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Measuring Plastic Wastewater Quality Using the Internet of Things

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ABSTRACT

This study evaluates the water quality in the plastic waste management process at CV. AAWW Perdana Usaha, located in Bogor, West Java, Indonesia. The sensors used to measure total dissolved solids (TDS) and turbidity operate using PPM (parts per million) and NTU (nephelometric turbidity units), respectively. To assess water quality during plastic waste processing, a WiFi-enabled Arduino Mega 2560 (ESP8266) microcontroller is connected to the TDS and turbidity sensors. The research methodology follows a structured approach comprising planning, analysis, design, implementation, and testing phases. Utilizing the Internet of Things (IoT), the study presents a system that monitors water quality in real time during the plastic waste treatment process. The results and conclusions of this study indicate that the wastewater quality measurement system has been successfully developed. The system enables classification of wastewater into "clean" and "contaminated" categories following regulation No. 78/M-IND/PER/11/2016 issued by the Indonesian Ministry of Industry. Furthermore, it facilitates easy water quality monitoring through a web-based interface.

1. INTRODUCTION

All living things require water to survive, making it a crucial natural resource [1, 2]. A plentiful supply of high quality water is necessary for many human activities, such as industry, agriculture, cleanliness, and consumption [3]. Additionally, water is essential to the processing of industrial waste, especially waste plastic [4].

Plastic waste is one of the main problems that many countries, including Indonesia, are dealing with [5]. One kind of inorganic trash that is not biodegradable and takes a long time to break down is plastic waste [6]. Decomposition of plastic waste might take hundreds of years to complete [7]. Out of the 270 million plastic products made from household and industrial garbage, eight million end up in the ocean [8]. Processing plastic waste is an essential step in addressing the problem of plastic waste accumulation and its negative environmental effects [9]. Processing plastic waste through recycling is one way to reduce the harmful effects that it has on the environment [10].

Whether plastic trash is recycled or processed to create goods with added value, water is an essential component [11]. To get the finest product outcomes, it is crucial to make sure the water utilized in these processes is of the proper quality and satisfies the established standards. Poor quality water can impede chemical reactions, lessen the efficacy of the treatment process, and provide an unsatisfactory final product [12].

Measuring the water quality during the plastic waste treatment process is crucial to guaranteeing that the generation of plastic waste is of the desired quality [13]. To obtain more objective results when testing water quality, sensors that measure the quality of plastic waste water must be used [14]. Sensors are employed to identify alterations in the properties of water that may be brought about by impurities, chemicals, or other problems. Additionally, impurities like soil, sand or dirt that contain high concentrations of dissolved solids from plastic trash can be detected using sensors to produce undesirable scents and colors in water [15]. To make it more effective and efficient to identify changes in the quality of the water used to treat plastic waste, monitoring of the water quality is also required [16].

Water quality is measured using a variety of sensors, depending on the requirements of the study project. Utilizing sensors, for instance, to gauge PH, temperature, oxygen concentration, turbidity, dissolved particles, and other parameters [17]. In order to check water quality, regular monitoring is necessary. Over time, variations in water quality can be seen by means of a consistent and ongoing monitoring procedure. Early detection of these changes enables appropriate processing or analysis of the data gathered from the monitoring procedure [18, 19]. All of which sensor can function independently or in combination [20].

Several previous studies have developed water quality monitoring systems using sensor technology and the Internet of Things (IoT). For water quality monitoring, a turbidity sensor is used to detect the amount of suspended particles in water [21]. Abdul Salim and Edidas [14] developed a water monitoring system for tilapia fish farming that tracks pH, temperature, and turbidity levels to help farmers maintain ideal pond conditions. TDS measurements using an Arduino device had a Sig. Value less than 0.05, confirming the device's validity [22].

Based on the issues that were previously discussed, notably those that have to do with measuring and keeping track of water quality. Therefore, using the Total Dissolved Solid (TDS) sensor and Turbidity sensor as a measurement parameter for dissolved solids in water and turbidity levels in water is the solution suggested in this study, which is based on references from multiple prior relevant works. The purpose of using these sensors is to measure the water quality after treating plastic trash, which is in line with research requirements. The TDS sensor and Turbidity sensor are used as parameters to measure the quality of the water in this study because contaminants like soil, sand, and other materials that are attached to plastic waste will dissolve in the water, increasing the amount of dissolved solids and decreasing the transparency of the water. In the meanwhile, the website will be used to monitor the condition water quality from the processing of plastic waste, allowing data on water quality to be presented in a way that best suits research requirements. Water quality data from the processing of plastic waste will be easier to access on the website, and it will be possible to archive water quality data in softcopy format. In order to meet these research goals, the Internet of Things (IoT) is used in this study to measure and monitoring the water quality of the processing plastic waste.

2. METHOD

In this study, the framework research method is utilized, the framework being a foundational concept that incorporates a blend of theory with facts, observations, and literature review, serving as the basis for the research, as shown in Figure 1.

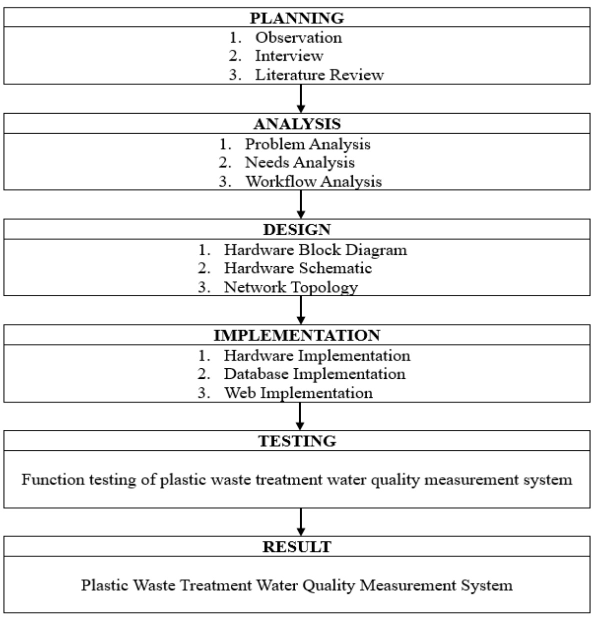

Figure 1. Research methodology

2.1 Planning

At this stage, the data needed in this research is collected. The data collection process includes observation, interview and literature review. This information will be used to create a system to measure the water quality of plastic waste treatment.

2.2 Analysis

In this research, three sequential analyses are conducted: problem analysis, needs analysis, and workflow analysis. Firstly, the existing problems are identified and understood (problem analysis). Then, what is needed to address these problems is determined (needs analysis). Finally, the steps or workflow required to tackle these problems are examined (workflow analysis).

2.3 Design

Illustrations will be made throughout this design stage in order to fully comprehend the needs associated with this research. Hardware block diagrams, hardware schematics, and network topology are among the designs that must be produced at this phase.

2.4 Implementation

This implementation phase involves three important stages in system create. Firstly, the hardware connection implementation stage involves the installation and configuration of hardware devices required to operate the system, such as microcontrollers, modules, sensors, and other IoT devices. Secondly, the database implementation stage focuses on creating and configuring the database that will be used to store and manage information regarding plastic wastewater quality data. Lastly, the web implementation stage aims to display or monitor water quality data obtained from Internet of Things (IoT) devices.

2.5 Testing

At this point, the plastic waste treatment water quality measurement system will be checked for functionality. Hardware, database, and web testing are all done as part of this process to confirm that the system is suitable for the intended use. To make sure the system performs as intended and meets the established specifications, the testing procedure will assess the hardware's dependability, the database's integrity, and the web interface's usefulness. The steps involved in evaluating the performance of the plastic waste treatment water quality measurement system are as follows, ESP8266 WiFi module testing, turbidity sensor testing, TDS sensor testing, push button testing, database testing, web testing.

3. RESULT

At this stage will discuss the results of the stages that have been carried out during the research on measuring the water quality of plastic waste treatment, using the Internet of Thing as a water quality measurement parameter and as water quality monitoring. Planning, analysis, design, implementation, and testing are some of the stages that have been completed during this research.

3.1 Planning

As data gathering methods required to support the plastic waste treatment water quality measurement system creation process, the planning stage consists of observation, interview, and literature review, as explained below:

3.1.1 Observation

Water quality data from CV. AAWW Perdana Usaha plastic waste treatment process in Bogor, West Java, Indonesia, were collected using the structured observation approach. The processing plant for plastic waste at CV. AAWW Perdana Usaha, is seen in Figure 2.

Figure 2. Plastic waste processing plant

The purpose of observation is to collect data methodically and objectively using predesigned observation instruments.

Table 1. Observations instrument

No	Variable
1	Plastic waste processing machine
2	Circulation of plastic waste treatment water
3	Plastic waste treatment water reservoir
4	Types and criteria of treated plastic waste
5	Criteria for water used in plastic waste treatment
6	Chemicals used in plastic waste treatment
7	Waste plastic processing
8	Water quality of plastic waste treatment

Table 1 is an observation instrument used as a guide for data collection during observations at CV. AAWW Perdana Usaha.

3.1.2 Interview

Following the completion of the observation phase, interviews are conducted utilizing interview instruments as the following step in the data collection process.

Table 2. Interview instrument

No	Questions
1	What kinds of plastic waste undergo processing?
2	What type of cleaning media is utilized in the waste plastic treatment process?
3	How do contaminants in plastic waste affect water quality?
4	How is the quality of the water produced from the plastic waste treatment process?
5	What are the criteria for water used in plastic waste treatment?
6	What chemicals are used in plastic waste treatment?
7	How is waste plastic processed?
8	How is the quality of water used in plastic waste treatment?

Interviews were conducted with resource personnel who work at CV. AAWW Perdana Usaha and are involved in the plastic waste processing process. The interview instrument has multiple primary inquiries, as shown in Table 2.

3.1.3 Literature review

The next step is to make a literature review that serves as a source of information to create a plastic waste treatment water quality measurement and monitoring system. Several articles that discuss water quality measurement and monitoring systems were selected as references for this research.

3.2 Analysis

Problem analysis, needs analysis, and workflow analysis are the three phases that make up the analysis process. This was done to collect objective data on water quality that would be needed for this research.

3.2.1 Problem analysis

At this point, data on the quality of water utilized in the plastic waste treatment process is only acquired using human senses such as sight and smell. However, it is critical to recognize that data collected in this manner has the potential to yield subjective data. As a result, this study incorporates sensors as a more objective parameter for measuring and monitoring water quality in the waste plastic treatment process.

3.2.2 Need analysis

At this stage, the discussion will focus on the hardware and software specification requirements needed to create a plastic waste treatment water quality measurement system, as shown in Tables 3 and 4.

Table 3. Hardware requirements

No	Hardware Name
1	Arduino Mega 2560 WiFi (ESP8266)
2	Turbidity Sensor
3	Total Dissolved Solid Sensor
4	LCD I2C (Liquid Crystal Display)
5	LED (Light Emitting Diode)
6	Buzzer

The Arduino Mega 2560 Wifi (ESP8266) board integrates several key components, including an Atmel ATmega2560 microcontroller, an ESP8266 Wi-Fi IC, 32 megabits of flash memory, and a CH340G USB-TTL converter, all of which can function independently or in combination [20]. For water quality monitoring, a turbidity sensor is used to detect the amount of suspended particles in water; it operates by emitting infrared light through an LED, which passes through the water and is detected by a phototransistor [21]. A Total Dissolved Solids (TDS) sensor is utilized to determine the concentration of dissolved substances in water—higher TDS values generally indicate more dissolved solids and lower water purity [22]. An LCD I2C module, which communicates via the I2C (Inter Integrated Circuit) protocol, is employed to display programmed text or numerical data from the microcontroller [23]. Light Emitting Diodes (LEDs), which are diodes made from semiconductor materials, emit monochromatic light when a forward voltage is applied; the color of the emitted light depends on the semiconductor material used [24]. A buzzer, composed of a coil connected to a diaphragm, converts electrical oscillations into sound by creating an electromagnet when energized [25]. Lastly, a push-button switch functions as a connection between the power source and the load or acts as a breaker; it can include emergency stop switches, reset switches, and start buttons [26].

Table 4. Software requirements

No	Software Name
1	Arduino Mega 2560 WiFi (ESP8266)
2	Turbidity Sensor
3	Total Dissolved Solid Sensor
4	LCD I2C (Liquid Crystal Display)
5	LED (Light Emitting Diode)
6	Buzzer

The Arduino IDE software is used to upload programs containing commands to microcontrollers, allowing them to function as intended. These programs are written in the C programming language, which provides instructions that guide the system's behavior according to the loaded code [27]. Visual Studio Code, a versatile source code editor, supports development across multiple operating systems including Linux, macOS, and Windows [28]. Additionally, XAMPP is a software package for Windows that includes several integrated services such as Apache, MySQL, and PHP, facilitating local web development and server-side application testing [29].

3.2.3 Workflow analysis

The workflow analysis, will elucidate the functionality of the system designed for measuring water quality in the treatment of plastic waste, as show in Figure 3.

In Figure 3, the system begins by activating the Arduino Mega 2560 WiFi (ESP8266) to control sensors and IoT devices, then the ESP8266 WiFi Module attempts to connect to the registered WiFi network. Upon successful connection, the green LED illuminates as an indicator. Subsequently, the Turbidity Sensor and TDS Sensor start operating to measure turbidity and dissolved substances in water, with the water quality value displayed on the I2C LCD. Pressing the push button sends the water quality data to the database, accompanied by a buzzer sound notification. The data is stored in the database and depicted as a graph on the web page for monitoring plastic waste treatment water quality. Pressing the push button again changes its status for data transmission, signaled by the red LED indicating a status of 0.

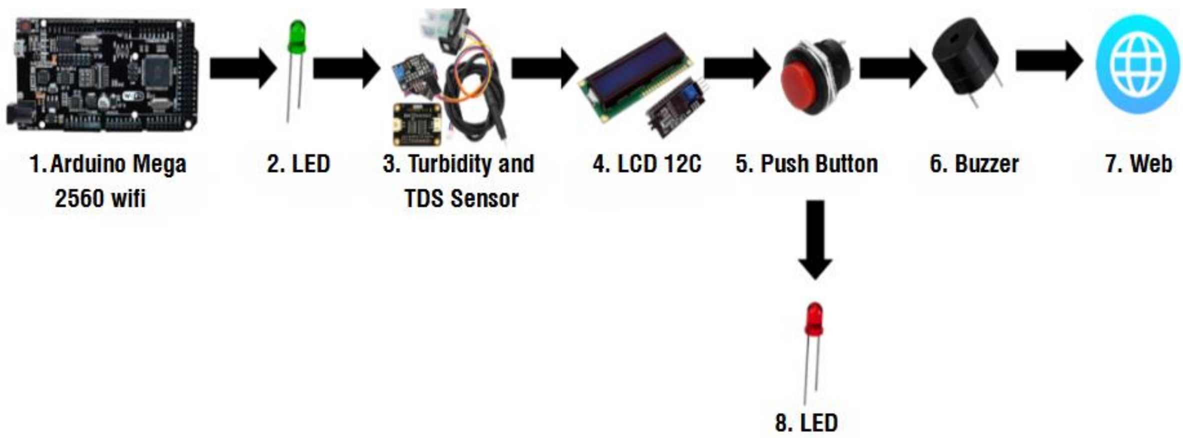

Figure 3. System workflow

3.3 Design

At this point, the plastic waste treatment water quality measurement system will undergo a number of designs, including hardware block diagram designs, hardware schematic and network topology.

3.3.1 Hardware block diagram

Overall, as seen in Figure 4, the design will be split into multiple hardware systems at this point, each of which will be represented by a block diagram.

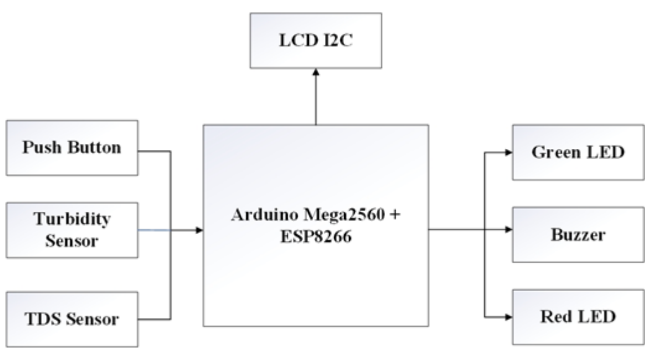

Figure 4. Functional system hardware block diagram

The system is divided into several parts. Turbidity and TDS sensors serve as inputs to measure turbidity and solutes in water. A push button is used as an input to send instructions. The microcontroller controls sensors and other IoT devices. The ESP8266 WiFi module on the Arduino Mega2560 connects the microcontroller to the WiFi network. An LCD I2C serves as output to display character data, while LED and buzzer act as light and sound outputs.

3.3.2 Hardware schematic

Figure 5 illustrates an IoT-based water quality monitoring system utilizing the Arduino Mega2560 WiFi as the central controller. The system is equipped with a TDS sensor to measure total dissolved solids (in PPM) and a turbidity sensor to assess water clarity (in NTU). Sensor data is displayed in real time on a 16×2 I2C LCD and classified using LED indicators—where the green LED lights up when the water is clean, while the red LED and buzzer are activated if the water is detected to be contaminated. A push button is used to initiate or reset the measurement process, and all components are interconnected via a breadboard. This system not only provides visual and audio alerts but also supports data transmission via WiFi for remote monitoring, making it an effective solution for water quality surveillance in plastic waste management processes.

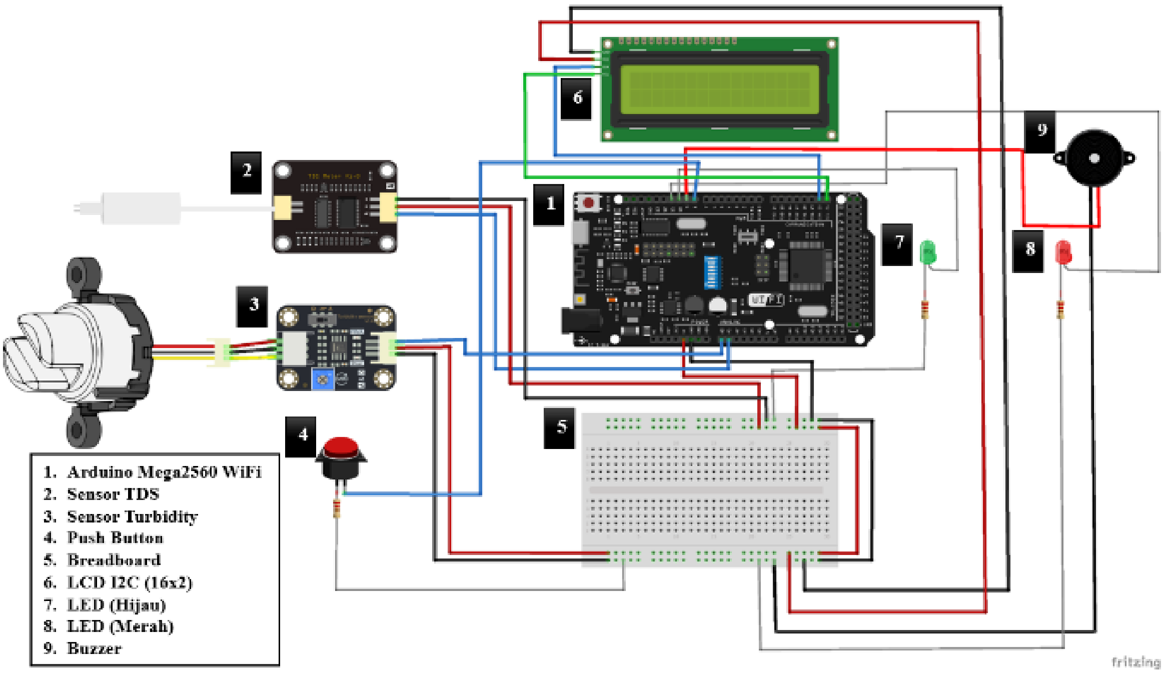

Figure 5. System schematic

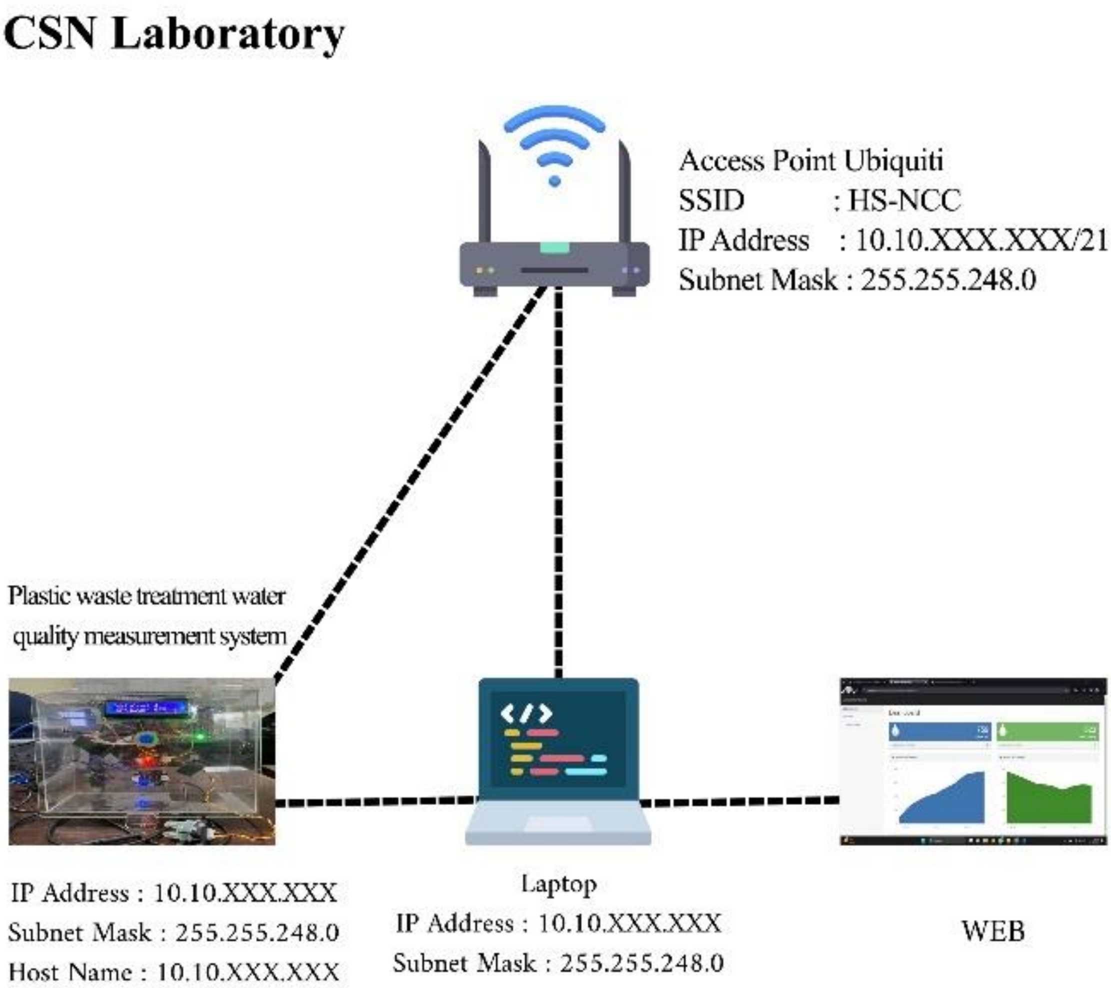

Figure 6. Network topology

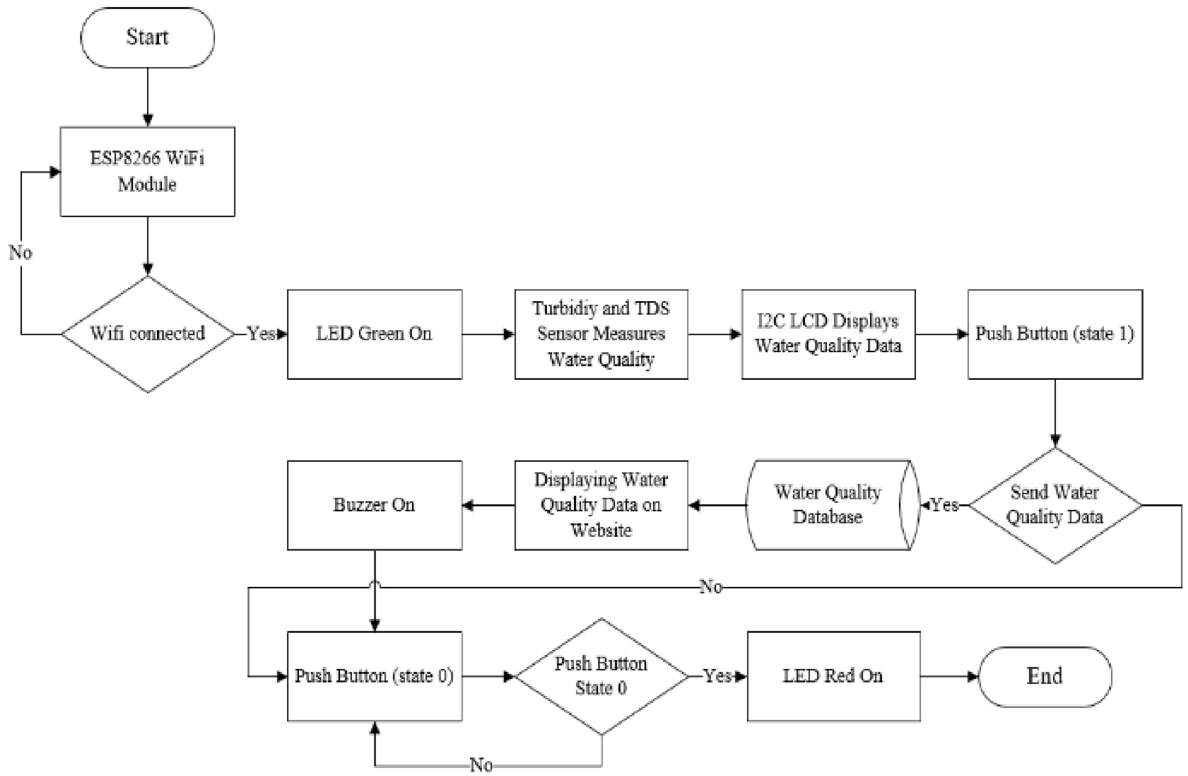

Figure 7. Flow chart

3.3.3 Network topology

The network topology circuit has been designed according to the needs of the Plastic waste treatment water quality measurement system, as shown in Figure 6.

The network topology in Figure 6 starts with a Ubiquiti Access Point with SSID "HS-NCC" to deploy a wireless internet network in the CSN Laboratory. This Access Point has the IP address 10.10.XXX.XX/21 and subnet mask 255.255.248.0 of the router in the FTS Building. The plastic waste treatment water quality measurement system and laptop are connected to the "HS-NCC" network with a network frequency of 2.4 Ghz. The system is configured with the host name according to the IP address of the laptop. The laptop serves as a communication and data storage tool. Plastic processing wastewater quality data is received and stored in a database on the laptop. Furthermore, this data is processed and displayed in graphical form on a web page.

3.4 Implementation

In this implementation process, the system workflow as a guide in the process of assembling or arranging all components with the aim that each component can be installed and function as expected as efficiently as possible, as shown in Figure 7.

The system workflow in Figure 7 explains the steps of how the plastic waste treatment water quality measurement system works. First, when the Arduino Mega 2560 turns on, the WiFi module is activated and tries to connect to the registered WiFi network. If it fails, the system will try again until it succeeds, the green LED will light up when successfully connected to the WiFi network. Furthermore, the system measures water turbidity and solute content using Turbidity and TDS sensors, the results of water quality data will be displayed on the I2C LCD. The push button functions as an instruction for sending water quality data to the database, if the data transmission fails then the push button is pressed again to change the status to 0 (sending water quality data is done when the push button has a status of 1). After the water quality data is successfully saved to the database, the water quality data is then displayed on the web page in the form of a graph, with an active buzzer as a confirmation of successful data transmission. The push button is pressed again to reset the status, and the red LED will light up if the push button status is 0.

3.5 Testing

To ensure that the plastic wastewater quality measuring system can work in accordance with the expected objectives, tests will be carried out on hardware, database, and web.

3.5.1 ESP8266 WiFi module testing

Testing of the ESP8266 WiFi module that has been integrated with the Arduino Mega2560 microcontroller is done by configuring the ESP8266 WiFi module with the WiFi network that will be used. The Arduino Mega 2560's LED light turns on when it is connected to an electrical power source, either directly through an AC/DC adapter or with a USB type A male to micro type B male cable, as seen in Figure 8. This shows that the Arduino Mega 2560's built-in ESP8266 WiFi Module is operational.

Following successful operation of the ESP8266 WiFi module and Arduino Mega 2560, the Arduino Mega 2560 eight dip pins are configured to allow the ESP8266 WiFi module and Arduino Mega 2560 to connect to one another. In this study, dip pins 1, 2, 3, and 4 are activated to establish the connection between the Arduino Mega 2560 and ESP8266 using the CH340 driver mode. This mode facilitates cooperation between the Arduino Mega 2560 and ESP8266, making device setup easier. In Figure 9, it can be observed when the ESP8266 WiFi module has successfully connected to the WiFi network via the serial monitor.

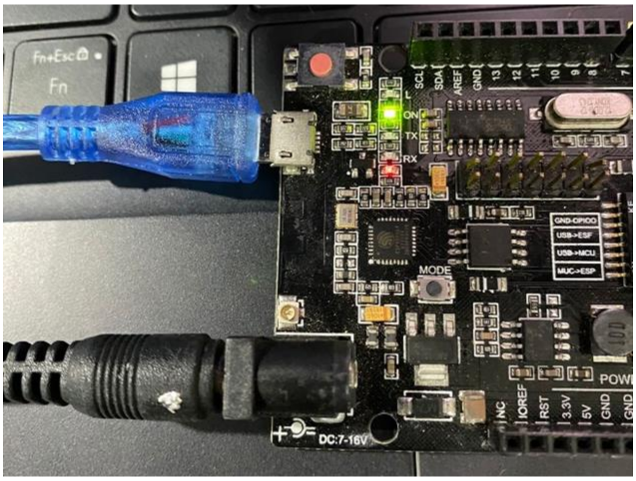

Figure 8. Arduino Mega 2560 WiFi (ESP8266)

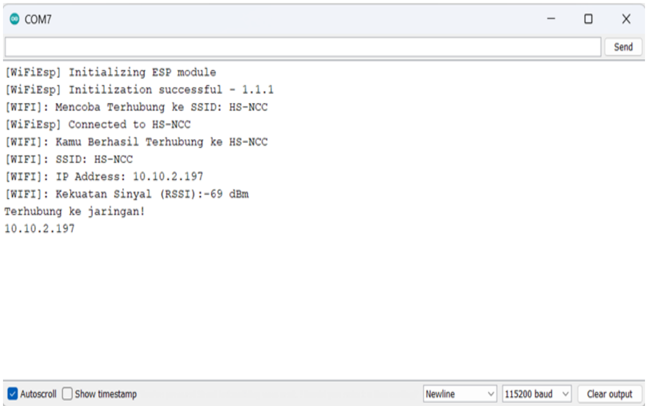

Figure 9. Serial monitor WiFi connected

The ESP8266 WiFi module has successfully connected to the HS-NCC WiFi network, as depicted in Figure 9, acquiring the IP address 10.10.2.197 via DHCP (Domain Host Control Protocol).

3.5.2 Testing TDS and turbidity sensor

Water samples from plastic waste treatment were used for the tests. As shown in Figure 10, TDS and turbidity probes were inserted into the sample water to assess the amount of turbidity and dissolved chemicals. Beakers are used as water containers during water quality testing in order to get the best possible measurements of water quality.

Table 5. Clean water quality requirements

No	Parameters	Unit	Maximum Allowable Level	Description
A	Physics			
1	Smell	-	-	No odor
2	Total dissolved solids (TDS)	PPM	1.500	
3	Turbidity	NTU	25	
4	Taste	-	-	Tasteless
5	Temperature	°C	± 3°C	
6	Colour	TCU	50	

The TDS and Turbidity sensor values in Figure 10 will be displayed on the I2C LCD (16×2) output device in real-time in order to know changes in the level of turbidity in water and dissolved substances in water directly. As shown in Figure 11, turbidity is measured in NTU (Nephelometric Turbidity Unit) units, while TDS is measured in PPM (Parts Per Million) values. The Republic of Indonesia's Minister of Industry's Regulation Number 78/M-IND/PER/11/2016 is the source of the clean water quality standards used in this study, as listed in Table 5.

Table 5 shows that the maximum value for the Turbidity sensor's NTU unit is 25 NTU and for the Total Dissolved Solids sensor's PPM unit is 1,500 PPM.

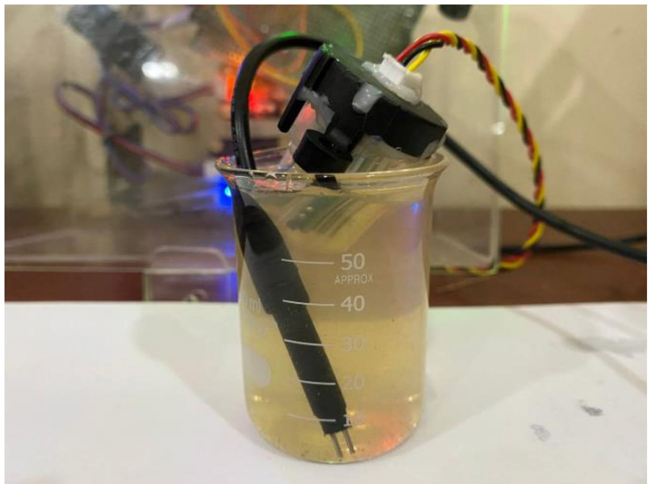

Figure 10. TDS and turbidity sensor testing

Figure 11. LCD displays sensor value

Figure 12. Plastic waste treatment water sample

Ten plastic waste treatment water samples from CV. AAWW Perdana Usaha were used in this study's function testing of the TDS (Total Dissolved Solids) and Turbidity sensors. As seen in Figure 12, the water samples utilized range from sources of water that will be utilized in the plastic waste treatment process to sources of water that have already been used in the process.

Each water sample from the plastic waste treatment was tested three times. Table 6 displays the test findings obtained from the TDS sensor.

Table 6. Water quality testing with TDS sensor

No	Sample Name	Test 1	Test 2	Test 3
1	Water Sample 1	76 PPM	74 PPM	76 PPM
2	Water Sample 2	233 PPM	233 PPM	233 PPM
3	Water Sample 3	296 PPM	302 PPM	297 PPM
4	Water Sample 4	344 PPM	353 PPM	346 PPM
5	Water Sample 5	373 PPM	377 PPM	373 PPM
6	Water Sample 6	409 PPM	413 PPM	409 PPM
7	Water Sample 7	448 PPM	458 PPM	448 PPM
8	Water Sample 8	526 PPM	535 PPM	520 PPM
9	Water Sample 9	530 PPM	538 PPM	524 PPM
10	Water Sample 10	552 PPM	558 PPM	545 PPM

The TDS sensor value increases in Table 6 in tandem with the rise in the amount of dissolved solids in the water used to process plastic trash. Solids dissolved in water are contaminants in plastic waste such as sand and soil. The PPM value found in Table 6 is computed using the subsequent formula:

$$x = (133{,}42 * v^3 - 255{,}86 * v^2 + 857{,}39 * v) * 0{,}5 \quad (1)$$

TDS value is represented by the x symbol in the PPM calculation formula, while the compensating voltage is represented by the v symbol.

Figure 13 shows that compensation voltage and PPM values, obtained from the TDS sensor, are displayed by the serial monitor. The PPM value, which is given in Table 7, is calculated using the compensation Voltage data that was acquired.

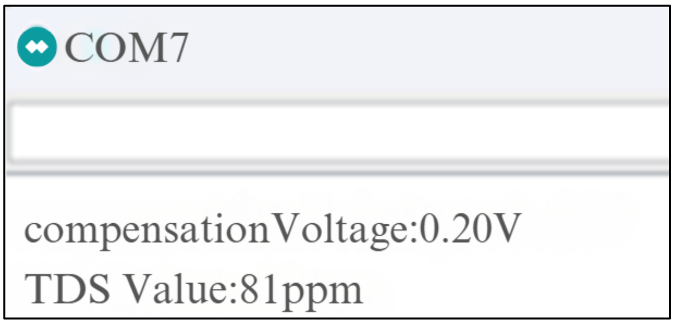

Figure 13. TDS sensor data capture

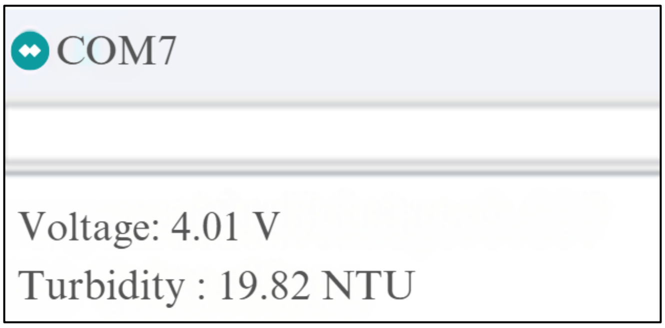

Figure 14. Turbidity sensor data capture

Table 7. PPM calculation formula

PPM Value	Rated Voltage (V)	Calculation Formula
81 PPM	0.20 V	$x = (133{,}42 * v^3 - 255{,}86 * v^2 + 857{,}39 * v) * 0{,}5$ $(133{,}42 * 0{,}20 * 0{,}20 * 0{,}20 - 255{,}86 * 0{,}20 * 0{,}20 + 857{,}39 * 0{,}20) * 0{,}5 = 81{,}15$ PPM

The PPM calculation formula yields a PPM value of 81.15, as listed in Table 7. This calculation's outcome matches the PPM value of 81 found in the water test, as seen in Figure 13 serial monitor.

Table 8. Water quality testing with turbidity sensor

No	Sample Name	Test 1	Test 2	Test 3
1	Water Sample 1	19 NTU	20 NTU	19 NTU
2	Water Sample 2	24 NTU	24 NTU	24 NTU
3	Water Sample 3	29 NTU	30 NTU	30 NTU
4	Water Sample 4	34 NTU	34 NTU	34 NTU
5	Water Sample 5	38 NTU	39 NTU	37 NTU
6	Water Sample 6	35 NTU	36 NTU	35 NTU
7	Water Sample 7	41 NTU	43 NTU	42 NTU
8	Water Sample 8	37 NTU	37 NTU	37 NTU
9	Water Sample 9	49 NTU	53 NTU	46 NTU
10	Water Sample 10	47 NTU	49 NTU	45 NTU

Table 8 provides access to the test data obtained from the Turbidity sensor. The turbidity sensor value in Table 8 indicates an increase in NTU value from water sample 1 to water sample 7 as a result of contaminants created by plastic trash. But in water sample 8, the NTU value has decreased. This is because plastic waste contaminants are beginning to dissolve or sink to the bottom of the water. The NTU value found in Table 8 is computed using the subsequent formula:

$$y = 100{,}0 - (v / 5) * 100{,}0 \quad (2)$$

The NTU value is represented by the symbol y in the NTU calculation formula, and voltage is represented by the symbol v.

The data from the Turbidity sensor is shown by the serial monitor in Figure 14 as voltage and NTU values. Based on the Voltage data obtained, calculations are carried out to obtain the NTU value, as listed in Table 9.

Table 9. NTU calculation formula

NTU Value	Rated Voltage (V)	Calculation Formula
19,82 NTU	4,01 V	$y = 100{,}0 - (v / 5) * 100{,}0$ $100{,}0 - (4{,}01/5) * 100{,}0 = 19{,}8$ NTU

The NTU value of 19.8 was obtained through the NTU calculation formula. The result of this calculation corresponds to the NTU value of 19.82 obtained from the water test, as shown in the serial monitor in Figure 14.

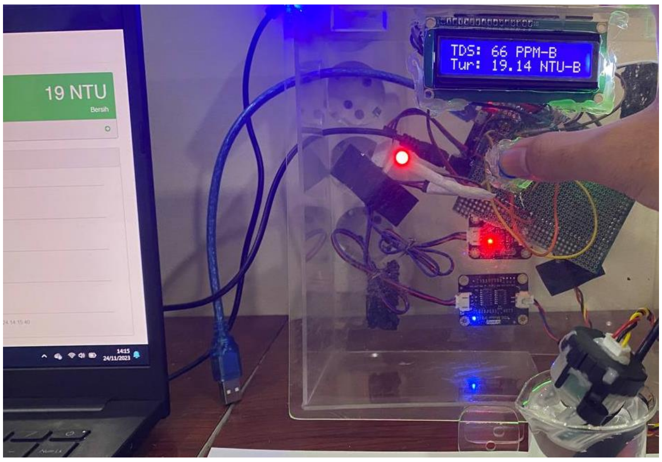

Figure 15. Push button testing

The buzzer will sound as a notification output if the push button sends data successfully from the Turbidity and TDS sensors to the database, with the push button status at value 1. On the other hand, as a notification output, the red LED will light up when the push button is set to value 0, as shown in Figure 15.

3.5.3 Database testing

At this stage, database testing will be carried out to ensure that the plastic waste treatment water quality data from the TDS sensor and Turbidity sensor sent to the database has been successfully stored.

As shown in Figure 16, the plastic waste treatment water quality data from the TDS (Total Dissolved Solid) sensor and Turbidity sensor have been stored in the db_water database in the monitoring table.

no	tdsValue	turValue	Description_tds	Description_tur	Time
35	76	19	Clean	Clean	2024-01-03 10:51:18
36	233	24	Clean	Clean	2024-01-03 11:53:22
37	296	29	Clean	Dirty	2024-01-03 12:54:25
38	344	34	Clean	Dirty	2024-01-03 13:54:50
39	373	38	Clean	Dirty	2024-01-03 14:55:13
40	409	35	Clean	Dirty	2024-01-03 15:55:36
41	448	41	Clean	Dirty	2024-01-03 16:56:05
42	456	36	Clean	Dirty	2024-01-03 17:56:44
43	524	56	Clean	Dirty	2024-01-03 18:57:04
44	542	50	Clean	Dirty	2024-01-03 19:57:28

Figure 16. Database testing

Table 10. Black box testing

No	Conditions	Input Provided	Reality Output	Conclusion
1	Send water quality data	Pressing the Push Button	Water quality data is displayed on the web page in graphical form	Successful
2	Send water quality data	Pressing the Push Button	Water quality data has been successfully displayed on the web page in the form of a table.	Successful
3	Export water quality data	Click the Tables Menu > click the Export PDF button	Water quality data has been successfully exported in PDF format	Successful

3.5.4 Web testing

After the data storage in the database is successful, the next step is to ensure that the data regarding the quality of plastic wastewater from the TDS sensor and the Turbidity sensor is successfully displayed on the web page.

Table 10 is a test conducted on the function of the plastic wastewater quality measurement system website.

As shown in Figure 17, the plastic waste water quality data obtained from the TDS (Total Dissolved Solids) sensor and Turbidity sensor are successfully represented in graphical form on the web page. The graph on the left in blue displays the water quality data from the TDS sensor that reflects the content of soluble solids in water, while the graph on the right in green displays the water quality data from the Turbidity sensor that indicates the level of turbidity in water. The plastic waste treatment water quality logger data is also made in tabular form, which can be seen in Table 11.

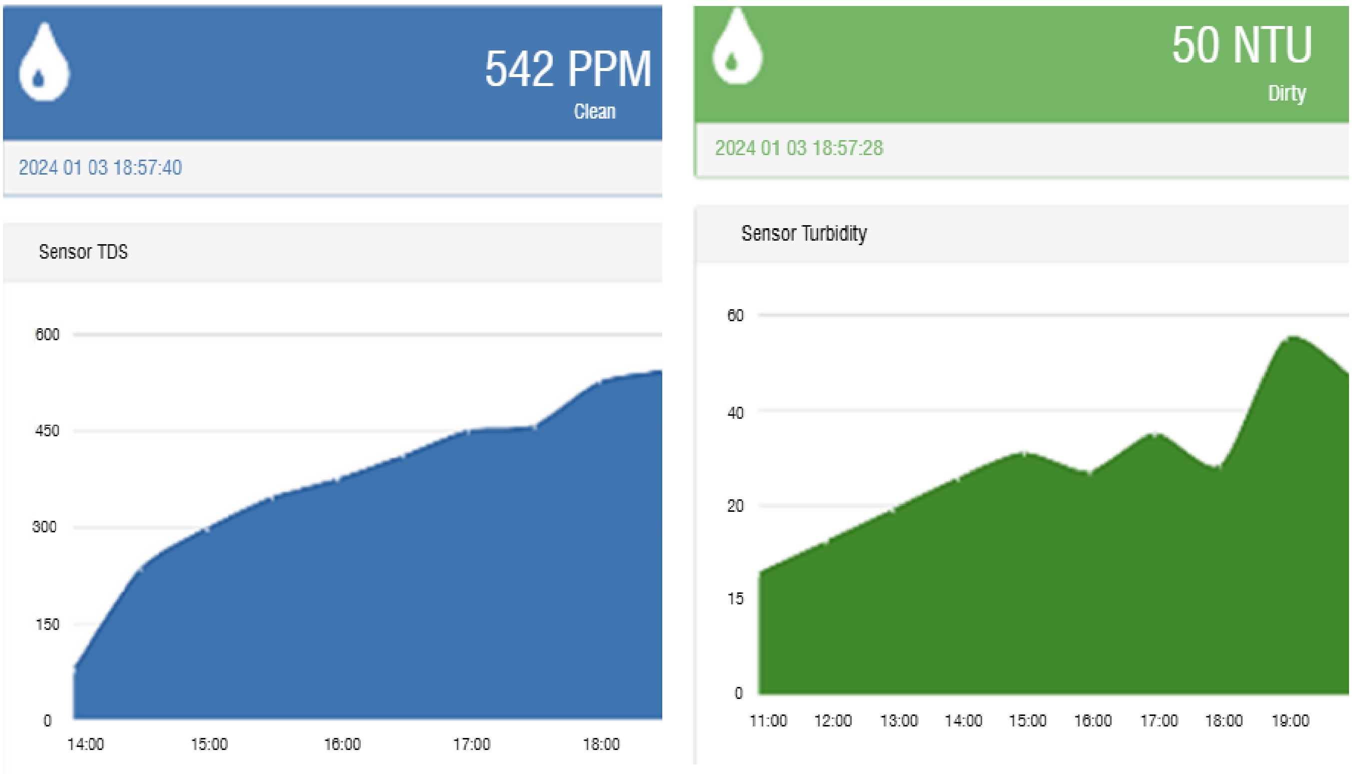

Figure 17. Water quality data in graphical form

Data may be presented more easily for monitoring, analysis, and archiving by using a table format, as seen in Table 11.

Table 11. Water quality data logger

ID	Tds Value	Turbidity Value	Time
1	558 PPM - Clean	49 NTU - Dirty	18:55:24
2	538 PPM – Clean	53 NTU - Dirty	18:54:17
3	535 PPM – Clean	37 NTU - Dirty	18:52:59
4	458 PPM – Clean	39 NTU - Dirty	18:50:57
5	413 PPM – Clean	36 NTU - Dirty	18:49:33
6	377 PPM – Clean	31 NTU - Dirty	18:48:47
7	353 PPM – Clean	34 NTU - Dirty	18:47:02
8	302 PPM – Clean	30 NTU - Dirty	18:46:06
9	233 PPM – Clean	24 NTU - Dirty	18:45:08
10	74 PPM - Clean	20 NTU - Clean	18:43:56

Table 12. Export fata logger to PDF

No	TDS Sensor	Turbidity Sensor	TDS Desc	TUR Desc	Time
1	76 PPM	19 NTU	Clean	Clean	10:51:18
2	233 PPM	24 NTU	Clean	Clean	11:53:22
3	296 PPM	29 NTU	Clean	Dirty	12:54:25
4	344 PPM	34 NTU	Clean	Dirty	13:54:50
5	373 PPM	35 NTU	Clean	Dirty	14:55:13
6	409 PPM	35 NTU	Clean	Dirty	15:55:36
7	448 PPM	41 NTU	Clean	Dirty	16:55:08
8	456 PPM	36 NTU	Clean	Dirty	17:56:44
9	524 PPM	56 NTU	Clean	Dirty	18:57:04
10	542 PPM	50 NTU	Clean	Dirty	19:57:28

To make printing data in hard copy easier, data loggers can be immediately exported as PDF files, as shown in Table 12 when the data logger has been exported in PDF form.

4. CONCLUSIONS

This study aims to measure water quality at the plastic waste treatment stage at CV. AAWW Perdana Usaha. Measurements were made using a TDS (Total Dissolved Solids) sensor and a turbidity sensor to assess water quality based on the amount of dissolved solids and the level of turbidity. A total of 10 plastic waste treatment water samples were taken from the beginning to the end of the process, with each sample tested three times. The test results showed that the average water quality before plastic waste treatment was 75.33 PPM and 19.33 NTU. This data still meets the clean water quality standards according to the Minister of Industry Regulation No. 78 of 2016, which stipulates a maximum turbidity level of 25 NTU and a maximum Total Dissolved Solids (TDS) of 1500 mg/L or PPM. Meanwhile, the average water quality after plastic waste treatment is 551.67 PPM and 47 NTU. Based on this data, it can be concluded that the water quality from plastic waste treatment at CV. AAWW Perdana Usaha, when measured in PPM (total dissolved solids), falls into the clean water category. However, when measured in NTU (turbidity level), it falls into the category of dirty water. The water quality data obtained will be stored in a database and presented in graphical form on a web page to facilitate monitoring of water quality changes. In addition, the data logger is also made in tabular form to facilitate data archiving in both softcopy and hardcopy formats. Based on these findings, it can be concluded that the plastic waste treatment water quality measurement system has functioned optimally as expected to measure the quality of plastic waste treatment water based on dissolved solids and water turbidity levels.

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