 https://doi.org/10.24191/jeesr.v29i1.009

# Development and deployment of water quality data logger system (WQDLS) at Arowana Farm in Bukit Merah, Perak, Malaysia

Mohamad Faizal Abd Rahman*, Mohamad Naim Ahmad, Muhammad Hazimudddin Mohd Hashim, Rohaiza Baharudin, Zuraida Muhammad, Mohd Suhaimi Sulaiman, Anis Diyana Rosli, and Khairul Anuar Ishak.

***Abstract*—Assessing the current water quality status is vital for arowana fish farmer. The Internet of Things (IoT) has enabled aqua farmers to access water parameters in real-time remotely. However, farmers based in rural and remote areas cannot be benefited from this IoT-based monitoring system due to unstable internet strength. Thus, the data logger is greatly needed as the alternative for farmers to access the water quality in real-time. The work proposed a water monitoring system with a data logger including sensors for measuring two important water parameters-pH and temperature. System development which includes calibration and testing were performed in laboratory before deploying on site involving 3 ponds at RedGold Arowana Farm in Bukit Merah, Perak. By comparing with a commercial device, the system shows good performance for both parameters with the accuracy up to 97% for laboratory tests with good linearity, sensitivity, and hysteresis pattern. In situ testing shows a very close pattern between the measured and actual values for both parameters, as well as a very small mean square error with good distribution of error histogram. It was found that the system worked reliably, and the data logging process from the sensor into the memory card was successful with acceptable performance after proper troubleshooting and mitigation process. The work has successfully developed and deployed a low cost system monitoring equipment equipped with a data logger to the tested industry, allowing fish farmers to obtain crucial aquatic life water quality parameters.**

***Index Terms*—Data Logging, Monitoring System, pH, Temperature, Thingspeak, Water Quality.**

## I. INTRODUCTION

Malaysia's arowana industry has expanded substantially since 2005 and is now the second-largest supplier of arowanas in the world after Indonesia [1], [2], [3]. Asian Arowana, or scientifically named as Scleropages formosus is a well-known freshwater ornamental fish in Malaysia due to its popularity among ornamental fish hobbyists despite its high price in the aquaculture industry [1], [2]. Generally, water quality has a significant impact on the growth of aquacultural items, which in turn affects fish health and productivity [1], [3], [4], [5], [6]. As a result, it is vital for fish farmers to be informed of the present status of water quality.

The water quality of arowana fishponds can be monitored using readily available commercial monitoring instruments. It would be advantageous if water quality monitoring systems able to record data in real-time and allow remote access. The Internet of Things (IoT), which was integrated into the water quality monitoring system, resulting in an innovation that provides real-time data collection and online access [7], [8], [9], [10]. On the other hand, the IoT-based monitoring system requires a stable internet connection [11], [12], [13]. The IoT feature restricts the benefits of IoT and implies that IoT-based monitoring systems can only be deployed in areas with a strong network [11], [14]. Regrettably, most fishing farms are located in rural locations without reliable internet connectivity [14], [15],[16], [19]. Moreover, most monitoring systems that lack of IoT capabilities can only display water quality parameter of interest, and the measured data must be manually logged.

Therefore, this study is significant in identifying alternate methods for farmers to get real-time water quality data without utilising the internet. The employment of a data logger in monitoring systems has been considered as an alternate option in this study [17], [18], [19]. This work develops a low-cost system monitoring that will benefit farmers, where it enables them to assess the water quality in real-time, and helps to make sound decisions on managing water quality today and in the future to ensure these valuable assets are of the best quality. This study aims to design and develop a low-cost system monitoring device equipped with a data logger to monitor the water quality in arowana ponds. Two sensors are used to determine the pH and temperature of the water. The standard water quality parameters require for arowana aquaculture are pH of 6.5 to 8.5, with temperature, 29°C to 31°C [20], [4], [6]. An arowana fish farm in Bukit Merah, Perak, has been chosen as the research location to deploy the developed monitoring system. This study may have specific impacts, especially for

This manuscript is submitted on July 15, 2026, revised on October 13, 2026, accepted on October 14, 2026, and published on October 31, 2026.

Mohamad Faizal Abd Rahman, Mohamad Naim Ahmad, Muhammad Hazimudddin Mohd Hashim, Rohaiza Baharudin, Zuraida Muhammad, Mohd Suhaimi Sulaiman, Anis Diyana Rosli and Khairul Anuar Ishak are with the Faculty of Electrical Engineering, Universiti Teknologi MARA (UiTM) Cawangan Pulau Pinang, Kampus Permatang Pauh, Pulau Pinang, Malaysia

*Corresponding author.
Email address: faizal635@uitm.edu.my

1985-5389/© 2026 The Authors. Published by UiTM Press. This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/).

small-scale farmers. The development of the system may assist farmers in more efficiently managing fishponds. Also, this approach can lower monthly internet finance expenses, as the suggested system does not require internet connectivity.

## II. METHODOLOGY

### A. System Development

#### 1) Sensor testing and calibration

In this work, temperature sensor, DS18B20 from Maxim Integrated and pH probe from Gravity/DFrobot were selected as the sensor to be integrated in the system. Both sensors were tested in the laboratory to verify their functionality, as well as to observe their output characteristics for measurement purposes.

Temperature sensor (DS18B20) is a digital output version that works based on one wire protocol. It is a factory-calibrated device that requires no calibration to be performed in the laboratory. The setup was performed by using the standard one wire protocol as specified by the manufacturer. By including the one wire protocol library, the microcontroller will be able to read and display the temperature values accordingly.

For pH sensor, the calibration was done by measuring the output voltage for different standard pH solution. Three buffer solutions with standard pH of 4,7 and 10 from Sigma Aldrich were used as calibration solutions. For each pH value of buffer, an appropriate voltage signal from the sensor was measured, recorded and plotted accordingly. An average of three voltage readings were taken for every pH measurement point to minimise the error. The plot of the relationship between pH and voltage is essential to see the linearity of the calibration curve. For a complete system, these voltages will then be converted into its appropriate pH values. Apart from that, the minimum power supply required was also tested in order to know the cut off voltage of the sensor in case the system is to be powered from a battery.

#### 2) Data logger system

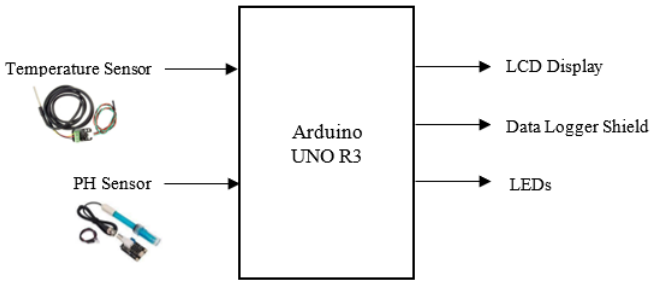



**Fig. 1.** Block diagram of the WQDLS system.

Fig. 1. shows the block diagram of the proposed system. Arduino UNO was used as the MCU for the system. In this design, analog input was assigned for the pH sensor, and digital input was set up for the temperature sensor. Values obtained for the calibration process were used for conversion purposes. The calibration of the sensors is important to convert the voltage received from the sensors into the accurate parameter values of pH and temperature, based on linear interpolation equation.

Based on the flowchart in Fig. 2, once the Arduino board is switched on, the system will read analog value of pH and digital value of temperature. Then, the analog value of pH sensor will be converted to digital value based on the VoltageValue = pHsensorValue/(1023/5). The temperature sensor's value does not have to go through Analog - Digital conversion (ADC) as its signal is already in digital input. The pH value is then calculated based on (1), which has been formulated based on linear interpolation from two-point calibration.

$$pH_{value} = pH_1 + (Voltage\ Value - E_1)\ x \left[\frac{pH_2 - pH_1}{E_2 - E_1}\right] \quad (1)$$

After the pH value and the temperature value are obtained, the LCD display will present the value. At the same time, the data of water quality will be logged into the SD card.

LED indicators were used to indicate if the measured value exceeded the threshold limits. The selected ranges of pH and temperature in this work were set between 6 to 8 and 25-27°C, respectively.

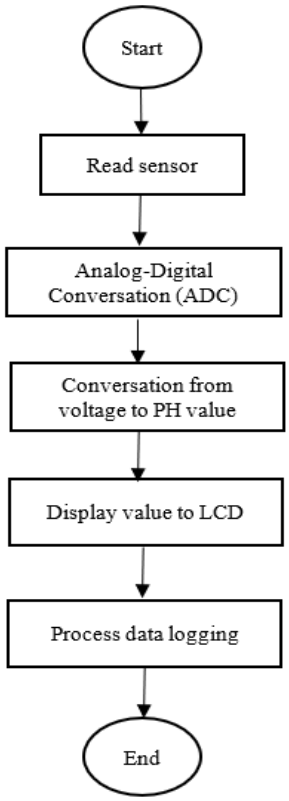



**Fig. 2.** Flowchart for the coding process.

### B. System testing and analysis

Several tests have been carried out for the developed system to observe its measurement performance. In each measurement, the commercial Hanna Instruments HI 98107 pH Meter was used to verify the reading for pH and temperature. Fig. 3 and Fig. 4 show the setup for both pH and temperature tests.

*1) pH*

For pH measurement, several solutions with different pH levels were prepared as given in Table 1 (Ranging from 3.2 to 9.37).

TABLE I. SOLUTIONS WITH DIFFERENT PH

| Solution | Hanna |
|---|---|
| Soft Drink | 3.2 |
| Hand Soap | 6.3 |
| Milk | 6.7 |
| Baking Soda | 8.4 |
| Bleach | 9.3 |

Fig. 3 shows the several solutions used to test the pH sensor. All the pH values for every solution were measured using the Hanna instrument and tabulated in Table I and labelled as reference values.

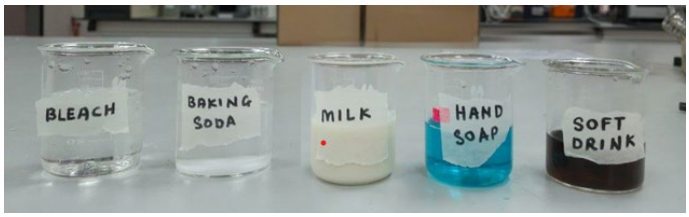



**Fig. 3.** pH measurement solution.

Then, the measurement was taken using the developed system to observe the measurement performance compared to the reference value. This step is significant in estimating its accuracy after being calibrated before deploying it on site.

*2) Temperature*

Similar to pH reading, temperature measurement was also verified. The test was performed in a boiled kettle from room temperature 32°C to 45°C at a 2.5°C gap interval, and the setup is illustrated in Fig. 4.



**Fig. 4.** Temperature measurement setup.

The reading was taken as temperature decreases to observe the hysteresis pattern of the system. Several performance parameters were then computed using the statistical analysis method to obtain measurement performance, like accuracy, error and hysteresis.

*C. Sensor deployment, data collection and performance analysis.*

In order to test the field performance and robustness of the system, in situ tests were carried out at an arowana pond located at Bukit Merah, Perak, Malaysia. Fig. 5 shows the final system developed in researcher's laboratory and ready to be used for pH and temperature data collection at the selected location.




**Fig. 5.** The completed developed WQDLS system.

The arowana farm situated in Bukit Merah is an ideal location for studying the habitat of arowana fish. This is due to the fact that there are numerous arowana farms in this area. Residents claim that Bukit Merah is an ideal location for arowana's habitat since it features a lake called Tasik Bukit Merah, which is the home to the arowanas. In this work, the RedGold Arowana Fish Farm at Bukit Merah, Perak, is chosen as the target location for the deployment of the system.

For the purpose of data collection, 3 ponds were identified as in Fig. 6. The tests were divided into 2 categories, namely single point and continuous. For each measurement, the readings were compared to readings taken using the Hanna meter. The measurements were taken 3 times a day on three different ponds for the initial test. These tests were continued for 17 days to collect about 153 data from 3 ponds. Then, the analysis was performed to obtain several performance parameters like the accuracy and error characteristics for in situ measurements. Based on these data, further analysis was carried out.

For the second test, the objective is to observe the ability of the system to work continuously for a specified period of time. The system was deployed on site and left to operate for 2 hours, 6 hours, 12 hours. The programme was set to log the data every 5 minutes, and the analysis were performed in order to see the ability of the system to capture and log all the expected data throughout the test period. The collected data were stored into a SD card by creating an Excel file. The programme were set to store the data in the file for both parameters: pH and temperature. For analysis, the SD card was removed and read

in Excel file. The amount of logical and illogical data was then counted to observe the capability of the system in storing the data for retrieval. Logical data is the expected data or the actual data that should be retrieved from the test. Meanwhile, the illogical data is the retrieved data that exceed the range of actual data. In the continuous test, the logical data for pH measurement were set between the range of pH 6 to pH 7 and for temperature, the logical data were set between 30°C to 35°C.




(a)



(b) (c) (d)

**Fig. 6.** The selected site (a) Map of the selected location, (b) Pond 1, (c) Pond 2 and (d) Pond 3.

## III. RESULT AND DISCUSSION

### *A. pH sensor verification and calibration (to obtain linearity and calibration values)*

Table II shows the calibration values used to verify the sensor's functionality and for calibration purposes. These values were obtained through initial measurement performed in the sensor and instrumentation laboratory.

TABLE II. MEASURED VOLTAGE FOR BUFFER SOLUTION

| pH value | Voltage |
|---|---|
| 4 | 2.03 |
| 7 | 1.5 |
| 10 | 1.07 |

The data was then plotted in order to observe its sensing performance, such as linearity and sensitivity. Fig.7 shows the voltage measurement for different pH levels of buffer solution.

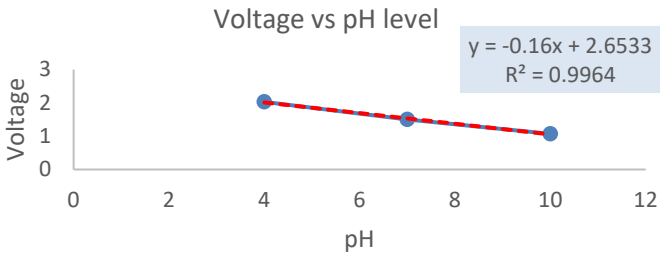



**Fig. 7.** The plot pH against voltage.

The graph shows a very good linearity relationship with $R^2$ equals to 0.9964, suggesting the ability of the probe to give a good performance for the interested range of pH level. Two calibration points will then be used for pH conversion, which to be set in the microcontroller during its operation. This relationship estimates that the system will produce a pH measurement system with a sensitivity of 0.16 pH/V. Using this probe, it is also found that the minimum voltage requirement for the probe's operation must be higher than 3.5V, indicating the need to maintain its supplied voltage higher than this value. These data were then used for configuration in the selected microcontroller to display the pH value and ready to be tested.

### *B. pH accuracy laboratory test*

Table III shows the measurement data performed in the same laboratory to predict the performance of the system's pH measurement, which is intended to be deployed on-site. The test is crucial to verify its performance before its deployment. In this work, accuracy was calculated based on (2).

$$Accuracy\ (\%) = \left(1 - \frac{|pH_{measured} - pH_{true}|}{pH_{true}}\right) x\ 100\% \qquad (2)$$

It is observed that for the range under test, the system gives a convincing result with an accuracy of detection of more than 97% and produces a minimal error of less than 3% compared to the measurement taken using the commercial device.

TABLE III. IN LAB ACCURACY TEST.

| Solution | pH measured (by WQDLS) | pH true (by Hanna instrument) | $\lvert pH_{measured} - pH_{true} \rvert$ | %accuracy |
|---|---|---|---|---|
| Soft Drink | 3.16 | 3.2 | 1.25 | 98.75 |
| Hand Soap | 6.43 | 6.3 | 2.06 | 97.94 |
| Milk | 6.65 | 6.7 | 0.75 | 99.25 |
| Baking Soda | 8.5 | 8.4 | 1.19 | 98.81 |
| Bleach | 9.37 | 9.3 | 0.75 | 99.25 |

It is observed that for the range under test, the system gives a convincing result with an accuracy of detection of more than 97% and produces a minimal error of less than 3% compared to the measurement taken using the commercial device. Using the calibration data, the system was capable of giving the measurement with the linearity of 0.9992, as shown in Fig. 8, with the calculated sensitivity is around 97%. It can be concluded that the system capable of detecting the pH variation within this range at very good linearity to represent the actual measurement.

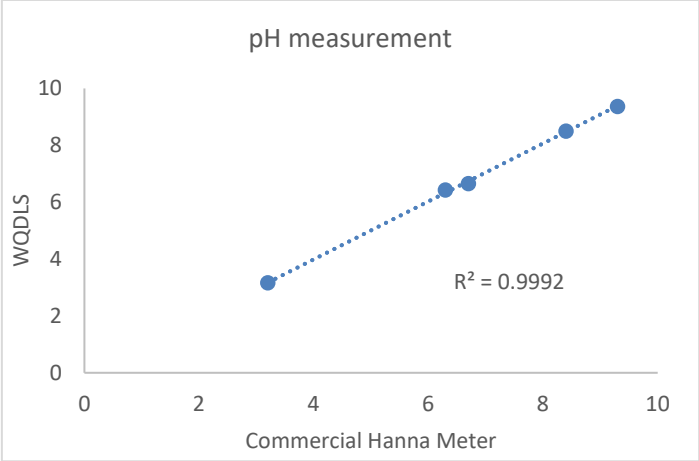



**Fig. 8.** The comparison of pH measurement between the developed system (WQDLS) and commercial device (Hanna meter).

*C. Temperature accuracy and hysteresis in lab test.*

Fig. 9 shows the temperature measurement in water during its rising and falling patterns that initially performed in the laboratory. Both patterns were obtained in other to observe hysteresis performance, apart from linearity and error performance.

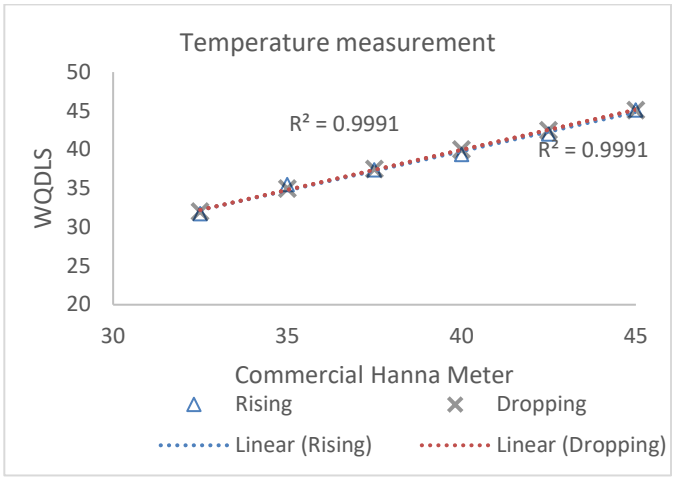



**Fig. 9.** Graph difference between the developed system and conventional device (Hanna meter) for temperature measurement.

In general, it can be observed that the measurement taken using WQDLS is very accurate as compared to the commercial meter, with mean square error (MSE) of 2.33 x $10^{-4}$, and produced an accuracy of higher than 97%. In terms of linearity, both rising and falling patterns showed a similar correlation coefficient, $R^2$ of 0.9991, with no hysteresis found. The lab test thus indicates that this system has excellent performance for the in-situ implementation at the selected installation site.

*D. In situ system testing.*

In order to verify the performance of the developed system, on-site evaluation was performed according to the methodology spelled out previously. Several other parameters such as accuracy, MSE, and histogram error were used to further verify the performance of the pH and temperature measurement system for the WQDLS application.

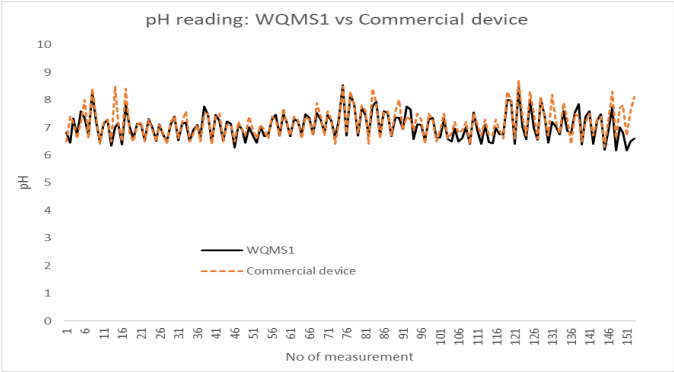
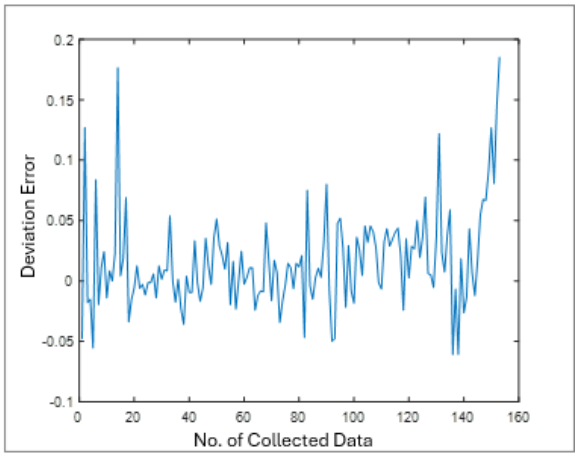



**Fig. 10**. Graph of collected data using the developed system and commercial device (Hanna meter).

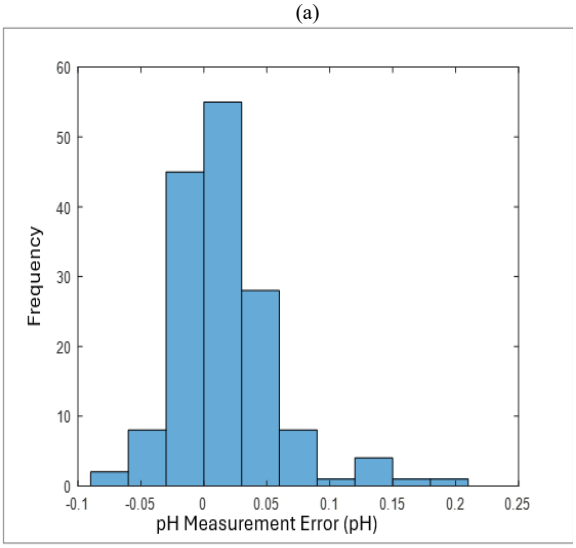
*1) pH*

Fig. 10 shows the in-situ pH measurement using WQDLS compared to the conventional device. Based on the 153 data collected, it was observed that the reading of pH at the selected

ponds lies between 6 to 10 and within the researchers' initial expectation. The trigger system was working well as the light LED turned on every occasion, where the pH level was out of the set range. The measurement for both WQDLS and commercial device were found to be very close, indicating a good accuracy of the system. The analysis showed that these data produced a very small deviation with the mean error and RMS error of 0.0161 and 0.0430, respectively.




(a)




(b)

**Fig. 11.** The error plot (a) Error fluctuation for all data and (b) Histogram error.

Fig. 11(a) shows the error fluctuation that stayed at low values, which can be further verified by the histogram error shown in Fig. 11(b). The histogram shows a good, normal distribution with the lowest error is concentrated at the centre region.

*2) Temperature*

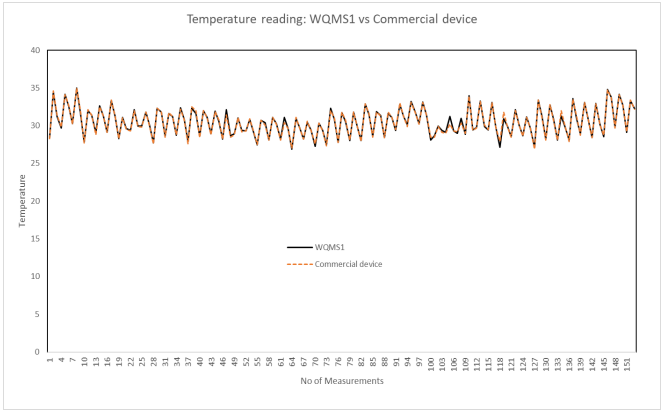
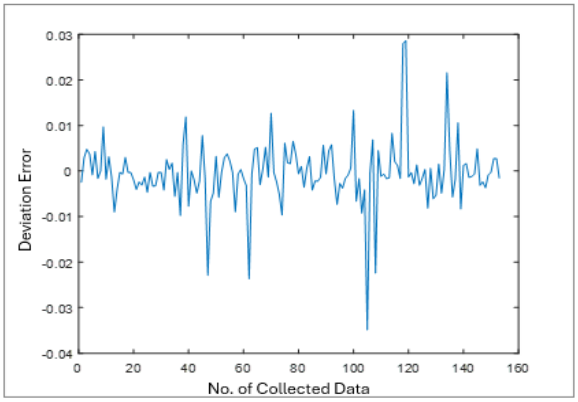
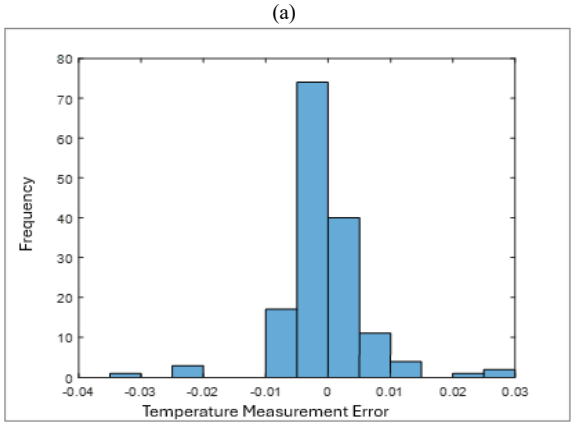



**Fig. 12.** Graph for collected data between the developed system and industrial-built Hanna meter.

Fig. 12 shows the in-situ temperature measurement using WQDLS compared to the conventional device. Based on the 153 data collected, it was observed that the readings of tenperature for both WQDLS and the commercial device were very close, as obtained in the lab test. The analysis showed that these data produced a very small deviation with mean error and RMS error of 0.00053956 and 0.0071, respectively. Fig. 13(a) shows the error fluctuation maintained at a low value, which can be further verified by the histogram error shown in Fig. 13(b). The histogram shows a good normal distribution with the lowest error is concentrated at the centre.




(a)




(b)

**Fig. 13.** (a) Graph error fluctuation and (b) histogram error.

### *E. In situ data logging test*

In situ data logging test was calculated to observe the capability of the system to store data for a specified period of time as well as to prove the ability of the system to work continuously as data logger. Table IV shows the result obtained from the 3 periods of tested time at the interval of 5 minutes.

All data were accessed from the memory card installed in the memory slot.

In general, it can be observed the data logging process from the sensor into the memory card was successful, indicating that all data has been successfully logged into the developed system.

TABLE IV: RETRIEVED DATA FROM SD CARD FOR PH AND TEMPERATURE FOR CONTINUOUS TESTING.

| Period (hrs) | Expected no. of data logged at 5 minutes time interval | pH | | | Temperature | | |
|---|---|---|---|---|---|---|---|
| | | Collected true data | Collected untrue data | % | Collected true data (30-35°C) | Untrue data | % |
| 2 | 24 | 24 | 0 | 100 | 24 | 0 | 100 |
| 6 | 72 | 72 | 0 | 100 | 26 | 46 | 37 |
| 12 | 144 | 144 | 0 | 100 | 116 | 28 | 80 |

## IV. CONCLUSION

In conclusion, the main objective of developing the data logger system for temperature and pH measurement for aquaculture application has been successfully met. The system displays a very good performance as compared to the conventional device in terms of its accuracy, linearity, resolution, and hysteresis. This performance thus validated the method that the researchers used, which can be replicated in other work.

The work has offered a low-cost system monitoring device equipped with a data logger to the tested industry as it gives the opportunity to the fish farmer to access the crucial parameters in aquatic life, namely temperature and pH in their ponds throughout the testing period by deploying the system and leave it to let the system do the continuous reading data. This data can be further analysed to classify the performance of each pond as well as to predict other parameters that have a relationship with the existing sensor, pH sensor, and temperature sensor if the model is obtained. The system can also be improved by integrating with other sensors like ammonia sensor, turbidity sensor, and dissolved oxygen sensor, which are known as the crucial parameters required based on the demands by the industry.

Despite the satisfactory overall performance of the system, some temperature readings were found to fall outside the expected range due to an intermittent connection between the temperature sensor and its connector. Although the issue was resolved by resoldering the connection, future development should focus on improving the reliability of the sensor connections and incorporating data validation mechanisms to detect abnormal readings. These improvements could further enhance the reliability and accuracy of the system for long-term

The total number of the retrieved data for both parameters were aligned with the expected number that is supposed to have based on the set interval. Specifically, all the stored pH data gives the true value for all the retrieved data (within the expected range) and is considered to have 100% of data retrieval succession. However, for temperature data, even though all data were successfully retrieved, some of the data were found to be misled and gave the untrue value (out of the range). From the mitigation process, the problem was identified to be due to the loose connection of the temperature sensor, which caused the intermittent problem. The issues were then resolved by resoldering the connection between the temperature sensor and the connector

aquaculture monitoring.

## ACKNOWLEDGMENT

This work was funded by Ministry of Higher Education (MOHE) under Fundamental Research Grant Scheme (FRGS) (FRGS/1/2021/TK0/UITM/02/103). The authors would like to thank Universiti Teknologi MARA and Redgold Aquatic Farm for all the research facilities provided in this work.

## REFERENCES

[1] N. A. A. Awalluddin, N. A. A. Rashid, I. Abustan, and N. H. Rosman, "Treatment of ammoniacal nitrogen in Arowana aquaculture wastewater using sand, activated carbon and zeolite in a horizontal prototype model," in *IOP Conference Series: Earth and Environmental Science*, 2025. doi: 10.1088/1755-1315/1495/1/012004.

[2] S. Rahman, M. Zakaria-Ismail, P. Y. Tang, M. Rizman-Idid, and S. Muniandy, "Genetic variability and estimation of effective population sizes of the natural populations of green arowana, scleropages formosus in Peninsular Malaysia," *Adv. Environ. Biol.*, vol. 4, no. 1, 2010.

[3] J. Mabrouki, M. Azrour, D. Dhiba, Y. Farhaoui, and S. El Hajjaji, "IoT-based data logger for weather monitoring using arduino-based wireless sensor networks with remote graphical application and alerts," *Big Data Mining and Analytics*, vol. 4, no. 1, 2021, doi: 10.26599/BDMA.2020.9020018.

[4] A. A. Nur Atiqah, I. Abustan, A. W. Mahyun, and M. Rose Farahnadrah, "Water quality changes due to effect of arowana aquaculture activities at Bukit Merah," *Adv. Environ. Biol.*, vol. 8, no. 22, 2014.

[5] S. A. H. Almetwally, M. K. Hassan, and M. H. Mourad, "Real Time Internet of Things (IoT) Based Water Quality Management System," in *Procedia CIRP*, 2020. doi: 10.1016/j.procir.2020.03.107.

[6] N. A. Atiqah, "Water Quality Monitoring on Golden Arowana (Scleropages formosus) Aquaculture Farm at Bukit Merah, Malaysia," *Caspian Journal of Applied Sciences Research*, no. 2, 2013.

[7] O. O. Olanubi, T. T. Akano, and O. S. Asaolu, "Design and development of an IoT-based intelligent water quality management system for aquaculture," *Journal of Electrical Systems and Information Technology*, vol. 11, no. 1, 2024, doi: 10.1186/s43067-024-00139-z.

[8] N. A. Mohd Jais, A. F. Abdullah, M. S. Mohd Kassim, M. M. Abd Karim, A. M, and N. 'Atirah Muhadi, "Improved accuracy in IoT-Based water quality monitoring for aquaculture tanks using low-cost sensors: Asian seabass fish farming," *Heliyon*, vol. 10, no. 8, 2024, doi: 10.1016/j.heliyon.2024.e29022.

[9] D. Amale, "Aquaculture Monitoring and Control System Based On IOT," *INTERANTIONAL JOURNAL OF SCIENTIFIC RESEARCH IN ENGINEERING AND MANAGEMENT*, vol. 08, no. 04, 2024, doi: 10.55041/ijsrem32363.

[10] A. B. Wibisono and R. Jayadi, "Experimental IoT System to Maintain Water Quality in Catfish Pond," *International Journal of Advanced Computer Science and Applications*, vol. 15, no. 3, 2024, doi: 10.14569/IJACSA.2024.0150340.

[11] M. C. Chiu, W. M. Yan, S. A. Bhat, and N. F. Huang, "Development of smart aquaculture farm management system using IoT and AI-based surrogate models," *J. Agric. Food Res.*, vol. 9, 2022, doi: 10.1016/j.jafr.2022.100357.

[12] L. F. Khalid and S. Y. Ameen, "SECURE IOT INTEGRATION IN DAILY LIVES: A REVIEW," *Journal of Information Technology and Informatics*, vol. 1, no. 1, 2021.

[13] M. Lauridsen, I. Z. Kovács, P. Mogensen, M. Sørensen, and S. Holst, "Coverage and capacity analysis of LTE-M and NB-IoT in a rural area," in *IEEE Vehicular Technology Conference*, 2016. doi: 10.1109/VTCFall.2016.7880946.

[14] R. O. Cacho, C. M. S. Quiambao, A. E. Tandoy, and L. R. V. Tecson, "A Prototype Web-Based Water Quality Monitoring System for Improved Aquaculture Management using Arduino Nano," in *International Exchange and Innovation Conference on Engineering and Sciences*, 2025. doi: 10.5109/7395686.

[15] U. W. Badarudin, W. I. S. W. Din, Y. A. Prasetyo, Z. Musa, and S. Kasim, "Internet of Things: An implementation and its challenges in Malaysia," *Int. J. Adv. Sci. Eng. Inf. Technol.*, vol. 8, no. 6, 2018, doi: 10.18517/ijaseit.8.6.5043.

[16] H. Rastegari *et al.*, "Internet of Things in aquaculture: A review of the challenges and potential solutions based on current and future trends," 2023. doi: 10.1016/j.atech.2023.100187.

[17] N. Hambali, A. A. M. Yusof, N. H. Sabri, W. N. F. A. Jani, and M. Abdullah, "An In-depth Review of the Critical Water Analysis Parameter and Water Quality Management Technology in Cage Aquaculture within Malaysian Coastal Regions," *Jurnal Kejuruteraan*, vol. 36, no. 3, 2024, doi: 10.17576/jkukm-2024-36(3)-03.

[18] K. G. Kokane, G. U. Kharat, and N. B. Bankhele, "IoT Based Weather Monitoring System with Data Logger System," *International Journal of Advanced Research in Science, Communication and Technology*, 2024, doi: 10.48175/ijarsct-18760.

[19] G. N. Santiago and I. Ciampitti, "Multiple channels, low-cost, and dual data storage data logger for building a soil temperature network," *HardwareX*, vol. 20, 2024, doi: 10.1016/j.ohx.2024.e00582.

[20] S. R. Medipally, F. M. Yusoff, N. Sharifhuddin, and M. Shariff, "Sustainable aquaculture of Asian arowana - A review," *J. Environ. Biol.*, vol. 37, no. 4, 2016.