Eksakta : Berkala Ilmiah Bidang MIPA
VOLUME 24 NO 02 2023, pp 133-143
ISSN : Print 1411-3724 — Online 2549-7464
DOI : https://doi.org/10.24036/eksakta/vol24-iss02/400

Eksakta
Berkala Ilmiah Bidang MIPA
http://www.eksakta.ppj.unp.ac.id/index.php/eksakta

Article

Design and Development a Smart Control System for Temperature and Turbidity of Bio Floc Fish Ponds

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Article Info

Article history :

Received February 08, 2023
Revised March 10, 2023
Accepted March 19, 2023
Published June 30, 2023

Keywords :

Bio floc, BME280 sensor, fishpond, , smart control, turbidity

Abstract. Bio floc aquaculture techniques are present as a solution to increase the productivity of fish farming. However, until now there are still problems, namely regarding the quality of the water from the pond. In this study, a monitoring tool was designed using an ESP32 microcontroller with the support of a BME280 sensor, RTD PT100 to measure water temperature and a turbidity sensor to measure floc volume. Furthermore, this sensor is planted on Wi-Fi to be able to connect to the internet network for IoT applications so that it can be monitored in real time. Likewise, the display results from the monitoring of the application system are directly read on the Google sheet display and in real time. From the test results of the system built, obtained the accuracy level of the BME280 sensor is 96.5%, PT100 RTD is 94.6% and for the turbidity sensor is 98%. Meanwhile the observed air temperature value can reach 34.36°C, the water temperature reaches 28.75°C, and the floc ratio reaches 30.15 $mL.L^{-1}$. From the results shown, it clearly indicates that the water quality monitoring system has been successful and is working very well.

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1. Introduction

Bio floc is a fish farming technique that uses an earthen pond and utilizes beneficial bacteria or probiotics to convert fish waste into the form of food scraps. With fish waste in the form of floc lumps to be used as food that can be re-consumed by fish in the pond [1-3]. Floc containing ammonia can affect water quality, which can cause the water temperature to increase so that excessive floc can cause fish death [4]. As we know that water, quality is still a problem in current bio floc fishpond cultivation techniques, so that water quality monitoring must always be done. Floc volume was measured using an Imhoff conical cup with a comparison between the scale value of the floc (*V*x) that settled at the bottom of the cup container and the overall volume value of the Imhoff conical cup (*V*a) as in equation 1 [5-7].

$$V_{bf} = \frac{V_x}{V_a} \tag{1}$$

A good floc volume ratio for fish is in the range of 15 $mL.L^{-1}$ to 35 $mL.L^{-1}$ [8-10]. As for the effect of temperature on the response to feed consumption in fish as shown in Table 1, the best-feed consumption response is at a normal temperature of around 28°C to 30°C.

Table 1. The effect of temperature on the response of fish feed consumption [11]

Temperature (°C)	Feed Consumption Response
Close to 0	Minimum critical conditions
8 - 10	No response to feeding
15	Feeding reduced
22	50% optimum
28 - 30	Optimum feeding
33	50% optimum
35	Feeding reduced
36 – 38	No response to feeding
38 – 42	Minimum critical condition

Since 1999, the Internet of Things (IoT) is a system where everything is done by utilizing internet network technology that functions as a liaison and can also be used as a data storage medium or database without human intervention [12]. Monitoring of IoT-based bio floc fishponds requires an internet network to be able to send data to a database so that the data can be displayed on android devices in real time. Firebase is an API for storing application data, one of its features is a Real-time database that can store data in the form of characters or text that is uploaded as JSON [13]. The interface used to display data on android devices is built using Android Studio software, which is an IDE software for developing android applications [14-15].

At present, IoT has played an important role in the intelligent aquaculture industry [16-20]. It allows remote monitoring of many conditions from biofloc, then IoT is an excellent choice to solve significant problems that occur in Biofloc. In this study, the biofloc monitoring tool is designed using an ESP32 microcontroller embedded in Wi-Fi so that it can connect to the internet network to apply the IoT concept to the device.

2. Experimental

2.1. Hardware Sensor Design

The monitoring tool for measuring the temperature and volume of the bio floc is built using four sensors and one microcontroller, which is integrated with a Wi-Fi module so that it can be connected to the internet network. Figure 1 illustrates the hardware sensor design.

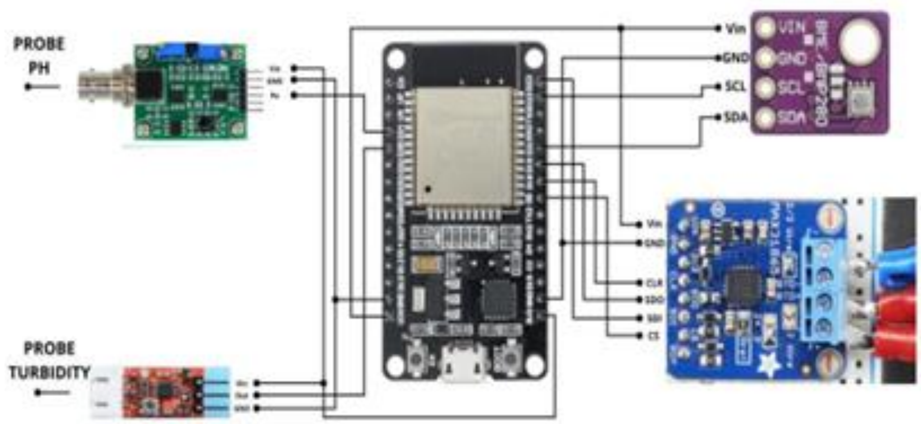


Figure 1. Hardware sensor layouts and pins

After the sensor has been made, it is then tested for the characteristics and accuracy of the sensor compared to the manufacturer's sensor. Each sensor requires a voltage supply and ground while the microcontroller only has two voltage sources so it is necessary to use a 5 cm x 7 cm PCB as a duplicate voltage source. The following is the use of pins on the microcontroller shown in the Table 2.

Table 2. The use of ESP32 microcontroller pins

No	Sensor Pins	Microcontroller Pins
BME280		
1	Vin	5V
2	GND	GND
3	SCL	GPIO 22
4	SDA	GPIO 21
Turbidity		
5	Vin	3.3 V
6	Out	GPIO 35
7	GND	GND
PH 4502C		
8	Vin	3.3 V
9	GND	GND
10	PIO	GPIO 34

MAX31865		
11	Vin	5 V
12	GND	GND
13	CLK	GPIO 18
14	SDO	GPIO 19
15	SDI	GPIO 23
16	Cs	GPIO 5

2.2. Monitoring System

In practice, the flowchart in testing this monitoring system is as shown in Figure 2. In this figure shows that the system works from the start of the active tool to the data collection process through the monitoring system application. At first the system will detect an internet connection using the While loop method on the ESP32 Microcontroller, if the Wi-Fi connection is not connected, the microcontroller will continue to be a Wi-Fi connection until it gets an IP from the owner of the Wi-Fi Hotspot connection.

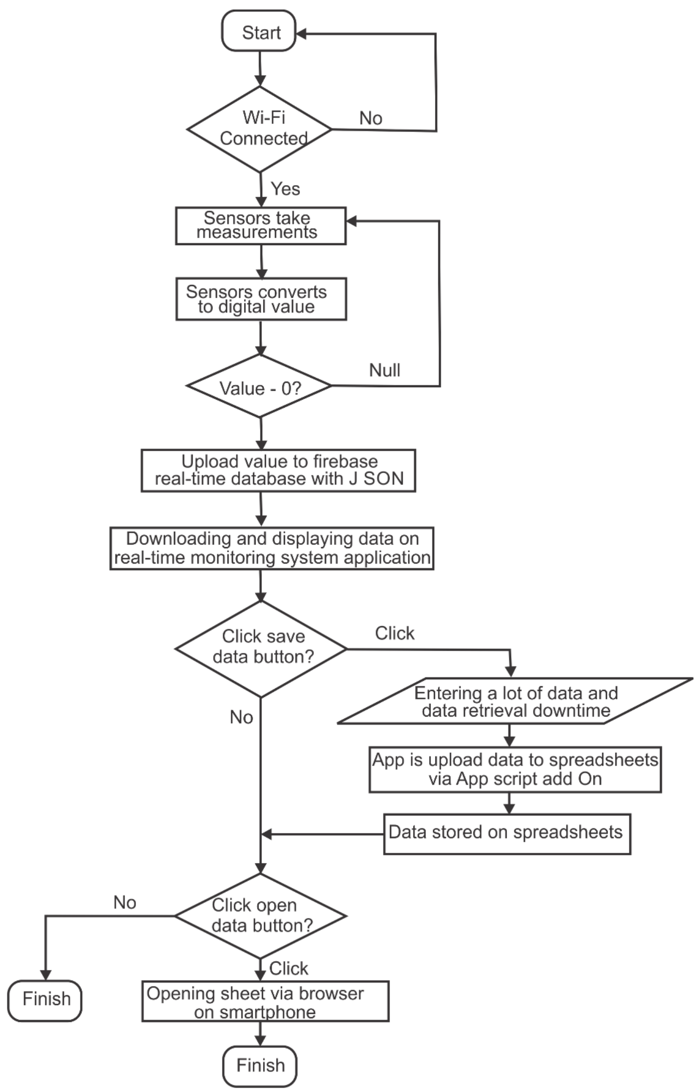


Figure 2. Flowchart of monitoring system

This is mandatory in this system because the tool will not work without an internet connection. After connecting to the internet connection, the sensors that have been installed will work according to their respective functions in this system, measuring and sending data to the microcontroller. Furthermore, the microcontroller will process the data obtained from each sensor with the ADC (Analog to Digital Converter) process, which aims to convert analog values into digital so that all values processed by the microcontroller will become digital values. In programming, the microcontroller that processes the data ensures that the data is not null or equal to 0 so that there are no errors in the process of uploading data to the Firebase Real-time Database [21-22].

After the data is uploaded, the application automatically displays the data in the database in real time. In the application, there are two buttons, namely Save Data and Open Data. The Save Data button functions to move the application activity to the input activity to enter a lot of data to be retrieved and the data retrieval pause time. While the Open data button functions to open data that has been saved on a Google Sheet via a browser on a smartphone.

3. Results and Discussion

3.1. Result of Hardware Sensor Design

The complete sensor design can be seen in Figure 3. Figure 3a are the whole sensor and Figure 3b of the inside of the sensor unit which has a RTD PT100 sensor, BME280 sensor and Turbidity sensor. The BME280 is a small sensor with dimensions of 2.5 x 2.5 x 0.93 mm [23]. From testing the characteristics and accuracy of the sensor compared to the manufacturer's sensor, it is obtained the accuracy of the BME280 sensor is 96.5%, RTD PT100 is 94.6% and for the turbidity sensor is 98%.

(a) (b)

Figure 3. Sensor hardware design (a) the whole sensor unit, (b) inside of the sensor unit

3.2. Result of Monitoring System

Schematically, the monitoring sensor system is shown in Figure 4. For data processing, the ESP32 microcontroller is used. ESP32 is powerful SoC (System on Chip) microcontroller with integrated Wi-Fi 802.11 b/g/n, dual mode Bluetooth version 4.2 and variety of peripherals [24]. Monitoring the environmental quality of bio floc fishponds can be done remotely via an android-based smartphone. The monitoring system application is built using android studio software with 2 activities including the main activity and data sending activity. Activity sends data using the on Data Change () loop method; from the firebase database library to retrieve data continuously as the data changes. Then the changed data is sent to the Google Sheet via the AppScript add on to enter data in the appropriate column for that data. The display results of all the processes of this program are shown in Figure 5.

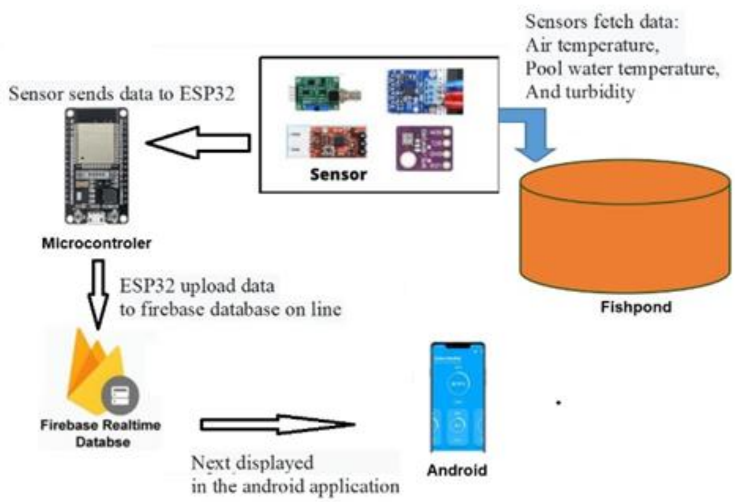
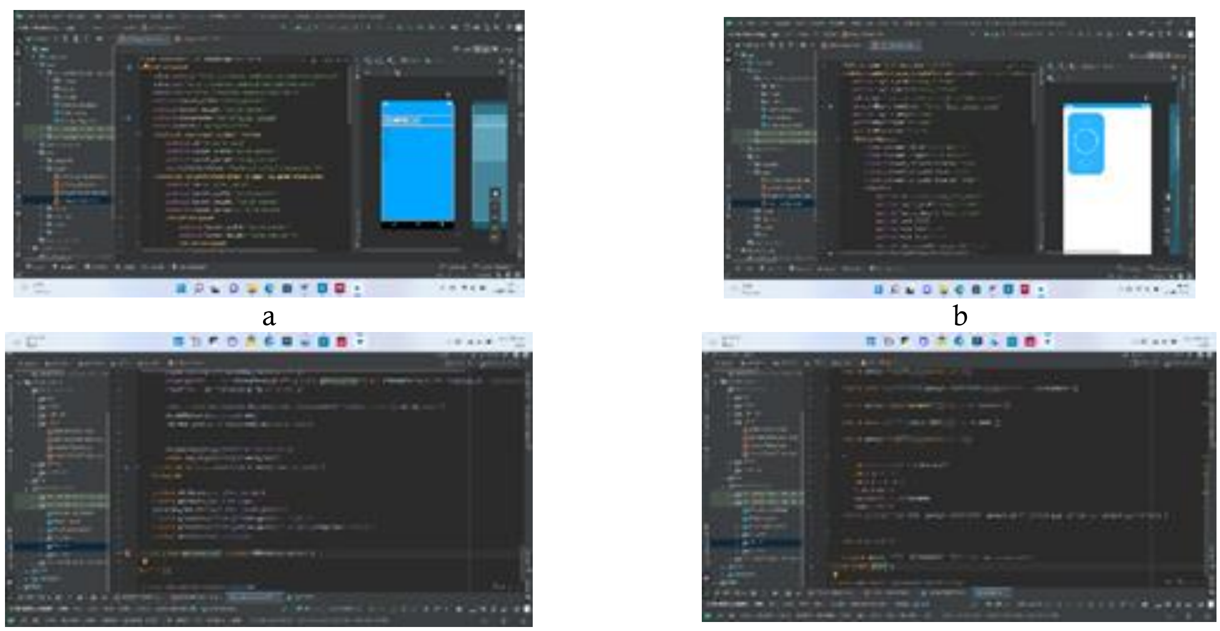


Figure 4. Monitoring system



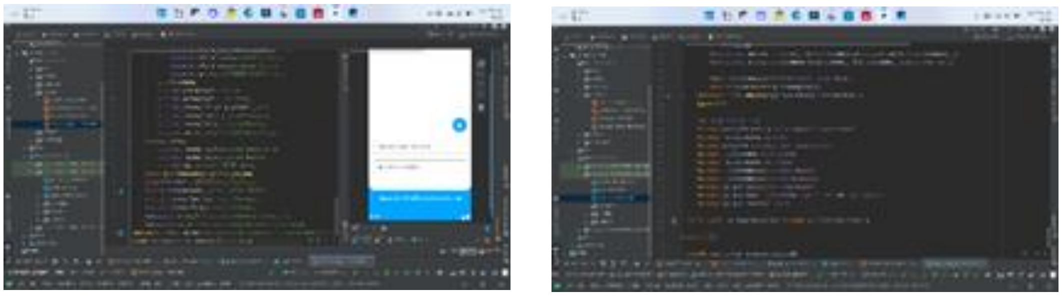
a b

c d

Figure 5. Android studio main activity programming views: (a) Activity_main.xml Layout Programming, (b) Item_monitor.xml Programming, (c) Main Activity Class Programming, (d) Value Model Programming Class.

To create an application that can perform data retrieval, the Save data feature is created. The Save data button on the monitoring activity or main activity can be clicked to go to the sending data activity, in this data sending activity, two edit texts are made to enter the amount of data to be retrieved and the data retrieval pause time in seconds. At the bottom right of the sending data activity, a floating action button functions to send data to Google Sheets via the AppScript add on in Google Sheets. Programming for data retrieval in this application is made using the loop function of Firebase's dependencies, namely onDataChange, where every data in the database changes, the data will be automatically sent.

Downloading data from the firebase database uses a data model created using the Java programming language according to the downloaded data. Then by using the library from firebase, the data is displayed on the card view using the recycler view layout. The display from this process shown as in Figure 6.



a b

Figure 6. Programming view send activity data android study (a) Programming Layout ctivity_kirim_data.xml and (b) Programming SendDataActivity.class.

3.3. Monitoring System Result

In testing the monitoring system of biofloc fish ponds, the turbidity sensor was calibrated for the first time. As is known, turbidity is the main environmental parameter used in determining water quality [25]. Turbidity sensor to measure the floc volume ratio in four biofloc fish ponds with equation 1. This result displayed in Table 3.

Table 3. Biofloc fishpond calibration data

Fishpond	Voltage (V)	Floc volume (mL)	V_{bf} (mL/L)
1	1.809	2.50	10
2	1.970	1.75	7
3	2.003	1.00	4
4	2.061	0.25	1

Based on the Table 3, pond 1 and pond 2 have a high floc volume ratio value because these ponds contain catfish, which produce more fish waste than ponds 3 and pond 4 which contain tilapia fish. The working principle of the turbidity sensor is to capture the light emitted by the transmitter, if particles then all the light will be caught by the photodiode so that the sensor produces a large voltage value indicating that the water is clear do not block the light. The more flocs floating in the water, the light will be blocked by particles floating in the water so that the voltage generated by the sensor will decrease. So that the relationship between voltage and V_{bf} is obtained as shown in Figure 7. Based on Figure 7, the equation used in the ESP32 microcontroller program to determine the value of the floc volume ratio is

$$V_{bf} = \frac{Volt - 2{,}1054}{-0{,}0263} \quad (2)$$

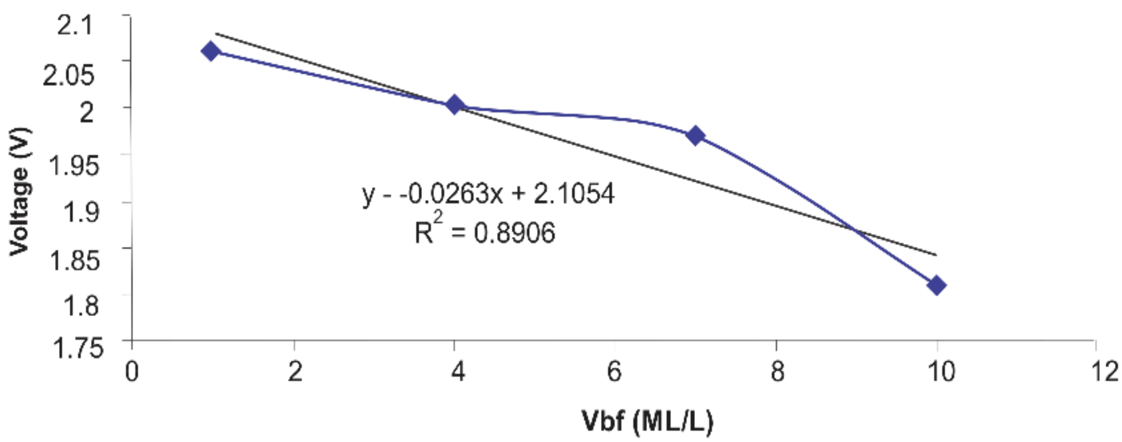


Figure 7. Graph of relationship between voltage and V_{bf}

Data collection to measure uncertainty in the bio floc fishpond monitoring system tool is carried out during the day and at night. The afternoon data retrieval was carried out at 14.25 WIB with 60 data every 5 seconds while the night data collection was carried out at 18.40 WIB with 60 data every 5 seconds.

Table 4. Data on air temperature, water temperature and V_{bf} of Bio Floc

No	Measurement	Max	Min	Average	Standard Deviation
Daytime Monitoring					
1	Air Temperature (°C)	34.36	33.78	34.10	0.191
2	Water Temperature (°C)	28.41	28.21	28.32	0.045
3	Vbf (mL/L)	25.71	16.15	19.17	1.468
Night Time Monitoring					
1	Air Temperature (°C)	33.93	30.97	31.68	0.538
2	Water Temperature (°C)	28.75	28.34	28.27	3.335
3	Vbf (mL/L)	30.15	16.55	24.69	1.659

Based on the data in the Table 4, it can be seen that during the day and night monitoring the average air temperature measured using the BME280 sensor is 34.10 °C and 31.68°C, these values tend to be safe. However, during the day the air temperature is not safe so it must be maintained because based on Table 1 the effect of temperature on the response to food consumption of bio floc pond fish, the air temperature value is included in an unsafe temperature because at that temperature the fish feeding response is 50% optimum so it must always monitor and keep the pool from being exposed to direct sunlight, and the water temperature measured using the RTD PT100 sensor obtained is 28.32°C during the day and 28.27°C at night, the water temperature tends to be safe and good and does not experience extreme temperature changes for bio floc fish ponds because the response to eating fish at that temperature is very good. Meanwhile, the value of V_{bf} during the day and night tends to be sufficient because the ideal floc ratio for fish is 15-35 mL/L.

Table 5. Data uncertainty of sensors in monitoring tools

No	Sensor	U1	U2	Uc	Uexp	Uncertainty
Daytime Monitoring						
1	BME280	0.025	0.029	0.038	0.076	0.22%
2	RTD PT100	0.006	0.029	0.029	0.059	0.21%
3	Turbidity	0.189	0.029	0.192	0.383	2.00%
Night Time Monitoring						
1	BME280	0.069	0.029	0.075	0.076	0.47%
2	RTD PT100	0.007	0.029	0.029	0.059	0.21%
3	Turbidity	0.214	0.029	0.192	0.432	1.75%

Table 5 shows the processing data of measurement uncertainty by each sensor. Uncertainty is calculated by comparing the exponential uncertainty (Uexp) with the average value for each sensor. Based on the table 5, it can be seen that the BME280 sensor has an accurate value because the exponential uncertainty value obtained is quite small so that the percentage of uncertainty obtained is 0.22% during the daytime and 0.47% at night time. Likewise, the PT100 RTD sensor, the exponential uncertainty value obtained is smaller than the BME280 sensor so that the PT100 RTD sensor is the most accurate sensor in this study where the uncertainty value is only 0.21%. However, the turbidity sensor has a large uncertainty value compared to other sensors; the uncertainty value exceeds 1%, namely 1.75% and 2%. This is because the turbidity sensor is an analog sensor, which in its use must be calibrated firstly so that there may also be errors in the calibration process.

4. Conclusion

The monitoring tool that has been built has succeeded, with the accuracy level of the BME280 sensor is 96.5%, PT100 RTD is 94.6% and for the turbidity sensor is 98% in being a solution for monitoring environmental quality and water quality, which includes air temperature, water temperature and Vbf (water turbidity) remotely via mobile devices connected to the internet using an android-based application and Firebase real time database.

Meanwhile the observed air temperature value can reach 34.36°C, the water temperature reaches 28.75°C, and the floc ratio reaches 30.15 mL/L. Measurements made by bio floc fishpond monitoring equipment have relatively small uncertainty so that errors in monitoring have a small possibility. From the results, it clearly indicates that the water quality monitoring system has been successful and is working very well.

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