https://doi.org/10.24191/jeesr.v27i1.005

Development and Deployment of IOT-Based Water Quality Monitoring System for Ornamental Fish Farm at Bendang Man, Sik, Kedah

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***Abstract*—In fish farming, water quality is important since inadequate water can affect the health and growth of fish. The need for real time and continuous monitoring are crucial to ensure the status of the farm is always in good condition, and appropriate action can be taken if water quality gets polluted. The work aims to develop a smart IoT system, known as WQMS2 (Water Quality Management System Version 2) to monitor the pH and temperature of fishponds equipped with a notification feature so that users can be notified of any abnormal reading. In this work, pH and temperature were selected as parameters of interest due to their importance in the aquatic life environment. System development which includes calibration and testing, were performed in the laboratory before deploying the system on site for three different locations at the selected fish farm. Thingspeak and Thingsview software were utilised as IoT platforms for smart monitoring system data, while Telegram was used for notification purposes. System performance in laboratory testing, gives a good accuracy of more than 90% with good linearity and hysteresis characteristics. For in situ testing, the system shows a similar pattern as compared to commercial devices with a very small and good distribution of errors. The system was also found to be capable of fetching all the transmitted data with nearly 100% of efficiency for online monitoring. Thus, it can be concluded that the system has been successfully developed and deployed for the meant application.**

***Index Terms*— IOT, monitoring system, pH, temperature, Thingspeak, water quality**

I. INTRODUCTION

Ornamental fish cultivation is the practice of raising attractive and colourful fish with a variety of features in a limited aquatic setting. It is mainly practiced by farmers and enthusiasts [1], [2], [3]. Living gems are another term for ornamental fish. Lyyne et al. stated that many fish are admired nowadays for their distinctive patterns. In the United Kingdom and the United States, one in every ten families has a pet fish, with an estimated 20–25 million are kept in aquaria and 20 million in ponds in the United Kingdom alone [4], [5], [6], [7]. As a result, many fish farmers have raised ornamental fish because it can make a financial resource for them [8], [9], [10]. Despite that, ornamental fish are sensitive to water quality.

Water quality is a measure of the status of water concerning at least one biotic animal type's basic needs [11]. Better water quality has a better impact on organisms, whether in health aspects or hygiene [12]. Moreover, fish farmers who breed ornamental fish need the best water quality to ensure fish production. The water quality in aquaculture and fish farming industries is usually monitored through manual data collection. This process is labourious, time-consuming, and needs to be performed on-site by workers. Thus, the ability to have a monitoring system that can overcome these drawbacks is crucial. It is essential to have a water quality monitoring system because it can check the quality of the water and notify the users that the water is being contaminated [13], [14]. IoT based water quality monitoring system is being developed to monitor the water quality of the ornamental fish pond by detecting the temperature and pH level of the water, as both can affect metabolism and fish growth [14], [15], [16], [17],[18]. The system works as equipment to monitor and record the temperature and pH levels of the ornamental fishpond and helps the farmers analyse and manage their farm remotely using IoT embedded in the system.

In recent years, there has been a surge in the development of IoT-enabled systems for water quality monitoring in both aquaculture and rural settings, reflecting broader environmental and food sustainability concerns. A systematic review by Flores-Iwasaki [22] highlights significant growth in the application of IoT-based systems for aquaculture, emphasizing sensor integration, low-cost design, and cloud connectivity. Similarly, Krklješ [23] developed a multiparameter node that includes pH, temperature, and coliform detection using LoRaWAN technology for freshwater applications. These innovations provide continuous, low-power monitoring and overcome the limitations of conventional manual sampling methods, especially in off-grid or remote environments. Abrajano [24] demonstrated how Arduino-based IoT systems with mobile dashboards could empower rural communities with reliable water data. Such system also exhibits many advantages to the farmers in terms of quality and productivity by reducing

This manuscript is submitted on 17th February 2025, revised on 6th August 2025, accepted on 12th August 2025 and published on 31st October 2025.

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the operation costs and increasing the profits for fish farmers [19].

Generally, in aquaculture industries, Internet of Things (IoT) technology has emerged and enabled the implementation of real-time data acquisition and remote monitoring through wireless connectivity [23-24]. However, most existing studies have focused on applications in large-scale aquaculture, environmental monitoring, or agriculture. Despite the progress in this field, a specific gap exists in applying IoT-based monitoring systems tailored for small ornamental fishponds, where constraints include cost, ease of use, and integration with mobile-based interfaces for non-technical users. Furthermore, few studies explicitly address the operational conditions and sensitivity of ornamental species, which often differ from commercial fish breeds [10].

This paper presents the design and evaluation of a low-cost, real time water quality monitoring system for ornamental fishponds, focusing on temperature and pH as primary indicators. The system is equipped with widely available sensors and leverages the ThingSpeak platform for data visualization and alert notifications. While the system architecture shares similarities with existing models, its novelty lies in the specific contextual application, custom alert logic, and user-centric design aimed at fish farmers.

II. METHODOLOGY

A. System Development

i) Sensor testing and calibration

In this work, the temperature sensor, DS18B20 from Maxim Integrated and pH probe from Gravity/DFrobot were selected as the sensor to be integrated into 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.

For the pH sensor, the calibration was done by measuring the output voltage for different standards of pH solutions. Three buffer solutions with normal pH of 4,7, and 10 from Sigma Aldrich were used. For each pH value of buffer, an appropriate voltage signal was measured and plotted accordingly. These values are important to see the linearity of the calibration curve, which to be used for voltage/pH conversion. Table I shows the value of output voltage from the pH probe for each pH buffer solution. Fig. 1. shows the calibration curve obtained for different pH levels of buffer solution.

TABLE I: PH VALUE and THE VOLTAGE VALUE SHOWN BY THE GRAVITY PH PROBE.

pH value	Voltage value
4	0.48
7	1.88
10	3.3

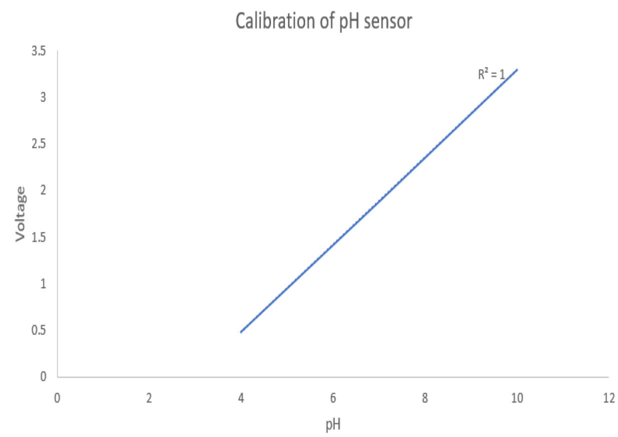


Fig. 1. Calibration curve obtained for different pH levels of buffer solution.

The graph demonstrates a perfectly linear relationship with an R_2 value equal to 1. The calibration curve will be used for converting any voltage into pH once the sensor is immersed into different solutions with different pH levels. From this relationship, it is estimated that the system will produce a pH measurement system with a sensitivity of 0.108V/pH.

Apart from that, the minimum requirement of power supply was also tested to know the cut off voltage to the sensor in case the system is supplied from the battery. It is found that for the pH sensor, the minimum requirement of operating voltage that needs to be applied for optimum operation is higher than 3.5 V. That means that during the process, the voltage should be maintained so as not fall below the set value.

ii) IoT based system

Fig. 2. shows the architecture or the block diagram of the proposed system. ESP32 microcontroller was used as the MCU for the system.

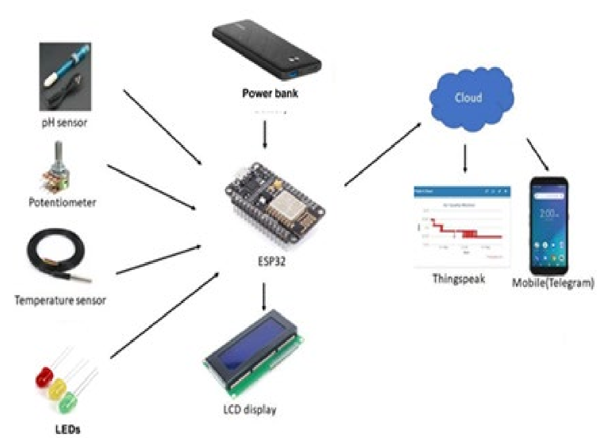


Fig. 2. Block diagram of the system.

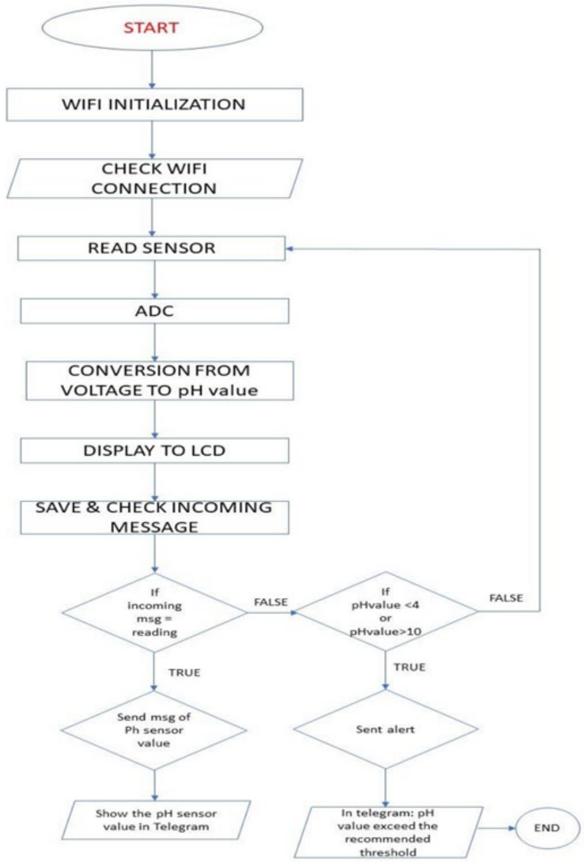
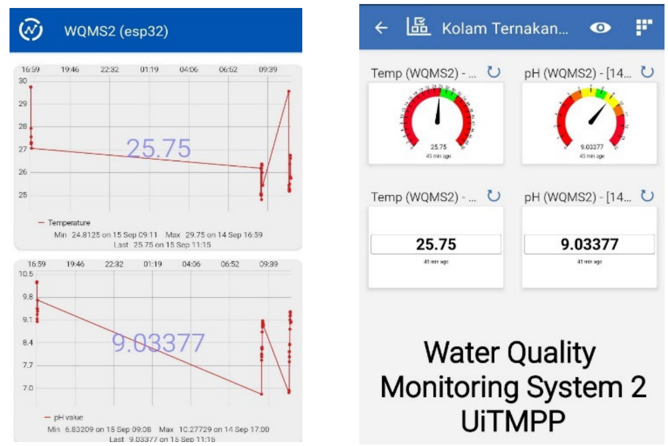


Fig. 3. Programming flow chart.

In this design, analog input was assigned for the pH sensor, and digital input was set up for the temperature sensor. The values obtained from the calibration process were used for conversion purposes. The system was programmed to operate based on a flow chart, as shown in Fig. 3.

For the voltage to pH conversion, the signal from the sensor needs to be converted from analog to digital using the ADC features in ESP32. Using the "same gradient approach", the conversion was achieved based on two calibration methods. For IoT implementation, built-in WIFI was used to get the connection to the cloud server via MQTT or HTTP. Fig. 4 shows the application used for remote monitoring to collect the data as well as to visualise the instant data of interests. For this purpose, Thingspeak and Thingsview were used due to their accessibility since the data will be displayed in both graph and gauge forms; thus, it is easy for users to understand the data collected.

While our system employs pre-calibrated sensor curves, future versions may adopt dynamic and adaptive calibration features to further optimize long-term accuracy as introduced by [25].



a)Thingspeak b)Thingsview

Fig. 4. Remote monitoring apps for Thingspeak and Thingsview

LED indicators were used to indicate if the measured value exceeds the threshold limits for notification purposes. In this work, the selected range of pH and temperature were set to be between 6 to 8 and 25-27°C, respectively. The Telegram application was used as a notification tool to alert the user if the value exceeded the threshold value for remote monitoring. Fig. 5 shows the telegram response obtained upon requests by the user.

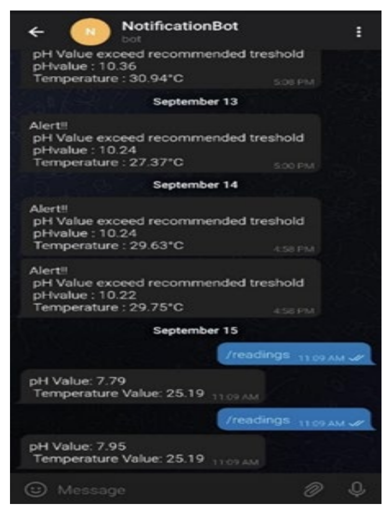


Fig. 5. Telegram notification alert and response upon user request.

B. System testing and analysis

For the developed system, several tests were carried out to observe its measurement performance. In each measurement, a commercial pHtemp meter (Hanna Instruments) was used to verify the reading.

i) pH

For pH measurement, several solutions with different pH levels were prepared, as given in Table II. The pH level ranges from

1.99 to 9.37 was measured by the calibrated meter from Hanna Instruments.

TABLE II: LIST OF THE PREPARED SAMPLE FOR LABORATORY TEST.

Solution	Hanna
Buffer	4
Hand Soap	6.3
Milk	6.7
Buffer	7
Baking Soda	8.4

Fig. 6 shows the pH measurement setup, and there are eight different solutions that the Hanna meter needs to measure the pH for each of the solutions. Then, the measurement was taken by using the developed system to observe the measurement performance as compared to the reference value. This step is significant to estimate its accuracy after being calibrated before deploying it on site.

Fig. 6. pH measurement setup.

ii) 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. 7. The reading was also taken as temperature decreases to observe the hysteresis pattern of the system. Several performance parameters were then computed to obtain the measurement performance such as linearity, accuracy, error and hysteresis using statistical analysis method.

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 ornamental fish farm located at Bendang Man, Kedah, Malaysia. Fig. 8 shows the final system developed in the researchers' laboratory and ready to be used for pH and temperature data collection at the selected location.

Fig. 7. Temperature measurement setup

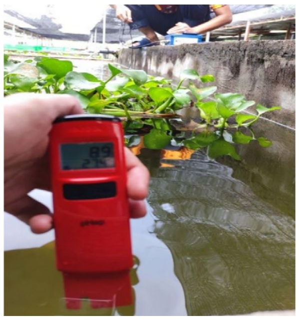
Fig. 8. Complete system of water quality monitoring system with IoT.

There are about 150 ponds in the Bendang Man ornamental fish farm, which places about 10 types of different ornamental fish. For the purpose of data collection, 3 ponds were identified.

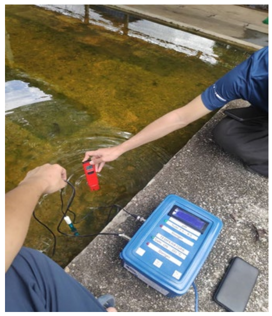
The tests were divided into 2 categories, namely single point and continuous. For each measurement, the reading was compared to the reading taken using the Hanna meter. For the initial test, the measurement was taken 3 times a day on three different ponds as shown in Figure 9(a), 9(b), and 9(c), respectively.

This test was continued for 17 days to collect about 153 data from 3 ponds. Then, the analysis was performed to obtain several performance parameters such as accuracy and error characteristics for in situ measurements. Based on these data, further analysis was carried out. The classification method was used to observe the pH and temperature behaviour of the pond of interest as compared to the standard set by the department of fisheries (DOF) as in Table III. The correlation between temp and pH for each pond was also analysed in order to conclude their relationship in the tested farms.

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 24 hours. The programme was set every 22 seconds to send the data towards the Thingspeak platform, and the analysis was performed in order to see the ability of the system capture the expected data throughout the test period. The data collection has been performed and viewed using Thingspeak and Thingsview platforms as illustrated in Fig. 10 and Fig. 11 respectively. The system is also embedded with a notification system to notify user when the measured temperature and pH values has exceeded the present values. During this event, the notification message will be sent to the user through the Telegram application as depicted in Fig. 12.



(a) Pond 1



(b) Pond 2

(c) Pond 3

Fig. 9. Three selected ponds

TABLE III: WATER QUALITY for ORNAMENTAL FISH.[20]

Water quality parameter	Water quality guidelines
Temperature	29°C - 31°C
pH	6.5 – 8.5

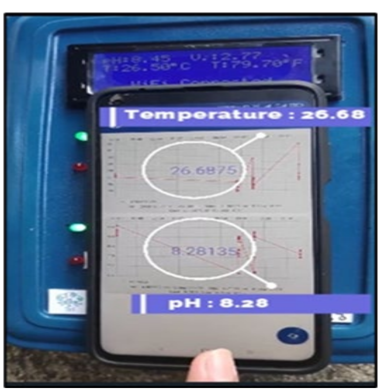


Fig. 10. Thingspeak for data collection and visualisation.

Fig. 11. Thingsview for data visualization through the dashboard.

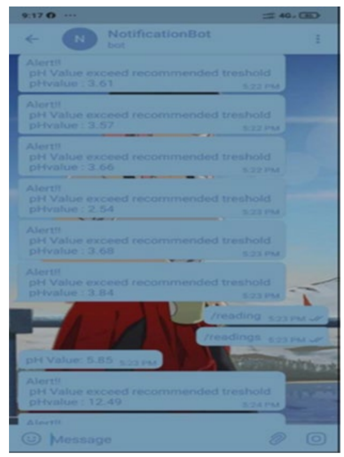


Fig. 12. Telegram for notification

III. RESULTS AND DISCUSSION

A. PH accuracy laboratory test

Table IV shows the in-lab measurement data performed in five samples, namely vinegar, coke, buffer solution pH 4, soap, milk, buffer solution pH 7, and baking soda to evaluate the performance of the pH sensor integrated into the developed WQMS2 system. A commercial-grade pH/temp meter from Hanna Instruments was used as a reference device to validate the accuracy of WQMS2 readings. The test is crucial to ensure the reliability and accuracy of the developed system before being used at the selected site.

It is observed that for the range under test, the system gives a convincing result with an accuracy of detection of more than 90% with a very small error as compared to the measurement taken using the commercial device. Using the calibration data done initially, the system is capable of giving the measurement with the linearity of 0.9993 as shown in Fig. 13.

The calculated sensitivity is around 97% and the system is capable to measure the pH of 4 to 9.1. 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.

TABLE IV: RESULTS for PH ACCURACY TESTS.

	Solution				
	Buffer pH 4	Soap	Milk	Buffer pH 7	Baking soda
Hanna	4	6.2	6.8	7.1	9.1
WQMS 2	3.71	6.1	6.24	6.72	8.6
Error	-0.07817	-0.01639	-0.08974	-0.05655	-0.05814
% of error	-7.81671	-1.63934	-8.97436	-5.65476	-5.81395
Abs % of error	7.816712	1.639344	8.974359	5.654762	5.813953
Accuracy (%)	92.18329	98.36066	91.02564	94.34524	94.18605

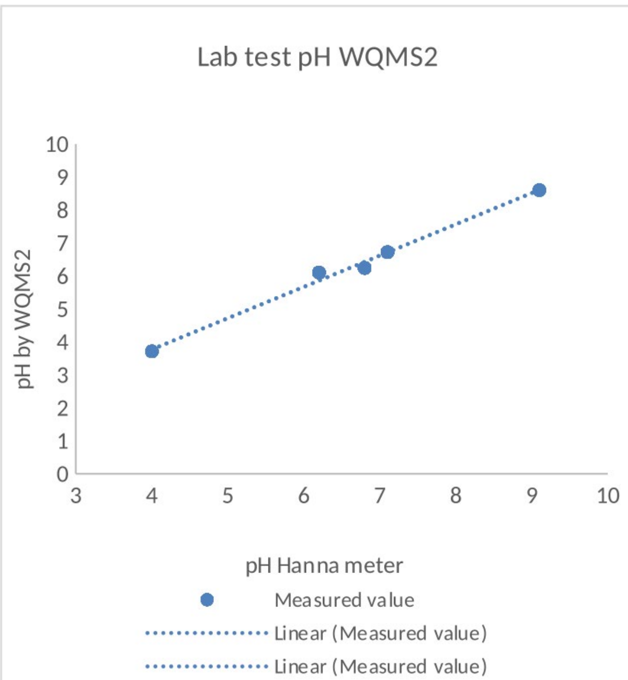


Fig. 13. Linear graph pH test WQMS2 vs Hanna meter

B. Temperature accuracy and hysteresis in lab test

This subsection presents the laboratory test results for temperature accuracy and hysteresis to evaluate the performance of the temperature sensor used in the WQMS2 system. Fig. 14 shows the temperature measurement of water during its rising and falling patterns.

In general, it can be observed that the measurement taken using WQMS2 is very accurate as compared to the commercial meter (HI98107), which is a temperature accuracy of ±0.5°C [1]. In terms of linearity, both rising and falling pattern show a good linear plot with the R2 equals to 0.9991 and no hysteresis was found. The lab test thus indicates that this system has a very good performance for in situ implementation at the selected installation site.

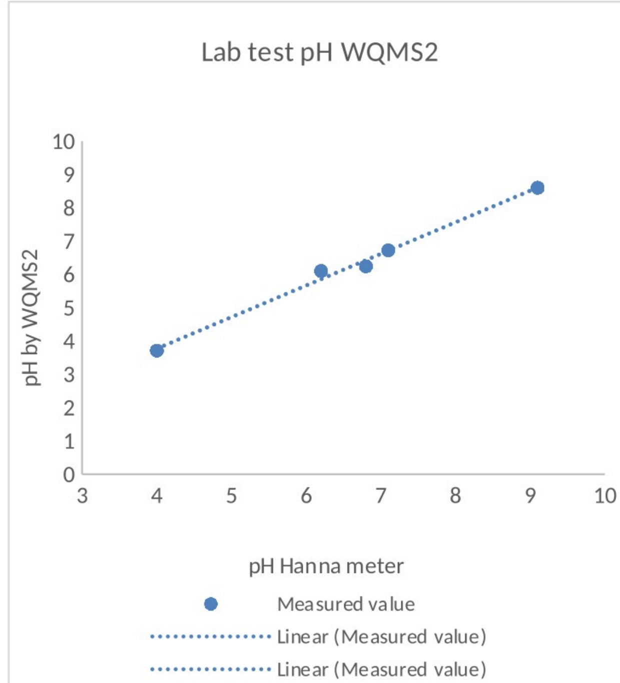


Fig. 14. Temperature measurement of water during its rising and falling.

C. In site system testing

In order to verify the performance of the whole system, on-site evaluation was performed according to the methodology spelt out previously. Several other parameters such as accuracy, mean square error (MSE), and histogram error were used to further verify the performance of pH and temperature measurement system for WQMS2 application.

i) pH

Fig. 15 shows the in-situ pH measurement using WQMS2 as compared to the conventional device.

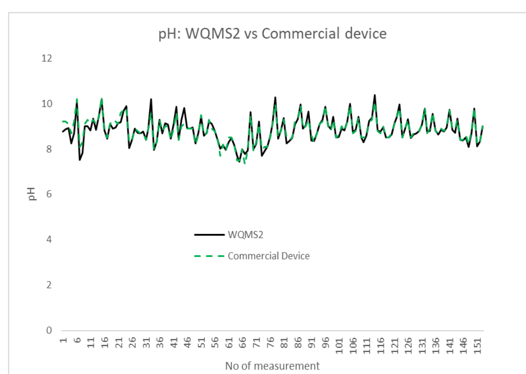
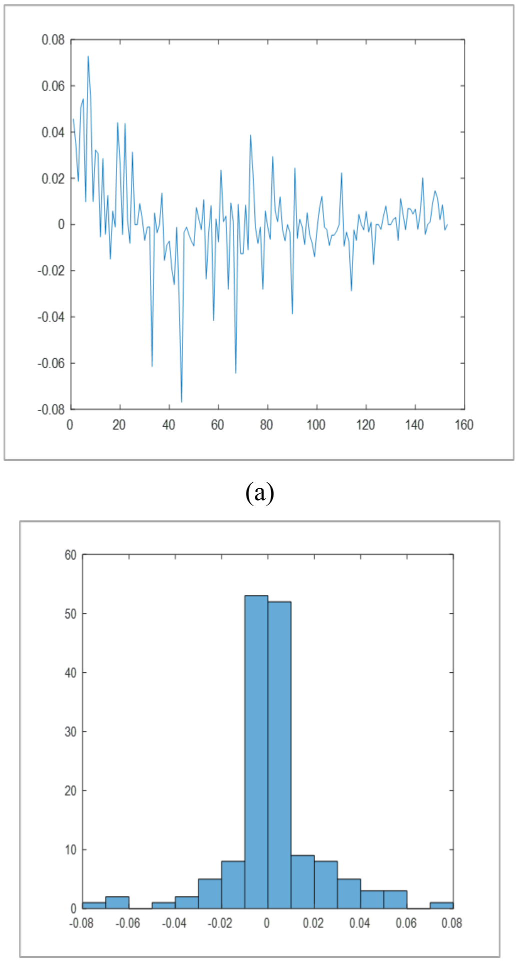


Fig. 15. pH value from WQMS2 compared with pH value from the conventional device.

Based on the 153 data collected, it is observed that the reading of the pH sensor and commercial device (Hanna meter) is between the range of 6 to 10. The range can be considered as safe as the fish inside the pond has a low death rate and high breeding rate. The trigger seems to be working very well as the LED light turns on every occasion where the pH level is out of the set range.

The measurement for both WQMS2 and commercial devices are found to be very closed, indicating a good accuracy of the system. The analysis shows that these data produced a very small deviation with the mean error and the RMS error of 0.0161 and 0.0430, respectively. Fig. 16(a) shows the error fluctuation that is maintained at a low value, and it can be further verified by the histogram error shown in Fig. 16(b). The histogram shows a good normal distribution with the lowest error is concentrated at the centre.



(a)

(b)

Fig. 16. (a) Fluctuation of RMS error (b) histogram error of WQMS

ii) Temperature

Based on the 153 data collected, it is observed that the reading of pH for both WQMS2 and the commercial device is very close as obtained in the lab test. The analysis shows that these data produced a very small deviation with the mean error and the RMS error of 0.00053956 and 0.0071, respectively. Fig. 18(a) shows the error fluctuation that is maintained at a low value, and it can be further verified by the histogram error shown in Fig. 18(b**)**. The histogram shows a good normal distribution with the lowest error is concentrated at the centre.

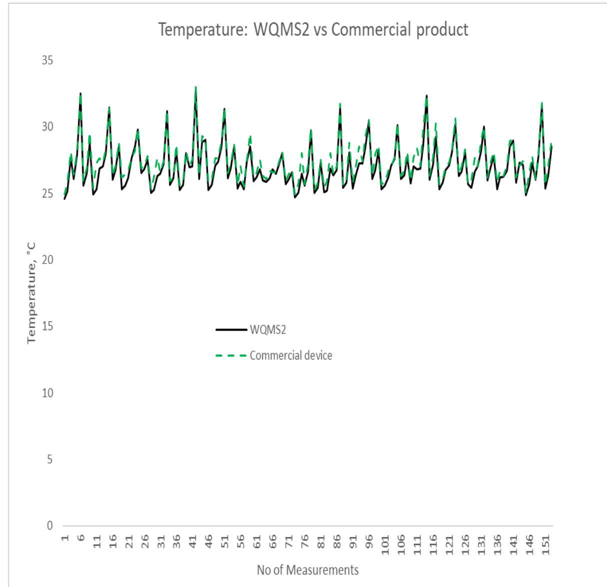
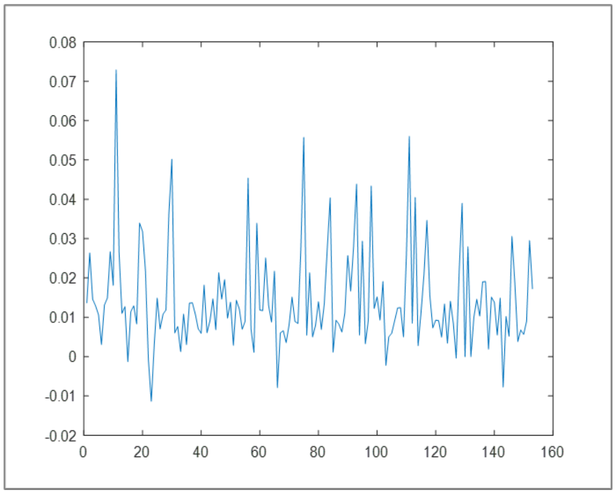


Fig. 17. Temperature value from WQMS2 compared with pH value from the conventional device.

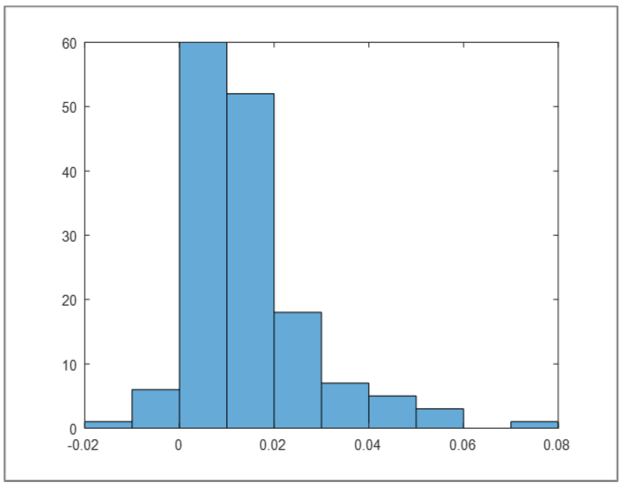
D. In situ data transmission test

In situ data transmission test was calculated to observe the capability of the system to store data continuously for 24 hours as well as to prove the ability of the system to work effectively by using the proposed IoT methods. Table V shows the result obtained from the tested period of time, at intervals of 22 seconds. All the data were accessed from the Thingspeak platform, where the data was sent from the system to the cloud storage.

In general, it can be observed the data logging process from the sensor into the cloud logging was successful, indicating that all data has been successfully logged into the developed system. The total number of the retrieved data for both parameters were aligned with the expected number based on the set interval. Specifically, all the stored pH and temperature data gave the accepted values for all the retrieved data (within the expected range) and were considered to have 99.7 of successful transmitted data. The expected data for 24 hours was 3927 data uploads, but only 3915 data being uploaded to the cloud. This might be due to several uncontrolled issues such as the inconsistency of the network connectivity and synchronisation issues that cause the data incompleteness [21]. However, since nearly 100% of data can be retrieved, the system is considered to have a good performance and reliability for this specific task.



(a)



(b)

Fig. 18. (a) Fluctuation of RMS error (b) Histogram error WQMS2 for temperature sensor measurement.

TABLE V: THE COLLECTED DATA OF 24 HOURS OPERATION FOR WQMS2.

Parameter	Data Transmission Test	
pH	Transmitted and logical data (pH 7-10)	3915
	Missing data	7
	% of Transmitted data	99.7
Temperature	Transmitted and logical data (30-35°C)	3915
	Missing data	7
	% of transmitted data	99.7

IV. CONCLUSION

In conclusion, the main objective of IoT based 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 validates the method that being used, thus can be replicated in other work.

The work has offered a low-cost system monitoring device with IoT function to the tested industry as it gives the opportunity to farmers to access the parameters in their pond throughout the testing period. This data can be further analysed to classify the performance of each pond as well to predict the performance of the pond by parameters measured if the model is obtained. The system can be improved by integrating it with other sensors for measuring the crucial parameter required based on the demands or requirements by the industry.

Recent developments also point to the growing use of machine learning (ML) models embedded within IoT systems for predictive water quality assessment. For instance, a smart monitoring system deployed in Bangladesh used ML algorithms to predict unsafe water conditions in real-time, enhancing responsiveness in tourist zones [25]. This identifies how cloud-edge architectures with ML support can forecast anomalies and reduce false alerts in IoT-based monitoring. These trends suggest strong potential for the WQMS2 system to evolve into a smart predictive platform, capable of not just detecting but forecasting water quality issues based on learned environmental patterns.

ACKNOWLEDGMENT

The authors would like to thank Universiti Teknologi MARA Cawangan Pulau Pinang and Pusat Ikan Hiasan Bendang Man for all the research facilities provided in this work.

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