Water Quality Monitoring System in Autonomous Underwater Vehicle Based on Internet of Things (IoT)

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***Abstract*— Water is a resource needed by mankind in many ways. Water quality is comparable to the benefits of water so that if the water quality decreases it will affect who will take advantage of it. Therefore, it is necessary to monitor the water quality to see the condition of water quality. For this purpose, this monitoring uses Autonomous Underwater Vehicle (AUV) that can move automatically. AUV is equipped with sensors such as pH sensors, total dissolved solids sensors, dissolved oxygen sensors and temperature sensors as water quality determinant parameters. The water quality obtained on the surface of Lake OPI Jakabaring at a depth of 9.45 cm is in normal condition where for the sensor value is: pH = 6.23; temperature = 33.45 ^{0}C; DO = 2.97 mg/L; TDS = 40.64 ppm and at a depth of 110.73 cm is in very good condition where for the sensor value is: pH = 7.65; temperature = 29.92 ^{0}C; DO = 5.14 mg/L; TDS = 29.33 ppm. Then it is done sending IoT-based data by using esp8266 module as a tool to send data to the website. The website can display the water condition that is monitored according to the parameters and each sensor.**

Keywords*— *Monitoring, pH, Total Dissolved Solids, Dissolved Oxygen, Temperature,Internet of Things.

I. INTRODUCTION

Indonesia is an island nation with many territorial glasses of water and seas. For the sea area to be utilized to the maximum, it is necessary to develop technology that can observe and explore the seas of Indonesia. One of them is by using an underwater robot or commonly referred to as a Remote Operated Underwater Vehicle (ROV). However, the ROV has limitations in maneuvering because the ROV is controlled via cable by the operator on board. To overcome these weaknesses, autonomous underwater vehicles (AUV) are developed with more flexible maneuverability and can move automatically to reach further areas.

One mission that requires far browsing coverage is water quality monitoring. AUV can carry out water quality monitoring tasks effectively and efficiently. Water quality monitoring is necessary because the role of water is so important for biota. Biota water needs a suitable environment to survive [1]. If the water quality is polluted, the water biota will be difficult to survive, resulting in a decrease in the amount of water biota. Therefore, efforts are needed to maintain water quality, one of which is through water quality control. Previously, water quality monitoring was done by manually collecting data, which depended on the human ability to collect water sample data, then analyzed in the laboratory. This method still uses manual calculations so it is considered not efficient. As a solution to overcome these weaknesses, Internet of Things (IoT) technology is needed that does not require water sample data to be taken to the laboratory. IoT is an integration of many newly developed digital or information technologies. The latest technologies now use IoT as a platform for monitoring and assessing water quality. IoT in terms of water quality monitoring is quite relevant for sustainable accounting purposes. It's difficult to assess water and sources clean enough to be consumed without any monitoring of water quality. In addition, IoT is quite important in its benefits because any potential water pollution arising from the point source can quickly be identified.

Previous studies have focused only on changes in water quality within a limited range as well as communication media that still have limitations on the distance between the sender and receiver. Therefore, the author will discuss water quality monitoring using IoT technology applied to autonomous underwater vehicles (AUV).

II. LITERATURE REVIEW

In this research, a water quality monitoring system will be conducted using AUV as the underwater robot, using data transmission and internet of things media.

A. Water Quality

Water quality refers to water quality that meets the criteria for a particular purpose. Requirements such as water quality standards vary depending on the purpose of their use. For example, irrigation water and drinking water have different quality standards. Based on article 1 of the Minister of State for Environment Regulation No. 115 of 2003, water quality is a qualitative state of water that is tested according to certain parameters and methods according to the prevailing laws and regulations [2]. Water quality testing criteria are chemical, physical, biological testing, especially for color and smell. Water quality management is a method of water maintenance to achieve the water quality necessary to ensure that it remains in its natural state. Standard indicators of river water quality and drinking water can be seen in table 1.

TABLE I. WATER QUALITY STANDARD

No.	Parameters	Unit	Water Quality Standard (River Water) PP 82 of 2001	Drinking Water Quality Standard (Permenkes RI No 492 of 2010)
1	Temperature	°C	3-5	±3
2	Total Dissolved Solids	PPM	1000	500
3	pH	-	5-9	6.5-8.5
4	Dissolved Oxygen	mg/L	0-6	-

B. *Water Quality Parameters*

1) Dissolved Oxygen (DO)

Dissolved oxygen is the amount of oxygen dissolved in water through photosynthesis as well as absorption by air. To know the quality of water in the water, it is considered some chemical parameters such as dissolved oxygen. The greater the DO value the better the quality of the water. Aquatic organisms need oxygen to breathe and must be dissolved in water. If the oxygen supply is limited and insufficient, all the activity of the organism in the water will also be restrained. Idealnya, do content for 8 hours at least 1.7 mg/L. Generally, scientists agree that water biota requires concentrations of 5.0 mg/L or more for dissolved oxygen for water biota to survive and develop. However, the oxygen required depends on the size and complexity of the biota and its place of residence [3].

2) Temperature

The main factor of water quality is temperature because the temperature can affect the metabolic activity of water biota. Water temperature will affect the surrounding environment and provide a fresh taste for the community, but the local climate or type of water source will affect the water temperature. Water temperature is affected by weather conditions. Factors that affect water temperature are humidity, temperature, wind speed, sunlight, and precipitation. Water-friendly temperatures are normal between 27°C and 32°C, with a relatively small drop in temperature (from 32°C to 28°C). The growth of aquatic organisms increases along with rising temperatures. If the temperature is too high, the water biota can experience death [4].

3) Power of Hydrogen (pH)

pH is an important parameter for determining water quality. The pH value describes the amount of hydrogen in the water. In general, the value at pH represents the condition of the water whether acidic or alkaline. The concept of pH was originally proposed in 1909 by Danish chemist Soren Peder Lauritz Sorensen. Pure water is neutral water and has a pH of 7.0 at 25°C. This is due to its high pH and H^+ content. Conversely, the higher the H^+ ion, the lower the pH. Water that has a low pH or is too acidic can cause water biota to be killed. This is because water at a low pH also reduces the concentration of dissolved oxygen in the water. On this basis the following conclusions can be drawn, high-quality water has a pH of 6.5-9 and the optimum range is pH 7.5-8.7 [5]. At pH solution values below 7 are considered acidic and pH solutions above 7 are considered alkaline.

4) Total Dissolved Solids (TDS)

TDS is required as an important parameter in determining water conditions because the salt concentration in water is very high and seawater contains many chemical compounds, therefore TDS is used to measure the amount of dissolved salt content in water. The use of TDS measuring instruments to detect TDS in water in the form of sticks which tool can work automatically and can display the number of pollutants present in the water. TDS values in seawater are higher because they contain many compounds that also cause high salinity and conductivity [6] [7].

C. *Autonomous Underwater Vehicle (AUV)*

An AUV is a type of underwater vehicle that can move without human control based on the commands given. The AUV carries a variety of equipment to be used for surveying and sampling such as cameras, sonar, depth sensors, pH level sensors, and dissolved oxygen sensors. AUV stores all data, including images and other sensor data, the stored data can be retrieved when the AUV has climbed to the surface. The AUV can dive from sea level to sea depth and then will come back again automatically.

D. *Internet of Things (IoT)*

The term IoT refers to access to electronic devices over the internet. This device can be accessed due to human connection with a device or device with any internet-connected device. Access to this device occurs because of the need to share data, share access permissions and consider the security of access. IoT uses programmatic parameters, where each parameter command can generate an automatic connection between connected *machines* without any manual intervention and no limit to distance. IoT can use electronic devices such as Arduino microcontrollers to develop specific purposes and can be developed as an application integrated into the android operating system. The IoT concept is illustrated in Figure 1 below.

Figure 1. IoT Concepts

III. METHODS

This research was conducted in Lake OPI Jakabaring Palembang South Sumatra, Indonesia. This study is generally divided into two parts, namely system design and system testing.

A. *Design System*

At the design stage, there is a flow chart created as a stage for this research shown in Figure 2.

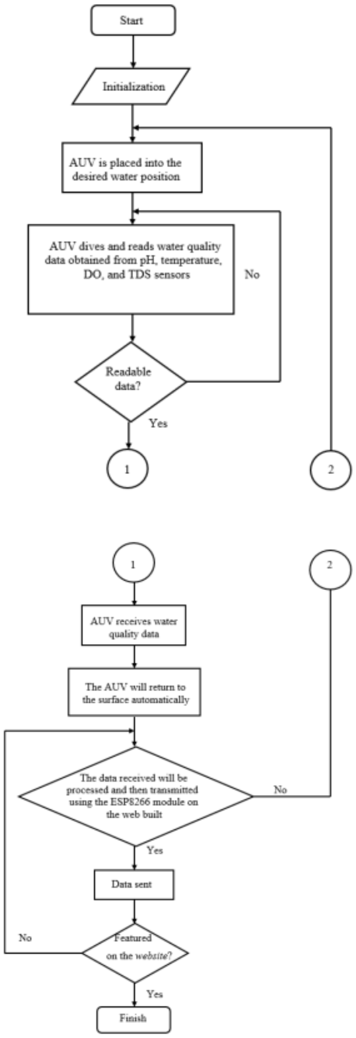

Figure 2. *Flowchart* Research

B. Hardware Design

In future research, some hardware is needed that helps to make the tool a medium for retrieving water data. The hardware needed is a microcontroller, sensors, and communication media.

1) Microcontroller

A microcontroller is a complete microprocessor system contained within a chip. Microcontrollers generally contain minimal microprocessor system support components, namely memory, and Input-Output programming. In this study, the authors used the Arduino Mega 2560 microcontroller as shown in Figure 3. Arduino Mega 2560 is equipped with ATMEGA 2560 that has 54 digital inputs/ outputs where 16 pins are used as PWM output, 16 analog inputs. It also has a USB connection, power, ICSP, and reset button. It requires microcontroller support by connecting it to a computer with a USB cable to turn it on using AC or DC and can also use a battery.

Figure 3. Arduino Mega 2560

2) pH Meter

A pH meter is a device for measuring acidity, also known as a device that measures the concentration of hydrogen ions in a solution. Typically, the results of pH measurements are based on known electrochemical potentials in glass electrodes between solutions outside unknown glass electrodes. Probes are an important part of the pH meter and electrodes have a nut rod-like structure. Under the electrode is a light bulb that is a sensitive part of the probe that contains the sensor. To measure the pH of the solution, soak the probe in solution, the probe attaches to an arm called an arm probe. The pH meter display used is seen in Figure 4.

Figure 4. pH Meter

3) Temperature Sensor

DS18B20 is used in this study and shown in Figure 5. The DS18B20 temperature sensor is a sensor that can read temperature values at an accuracy of 9 to 12 Bits and in the range of accuracy of -55 to 125ºC. The working principle of the DS18B20 sensor itself is to regulate the amount of heat and cold energy generated through an object, then the symptoms of temperature changes can be understood or detected in analog output values [4].

Figure 5. DS18B20

4) Dissolved Oxygen Sensor

The working principle of DO meters is based on the polarization that occurs between two electrodes: the cathode and the anode. A negative potential is applied to the cathode. This negative voltage causes a rapid chemical reaction between water and dissolved oxygen on the cathode surface. When all oxygen is diffused on the surface of the cathode electrode, the dissolved oxygen value is obtained from the current value. In other words, the current that flows when the system reaches a saturation voltage equals the amount of dissolved oxygen [5]. DO is shown in Figure 6.

Figure 6. Dissolved Oxygen Sensor

5) Total Dissolved Solids Sensor

TDS sensors are used to measure TDS values. The TDS sensor kit is precise and can transmit data to the control system. It is compatible and easy to use with Arduino as well as plug and play. PPM is the unit used to measure TDS. Here is the shape of the components of the TDS in Figure 7.

Figure 7. TDS Sensor

6) Wifi Module (ESP8266)

ESP8266 is a *wifi* module used as an enhancement for microcontrollers such as Arduino, so it can connect directly to *wifi* to create a TCP/IP connection. ESP8266 display is shown in Figure 8. This module requires a power supply of about 3.3 V to 5 V and is only a *wifi* model: station, access point, or both. The module also comes with a processor, memory, and GPIO and the number of pins depends on the type of ESP8266 used. In this way, the module can be used independently without a microcontroller, because it already has a device such as a microcontroller.

Figure 8. Wifi Module (ESP8266)

C. Website Monitoring Design

The website is designed as a display of water quality levels monitored by the AUV. Built-in web displays contain water quality data based on temperature, pH, TDS, and DO sensors. Website mockups are created using Visual Studio Code with the Code Igniter framework. For the data to appear, this monitoring data use the IoT architecture that can be seen in Figure 9, where the architecture starts by retrieving data through data on the sensor using a microcontroller, and then the data is sent to ESP8266 with serial communication to be sent to the server via wi-fi network by API intermediary on Code Igniter.

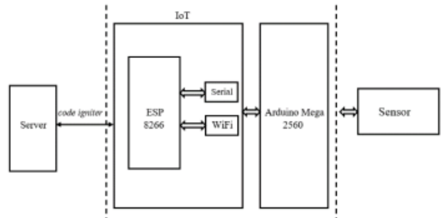

Figure 9. IoT Architecture

D. System Testing

At this stage, tests will be conducted on pre-designed systems. Testing is conducted to know the success and errors of the system that has been designed. In the process of testing the AUV will be placed on the surface of the water, then the AUV will enter the water and begin collecting data obtained from sensors that read the quality of the water. The sensors will start working and read the pH, temperature, DO, and TDS levels of the intended water. If the data is successfully read the data will be forwarded to the next process i.e. the AUV will rise back to the surface automatically. On the surface, the AUV will send the data using a communication module to the website that is built to view the data as well as display the water quality of each parameter. Testing is also conducted to determine the performance of the test, namely the accuracy of the reading of the AUV sensor as well as the functionality of the website to be built.

IV. Result And Discussion

The discussion in this chapter is about the results of the implementation of AUV to measure water quality levels in areas studied in real-time with IoT technology. The way AUV works in measuring water quality levels starts from sensor readings to receipt of data to be viewed through the website.

A. Tool Design

AUV has two microcontroller units that each serves to control the movement of the AUV as well as read the parameters of the water quality sensor. The AUV is made to move using a propeller controlled by one of the microcontrollers with the help of a motor driver. Other microcontrollers measure water quality on some sensors located on the left outside of the AUV. Figure 10 shows the view of the AUV.

Figure 10. AUV

AUV that is ready to use is then tested the results of sensor readings so that the sensor readings on the AUV are thorough and accurate. The sensors tested included pH sensors, DO sensors, TDS sensors, and temperature sensors.

B. Sensor Advancement on AUV

Testing is conducted to get the best results for water quality monitoring systems.

1) pH Sensor Testing

This test was conducted by comparing the pH reading value with the digital pH meter as a reference. PH testing samples use several solutions such as pH 4.01 buffer solution, pH 6.86 buffer solution, and soapy water solution. Test results can be found in Table 2.

TABLE II. pH SENSOR TESTING

Solution Name	Sensor Readings	Measuring Instrument Reading	Difference in Value
Buffer Solution 4.01	4.09	4.0	0.09
Buffer Solution 6.86	6.86	6.9	0.04
Soapy Water Solution	9.92	9.9	0.02

Based on the results of the test, it can be seen that the sensor readings and measuring instrument readings do not differ much or in other words, the sensor readings are accurate so that the sensor can be used to measure water quality parameters. The difference in the reading value on the sample buffer solution with a pH of 4.01 is 0.09, the buffer solution with a pH of 6.86 is 0.04, and the solution from soapy water is 0.02.

2) Temperature Sensor Testing

In this discussion will be conducted temperature sensor testing with several conditions, namely cold water temperature conditions, normal water, and hot water to find out the performance temperature sensor in the sample. The temperature sensor value reading compared to the temperature reading on the digital thermometer measuring instrument is shown in Table 3.

TABLE III. TEMPERATURE SENSOR TESTING

temperature	Sensor Readings	Measuring Instrument Reading	Difference in Value
Cold Water	9.91	9.9	0.01
Normal Water	29.62	29.4	0.22
Hot Water	52.1	52.1	0

From the results of the temperature sensor test above, it can be seen that the results of temperature sensor readings are close to the digital thermometer reading value. In cold water temperature conditions, there is a difference in the value of 0.01 °C, the normal water temperature has a difference of the value of 0.22 °C and in hot water temperature conditions, there is no difference in value difference between the temperature sensor and digital thermometer measuring device. This indicates that the temperature sensor used can already be one of the water quality parameters.

3) DO Sensor Testing

Furthermore, a value test is performed on the DO sensor where the DO sensor measures the level of dissolved oxygen contained in the water. Before being tested, the DO sensor must first be filled with a NaOH solution on the membrane cap contained in the sensor probe. Testing is conducted with several types of mineral water, tap water, and pool water whose results can be seen in Table 4.

TABLE IV. DO SENSOR TESTING

Solution Name	Sensor Readings	Water Condition
mineral water	7.84	Excellent
Tap Water	7.29	Excellent
Pool Water	5.75	good

Based on doing sensor test data if the DO value is categorized based on water condition value reference [8] then mineral water and tap water are in very good condition and pool water is in good condition, which means that it indicates that the DO sensor used can already measure DO values in various categories of DO that have been determined so that the DO sensor can be used to measure the DO value which is one of the water quality parameters

4) TDS Sensor Testing

TDS sensor testing is conducted at the beginning of the calibration process on the sensor. The TDS sensor is calibrated using 500 ppm TDS Calibration Liquid Water. The test value is shown in Figure 11.

```
TDS Value:498ppm
TDS Value:498ppm
TDS Value:498ppm
TDS Value:500ppm
TDS Value:502ppm
TDS Value:504ppm
TDS Value:504ppm
TDS Value:506ppm
```

Figure 11. TDS Sensor Testing

Based on Figure 5, the value of the TDS sensor is close to the calibration water value of 500 ppm so that the TDS sensor can read the dissolved salt content in water and can be used on the AUV as one of the parameters.

5) Sensor Performance in Research

Sensor performance is calculated to be able to know the level of accuracy of the sensors used in this study. Performance is calculated by various metrics such as error percentage and MAPE (Mean Absolute Percentage Error). Following is the error percentage equation:

$$\text{Error Percentage} = \frac{tool\ value - sensor\ value}{tool\ value} \times 100\% \quad (1)$$

Once the error percentage value in the data is calculated, the MAPE value that includes the overall error percentage can be calculated by calculating the average value of that error percentage. MAPE calculations are intended to measure the accuracy of the readings of the sensors used. The MAPE equation is shown as follows:

$$\text{MAPE} = \sum_{t=1}^{amount\ of\ data} \left| \frac{tool\ value - sensor\ value}{tool\ value} \right| \times 100\% \quad (2)$$

. The results of the perfomation calculation can be seen in Table 5.

TABLE V. CALCULATION OF ERROR PERCENTAGE OF PH SENSOR AND TEMPERATURE SENSOR

Sensor Parameters	Error (%)	MAPE
pH Sensor	0.022%	6.2%
	0.005%	
	0.002%	
Temperature Sensor	0.001%	2.8%
	`0.007%	
	0%	

From the results of the error and MAPE can be seen that the percentage of the overall error value of the pH sensor is 6.2% and on the temperature sensor by 2.8%. DO and TDS sensors are not calculated due to the absence of comparisons with the measuring instrument so cannot determine the error value of the sensor test.

C. Internet of Things (IoT) System Testing

Testing of IoT-based data delivery systems using ESP8266 modules through coding intermediaries on the Arduino Mega 2560 microcontroller. The address of the website that was built is siapbot1.com/tugasakhiraisyah/. The data received is stored through the database and further displayed on the website.

1) Sending Wifi Connected

ESP8266 connects to the wifi network by using the Arduino Mega serial pin and further creates an Arduino program where ESP8266 is given a command to detect the specified wifi network. ESP8266 program view can be seen in Figure 12.

```
#include<KRwifi.h>
char* ssid = "belikuota";
char* pass = "jangankepohehe";

void setup() {
  Serial.begin(9600);
  setWifi(ssid, pass);
}

void loop() {

}
```

Figure 12. ESP8266 programming on Arduino

System testing is done by sending data to the internet where the microcontroller must be connected to the internet network using ESP8266 as an intermediary wifi module. The module can connect microcontrollers on the internet network and access the process of sending data to a predetermined server address. The result of the connection between the microcontroller to wifi via the intermediary ESP8266 module can be seen in Figure 13.

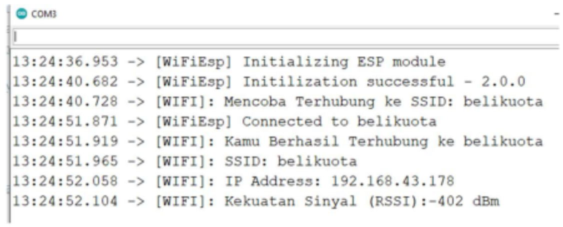

Figure 13. Wifi Connected

2) Data View on the Website

The data is sent to the database server in the form of sensor values that become parameters of water quality monitoring, including the value of pH sensors, temperature sensors, TDS sensors, and DO sensors. The data will be displayed on the address of the website that has been built. The display of water quality monitoring conditions in the water of Lake OPI Jakabaring Palembang can be seen in Figure 14 to Figure 17.

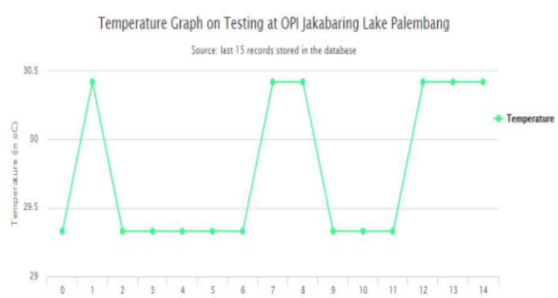

Figure 14. Temperature Data Visualization View in Graph

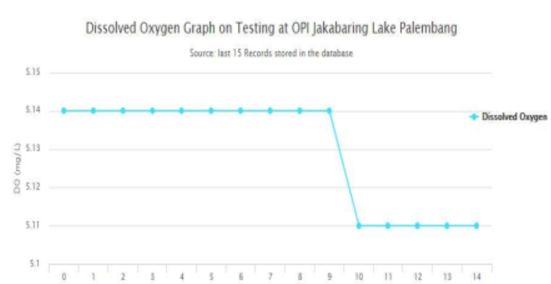

Figure 15. DO Data Visualization View in Graphs

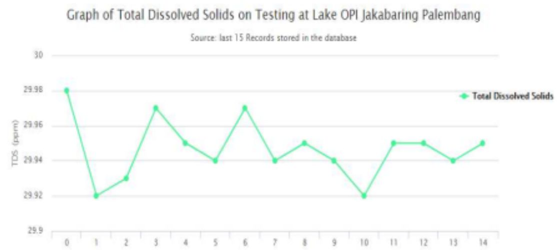

Figure 16. TDS Data Visualization View in Graph

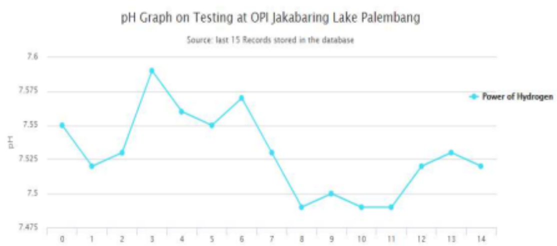

Figure 17. pH Data Visualization View in Graph

Figures 6 - 9 represent visualizations of website addresses viewed through PCs and Handphones. The data displayed on the website works in real-time by providing 15 of the latest data that is on the database server. It can be said that the process of sending data through IoT works well and can be seen through the address of the website built. The IoT of this research works is that it starts from a microcontroller as a data processing site from sensor readings installed at measuring points which is then sent to NodeMCU through serial communication between the microcontroller and NodeMCU. The data is then sent to the database server over the internet network so that it can be accessed from anywhere for monitoring and control purposes to prevent obstacles in the power supply process. The process of sending data requires a pause of ± 9 seconds in the transmission of data to the database server and will continue to grow as the amount of data entered the database increases. Data sent on the database server in Figure 18.

←T→	id	ph	do	suhu	tds	depth	fuzzy	waktu
Edit Copy Delete	395	5.7	2.97	33.45	42.43	0.83	Medium	2021-06-08 17:24:49
Edit Copy Delete	396	6.36	2.97	33.41	47.34	5.4	Medium	2021-06-08 17:24:58
Edit Copy Delete	397	6.23	2.97	33.41	40.64	5.07	Medium	2021-06-08 17:25:07
Edit Copy Delete	398	6.48	2.97	33.4	40.64	6.89	Medium	2021-06-08 17:25:16
Edit Copy Delete	399	6.23	2.97	33.45	40.64	9.45	Medium	2021-06-08 17:25:26
Edit Copy Delete	400	6.39	2.97	33.43	40.64	15.21	Medium	2021-06-08 17:25:35
Edit Copy Delete	401	6.2	2.97	33.46	41.98	17.83	Medium	2021-06-08 17:25:46
Edit Copy Delete	402	6.53	2.97	33.51	41.98	20.78	Medium	2021-06-08 17:25:55
Edit Copy Delete	403	6.45	2.97	33.53	40.64	21.92	Medium	2021-06-08 17:26:04
Edit Copy Delete	404	6.43	2.97	33.49	40.64	22	Medium	2021-06-08 17:26:13
Edit Copy Delete	405	6.44	2.97	33.54	40.64	25.74	Medium	2021-06-08 17:26:22
Edit Copy Delete	406	6.59	2.97	33.57	40.64	24.93	Medium	2021-06-08 17:26:30
Edit Copy Delete	407	6.37	2.97	33.58	41.98	27.93	Medium	2021-06-08 17:26:39
Edit Copy Delete	408	6.47	3	33.52	40.64	32.79	Medium	2021-06-08 17:26:49
Edit Copy Delete	409	5.98	3.07	33.52	40.64	34.32	Medium	2021-06-08 17:26:58
Edit Copy Delete	410	5.96	4.43	33.54	41.98	35.53	Medium	2021-06-08 17:27:07
Edit Copy Delete	411	5.99	7.14	33.55	41.98	41.23	Good	2021-06-08 17:27:16
Edit Copy Delete	412	5.33	7.14	33.62	41.98	47.93	Medium	2021-06-08 17:27:25
Edit Copy Delete	413	4.73	7.14	33.63	43.33	50.39	Medium	2021-06-08 17:27:34
Edit Copy Delete	414	4.56	7.14	33.62	41.98	52.22	Medium	2021-06-08 17:27:44
Edit Copy Delete	415	4.5	7.14	33.62	348.33	58.46	Bad	2021-06-08 17:27:53
Edit Copy Delete	416	5.36	7.14	33.68	438.83	57.98	Bad	2021-06-08 17:28:02
Edit Copy Delete	417	5.62	7.14	33.65	41.98	56.96	Good	2021-06-08 17:28:11
Edit Copy Delete	418	5.71	7.14	33.68	235.01	56.88	Good	2021-06-08 17:28:20
Edit Copy Delete	419	5.69	7.14	33.66	41.98	55.93	Good	2021-06-08 17:28:29

Figure 18. Test Data at Lake OPI Jakabaring on Database Server

V. CONCLUSION

Based on the results of the research that has been done, it can be concluded that the sensors used to measure water quality parameters in AUV have an average error value of 6.2% for pH sensors and 2.8% for temperature sensors. Data reading sensor water quality parameters can be stored in the database and can be monitored in real-time on the website so it can be said that IoT-based data delivery works well. Furthermore, the water quality reading performance also worked well with the water quality obtained on the surface of Lake OPI Jakabaring Palembang was in normal condition at a depth of 9.45 cm where the value on each sensor was worth 6.23 for pH, 33.45 °C for temperature, 2.97 mg/L for dissolved oxygen and 40.64 ppm for total dissolved solids, then continued at the depth of Lake OPI Jakabaring Palembang is in excellent condition at a depth of 110.73 cm where the value on each sensor is worth 7.65 for pH, 29.92°C for temperature, 5.14 mg/L for dissolved oxygen and 29.33 ppm for total dissolved solids.

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