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Automated Monitoring System for Rainwater Harvesting Tank at Telkom University

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Abstract. The use of ground tank constructed by Telkom University for Rainwater Harvesting (RWH), is limited to environmental maintenance due to concerns regarding the quality of water in the underground tank. Therefore, this research aims to develop a remote monitoring device that uses Internet of Things (IoT) technology to monitor the pH, water surface, submerged materials, and water clarity levels in ground tank. To achieve the requirements, pH, ultrasonic-based volume, Total Dissolved Solids (TDS), and Turbidity sensors were selected due to the IoT connectivity. The enabling device, namely the ESP 32 microcontroller and Blynk platform were installed on monitoring dashboard on a tablet computer with 4GB of RAM. The result showed that calibration of each sensor had good accuracy, except for the Turbidity sensor due unavailable materials. In conclusion, the RWH monitoring system is suitable for use.

Keyword:
Rainwater harvesting, pH sensors, ultrasonic volume sensor, turbidity sensor, TDS sensor, internet of things.

1. Introduction

Telkom University is a private institution in Indonesia, deeply committed to maintaining a safe and sustainable environment to support education, research, and community service activities. The dedication was reflected in the high ranking on the Universitas Indonesia Greenmetric (UIGM) for several consecutive years, positioning it among the top institutions in the country. However, achieving a high UIGM ranking served as a guide regulating the daily activities of the university. Significant organizational changes were in line with these sustainability objectives, as stipulated in the Telkom Education Foundation Decision Letter No. PDP.0661/00/DGS-HK01/YPT/2024 [1]. Article 17 of this document redefined the

Directorate of Logistics and Assets (LogAs) as the Directorate of Assets and Sustainability (Asus). In addition, Article 25 supported the implementation of Sustainable Development Goals (SDGs) and the use of the institution full potential by establishing an ad hoc unit, the SDGs Center with the tagline Digital Collaboration for Sustainability (DCS). These changes and the inclusion of a new name clarified the direction and focus of the directorate. The process of organizational restructuring enhanced the contributions of the entire academic community in terms of quantity, quality, scope, and level of collaboration.

In response to climate change and water conservation objectives, the institution was forced to construct infiltration wells and biopores. Rainwater refers to the product of natural evaporation, providing numerous benefits for all living beings on Earth. However, improper usage led to floods and drought during rainy and dry seasons, respectively [2]. A typical method of collection is through Rainwater Harvesting (RWH). The method required capturing rainwater from rooftops and collecting it in a container or storage system. The research by [3], stated that despite the two RWH tank in Telkom University, the stored water was not completely used. This is because the rainwater quality was inadequately monitored, and the composition influenced by the surrounding atmospheric conditions [4]. Air pollution in a region, enabled rainwater to convey pollutants determining the quality, including causing acidic rain [5]. The use of RWH for domestic activities, such as washing of clothes and bathing caused skin irritation. The high acidity also altered the soil pH, when used to water plants affecting the balance of essential nutrients and minerals essential for growth. Plants exposed to acidic rainwater exhibited stress symptoms including yellowing leaves, stunted growth, or even death in severe cases. Additionally, it damages plant structures, affecting the root system, and hindering growth and health. Since RWH at the campus was frequently used for garden maintenance, it was necessary to implement filtration and monitoring devices to assess the conditions before usage.

Various references had identified multiple methods, which could serve as a model for monitoring the condition of RWH. These methods were broadly categorized into several aspects, including Internet of Things (IoT) technology [6,7,8], blockchain [9], intelligent system [10], and even smart-home facilities [11]. While many references were excluded in this text, the crucial aspect focused on the use of resources in mastering current or trending technologies by engaging the academic community, comprising lecturers, students, educational staff, and laboratory facilities. The participation process fostered a sustainable academic climate. The customized development of monitoring system designed to suit specific needs minimized dependency on vendors. Though the method is gradual and less sophisticated, it helped reduce costs. Consequently, the implementation was integrated into the university main programs. In the initial phase, an experiment was conducted to monitor the condition of underground RWH tank, focusing on certain parameters. These included pH, water level in tank, clarity, and content, which was monitored through a dashboard on a tablet device.

2. Experiment Design and Components

Figure 1 shows the operational relationship between the ESP32, Blynk, pH, ultrasonic, TDS, and turbidity sensors. The ESP32 acted as the central controller receiving data from various sensors. Blynk, an IoT platform connected to the ESP32, enabled remote monitoring and control of system. The pH and ultrasonic sensors measured the acidity or alkalinity of the solution, and the height of the liquid surface, respectively with the acquired data conveyed to the ESP32. Similarly, the TDS sensor measured the total dissolved solids (TDS) in the water and the process flow is outlined as follows

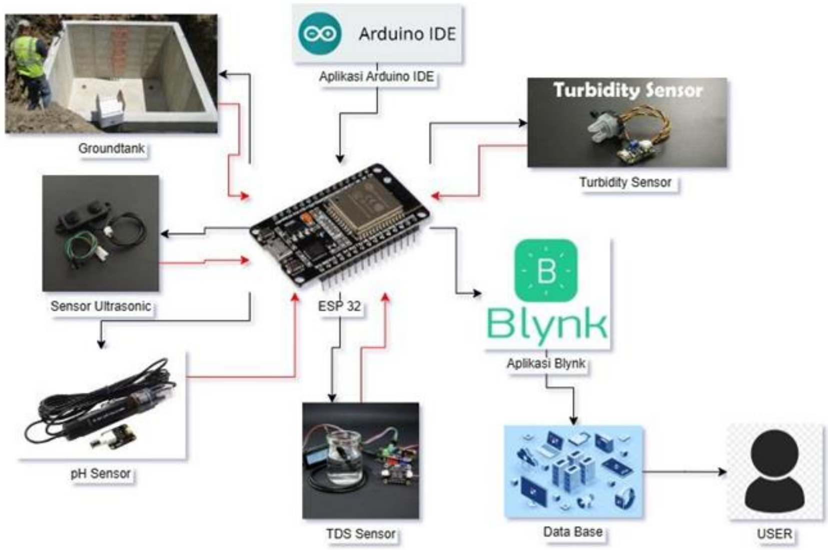


Figure 1. Design of the connection and operational components in the automated RWH monitoring system.

- The pH, ultrasonic, TDS, and turbidity sensors sent the acquired data to the ESP32.
- The ESP32 processed the data, sending it to the Blynk platform.
- Blynk enabled users to monitor the data in real-time, while controlling system through a mobile application.

A detailed explanation of these components were further stated in the subsequent section.

2.1 Microcontroller NodeMCU-ESP32

The NodeMCU-ESP32 is a microcontroller module based on the ESP32 chip from Espressif System, designed for IoT projects. It provided a powerful combination of a dual-core Xtensa LX6 processor, 520 kB RAM, and support for Wi-Fi and Bluetooth v4.2, making the module an ideal choice for applications requiring wireless connectivity. However, with a variety of GPIO pins supporting multiple communication protocols namely I2C, SPI, PWM, ADC, and DAC, the NodeMCU-ESP32 enabled easy integration with various sensors and actuators. The power-saving features embedded in this chip enabled users to develop energy-efficient solutions, crucial for IoT applications relying on battery resources. An example of the implementation process was found in Smart Farming projects [12].

2.2 Blynk

Blynk is an IoT platform that allows users to easily control hardware devices through a smartphone application. The platform provided an intuitive user interface for generating customizable dashboards, because it was developed to support various microcontroller devices, including Arduino, Raspberry Pi, and NodeMCU enabling users to monitor and control distinct IoT devices remotely. This application also allowed users to drag-and-drop widgets such as buttons, sliders, and graphs into the dashboard, creating interactive controls. The platform supported connectivity through Wi-Fi, Bluetooth, Ethernet, including Blynk Cloud, responsible for managing the communication between the application and hardware. Additionally, Blynk offered integration with various cloud services and APIs, allowing the development of more complex and integrated IoT solutions [12].

2.3 pH Sensor Module

The DFRobot Gravity Analog module was designed to measure the acidity or alkalinity (pH) of a solution with high accuracy, making the pH sensor ideal for certain applications such as hydroponics, aquariums, and laboratory research. The module has a corrosion-resistant pH probe, easily replaced through a BNC connector, and a signal conditioning circuit. This converts the signal from the probe into an analog voltage read by the following microcontrollers Arduino, Raspberry Pi, or NodeMCU. The operation included the probe detecting hydrogen ions in the solution, generating an electrical signal proportional to the concentration of these ions. The signal was further converted by the signal conditioning circuit into an analog voltage interpreted by the microcontroller to provide an accurate pH value. The module consisted of automatically calibrated features based on standard buffer solutions, compatible with the Gravity interface from DFRobot, enabling easy integration and application in various pH monitoring projects.

2.4 Ultrasonic Sensor Module

The ultrasonic sensor module used is a product of DFRobot, designed to measure distance or detect the presence of objects using ultrasonic waves. The sensor consisted of a transmitter emitting ultrasonic sound waves and a receiver capturing the waves reflected from the object. The sensor calculated the distance based on the speed of sound in air, by measuring the time, it takes the sound waves to travel from the transmitter to the object and the receiver. Mathematically, this was expressed as follows

$$d = \frac{V_s \times t}{2} \quad (1)$$

where d = the measured distance (m), V_s = the speed of sound (m/s) and t = the travel time of the sound wave (s).

Ultrasonic sensors were commonly used in applications such as robotics for navigation, obstacle detection, vehicle parking system, and various industrial automation requiring non-contact distance measurement. The reliability and ease of integration with microcontrollers namely Arduino makes it a popular choice for various technical and side projects.

2.5 TDS Sensor Module

The TDS sensor by DFRobot measured the total dissolved solids in water, expressed in parts per million (ppm). This sensor operates using a probe that detects the electrical conductivity of the water, the greater the dissolved solids, the higher the conductivity. The probe consisted of two electrodes measuring the electrical current passing through the water. The generated conductivity signal was further processed by a signal conditioning circuit within the module, converting it into an analog voltage read by a microcontroller such as Arduino. This converts the analog voltage into the corresponding TDS value. The DFRobot TDS sensor, characterized by easy calibrated features and a simple interface was well-suited for water quality monitoring applications in the following fields hydroponics, aquaculture, and water purification.

2.6 Turbidity Sensor Module

The turbidity sensor measured the turbidity or cloudiness of water, showed by the number of suspended particles including silt, algae, and other organic matter. The operation depended on an LED transmitter that emits infrared light into the water sample. The light collides with the particles in the water, causing it to scatter. Additionally, a photodetector sensor positioned at a specific angle from the LED, captured the scattered light. The intensity correlated with the turbidity level, the greater the particles in the water, the more light was scattered and received by the photodetector. The signal from the photodetector was processed by the circuitry of the sensor, converting it into an analog voltage read by Arduino. The microcontroller then converts the voltage into a turbidity value in Nephelometric Turbidity Units (NTU). However, turbidity sensors were used in various applications, including water quality monitoring, wastewater treatment, and aquaculture system, ensuring potable water.

Based on this context, the turbidity standard for humans was established by several organizations, including the World Health Organization (WHO), the United States Environmental Protection Agency (EPA), and the European Union. WHO stipulated that potable water should have a turbidity level less than 5 NTU, with an ideal level less than 1 NTU to ensure the effectiveness of disinfection processes such as chlorination [13]. The EPA regulated that the turbidity level of potable water distributed to the public must not exceed 1 NTU at the distribution point, with an average less than 0.3 NTU in 95% of the samples tested each month [14]. According to the European Union regulations, qualified potable water must have a turbidity level less than 1 NTU [15].

3. Results and Discussions of Monitoring System Implementation

3.1 Functional Testing of Sensors

When testing the functionality of sensors, multiple measurements were taken to account due to variations in the readings. All functional sensor testing was conducted in the optical communication laboratory. Several error calculation methods were to evaluate the accuracy and precision of the sensors [16]. These methods comprised absolute, relative, percentage, mean absolute (MAE), mean squared (MSE), and root mean squared errors (RMSE).

1. Absolute Error (E_{abs}) is the difference between the measured (x) and true values (x_{tr}). In the experiment, x_{tr} is a variable with a predetermined value.

$$E_{abs} = \left| x - x_{tr} \right| \tag{2}$$

2. Relative Error (E_{rel}) refers to the ratio of the absolute error to the true value, providing a measure of the error relative to the magnitude of the quantity being measured. This provides a measure of the error relative to the magnitude of the quantity being measured.

$$E_{rel} = \frac{\left| x - x_{tr} \right|}{\left| x_{tr} \right|} \tag{3}$$

3. Percentage Error is the relative error expressed as a percentage.

$$E_{\%} = \frac{\left| x - x_{tr} \right|}{\left| x_{tr} \right|} \times 100\% \tag{4}$$

4. MAE refers to the average absolute errors for multiple measurements.

$$E_{MA} = \frac{1}{n} \sum_{i=1}^{n} \left| x_i - x_{tr} \right| \tag{5}$$

5. Mean Squared Error (MSE) is the average squared differences between the measured and true values.

$$E_{SE} = \frac{1}{n} \sum_{i=1}^{n} \left(x_i - x_{tr} \right)^2 \tag{6}$$

6. RMSE refers to the square root of the mean squared error.

$$E_{RMS} = \sqrt{\frac{1}{n}\sum_{i=1}^{n}\left(x_i - x_{tr}\right)^2} \quad (7)$$

The testing method for each sensor varied depending on the nature of the device. Considering no changes were detected in the properties of the sensor, the obtained values were presumed to be valid. Object measurements were carried out multiple times to obtain more objective values, including understanding the characteristics of the sensor. Proper testing followed specific procedures, using test devices with known values. The measurement obtained were approximated to the true figures otherwise, it would had shown relative and biased values. Therefore, the measurement error rate must be obtained to approximate the true value. The following are the tests for each sensor earlier mentioned.

1. pH Sensor was tested against solutions with known values, including acidic (pH = 4.0), neutral (pH = 7.0), and basic (pH = 10.0). The pH values in Table 1 were represented as x_{tr}, with the accuracy of the sensor tested against several pH levels with known values. The measurements were repeated four times, and the frequency of repetition represented as x_i
2. Ultrasonic Sensor measured the water surface level in an underground tank. This was represented as a percentage of tank capacity. The actual volume tend to be calculated by determining tank capacity. In addition, the sensor accuracy testing was conducted on a surface positioned at distances of 50 cm, 100 cm, 150 cm, and 200 cm from the sensor. Table 1, shows the distance from the sensor to the surface represented as x_{tr}. The measurements were repeated 10 times, and the frequency of repetition showed as x_i.
3. TDS Sensor was tested in respect to several specific solutions with known properties, namely dissolved content measured in ppm. The test used three sample solutions including a pH with a known dissolved content of 500 ppm, deep-well water from the campus environment, and reverse-osmosis (RO) potable water.
4. Turbidity Sensor was not tested, due to lack of standard equipment, although the analysis was intended to ensure the device functioned effectively.

The results of the sensor functionality tests were briefly discussed in Table 1. Meanwhile, for pH sensor, the error values were highest at low pH (4.0) but improved at higher levels (7.0 and 10.0). The inaccuracies were caused by several factors, including the characteristics of the sensor material, the limited frequency of data obtained, or readings taken before the measurements stabilized. There is need to refine the measurement methods before making other decisions. Furthermore, the test data for ultrasonic sensor showed increasingly stable results at greater distances, with decreasing error levels, implying the measurements were reliable. For TDS sensor, the measurement data for all object categories were within the range of actual measurements, and the results logically acceptable. Considering the turbidity sensor, no changes were detected in the results of the measurement, because the research team was unable to find a liquid material that could be used as a calibration standard.

3.2 IoT Functionality Testing

Functionality tests were conducted to ensure the IoT devices for monitoring the RWH conditions operated normally, as well as verified the data transmission capability. These devices comprised the ESP32, Blynk server, and Wireshark software, with the testing scenario including data transmission between the ESP32 and the Blynk server over a mobile hotspot network for 10,129 seconds. Traffic was monitored at both points, the ESP32 and Blynk server. Additionally, Wireshark was installed on a tablet, serving as the data traffic gateway for the ESP32 as well as monitoring dashboard. The setup enabled monitoring of data traffic without decrypting it when the ESP32 was connected to the same WiFi network.

Table 1. Sensor calibration test results

Measurement results in x_i and x_{tr}	pH Sensor			Ultrasonic Sensor				TDS Sensor			Turbidity Sensor
	pH 4	pH 7	pH 10	50 cm	100 cm	150 cm	200 cm	Calibration solution	Deep-well water	RO water	Calibration solution
x_{tr}	4.0	7.0	10.0	20	40	60	80	500 ppm	50-150 ppm	0-20 ppm	500 ppm
x_1	5.09	7.39	10.16	19.89	40.33	60.74	80.19	471	143	0	-1000
x_2	4.74	7.62	10.05	20.85	40.92	60.72	80.36	428	117	0	-1000
x_3	4.89	7.84	10.24	20.45	40.42	60.53	80.38	473	142	14	-1000
x_4	4.98	7.79	10.5	20.33	40.21	60.7	80.53	464	121	0	-1000
x_5	---	---	---	21.43	41.56	60.2	80.36	456	137	0	-1000
x_6	---	---	---	20.73	41.09	60.72	80.19	---	---	---	---
x_7	---	---	---	19.46	40.92	60.4	79.78	---	---	---	---
x_8	---	---	---	19.3	40.42	60.41	80.12	---	---	---	---
x_9	---	---	---	21.01	41.37	60.57	80.29	---	---	---	---
x_{10}	---	---	---	21.07	40.74	60.31	80.45	---	---	---	---
Average	---	---	---	---	---	---	---	458.4	132	2.8	---
E_{abs}	0.9250	0.6600	0.2375	0.722	0.798	0.53	0.309	---	---	---	---
E_{rel}	0.2313	0.0943	0.0238	0.0361	0.0200	0.0088	0.0039	---	---	---	---
$E_{\%}$	23.13%	9.43%	2.38%	3.61%	2.00%	0.88%	0.39%	---	---	---	---
E_{-MA}	0.2742			0.0172				---	---	---	---
E_{-MS}	0.1449			0.0734				---	---	---	---
E_{-RMS}	0.3806			0.2710				---	---	---	---

The parameters for measuring data transmission integrity included jitter, delay, throughput, and packet loss. Figure 2 shows the recorded data transfer process using Wireshark. It was then processed using a spreadsheet application to calculate the value of each parameter in two data transport scenarios. Moreover, the Quality of Service (QoS) parameter assessment standard refers to Telecommunications and Internet Protocol Harmonization Over Network (TIPHON) issued by the European Telecommunications Standards Institute (ETSI). Associating the implementation with ETSI performance standards is crucial as this technology development tends towards remote device control within system. For example, ETSI TS 101 329-2 V2.1.3 (2002-01) focused on TIPHON Release 3, End-to-end Quality of Service in TIPHON system, and the definition of speech Quality of Service (QoS) classes. Assuming the required performance information was not found in a standard number, exploration of other versions may be considered. However, understanding and interpreting standards is challenging, requiring multidisciplinary collaboration in terms of working on SDGs projects. It is also crucial to stay updated on technological standardization developments to make and execute decisions accurately. Table 2 shows the QoS parameter standard values according to ETSI.

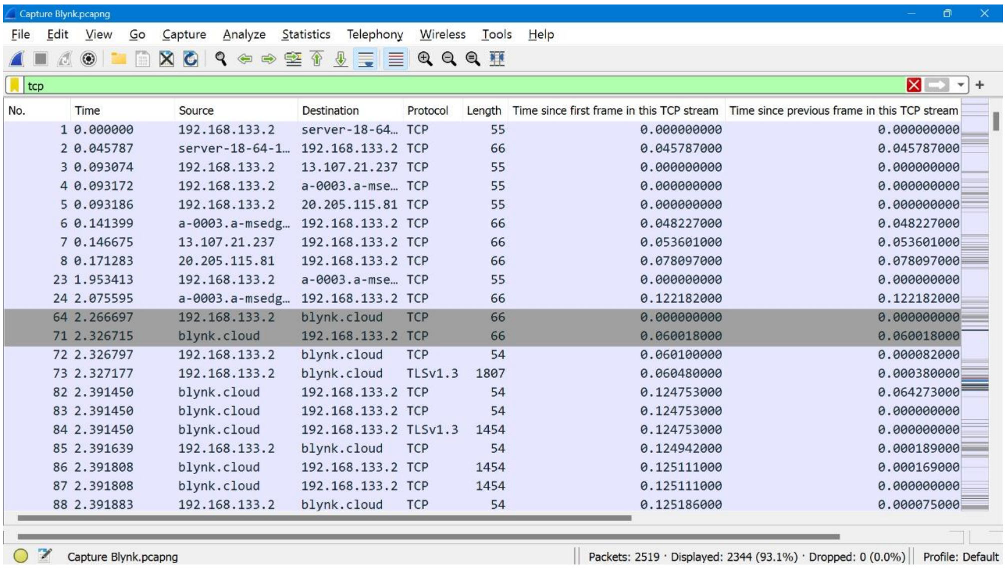


Figure 2. Data Traffic Capture on Wireshark

Table 2. ETSI Standard QoS Parameter Values

Category	Delay in ms	Jitter in ms	Packet loss
Very good	< 150	0	0
Good	150 – 300	0 - 75	3
Moderate	300 - 450	75 - 125	15
Bad	> 450	125 - 225	25

Common formulas used in the data transfer process such as calculating the QoS parameter values were discussed in most Data Communication books [17]. In addition, the commonly used formulas were stated as follows

1. Delay

$$D_{av} = \frac{D_{tot}}{\sum P_{rec}} \quad (8)$$

where D_{av} = average delay, D_{tot} = total delay and P_{rec} = data packets received.

2. Jitter

$$J = \frac{\sum D_{\mathrm{var}}}{\sum P_{rec} - 1} \quad (9)$$

where J = jitter, and D_{var} = delay variation.

3. Packet loss

$$P_{loss} = \frac{\sum P_{st} - \sum P_{rec}}{\sum P_{st}} \times 100\% \quad (10)$$

where P_{loss} = packet loss, and P_{st} = data packet transmitted.

4. Throughput

$$S = \frac{\sum P_{rec}}{\sum t_{obs}} \tag{11}$$

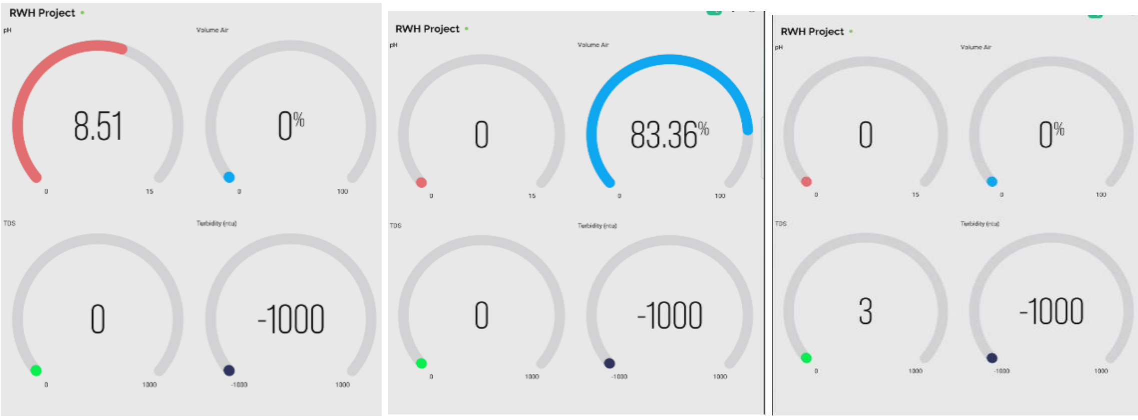
where S = throughput and t_{obs} = observation duration.

The raw data captured by Wireshark was excluded due to space limitations. Using simple logic and adhering to established principles, the raw data was easily processed with the aid of spreadsheet software. The observation duration was 10.13 seconds, with a total of 2,519 data packets sent, and 2,518 packets, or 1,260,598 bits received. In this simulation, many packets were found outside the experimental category, requiring sorting of the relevant data packets for calculation. However, by processing the sorted data packets and summing the transmission duration between the start and received times resulted in a total of 107.28 seconds. In order to calculate jitter, the delay data was processed to obtain various values, which were then summed. The total delay variation was 0.045787 seconds, and the next step required substituting several found values into formulas (8) to (11), obtaining the following results D_{av} = 4.02 ms, J = 18.1767 µs, P_{loss} = 0.039%, and S = 124,454.339 bits = 15.5567 kB. Subsequently, the QoS values of the IoT system were compared against the standard values in Table 2. The delay, jitter and packet loss were classified under the very good, good, and very good categories, respectively.

3.3. Development of Monitoring Dashboard

The Asus Directorate currently has a large monitor wall based on CCTV technology to oversee campus security at many strategic points within classrooms, hallways, inter-building corridors, gardens, forests, and other areas. Security personnel were needed to take action on ground. However, this facility was unable to monitor the sensors installed in various locations, resulting in the need to develop a flexible, portable, compact dashboard model that provides real-time and accurate information at an affordable cost. The development process was realized in stages, including monitoring and control capabilities. Monitoring capability implied the ability of the dashboard to provide up-to-date data from the installed sensors. The control capability showed the ability of the dashboard to initiate actions in the sensor environment to change the readings. This was implemented by an external system, considered more complex than monitoring device. Despite the similarity with CCTV, human intervention was required for immediate action.

This monitoring device uses a tablet with a minimum specification of 4GB RAM to facilitate execution. An open-source software, compatible with the designed sensor system was used. After the installation process, the Blynk dashboard display appeared as shown in Figure 3. The dashboard features several sensor indicators, namely a pH, volume, TDS, and turbidity sensors. In a specific measurement event, only one sensor actively showed the measurement value. For example, during a measurement event, the pH had a value of 8.51 with the percentage level depicted by a red curve. Meanwhile, other indicators remained at a neutral position or depend on the setting level of sensor. Monitoring process was performed sequentially and cannot be conducted simultaneously, with the dashboard model.



pH Sensor Volume Sensor TDS Sensor

Figure 3. Dashboard Display and Sensor Value Indication

3.4. Practical Measurement of Water Conditions in the RWH Ground Tank

After the completion of the calibration process, the next step necessitated conducting field measurements to determine the water conditions in the RWH ground tank located near the Telkom University Convention Hall (TUCH), as shown in Figure 4. The dimensions of the water tank were 5 meters, 3 meters, and 2.5 meters in length, width, and depth, respectively resulting in a water capacity of 37.5 cubic meters [3]. In addition, the measurement position was taken at a corner of the RWH roof. The measurements were obtained using four sensor types, monitored through the dashboard. The volume sensor was hung without touching the water, while the others were submerged in the water. From the dashboard in Figure 3, the volume sensor showed a stable reading of 83.36%. Some of the readings were unstable or fluctuated, resulting in the need for repeated measurements, and calculated averages, as shown in Table 3. All measurement were carried out in a day, with the values obtained remaining unchanged unless influenced by external factors, such as rain, debris, or other conditions, which led to the periodic monitoring.

Figure 4. Location of RWH Tank Water Measurement

Table 3. Water Measurement Results of the RWH Tank

No.	pH	TDS
1	8,54	3
2	8,67	3
3	8,63	4
4	8,73	3
5	8,65	3
Average	8,64	3,2

3.4.1 Discussion of pH Measurements

The hypothesis that rainwater is acidic contradicted the results obtained in the underground tank at the measurement site. Based on Table 3, the average pH value is 8.64, showing that the water was slightly basic. It could be used for domestic purposes, religious rituals, potable for pets and livestock, including plant irrigation. The variation in measurement readings were attributed to several factors, namely inhomogeneity of contaminants in the water, temperature changes, sensor aging, and maintenance.

In accordance with the calibration review, this pH sensor type deviated and remained relatively stable when used for low and high measurements, respectively. The current measurement results were reliable, and in the future, the sensor should be calibrated earlier and cleaned of any adhering contaminants to maintain accuracy. Meanwhile, pH measurements were conducted periodically or intermittently, as changes were gradual unless there was an atmospheric change due to pollution. Asides routine measurements, pH should be measured after rainfall, and before using the water for specific purposes. The pH monitoring could be conducted remotely using IoT technology.

3.4.2 Discussion of Tank Water Volume Measurements

The measurement was conducted by hanging the sensor at the top of tank. Since the water surface maintained a consistent level, the sensor provided similar responses regardless of the position on tank roof. The difference depended on the reflection delay produced. A shorter delay implied that the sensor was closer to the water surface, showing the high or nearly full volume, and vice versa. Figure 3 shows the sensor was used to measure a volume of 83.36% in tank designed to accommodate 37.5 m^3 of water, depicting the actual volume detected by the device was 31.26 m^3.

The ultrasonic installed sensor was used to acquire consistent and accurate measurements. The sensor could be installed and operated continuously, providing information whenever needed. Meanwhile, the sensor was suitable for remote monitoring using IoT technology.

3.4.3 Discussion of TDS Measurements

Rain formations depended on the evaporation of surface water, and the mineral content was low. When water vapor interacted with the atmosphere containing many contaminants, the rainwater became impure. Additionally, dust on rooftops could flow into the RWH tank, and all these factors contributed to increased contamination.

The TDS sensor readings showed varying values with an averaged of 3.2 ppm. This figure showed the amount of dissolved solids in the water, serving as an indicator of the water purity in the ground tank. Meanwhile, the average value was monitored to ensure that the water quality was within the desired limit. Given the performance, the sensor was suitable for automated monitoring.

3.4.4 Discussion of Turbidity Measurements

In subsection 3.4.3, the contaminants that entered the RWH tank were discussed. These contributed to the water turbidity, and technically, the module had not yet functioned correctly or as expected according to theory. However, since the water in the RWH tank was not for human consumption, this situation was acceptable. The research team continued respective efforts to ensure the module worked properly.

4. Summary

In conclusion, this research developed an automated water condition monitoring device, for the RWH tank using IoT technology. A tablet was used to generate a Blynk-based monitoring dashboard for conducting sensor calibrated tests. This was realized by connecting the device to the internet to monitor the system in the field, with the result obtained showing generally acceptable performance. However, the turbidity sensor required further research to function properly.

5. Acknowledgment

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