

# Water Depot Quality Monitoring System Based On Internet Of Things

Marchel T. Tombeng\*<sup>1</sup>, George M. W. Tangka<sup>2</sup>, Regino J. S. Kaloh<sup>3</sup>, Imanuel O. Mantow<sup>4</sup>, Jonathan K. Kongen<sup>5</sup>

<sup>1,2,3,4,5</sup>Computer Science Faculty, Universitas Klabat, Indonesia

e-mail: \*<sup>1</sup>[marcheltombeng@unklab.ac.id](mailto:marcheltombeng@unklab.ac.id), <sup>2</sup>[gtangka@unklab.ac.id](mailto:gtangka@unklab.ac.id),  
<sup>3</sup>[s11310229@student.unklab.ac.id](mailto:s11310229@student.unklab.ac.id), <sup>4</sup>[s21910480@student.unklab.ac.id](mailto:s21910480@student.unklab.ac.id),  
<sup>5</sup>[s21730016@student.unklab.ac.id](mailto:s21730016@student.unklab.ac.id)

## Abstract

*This study evaluates water quality at refillable drinking water depots in Bitung City, Indonesia, focusing on physical, chemical, and biological parameters compared against Indonesian Ministry of Health standards. The prototype method was employed, using Unified Modeling Language (UML) for system design and architecture modeling. Water samples were tested directly for pH, TDS (Total Dissolved Solids), and temperature. Results indicate that 5 out of 6 depots met health standards with contaminant levels below permissible limits. The study underscores the need for enhanced supervision and quality control at these depots to ensure safe water for public consumption. It proposes implementing microcontroller and sensor-based monitoring systems for real-time water quality monitoring to improve accuracy and efficiency. This technology aims to safeguard public health by ensuring consistent adherence to safety standards. In conclusion, the research provides crucial insights into Bitung City's refillable drinking water depot quality and advocates for technological advancements to ensure safe drinking water.*

**Keywords**— IoT, Water Quality Monitoring, pH Sensor, TDS Sensor, Temperature Sensor, ESP32

## 1. INTRODUCTION

Fulfillment of the need for clean and healthy water is a fundamental right of every individual. However, equal access to clean and healthy water resources is not yet available to all, facing challenges such as inequality of access, water pollution, and unsustainable water resource management practices [1]. The Refuel Drinking Water Depot in Bitung City has become an alternative to providing drinking water that meets quality standards. However, potential fraud and lack of monitoring lead to contamination risks [2]. Strict monitoring of refilled drinking water deposits is essential to reduce the risk of diseases such as Diarrhea, Cholera, and Meningitis that can increase with the growth of such deposits. Hygiene and water quality are crucial to public health [3].

The Ministry of Health of the Republic of Indonesia Regulation No. 2 of 2023 on the Implementation of Government Regulations No. 66 of 2014 on Environmental Health has established a standard for the quality of drinking water with specific parameters, including a maximum hardness of 3 Nephelometric Turbidity Units (NTUs) and a maximum Total Dissolved Solid (TDS) content of 300 mg/L. The standard also lists a maximum water color quality of 10 TCUs, while drinking waters must be odour-free. The pH of water should be in the range of 6.5 to 8.5. The test method used to verify these parameters is in accordance with the Indonesian National Standard (SNI) and the American Public Health Association (APHA), ensuring that drinking water is consumed by the public safe and minimizes health risks [4].

As of December 2023, Bitung City 5,704 cases of diarrhea in young people and all age groups, equivalent to 2.89% of the total cases. In addition, the results of researchers' interviews

with drinking water depot owners also showed water stocks of about 5000 liters per filling, with a total monthly supply of 1.8 million liters. Drinking water production of Bitung City is also known to increase to 8,311,647 m<sup>3</sup> by 2023, this data is obtained from the Bitung Central Statistical Agency [6].

This research needs to be carried out because according to data from the Central Statistical Authority of the North Sulawesi Province [7], the percentage of water use of packaging and refueling in Bitung City has fluctuated significantly, reaching 72.76% by 2021. These fluctuations indicate instability in public confidence in pipeline water quality and describe the urgency to improve water quality monitoring systems. Poor water quality pollution and consistency, combined with a lack of effective monitoring and potential fraud in the operation of refilled drinking water depots, pose serious health risks for the population. There is therefore a need for systematic efforts to increase public confidence and the quality of water consumed through the development and implementation of more sophisticated and automated monitoring technologies.

The research gained full support from Bitung City Health Service and used prototype development methods to automate drinking water quality monitoring. Although this research will be developed in all drinking water depots, for the time being it will be tested and developed only in a few willing depots. The initiative aims to replace the existing manual data collection with efficient electronic monitoring technology, ensure that health standards are met in refueling water depots and support public health [8], [9]. The existence of this automated monitoring system is expected to strengthen public confidence in the quality of drinking water and help the government in taking appropriate policies to ensure access to clean and healthy water for all citizens of Bitung City.

## 2. RESEARCH METHODS

A simple development model known as a prototype method allows users who have a basic understanding of an application to undertake initial testing of a built-in application [10]. So that developers can easily model a created application, this method allows developers and users to communicate with each other during the manufacturing process. One of the important conditions for the success of this method is that both sides understand that the prototype is made to determine the initial need. These are phases in the Prototype Method: Communication, Quick Plan, Modelling Quick Design, Construction, Deployment, Delivery & Feedback [11]. The prototype development methods described in Figure 1 involve repeated iterative cycles to the desired results.



Figure 1. Prototype Model

## 1. Communication

Communication is the key to any iteration in the prototyping process [12]. At this stage, the feedback received is analyzed and discussed to guide further development and perfection of the prototype. Team discussions Conduct discussions with the developer team and stakeholders to discuss feedback received and determine improvement actions. Change Documentation Documents all changes proposed and made to the prototype based on feedback. Further planning Planning further to repair and refine the prototype, ensuring that the system finally meets all the requirements and expectations of the user. After the communication phase, the cycle returns to rapid planning with the newly acquired knowledge to start the next iteration. This process is repeated until the prototype reaches the expected quality and functionality and is ready to be used as a final product or for further research purposes. This cycle supports continuous improvement and adaptation to the needs of the user and the research results obtained during the process.

## 2. Quick plan

Quick planning stage is the initial step in which the basic ideas of the prototype are formed. It involves some key steps. Identification of problems and purposes Determining the main problems to be solved with the water quality monitoring system. The main objective is to ensure that the water consumed properly and meets the quality standards. Defining Features and Functions Identifying key features and functions that a system should have, such as real-time pH, TDS, and water temperature measurement. Specifying Technical Requirements Defining technical requirements such as the type of sensor to be used, hardware and software requirements, as well as integration requirements with cloud platforms for data storage and analysis.

## 3. Modeling Quick Design

After the planning stage, the process moves to modeling or rapid design. Here, the basic concepts generated during planning are transformed into the initial model or design of the prototype. Create a sketch or system workflow diagram that shows how the sensor will collect data, how data is processed by the microcontroller, and how data will be displayed and stored. User Interface Design initial user interfaces for LCD modules and web applications. This interface should be intuitive and easy to use by drinking water depot operators. In Technical Specification Drafting, drafts detailed technical specifications that describe how each component of the system will function and interact.

## 4. Construction of Prototype

Based on the model or initial design, the prototype is built. It is an early version of a functional product, allowing researchers and users to interact with the planned features and functions. Hardware components assembly all hardware components, including pH, TDS, and temperature sensors, as well as ESP32 microcontroller. Each sensor is connected to the microcontroller using a breadboard and a jumper cable. Microcontroller programming Develops software for ESP32 microcontrollers using Arduino IDE, which will control the sensor, collect data, and send it to the cloud server. In addition, a website monitoring is being developed that integrates the results of the three sensors within a given time frame. Preliminary testing Conduct preliminary tests to ensure that all components work properly, and the data collected is as expected.

## 5. Deployment Delivery & Feedback

Prototypes that have been created are then tested or launched on a smaller scale to get feedback. This stage is crucial to gathering information from end users and other stakeholders about the effectiveness of the prototype. Field implementation Installing

prototypes in several drinking water depots for field testing. Drinking Water depot operators will use the system to monitor water quality. Feedback Collection Collects feedback from operators and other users on ease of use, data accuracy, and overall system functionality. Feedback analysis is to identify the strengths and weaknesses of the prototype, as well as areas that require improvement.

### 3. RESULT AND DISCUSSION

#### 3.1. Research Design

The researchers choose to use the Unified Modeling Language (UML), the user interface, and Firebase as databases to support the application development process to be designed. Using UML allows researchers to describe various aspects of the application clearly [13]. UML is used to design applications through use case diagrams, sequence diagram, activity diagram and class diagram as well as a platform for design.

#### 3.2 Use Case Diagram

In this study, the use case diagram becomes a vital tool to visually and in detail describe interactions between users and websites [14]. Using the use case diagrams shown in Figure 2, explain every aspect of the relationship between the user and the website interface can be thoroughly described [15], enabling a better understanding of such interactions.

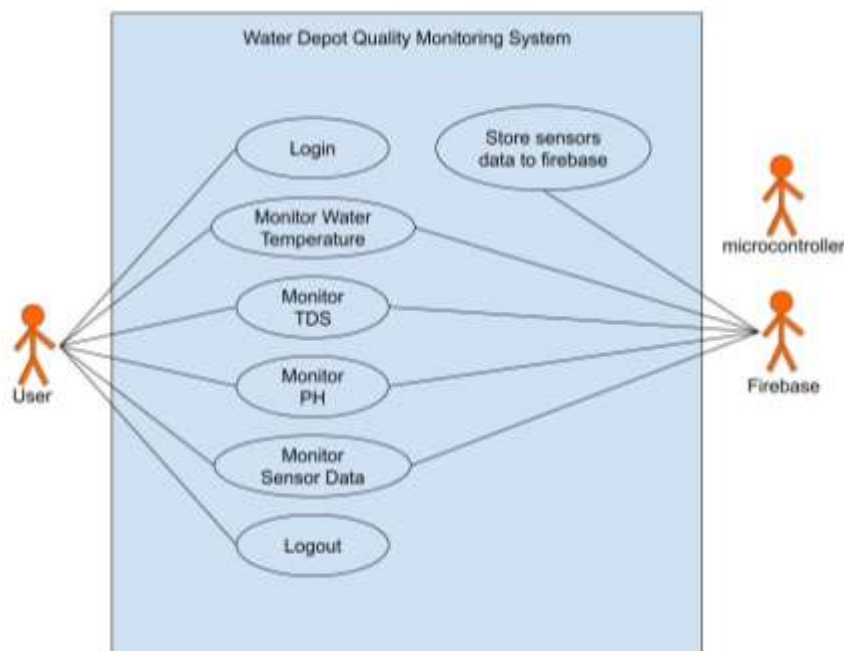


Figure 2. Use Case Diagram

This system allows users to Login to system dashboard, View Total Dissolved Solids (TDS) values, monitor water pH values, Check water temperature, monitor sensor data in real time, manage sensor data (delete or hide), display data in various formats (cards, gauge, graphics), and Logout from system.

Each use case is described in detail, including purpose, prerequisites, main actors, and mainstream. The system uses Firebase for authentication and data storage. Users can access a

variety of features after logging in, including viewing water sensor values (TDS, pH, temperature) in real time, managing data, and displaying it in different formats. Overall, the system is designed to facilitate the monitoring and management of water quality data efficiently through a user-friendly web interface [16].

### 3.3. Activity Diagram

The activity diagram shown in Figure 3 describes the login process on a system. The flow starts when the user enters the username and password, continued with authentication by the system. The diagram shows two possible outcomes: if the credentials are valid, the user is allowed to log in and the login is successful; if not valid the system displays an error message and returns the user to the start of the process. This structure reflects a basic security mechanism to ensure that only users with the correct credentials can access the system, while providing an option to try again if an error occurs.

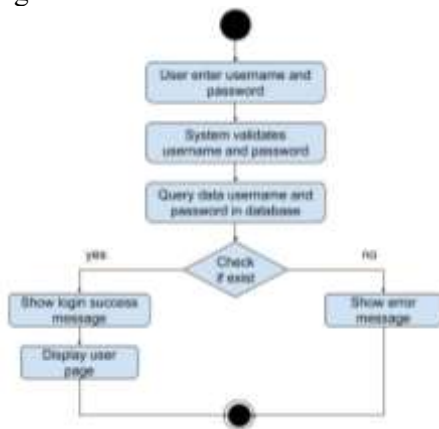


Figure 3. Activity Diagram Login



Figure 4. Activity Diagram TDS Sensor

The diagram shown in Figure 4 illustrates the TDS (Total Dissolved Solids) monitoring process. The stream starts from the user who opens a TDS monitoring page. The ESP32 reads TDS data from the sensor and sends it to the Firebase. The firebase stores the data, then the website retrieves and displays that TDS. The process demonstrates the implementation of a real-time water quality monitoring system using the TD sensor, the ESP32 microcontroller, and the web platform.



Figure 5. Activity Diagram pH Sensor

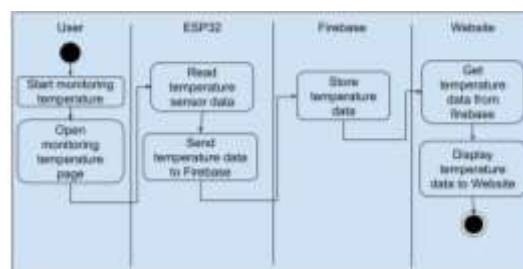


Figure 6. Activity Diagram Temperature Sensor

This activity diagram shown in Figure 5 explain the process of monitoring the pH of the water. The flow begins when the user opens the pH monitoring page. ESP32 reads the pH data from the sensor and sends it to the Firebase for storage. The website then takes the pH information from the firebase and displays it. This diagram shows a real-time water pH monitoring system, integrating pH sensors, ESP32, Firebase, and interfaces.

The diagram shown in Figure 6 describes the temperature monitoring process. The circuit starts from the user who opens the temperature Monitoring page. ESP32 reads the temperature data from the sensor and sends it to the Firebase. The temperature data is stored in the firebase, then taken and displayed by the website. This process illustrates the implementation of a real-time temperature monitoring system, connecting temperature sensors, ESP32, Firebase cloud services, and web interfaces for data visualization.

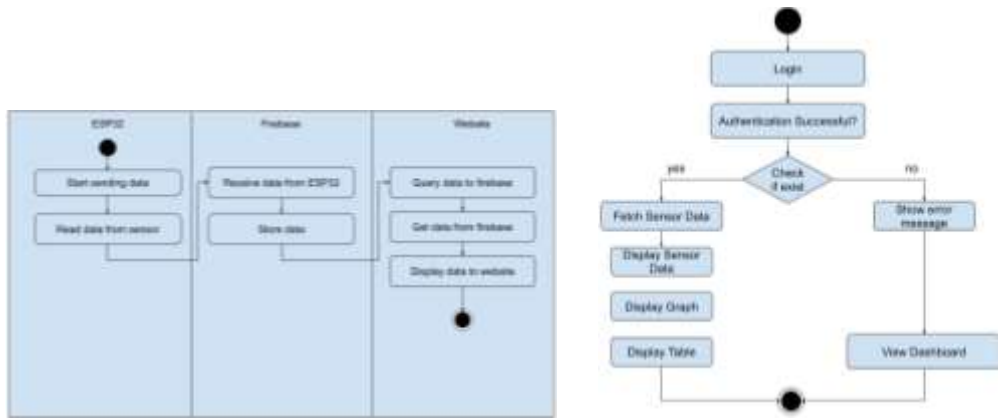


Figure 7. Activity Diagram Firebase Figure

8. Activity Diagram Monitoring Data

This activity diagram shown in Figure 7 describes the process of sending and storing data from ESP32 to Firebase, as well as the retrieval and display of data on the website. The stream starts from the ESP32 that sends sensor data to firebase. Firebase stores the data, then the website performs data requests to Firefox, retrieves it, and displays the data on a web page. The Figure 8 depicts user interaction with the monitoring system from login to sensor data visualization. After login, users can select a monitoring view to view general sensor data, as well as select specific data in the form of graphs or tables. The diagram shows system flexibility with intuitive navigation options between the general and detail views, allowing users to explore data further or exit the system. Overall, this diagram design offers efficient workflows and supports decision-making based on comprehensive data analysis.

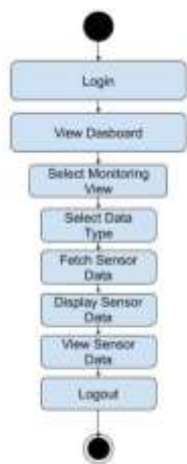


Figure 9. Activity Diagram View Data

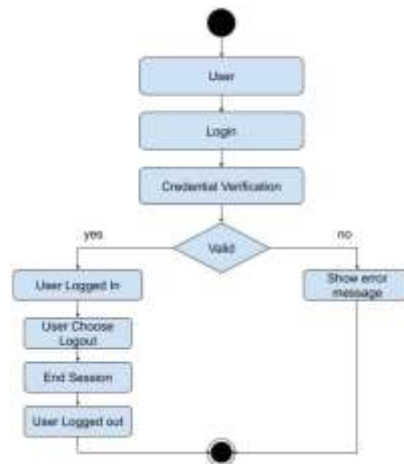


Figure 10. Activity Diagram Logout

The Figure 9 describes the flow of data access processes on the monitoring system. Starts with credential verification, if true, the user logged in successfully. The user then selects the monitoring display and the type of data to be viewed (TDS, Temperature, or pH). The system displays sensor data as optional, with the option of displaying specific data (TD, temperature, pH)

or a combination thereof. This channel shows the flexibility of the system in presenting different types of sensor data according to the user's needs, with an option to view data separately or in combination. This design allows users to access the information they need efficiently after successfully logging into the system. The Figure 10 describes the logout process on a system. The flow starts with the User logging in. The system verifies the user's credentials. If true, User logged in and can choose to log out. When Logout is selected, the system ends the session and User logs out. If verification fails, the process starts again. This diagram shows a simple but important stream in user access management, emphasizes security through verification and gives clear exit options, properly ending user interaction with the system.

### 3.4. Application Construction

At this stage of implementation, the author will show the results of the website and the monitoring system that has been designed and built.



Figure 11. Login View



Figure 12. Accounts used

Figure 11 shows an interface that offers an option to log in. Users can log in using the email and password already available. In Figure 12, users can see information related to the account used to access the monitoring system.



Figure 13. Last Update

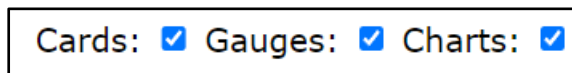


Figure 11 Data Selection Feature

In Figure 13, users can see the current timestamp or the last time when data in the website dashboard of this monitoring system was updated. This information is important because it allows users to know how up to date the information they are viewing, ensuring the accuracy and relevance of the data available in the system. Figure 14 displays an interface that gives users the option to display data in several different visual formats. Users are given the option of choosing between cards, gauges, or charts according to their preferences. This option allows users to customize the way they interpret and analyze the information presented to suit their needs.

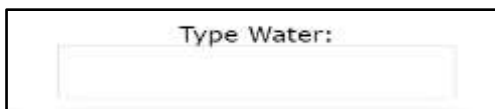


Figure 12 Eter Water Type



Figure13 Data in Chart

In Figure 15, the user is given the ability to choose the type of water to be tested. This interface allows the user to enter specific information about the kind of water being analyzed, ensuring that the data generated corresponds to the desired test context. Figure 16 displays an informative display of cards, showing the values of TDS (Total Dissolved Solids), pH, and water temperature. These cards are designed to provide users with clear and easy-to-understand information about

the water condition being tested. Each value displayed can help users make the right decisions regarding the quality and safety of the water being monitored.



Figure 14 Data in Gauges

Figure 17 displays a display of gauges that show the actual values of key parameters such as TDS, pH, and water temperature. Users can easily view and monitor these values in an intuitive visual form, which helps in rapid understanding related to the water condition being monitored.

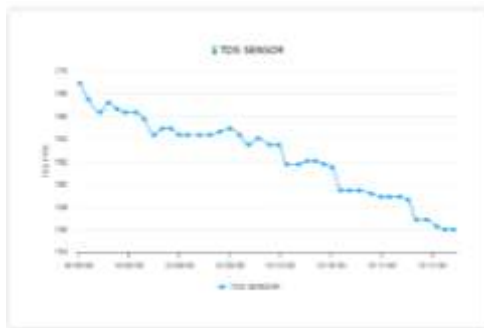


Figure 15. TDS Data Graph

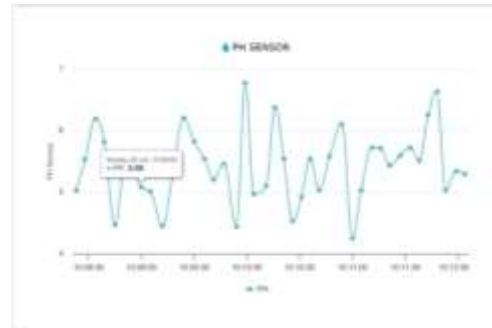


Figure 19. pH Data Graph



Figure 20. Temperature Data Graph

Time	TDS	pH	Temperature	Status
2024-09-10 14:00	120.75	6.50	27.70	ok
2024-09-10 14:10	120.42	6.60	27.50	ok
2024-09-10 14:20	119.11	6.40	27.60	ok
2024-09-10 14:30	118.20	6.70	27.60	ok
2024-09-10 14:40	118.75	6.70	27.60	ok
2024-09-10 14:50	118.00	6.60	27.60	ok
2024-09-10 15:00	117.24	6.60	27.70	ok
2024-09-10 15:10	116.50	6.60	27.70	ok
2024-09-10 15:20	116.00	6.60	27.70	ok
2024-09-10 15:30	115.44	6.60	27.70	ok
2024-09-10 15:40	114.88	6.60	27.70	ok
2024-09-10 15:50	114.32	6.60	27.70	ok
2024-09-10 16:00	113.76	6.60	27.70	ok
2024-09-10 16:10	113.20	6.60	27.70	ok
2024-09-10 16:20	112.64	6.60	27.70	ok
2024-09-10 16:30	112.08	6.60	27.70	ok
2024-09-10 16:40	111.52	6.60	27.70	ok
2024-09-10 16:50	110.96	6.60	27.70	ok
2024-09-10 17:00	110.40	6.60	27.70	ok
2024-09-10 17:10	109.84	6.60	27.70	ok
2024-09-10 17:20	109.28	6.60	27.70	ok
2024-09-10 17:30	108.72	6.60	27.70	ok
2024-09-10 17:40	108.16	6.60	27.70	ok
2024-09-10 17:50	107.60	6.60	27.70	ok
2024-09-10 18:00	107.04	6.60	27.70	ok

Figure 21. Total Data

In Figure 18,19,20 the user is presented with a chart display that depicts trends or changes in TDS, pH, and water temperature values over time. This graph allows the user to conduct a more in-depth analysis of historical data or patterns that may occur in monitored water conditions, facilitating better decision-making and more detailed information related to water quality.

In Figure 21, users are given access to view historically stored data in the form of tables. This table displays key parameter values such as TDS, pH, and water temperature of various recorded times. In addition, this table is also accompanied by a description of whether the tested water is proper or not according to the established standard. This information provides users with a direct view of the water condition at any observed time point, enabling them to quickly evaluate water quality and take necessary action if necessary.

### 3.5. Hardware Construction

The first step in building the hardware components is connecting the ESP32 microcontroller to the breadboard. This step is very important because the ESP32 is the microcontroller that will serve as the central control and data processing unit in the potable water monitoring system [17][18][19][20].

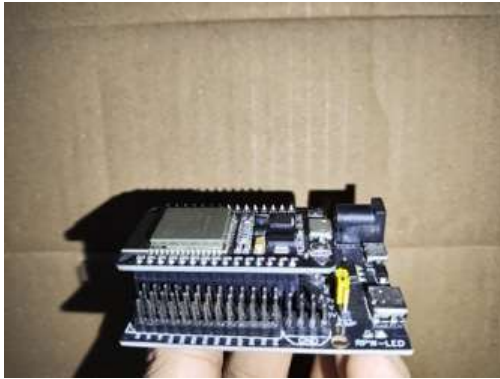


Figure 22. ESP and Breadboard



Figure 23. pH Module Cable Assembly

Figure 22 show a breadboard, or solderless circuit board, is a tool that allows rapid prototyping of electronic circuits without the need for soldering. It has internally connected holes, making it easy for users to insert and connect electronic components such as resistors, capacitors, and jumper wires. The use of a breadboard enables easy experimentation and modification of the circuit before final implementation. Figure 23 describe the process for connecting the GND (ground) pin of the pH sensor module: First, to ensure that the pH sensor module is properly connected to the system, the initial step is to connect the GND (ground) pin of the pH sensor module to the breadboard. This is done using a brown jumper wire. The wire is securely connected to row D32 with the G code on the breadboard, ensuring that the pH module has a stable connection path to ground for proper voltage reference.



Figure 24. Assembly of pH Module Cables on the Breadboard



Figure 25. TDS Module Cable Assembly

Figure 24 shows the way for Connecting the VCC (Power Supply) pin of the pH sensor module. The next step is to connect the VCC (power supply) pin of the pH sensor module to the breadboard. This is done using a red jumper wire. The wire is connected to row D32 with the V code on the breadboard, ensuring that the pH module receives a stable power supply for consistent and accurate operation.

Figure 25 show the way to connect the GND (ground) pin of the TDS sensor module to the breadboard. This is done using a black jumper wire. The black wire is securely connected to

row D33 with the G code on the breadboard, ensuring that the TDS module has a stable ground path for proper voltage reference.

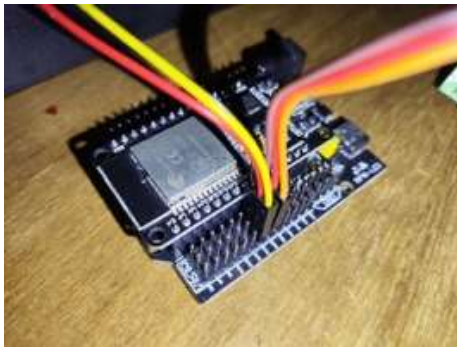


Figure 26. TDS Module Cable Assembly on the Breadboard

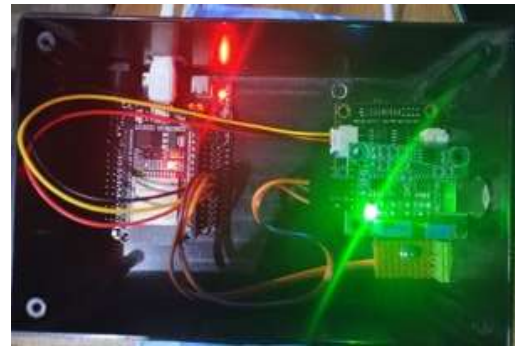


Figure 27. ESP32 Microcontroller Constructed

Next following step which shown on Figure 26 is to connect the VCC (power supply) pin of the TDS sensor module to the breadboard. This is done using a red jumper wire. The red wire is connected to row D33 with the V code on the breadboard, ensuring that the TDS module receives a stable power supply for consistent and accurate operation. The hardware display after assembly and powering on which shown on Figure 27 will show all components properly connected. The pH, TDS, and temperature sensor modules will be connected to the ESP32 microcontroller via the breadboard using the appropriate jumper wires. The ESP32 microcontroller will also be connected to the required power supply.

### 3.6. Testing

In testing, the author compares the quality of branded drinking water with drinking water sourced from refill water depots. The author uses various sensors, such as pH sensors, temperature sensors, and TDS (Total Dissolved Solids) sensors, to measure and analyze water quality parameters. The data obtained from this device helps determine whether drinking water from refill depots meets the same quality standards as branded drinking water. This testing aims to provide accurate information regarding the safety and quality of the water consumed by the public.

Table 1. Testing

No	Water Type	pH	TDS	Temp	Expected Result	Testing PIC (tester)	Actual Result
1	Branded Drinking Water	7.33	151	26.15	Parameter are met and it is safe to consume	Author	Pass
2	Depot A	6.92	125.03	27.06	Parameter are met and it is safe to consume	Author	Pass
3	Depot B	8.12	93.21	26.91	Parameter are met and it is safe to consume	Author	Pass
4	Depot C	7.92	102.92	26.06	Parameter are met and it is safe to consume	Author	Pass
5	Depot D	5.96	137.43	27.25	Parameter are met and it is safe to consume	Author	Pass
6	Depot E	6.76	112.01	27.13	Parameter are met and it is safe to consume	Author	Pass
7	Depot F	7.21	124.44	27.00	Parameter are met and it is safe to consume	Author	Pass

## 4. CONCLUSION

The research successfully implemented Internet of Things (IoT) technology for water quality monitoring systems in drinking water depots in Bitung City. The system uses pH, TDS,

and temperature sensors connected to the ESP32 microcontroller to collect real-time water quality data and send it to a cloud-based server. The monitoring system is accessible through a website with login/logout features for data security, as well as providing data visualization in the form of tables and graphs that make it easy for users to monitor water quality conditions. The research benefits the Bitung City Government in ensuring that drinking water deposits comply with established water quality standards and contributes to the application of IoT technology in water quality monitoring that can drive further research in this field.

The authors also compared the results of tests on Brand Mineral Water performed in this study with related studies. The results show that there is a significant difference in the value of TDS between Brand Mineral Water tested in the study with the result of previous studies. However, there were no significant differences in pH and temperature values between the two studies. To improve the accuracy and coverage of water quality monitoring, it is recommended to add sensors that can detect specific contaminants such as microorganisms or specific chemicals. It is also important to ensure that WIFI connectivity is available throughout the area covered by the monitoring system to avoid problems in data transmission. Enhanced cooperation with the Health Service and the Capital Plantation & Integrated Services Unit of Bitung City is essential to ensure that this monitoring system can be integrated with existing regulatory procedures. Periodic evaluation of the performance of the monitoring system and collection of user feedback are essential for further optimization. By implementing these recommendations, the water quality monitoring system developed could be more effective and provide greater health benefits for the public in Bitung City.

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