Iot-Based Water Condition Monitoring System for Watersheds

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ABSTRACT
The condition of river water in the watershed is an important indicator in assessing the success of forest and land rehabilitation and water resources conservation carried out by Balai Pengelolaan Daerah Aliran Sungai (BPDAS). BPDAS is responsible for developing plans and implementing land and water rehabilitation and conservation to maintain the sustainability of watershed ecosystem functions. However, manually monitoring water conditions is still inefficient and requires large resources. This research aims to develop an IoT system that integrates pH sensor, turbidity sensor, Total Dissolved Solids (TDS) sensor for monitoring river water conditions in watershed areas. The system is designed to provide real-time data, which can be accessed by BPDAS officers through cloud-based applications. The test results show that this system is able to detect changes in water condition parameters quickly and accurately, thus facilitating more responsive watershed management in making decisions related to rehabilitation and conservation actions to be more timely and based on factual data.

***Keywords**:* Water Conditions Monitoring, Internet of Things (IoT), Watershed, pH Sensor, Turbidity Sensor, Total Dissolved Solids (TDS) Sensor.

Introduction
Living resources require water, and the availability of clean water is currently being increasingly depleted due to a number of problems [1]. Effective management of river basins (DAS) is necessary to preserve water quality and prevent further environmental damage. A watershed (DAS) is a land area that is unit with its river and tributaries and that serves to collect, store, and naturally flow rainwater into lakes or the sea, with sea boundaries extending to water areas still impacted by land activities and land boundaries serving as topographical separators [2].
Watershed management is a human effort to control the reciprocal relationship between natural resources and humans within the watershed and all its activities, with the aim of fostering the sustainability and harmony of the ecosystem and enhancing the utility of natural resources for humans in a sustainable manner [3]. Watershed management activities include four main efforts: land management, water management, vegetation management, and fostering human awareness and ability in the wise use of natural resources [3].

In this case, the River Basin Management Agency (BPDAS) plays an important role in planning and implementing the rehabilitation and conservation of land and water to maintain the sustainability of river basin ecosystem functions [4]. However, monitoring river water conditions often poses a challenge for BPDAS. Monitoring water conditions is a method of periodically sampling water to analyses the river's water conditions and characteristics [5]. Manual monitoring tends to require significant resources and cannot provide quick and accurate data for timely decision-making. Traditional water quality monitoring often involves periodic water sampling and laboratory testing [6].

By utilizing the latest technology and strengthening the existing monitoring system, we can move towards the future [7]. Internet of Things (IoT) is a term that has recently been widely encountered, but few understand its meaning. The Internet of Things can generally be defined as objects around us that can communicate with each other through the internet. The Internet of Things has the concept of extending benefits that are connected through continuous internet connectivity [8].

With the advancement of technology, IoT has emerged as a solution that can enhance the effectiveness of water quality monitoring. The utilization of IoT in water resource management has also proven to reduce dependence on manual monitoring methods and accelerate the decision-making process. IoT-based water quality monitoring systems enable automatic and continuous data collection, thereby helping to maintain the stability of aquatic ecosystems in watersheds. These monitoring systems are not only efficient in data collection but can also be integrated with cloud-based technology for further analysis and prediction of potential environmental damage.

Prior researchers have carried out a number of studies on water quality monitoring systems, including those by [9], [10]. A system for monitoring river water quality in real time was covered in the 2019 study by [9]. In order to compare observed water parameters with standard values, data from a wireless sensor network was gathered on a personal computer and analysed using artificial neural networks and belief rules-based systems. An SMS warning would be delivered if the parameter values were higher than the threshold limit. A water quality monitoring system for Lake Siombak was then designed in 2020 by [10], who used an Arduino Uno to assess water parameters like temperature, pH level, DO, TDS, and turbidity. The measured data were then relayed via SMS.

Research Methodology

The method used in this research is the application method with demonstration [11]. The research steps taken by the author to complete this research are as shown in Figure 1:

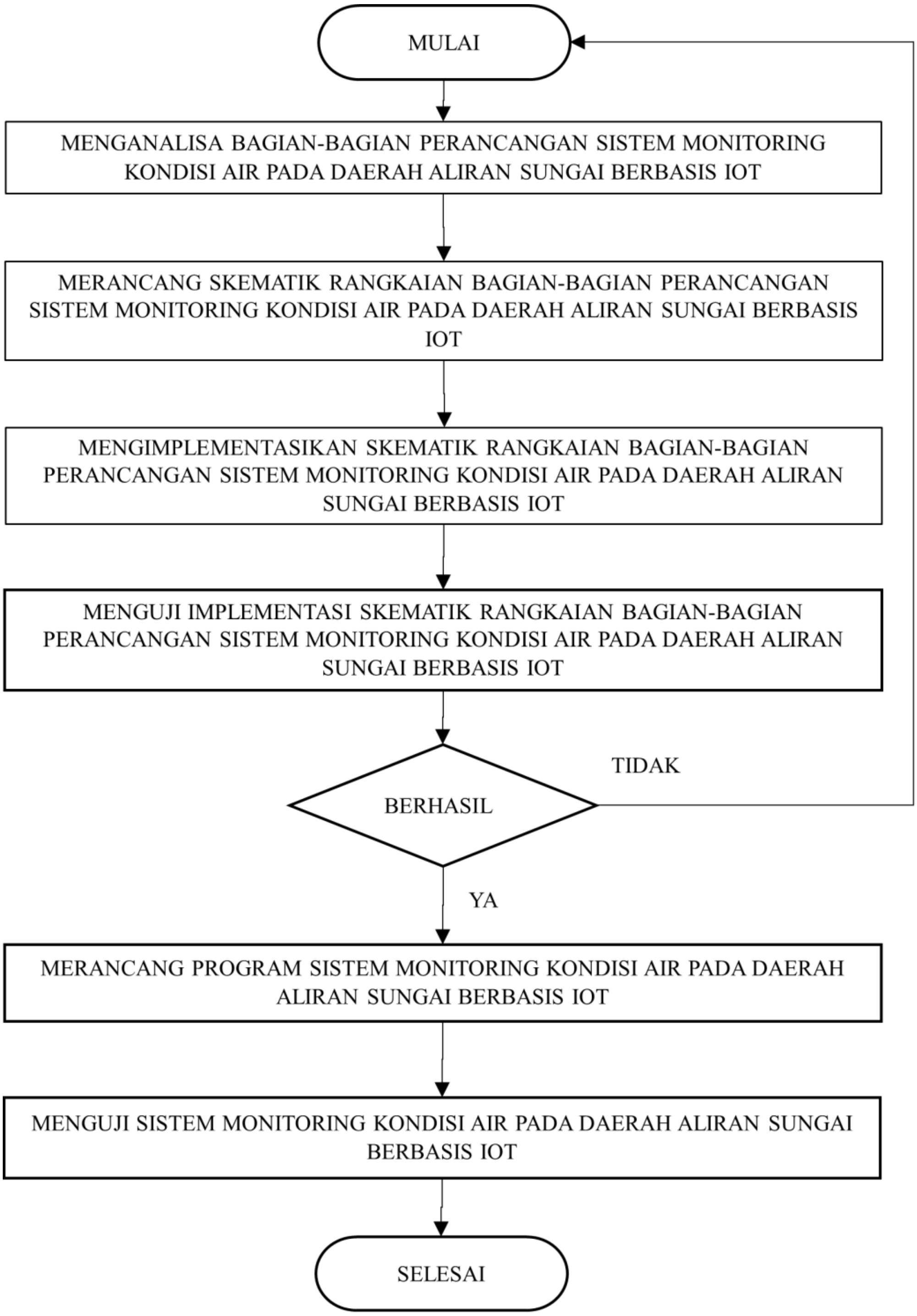

Figure 1. Research Stages

Explanation:

a. Examining the Monitoring System Design's Elements
   To determine the necessary elements for the Internet of Things-based watershed water condition monitoring system, an analysis is carried out in the first stage. In this step, the hardware requirements (such as pH, turbidity, and TDS sensors) and software that will be utilized for data collection, processing, and transmission are identified. Additionally, included in this identification is the communication network that will be utilized to link the sensors to the Blynk IoT platform.

Table 1. List of Hardware Used

No	Name Hardware	Function	Amount
1	ESP32	The main microcontroller responsible for processing data from sensors and sending it to the IoT platform.	1
2	pH Sensors	To measure the acidity or alkalinity of water	1
3	TDS Sensors	To measure the content of dissolved solid particles in water	1
4	Turbidity Sensors	To measure water turbidity	1
5	LCD	To display water quality data such as pH value, turbidity, and TDS	1
6	Resistors	To stabilize and regulate the input voltage from the sensor to ensure accurate readings	4
7	Wifi (Internet)	To facilitate data transmission from ESP32 to a web-based platform (Blynk)	1

Table 2. List of Software Used

No	Name Software	Function
1	Arduino IDE	For editing program syntax, compiling and uploading programs
2	Blynk Web	As an IoT-based platform that displays data from sensors in an interactive form (graphs, indicators, or tables)

b. Designing the System Circuit Schematic
After the equipment needs have been identified, the next step is to create a schematic design of the circuit that will be used. This schematic involves the placement of sensors, microcontroller setup, and communication connections.

c. Implementing the Schematic Circuit
At this point, the developed schematic is used to guide the actual circuit's implementation. The design will dictate how sensors and microcontrollers are connected, and the required hardware will be physically put together. Block diagram of the water condition monitoring system is as shown in the following Figure 2:

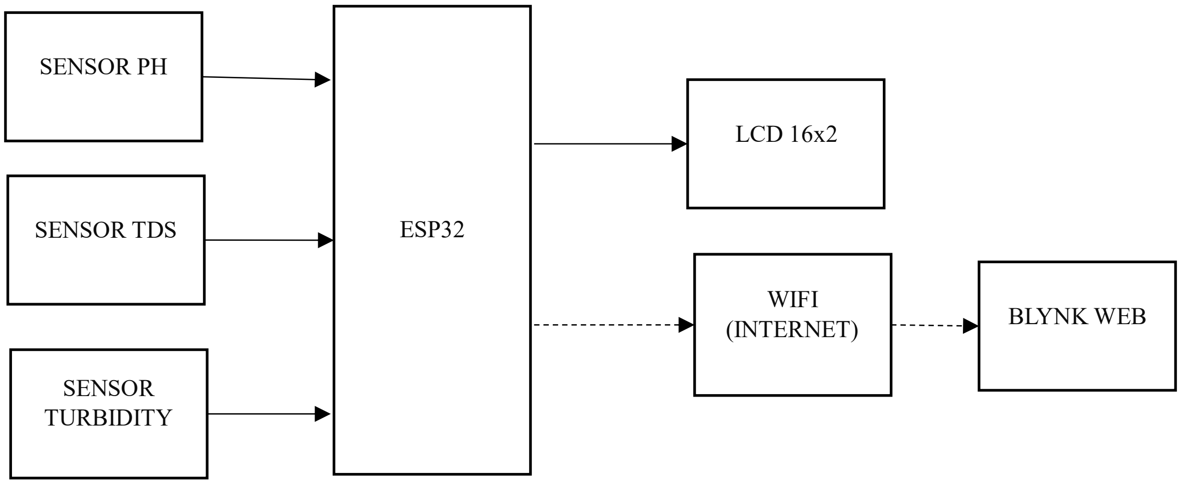

Figure 2. Block Diagram of the Water Condition Monitoring System

d. Testing the Implementation of the Schematic Circuit
Following system assembly, testing is done to make sure the implementation—which includes sensor data collecting and data transmission to the IoT system—runs as planned.

e. Designing the Monitoring System Program
Designing the software or program to handle the monitoring data comes next, when the hardware is operating efficiently. In addition to processing and transmitting data, this program displays monitoring findings in real time on the Internet of Things platform. Creating a program on Arduino IDE to make a monitoring system as shown in Figure 3

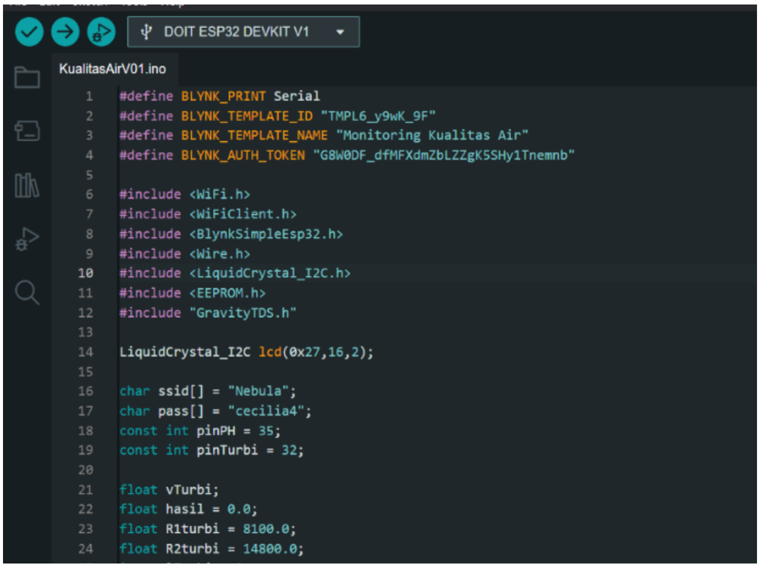

Figure 3. Creating a program on Arduino IDE

f. Testing the Water Condition Monitoring System
Final testing of the entire monitoring system is carried out following the design of the hardware and software. Making ensuring the system can efficiently track water conditions for a predetermined amount of time is the aim.

g. Finishing
The system is prepared for full field operation once it has been tested and found to meet the required standards. In this phase, the monitoring system's final documentation is completed, and the test results report that will be published in the journal is prepared.

Results

The results of this research are divided into two parts: hardware (architecture) and software.

a. Hardware

The design of the hardware is as shown in the following Figure 4:

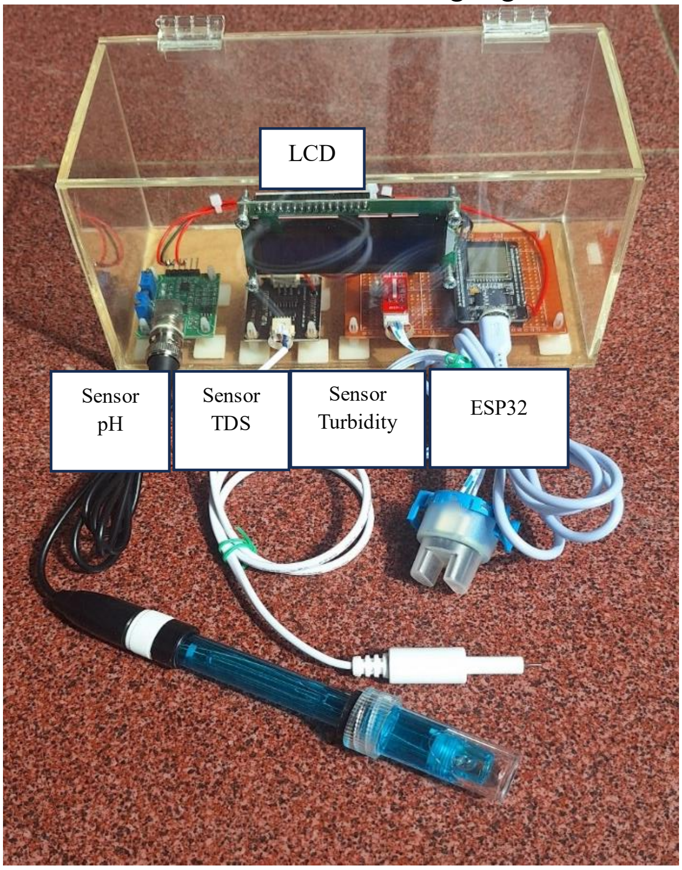

Figure 4. Final Results of the IoT-Based River Basin Water Condition Monitoring System Prototype

The function of each part of the IoT-based river basin water condition monitoring system can be explained as follows:

1) Sensor
   - Sensor for pH: serves to quantify the water's acidity and alkalinity, which is crucial for assessing the water's appropriateness. On a scale of 0 to 14, the sensor generates data in the form of pH readings.
   - TDS Sensor Features for quantifying the concentration of dissolved components, including organics, minerals, and salts, in water. The information is presented as TDS values in parts per million, or ppm.
   - Turbidity sensor features that allow you to gauge how turbid the water is because of suspended particles like sand, dirt, or biological compounds. The water's transparency level is indicated by the value, which is expressed in NTU (Nephelometric Turbidity Unit).

2) ESP32

   All of the data from the pH, TDS, and turbidity sensors are integrated by the ESP32, which also processes the data before transmitting it to the IoT platform or displaying it on the LCD. ESP32 is not here to replace ESP8266, but provides improvements in all lines. Not only does it have support for WLAN connectivity, but also Bluetooth makes it more versatile[12]. As the primary controller, the ESP32 makes sure that the data produced by the sensors can be transmitted to the Blynk IoT dashboard and shown in real-time on the LCD.

3) LCD
LCD features that allow users on-site to see the sensor reading findings directly. The data is presented in an easily understandable manner and contains the pH value, TDS, and turbidity.

4) Wi-fi
facilitates the transfer of data from the ESP32 to the web-based platform Blynk, which enables remote water condition monitoring in real time and from any location as long as the device is online.

5) Blynk
Serves as an Internet of Things platform that presents sensor data in an interactive format. (table, indicator, or graph). Notifies users when water quality parameters deviate from the norm.

Due to the differences in parameters such as current and voltage between the microcontroller and the water pump motor, an interface is required[13]. Interface architecture of an IoT-based water condition monitoring system is as shown in the following Figure 5:

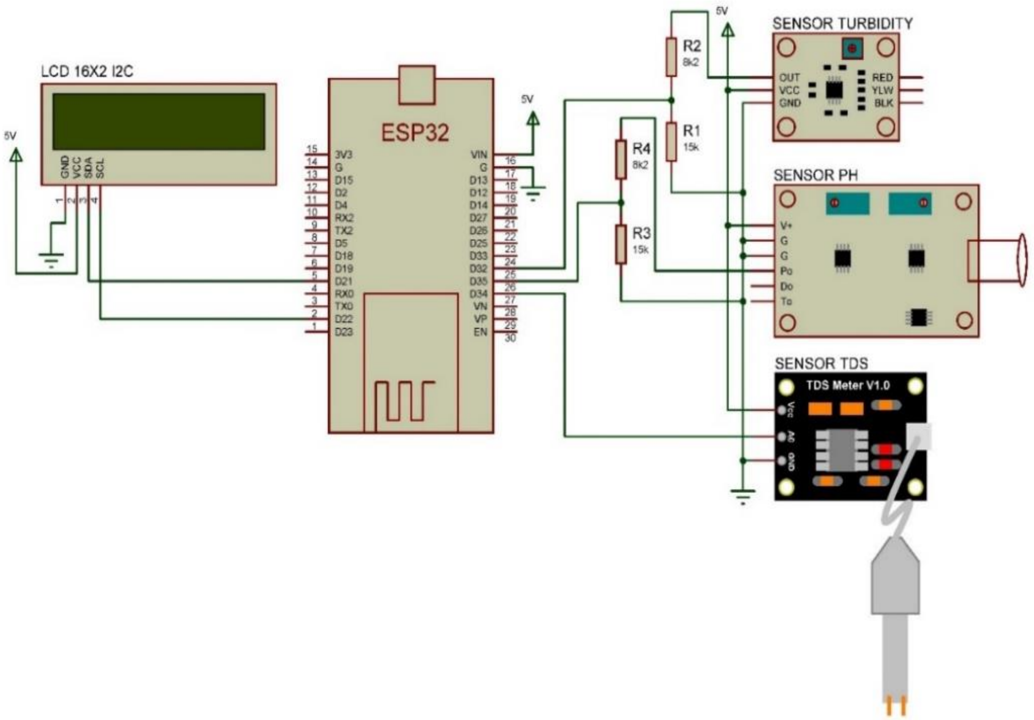

Figure 5. Architecture of the Water Condition Monitoring System Circuit

b. Software
Software must be integrated into the ESP32 flash memory for the hardware design to work as a complete. The following is the primary program flow of the software created for the Internet of Things-based river basin water condition monitoring system, flowchart of water condition monitoring system software is as shown in the following Figure 6:

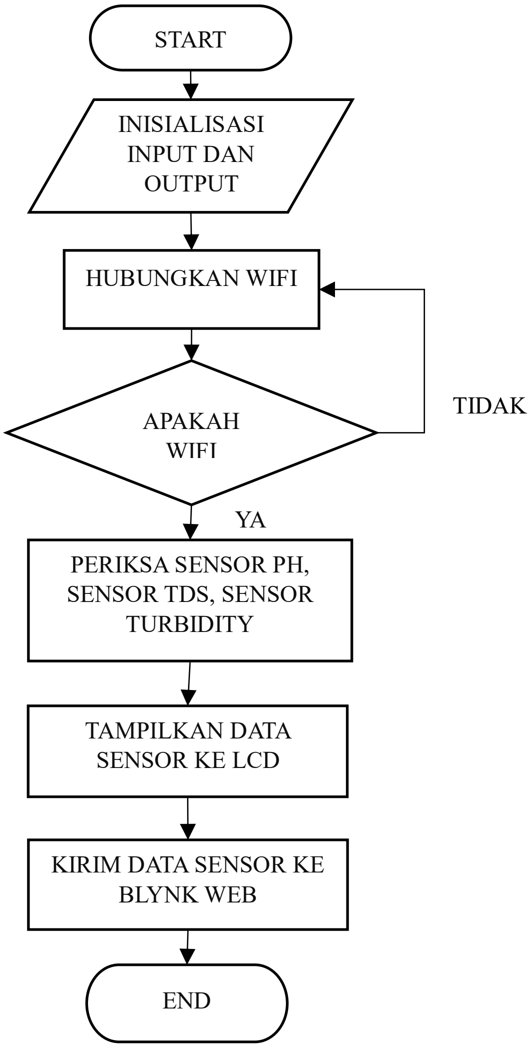

Figure 6. Flowchart of Water Condition Monitoring System Software

c. Testing the IoT based Water Condition Monitoring System for Watersheds

1) Testing of pH Sensor

Before conducting the circuit testing, the pH sensor electrode is first cleaned with clean water, and then measurements are taken by immersing the sensor in water. The measurement results obtained from the test are shown in Table 3 and Figure 7 below:

Table 3. Data from pH Sensor Test Results

No	pH Sensor		
	Date	**Time**	**Display on Blynk Web**
1	16-11-2024	08.00	pH 5.1
2	16-11-2024	13.00	pH 6.3
3	16-11-2024	14.00	pH 3.8
4	16-11-2024	16.00	pH 5.6
5	16-11-2024	17.00	pH 4.7
6	18-11-2024	10.00	pH 6.6

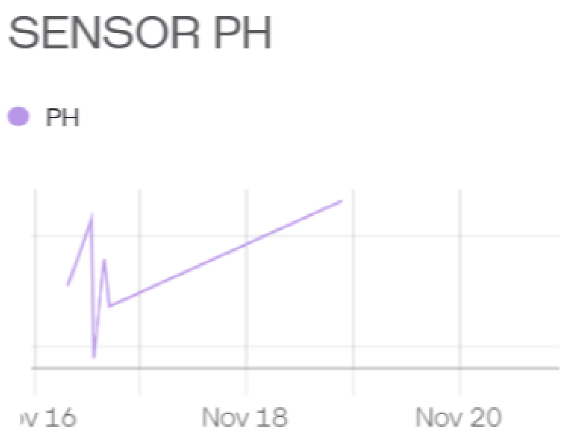

Figure 7. Graph of pH Sensor Testing on Blynk

2) Testing of TDS Sensors
The TDS sensor is tested by monitoring the interface module's voltage output after each addition of dissolved particles to the water container under observation. Table 4 and Figure 8 below displays the measurement data that were derived from the test results:

Table 4. Data from TDS Sensor Testing

No	TDS Sensor		
	Date	**Time**	**Display on Blynk Web**
1	16-11-2024	08.00	0
2	16-11-2024	13.00	95.6
3	16-11-2024	14.00	33.3
4	16-11-2024	16.00	54.5
5	16-11-2024	17.00	0
6	18-11-2024	10.00	0.2

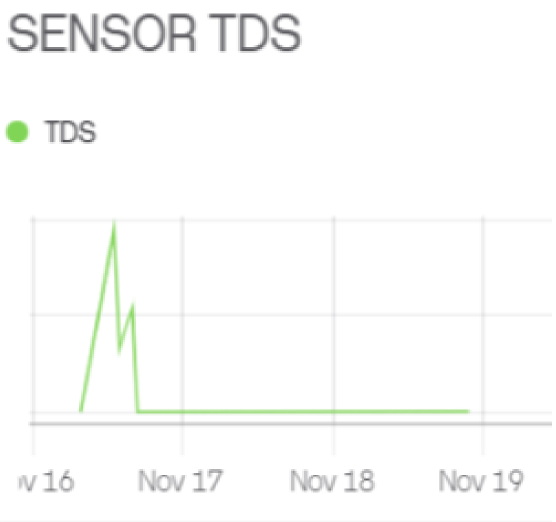

Figure 8. Graph of TDS Sensor Testing on Blynk

3) Testing of Turbidity Sensors

The circuit is tested using three different water turbidity levels to see if it is operating correctly. The test's measurement results are displayed in Table 5 and Figure 9 below:

Table 5. Data from Turbidity Sensor Test Results

No	Turbidity Sensor		
	Date	**Time**	**Display on Blynk Web**
1	16-11-2024	08.00	99
2	16-11-2024	13.00	153
3	16-11-2024	14.00	62
4	16-11-2024	16.00	21
5	16-11-2024	17.00	198
6	18-11-2024	10.00	50

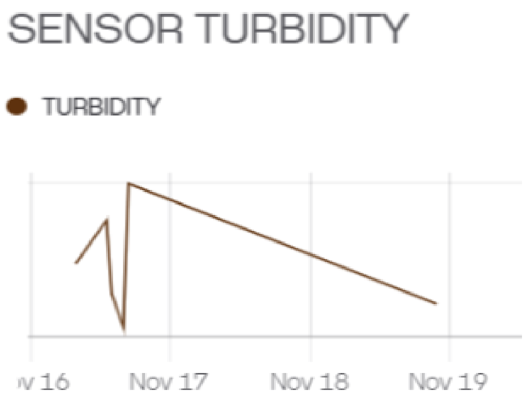

Figure 9. Graph of Turbidity Sensor Testing on Blynk

Conslusion

From the test results, it is known that the monitoring system developed in this research can operate effectively in every component of the system. The connection to the Blynk cloud is also fast and the results depend on the internet provider used. Although there are challenges such as transmission interference and the need for sensor maintenance, this system is capable of identifying changes in water quality. This research can be developed to obtain more accurate data for algorithm calculations in determining water quality.

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