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Design of IoT-based monitoring system for temperature and dissolved oxygen levels in catfish aquaculture pond water

Nurma Sari, Yuniar Savitri, Sri Cahyo Wahyono, Joko Santoso, Amar Vijai Nasrulloh
Department of Physics, Faculty of Mathematics and Natural Sciences, University of Lambung Mangkurat, Banjarbaru, Indonesia

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ABSTRACT

One of the fish in Indonesian waters that has been successfully bred and cultivated is the catfish (*Pangasius sp.*). In catfish farming, there are several water quality factors that need to be considered, such as temperature and dissolved oxygen levels. Based on the existing description, it is very important to pay attention to the water quality of aquaculture ponds, especially temperature and dissolved oxygen levels for fish survival. This study aims to create an internet of things (IoT) based monitoring system for temperature and dissolved oxygen levels in catfish aquaculture pond water based on NodeMCU ESP8266. Monitoring system is using SEN0237 gravity analog dissolved oxygen sensor, DS18B20 sensor module, NodeMCU ESP8266, 20×4-character liquid-crystal display (LCD), micro secure digital (SD) card module, internet modem. Data from measurements of temperature and dissolved oxygen levels are stored online in the Adafruit.io database in the .csv format and on a micro secure digital (SD) card in the device in the .txt format. The lowest value of dissolved oxygen levels and temperature are 3.4 mg/L or 3.4 ppm and a temperature of 27.9 °C, respectively. Meanwhile, the highest value of dissolved oxygen levels and temperature are 4.6 mg/L or 4.6 ppm and temperature of 30.9 °C, respectively.

Corresponding Author:

Nurma Sari
Department of Physics, Faculty of Mathematics and Natural Sciences
University of Lambung Mangkurat
70714, Banjarbaru, Kalimantan Selatan, Indonesia
Email: nurmasari01@ulm.ac.id

1. INTRODUCTION

Catfish is one of the native fish in Indonesian waters that grows well. Catfish is a freshwater fish that belongs to the catfish (*Pangasius sp*.) type. Pangasiidae can be mass-produced and offers the potential for industrial-scale development due to its basic characteristics of lacking scales, having few spines, having a fairly fast growth rate, and having high fertility and survival rates. With all these benefits, this fish has increased economic value among fishery commodities, both in the hatchery and grow-out business sectors [1], [2]. In recent times, real time water quality monitoring in aquaculture has been brought by the fast development of internet of things (IoT) technology effectively. Globally, water quality monitoring systems based on IoT and wireless communication technologies have been widely studied intensively [3]–[13].

Dissolved oxygen levels are one of the water quality parameters that can cause large numbers of fish to die. The processes of decomposition, reproduction and development in ponds are hampered by low dissolved oxygen levels. According to Indonesian National Standard (SNI) number 01-6483.3-2000 for catfish culture, dissolved oxygen levels range from >4 mg/L. The need for fish for dissolved oxygen levels depends on the age of the fish, fish activity, and water quality [14]. Dissolved oxygen levels in ponds vary from time to time. Research show that dissolved oxygen levels change due to the influence of changing temperatures due to unstable weather [15]. According to Effendi [16], dissolved oxygen levels for fisheries must be at least 5 mg/L. If the concentration of dissolved oxygen is not balanced, the fish will be stressed because the brain does not get enough oxygen. Fish will experience anoxia because their body tissues are unable to bind dissolved oxygen in the blood.

The water temperature of fish farming ponds is an important factor. The ideal temperature tolerance range for catfish according to SNI number 01-6483.3-2000 is between 25-30 ℃. Pool water temperature affects water quality [17]. Oxygen solubility is one of the characteristics of water quality that is affected by temperature variations. With increasing temperature, the level of solubility of oxygen decreases [18], [19]. Once there is an increase in temperature, the amount of solubility of oxygen in water will decrease. An increase in temperature causes the metabolic activity of fish to be greater which results in a doubling of oxygen consumption in fish. Low water temperature can affect the ability of fish to bind oxygen so that it can inhibit fish development [20]. Fish that experience stress reduce stamina and reduce hunger, and eventually starve to death [16].

The DS18B20 temperature sensor is a device that can read temperature variations and then translate these changes into electrical quantities. This sensor is connected to the microcontroller using a single cable and is a digital sensor. These sensors are special because each sensor contains a serial code that allows the use of multiple DS18B20s in one-wire transmission. This sensor can be used with 3.0 to 5.5 V. The sensor has ±0.5 °C accuracy from -10 to +85 °C and can be used in the temperature range of -55 to 125 °C (-67 to +257 °F) with a resolution of 9 to 12 bits [21]. SEN0237 gravity analog dissolved oxygen sensor is a sensor for measuring dissolved oxygen levels in water. These sensors are widely used in various water-related sectors, including research, aquaculture, and monitoring of the aquatic environment. This sensor is open source and compatible with various microcontrollers, allowing users to use it freely and openly. This sensor has a galvanic probe type with a detection range of 0 to 20 mg/L. This sensor has a response time of up to 98% full response, within 90 seconds (25 ℃) sensor pressure range from 0 to 50 psi with electrode service life generally for 1 year for normal use [22]. NodeMCU ESP8266 is a microcontroller equipped with the ESP8266 chip. This microcontroller has multiple input or output ports to enable monitoring and control applications for IoT projects. The NodeMCU ESP8266 is an evolution of the ESP8266 version of the ESP-12 IoT platform module family. This module works very similarly to the Arduino module platform in terms of functionality, but the difference is "connected to the internet" [23].

Several studies that have been conducted regarding the measurement of water quality in aquaculture ponds. For instance, Moreno-Rodenas *et al.* [24] in 2017 was working on a data acquisition system for measuring dissolved oxygen levels with the results that the average dissolved oxygen level is in the range of 3 to 5 mg/L in rainy conditions and between 3 to 7 mg/L on cloudy conditions. Next, research by Kustija and Andika [25] in 2021, was showing a system for monitoring temperature and dissolved oxygen levels in catfish ponds with the Raspberry Pi that was obtained the water temperature varied with time. Furthermore, research by Bima *et al.* [26] in 2018 built a temperature remote monitoring system in Bangkok tilapia ponds, the effective temperature for fish pond water was an indicator of 28 to 30 °C. To fill the needs of fish consumes, aquaculture methods have been forced to overproduce and resulting in the accelerated water environment degradation and the old of agricultural workers in many parts of the world so will face the dilemma of shortage of labor, and IoT aquaculture method is one of the method that can resolve the issue [27]. Fish farming has been applied widely recently. In Bangladesh, fish monitoring had been studied based on IoT so it notified the user the amount of dissolved oxygen, ammonia level, pH level, and water body temperature. It can help fish farmers to measure the parameters and provide necessary things to grow more fish and facing water pollution [28]. Latest research by Loh *et al.* [29] showed that to address the challenges of maintaining aquatic environment, IoT fish farm monitoring system has been done to provide several features such as temperature, pH, dissolved oxygen, total dissolved solid, and energy usage of the water pump.

Erratic weather patterns cause poor water quality for fish farming, which makes fish susceptible to disease and if it continues will result in mass fish mortality. Based on the existing description, it is very important to pay attention to the water quality of aquaculture ponds, especially temperature and dissolved oxygen levels for fish survival. In this research, a remote and IoT based monitoring system for temperature and dissolved oxygen levels in catfish farming ponds will be made using the DS18B20 and SEN0237 gravity analog dissolved oxygen sensor internet-based sensors which will be tested and implemented in catfish farming ponds. This monitoring system uses NodeMCU ESP8266 as a microcontroller and Adafruit.io as an online interface. By applying IoT technology with an internet network, this up-to-date technology is able to send data and offer speed and a vast distance [30]. This research develops IoT technology for sending parameter data from dissolved oxygen level and temperature directly to a web server. Then, the stored data for 24 hours on the webserver can be processed for further identification all the time.

2. RESEARCH METHOD

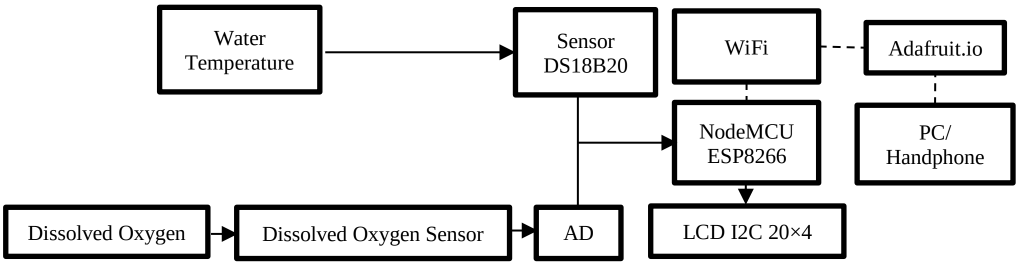
2.1. Material

The materials used are the sensor modules which are DS18B20 temperature sensor and SEN0237 gravity analog dissolved oxygen sensor. Next is the microcontroller kit that consists of NodeMCU ESP8266, 20×4-character liquid-crystal display (LCD) with inter-integrated circuit (I2C) and secure digital (SD) card module. It is also supported by 12 V 2 A adapter, step down DC to DC converter, tin, electronic components, connecting cables, and control panel box.

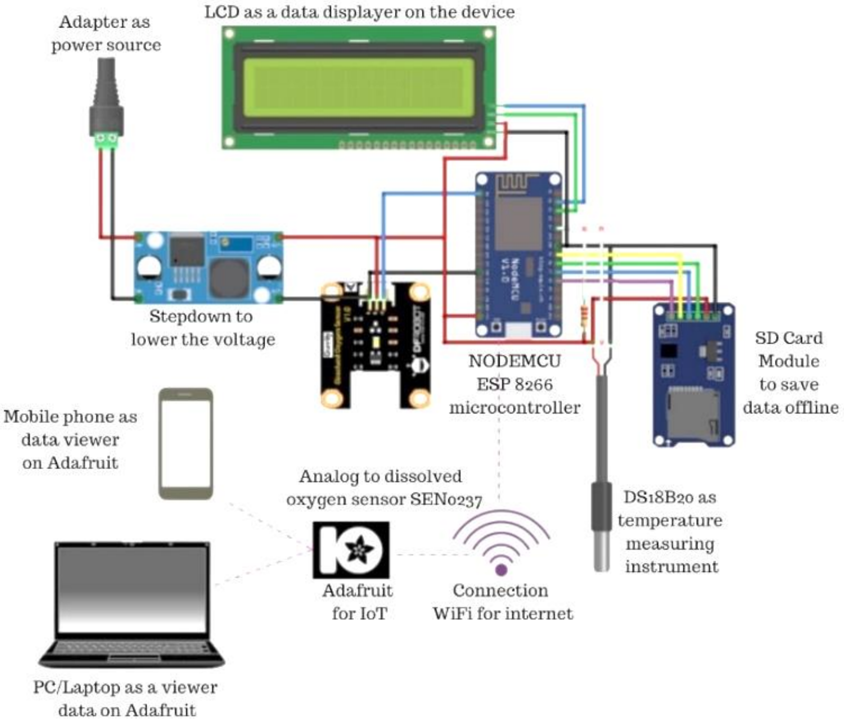
2.2. Method

2.2.1. Hardware

The proposed of the NodeMCU ESP8266-based IoT monitoring system for temperature and dissolved oxygen consists of several stages starting with preparing the tools and materials needed in this research (Figure 1). It proceeds with assembling the hardware, namely integrating the NodeMCU ESP8266 with the sensor, and assembling a remote monitoring system for temperature and dissolved oxygen based on the NodeMCU ESP8266. Furthermore, the manufacture of software includes the manufacture of microcontroller software, manufacture of LCD interface software and manufacture of IoT software. Followed by determining the transfer function of measuring instruments, testing the system as a whole and finally data collection. The details of the proposed system can be seen clearly in Figure 1(a). Meanwhile, Figure 1(b) shows layout of the circuit design of remote monitoring of temperature and dissolved oxygen levels based on Node MCU ESP8266. It is included SEN0237 analog dissolved oxygen sensor, DS18B20 sensor, SD Card module, and 20×4 characters I2C LCD module are integrated into the NodeMCU ESP8266.



(a)



(b)

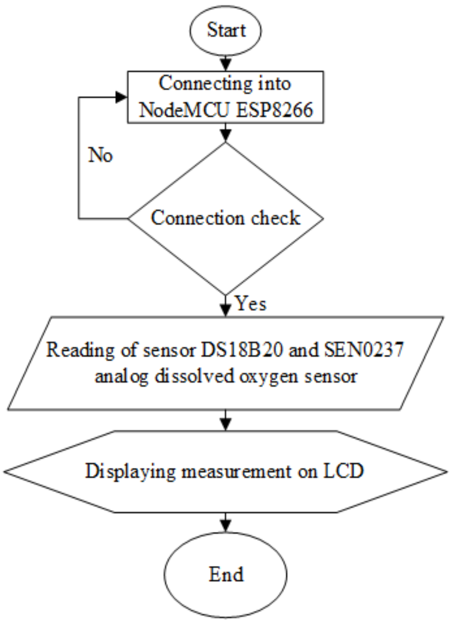
Figure 1. Proposed system of (a) block diagram and (b) circuit design

2.2.2. Software

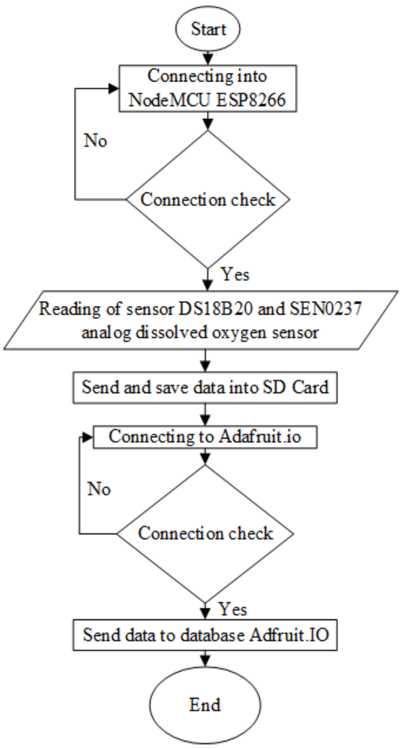
Figure 2 shows the function of NodeMCU ESP8266 for both with sensors and LCD and also with IoT. The software on NodeMCU ESP8266 is made using the Arduino integrated development environment (IDE) software. The software interface to LCD using Arduino IDE software that connecting between NodeMCU ESP8266 and sensors (DS18B20 dan SEN0237 analog dissolved oxygen sensor). The stages include LCD pin configuration, library input, and giving commands to retrieve data from the output of the measuring instrument circuit. The flowchart of the programme interface to display characters on the LCD can be seen in Figure 2(a).

Calibration was accomplished by comparing the measured value on the sensor with the measured value on a standard measuring instrument. For the DS18B20 sensor, a digital thermometer is used as a comparison. The measurement range used is 10 to 50 ℃. Meanwhile, for the SEN0237 grativy analog dissolved oxygen sensor, a dissolved oxygen meter is used as a comparison. Measurements were made using zero dissolved oxygen powder which was added little by little until a measured dissolved oxygen value of 0 mg/L was obtained.

Figure 2(b) presents connection of NodeMCU ESP8266 with IoT. The system developed by the Arduino IDE software and the IoT interface used Adafruit.io. In details, to connect NodeMCU ESP8266 with IoT, it is mandatory to write down the WiFi name and password of the wifi used. To link readings to Adafruit.io, the listing should include the Adafruit.io web address, the username of the Adafruit.io account used, the active key, and the name of the feed used. The monitoring system that is made is tested first by observing each part whether it is working properly. Next, a performance check of the NodeMCU ESP8266 is carried out by connecting to the internet so that it reads Adafruit.io. After connected to the internet and a notification appears that Adafruit.io has been connected, a comparing the values between on the LCD of the device and Adafruit.io. Once the reading value of the measuring instrument that appears is appropriate, the tool can be used.



(a)



(b)

Figure 2. Flowchart of NodeMCU ESP8266 with (a) sensors and LCD, and (b) IoT

Calibration was accomplished by comparing the measured value on the sensor with the measured value on a standard measuring instrument. For the DS18B20 sensor, a digital thermometer is used as a comparison. The measurement range used is 10 to 50 ℃ with the sensor readings obtained, the (1) is obtained.

$$y = 1{,}0129x + 0{,}2557 \text{ with } R^2 = 1 \quad (1)$$

The (1) is then entered into the Arduino program. It is intended that the readings from the DS18B20 sensor are the same as standard measuring instruments. After the equation is entered into the Arduino program, retesting is carried out with a temperature range of 20 to 35 °C as a representative of the reasonable limit for measuring catfish pond water. Data on the results of retesting the DS18B20 sensor can be seen in Table 1. Meanwhile, for the SEN0237 grativy analog dissolved oxygen sensor, a dissolved oxygen meter is used as a comparison. Measurements were made using zero dissolved oxygen powder which was added little by little until a measured dissolved oxygen value of 0 mg/L was obtained. Based on the sensor readings obtained, the (2) is obtained.

$$y = 126{,}22x - 129{,}85 \text{ with } R^2 = 0{,}9664 \quad (2)$$

The (2) is then entered into the Arduino program. This aims to convert the reading from SEN0237 analog dissolved oxygen sensor into mg/L like the reading from dissolved oxygen meter. After the equation is entered into the Arduino program, a retest is carried out using local government-owned water utility (PDAM) water with calibration powder added little by little until the dissolved oxygen level in PDAM water becomes 0 mg/L. The data of SEN0237 analog dissolved oxygen sensor retest can be seen in Table 2.

Table 1. DS18B20 sensor retest result data

No	Calibrator ($\bar{x}$)	DS18B20 sensor ($\bar{x}$i)	Difference ($\bar{x}$-$\bar{x}$i)	|Error| (%)
1	20	20	0	0.00
2	21	21.02	-0.02	0.10
3	22	22.03	-0.03	0.14
4	23	23.04	-0.04	0.17
5	24	23.99	0.01	0.04
6	25	25.00	0.00	0.00
7	26	26.02	-0.02	0.08
8	27	27.03	-0.03	0.11
9	28	28.04	-0.04	0.14
10	29	28.99	0.01	0.03
11	30	30.01	-0.01	0.03
12	31	31.02	-0.02	0.06
13	32	32.03	-0.03	0.09
14	33	33.04	-0.04	0.12
15	34	34.06	-0.06	0.18
16	35	35.01	-0.01	0.03
		Error mean		0.1

Table 2. Result of the retest data on SEN0237 analog dissolved oxygen sensor

No	Calibrator ($\bar{x}$)	SEN0237 sensor ($\bar{x}$i)	Difference ($\bar{x}$-$\bar{x}$i)	|Error| (%)
1	6.50	6.82	-0.32	4.92
2	6.03	6.57	-0.54	8.9
3	5.90	6.07	-0.17	2.82
4	5.70	5.58	0.12	2.05
5	5.27	5.18	0.09	1.71
6	4.53	4.35	0.18	4.12
7	3.80	3.09	0.71	18.77
8	2.53	1.75	0.78	31.05
		Error mean		9.3

2.2.3. System realization

Figures 3 show the location and configuration of the equipment and its placement in the catfish farming pond. Pre-data collection was retrieved for 2 days to determine the readiness of the tool before the actual data collection was carried out. Pre-data collection was carried out during weather conditions after rain and in ponds with cloudy weather conditions accompanied by rain. Data monitoring can be monitored via mobile phones and laptops or other devices that can access the internet. To monitor the measurement results via the internet, users can open the link that has been provided for this monitoring system. Measurements will begin when the NodeMCU ESP8266 microcontroller is connected to the internet. The process of connecting the microcontroller to the internet takes ±40 seconds depending on the speed of internet access. The better the internet network used, the faster the microcontroller is connected. If the internet network is disconnected, the data displayed is the last data before the network is disconnected. This monitoring system has a weakness in the dissolved oxygen sensor used, which is a probe filling solution sensor that must always be monitored. During the pre-take, it is known that the effective use of the probe filling solution is about 3-4 hours. Therefore, every 3-4 hours it is necessary to check and replace the probe filling solution so that the measurement results obtained have a good value. The probe filling solution used should always be in good condition and no bubbles should form on the filling membrane. The formation of bubbles and poor probe filling solution can affect the measurement results.

Location of the ponds in this research can be clearly seen in Figure 3(a). The laying tools in the field using a box that is given a hole and then associated with a paralon pipe tied to the bridge. The tool box, modem, and power outlet (Figure 3(b)) are placed in a green box which is then given a hole for the sensor probe. The sensor probe is connected to the outside of the box and then inserted into the paralon pipe that has been tied to the bridge to prevent the position of the probe from moving if it is hit by a fish that has an impact on the measurement (Figure 3(c)).

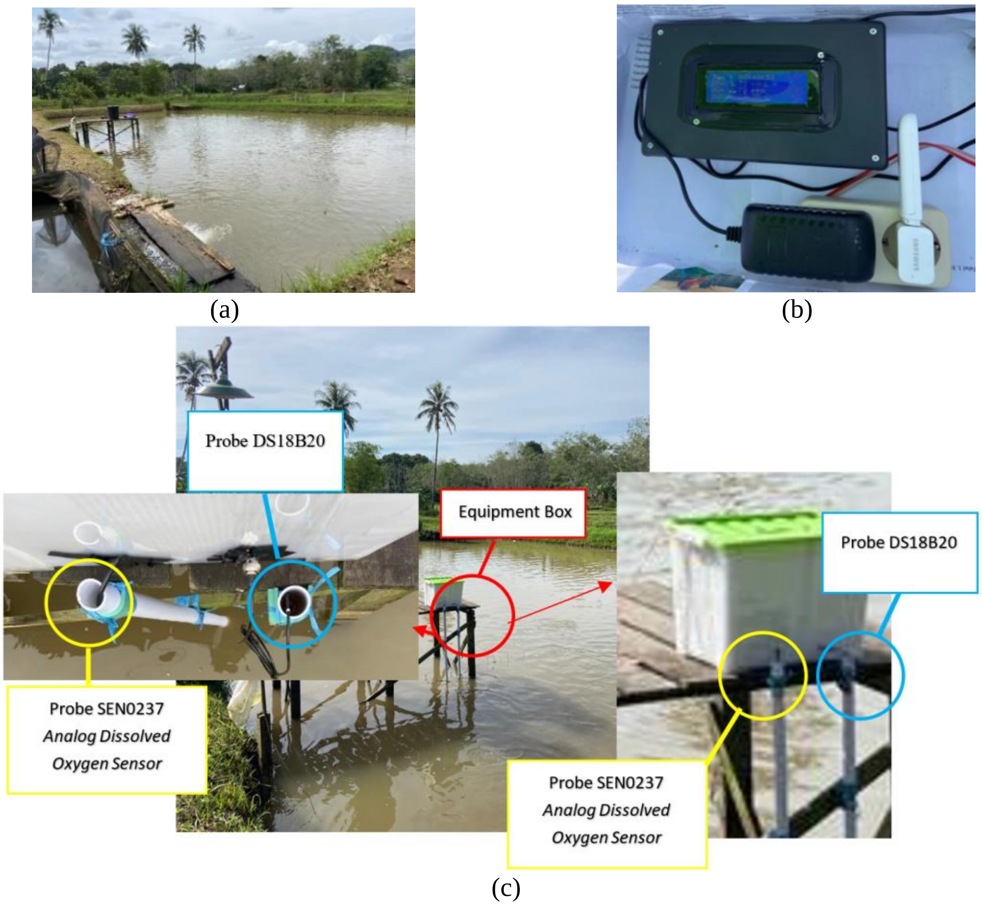


Figure 3. The location and configuration of the equipment and its placement in the catfish farming pond by (a) location of catfish ponds where data is collected, (b) measurement and IoT system processing equipment, and (c) IoT based monitoring system for temperature and dissolved oxygen levels in catfish farming ponds

3. RESULTS AND DISCUSSION

The calibration process of the SEN0237 analog dissolved oxygen sensor. Measurements were carried out three times using water mixed with zero dissolved oxygen powder until the dissolved oxygen level in the water was 0 mg/L. Based on the results of the sensor readings obtained the regression formula in (2) and adapted into Arduino program. From the results of retesting conducted, it is known that the average error in sensor readings is 9.3% (Table 2). Meanwhile, based on the results of the DS18B20 temperature sensor during calibration, it is obtained the regression formula in (1). This equation is then adapted into the Arduino program. It is intended that the readings from the DS18B20 sensor are the same as standard measuring instruments. From the results of retesting, it is known that the average error value of reading is 0.1% (Table 1).

The readings that appear on the Adafruit.io dashboard are temperature, dissolved oxygen (mg/L), and dissolved oxygen (ppm) in the form of images and gauges. Figure 4 is the interface display on Adafruit.io. The gauge is given a limit value, where if the dissolved oxygen value is below 4 mg/L or 4 ppm and the temperature is below 25 ℃ and more than 30 ℃ then the gauge will turn red as a sign that the measurement was carried out in a condition that is not in accordance with SNI number 01-6483.3-2000. Meanwhile, when the measurement results are >4 mg/L or 4 ppm for dissolved oxygen and the temperature is around 25-30 ℃, the gauge will turn green. Data display indicators for monitoring can be said to be real-time if the interface for sensor readings that appear on the LCD and the Adafruit.io dashboard is "same". Figure 5 shows the real-time readings of the Adafruit.io LCD and dashboard.

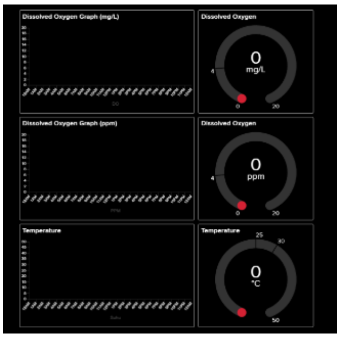
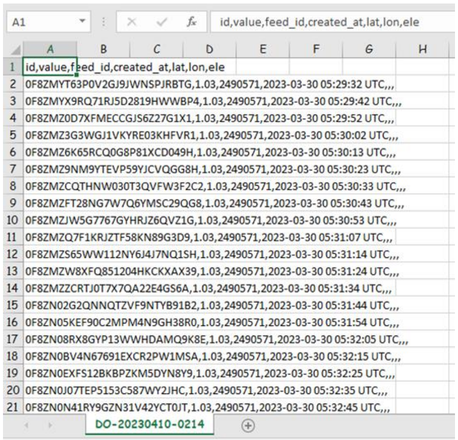


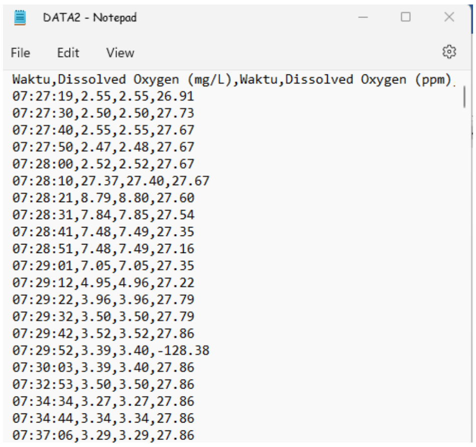
Figure 4. Adafruit.io display developed

Figure 5. Testing and validating of the IoT-based system

Data measurement from the downloaded of Adafruit.io database is in .csv file format, while stored on the micro SD card is in the .txt file format (Figure 6). Data stored in the Adafruit.io database can be downloaded in .csv file format for each feed (Figure 6(a)). Along side stored online in the Adafruit.io database, measurement data is also stored offline on a micro SD card in the form of a .txt file. The stored data contains time data, SEN0237 analog dissolved oxygen sensor readings in mg/L and ppm units, as well as DS18B20 sensor module readings which are separated by commas ",". This data can be converted into an spreadsheet table for comparative image analysis. Figure 6(b) shows the .txt file data written to and stored on the micro SD card.



(a)



(b)

Figure 6. Display of measurement results data of (a) the downloaded from the Adafruit.io database in .csv file format and (b) the .txt file data written to and stored on the micro SD card

Data collection was retrieved for three days (Figure 7). The measuring instrument is placed on a bridge with a height of ±80 cm from the water surface with the sensor probe submerged about 2-4 cm from the water surface. During data collection, the weather is constantly changing. Data collection on first day was in cloudy weather conditions accompanied by rain during the day. The relationship between temperature and dissolved oxygen levels from data collection on the first day can be seen in Figure 7(a). From the figure it is known that when the temperature increases the dissolved oxygen levels decrease and vice versa. From the Figure 7(a), the relationship between temperature and dissolved oxygen levels is most clearly seen at point a at 13:15, where the dissolved oxygen value reaches 4.5 mg/L or 4.5 ppm with a measured temperature of 28.6 ℃. It also shows a decrease in dissolved oxygen values and temperature due to rain during the day, from 13:15 to 14:30. Apart from when it rains, dissolved oxygen values and measured temperatures also tend to decrease at night at 19:15. The dissolved oxygen value measured after rain and at night fell below 4 mg/L.

Data collection on second day was cloudy in the morning, then hot during the day and cloudy again in the late afternoon. Figure 7(b) is a graph of the relationship between temperature and dissolved oxygen levels. From the Figure 7(b) it is known that when the temperature increases the dissolved oxygen level decreases and vice versa as seen at 19:30 to 20:00. In some conditions there are temperature values that are not in accordance with the theory, such as at points d to e where the temperature values measured exceed the value of 30 ℃ at 13:00 to 17:30 caused by the hot sun during the day. The dissolved oxygen value between 10:00 and 11:30 is measured to be less than 4 mg/L in the morning with cloudy weather conditions after rain. The low dissolved oxygen value measured is the dissolved oxygen value measured at the time of changing the probe filling solution because when changing the probe is removed from the water. The low dissolved oxygen measured, aside from the effect of temperature, is also caused by other factors such as the water level and the water content.

Data collection on third day in sunny weather conditions in the morning then hot during the day, cloudy in the late afternoon accompanied by rain at night. Figure 7(c) is a graph of the relationship between temperature and dissolved oxygen levels. The Figure 7(c) during the temperature increases the dissolved oxygen levels decrease and vice versa. The relationship between temperature and dissolved oxygen can be seen at 15:45 to 17:15 once dissolved oxygen increases the temperature value decreases. In some conditions there are temperature values measured outside the limits of SNI provisions at 11:30 to 16:30 with the measured values are more than 30 ℃. This condition occurs due to the hot weather during the day that causes the temperature to increase. Dissolved oxygen values that were measured outside the regulatory limits were seen between 10:00 and 10:45 and at 17:15 to 20:00, where dissolved oxygen values were measured below 4 mg/L. The low dissolved oxygen measured apart from temperature is also caused by other factors such as water level and water content. From the data image, the most obvious one is at 14:00 where the dissolved oxygen value reaches 4.2 mg/L or 4.2 ppm with a measured temperature of 30.9 ℃.

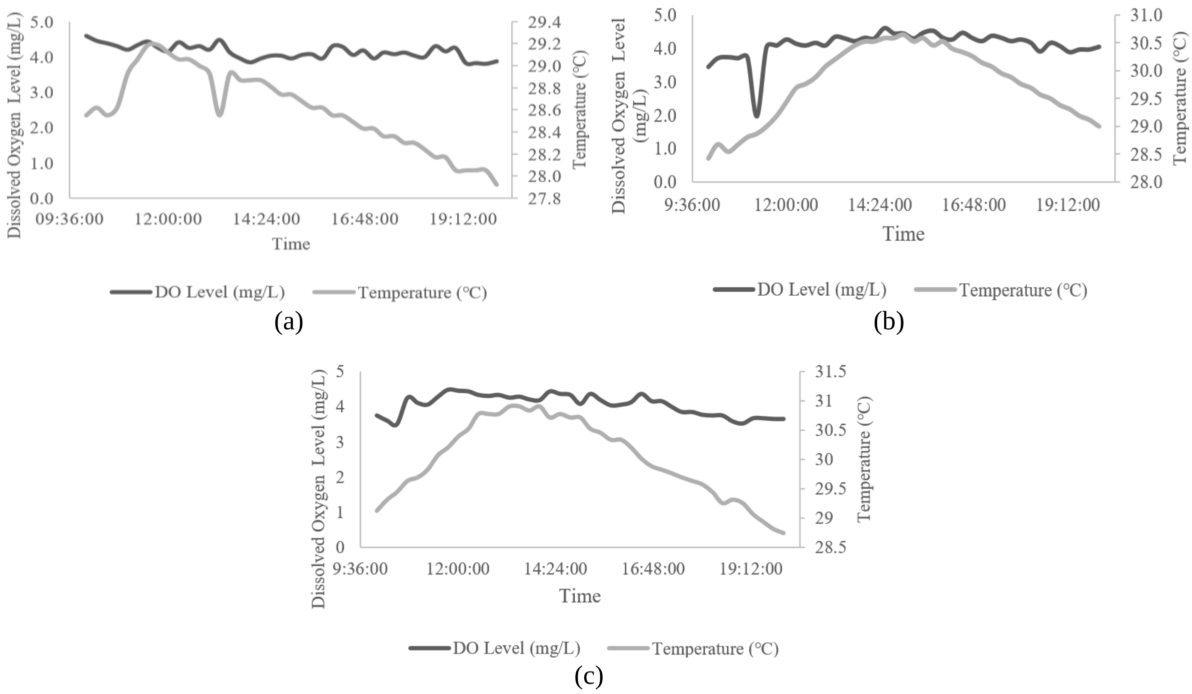


Figure 7. Data collection of dissolved oxygen level (black line) and temperature (gray line) for three days (a) first day, (b) second day, and (c) third day data collection

Based on measurements carried out for three days, from 10:00 to 20:00 (Table 3), it is known that the temperature and dissolved oxygen values of the Karang Intan catfish pond are relatively safe and quite good. In the morning dissolved oxygen in fish pond water is quite low, then it increases as the day progresses. When it rains, the measured dissolved oxygen levels also decrease. This is similar to research conducted by Mardhiya *et al*. [31] in 2017 which obtained an average dissolved oxygen level in the range of 3 to 5 mg/L in rainy conditions and a range of 3 to 7 mg/L in cloudy conditions. Abundant oxygen levels during the day with sunny weather due to the process of respiration by macrophytes in the mechanism of photosynthesis with the help of sunlight. While at night dissolved oxygen decreased again. The decrease in dissolved oxygen levels at night is due to the absence of photosynthesis at night, also caused by the level of temperature fluctuations by the air, the increased respiration rate of sediment by bacteria and the more intense respiration rate in fish ponds by aquatic organisms. As for the temperature, it is influenced by the surrounding conditions. As the day gets darker, when the weather is cloudy and it rains, the measured temperature decreases and vice versa, when the weather is sunny and the sun is hot enough, the measured temperature increases. This is similar to research conducted by Sumardiono *et al*. [32] in 2020, for example when it is sunny the temperature will rise to around 29 °C, when it is foggy it will drop to around 27.7 °C, and at night it will generally drop to around 29.4 °C. The graph of the maximum and minimum values of dissolved oxygen and temperature measured for 3 days can be seen in Figure 8.

Table 3. Maximum and minimum values of data for three days of measurement

Day	Dissolved oxygen (mg/L)				Temperature (°C)			
	Time	Max	Time	Min	Time	Max	Time	Min
1	10:00:01	4.6	19:45:01	3.81	11:45:09	29.19	20:00:37	27.92
2	14:30:15	4.6	10:00:42	3.44	15:00:09	30.64	10:00:42	28.43
3	11:45:20	4.49	10:30:05	3.5	13:30:38	30.9	20:00:12	28.74

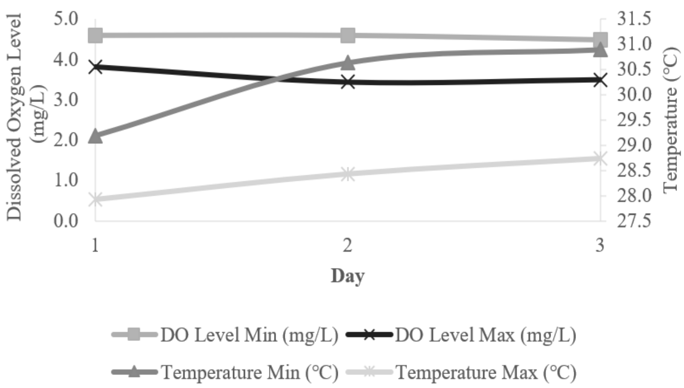


Figure 8. The maximum and minimum values of dissolved oxygen level and temperature of 3 days of measurement

In Figure 8 it can be seen that dissolved oxygen tends to be lower in the morning, then increases as the day progresses. During 3 days the measurement was carried out, the dissolved oxygen levels and temperature measured during the measurement had the lowest value of 3.44 mg/L or 3.44 ppm with a temperature of 27.92 ℃ and the highest value of 4.6 mg/L or 4.6 ppm with a temperature of 30.9 ℃. From the measurements taken, it is known that dissolved oxygen levels have good values during the daytime, while in the morning and night have poor values. The maximum value of dissolved oxygen that was measured was obtained at 10:00, 14:30, and 11:45. At night dissolved oxygen tends to decrease, where from the data obtained it is recorded that the minimum dissolved oxygen value is at 19:45, 10:00, and 10:30. Meanwhile, the temperature tends to increase during the day and decreases in the afternoon until the evening. From the data recorded from measurements for three days, it was found that the temperature experienced a maximum value at 11:45, 15:00, and 13:30. The minimum temperature recorded is at 20:00 and 10:00. The low temperature measured in the morning is caused by temperature changes that occur at night accompanied by rain, so that when measurements are taken in the morning the measured temperature tends to be low. From the measurement data obtained, it is known that dissolved oxygen levels are indeed affected by temperature, but this factor does not have a significant effect. There are other factors that affect dissolved oxygen levels in fish pond water. Even so, the water quality measured in the catfish pond is fairly good because the dissolved oxygen and measured temperatures are still within safe limits. The circulation of fish pond water is quite good so that even though the measured dissolved oxygen was below the SNI number 01-6483.3-2000 standard for catfish cultivation, dissolved oxygen can again increase to the threshold according to SNI number 01-6483.3-2000. This system also spent a low cost for its operation. In details, for the distilled water solution as a neutralizer or rinsing probes before and after use, approximately 500 ml of distilled water is enough for one week of data collection. As for probe filling or sodium hydroxide (NaOH) liquid, approximately 30 ml is enough for one week of data collection. Cost calculation for 1 week, 500 ml of distilled water costs USD 0.45 and 30 ml of 0.5 molar NaOH costs USD 0.032 so the total cost for 1 week is USD 0.48. (USD 1=IDR 15,719).

4. CONCLUSION

An IoT-based monitoring system for temperature and dissolved oxygen levels in catfish farming ponds using the DS18B20 and an internet-based dissolved oxygen sensor has been successfully developed. This monitoring system are able to measure temperature and dissolved oxygen levels which have a reading error value for the DS18B20 sensor of 0.1% and for the SEN0237 analog dissolved oxygen sensor 9.3%. The effective value of the probe filling solution on the SEN0237 analog dissolved oxygen sensor is around 3-4 hours. A water quality monitoring system has been implemented in catfish pond in Karang Intan for 3 days starting from 10:00 to 20:00. From the measurements that have been made, it is obtained that the dissolved oxygen level and temperature measured during the measurement have the lowest value of 3.4 mg/L or 3.4 ppm with a temperature of 27.9 ℃ and the highest value of 4.6 mg/L or 4.6 ppm with a temperature of 30.9 ℃. The main limitation of the dissolved oxygen sensor is the effective use of the probe filling solution is about 3-4 hours. Therefore, every 3-4 hours it is necessary to check and replace the probe filling solution. In the future, dissolved oxygen sensor replacement with longer lifetime of used for the probe filling solution replacement. This future research also using photovoltaic cells as independent energy to supply to system so it can be implemented into remote ponds that are unavailable electricity source.

REFERENCES

[1] S. M. Limbu, "The effects of on-farm produced feeds on growth, survival, yield and feed cost of juvenile African sharptooth catfish (Clarias gariepinus)," *Aquaculture and Fisheries*, vol. 5, no. 1, pp. 58–64, 2020, doi: 10.1016/j.aaf.2019.07.002.

[2] Y. Sukrismon, Aripriharta, N. Hidayatullah, N. Mufti, A. N. Handayani, and G. J. Horng, "Smart fish pond for economic growing in catfish farming," in *2019 International Conference on Computer Science, Information Technology, and Electrical Engineering (ICOMITEE)*, IEEE, Oct. 2019, pp. 49–53. doi: 10.1109/ICOMITEE.2019.8921233.

[3] D. S. Simbeye and S. F. Yang, "Water quality monitoring and control for aquaculture based on wireless sensor networks," *Journal of Networks*, vol. 9, no. 4, pp. 849–849, Apr. 2014, doi: 10.4304/jnw.9.4.840-849.

[4] L. Xu, N. Wang, Y. Feng, D. Bao, and K. Jorshin, "Design of aquaculture system based on wireless monitoring and its testing," *International Journal of Online and Biomedical Engineering*, vol. 10, no. 5, pp. 68–73, Sep. 2014, doi: 10.3991/ijoe.v10i5.4035.

[5] L. Hongpin, L. Guanglin, P. Weifeng, S. Jie, and B. Qiuwei, "Real-time remote monitoring system for aquaculture water quality," *International Journal of Agricultural and Biological Engineering*, vol. 8, no. 6, pp. 136–143, 2015, doi: 10.3965/j.ijabe.20150806.1486.

[6] C. Encinas, E. Ruiz, J. Cortez, and A. Espinoza, "Design and implementation of a distributed IoT system for the monitoring of water quality in aquaculture," in *2017 Wireless Telecommunications Symposium (WTS)*, IEEE, Apr. 2017, pp. 1–7. doi: 10.1109/WTS.2017.7943540.

[7] M. Zhang, D. Li, L. Wang, D. Ma, and Q. Ding, "Design and development of water quality monitoring system based on wireless sensor network in aquaculture," in *IFIP Advances in Information and Communication Technology*, vol. 347 AICT, no. PART 4, 2011, pp. 629–641. doi: 10.1007/978-3-642-18369-0_76.

[8] S. Saha, R. H. Rajib, and S. Kabir, "IoT based automated fish farm aquaculture monitoring system," in *2018 International Conference on Innovations in Science, Engineering and Technology (ICISET)*, IEEE, Oct. 2018, pp. 201–206. doi: 10.1109/ICISET.2018.8745543.

[9] C. Dupont, P. Cousin, and S. Dupont, "IoT for aquaculture 4.0 smart and easy-to-deploy real-time water monitoring with IoT," in *2018 Global Internet of Things Summit (GIoTS)*, IEEE, Jun. 2018, pp. 1–5. doi: 10.1109/GIOTS.2018.8534581.

[10] L. Parra, S. Sendra, L. García, and J. Lloret, "Design and deployment of low-cost sensors for monitoring the water quality and fish behavior in aquaculture tanks during the feeding process," *Sensors*, vol. 18, no. 3, Mar. 2018, doi: 10.3390/s18030750.

[11] M. Li, C. Lin, J. Ren, and F. Jiang, "A wireless ecological aquaculture water quality monitoring system based on LoRa technology," in *Proceedings of the 2019 International Conference on Wireless Communication, Network and Multimedia Engineering (WCNME 2019)*, Paris, France: Atlantis Press, 2019, pp. 5–7. doi: 10.2991/wcnme-19.2019.2.

[12] F. A. Saparudin, T. C. Chee, A. S. A. Ghafar, H. A. Majid, and N. Katiran, "Wireless water quality monitoring system for high density aquaculture application," *Indonesian Journal of Electrical Engineering and Computer Science (IJEECS)*, vol. 13, no. 2, pp. 507-513, Feb. 2019, doi: 10.11591/ijeecs.v13.i2.pp507-513.

[13] L. V. Q. Danh, D. V. M. Dung, T. H. Danh, and N. C. Ngon, "Design and deployment of an IoT-based water quality monitoring system for aquaculture in Mekong Delta," *International Journal of Mechanical Engineering and Robotics Research*, vol. 9, no. 8, pp. 1170–1175, 2020, doi: 10.18178/ijmerr.9.8.1170-1175.

[14] B. Ali, Anushka, and A. Mishra, "Effects of dissolved oxygen concentration on freshwater fish: a review," *International Journal of Fisheries and Aquatic Studies*, vol. 10, no. 4, pp. 113–127, 2022, doi: 10.22271/fish.2022.v10.i4b.2693.

[15] G. Zdorovennova *et al.*, “Dissolved oxygen in a shallow ice-covered lake in winter: effect of changes in light, thermal and ice regimes,” *Water (Switzerland)*, vol. 13, no. 17, pp. 1–20, 2021, doi: 10.3390/w13172435.
[16] X. Dong and J. G. Qin, “Fish adaptation to oxygen variations in aquaculture from hypoxia to hyperoxia,” *Journal of Fisheries and Aquaculture*, vol. 2, no. 2, pp. 23–28, 2011.
[17] J. S. Lucas and P. C. Southgate, *Aquaculture: farming aquatic animals and plants*, 2nd ed. Wiley, 2012. doi: 10.1002/9781118687932.
[18] D. A. Chin, *Water-quality engineering in natural systems*. Wiley, 2006. doi: 10.1002/0471784559.
[19] R. Parker, “Review of life cycle assessment research on products derived from fisheries and aquaculture,” *Sea Fish Industry Authority*, 2012.
[20] C. E. Boyd and F. Lichtkoppler, *Water quality management in pond fish culture*, no. 22. Auburn: Auburn University, 1979.
[21] Analog, p. 1, 2015, “Datasheet DS18B20: Programmable resolution 1-wire digital thermometer,” Analog, [Online]. Available: https://www.analog.com/media/en/technical-documentation/data-sheets/ds18b20.pdf
[22] D. A. Aziz, “Webserver based smart monitoring system using ESP8266 node MCU module,” *International Journal Of Scientific & Engineering Research*, vol. 9, no. 6, pp. 801–807, 2018
[23] A. Zaini, D. P. Wulandari, and R. Wulandari, “Data visualization on shrimp pond monitoring system based on temperature, pH, and DO (dissolved oxygen) with IoT,” *2020 International Conference on Computer Engineering, Network, and Intelligent Multimedia (CENIM)*, 2020, pp. 174–179, doi: 10.1109/CENIM51130.2020.9297851.
[24] A. M. Moreno-Rodenas, F. Cecinati, J. Langeveld, and F. H. L. R. Clemens, “Impact of spatiotemporal characteristics of rainfall inputs on integrated catchment dissolved oxygen simulations,” *Water (Switzerland)*, vol. 9, no. 12, pp. 1–21, 2017, doi: 10.3390/w9120926.
[25] J. Kustija and F. Andika, “Control - monitoring system of oxygen level, pH, temperature and feeding in pond based on IoT,” *REKA ELKOMIKA: Jurnal Pengabdian kepada Masyarakat*, vol. 2, no. 1, pp. 1–10, 2021, doi: 10.26760/rekaelkomika.v2i1.1-10.
[26] A. Bima, C. Irawan, D. A. W. Laksana, A. D. Krismawan, and F. O. Isinkaye, “A text security evaluation based on advanced encryption standard algorithm,” *Journal of Soft Computing Exploration (JOSCEX)*, vol. 4, no. 4, pp. 250–261, 2023, doi: 10.52465/joscex.v4i4.274.
[27] C. Wang, Z. Li, T. Wang, X. Xu, X. Zhang, and D. Li, “Intelligent fish farm—the future of aquaculture,” *Aquaculture International*, vol. 29, no. 6, pp. 2681–2711, Dec. 2021, doi: 10.1007/s10499-021-00773-8.
[28] A. T. Tamim *et al.*, “Development of IoT based fish monitoring system for aquaculture,” *Intelligent Automation & Soft Computing*, vol. 32, no. 1, pp. 55–71, 2022, doi: 10.32604/iasc.2022.021559.
[29] S. H. Loh, P. C. Teh, G. Y. Goay, and J. J. Sim, “Development of an IoT-based fish farm monitoring system,” in *2023 IEEE 13th International Conference on Control System, Computing and Engineering (ICCSCE)*, IEEE, Aug. 2023, pp. 281–286. doi: 10.1109/ICCSCE58721.2023.10237168.
[30] A. C. Subrata, T. Sutikno, S. Sunardi, A. Pamungkas, W. Arsadiando, and A. R. C. Baswara, “A laboratory scale IoT-based measuring of the solar photovoltaic parameters,” *International Journal of Reconfigurable and Embedded Systems (IJRES)*, vol. 11, no. 2, pp. 135-145, Jul. 2022, doi: 10.11591/ijres.v11.i2.pp135-145.
[31] I. R. Mardhiya, A. Surtono, and S. W. Suciyati, “Data acquisition system for measuring dissolved oxygen levels in shrimp pond water using a dissolved oxygen (DO) sensor (in Indonesian: S*istem akuisisi data pengukuran kadar oksigen terlarut pada air tambak udang menggunakan sensor dissolve oxygen (DO)*),” *Jurnal Teori dan Aplikasi Fisika*, vol. 5, no. 2, pp. 133–140, 2017.
[32] A. Sumardiono, S. Rahmat, E. Alimudin, and N. A. Ilahi, “Temperature control-monitoring system and oxygen levels in catfish cultivation ponds (in Indonesian: *Sistem kontrol-monitoring suhu dan kadar oksigen pada kolam budidaya ikan lele*),” *JTERA (Jurnal Teknologi Rekayasa)*, vol. 5, no. 2, p. 231, 2020, doi: 10.31544/jtera.v5.i2.2020.231-236.

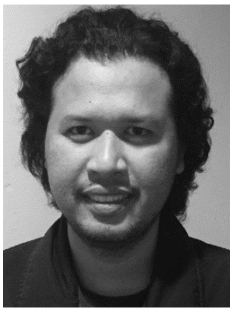
BIOGRAPHIES OF AUTHORS

Nurma Sari received the bachelor's degree in physics (1996) from University of Diponegoro (UNDIP) and a masters degree in physics (2007) specializing in waveguide antenna from Institut Teknologi Sepuluh Nopember (ITS). She received doctoral degree in physics (2022) at Institut Teknologi Sepuluh Nopember (ITS), Indonesia, funded by BUDI-DN LPDP Indonesia. Her interdisciplinary research interests focus on applying physics, applying electromagnetics, applying optics, and waveguide antenna. She can be contacted at email: nurmasari01@ulm.ac.id.

Yuniar Savitri was born in Banjarmasin in 2001. Her educational history went to MIN Langkai Palangkaraya, MTsN 1 Model Palangkaraya, MAN Kota Palangkaraya (2019), and completed his studies in the bachelor's degree in physics (2023) in the field of instrumentation at the University of Lambung Mangkurat. Her research interests focus on electronics and instrumentation of physics. She can be contacted at email: yuniarsavitri147@gmail.com or yuniarsavitri048@gmail.com.

Sri Cahyo Wahyono received the bachelor's degree in physics (1997) from University of Diponegoro (UNDIP) and a masters degree in physics (2004) specializing in waveguide antenna from Institut Teknologi Sepuluh Nopember (ITS), Indonesia, funded by DIKTI Indonesia. His interdisciplinary research interests focus on applying physics and geophysics. He can be contacted at email: scwahyono@ulm.ac.id.

Joko Santoso received the bachelor's degree in physics (2019) from University of Lambung Mangkurat (ULM). He is currently a technician in instrumentation and computational physics laboratories at University of Lambung Mangkurat, Indonesia. He can be contacted at email: jokosantoso1507@gmail.com.



Amar Vijai Nasrulloh received an undergraduate degree in physics (2004) from Institut Teknologi Sepuluh Nopember (ITS) and a master's degree in electrical engineering (2010) specializing in biomedical engineering from Institut Teknologi Bandung (ITB) and a Ph.D. degree in bioimage informatics from Durham University, UK, funded by LPDP Indonesia. He is currently a lecturer in physics study program at University of Lambung Mangkurat, Indonesia. His interdisciplinary research interests focus on applying physics and image processing methods to biology and medicine. He can be contacted at email: amarvijai01@ulm.ac.id.