Design of Water Quality Monitoring System for Koi Fish Farming Using NodeMCU ESP32 and Blynk Application Based on Internet of Things

Dendi Rosandi[1*], Junaidi[1], Donni Kis Apriyanto[1], Arif Surtono[1]
[1]Department of Physics, Faculty of Mathematics and Natural Science, University of Lampung;
junaidi.1982@fmipa.unila.ac.id, donni.kis@fmipa.unila.ac.id, arif.surtono@fmipa.unila.ac.id
[*]Correspondence: dendirosandi85@gmail.com

Intisari* – *Penelitian tentang rancang bangun sistem pemantauan kualitas air budidaya ikan koi telah dilakukan menggunakan NodeMCU ESP32 berbasis Internet of Things (IoT) yang terhubung dengan perangkat Android melalui aplikasi Blynk. Sistem ini terdiri dari empat sensor kualitas air, yaitu jumlah padatan terlarut, tingkat keasaman, tingkat amonia, dan besar suhu. Sistem ini dibuat agar kualitas air ikan koi selalu terpantau secara langsung lewat Android. Keuntungan menggunakan perangkat Android sebagai penampil sistem pemantauan adalah memudahkan pengguna untuk memantau kondisi air di lokasi manapun. Hasil dari sistem ini ditampilkan dalam bentuk pemantauan pada aplikasi Blynk dan pada* liquid crystal display *(LCD) 20×4, dengan notifikasi tentang ambang batas kualitas air. Hasil penelitian menunjukkan bahwa sensor memiliki akurasi sebesar 94,92% untuk jumlah padatan terlarut, 98,88% untuk tingkat keasaman, 90,49% untuk tingkat amonia, dan 98,77% untuk suhu, dengan waktu tunggu selama 5 menit untuk tampilan hasil pemantauan. Tingkat akurasi yang tinggi menunjukan alat ini dapat digunakan untuk melakukan pemantauan kualitas air budidaya ikan koi.

Kata kunci: Blynk, ESP32, IoT, pemantauan, kualitas air

Abstract - A research study on the design and development of a water quality monitoring system for koi fish farming has been conducted using the Internet of Things (IoT) based NodeMCU ESP32, connected to an Android device through the Blynk application. This system consists of four water quality sensors, namely dissolved solids, acidity level, ammonia level, and temperature. The purpose of this system is to ensure direct monitoring of the koi fish water quality through an Android device. The advantage of using an Android device as the monitoring interface is that it allows users to monitor the water conditions from any location. The system's results are displayed through the Blynk application and a 20x4 liquid crystal display (LCD) screen, with notifications indicating the threshold limits of water quality. The research findings indicate that the sensors have an accuracy of 94.92% for dissolved solids, 98.88% for acidity level, 90.49% for ammonia level, and 98.77% for temperature, with a waiting time of 5 minutes for the monitoring results to be displayed. The high level of accuracy demonstrates that this device can be used effectively for monitoring the water quality in koi fish farming.

Keywords: Blynk, ESP32, IoT, monitoring, water quality

I. INTRODUCTION

The quality of the aquarium water for breeding koi fish is crucial to consider. Water conditions that do not meet the requirements can become a source of diseases, such as *Myxobolus sp*., which can be highly dangerous to the growth of koi fish. The water quality considered to be good for breeding koi fish is at an optimal temperature range of 30 to 32°C [1]. Other parameters that need to be considered are changes in the water's potential hydrogen (pH) level, which represents the acidity of the water. The pH level of aquarium water that is good for koi fish is around 6 to 7 [1]. Additionally, the level of total dissolved solids in the water must not exceed 400 nephelometric turbidity units (NTU) or 333 parts per million (ppm) [2]. The maximum limit of ammonia in the aquarium is 0,3 ppm. If the water quality does not meet the specified levels, the disease *Myxobolus sp*. will develop [3].

The internet is part of the technological development that has rapidly progressed in society. The internet can now be used as a communication medium and control devices from a distance as long as the devices are connected and interconnected. The development of Internet communication networks, the Internet of Things (IoT), makes objects interconnected through Internet communication and exchange data, turning it into information [4].

Based on the explanation, this research builds a water quality monitoring system based on IoT connected to Android through the Blynk application. This system is designed to enable real-time monitoring of the water quality for koi fish directly through an Android device. The advantage of using an Android device as the monitoring interface is that it facilitates users to monitor the water conditions from any location. This monitoring system will be implemented in the koi fish aquarium, by measuring four water quality parameters such as total suspended solids, acidity level, ammonia level, and temperature. This system uses a NodeMCU ESP32 microcontroller, which is equipped with wireless fidelity (Wi-Fi) communication that is installed in the module that will be connected to the IoT system.

II. BASIC THEORY

In this research, four water quality parameter sensors are used with the NodeMCU ESP32 as the microcontroller. The four water quality parameter sensors used include sensors for measuring total dissolved solids (TDS), acidity, ammonia, and temperature.

A. NodeMCU ESP32

Compared to the Arduino Uno, ESP32 does not require any additional devices to access Wi-Fi or Bluetooth. Both wireless networks are already built-in within the ESP32 module.

The advantages of the ESP32 microcontroller compared to the ESP8266 include the use of a NodeMCU Xtensa Dual Core 32-bit LX6 with 600 Dhrystone Million Instructions per

Second (DMIPS), while the ESP8266 still uses a NodeMCU Xtensa Single-core with 32-bit L106. In terms of Bluetooth and Wi-Fi, the ESP32 has been integrated as a system-on -chip, whereas the ESP8266 is still separate. This means that in terms of the tools required, the ESP32 is superior compared to the ESP8266, as the ESP8266 requires additional devices for the same research purposes. Additionally, the ESP32 has the most general-purpose input/output (GPIO) pins at 32 pins compared to the ESP8266 which only has 17 GPIO pins [5].

B. *Total Dissolved Solid* (TDS) *Sensor (DFRobot)*

The selection of the DFRobot TDS sensor is based on its ability to measure dissolved solids ranging from 0 to 1000 ppm, with an operating temperature of up to 80°C according to its datasheet. The TDS sensor uses the electrical conductivity method, wherein two probes are submerged in a liquid or solution. The signal processing circuit will produce an output indicating the conductivity of the solution [6]. The electrode that is given a voltage source will conduct an electrical current. The conductance of a sample is proportional to the ions in the sample solution. The signal conditioning module subsequently converts the conductance value into voltage [7].

TDS is a physical parameter of raw water, the measure of dissolved substances, both organic and inorganic, in the solution. This includes the amount of material in the water, which can be carbonates, bicarbonates, chlorides, sulfates, phosphates, nitrates, calcium, magnesium, sodium, organic ions, and other ions [8].

C. *Acidity Level Sensor*

The pH sensor is designed to detect hydrogen ions (H^+) using a thin, spherical glass electrode containing a 0.1 M HCl solution. A silver wire is dipped into the HCl solution, forming an AgCl compound. The exchange of hydrogen ions with H_3O ions from the sample solution results in a potential difference between the electrode (glass wall and silver wire) with (1).

$$E = (RT/2.303F)\ log_{10}(H_3O^+) \tag{1}$$

with,

E	potential difference (V)
R	molar gas constant (8,314 J/mol K)
T	solution temperature (K)
F	the Faraday constant (96,485.3 C/mol)
H_3O^+	ion activity of the measured sample. [9]

This type of pH meter is widely used in quantitative chemical analysis. The probe on the pH sensor is used to measure the activity of hydrogen ions surrounding the thin-walled glass bulb at its tip. There is an increase of about 0.06 volts per pH unit measured and displayed as the measured pH value reading [10].

D. *MQ-135 Ammonia Sensor*

The MQ-135 sensor is a type of chemical sensor that is sensitive to compounds such as ammonia (NH_3), nitrous oxide (NO_x), alcohol, benzene, smoke (CO), carbon dioxide (CO_2), and others. This sensor works by receiving changes in resistance (analog) when exposed to the gas. It offers good durability for use as a pollution hazard indicator due to its practicality and low power consumption. The adjustment of the sensor's sensitivity is determined by the resistance value of the MQ-135, which varies for different gas concentrations. Therefore, when using this component, it is crucial to adjust the sensitivity [11].

The MQ-135 sensor has high sensitivity and low cost. This sensor consists of a micro aluminum oxide (Al_2O_3) ceramic tube, a tin dioxide (SnO_2) sensitive layer, and nickel-chromium serving as a heating coil. The sensor has six pins, with four dedicated to the signal and electrodes, and the remaining two for the heating coil. The tin dioxide semiconductor is the sensitive part of the sensor that has low conductivity in clean air. The operating principle of this sensor is based on its resistance variation when in contact with the gas to be sensed. The magnitude of the sensor's output signal depends on the gas concentration, its nature, and the type of metal oxide used for the sensor surface[12].

The semiconductor particles are heated at high temperatures in clean air, resulting in their absorption of oxygen on the particle surfaces and capturing free electrons. Donor electrons in tin dioxide are attracted towards the absorbed oxygen on the sensing material surface in clean air, then preventing the flow of electric current. For the sensor that comes into contact with reducing gas, the density of absorbed oxygen on the sensing material decreases due to the reaction with the reducing gas. This release of electrons into tin dioxide allows current to flow freely through the sensor [13].

E. *DS18B20 Temperature Sensor*

The DS18B20 temperature sensor is a digital sensor that operates using a single wire, commonly referred to as a one-wire bus. This one-wired protocol allows data and ground to be connected to the microcontroller using only one wire [14]. features a unique silicon serial number, enabling multiple DS18B20 sensors to be connected to a single bus in a circuit. The DS18B20 sensor can measure temperature in various locations, both in dry rooms and in water [15]. The DS18B20 temperature sensor is a high-accuracy sensor with an accuracy of ± 0.5 °C in the temperature range of -10 °C to 85 °C. It is widely used for temperature monitoring system applications [16].

III. METHODOLOGY

This research was carried out in several stages, including system design, testing, and data collection.

A. *System Design*

The input consists of four parameter sensors: TDS sensor, pH sensor, ammonia sensor, and temperature sensor. The input values will be read by the ESP32, which is connected to the power supply. The input values will be converted into unit values. The parameter values in the unit form will be sent to Android and displayed in the Blynk application as the output. They will also be sent directly to the 20x4 liquid crystal display (LCD) screen as the output of the system. The block diagram of the system design can be seen in Figure 1.

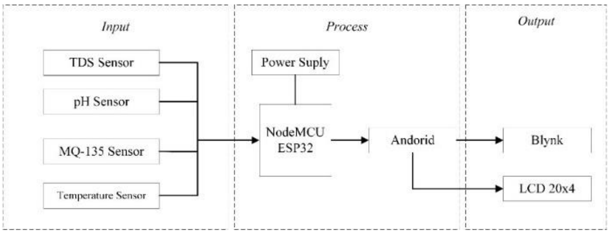

Figure 1. Block diagram of system design

The designed system includes parameter reading, processing, and data transmission to the Blynk app and LCD. In the parameter reading stage, sensors read physical parameters and convert them into electric signals (analog and digital signals). Sensors that produce analog signals will be converted into digital signals using the NodeMCU ESP32 processor. The digital values of the sensor readings and conversions will be displayed on the LCD, then the data will be sent to the Android interface application, the Blynk app, through the wireless network using Wi-Fi. The circuit diagram of the monitoring system is shown in Figure 2.

B. System Testing

The system testing process involves conducting tests on each component using software programs. If each component functions according to the software program instructions, the system operates effectively and data can be collected. However, during sensor testing, measurements are performed to assess accuracy and precision.

There are four parameters tested on the sensor including dissolved solids, acidity level, ammonia concentration, and temperature. The measurement data is used to calculate the error, accuracy, and precision of the monitoring system using (2)-(4).

$$\%Error = \left|\frac{Y - X_n}{Y}\right| \times 100\% \quad (2)$$

$$\%Accuracy = \left(1 - \left|\frac{Y - X_n}{Y}\right|\right) \times 100\% \quad (3)$$

$$\%Precision = \left(1 - \left|\frac{X_n - \overline{X}_n}{\overline{X}_n}\right|\right) \times 100\% \quad (4)$$

with,

Y reference parameter value

X_n measured parameter value n-th

$\overline{X}_n$ the average value of n measured parameters [17]

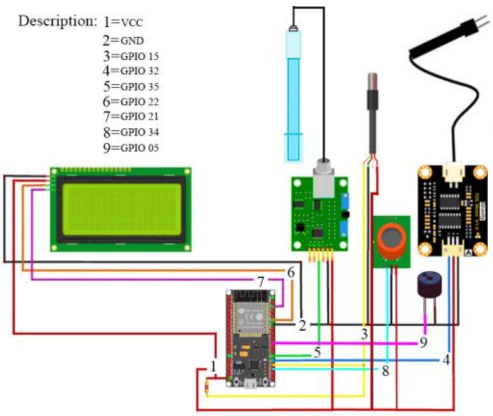

Figure 2. Circuit diagram for water quality monitoring

C. Data Collection

Data collection is performed by running the entire system, both hardware and software, and implementing the monitoring system instrumentation in a koi breeding aquarium. Data is collected by measuring the dissolved solids, acidity level, ammonia level, and water temperature. Measurements are taken in real-time, where measurements are taken for 65 minutes at three different times.

IV. RESULTS AND DISCUSSION

A. Realization of Monitoring System

The IoT-based water quality monitoring instrumentation system using NodeMCU ESP32 and Blynk application has been realized with the results shown in Figure 3. The box used for this hardware device has a dimension of (18 × 11 × 6) cm made of plastic.

B. Testing of Monitoring Sensor

1) *Total Dissolved Solid Sensor:* The supporting media used is a plastic glass sample container with a volume of 250 ml. The testing mechanism in this research is a digital measuring tool TDS Meter and an analog TDS DFRobot sensor alternately placed in the sample container which previously was given distilled water added with ten samples of coffee powder.

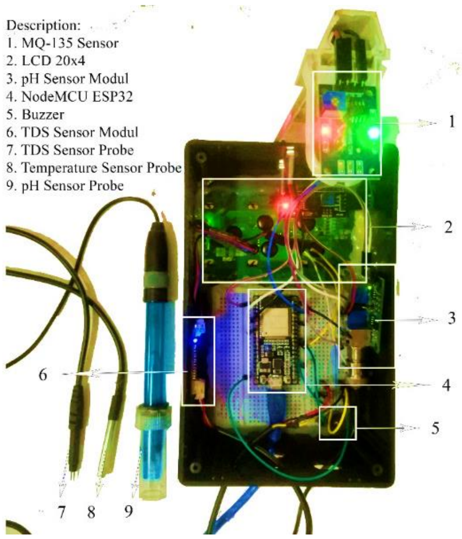

Figure 3. Realization of the monitoring system instrumentation tool

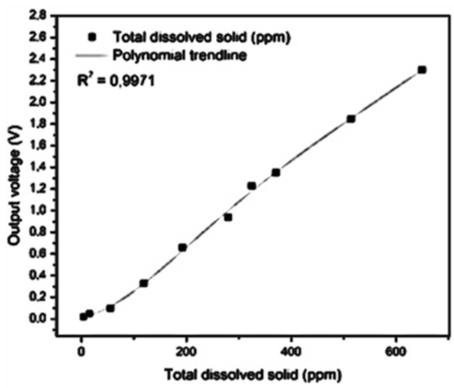

Figure 4. The characteristics of the TDS sensor

Table 1. The results of testing the fifth-degree polynomial equation for total dissolved solids in the Analog TDS DFRobot sensor

TDS Sample (ppm)	TDS (ppm) on the TDS DFRobot Sensor			Average (ppm)	Error (%)
	1	2	3		
(4.00 ± 0.08)	4.00	4.00	6.00	(4.67 ± 1.63)	16.67
(15.00 ± 0.32)	18.00	16.00	17.00	(17.00 ± 1.41)	13.33
(55.00 ± 1.00)	45.00	50.00	48.00	(47.67 ± 3.56)	13.33
(119.00 ± 2.38)	121.00	119.00	120.00	(120.00 ± 1.41)	0.84
(193.00 ± 3.88)	192.00	194.00	199.00	(195.00 ± 5.10)	1.38
(280.00 ± 5.62)	270.00	281.00	266.00	(272.33 ± 10.98)	2.98
(325.00 ± 6.48)	336.00	324.00	330.00	(330.00 ± 8.49)	1.74
(371.00 ± 7.36)	370.00	368.00	371.00	(369.67 ± 2.16)	0.36
(514.00 ± 10.30)	513.00	515.00	514.00	(514.00 ± 1.41)	0.13
(650.00 ± 13.00)	650.00	650.00	651.00	(650.33 ± 0.82)	0.05

Figure 4 shows the TDS sensor characteristics with an R2 value of 0.997 and a polynomial trend line. A 5th-degree polynomial equation is obtained to measure TDS in ppm as shown in (5), with V as the output voltage (V).

$$TDS = -2.97315+(502.27811\times V) + (-497.64512\times V^2)+ (396.01364\times V^3)+ (-136.34245\times V^4)+ (17.51903\times V^5) \quad (5)$$

The polynomial equation used will make the sensor readings more accurate. The obtained fifth-degree polynomial equation is entered into the monitoring instrumentation system program to ensure that the readings from the TDS DFRobot analog sensor match the calibrated measuring tool. The average error of the sensor is 5.08%, accuracy is 94.92%, and precision is 96.75%.

2) pH Sensor: The supporting media used is a 250 ml plastic glass sample container. The testing mechanism in this research is distilled water that has been previously given 1-10 drops of vinegar to obtain different pH values and output voltage. The results of testing the output voltage of the analog pH sensor compared to the pH value read by the digital ATC pH meter are shown in Figure 5.

Figure 5 shows the characteristic of the pH sensor with an R2 value of 0.985. Then, with a linear trend line, a linear equation was obtained to calculate the pH value shown in (6).

$$pH = (-2.98934) \times V + 13.19243 \quad (6)$$

The testing of the sensor that has the equation incorporated into the program to ensure the accuracy and precision levels are in line with the calibrated digital ATC pH meter. The average error of the sensor is 1.12%, accuracy is 98.88%, and precision is 99.81%

3) MQ-135 Ammonia Sensor: The testing process of the analog MQ-135 sensor was carried out in the laboratory room with the ammonia (NH3) concentration detected by the analog pH sensor compared to the sample PPM ammonia value using (7)-(8).

$$NH_3 = m/V \quad (7)$$

$$M = (m/Mr) \times (1000/V) \quad (8)$$

with,

NH_3	ammonia concentration (ppm)
m	mass of ammonia substance (mg)
V	volume of the room (L)
M	ammonia molarity (mol/L)
m	mass of ammonia substance (mg)
Mr	relative molecular mass of ammonia (g/mol)

The supporting media used is a 600 ml Erlenmeyer flask as the sample container. The testing mechanism in this research is an MQ-135 analog sensor placed on top of the sample container. The results of the analog sensor MQ-135 output voltage testing are compared to the results of the liquid ammonia sample ppm value shown in Figure 6. Figure 6 shows the R2 value of 0.982 with a polynomial trend line. The polynomial equation of power 3 to calculate the ammonia concentration in ppm is shown in (9).

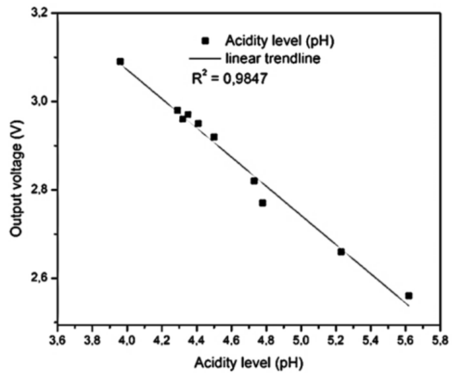

Figure 5. Graph of pH value testing against voltage output (V) of the sensor

Table 2. Results of the linearity test of the acidity level (pH) on the analog pH sensor

pH sample	pH on pH sensor			Average	Error (%)
	1	2	3		
(5.62 ± 0.2)	5.37	5.37	5.38	(5.37 ± 0.01)	4.39
(5.23 ± 0.2)	5.24	5.29	5.30	(5.28 ± 0.03)	0.89
(4.78 ± 0.2)	4.89	4.90	4.88	(4.89 ± 0.01)	2.30
(4.73 ± 0.2)	4.75	4.78	4.77	(4.77 ± 0.02)	0.78
(4.32 ± 0.2)	4.33	4.33	4.34	(4.33 ± 0.01)	0.31
(4.41 ± 0.2)	4.37	4.38	4.37	(4.37 ± 0.01)	0.83
(4.50 ± 0.2)	4.48	4.48	4.49	(4.48 ± 0.01)	0.37
(4.29 ± 0.2)	4.30	4.29	4.28	(4.29 ± 0.01)	0.16
(4.35 ± 0.2)	4.30	4.31	4.33	(4.31 ± 0.02)	0.84
(3.96 ± 0.2)	3.97	3.95	3.98	(3.97 ± 0.02)	0.34

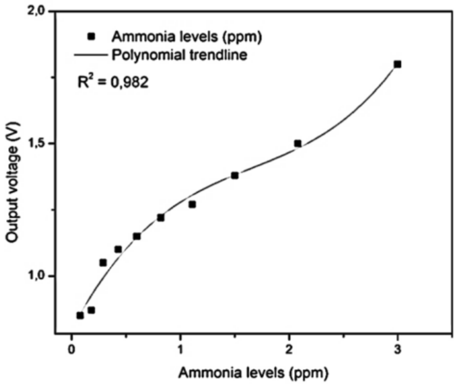

Figure 6. Graph of ammonia concentration testing against output voltage (V) of the sensor

$$NH_3 = (-6.08955 \times V^3)+(25.42202 \times V^2)+(-30.90137 \times V)+11.77048 \quad (9)$$

The test was then performed again on the sensor that had been programmed to ensure the level of accuracy and precision in accordance with the samples whose ammonia concentration was known. The results of the MQ-135 sensor test for measuring ammonia concentration are shown in Table 3, with three repeat tests. The average error of the sensor is 9.51%, accuracy is 90.49%, and precision is 93.77%.

4) DS18B20 Temperature Sensor: The DS18B20 sensor can be used to measure temperature parameters in aquatic environments because it is waterproof. The sensor will be compared with the HTC-2 temperature-measuring device. The supporting media used is a 600 ml Erlenmeyer flask for filling with 400 ml of water, and an electric stove that functions as a heater for the water temperature. The results of the temperature sensor test, with three repeat tests, are shown in Table 4. The average error is 1.18%, accuracy is 98.79%, and precision is 99.71%.

C. Data Collection

Data collection was carried out by implementing the system in the koi fish farming place. The realized system is shown in Figure 7.

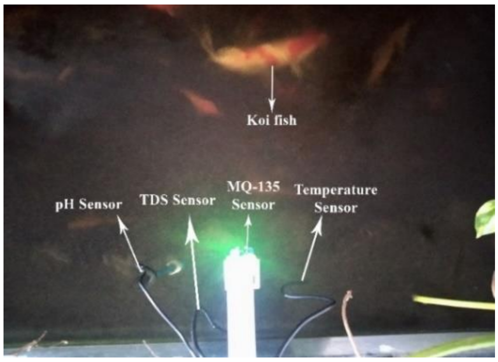

Figure 7. Display of the 4 parameter sensors

Table 3. Results of the testing of the polynomial equation of power 3 for ammonia (NH_3) concentration on the analog MQ-135 sensor

Ammonia sample (ppm)	**Ammonia Concentration (ppm) on the Analog MQ-135 Sensor**			**Average**	**Error (%)**
	1	**2**	**3**		
0.08	0.07	0.08	0.06	(0.07 ± 0.01)	13.58
0.18	0.19	0.17	0.18	(0.18 ± 0.01)	4.55
0.29	0.35	0.27	0.40	(0.34 ± 0.07)	21.84
0.43	0.39	0.48	0.55	(0.47 ± 0.08)	16.39
0.60	0.67	0.71	0.59	(0.66 ± 0.06)	10.56
0.82	0.85	0.81	0.87	(0.84 ± 0.03)	3.75
1.11	1.15	1.18	1.16	(1.16 ± 0.02)	5.28
1.50	1.52	1.55	1.60	(1.56 ± 0.04)	3.78
2.08	2.28	2.20	2.05	(2.18 ± 0.12)	5.67
3.00	2.80	3.46	3.21	(3.16 ± 0.33)	9.67

Table 4. Results of temperature measurement of the DS18B20 sensor against the HTC-2

HTC-2 (ºC)			**DS18B20 (ºC)**			**Average**		**Error (%)**
1	**2**	**3**	**1**	**2**	**3**	**HTC-2**	**DS18B20**	
28.40	28.50	28.70	28.60	28.80	29.00	(28.53±0.50)	(28.80±0.20)	0.93
29.20	29.50	29.60	29.50	29.90	29.90	(29.43±0.50)	(29.77±0.23)	0.79
30.50	30.50	30.50	30.80	30.90	30.90	(30.50±0.50)	(30.87±0.06)	1.20
31.50	31.60	31.50	31.80	31.90	31.90	(31.53±0.50)	(31.87±0.06)	1.06
32.40	32.60	32.50	32.80	33.00	32.90	(32.50±0.50)	(32.90±0.10)	1.23
33.30	33.40	33.50	33.80	33.80	33.90	(33.40±0.50)	(33.83±0.06)	1.30
34.30	34.50	34.50	34.80	34.90	34.90	(34.43±0.50)	(34.87±0.06)	1.26
35.50	35.60	35.50	36.10	36.00	35.90	(35.53±0.50)	(36.00±0.10)	1.31
36.30	36.50	36.30	36.90	37.00	36.70	(36.37±0.50)	(36.87±0.15)	1.37
37.50	37.20	37.30	38.20	37.60	37.70	(37.33±0.50)	(37.83±0.32)	1.34

Figure 8. Display of water quality parameters on the LCD

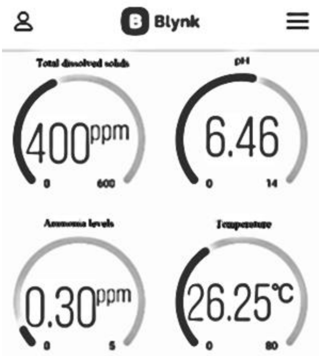

Figure 9. Results of water quality parameter measurement on the Blynk IoT interface application

The dimensions of the aquarium are (500×130×100) cm. The measurement results are displayed on the LCD in real-time, the Blynk IoT interface application, and stored in an Excel format (.xlsx). The display of the measurement results in the first 5 minutes on the LCD is shown in Figure 8.

The Blynk IoT interface application can run after the NodeMCU ESP32 is connected to the Wi-Fi. The Blynk IoT interface application can also automate notifications in the Android system that can inform the monitoring system user if there are values from the parameters outside the established limits of the parameters that are in line with the optimal water conditions for koi breeding. The data collection process in this study was conducted with time allocations in the morning, afternoon, and late afternoon in a 5-minute interval, as in [18]. The results of the system measurement in the Blynk IoT interface can be seen in Figure 9.

Figure 9 shows the results of the measurement system, indicating that the Blynk IoT interface application can perform readings of data sent from the ESP32 to the Blynk server and displayed in the form of streaming data in the Blynk IoT application. The measurement of three different times, namely morning, afternoon, and late afternoon, in the form of a graph, is shown in Figure 10.

Figure 10 shows the monitoring data from four parameters at three different times: morning (07.00-08.00), afternoon (13.00-14.00), and late afternoon (16.00-17.00). The monitoring data indicate that the water quality is in a good state, as the water quality parameters are still within the normal range for the koi habitat. However, a temperature below 30 °C is not optimal for the koi environment.

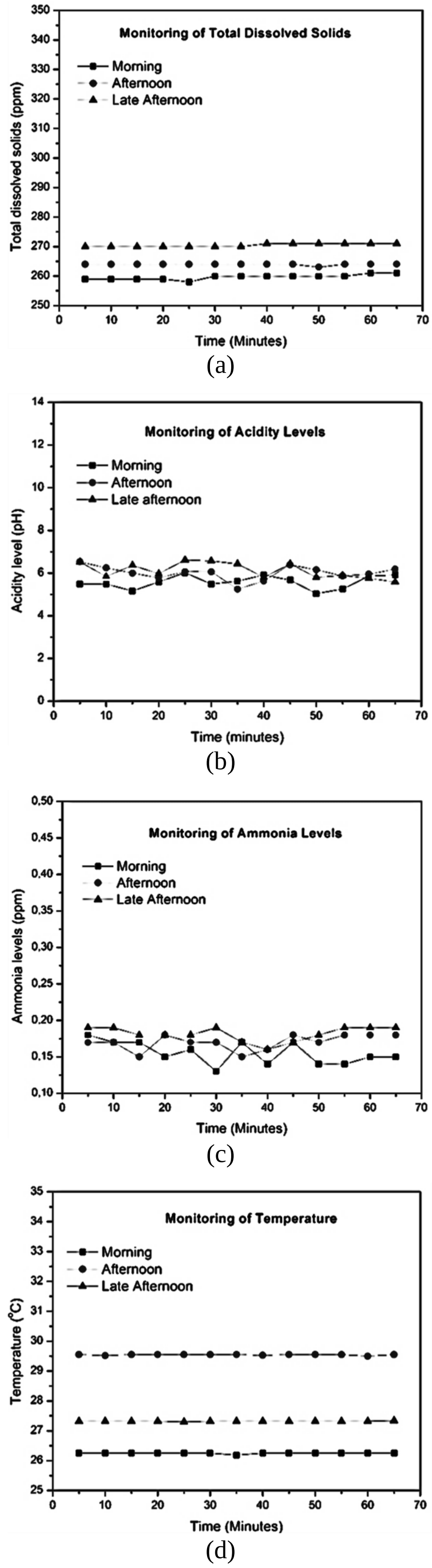

Figure 10. Data monitoring of water quality parameters, (a) TDS sensor, (b) pH sensor, (c) ammonia sensor, (d) temperature sensor

V. CONCLUSIONS

Based on the test results and discussions that have been conducted, it can be concluded that the water quality monitoring system, which measures four parameters, namely total dissolved solids, acidity level, ammonia level, and temperature, using IoT technology connected to a smartphone through the Blynk application, has been successfully implemented. The device has been calibrated with an error of 5.08% for the TDS sensor, 1.12% for the pH sensor, 9.51% for the ammonia sensor, and 1.22% for the temperature sensor. The low error values indicate that the design of the monitoring system can be used in koi fish farming aquariums.

REFERENCES

[1] E. E. Barus, R. K. Pingak, and A. C. Louk, "Otomatisasi Sistem Kontrol pH dan Informasi Suhu Pada Akuarium Menggunakan Arduino Uno dan Raspberry PI 3," *J. Fis. Fis. Sains dan Apl.*, vol. 3, no. 2, pp. 117–125, 2018, doi: 10.35508/fisa.v3i2.612.

[2] I. G. H. Putrawan, P. Rahardjo, and I. G. A. P. R. Agung, "Sistem Monitoring Tingkat Kekeruhan Air dan Pemberi Pakan Otomatis Pada Kolam Budidaya Ikan Koi Berbasis NodeMCU," *Maj. Ilm. Teknol. Elektro*, vol. 19, no. 1, p. 1, 2019, doi: 10.24843/mite.2020.v19i01.p01.

[3] H. Azmi, D. R. Indriyanti, and N. Kariada, "Identifikasi Ektoparasit pada Ikan Koi (Cyprinus carpio L) dI Pasar Ikan Hias Jurnatan Semarang," *Unnes J. Life Sci.*, vol. 2, no. 2, pp. 64–70, 2013, ISSN 2252-6277.

[4] B. Artono and R. G. Putra, "Penerapan Internet Of Things (IoT) Untuk Kontrol Lampu Menggunakan Arduino Berbasis Web," *J. Teknol. Inf. dan Terap.*, vol. 5, no. 1, pp. 9–16, 2019, doi: 10.25047/jtit.v5i1.73.

[5] A. Setiawan and A. I. Purnamasari, "Pengembangan Smarth Home Dengan Microcontrollers ESP23 Dan MC-38 Door Magnetic Switch Sensor Berbasis Internet of Things (IoT) Untuk Meningkatkan Deteksi Dini Keamanan Perumahan," *J. Resti (Rekayasa Sist. dan Teknol. Informasi)*, vol. 5, no. 3, p. Halaman 541-457, 2019, ISSN 2580-0760.

[6] Y. Irawan, A. Febriani, R. Wahyuni, and Y. Devis, "Water Quality Measurement and Filtering Tools using Arduino Uno, PH Sensor and TDS Meter Sensor," *J. Robot. Control*, vol. 2, no. 5, pp. 357–362, 2021, doi: 10.18196/jrc.25107357.

[7] M. Martani, "Perancangan dan Pembuatan Sensor TDS pada Proses Pengendapan CaCO3 dalam Air dengan Metode Pelucutan Elektron dan Medan Magnet," vol. 17, no. 3, 2014, ISSN : 1410-9662.

[8] R. Afrianita, T. Edwin, and A. Alawiyah, "Analisis Intrusi Air Laut dengan Pengukuran Total Dissolved Solids (TDS) Air Sumur Gali di Kecamatan Padang Utara," *J. Dampak*, vol. 14, no. 1, p. 62, 2017, doi: 10.25077/dampak.14.1.62-72.2017.

[9] Suryono, *Teknologi Sensor : Konsep Fisis dan Teknik Akuisisi Data Berbasis Mikrokontroler 32 Bit ATSAM3X8E (ARDUINO DUE)*, 1st ed. Semarang: Undip Press, 2018.

[10] N. Sitorus, "Pendetaksi pH Air Menggunakan Sensor pH Meter V1.1 Berbasis Arduino Nano," Fisika, Universitas Sumatera Utara, Medan, 2017.

[11] A. A. Rosa, B. A. Simon, and K. S. Lieanto, "Sistem Pendeteksi Pencemar Udara Portabel Menggunakan Sensor MQ-7 dan MQ-135," *Ultim. Comput.*, vol. XII, no. 1, pp. 23–28, 2020, ISSN 2355-3286.

[12] A. T. Ajiboye, J. F. Opadiji, A. O. Yusuf, and J. O. Popoola, "Analytical determination of load resistance value for MQ-series gas sensors: MQ-6 as case study," *Telkomnika (Telecommunication Comput. Electron. Control.*, vol. 19, no. 2, pp. 575–582, 2021, doi: 10.12928/TELKOMNIKA.v19i2.17427.

[13] M. Yusro and A. Diamah, *Sensor & Tranduser, Teori dan Aplikasi*. Jakarta: Fakultas Teknit Universitas Negeri Jakarta, 2019.

[14] O. Bondarenko, S. Kininmonth, and M. Kingsford, "Under Water Sensor Network, Oceanography and Plankton Assemblages," *IEEE*, vol. 3, no. 1, pp. 657–662, 2007, doi: 10.1109/ISSNIP.2007.4496921.

[15] S. Alam, A. Y, M. A. Kadir, and E. Elihami, "Sistem Otomatis Sirkulasi Udara pada Tambak Udang," *JUTKEL J. Telekomun. Kendali dan List.*, vol. 2, no. 1, pp. 1–10, 2020, ISSN 2721-9372.

[16] R. Pratiwi, "Penelitian Sumber Panas dengan Metode Tomografi Menggunakan Sensor Thermometer Digital DS18B20," Fisika, Universitas Indonesia, Depok, 2009.

[17] L. D. Jones and A. F. Chin, *Electronics Instruments and Measurements*. Upper Saddle River: Prentice-Hall, 1991.

[18] E. Rohadi *et al.*, "Sistem Monitoring Budidaya Ikan Lele Berbasis Internet Of Things Menggunakan Raspberry Pi," *J. Teknol. Inf. dan Ilmu Komput.*, vol. 5, no. 6, p. 745, 2018, doi: 10.25126/jtiik.2018561135.