Research Article

Smart Water Tank for Control and Monitoring Based on IoT Technology

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Abstract:
This research is a Research and Development study, developing a tool to overcome water wastage and monitor water conditions in the tandon. This tool uses water flow, pH, and turbidity sensors connected to a telegram bot and LCD. This research applies a prototype model that includes problem identification, needs analysis, literature study, tool design, program coding, tool installation, and tool testing. Functional testing of the tool shows that all components function correctly. From the test results obtained comparison test of measuring water volume entering using the water flow in the sensor and measuring cup results in an MPE of 0.067, while measuring water volume exiting using the water flow out the sensor and measuring cup results in an MPE of 0.048. Comparison test of measuring pH using a pH sensor and pH meter results in an MPE of 0.067. Measuring water turbidity level using a turbidity sensor shows the ability of the sensor to measure turbidity on various water samples. The telegram bot, LCD monitoring, and automatic water pump systems work well.

Keywords: Smart water tank, turbidity, pH, water flow sensor, NodeMCU

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1. INTRODUCTION

Water is a basic human need to support daily activities now and in the future [1]. Living creatures in this nature need water to survive. Almost 75% of the human body is water, so no one can survive for 4-5 days without drinking water [2]. Water use in daily life covers various fields ranging from household environmental to factory needs. Therefore, it is essential to maintain water availability for our daily lives to remain normal. Besides, knowing the condition and quality of the water to be used is also essential. Poor water quality is one of the causes of disease, especially diseases that interfere with digestion [3]. The requirements issued by the Minister of Health of the Republic of Indonesia No. 32 of 2017 related to water that can be used for hygiene sanitation include pH with the highest permissible level of 6.5-8.0, while the turbidity value is 25 NTU (Nephelometric Turbidity Unit), [4].

People place water tanks on the top of the house using gravity so that the water flows swiftly [5]. When filling water into the tank, they still use a manual way to channel it. This often causes waste if the user forgets to turn off the water pump when the water tank is full and causes the water flow to continue. In addition, users also have difficulty controlling the condition of water cleanliness quality in the reservoir. In line with the times, information technology is increasingly sophisticated.it is known together that information technology can help reduce the burden of the government in terms of saving electrical energy resources or other resources, such as water resources, that can be combined with electronic circuits.

Several efforts have been previously made in research to overcome these problems. A study on the Design of Automatic Tanks with an SMS Gateway Monitoring System Based on Arduino found that the accuracy level of the pump controller control circuit works well in controlling the height and volume of water in the storage tank with a time difference of 10.17 seconds (s) SIM800L also works well by sending data to users via SMS [6]. Whereas in research with the title Water Level Control Simple Automatic System in Water Tanks in Residential Areas, it was found that after testing, this simple Water Level Control device has accuracy in determining when the water pump should turn on or off, so this device is quite effective and efficient in saving water and electricity in the residential area. However, in the study, no testing was done on the durability of each material used, so further research needs to be done on this matter to find out the economic life of the device [7]. Based on the above explanation, an idea emerged to design a device that is expected to overcome these problems with the title "Smart Water Tank for Control and Monitoring Based on IoT Technology." The device to be designed is helpful to overcome water wastage and can monitor the water condition in the tank, such as knowing the volume of water entering and exiting the tank, measuring the pH and turbidity of water [19,20,21] in the tank that can be monitored through LCD and telegram bot. This system is expected to work well according to the initial plan so that this device can be helpful in daily life [18].

2. THEORY

A. Review of Related Literature

The following research related to this research can be seen in the previous research in 2021, titled Design of Water Storage System Using Automatic Top Tank Based on Microcontroller. This research utilizes Arduino Nano as a microcontroller, an ultrasonic sensor [17] to detect the water level in the top tank, an electrode as a water level detector, a flow switch as a sensor used to detect water flow, and GSM (Global System for Mobile Communications) module functions as a notification sender in the form of SMS to users [5]. The similarity between previous research and the one to be researched is to control and monitor water storage automatically, even with different sensor tools. And the difference is that the previous research used an ultrasonic sensor while this research used a water flow sensor, and the previous research used SMS and manual while this research used a telegram bot. In addition, this research will also add turbidity detection and pH detection to determine the condition of the water in the tank. Accordingly, the research was done in 2016 with the topic Water Level Control Simple Automatic System in Water Tanks in Residential Areas. The results of this simple Water Level Control device can determine when the water pump should turn on or when the water pump will turn off, allowing this device to work effectively and efficiently in saving water and electricity in residential areas. Still, in this study, no testing was done on the durability of each material used, so further research is needed to determine the lifespan or economic life of the device [7]. The difference between current and previous research is that previous research monitored water level while the research to be done monitored water height for tank filling automation and detected water conditions such as pH and turbidity.

B. System Component

This study divides the system components into three essential parts: input, process, and output. The division of features can be seen in Figure 1.

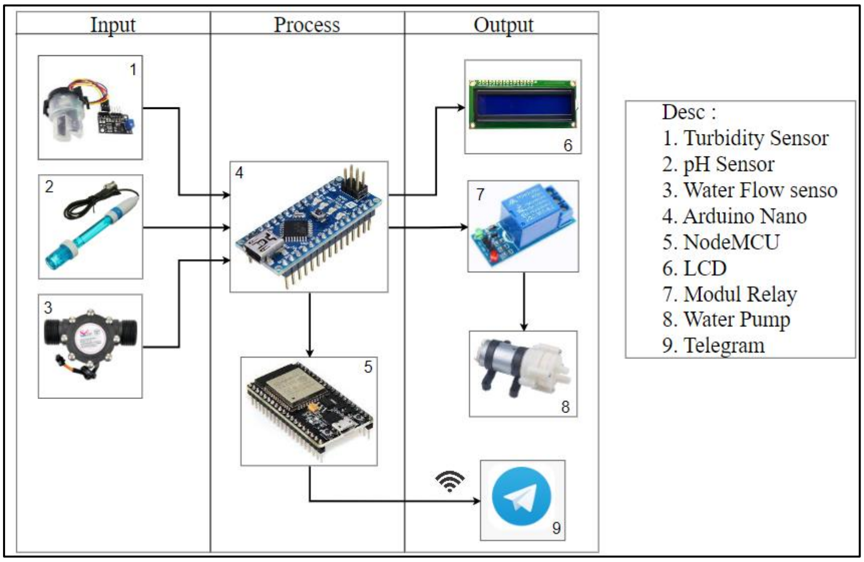

Figure 1. Component of System

The input components used in this study are the water flow sensor, pH sensor, and turbidity sensor. The water flow sensor is a measuring device used to measure the flow rate or amount of fluid that moves through a closed pipe or open channel [9]. The working principle of the water flow sensor is that when water flows through the rotor, the rotor will rotate according to the speed of the water flow that passes through the rotor on the sensor. This rotor rotation is the basis for calculating how much water comes out or passes through the faucet. Next, the pH sensor is an electronic device that can be used to measure the pH (acid or base) of a liquid (although unique probes are sometimes used to measure the pH of semi-solid substances) [10]. This tool has a working principle: the more electrons in the sample, the more acidic it will be, and vice versa because the rod in the pH meter contains a weak electrolyte solution. This tool is digital and analog [11].

A turbidity sensor is used to measure the water turbidity level based on several methods of measuring the turbidity level of liquid substances distinguished based on the intensity of light measured [12]. The Turbidity sensor module has a sensitivity level can be adjusted with a potentiometer on the board. Measuring the water turbidity level using a turbidity sensor is significantly influenced by the sensitivity and ADC conversion of the sensor [10].

The process components used in this study are nodeMCU and Arduino Nano. NodeMCU is an IoT platform that has an open source nature which consists of hardware in the form of a System On Chip ESP8266 from ESP8266 made by Espressif Systems; also, the firmware used, with the Lua scripting programming language, requires a power supply of about 3.3v and three Wi-fi modes namely station, access point and both (both) [11]. The working principle of NodeMCU as an IoT platform is likened to a brain in a circuit tasked with processing information and controlling the performance of the components connected to the course. Simply put, the way NodeMCU works starts by reading data on the input component, then the data enters the microcontroller. The data is processed and will come out through the output pin, which is forwarded to the output component [12].

In comparison, Arduino Device is a single-board microcontroller with an open-source nature derived from the wiring platform with the C programming language [13]. This study uses Arduino Nano type. Arduino Nano can connect to a computer using RS232 to TTL converter or USB to serial converter chip such as FTDI FT232, which is widely used [13]. In this study, Arduino Nano was used as a microcontroller because this tool can work even without an internet connection.

The output components used in this study are telegram and Liquid Crystal Display. Telegram is a free cloud-based multiplatform instant messaging service that can be used on mobile devices and computer devices [14]. Telegram Bot is a particular Telegram account designed to handle messages automatically. Users of this platform can interact with Bots by sending command messages directly via private messages or groups. In addition, users can also take advantage of the Open API (Application Programming Interface) and Protocol available through the development of Telegram Bots and documented on the official Telegram website [15]. Liquid Crystal Display (LCD) is a hardware device that can display two lines of characters, with each line 16 characters. LCD is an electronic display created using CMOS logic technology that works without producing light but by reflecting light around it to the front-lit or transmitting light from the back-lit. LCD functions to display data in the form of characters, graphics, numbers, or letters [16].

3. METHOD

A. System Development Method

This research employs the Research and Development (R&D) method, which focuses on developing or producing a product and then testing its effectiveness [8]. Furthermore, this study utilizes the prototype development model. The development stages conducted are shown in Figure 2.

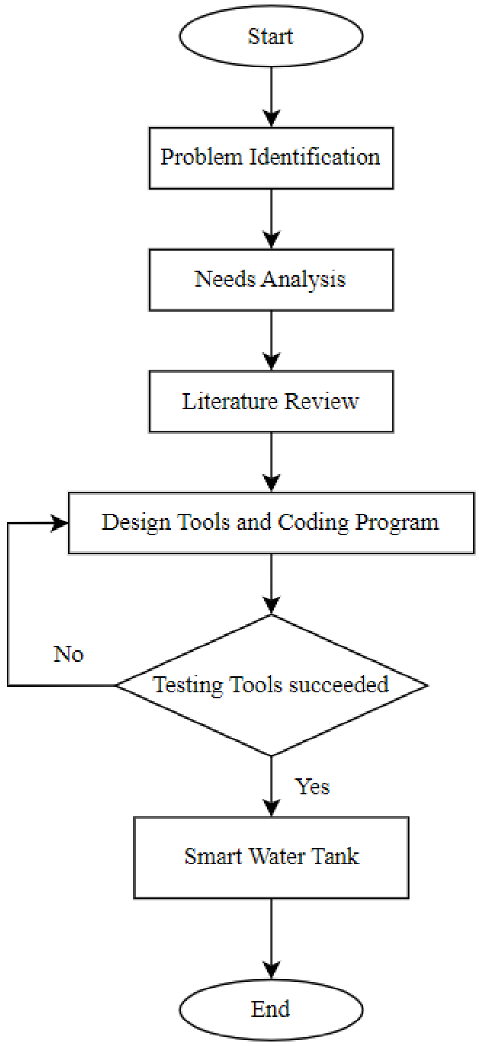

Figure 2. System Development Procedure

Figure 2 explains that this study starts from the problem identification stage with direct observation of the object to be studied. Then, a needs analysis is carried out to determine the extent to which the development of the study is needed and the things that need to be developed. After that, a literature study is carried out by reading various sources such as scientific works, library materials, books, the Internet, etc. The next stage is designing tools and coding programs, where the researcher develops the tools, then makes coding programs, and continues to install the devices. After that, the next stage is testing the means to produce an intelligent water tank and evaluating if needed.

B. System Design Phase

At the system design stage, there are flowcharts of system design and planning of tool design. Flowcharts to make it easier to see the flow of the system that will be built in outline so that it will facilitate the system's design. The system design flowchart in this study can be seen in Figure 3.

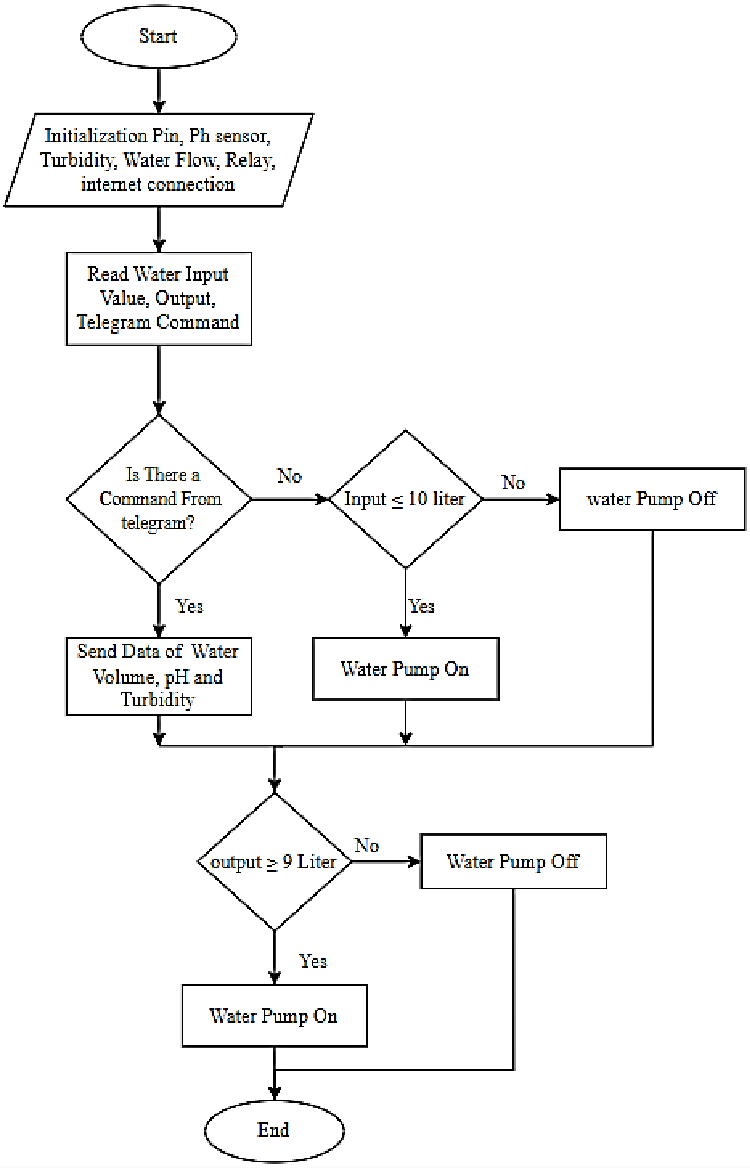

Figure 3. Flowchart of Design System

Figure 3 shows the steps of filling the water reservoir automatically until the process of detecting the water's pH and the turbidity of the water in the reservoir or water tank. The flowchart above explains how to fill the water reservoir automatically and detect the pH and turbidity of the water. The flow on this flowchart will repeat continuously as long as this device is connected to the power supply. In this research, several test scenarios will be carried out where functional testing of the tool will be performed, testing the accuracy of the water flow sensor in measuring water volume, testing the accuracy of the pH sensor in detecting water pH, and testing the turbidity sensor in measuring the level of water turbidity. Figure 4 is a scheme or illustration of the testing scenario designed for this study.

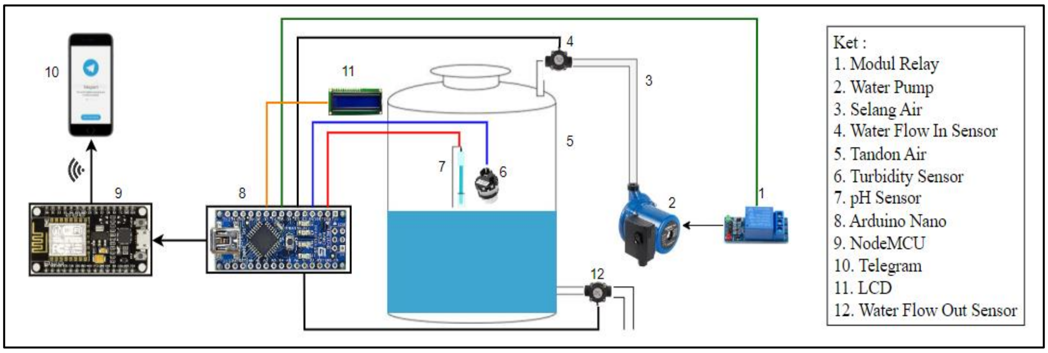

Figure 4. System Testing Scheme

The following is a description of the testing process on the NodeMCU-based innovative water tank system that has been planned. In this prototype, a replacement container will be used to facilitate the design of this system. The sensors used will be placed inside the water tank. The water flow sensor is placed at the position of the water inlet pipe into the tank, while the second water flow sensor is placed at the position of the water outlet from the tank to the daily-use water pipe. The pH and turbidity sensors are placed inside the tank, as shown in the figure above. A mini 12 volt DC water pump will be used for automatic water filling, where a relay module will be used to connect and disconnect electricity to the pump. The Arduino Nano microcontroller will be used as a controller that will read data from installed hardware devices. Meanwhile, NodeMCU ESP8266 will obtain sensor data through an installed intermediary Arduino Nano microcontroller, which will be forwarded to output components such as the telegram bot. Then users will get information on the telegram bot after giving commands to get information about the condition of the water in the tank. In addition, users can obtain information related to sensor readings through Liquid Crystal Display.

4. RESULT AND ANALYZES

The design and development carried out in this research consists of several parts. The first is the measuring instrument sensors that will be used consisting of a pH sensor to determine the acidity of the water in the tank, a turbidity sensor to determine the turbidity of the water, and a water flow sensor to calculate the volume of water entering and leaving the tank which will be used as input values to turn off and turn on the water pump. The second part is the microcontroller, which uses Arduino Nano, NodeMCU, and Arduino IDE software. The third part is the output in the form of a display on LCD and information via a telegram bot. Furthermore, Functional testing of this product aims to determine whether the functionality of the smart tank tool has worked and run well. Below is Table 1, functional testing of the product.

Table 1. Functional testing of the devices

Component	Function	Description
Arduino Nano	As a control center for the tool and also as a program storage memory	Working
NodeMCU ESP8266	As a connection to WiFi as well as a bridge connecting Arduino with telegram as monitoring	Working
water flow in the sensor	Able to calculate the volume of water entering the tank	Working
water flow out sensor	Able to calculate the volume of water coming out of the tank	Working
pH Sensor	Measuring the pH value in the water in the tank	Working
Turbidity Sensor	Measuring the level of turbidity in the water in the tank	Working
Module Relay	As a breaker and current connector to the water pump	Working
Water Pump	Able to flow water into the tank automatically	Working
LCD	Displaying measurement results of water volume, pH value, and turbidity	Working
Telegram	Providing the information requested by users, such as volume, turbidity, pH, and notifications	Working

Table 1 contains available testing information on the tool that has been made. This test is carried out to determine whether the tool works or not. Based on observations of functional testing of the product, it was found that all components used can function appropriately according to their respective functions. Testing of the water flow sensor hardware is helpful to determine whether the sensor can work to detect the amount of water that has passed through the sensor to enter and exit the tank. At this stage, two sensors are used to calculate the volume of water. The sensor is placed at the inlet of the water into the tank with an initial condition of 0 liters of water in the tank. The data obtained from the water flow in sensor measurement will be used as input value to turn off the water pump. If the sensor at this position has detected water entering the tank ≥ 10 liters, then the device will automatically work to turn off the water pump. The volume of water can be seen in Table 2 and the graph in Figure 5.

Table 2. Measurement Results of Water Volume Using Inlet Water Flow Sensor and Graduated Cylinder

No	Water Flow In Sensor (Liters)	Graduated cylinder (Liters)	Error
1	0,52	0,5	0,02
2	1,04	1	0,04
3	2,06	2	0,06
4	3,10	3	0,1
5	4,04	4	0,04
6	5,08	5	0,08
7	7,10	7	0,1
8	9,11	9	0,11
9	10,05	10	0,05
		MPE	**0,067**

Table 2 is a testing table to compare the measurement results based on the water flow in the sensor and measuring cup. After testing the volume of water using the water flow in the sensor and measuring cup, the results are shown in the table above. This table shows the difference between the two measuring instruments used. In this case, different measurements between the water flow in the sensor and the measuring cup can be caused by several factors. In research that has been conducted, factors that affect different measurement results can occur because the water flow in the sensor and measuring cup use other measurement methods. In addition, differences in measurements can also arise due to the influence of water pressure and calibration processes on less accurate sensors, so measurement results vary. The MPE (Mean Prediction Error) result obtained from testing the volume of water by comparing measurements using the water flow in the sensor with a measuring cup is 0.067.

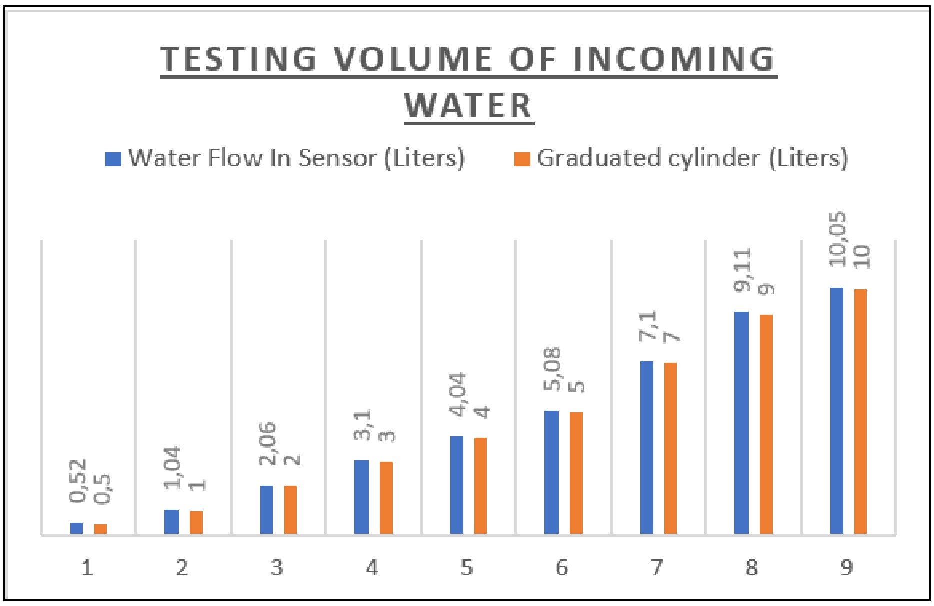

Figure 5. Graph of Incoming Water Volume Measurement Results

Figure 5 is a graph that refers to Table 2. It can show the comparison of testing the volume of water entering using the water flow sensor with the comparison of using a measuring cup where the results obtained are the difference between the two measurements of water volume carried out is relatively small. The water flow sensor is placed on the water outlet hose from the tank. The data obtained from the measurement of this water flow sensor will be the input value for turning on the water pump automatically. If the sensor at this position detects as much as ≥ 9 liters that have passed through the sensor or the remaining water in the tank is as much as ≤ 1 liter, then this tool is. The results of testing this sensor are in Table 3, and the graph in Figure 6.

Table 3. Water Volume Measurement Results using Water Flow Out Sensor and Measuring Glass

No	Water Flow Out Sensor (Liter)	Graduated cylinder (Liter)	Error
1	0,41	0,5	0,09
2	1,04	1	0,04
3	2,03	2	0,03
4	3,03	3	0,03
5	5,02	5	0,02
6	7,04	7	0,04
7	9,09	9	0,09
		MPE	**0,048**

Table 3 is a test table to compare the measurement results based on the water flow out of a sensor and measuring cup. The test on the volume of water coming out of the tank is the same as the test on the incoming water. After testing the volume of water using the water flow out of the sensor and using a measuring cup, the results are obtained as in the table above. In this table, it can be seen that there is a difference between the two measuring tools used. There is a difference between the two measuring tools used in testing the volume of water. The factors that affect different measurement results can occur because the water flows out of a sensor, and the measuring cup uses other measurement methods. In addition, differences in measurements can also arise due to the influence of water pressure and calibration processes on less accurate sensors, so measurement results vary. The MPE (Mean Prediction Error) obtained from testing the volume of water by comparing measurements using the water flow in the sensor with a measuring cup is 0.048.

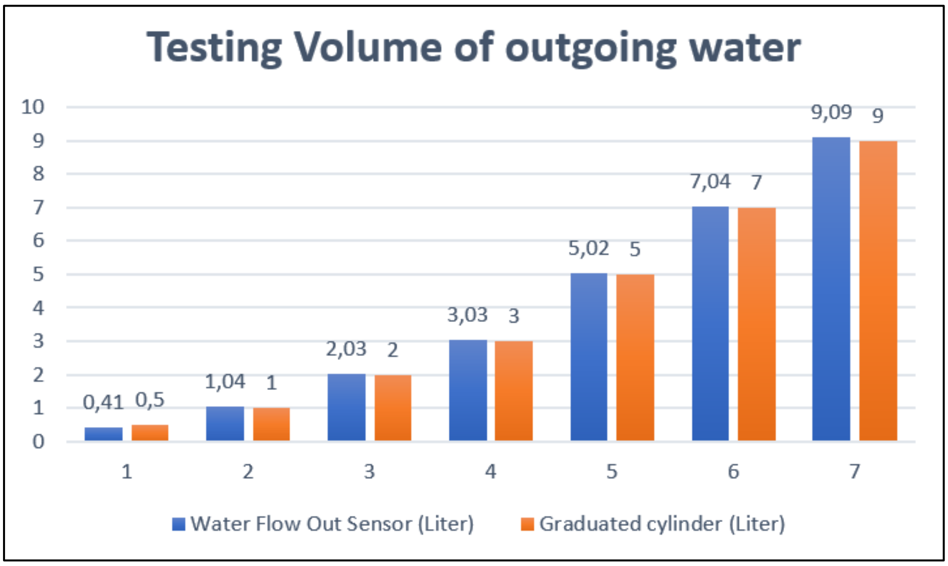

Figure 6. Graph of Outgoing Water Volume Measurement Results

In figure 6, it is a graph that can show the comparison of testing the volume of water coming out with the calculation of the water flow sensor and measuring cup, where the results obtained are the difference between the two measurements of water volume carried out is relatively small. Testing on the water pump is carried out so that researchers know that the water pump can run commands as expected and where the pump will work according to the measurement results of the two water flow sensors. The results of this water pump test are in Table 4.

Table 4. Testing Water Pump During Inlet Water Flow

No	Water Flow In Sensor (Liters)	Water Pump
1	0	On
2	0,52	On
3	1,04	On
4	2,06	On
5	3,10	On
6	4,04	On
7	5,08	On
8	7,10	On
9	9,11	On
10	10,05	Off

Table 4 is a test table to test that the water pump, when entering the tank used in this study, can turn off and on automatically so that it can pump water automatically without the need to be operated manually. This table shows that the pump can work as expected; when the water flow in the sensor detects as much as ≥10 liters of water entering, the pump will turn off; if less than 10 liters of water enters, the pump will continue to work. This is by the command from Arduino Nano to the relay module so that the relay module can connect and disconnect the current to the water pump automatically.

Table 5. Testing Water Pump During Outlet Water Flow

No	Sensor Water Flow Out (Liter)	Water Pump
1	0,41	Off
2	1,04	Off
3	2,03	Off
4	3,03	Off
5	5,02	Off
6	7,04	Off
7	9,09	On

Table 5 is a test table to test that the water pump, when entering the tank used in this study, can turn off and on automatically so that it can pump water automatically without the need to be operated manually. This table shows that the pump can work as expected; when the water flow in the sensor detects as much as ≥10 liters of water entering, the pump will turn off, while if less than 10 liters of water enters, the pump will continue to work. This is by the command from Arduino Nano to the relay module so that the relay module can connect and disconnect the current to the water pump automatically.

The pH sensor is used for testing to check the sensor's functionality when reading the acidic and basic conditions of the water. At this stage, the test compares the measurement results using a pH sensor with a digital pH meter. Testing by comparing these two tools uses the same sample: gallon water, PDAM water, well water, pH 4.0 solution, pH 6.86 solution, and seawater. Below are the results of testing the pH measurement of water using a pH sensor and a pH meter. The measurement results of this sensor are in Table 6 and Graph 7.

Table 6. Measurement Results of Water pH using pH Sensor and pH Meter

No	Water Sample	Sensor pH Data	pH Meter Data	Error
1	Water gallon	7,2	7,2	0
2	PDAM Water	6,8	6,8	0
3	Water Well	7,4	7,2	0,2
4	pH 4.0 Solution	4,1	4,1	0
5	pH 6.8 solution	7,1	6,9	0,2
6	Seawater	7,6	7,6	0
		MPE		0,067

Table 6 compares pH measurements using a pH sensor with a pH meter. Measurements using a pH sensor and pH meter are done by dipping the sensor or pH meter into the water to be tested. Judging from the pH meter test results, it tends to be more accurate when using a pH meter than a pH sensor because it uses a more sensitive electrode and has better calibration capabilities.

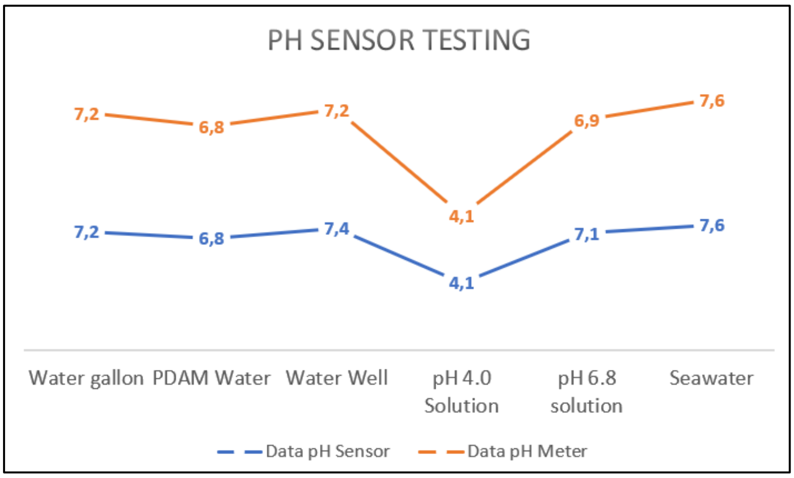

Figure 7. Graph of Water pH Measurement Results

Figure 7 is a graph that refers to Table 4.6, which compares the results of pH measurement tests on several water samples using a pH sensor and pH meter. The chart and Table 7 show the MPE (Mean Prediction Error) results of pH measurements obtained from a pH sensor and pH meter are 0.067. Moreover, Turbidity sensor testing is a sensor to determine the level of turbidity in water in the tank. The test is carried out at this stage by taking water samples to determine the turbidity level. The examples used are PDAM water, well water, and coffee water. Figure Sample Test of Measuring Water Turbidity Using a Turbidity Sensor. The results of testing the water's turbidity of water can be seen in Table 7.

Table 7. Measurement Results of Water Turbidity Using Turbidity Sensor

No	Sample name	Turbidity Sensor Data (NTU)	Average (NTU)
1	PDAM water	2,2 1,9 2,2	2,1
2	Water well	2,5 2,5 2,2	2,4
3	coffee	53,7 54,4 54,1	54,06

In Table 7, three different types of water are used, whereas in this test, three experiments are carried out for each sample. From the results of the sample experiment, the researcher takes the average value of the measurement results from the turbidity sensor. In testing water turbidity in this study, the turbidity sensor must be calibrated periodically because the sensor sometimes detects different measurements on the same sample within a few days. Furthermore, at this stage, testing is carried out on the output device of this system. In the smart tank, a telegram bot and LCD are used as devices to display data from components such as turbidity, pH, and water flow sensors. Figure 8 is an LCD and display on the monitoring system telegram in this study.

Figure 8. Smart Water Tank Monitoring System

Figure 8 is the output of the system created where there is an LCD to display sensor reading data and a telegram but also to display sensor reading results and provide notifications if the water in the tank is sufficiently turbid to find out the results of the monitoring system test, a communication direction test is carried out between Arduino Nano, NodeMCU ESP8266, telegram, LCD, and users. The smart tank monitoring system communication direction test results can be seen in Table 8.

Table 8. System Monitoring Testing

No	Communication Direction Testing	Test Results
1	LCD Displays pH value, turbidity, and water volume inside the tank	Success
2	NodeMCU sends data to telegram	Success
3	Telegram provides the user with pH, turbidity, and water volume information and notifications.	Success

Table 8 shows the results of the monitoring system testing from this study. At this stage, communication direction testing can be considered successful because the telegram provides information about the water's volume, pH, and turbidity, which was successfully conducted. Users can also receive telegram notifications if the tank's water is sufficiently turbid. The delivery of pH and turbidity notifications, as well as the delivery of user-requested data through telegram, is highly influenced by the speed of the internet network. The higher the internet network speed, the faster the data transmission and reception. Conversely, if the network speed decreases, the data transmission and reception will be slow.

5. CONCLUSION

Based on the results obtained from the smart tank control and monitoring research based on NodeMCU, it can be concluded that the design of the smart tank control and monitoring device based on NodeMCU has functioned well, and the parameters in this study can be monitored through LCD and telegram. Two water flow in and out sensors in this study functioned quite well in calculating the volume of water entering and exiting the tank with MPE results of 0.067 and

0.048. The pH sensor used in this study worked quite well in measuring water pH with an MPE result of 0.067. The turbidity sensor can also be used to measure the different water turbidity levels in the smart tank quite well. For suggestions in this research, future developers should use components such as pH and turbidity sensors that have better quality and good sensor sensitivity to obtain more optimal results. Furthermore, the next developer needs to develop this research based on Android so that the sensors used can be controlled through Android.

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AUTHOR CONTRIBUTIONS

Conceptualization; Jumadi M.Parenreng [J.M.P], Mustari S Lamada [M.S.L], Nurul Isra Humaira [N.I.H], Fhatiah Adibah [F.A], Andi Akram Nur Risal [A.A.N.R], Methodology; [J.M.P], [M.S.L], [N.I.H], [F.A], [A.A.N.R], validation; [J.M.P], [M.S.L], [N.I.H], [F.A], [A.A.N.R], formal analysis: [J.M.P], [M.S.L], [N.I.H], [F.A], [A.A.N.R], investigation; [J.M.P], [M.S.L], [N.I.H], [F.A], [A.A.N.R], data curation; [J.M.P], [M.S.L], [N.I.H], [F.A], [A.A.N.R], writing—original draft preparation; [J.M.P], [M.S.L], [N.I.H], [F.A], [A.A.N.R], writing—review and editing; [J.M.P], [M.S.L], [N.I.H], [F.A], [A.A.N.R], visualization; [J.M.P], [M.S.L], [N.I.H], [F.A], [A.A.N.R], supervision project administration; [J.M.P], [M.S.L], [N.I.H], [F.A], [A.A.N.R], funding acquisition; [J.M.P], [M.S.L], [N.I.H], [F.A], [A.A.N.R], have read and agreed to the published version of the manuscript.

CONFLICTS OF INTEREST

The authors declare no conflict of interest.

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