Prototype of Household Water Quality Monitoring System by Utilizing Internet of Things

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ABSTRACT

This research aims to develop a household water quality monitoring system using the Internet of Things (IoT) by monitoring water quality parameters such as pH, Total Dissolved Solids (TDS), turbidity, and temperature in real time. The prototyping method in the development of this system allows continuous interaction between developers and users to meet the needs of the system. Data is collected through literature studies and observations to support system development. The results of this study are that every 1 minute, the sensor data is sent to the server, and then the sensor data will be displayed on the web platform; if the sensor data value is not at the predetermined value limit according to Permenkes number 2 of 2023, the displayed value will be red. The data collected by the sensor is sent to the server built with Node.js and stored in the PostgreSQL database. The monitoring results will also be displayed on a 20x4 I2C LCD. The system successfully monitors water quality parameters in real time, with results displayed on a web platform that is easily accessible to users. The implementation of IoT technology in this system provides an innovative solution for increasing public awareness of the importance of clean water quality. With this system, it is expected to create a healthier and safer household environment for families.

I. Introduction

Clean water is one type of water-based resource that humans use for daily purposes such as washing, bathing, and consumption. Clean water must be of good quality and have physical parameters that meet environmental health standards commonly used by the community [1]. Indonesians should have access to clean water. It is used for various functions, such as drinking, cooking, bathing, and washing. However, it is not easy to obtain clean water in areas far from natural water sources, especially for those who rely on private wells. Often, most water sources derived from these wells exhibit turbidity and pH levels that deviate from the standard threshold [2]. One of the entities responsible for enforcing water quality standards for its clients is the PDAM. PDAMs, also recognized as Regional Water Supply Companies, operate as government organizations with jurisdiction over water treatment and purification procedures [3]. Pacitan residents use various sources of clean water, including wells, mountain springs, and PDAM. However, there are issues of contamination during the rainy season and the need for more output to meet daily demand in the dry season. Although there is a PDAM system in Pacitan, there still needs to be a general problem of inadequate access to clean water, especially in highland and coastal communities [4].

The karst region of Pacitan exhibits a unique topography consisting of soluble carbonate rocks with secondary porosity [5]. The attributes of karst areas are particularly prominent in areas characterized by high CaCO3/dolomite CaMg (CO3) 2 lime contents. Cracks in the breccia allow water to move through to accelerate the dissolution process. The dissolution potential of limestone increases the alkalinity level and concentration of lime in the water, resulting in water hardness [6]. Water used for clean water needs to meet certain pH and TDS criteria in accordance with established

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standards to ensure a satisfactory experience for all individuals who consume it. Suppose any of these criteria still need to be met. In that case, it is possible that the water could be deemed unfit due to the presence of various chemical substances, minerals, or organic compounds that could pose a threat to human health [7]. The turbidity level of water is measured in Nephelometric Turbidity Units (NTU), which are measured by a turbidimeter. High turbidity levels not only increase the risk of gastric diseases in humans but can also reduce the ability of water to be penetrated by light, stop the photosynthesis of aquatic plants, and reduce the oxygen content in the water [8].

Water quality is strongly influenced by temperature, which should be equivalent to air, or at least 20°C. Suppose the water temperature is higher or lower than the air temperature. In that case, it indicates the presence of certain substances (such as high levels of dissolved phenols) or certain processes (such as microorganisms producing energy from processing organic matter) [9]. Water quality for household hygiene and sanitation purposes must meet established standards, namely for pH levels between the ranges of 6.5 - 8.5, TDS (Total Dissolved Solid) levels < 300 mg/L, then for turbidity < 3 NTU (Nephelometric Turbidity Units), and normal temperature is ± 3 ° from the air temperature where the water is located [10].

The purpose of this research is to build a system that can monitor household water quality in real-time measured by pH, TDS, turbidity, and temperature levels using the Internet of Things (IoT) to integrate sensors and use ESP32 as a microcontroller. Then, the information from the monitoring results of pH, TDS, turbidity, and temperature levels will be displayed on the LCD in the form of a web platform. By applying IoT technology to monitor domestic or household water quality, this system will be an innovative solution that can provide benefits. Through the application of this technology, it is expected to create a healthier and safer household environment for families.

II. Method

A. System Development Method

The author used the prototype method in this study, which is a commonly used system development technique. Prototyping also allows developers and users to interact with each other during the creation process, allowing developers to model the software to be created [11] easily. Figure 1 depicts the steps in performing the prototype method.

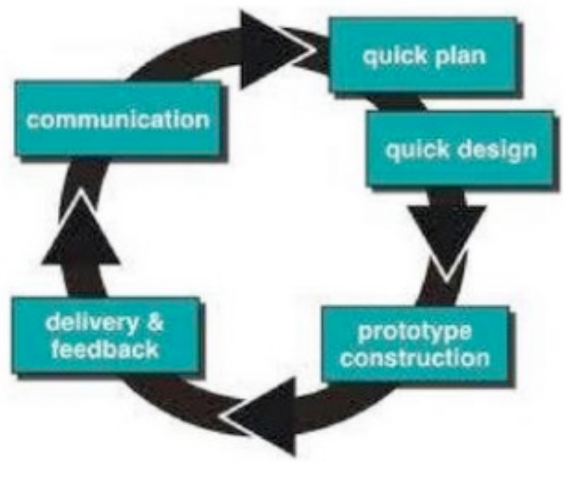

Fig. 1. Prototype Method [11]

B. Data Collection Method

In collecting data, the author conducts literature studies and observations. A literature study is an observation to find data in accordance with predetermined problems that can be obtained from appropriate books, journals, articles, and theses. The author made observations by taking samples of Pacitan Regency PDAM water in the Punung Village area.

C. System Design

Design involves the operational steps in the data processing process and procedures to support system operations. The purpose of design is to provide a clear description or process flow of the system to be built so that it can properly process data [12].

1. Block Diagram

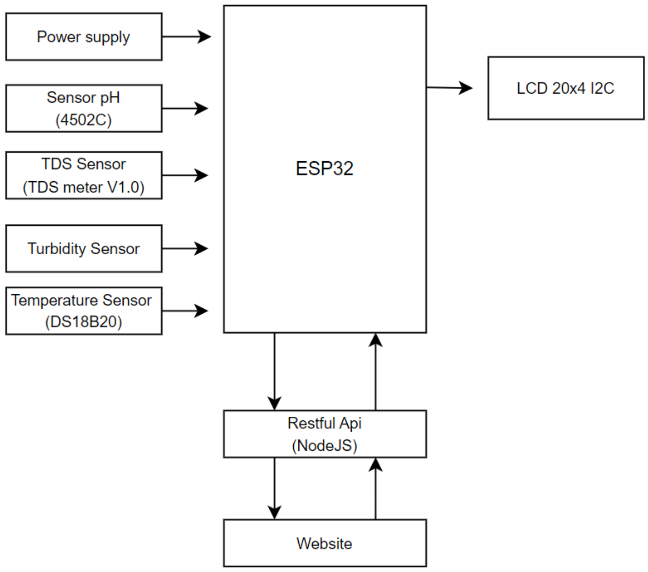

Fig. 2. Block Diagram

From the block diagram above, the system framework above can be explained as follows :

a. The 5V power supply used in this tool can be taken from a laptop USB or a cellphone charger.
b. The pH sensor has a voltmeter placed on the reference electrode (unchanged) and an electrode that shows the pH level [13].
c. The TDS sensor is an Arduino-compatible TDS meter kit that measures water TDS levels and reflects water cleanliness [14].
d. Turbidity sensor measures the turbidity of water to determine water quality [15].
e. The Temperature Sensor consists of three wires: red (+), yellow (data), and black (-) [16].
f. ESP32 is an ideal component for Internet of Things (IoT) projects because it can control electronic devices over a wireless network [17].
g. Restful API is a communication tool that uses the HTTP protocol to exchange data [18].
h. A website is an information media that provides various facilities for users to share information [19].
i. 20X4 I2C LCD produces a good character display, with 20 characters per line up to 4 lines [20].

2. System Workflow

The ESP32 will send the data to the server built with Node.js. This server will receive data from the ESP32 and process it through a controller connected to the PostgreSQL database. Node.js uses various modules to manage and process URL requests from the application. The data sent by the ESP32 will be stored in the PostgreSQL database. Once the data is stored, the controller will call the data from PostgreSQL and prepare it for display in the application views. These views will then display the data in real time or according to user needs. Figure 3 illustrates the system workflow.

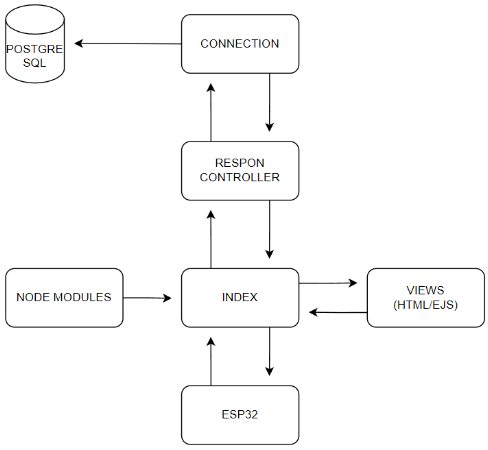

Fig. 3. System Workflow

3. Flowchart

Figure 4 explains the flowchart of sensor data visualization; the database used is PostgreSQL. First, the user logs in to the website, and then, after successfully logging in, the Dashboard page displays. There are three menus: Profile, Help, and Logout.

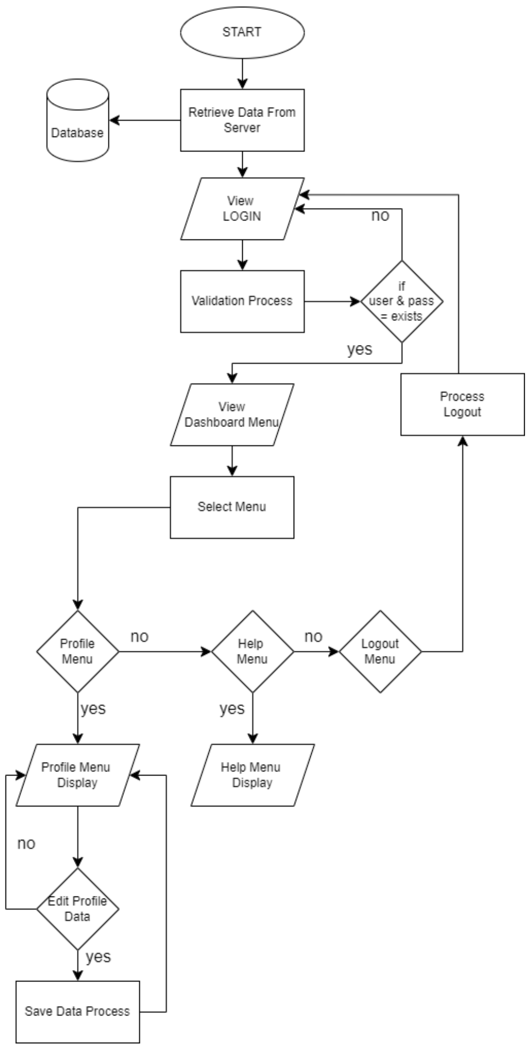

Fig. 4. Sensor Data Visualization Flowchart

Figure 5 explains the flowchart of the sensor readings made. First, the user is asked to connect to Wifi with Wifi Manager, and then after that, the new tool can be used. This water quality monitoring tool will send data to the server every 1 minute, and then the data will be displayed on the 20x4 I2C LCD screen

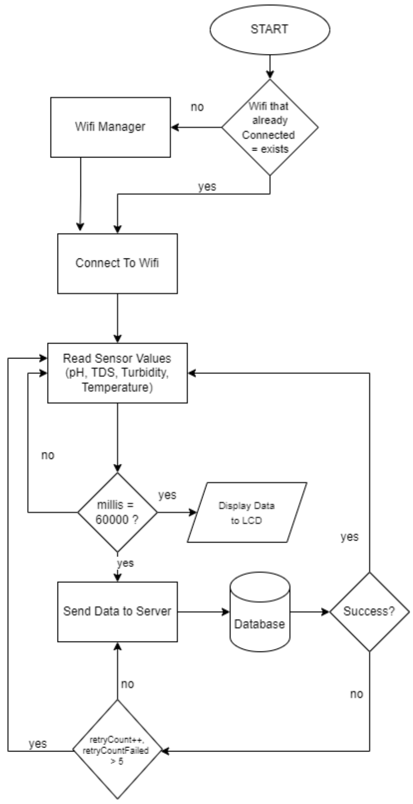

Fig. 5. Sensor Reading Flowchart

4. Sensor Reading Schematic Design

The design of the IoT-based water quality monitoring tool is that the ESP32 component is assembled with other sensor components. In this tool, a circuit description is made with pH-4502C sensor components, TDS meter V1.0 sensor, turbidity sensor, DS18B20 temperature sensor and 20x4 I2C LCD. The series of components as shown in Table 1, Table 2, Table 3, Table 4, Table 5.

Table 1. pH-4502C Sensor Circuit

pH–4502C Sensor	**ESP32**
G (GND)	GND
V+ (VCC)	3V3
Po	GPIO34

Table 2. TDS Sensor Circuit

TDS Sensor	**ESP32**
- (GND)	GND
+ (VCC)	VIN
A	GPIO35

Table 3. Turbidity Sensor Circuit

Turbidity Sensor	ESP32
G (GND)	GND
V (VCC)	3V3
A	GPIO33

Table 4. Temperature Sensor Circuit

Temperature Sensor	ESP32
G (GND)	GND
V (VCC)	3V3
A	GPIO33

Table 5. 20x4 I2C LCD circuit

20x4 I2C LCD	ESP32
GND	GND
VCC	VIN
SDA	GPIO21
SCL	GPIO22

Figure 6 is the sensor reading schematic. In this schematic, it can be seen that each sensor has its own connection line that leads to the ESP32.

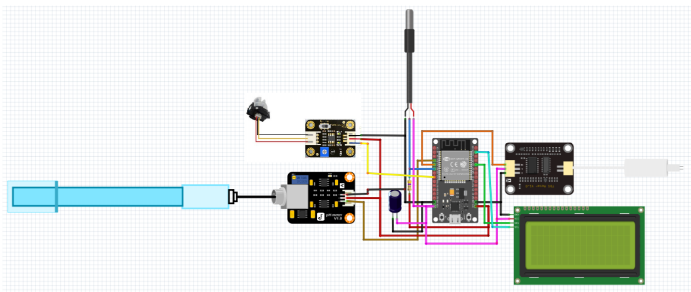

Fig. 6. Sensor Reading Schematic

III. Results and Discussion

All forms of input data from sensors and forms of output from existing components are taken to be analyzed in this section, which shows that the tool has worked according to the author's wishes. Figure 7 is the result of the installation of components on the multi box.

Fig. 7. Component Installation on Multi Box

In Figure 8 all sensors are installed on the pipe in order to calculate the parameters of pH, TDS, turbidity and temperature in the water collected in the pipe.

Fig. 8. Sensor Installation on Pipe

Then Figure 9 is the installation of the tool on the water channel, the water will be collected in the pipe then the sensor will calculate the value according to the sensor.

Fig. 9. Installation of Tools on Waterways

This water quality monitoring tool will read data from pH, TDS, turbidity and temperature sensors which then the data will be sent to the server and then displayed on a website that has been created using a Node.js server and using a PostgreSQL database. The Dashboard menu will display data from the pH, TDS, turbidity and temperature measurements. If the measurement value is not within the normal limits, it will be colored red as regulated by Permenkes Number 2 of 2023 concerning the limits for pH, TDS, turbidity and temperature in Hygiene and Sanitation purposes. The user can also filter the search according to the date and time that has been selected. Can be illustrated in Figure 10.

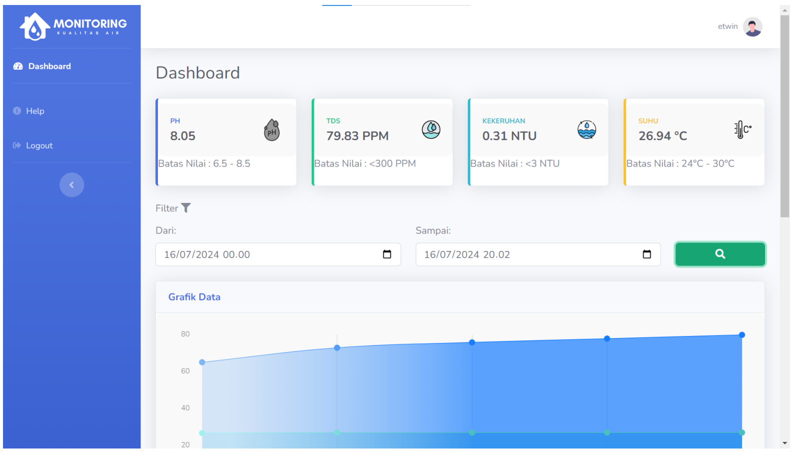

Fig. 10. Website Dashboard Menu

Users can print data from the table displayed and can download into Excel and PDF formats. The following display is shown in Figure 11.

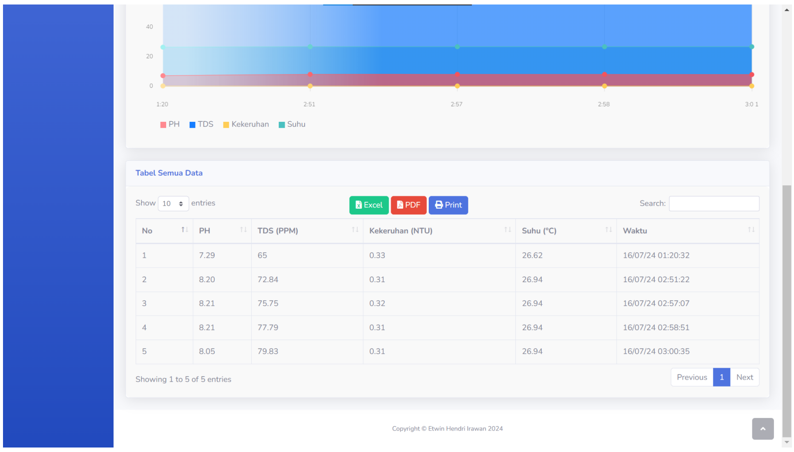

Fig. 11. Website Dashboard Table

Table 6 explains the testing of sensor components contained in this water quality monitoring tool.

Table 6. Sensor Testing

Component	Testing	Expected Results	Results
pH–4502C Sensor	pH of water	The sensor can measure the pH of water in 1 minute and can send data to the server	Successful
TDS Meter V 1.0 Sensor	Substances dissolved in water	The sensor can take measurements of dissolved substances in water (TDS) in 1 minute and can send data to the server	Successful
Sensor Turbidity	Water turbidity	The sensor can measure water turbidity in 1 minute and can send data to the server	Successful
temperature sensor DS18B20	Water temperature	Sensors can measure water temperature and can send data to the server	Successful

In Table 7, it can be explained about sensor accuracy testing, to measure the accuracy of pH, TDS and Temperature sensors, the author uses a pH meter and TDS / Temperature meter as a comparison tool. Then for turbidity sensor testing, the author uses distilled water with a value of <0.5 NTU as a reference value or comparison value.

Table 7. Sensor Accuracy Testing

Testing	Result on sensor	Comparison result	Accuracy
pH of water	7,29	7,9	92,3%

Testing	Result on sensor	Comparison result	Accuracy
Water TDS	65 PPM	55 PPM	81,8%
Water turbidity	26,62 °C	26 °C	97,6%
Water Temperature	0,33 NTU	0,5 NTU	66%

Figure 12 is a pH meter that measures the pH value used for calibrating the pH-4502C sensor. In Figure 13 is a TDS / Temperature Meter this tool is used for calibrating TDS and water temperature.

Fig. 12. pH Meter

Fig. 13. TDS / Temperature Meter

The following is the overall tool test described in Table 8.

Table 8. Overall testing

Time	PH	TDS	Turbidity	Temperature
01:20 16/07/2024	7,29	65 PPM	0,33 NTU	26,62°C
02:57 16/07/2024	8,20	72,84 PPM	0,31 NTU	26,94°C

Time	PH	TDS	Turbidity	Temperature
02:57 16/07/2024	8,21	75,75 PPM	0,32 NTU	26.94°C
02:58 16/07/2024	8,21	77,79 PM	0,31 NTU	26.94°C
03:00 16/07/2024	8,05	79,83 PPM	0,31 NTU	26.94°C

In this research, the author uses the ESP32 microcontroller which functions as the control center of the various sensors used, such as the pH-4502C sensor, TDS V1.0 meter, turbidity sensor, and DS18B20 temperature sensor. In research by [21] the sensors used in monitoring water quality are pH, turbidity, TDS and temperature sensors, data from these sensors will be displayed to the 16x2 I2C LCD, and use ATMega 328 as a microcontroller. While in this research there are several developments, such as the use of ESP32 which can connect to WIFI so that it allows sending data to the server every minute in real-time, then in displaying data using a web platform and I2C 20x4 LCD. In the research from [22] shows the reliability of ESP32 in IoT systems gives confidence to its adoption as a key component. In this study, the parameters measured are pH, TDS, turbidity and water temperature, then for the limit of the standard value of each parmeter taken from Permenkes number 2 of 2023 concerning hygiene and sanitation.

IV. Conclusions and Suggestions

A. Conclusions

The study successfully designed and tested an IoT-based Water Quality Monitoring Tool using pH-4502C, TDS meter V1.0, turbidity, and DS18B20 temperature sensors, all integrated with an ESP32 microcontroller. The use of a web platform and 20X4 I2C LCD to display monitoring results makes it easier for users to access information from real-time water quality measurements. The results of testing the overall tool suggest that the water in the Pacitan Regency PDAM in the Punung Village area is within the safe limit according to the range of values contained in Permenkes Number 2 of 2023. The use of an ESP32 microcontroller and IoT technology proved effective in integrating various sensors and sending data to the server. This allows continuous and real-time monitoring of water quality; data from sensors is sent to the server every minute. If the value displayed on the web platform is outside the predetermined value according to the value in Permenkes Number 2 of 2023, the displayed value will be red. The implementation of this IoT-based water quality monitoring system provides an innovative solution to increasing public awareness of the importance of clean water quality. This system is expected to create a healthier and safer household environment for families.

B. Suggestions

1. Further development can be done by adding notification features through digital messages to notify users if water quality parameters are outside normal limits.
2. Further calibration of the turbidity sensor is needed to obtain a more accurate value.
3. Integration with mobile applications can provide easy access and control for users in monitoring water quality.

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