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Application of IoT in Measuring Consumption Water Quality in Water Sources

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Abstract

Drinking water quality that is not accurately monitored can pose serious health risks, especially in rural areas such as Tanambanas Village which have geological conditions containing high levels of lime. Based on the results of observations, the people in this village still use traditional methods to assess the feasibility of water, without involving scientific measurements of important parameters, namely pH and Total Dissolved Solids (TDS). To answer this problem, this study aims to design and implement an Internet of Things (IoT)-based water quality monitoring system that is able to evaluate the feasibility level of drinking water automatically and in real-time. The developed system uses an ESP32 microcontroller integrated with a pH sensor and a TDS sensor as the main input. The data obtained from the sensors is processed using Mamdani's fuzzy logic to determine the level of water feasibility in three categories, namely Feasible, Less Feasible, and Unfeasible. The output of the system is displayed locally via a 20x4 LCD, LED indicator, and buzzer, as well as remotely via the smartphone-based Blynk app. The test results show that the system is able to provide water quality information quickly, accurately, and easily accessible to the public. This system also provides early warning if the water does not meet the set quality standards, so that it can be the basis for decision-making to carry out additional filtration. Thus, this system is expected to increase public awareness and accuracy in assessing the feasibility of daily drinking water.

Keywords: *IoT, water quality consumption, pH sensor, TDS sensor, fuzzy Mamdani.*

1. Introduction

Advances in information and communication technology have had a significant impact in various fields of life, including the environment and health. One of the rapidly developing technologies is the Internet of Things (IoT), which is a concept where physical devices can connect to the internet to exchange data automatically. This technology has great potential in supporting real-time environmental monitoring, including in terms of monitoring safe and decent drinking water quality. The use of IoT in water monitoring systems can be an effective solution, especially in areas that do not have adequate water quality control systems.

Water is one of the basic human needs that is very vital for health and survival. However, not all water sources are suitable for direct consumption. Based on the Regulation of the Minister of Health No. 492/Menkes/Per/IV/2010, suitable drinking water must meet certain parameters, such as tasteless, colorless, odorless, and have a pH value between 6.5-8.5 and a maximum Total Dissolved Solids (TDS) content of 500 ppm/L. Unfortunately, many people in rural areas have not been able to test these parameters due to limited equipment and lack of technical knowledge. As a result, they often use water based solely on physical observation.

Tanambanas Village is one of the areas that has geological conditions in the form of coral soil. This causes well water in the area to tend to contain quite high levels of lime. Based on interviews with local communities, it is known that the water quality assessment process is still carried out traditionally by residents taking water from drilled wells and holding it in large containers, and letting it sit for a few hours so that the lime can settle. Although this method has become the norm, the method does not guarantee that the water consumed is completely safe in terms of chemical content, because it is not followed by accurate measurements of pH and TDS values.

The lack of public understanding of the quality of water consumed every day is one of the main problems that can have an impact on health. One of the risks that may occur is kidney stone disorders due to the high content of lime in water that is not detected without a measuring device. The absence of water quality monitoring tools or systems causes people to rely only on physical observations so that they are not accurate in making decisions to consume water that are not based on objective data.

Based on the description of the problems that have been explained, the researcher proposes the design and development of an Internet of Things (IoT)-based water quality monitoring system with Mamdani's fuzzy logic approach. The system is designed to measure pH and Total Dissolved Solids (TDS) parameters automatically and in real-time. The measurement data from the sensor will be processed using the Mamdani fuzzy method to determine the feasibility level of water in three categories, namely feasible, less feasible, and unfeasible. The results of the evaluation will be displayed through visual and digital indicators, such as LCD screens for local display and Blynk IoT applications for remote monitoring. The information obtained from this system can be used as a basis for the public to take follow-up action by conducting additional filtration using filter tools, to ensure that the water is completely safe to consume in accordance with applicable health standards.

2. Literary Studies

2.1. Water Resources

Water is an essential necessity for the survival of all living things, including humans, animals, and plants. About 70% of the human body is made up of water, so the quality of the water consumed has a direct impact on health and well-being. However, access to clean water that meets health standards remains a global challenge, especially in rural and remote areas. One of the problems that often occurs is the high level of lime in drinking water, which if exceeded 500 mg/L is categorized as hard water or hard water and can cause health problems such as kidney stones and skin irritation. In addition, the pH parameters of the water are also very important; The pH scale ranges from 0 to 14, with a range of 6.5 to 8.5 considered neutral and safe to consume, while values below 6 indicate acidic conditions and above 8 indicate alkaline conditions. A mismatch in pH levels can affect the corrosive properties of water, mineral solubility, and increase health risks if consumed continuously [1]

2.2. Internet of Things

Internet of Things (IoT) is a concept created to increase the benefits of an internet network that stays connected continuously. This concept allows us to connect to machine equipment and other physical objects with a network of sensors and actuators to generate data and manage its own performance. Thus, these machines can collaborate and even act on new information obtained independently [2]

The term " *Internet of Things*" consists of two main words, namely "*Internet" which* regulates and connects connectivity, and "*Things*" which means objects or devices. In simple terms, IoT involves "*Things*" that can be connected to each other to collect and transmit data to the internet. This data can also be accessed by other "*Things*". Certain objects can send data over a network wherever we are without human-to-human interaction or human-to-human interaction with a computer device

2.3. Arduino IDE

The Arduino IDE is an open-access software that supports the creation of program code as well as the uploading of the code to a microprocessor. In addition, the Arduino IDE comes with a compiler for C or C++ languages. The main goal is to make it easier to program for different types of microprocessors.

The Arduino Programming Language is the dominant language used in creating programs for Arduino boards. The Arduino programming language is derived from the C programming language. Since it comes from the C programming language, the Arduino programming language has a lot in common, although there are some changes. The Arduino system is an open-source system in terms of both hardware and software.[3]

2.4. ESP32 Microcontroller

The ESP32 microcontroller is a low-power, low-cost System on a Chip (SoC) developed by Espressif Systems, a semiconductor company based in Shanghai, China. The ESP32 is very popular in various Internet of Things (IoT) projects due to the integration of dual-mode Wi-Fi and Bluetooth connectivity in it. The device has a dual-core CPU, adequate memory, as well as multiple General Purpose Input/Output (GPIO) pins that allow connection with various sensors and actuators. Its main function is to read data from sensors, process them, and send them to cloud platforms or other devices over wireless networks [4]

2.5. *Bread cutting board*

2.6. Hydrogen Potential *(pH)* Sensor

Sensor pH is an electronic device used to measure the acidity or alkalinity (alkalinity) of a solution based on the concentration of hydrogen ions (H^+) contained in it. The pH value is expressed on a scale of 0 to 14, where a pH value of less than 7 indicates acidic properties, pH equal to 7 is neutral, and a pH of more than 7 is alkaline. pH sensors generally consist of glass electrodes that are sensitive to hydrogen ions and a reference electrode that serves as an electrical potential comparator. In use, this sensor produces an output in the form of an analog voltage which is then converted into a pH value through a calibration process [5]

2.7. *Sensor Total Dissolved Solids* (TDS)

Sensor *Total Dissolved Solids* (TDS) is a sensor used to detect solid particles dissolved in water or other liquids. These solid particles can be organic or non-organic compounds, such as salts, minerals, heavy metals, or chemical residues. The higher the TDS value detected, the more solute content in the water, which often causes the water to appear more cloudy. On the other hand, if the TDS value is low, then the water tends to be clearer and cleaner. The TDS value is usually expressed in ppm (parts per million) and is one of the important indicators in assessing the purity and feasibility of water for use or consumption [6]

2.8. *Liquid Crystal Display* (LCD)

LCD is a display screen used in IoT devices to display information directly to users. In IoT projects, LCDs are often used to display sensor data in real-time so that it is easy to read without the need to access a computer or the internet.

2.9. Blynk

Blynk is an IoT Cloud platform developed for iOS and Android applications, which functions to control Arduino, Raspberry Pi, and similar boards over an Internet connection. To create an attractive graphical interface, Blynk provides a digital dashboard that can be customized with various widgets. It is very easy to use and only takes about 5 minutes. Blynk allows online creation of tools with the concept of the Internet of Things because it is not tied to a specific microcontroller or shield, such as the Arduino Wemo D1 mini and Raspberry Pi, via a Wi-Fi, Ethernet, or ESP32 chip connection [7]

2.10. Cable Jumper

Cable *Jumper* It is an electrical cable that has an electrical pin at each end that allows the user to connect two components involving the Arduino without soldering. The jumper cable is the component connector at the end of the cable. There are two types of connectors, namely male connectors and female connectors. Jumper cables are commonly used on boards *Bread Cutting Board* and tools *Prototyping* So it is easier to string the network. Cable *Jumper* It works like a regular wire—conducting an electric current from one point to another. The inside of the cable is a conductor wire (usually copper) coated by a plastic insulator. When a wire is connected from one pin to another (e.g. from a digital pin in an Arduino to a bread board), it creates a conductive path for electrical flow or digital signals.[8]

2.11. Fuzzy logic

Fuzzy Logic is one of the branches of Artificial Intelligence science that allows computers to mimic human intelligence. Its main purpose is to enable computers to perform tasks that normally require a high level of human intelligence. Fuzzy logic functions to imitate human intelligence in performing actions and apply it to various devices such as robots, vehicles, household appliances, and others. This technique is usually used in situations where there is uncertainty, inaccuracy, noisy, and other elements that are not precise. Fuzzy logic helps combine highly accurate machine language with human language that focuses more on the interpretation or meaning of information [9]

2.12. Fuzzy Mamdani

Fuzzy Mamdani logic is one of the fuzzy inference system methods introduced by Ebrahim Mamdani (1975). This system is suitable for making decisions in uncertain or ambiguous conditions, using IF–THEN-based linguistic rules. It handles continuous input values by translating them into membership functions, and then processes them through the processes of fuzzification, fuzzy inference, aggregation, and defuzzification to produce outputs that are easy for humans to understand [10]

3. Research Methods

This research uses a prototyping method approach, which aims to design and build an Internet of Things (IoT)-based drinking water quality monitoring system. The system utilizes ESP32 **microcontrollers,** pH sensors, and TDS sensors to detect water quality in real-time, then classifies the water feasibility status using Mamdani's fuzzy logic into three categories, namely Feasible*,* Less Feasible*, and* Unfeasible.

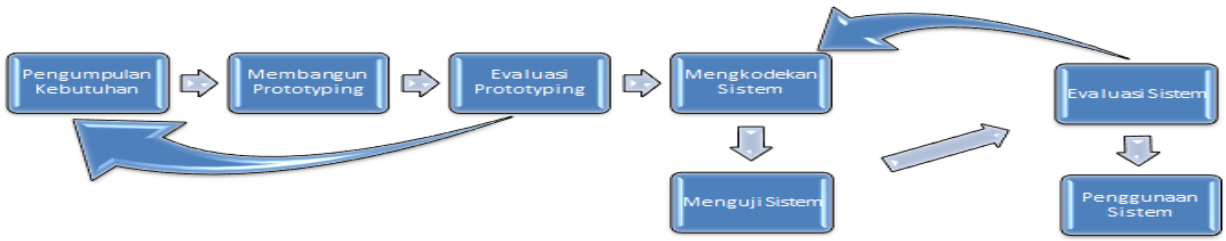

Fig. 1: Research Flow

Figure 1 is a flow of system development methods using the Prototype **approach,** which is used in this study to design and build an Internet of Things (IoT)-based water quality monitoring system. The stages start from the collection of needs, which is the process of identifying problems and needs of users in the field. Furthermore, the stage of building an initial prototype of the system based on these needs is carried out, then a prototype evaluation is carried out to assess whether the system meets the expectations of users. If it is not appropriate, the process returns to the initial stage for improvement. Once the prototype is approved, it proceeds to the system coding process, which is the creation of the main program using the Arduino IDE. The program that has been created then goes into the system testing stage to ensure that all

components are working properly and the results are accurate. After testing, the system enters the final evaluation stage, where a thorough assessment of the system's functionality and effectiveness is carried out. If it passes the evaluation, then the system is ready for real use by users**.** This approach allows the system to be developed iteratively and responsive to the needs of the user.

3.1. System Architecture Diagram

Block diagram design is a visual image used to illustrate the structure and function of the internet of things's free water quality monitoring system to detect the quality of drinking water.

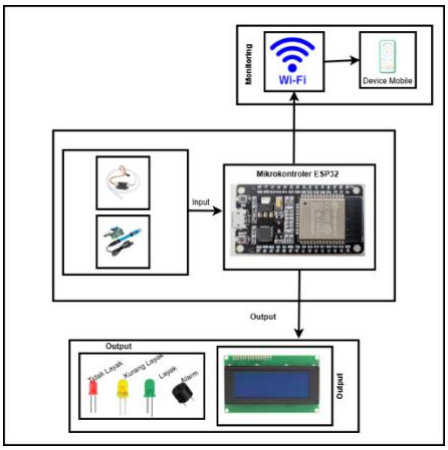

Fig. 2: System Architecture Diagram

Figure 2. The architecture diagram above illustrates a water quality monitoring system designed based on the Internet of Things (IoT). The system works by reading two important parameters of the water, namely the acidity level (pH) and the amount of dissolved solids (TDS). For this reason, two main sensors are used: pH sensors and TDS sensors that are directly connected to the water source. These two sensors then transmit data to the ESP32 microcontroller, which is the brain of the system. Here, the data will be processed using Mamdani's fuzzy logic method to assess whether the water is suitable for use or not. The results of this data processing are displayed locally through LCD screens and colored LED lights. The green LED lights up if the water is declared viable, yellow for less than the viable, and red for the water that is not viable. If water conditions are dangerous, a buzzer or alarm will also sound as a form of warning. In addition to being displayed directly, this information is also sent to the mobile application via the internet network. That way, users can monitor water quality conditions in real time through smartphones.

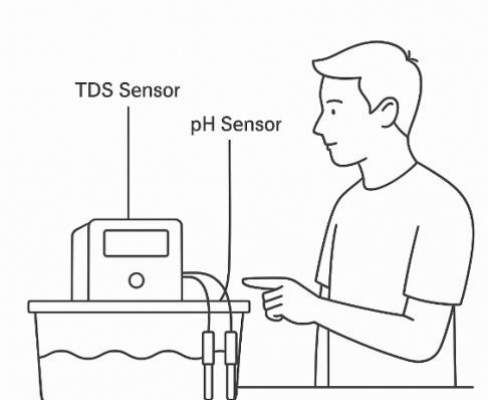

Fig. 3: System Placement Sketch

Figure 3. showing the physical design of the Internet of Things (IoT)-based water quality monitoring system that has been implemented. All the main components of the system, namely the ESP32 microcontroller, pH sensor, TDS sensor, indicator LED, and buzzer, are placed in a box as the center of the system. At the top of the box, a 20x4 LCD is installed to display the pH value, TDS, and water feasibility status in real-time, so that it can be seen directly by the user. The pH and TDS sensors are connected by wires that are removed from the box and dipped into a container filled with water as a measurement object. The system is designed to be portable and easy to use, and provides results that can be observed directly visually through the LCD display and indicators. The sketch also shows the interaction of users who are monitoring the measurement results, illustrating how the system is used in real life in the field to evaluate the quality of drinking water.

3.2. System Workflow

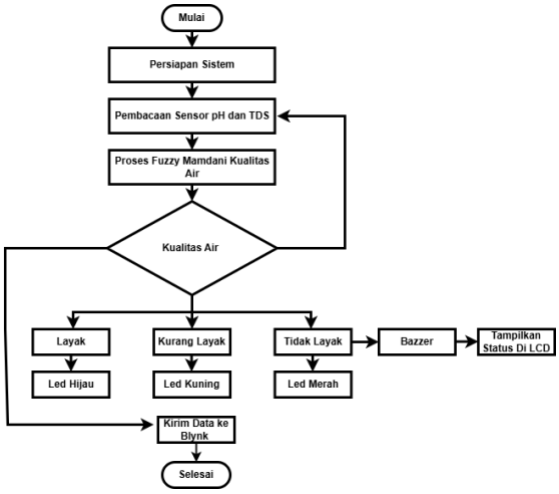

Fig. 4: System Workflow

Figure 4. shows the workflow of the water quality monitoring system that starts with the process of initializing all system devices. Once the system is active, the pH sensor and TDS sensor immediately read the acidity value and the content of dissolved solids in the water. The data obtained from the two sensors is then sent to the ESP32 which acts as the main microcontroller. Furthermore, the data was processed using the Fuzzy Mamdani logic method to evaluate the feasibility of water based on the predetermined fuzzy rules. The results of this process will determine the status of water quality with three categories, namely Feasible, Less Feasible, and Not Feasible. As a form of feedback, the system provides output through LED and buzzer indicators: Green LED illuminates for Eligible status (no buzzer sound), Yellow LED illuminates with a slow buzzer sound for Less Suitable status, and Red LED illuminates with a quick buzzer sound when water is declared Unsuitable. In addition, information such as pH values, TDS, fuzzy scores, and final status are also displayed on the 20x4 LCD directly. The data can also be displayed in the Blynk IoT application, so users can monitor water quality in real-time using mobile devices.

3.3 Diagram Skematic

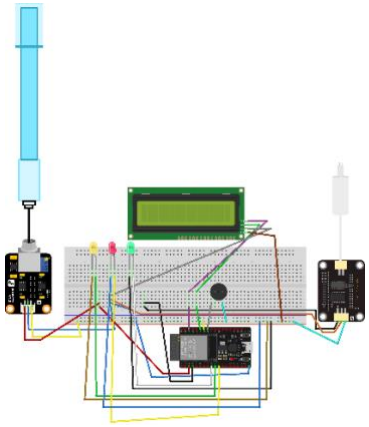

Fig. 5: schematic digrams

Figure 5. shows the design of an IoT-based water quality monitoring system electronic circuit built using a breadboard platform. The system uses an ESP32 microcontroller connected to two main sensors, namely a pH sensor and a TDS sensor, which serves as an input to read water quality parameters. The reading results are displayed on the 20x4 I2C LCD, and the water feasibility status is marked by three LEDs (red for *Not Feasible*, yellow for *Less Feasible*, and green for *Feasible*) as well as a buzzer as a sound indicator if the water is in poor or unsuitable conditions. All components are assembled on a breadboard with a jumper cable connection, and the system is powered via a USB connection to the ESP32. This series shows the real implementation of the design of a water quality monitoring system that is able to provide visual, audio, and digital information in real-time.

Table 1: Schematic Diagram of Tool Table

Hydrogen *pH* Postenial Sensor	VCC connected to ESP32 5V GND connected to GND ESP32	PO connected to GPIO 36 ESP32
Sensor *Total Dissolved Solids* TDS	VCC connected to ESP32 3V GND connected to GND ESP32	A+ connected to GPIO 39 ESP32
Liquid Crystal Display LCD	VCC connected to ESP32 5V GND connected to GND Arduino	SDA connects to GPIO 21 ESP32 SLC connected to GPIO 22 ESP32
LED	Green (+) connected to GPIO 25 ESP32 Yellow (+) connected to GPIO 26 ESP32 Red (+) connected to GPIO 27 ESP32	(-) connected to GND ESP32 (-) connected to GND ESP32 (-) connected to GND ESP32
Buzzer	(+) connected to GPIO 19 ESP32	(-) connected to GND ESP32

4. Results and Discussion

4.1 Analysis

Based on field observations and interviews with the community in Tatambanas Village, the process of assessing the quality of well water for daily needs is still carried out manually, namely by leaving the water to settle so that lime substances settle without any measurement of chemical content such as pH and TDS. This shows the low efficiency and accuracy in the water feasibility assessment process, because people only rely on visuals and habits, not scientific data. As a solution to this problem, a water quality monitoring system based on Internet of Things (IoT) technology is implemented which is able to detect water parameters automatically and in real-time. The system is designed to read pH and TDS values, then process them using Mamdani's fuzzy logic to determine the feasibility status of the water directly. With accurate information displayed in real-time through LCD and Blynk applications, people no longer need to guess water quality. They can immediately find out if the water is suitable for consumption or needs additional filtering. This system helps people make faster and more informed decisions, and has the potential to reduce the risk of health problems due to non-standard water consumption.

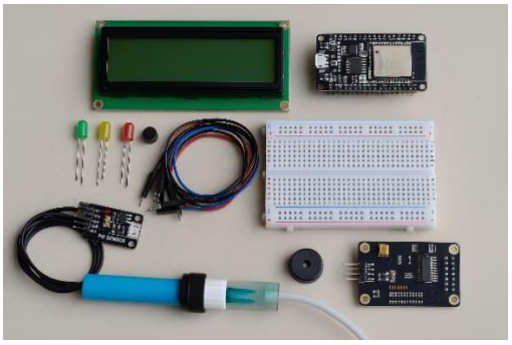

Fig. 6: Hardware Components

The image above is the components of the tool used for drinking water quality measurement. The components consist of 2 sensors, namely pH sensor and TDS sensor, ESP 32 microcontroller, bread cutter, jumper cable, LCD, LED, and Buzzer.

4.2 Planning

The design of an IoT-based water quality monitoring system includes the design of the hardware, system model, and program used to operate all components. The system is designed by integrating a pH sensor and a TDS sensor to detect water quality, as well as an ESP32 microcontroller as a data control center. These components are arranged in a box equipped with a 20x4 LCD at the top as an interface to display the pH value, TDS, and water feasibility status. In addition, the system is equipped with indicator LEDs and buzzers as visual and sound markers based on the status of the water. The system program is developed using an Arduino IDE and is connected to the Blynk IoT platform via a Wi-Fi connection, which allows users to monitor water quality data in real-time through a mobile app. This design aims to provide water quality information in a practical, automatic, and responsive manner in environments that do not have access to modern water monitoring systems.

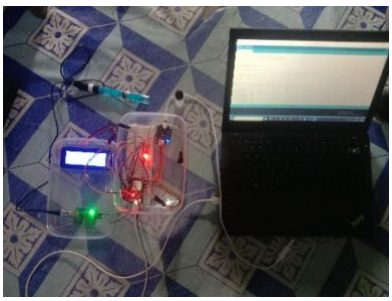

Fig. 7: Tool Array

Figure 7 shows a series of IoT-based water quality monitoring systems assembled using ESP32 microcontrollers, pH sensors, and TDS sensors. All components are connected via a breadboard and jumper cable, with an output of a 20x4 LCD, three indicator LEDs, and a buzzer. The sensor is placed outside the box and dipped in water to detect pH and TDS parameters. The measurement results are processed by ESP32 using Mamdani's fuzzy logic, then displayed locally on the LCD and sent to the Blynk app in real-time via a Wi-Fi connection. This series allows for practical and informative water quality monitoring.

4.3 Implementation

The process of implementing a pre-designed Internet of Things (IoT)-based water quality monitoring system includes the development of programs in the Arduino IDE and user interfaces through the Blynk application. The program was developed using the Arduino IDE to program the ESP32 microcontroller. The program regulates data readings from pH sensors and TDS sensors to detect water quality parameters, then processes the data using Mamdani's fuzzy logic to automatically determine the water feasibility status. The system is also set to display the processing results to a 20x4 LCD and provide a response via indicator LEDs and buzzers. In addition, the system is configured to be able to transmit data in real-time to the Blynk app over a Wi-Fi connection, allowing users to remotely monitor pH, TDS, and water status values. This implementation process ensures that the system can work accurately, responsively, and easily in a community environment.

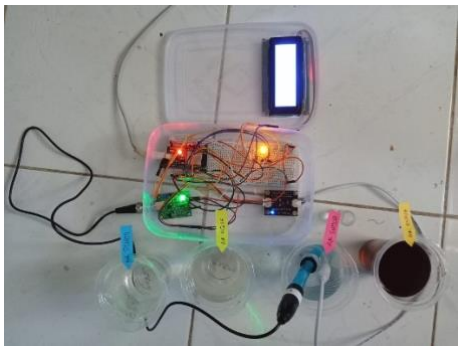

Fig. 8: Implementation of Tools in the bin container

Figure 8. Above is a prototype of an IoT-based water quality monitoring system that has been implemented. This prototype is a physical form of the designed system, integrating all hardware components such as pH sensors, TDS sensors, ESP32 microcontrollers, breadboards, jumper cables, indicator LEDs, buzzers, and 20x4 LCDs. All components are assembled in a transparent box, while the pH and TDS sensors are connected to the outside of the box and dipped in several types of test water, such as PDAM water, Aqua water, well water, and turbid water. This implementation is an important step to ensure that the system can work in real-time, read sensor data accurately, display results on LCD, provide alerts via LEDs and buzzers, and send data to the Blynk application in real-time according to the objectives of the study.

4.4 LCD Testing

Testing is carried out to ensure that the 20x4 LCD can display pH, TDS, fuzzy score, and water feasibility status data in real-time. The test results showed that the LCD was working properly, displaying the data clearly and responsively when the sensor was immersed in water. This display makes it easy for users to immediately see the measurement results without the need to open the application.

Fig. 9: Tamplan Outpu on LCD

In figure 9. above, is the result of monitoring of the system that displays the status of water quality through the LCD according to the command of the control system that has been designed. pH values, TDS, fuzzy scores, and water feasibility status are displayed in real-time, so that the monitoring process can run well according to the program that has been implemented. This display makes it easier for users to read the measurement results directly.

4.1 Blynk Testing

Testing is conducted to ensure that Blynk applications can receive and display pH, TDS, and water feasibility status sensor data in real-time. The system sends data over a Wi-Fi connection from the ESP32 to Blynk. The test results showed that Blynk could display the data well and responsively according to the sensor readings. The water status information is displayed automatically, so users can monitor the water quality remotely.

Fig. 10: Waste Monitoring System Website

In figure 10. above, is the result of monitoring on the system where the Blynk application displays real-time water quality data, including pH values, TDS, and water feasibility status. This display works according to the control system commands that have been designed, so that the monitoring process can run properly and in accordance with the program. Users can see the water condition directly through the app, without having to be at the measurement location.

Table 2: Tool Test Results

Yes	Water Type	pH value	TDS/ ppm value	Score Fuzzy	Eligibility Status	Active LED	Buzzer	Information
1	Well Water	6.40	300	50.00	Less Worthy	Yellow	Active	Water Source of Tatambanas Village
2	PDAM Water	6.90	180	75.00	Proper	Green	Not	Urban Plumbing
3	Bottled Drinking Water	7.50	95	85.00	Proper	Green	Not	Industrial Standards of PT. Aguamor
4	Murky Water	5.50	570	40	Not Eligible	Red	Active	High Lime Cured Water

Table 2. is the result of measuring the quality of drinking water from several types of water sources using an Internet of Things (IoT)-based monitoring system that has been designed with the application of Mamdani's fuzzy logic. The system utilizes pH and TDS sensors to read key water quality parameters in real-time. The data obtained was then processed using Mamdani's fuzzy logic to determine the level of water feasibility which was classified into three categories, namely Feasible, Less Feasible, and Unfeasible. The results of these measurements are not only displayed through the LCD display, but are also sent to the Blynk IoT application as a remote monitoring medium. In addition, the system also activates indicators in the form of LEDs and buzzers as visual and audio warnings based on fuzzy classification results. Through this test, it can be found that the system is able to distinguish water quality based on its type and provide automatic feedback according to the water condition.

4. Conclusion

Based on the results of the design, implementation, and testing of an Internet of Things (IoT)-based water quality monitoring system using Mamdani's fuzzy logic, it can be concluded that the system successfully works according to the set objectives. The system is able to read the pH and TDS values of the water in real-time using pH sensors and TDS sensors, then process them through Mammani's fuzzy logic method to determine the feasibility status of water in three categories, namely Feasible, Less Feasible, and Unfeasible. The results of the assessment are displayed locally via LCD and LED indicators as well as buzzers as visual and sound responses, as well as sent to the Blynk IoT app for remote monitoring via the internet. Based on tests on a wide range of water samples, the system performs well in detecting and evaluating water quality, with fast response, stable reading accuracy, and an informative and accessible user interface. Thus, this system can be a simple yet effective to assist the community in monitoring the feasibility of drinking water in a sustainable manner.

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