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The Internet of Things for Water Quality Control Systems on Freshwater Fish Lake Tondano Farming

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ABSTRACT

Freshwater fish farming is an important segment in the fisheries industry that requires extraordinary consideration of water quality to ensure optimal fish welfare and growth. This research creates an Online of Things (IoT)-based water quality control framework to monitor and control basic parameters in freshwater fish farming lakes, such as temperature, pH, turbidity, and water particle levels. The framework consists of sensors associated with the ESP32 microcontroller, which can collect data in real-time. The information is then sent to the IoT stage using a Wi-Fi network, enabling checks that cannot be accessed via the web or portable applications. In addition, the system is equipped with mechanization instruments to direct water conditions, such as moving the aerator or radiator automatically based on known parameters. The tests showed that this skeleton can accurately filter water quality and provide a quick reaction to changes in natural conditions. The use of this framework is expected to increase effectiveness and efficiency in the development of freshwater fish, as well as reduce the possibility of fish passing by due to poor water quality, Therefore, this IoT-based water quality control framework is an imaginative solution that can support the sustainability and increase of production in the development of freshwater fish.

Keywords: Freshwater fish farming, water quality, Internet of Things, ESP32, control sensor.

INTRODUCTION

Water is the most important natural resource for all life in the world. Water is the material that makes life possible on Earth (Kodoatie & Sjarief, 2010). Water is the most important substance needed by living beings, humans, plants, and animals. The benefits of water for life are used in many industries, including agriculture, manufacturing, construction, and as an energy source through hydroelectric power plants. There are several forms of water on Earth, including a lake. Lakes are inland aquatic ecosystems that are very important for human life, especially as a water reserve for irrigation, as a source of drinking water for electricity production, as a place for water regulation to prevent flooding, and as a place for fishery activities (shrimp and fish ponds) and other benefits (Nugroho el al., 2014). Water is the main element and the most important thing is to keep it clean. Clean water affects the survival of living things. Water quality management is an effort to maintain water to achieve the desired water quality according to its use to ensure that water quality remains in its natural state. However, the difference in the use of the lake and the activities of the people around the lake exerts environmental pressure on the lake waters. Due to environmental pressure, the activities and benefits of this lake continue to decline. Water can be polluted. Water pollution is a situation where the quality of water in an area decreases due to various factors such as the entry of foreign substances either in the form of other substances, elements, or energy into the water that can affect water quality. If the water is contaminated, it is often characterized by changes in taste, color, and aroma in the water in the area. Lake pollution can affect the survival of fish in the lake. The observable changes or indications that indicate environmental water pollution fall into the following categories: 1) Physical observation, which refers to assessing water pollution based on temperature, color, and the presence of Arduino, taste, and water clarity (turbidity). 2) Chemical measurements, such as pH variations and observations of water pollution based on dissolved compounds. 3) Biological observations depend on the presence or absence of pathogenic bacteria to determine whether the water is contaminated (Lina, 2004).

Water quality management is one of the efforts that can be made to increase the productivity of fish farming activities. Water quality is said to be good if the physical, chemical, and biological parameters of the water are following those needed by the organism being maintained. The majority of aquatic species that are known to the community live and thrive in the waters and can be used as research subjects for water quality tests are fish. One of the many impacts of water pollution on fish life is the decline in the nutritional condition of fish, causing fish to die (Sedana et al., 2018). One of the industries that is important for Indonesia is aquaculture. As consumers and producers, most Indonesian people will always be in contact with fish, including freshwater fish. So, paying attention to environmentally friendly fish farming is very important. If the environmental conditions provided are suitable or close to the conditions in their natural habitat, fish will live and breed healthily, because one of the most important factors in fish farming is water quality.

Lake Tondano has an area of about 4,638 hectares and is at an altitude of 600 meters above sea level. Lake Tondano is one of the water areas used by residents as a place for fish farming. Fisheries activities carried out in Lake Tondano consist of cultivation and fishing. The fish farming system applied by the community around Lake Tondano is Karamba Neting Tancap (KJT), (Tamanampo et al., 2017). One of the villages that is a place for Lake Tondano fish cultivation is Tounelet Village, Kakas District, Minahasa Regency. Fish cultivation is carried out by raising mujair fish and goldfish. Because of this, water quality greatly affects the sustainability of fish farming in Lake Tondano. Polluted water causes farmed fish to die and can harm entrepreneurs. Every year, hundreds of thousands of fish

International Journal of Information Technology and Education (IJITE)
Volume 3, Number 4, September 2024
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cultivated by entrepreneurs often die. The change of seasons in the water temperature at the bottom of the lake, all the organic matter at the bottom of the lake rises to the top. The phenomenon of fish deaths in Lake Tondano, precisely in Kakas District, is suspected to be due to volcanic activity, due to the discovery of high sulfur content around Kaweng Village and Toulibett Village. The appearance of bubbles on the surface of the water is suspected to be caused by sulfur gas. Because of this, it is a concern for the people who have fish farming businesses in Kakas Village because the water suspected of sulfur appeared suddenly. Therefore, a system is needed that can be an alarm to detect the appearance of sulfur water and control the water quality in Lake Tondano.

Currently, we are in the era of the Industrial Revolution 4.0 which applies the concept of machine automation without the need for human labor to apply it. One of the innovations in Industry 4.0 is the Internet of Things (Amin et al., 2020). With the development of technology that is increasingly advanced, the above problems can be solved with the Internet of Things. The concept of the Internet of Things (IoT) is useful in various industries, one of which is aquaculture, and water quality assessment. With the latest technology, water quality has a significant impact, and water quality maintained in good condition will please the community and also benefit the aquatic ecosystem (Adella et al., 2020). Changes in the color and turbidity of the water that can be controlled with sensors through devices will greatly facilitate entrepreneurs to monitor their fish farming efforts (Kissan et al., 2021).

Based on this background, the author is interested in raising a research topic with the title "Lake Tondano Water Quality Control System for Internet of Things Based Freshwater Fish Farming". From the observation of the background of the problem, it can be identified that the problems are: 1) The sulfur water problem in Lake Tondano cannot be predicted when it will appear and stop. 2). Water quality monitoring must follow standard standards for the sustainability of cultivated fish. 3) no control system can detect and monitor water quality, especially detecting sulfur water in Lake Tondano precisely in Kakas District. The limitation of the problem, namely that the Control System Research was carried out to meet the needs of Fish Farming entrepreneurs in Lake Tondano, precisely Kakas District, and the system focuses on detection and control only. The purpose of this research is to design a water quality control system on Lake Tondano that can be monitored through devices, making it easier for the community and fish farming entrepreneurs.

METHODS

Place and Time of Research

This research will be carried out from November 2023 to February 2024. The research site was carried out in the Lake Tondano aquaculture area around Tounelet Village, Kakas District, Minahasa Regency, North Sulawesi Province.

System Development Methods

The type of research method carried out by the author is the Research and Development (R&D) research method. The research and development method (RnD) is a research method used to design new products, test the effectiveness of existing products, and develop and create new products.

International Journal of Information Technology and Education (IJITE)
Volume 3, Number 4, September 2024
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Furthermore, the system development methodology used by the author is the Prototyping method. Prototyping is a system development technique that describes a system using a prototype so that the user or system owner can understand the type of system development to be carried out. Reports generated during the development of the application program's information and user interface are common examples of how prototypes are implemented. Prototyping is a system development method that uses prototypes to describe the system and is often manifested in the form of user interfaces and reporting generated in system development (Mulyani, 2016). Ideally, a prototype has a function as a mechanism to identify system needs, if an applicable one is built, the prototype should use existing program fragments or use tools that allow a working program to be generated quickly.

The design model to be designed uses the Prototype research model which can be seen in figure 1 of the Prototyping Model.

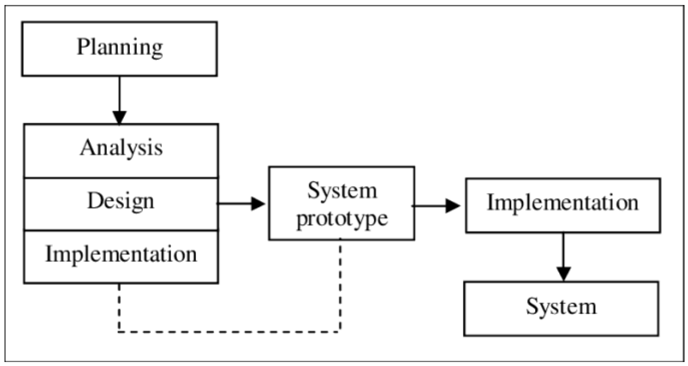

Figure 1. Prototyping Methods

The author uses system development with the Prototyping method because this method has advantages, including:

- The Prototyping method is following what the author wants to do in designing the system.
- It saves development time and costs because it allows developers to identify issues and errors early in the development process.
- Allows writers to determine the needs of clients well and produce more quality products.
- Deployment becomes easier because the client knows what to expect.
- Allows developers to make improvements and changes to systems that have been created more easily.

1. Needs Analysis Stage

The needs analysis stage is a step in planning and identifying the needs of the system to be created. At this stage the author:

- Identify problems that occur in Lake Tondano and identify user needs.
- Specifies the goals that must be achieved to meet user needs.
- Choosing the most appropriate problem-solving method and following the user's wishes and needs.

2. Planning Stage

The main goal of the system design stage is to meet the needs of users and produce a system that can be a solution to the problems experienced by users.

• Process Design

In the process design, the author uses a flowchart to outline the process of the lake water quality control system which will be made as follows:

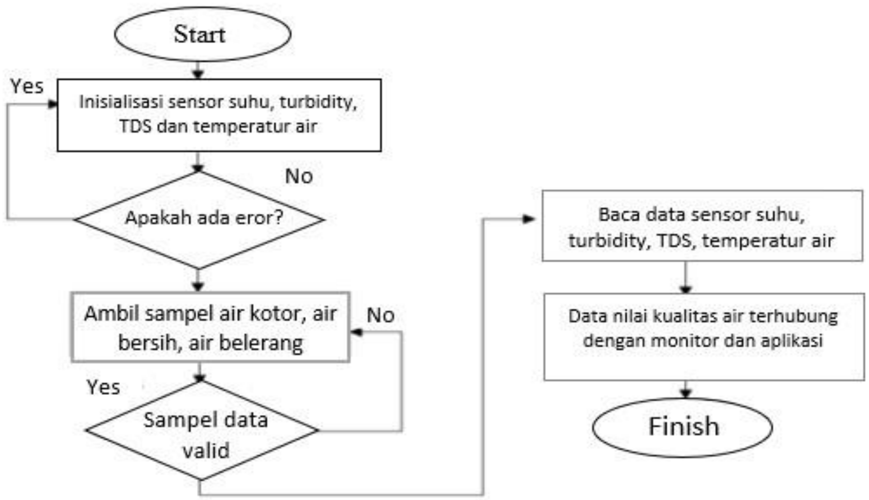

Figure 2. Flowchart Control System

In Figure 2, it is explained that the system starts by initializing the temperature level, particle level in the water, and the turbidity/color of the water. After reading the data, if there is an error module, then the detection process of TDS sensors, temperature sensors, pH sensors, and turbidity sensors will return to the initial process (Lestari & Zafia, 2022). However, if there is no error, it will continue to take data sampling, and later, the data obtained will be read and displayed on the Blynk application on the smartphone. The Blynk application is used for the monitoring system in the research to be carried out.

This application was chosen because it is easy to implement using a microcontroller, starting from the preparation of the application display that can be adjusted according to needs. This application also offers features that are free and easy to install on Android devices or download. The Arduino IDE is used to program the commands that are used to operate the Blynk application.

• System Architecture Design

International Journal of Information Technology and Education (IJITE)
Volume 3, Number 4, September 2024
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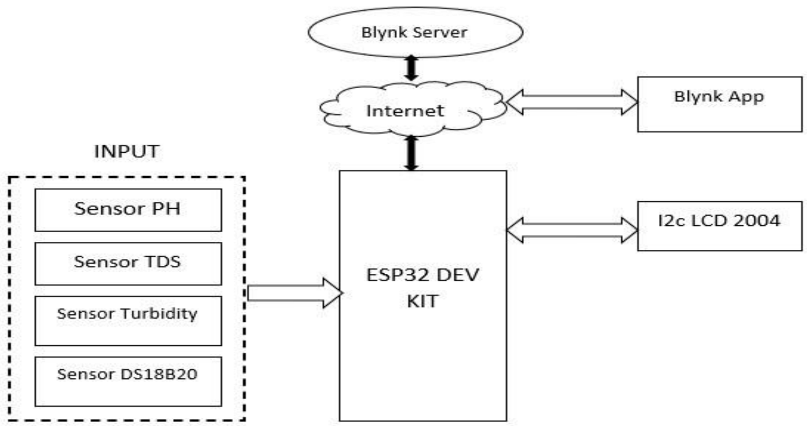

Figure 3. System Block Diagram

Figure 3 is a system block diagram, which is an important part of the design because it can show the working principle of the entire system series to be made.

3. Building a Prototype

The prototype is set up to meet the integrity of the user, where developers can clearly understand what needs to be done to develop the system. At this stage, the Internet of Things was applied to the prototype of the pH, TDS, temperature, and water color change control system with the ESP32 microcontroller. At this stage, a prototype series consisting of the ESP32 microcontroller was built using a temperature sensor, a pH sensor, a TDS sensor, and a turbidity and watercolor sensor. At this stage, it also designs a system that will connect to a monitoring application called Blynk.

4. Evaluation

After carrying out the 3 steps of prototyping, the next stage is to enter the Evaluation stage. This stage is to make and design the actual product. This stage carries out implementation as well as testing for systems that are ready to be operated. Evaluations are still made in terms of system technical and operational aspects as well as system user interaction.

Data Collection Techniques

In conducting a research entitled "Lake Tondano Water Quality Control System for Freshwater Fish Farming based on the Internet of Things", the author applies several research methods needed. The data collection methods carried out are as follows:

1. Observation
   At this stage, the author makes observations by making direct observations in the field where the research is located to get the actual problem and recording and sampling the water of Lake Tondano to be researched.
2. Interview Methods
   At this stage, the author collects data by conducting interviews through a question-and-answer process directly from the source by interviewing the community and fish farming

entrepreneurs around Lake Tondano to collect the information needed for this final project research.

3. study book

   The author collects data by searching and collecting written sources that are relevant to the object to be researched, by reading, studying, and recording important things related to the problem discussed to get a theoretical picture to support the preparation of the proposal.

Tools and Materials

System Requirements used for system creation consist of hardware and software.

1. Hardware
   - ESP32
   - Sensor pH Meter
   - Sensor Turbidity
   - Sensor DS18B20
   - Sensor TDS
   - I2C LCD 2004
   - Adaptor 5v
2. Software
   - Microsoft Windows 10
   - Arduino IDE
   - Blynk

RESULTS AND DISCUSSION

1. System Design Analysis

The system is to be designed and run by the user by placing the four sensors on the fish cage, and then the results of the test will appear on the LCD. If the user wants to see the results of the measurements of the system that has been designed, then the user can see the measurement results through a mobile phone (Mentouk et al., 2020).

International Journal of Information Technology and Education (IJITE)
Volume 3, Number 4, September 2024
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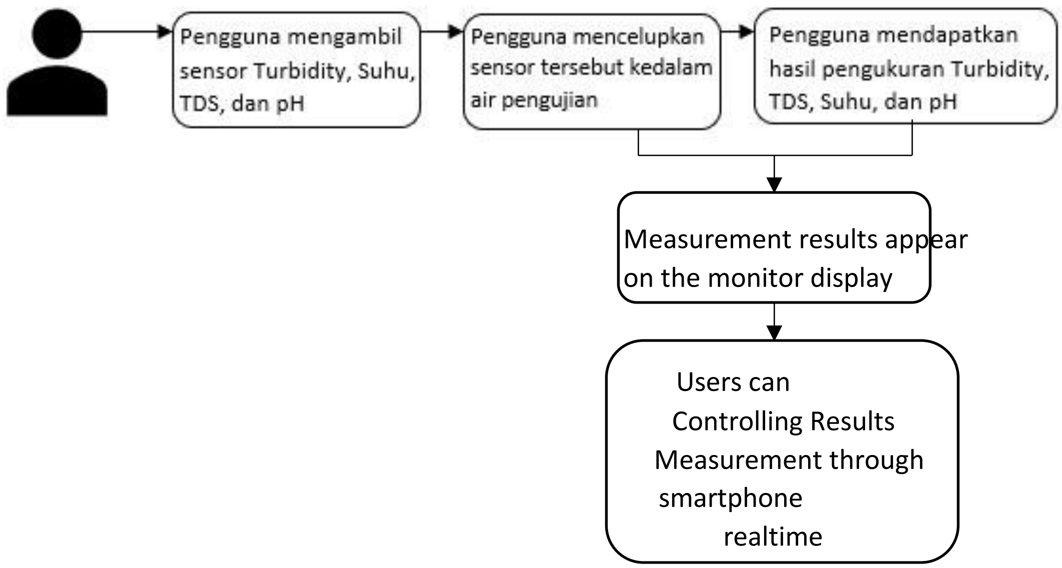

Figure 4. System steps that will run

2. How the System Works

The microcontroller is turned on via a power supply so that it can display the measurement results properly. The sensors are connected to a microcontroller, and then when the sensor is used, each sensor sends its measurement results to the microcontroller, and the sensor data is processed and displayed on the LCD monitor and the Blynk server (Mulyadi, 2020). See Figure 5.

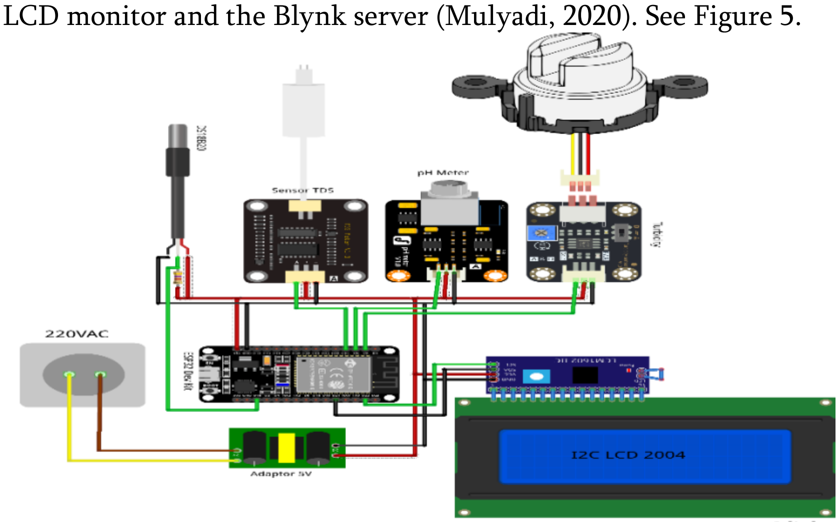

Figure 5. Water Quality System Design

3. Identify features in the system

The features in the designed system must be able to display data from sensors that have been calibrated so that the data is valid and *real-time*. See table 1

- Turbidity sensors, pH sensors, TDS sensors, and DS18B20 sensors are system-readable.

- The system can operate in the state of the lake water environment and can run 4 sensors at once

Table 1. System Components and Functions

Component	Function
ESP32	The most important part of the system as a microcontroller for processing, processing the data that display sensor
Sensor Turbidity	Provides data and reads the level of water turbidity
Sensor pH	Measuring and providing data on the pH content of water
Sensor TDS	Provides data and measures the amount of dissolved solids and particles on water
Sensor Suhu DS18B20	Providing data and measuring the temperature of hot and cold water
LCD	Displaying processed data results

4. System Building Stage

After the system description has been completed, it enters the design stage. At this stage, a system design scenario is created to implement it into hardware.

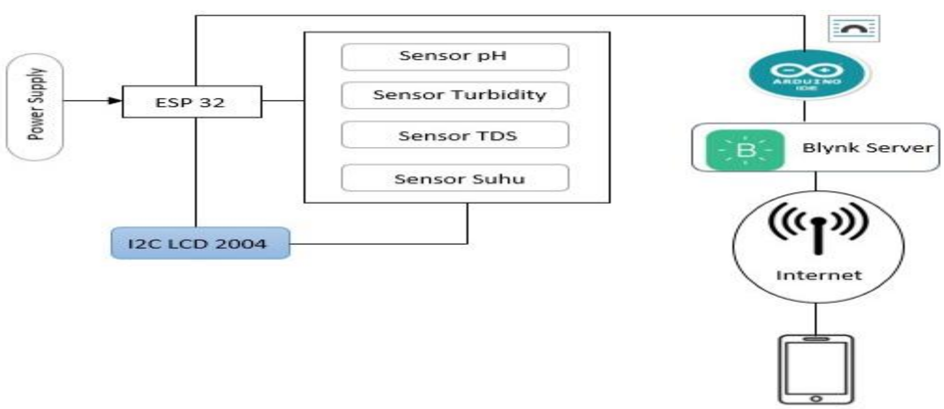

Figure 4.3 System Stage Diagram

5. Schematic ESP32 System with Turbidity Sensor

This schematic shows the connection of ESP32 with a turbidity sensor as the output of processed data on the turbidity level of the test water and the high and low turbidity levels read on the system (Pramana, 2018). See Figure 6.

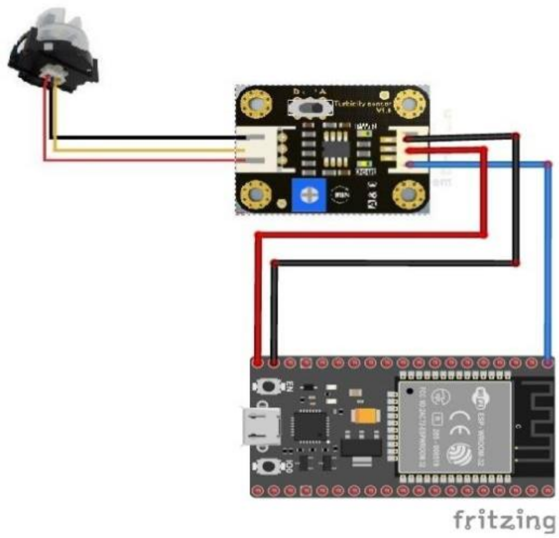

Figure 6. Turbidity Sensor Network

6. Schematic ESP32 System with pH Sensor

This schematic displays the connection of the ESP32 with a pH sensor which will later receive data on the pH content of the test water and the high and low acidity level of the water read on the system (Rahman et al., 2020). See figure 7

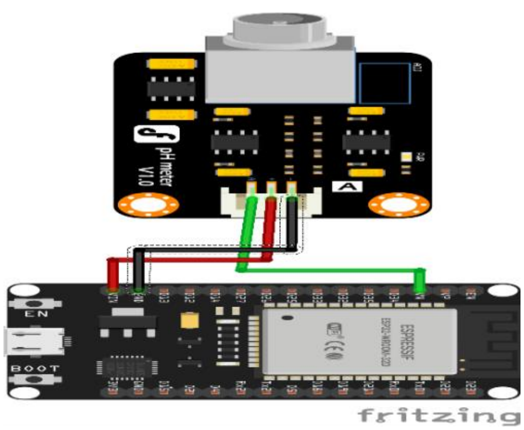

Figure 7. pH Sensor

7. ESP32 System Schematic with Temperature Sensor

This schematic displays the connection of ESP32 with a temperature sensor as the output of processed data on the amount of heat level and low water temperature that is measured. See figure 8

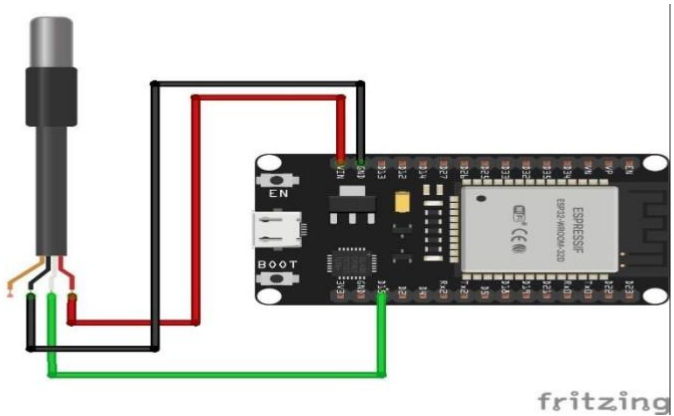

Figure 8. Temperature Sensor

8. ESP32 System Schematic with TDS Sensor

This schematic shows the connection of the ESP32 with a TDS sensor, which later the sensor can display data measuring dissolved particles in water, molecules, ionic, and micro-granular water (Rangkuti et al., 2020) (Sadali et al., 2022). See figure 9

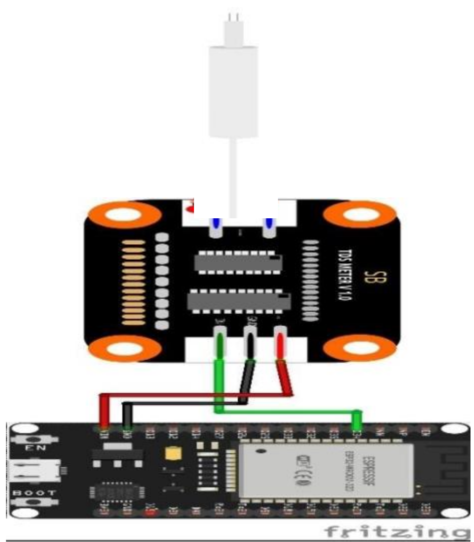

Figure 9. TDS Sensor

9. ESP32 System Schematic with I2C LCD

As seen in this schematic, the ESP32 is connected to an I2C LCD which is a monitor screen that will display the sensor measurement results in real-time and accurately (Sari, 2009). See Figure 10.

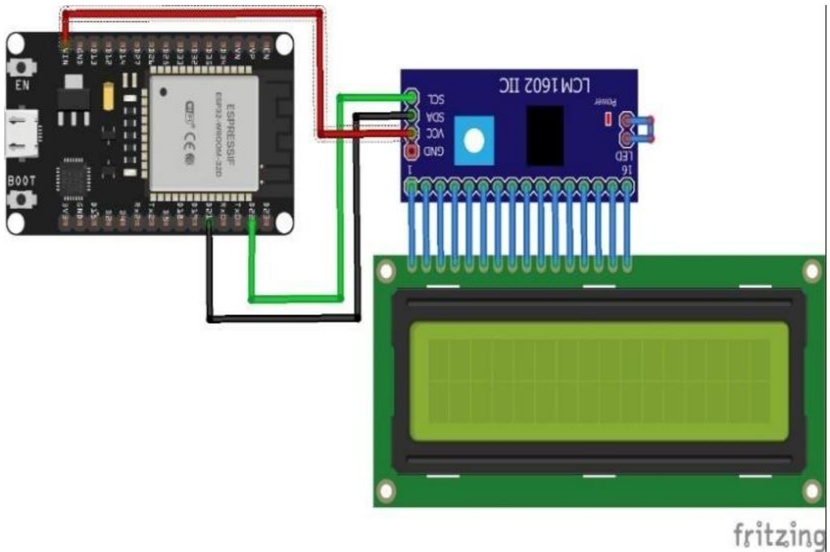

Figure 10. ESP32 schematic range with I2C LCD

10. Blynk App View

Below is the display of the Blynk application which is used to monitor water quality systems in real time and remotely. Blynk connects with the tool through an internet network supported by hotspots (Sasmito & Wijayanto, 2020). In Figure 11, there is a display of monitor data in Blynk that has no value.

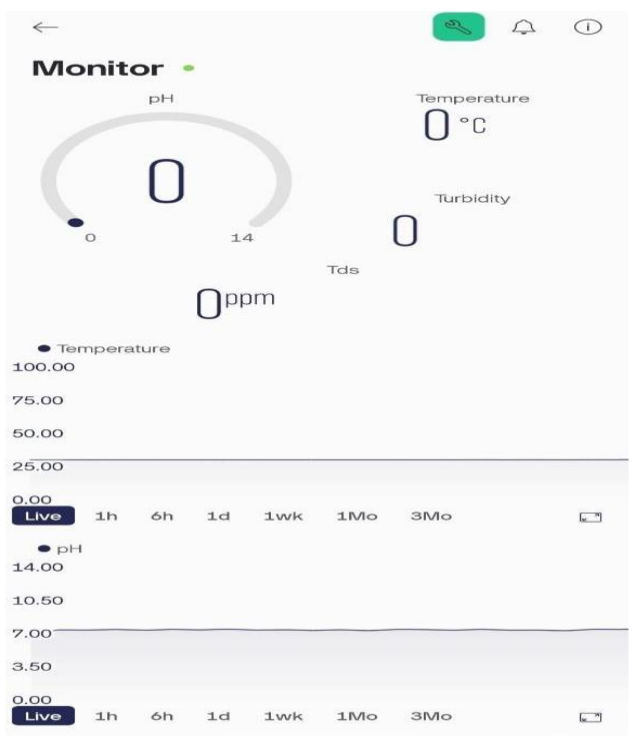

Figure 11. Basic view of the Blynk App

11. Pre-designed Water Quality Control System Display

The stage of building this system is focused on manufacturing and assembling water quality control tools for freshwater fish farming based on the Internet of Things. The steps carried out are by arranging each component and module by leading to the configuration of the pins that are adjusted to the previous schematic stages.

1) ESP32 Microcontroller Assembly

First of all, the most important thing to assemble is the connection of all sensors, namely the ESP32 microcontroller. This is what the ESP32 looks like after it has been assembled and the adapter is installed so that it can turn on (Sedana et al., 2018). See Figure 12.

Figure 12. Microcontroller ESP32

As seen in Figure 12, for the sensors to work properly, the components must be connected to the ESP32.

2) pH Sensor Assembly

At this stage, it starts by assembling the pH sensor by connecting its connecting cable to the ESP32. Components are well installed to make them sturdy. See Figure 13.

International Journal of Information Technology and Education (IJITE)
Volume 3, Number 4, September 2024
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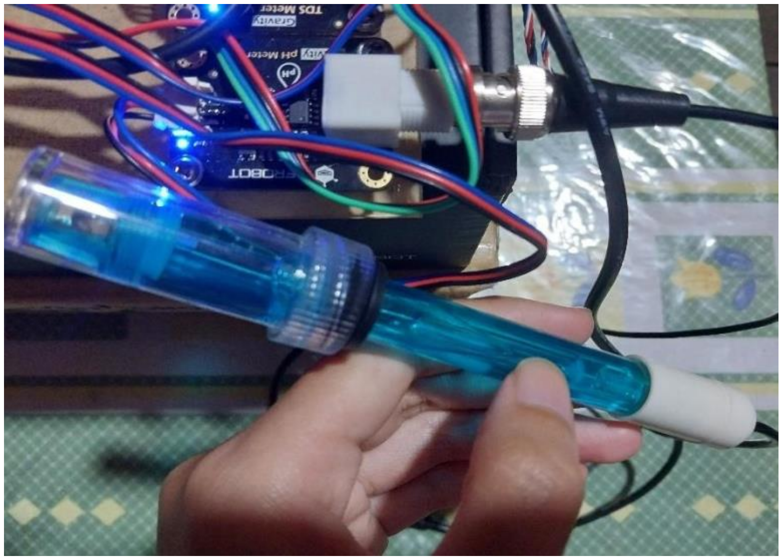

Figure 13. pH Sensor Assembly

3) Turbidity Sensor Assembly

At this stage, it is necessary to install the board and the Contacless Turbidity sensor and connect it to the ESP32 microcontroller. See figure 14.

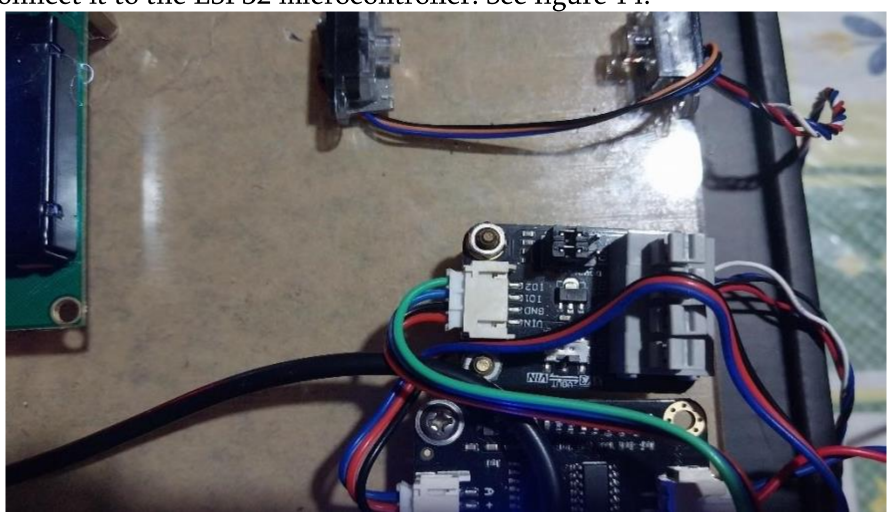

Figure 14. Contactless Turbidity Sensor Assembly

4) Temperature Sensor Assembly

Next, it comes to the assembly of the temperature sensor. The temperature sensor itself is directly connected to the microcontroller. See Figure 15.

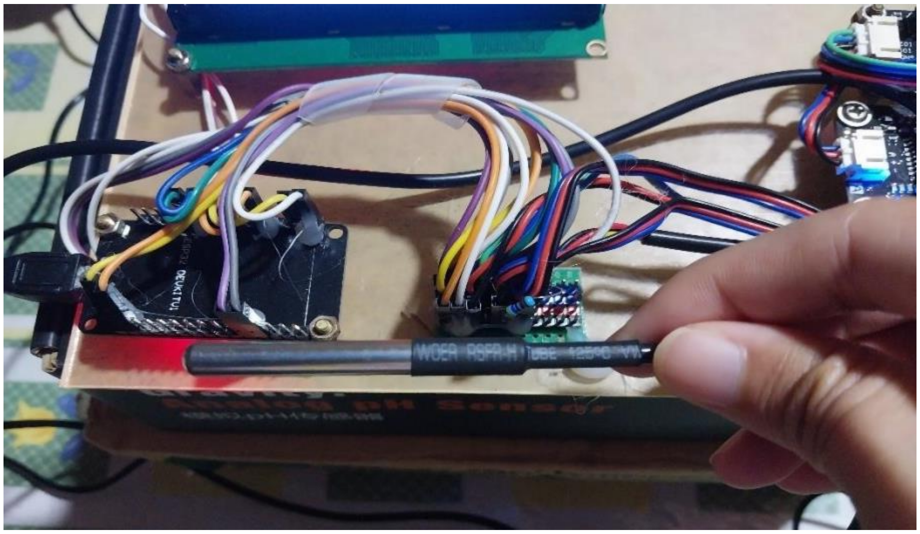

Figure 15. Temperature Sensor

5) TDS Sensor Assembly

The next stage is to assemble the board and install the TDS sensor device. See figure 16

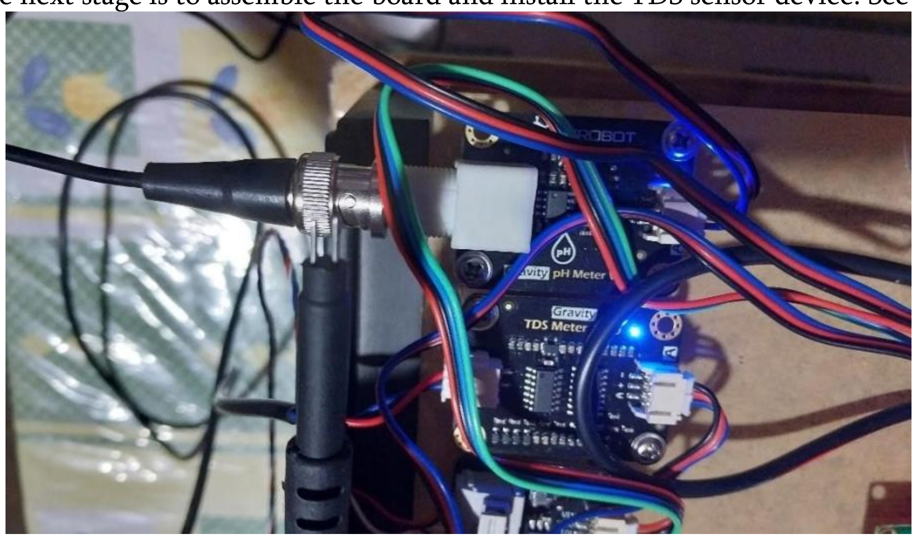

Figure 16. TDS Sensor Assembly

12. System Coding Stage

At this stage, it codes the system, which implements the design form into program code. See Figures 17,18,19, and 20.

1) *pH Sensor Coding*

```
phValue = ph.readPH(voltage1, temperatureC);
Serial.print("pH:");
Serial.println(phValue, 4);
```

Figure 17. pH Sensor Coding

2) TDS Sensor Coding

```
gravityTds.setTemperature(temperatureC);
gravityTds.update();
tdsValue = gravityTds.getTdsValue();
Serial.print(tdsValue,0);
Serial.println("ppm");
```

Figure 18. TDS Sensor Coding

3) Temperature Sensor Coding

```
sensors.requestTemperatures();
temperatureC = sensors.getTempCByIndex(0);
Serial.print(temperatureC);
Serial.println("ºC");
```

Figure 19. Temperature Sensor Coding

4) Turbidity Sensor Coding

```
int sensor = 0; // variable for averaging
int n = 25; // number of samples to average
int sensorValue = 0;
float voltage = 0.00;
float turbidity = 0.00;
float Vclear = 2.85; // Output voltage to calibrate (with clear water).
```

Figure 20. Turbidity Sensor Coding

1. System Testing

After completing the design, the author conducted a system test. At this stage, the authors conducted tests on each sensor. The author tests the microcontroller and supporting sensors that have been assembled and connected to find out whether the system that has been created has been running and functioning properly or not. See Figure 21.

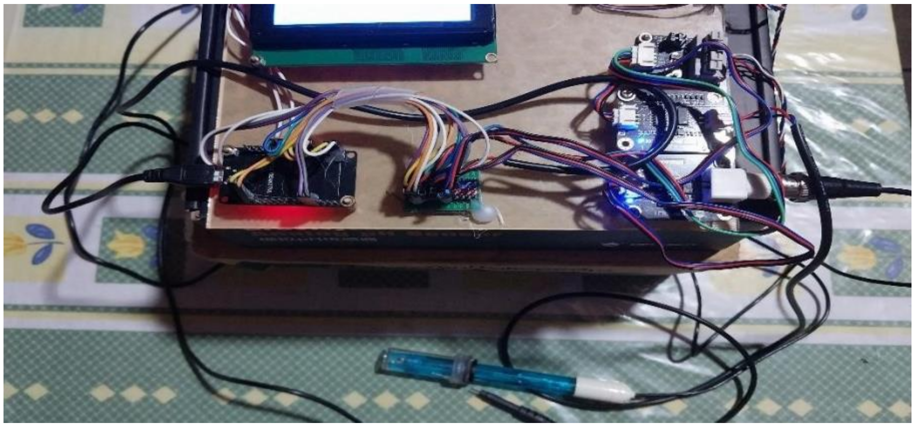

Figure 21. System-Wide View

2. Testing Systematics

1) Turbidity Sensor Testing

In this stage, the author conducted two tests, namely using a sensor by putting a container filled with clean and dirty water into the sensor.

Figure 22. Clean water testing

As seen in Figure 22, the author tested clean water and the monitor screen displayed a turbidity of 10, which is the minimum basis of the number on the sensor. This shows the water is clean. Next, the author tested the dirty water (Tamanampo et al., 2017), (Tarigan, 2021).

Figure 23. Dirty Water Testing

As seen in Figure 23 the author tested dirty water on a turbidity sensor. The sensor displays water turbidity data with the number 243. It looks very much murky compared to the clean water that was tested previously.

2) TDS Sensor Testing

At this stage, the author tested the TDS sensor using sulfur water which is the topic of the problem that the author takes. See Figure 24.

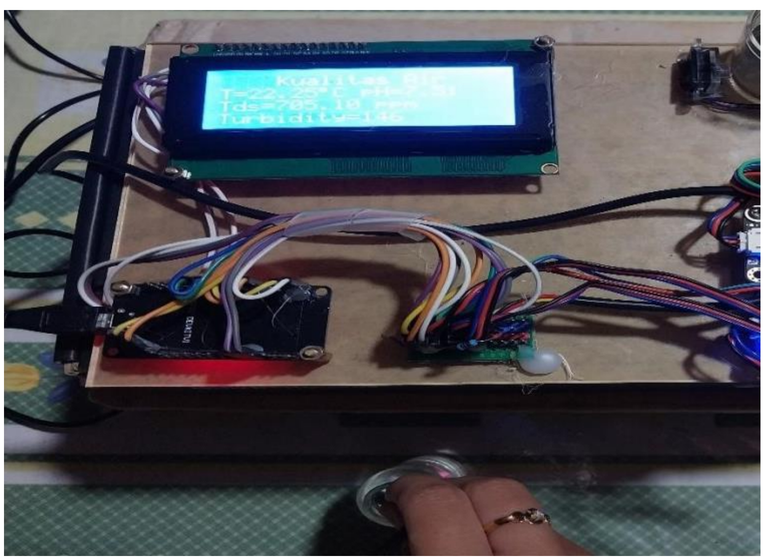

Figure 24. TDS Sensor Testing

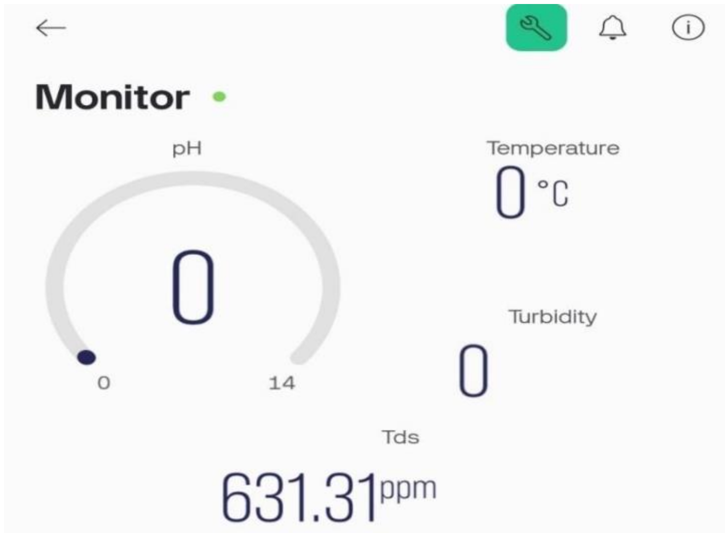

Figure 25. Test data view

As shown in Figure 25, the test data can be seen through the monitor screen and Blynk with a TDS value of 631-705.10 ppm. This shows that the particle content in sulfur water is very high and the oxygen levels in the lake water are high.

3) Temperature Sensor Testing

The author tested the temperature sensor by using hot water to see the water temperature.

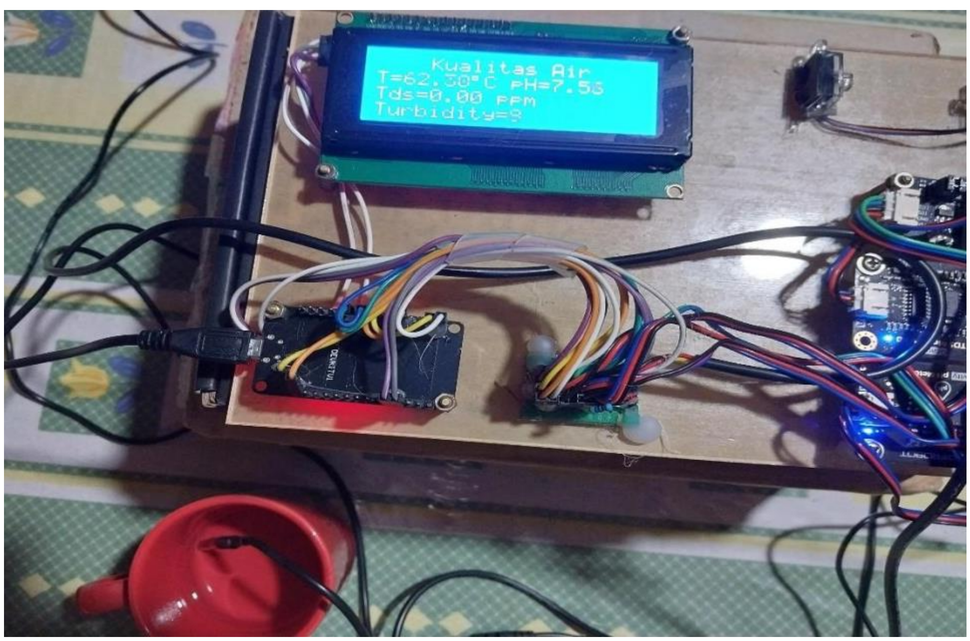

Figure 26. Temperature Sensor Testing

International Journal of Information Technology and Education (IJITE)
Volume 3, Number 4, September 2024
e-ISSN: 2809-8463

As seen in Figure 26, when the author inserts the temperature sensor into the hot water, the temperature sensor immediately displays the hot water temperature data.

Figure 26. Temperature Sensor Display Monitor Screen

In Figure 27, it can be seen that the temperature level of hot water reaches 62 °C. This indicates that the sensor is working properly, displaying data as per the measurement.

4) pH Sensor Testing

Next, it enters the pH sensor testing stage. At this stage, the tester conducts a test with clean water (Warlina, 2004).

Figure 28. pH Sensor Monitor Screen

In Figure 28, you can see a monitor screen that displays the pH sensor data that has been tested.

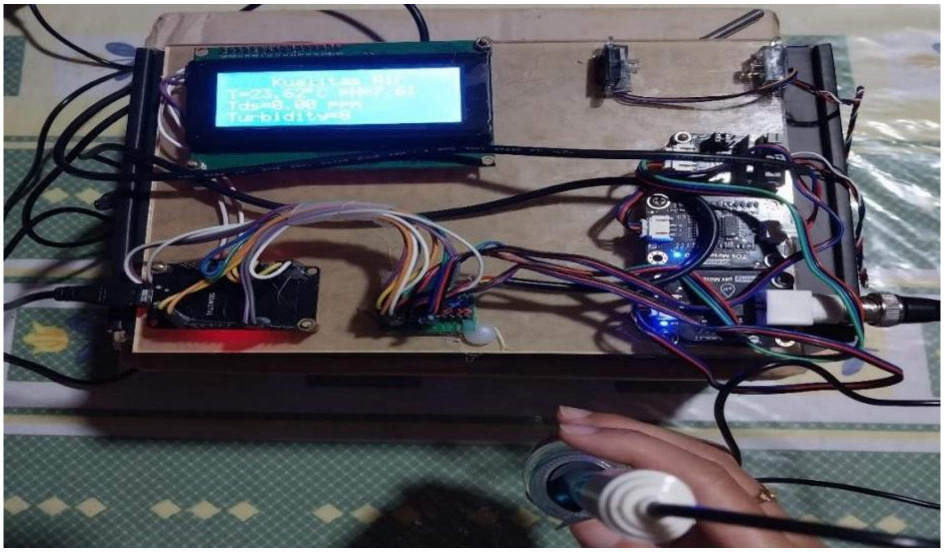

Figure 29. pH Sensor Testing

In Figure 29, the tester tests the pH sensor by inserting the pH sensor into clean water and the monitor screen displays the data value on clean water as pH=7.56

3. Testing the System against Different Water

The purpose of this test is to find out whether the system works well on various types of water with different conditions. The author uses 4 types of water, namely dirty water, sulfur water, lake water, and hot water. The results of the pH, TDS, Temperature, and Turbidity content tests are shown in the following table 2.

Table 2. Water Testing

No	Sample	pH	TDS	Temperature	Turbidity
1.	Dirty Water	7.56	412 ppm	27.35°C	243
2.	Sulfur Water	4.50	710 ppm	29.78°C	131
3.	Lake Water	6.45	210 ppm	25.49°C	45
4.	Hot Water	7.00	200 ppm	55.06°C	11
5.	Air Mineral	7.20	198 ppm	24.22°C	10

In Table 2, it can be seen that the results of testing the system using 5 different types of water, and it can be seen that the dirtier and higher the acid content, the greater the presentation of the water change.

After designing and testing the system, it can be found that different types of water have different levels of pH, Temperature, Turbidity, and TDS. This can be found out by taking measurements (Wijaya & Sukarni, 2019). So, after testing the water, the test results appear and are read in Blynk in real time. See Figure 30.

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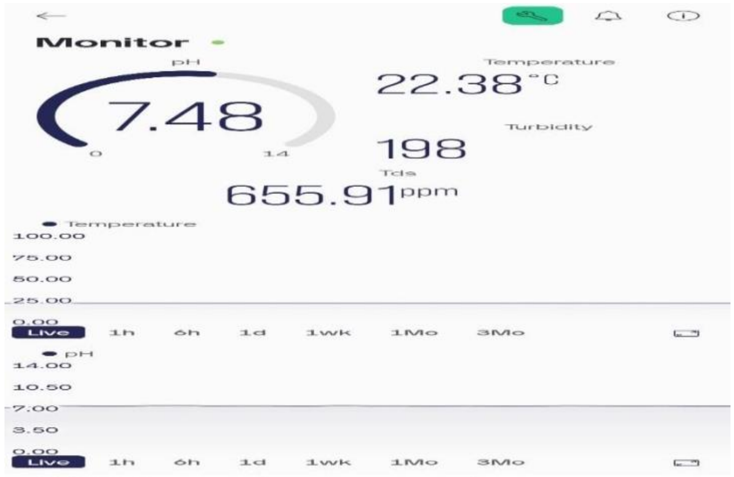

Figure 30. Data Results on Blynk

CONCLUSION

From the results of the design and development of the Lake Tondano Water Quality Control System for Freshwater Fish Farming, it can be concluded that: This system provides convenience for the community around Lake Tondano, especially for freshwater fish farming entrepreneurs to be able to find out the emergence of hazards that arise so that they can immediately save the fish from sulfur water. This system is a breakthrough that is beneficial for the village where the research is conducted. This system can be used as a benchmark and alarm for fish farming entrepreneurs.

Suggestion

The results of this study are still very far from perfect, so the suggestions that can be submitted by the next researcher regarding the development of this system are as follows:

- Further research is expected to develop a system to evacuate fish automatically using fishing motors so that fish can be rescued when sulfur water appears.
- Further research could use other microcontrollers such as the NodeMCU ESP8266, and use a variety of other parameters.

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