palm oil mill effluent using Poly Aluminium Chloride (PAC) based on a microcontroller integrated with Google Spreadsheet has been developed. The system test results indicate that the system is capable of meeting the quality standards for POME effluent, namely turbidity (≤150 NTU), pH (6-9), and TDS (≤500 ppm). The accuracy levels of the turbidity, pH, and TDS sensor components were 1.110%, 1.320%, and 1.324%, respectively.

Declaration by Authors

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Conflict of Interest: No conflicts of interest declared.

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