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Development of an Automated Aquarium Monitoring System with an IoT Interface using Google Sheets

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Abstract: *This paper presents the development of an automated aquarium monitoring system with an IOT interface using google sheets; the system autonomously monitors key water quality parameters temperature, pH, and turbidity while automating fish feeding and water replacement functions. An ESP32 microcontroller serves as the system's core, control unit which is programmed using C++ to transmit environmental data to a cloud-based Google Sheet. A servomotor dispenses feed precisely every 12 hours, while two DC pumps are triggered automatically when turbidity exceeds 50 NTU, ensuring proactive water quality management. The designed system is powered by a 30W solar panel and a charge controller coupled with a 12V lead-acid battery, allowing continuous operation in off-grid locations. The system performance test was conducted over a period of five days and was validated by comparing the sensor outputs with results of the manual measurements obtained by using laboratory-grade instruments. The results demonstrated high accuracy, with average deviations of only 1.95% for temperature, 2.09% for pH, and 1.96% for turbidity when compared with the result obtained from the manual measurement. Also the automated feeding and water replacement mechanisms operated with 100% reliability by being able dispense the feed from the hoper at every 12 hours interval and changing the water once the turbidity is equals or above 50 NTU. Hence the proposed system successfully enhanced automation, real-time cloud integration, and renewable power supply for improved fish aquarium management, thereby offering a compelling alternative to labour-intensive and manually operated systems while laying the groundwork for intelligent, data-driven fish farming practices.*

Keywords: *Fishpond Monitoring System, Internet of Things (IoT), Google Sheet, ESP32 Microcontroller, Intelligent Systems*

1. INTRODUCTION

The aquaculture plays a crucial role in global food production as it provides a sustainable source of protein to meet the nutritional needs of the growing global population [1]. In Nigeria, the fishery and aquaculture sector significantly contribute to national food security and economic growth but has been experiencing developmental challenges resulting from inefficient monitoring, suboptimal environmental conditions, labour-intensive management practices etc. [2]. Traditional fish farming in Nigeria is largely manual and often lacks consistent surveillance of critical parameters such as water temperature, pH, and turbidity. This results in delayed interventions, higher fish mortality rates, and diminished productivity. Furthermore, existing automation systems are mostly expensive, limited in functionality, and not suited for rural environments due to power constraints. As such, there is an urgent need for an affordable, scalable, and energy efficient solution that supports real-time monitoring and control, thereby enabling more sustainable and data driven aquaculture practices in resource constrained environments.

Over the years, numerous researchers have explored the integration of IoT and automation in aquaculture, each contributing valuable innovations to improve fish farming practices. Harun *et al*., [3] pioneered a real-time fishpond monitoring system using Arduino, which incorporated pH, dissolved oxygen, and temperature sensors to track essential water parameters. Around the same period, Osueke et al., [4] developed an automatic fish feeder controlled by an Arduino microcontroller, capable of dispensing precise feed quantities at scheduled intervals. Similarly, Ojo and Benard [5] introduced a feeding mechanism based on the Atmel 8052 microcontroller, utilizing a DC motor to regulate feed dispensation through adjustable speed control.

Building on these foundational efforts, Azhra and Anam [6] presented a more advanced IoT-enabled fishpond control system that merged automated feeding with comprehensive water quality monitoring. Their system included temperature, salinity, and dissolved oxygen sensors and was operated through a mobile application, allowing farmers to control feeding remotely. More recently, Akosuga and Abdulsalam [7] enhanced this approach by designing a smart aquaculture monitoring and control system that leverages multiple sensors to ensure real-time data acquisition and automated management of pond conditions. In a similar vein, Olanubi et al., [8] proposed an intelligent IoT-based water quality management system tailored to optimize the aquatic environment and boost farm productivity through continuous monitoring and responsive control mechanisms.

The primary aim of this study is to develop an automated aquarium monitoring system with an IoT interface for real-time monitoring and autonomous management of water quality and feeding in small-scale fish aquarium. To address the key limitations identified in previous works, the system is designed to integrates real-time sensor monitoring with remote access via Google Sheets, automated control of water quality to ensure that the water turbidity stays below 50 Nephelometric Turbidity Units (NTU) which is required for a healthy catfish aquarium and automated feeding control. Unlike earlier models that either lacked cloud connectivity or combined control mechanisms, this system unifies automated feeding and water quality management using real-time readings of temperature, pH, and turbidity. It further distinguishes itself by incorporating a solar power system composed of a 30W solar panel, a 12V lead-acid battery, and a charge controller, ensuring continuous, eco-friendly operation even in off-grid or rural environment. By utilizing low-cost components such as the ESP32 microcontroller and leveraging Google Sheets, a free and widely accessible cloud platform the system promotes scalability, affordability, and energy sustainability, while significantly reducing labour and operational costs associated with traditional aquaculture practices.

2. MATERIALS AND METHOD

2.1 Materials

i. ESP32 Microcontroller: The ESP32 serves as the central processing unit (CPU) for the system, collecting data from various sensors and controlling automation processes. It also communicates with a remote server via Wi-Fi to upload sensor data and enable real-time monitoring via Google Sheets.
ii. pH Sensor: This sensor measures the acidity or alkalinity of the pond water, ensuring that the water remains within the optimal range for fish health.
iii. Water Temperature Sensor: A temperature sensor monitors water temperature, which is crucial for fish metabolism and overall pond conditions.
iv. Turbidity Sensor: The turbidity sensor measures water clarity, detecting changes that indicate poor water quality, debris accumulation, or potential contamination.
v. LCD Display: The LCD provides real-time visualization of collected data, allowing on-site monitoring of pond conditions.
vi. Ultrasonic Sensor: A pair of ultrasonic sensors is used in the system to measure the water level in the pond and to measure the level of feed in the hopper
vii. Servo Motor: The servo motor controls the outlet of the automatic fish feeder, dispensing food at preprogrammed time intervals to ensure consistent feeding.
viii. 12V DC Mini Water Pumps: Two 12V DC mini water pumps are responsible for removing and replacing pond water when the sensors detect that the water quality has deteriorated, helping to maintain a healthy environment for the fish.
ix. Power Supply Unit: The system is powered by a solar power supply system comprising of a 30W solar panel, a 12v led acid battery, 30A charge controller and a DC bulk converter.

2.2 Method

The prototyping method was employed in development of the automated aquarium monitoring system with an IOT interface using google sheets. This approach allowed for iterative testing, refinement, and validation of the system's functionalities. In other to achieve this, the system design process was divided into hardware system design which involves the development of the physical subsystem and software system design which involves the development of the microcontroller program using C++ and the integration of the google sheet which serves as the platform for the sensor data storage and visualization.

2.2.1 Hardware system block diagram

Figure 1 below is the block diagram of the proposed automated Fishpond with IoT interface. The block diagram illustrates how the modules that makes up the system are connected with each other. These modules include the power module, the control module, the display module. the sensors and the actuators.

2.2.2 System circuit diagram

The circuit diagram or the wiring diagram of the system shows the connection of the main hardware components makes up the electronics system. The hardware design of the automated aquarium monitoring system with an IOT interface presented in this paper follows the drawing of the circuit diagram that illustrates the connection of the main hardware components that makes up the system using Cirkit Designer simulation platform as shown in Figure 2.

At the heart of the system is the ESP32 microcontroller, which receives power from a solar setup consisting of a solar panel, a solar charge controller, and a 12V lead-acid battery. The battery’s output is regulated by a DC buck converter to supply the appropriate voltage to the ESP32 and other low-voltage components. Connected to the ESP32 are three key sensors: a pH sensor to monitor water acidity, a DS18B20 sensor to measure water temperature, and a turbidity sensor to assess the clarity of the water. These sensors collect real-time environmental data and send it to the ESP32 for processing. The ESP32 is configured to upload this data to the 16 X 2 LCD and the Google Sheets via HTTP protocol, enabling remote monitoring of the aquarium's condition.

The system includes a servo motor that controls the release of fish feed. It is programmed to rotate and let out feed through the feed hoper at twelve-hour intervals, ensuring consistent and timely feeding without the need for manual intervention. To maintain water quality, the system uses two water pumps connected through a relay module. When the turbidity sensor detects that the water has become too dirty or cloudy, the ESP32 triggers Pump 1 to drain the contaminated water while the ultrasonic sensor monitors the water level to ensure the water is completely drained and then Pump 2 is activated to refill the aquarium with clean water for the fishes. The Ultrasonic sensor also monitors the water level while pump 2 is active to signal the microcontroller to turn of the Pump once the required water level is reached. The relay module acts as the switching interface between the ESP32 and the pumps, allowing them to operate safely as the require 12v for their operation unlike the other components that require just 5v

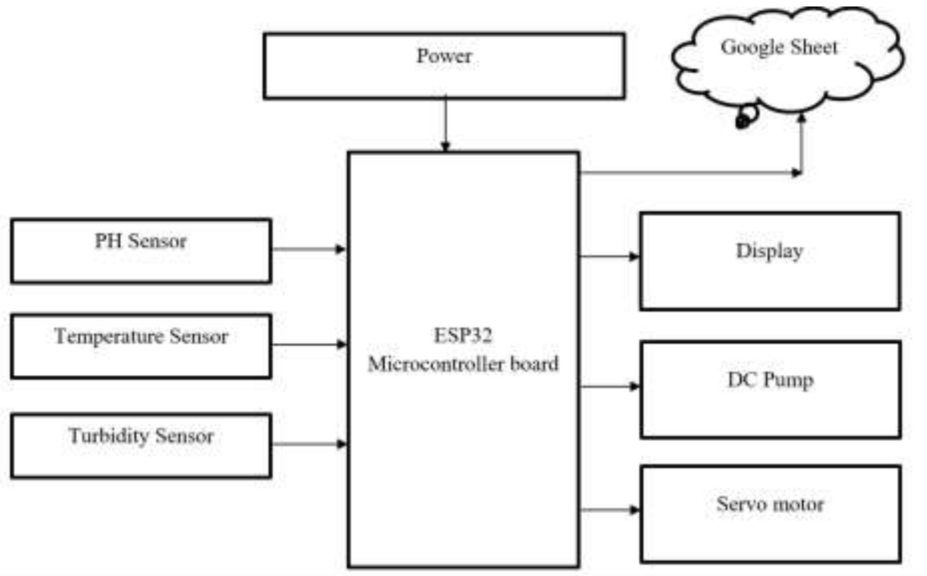


Figure 1: System block diagram

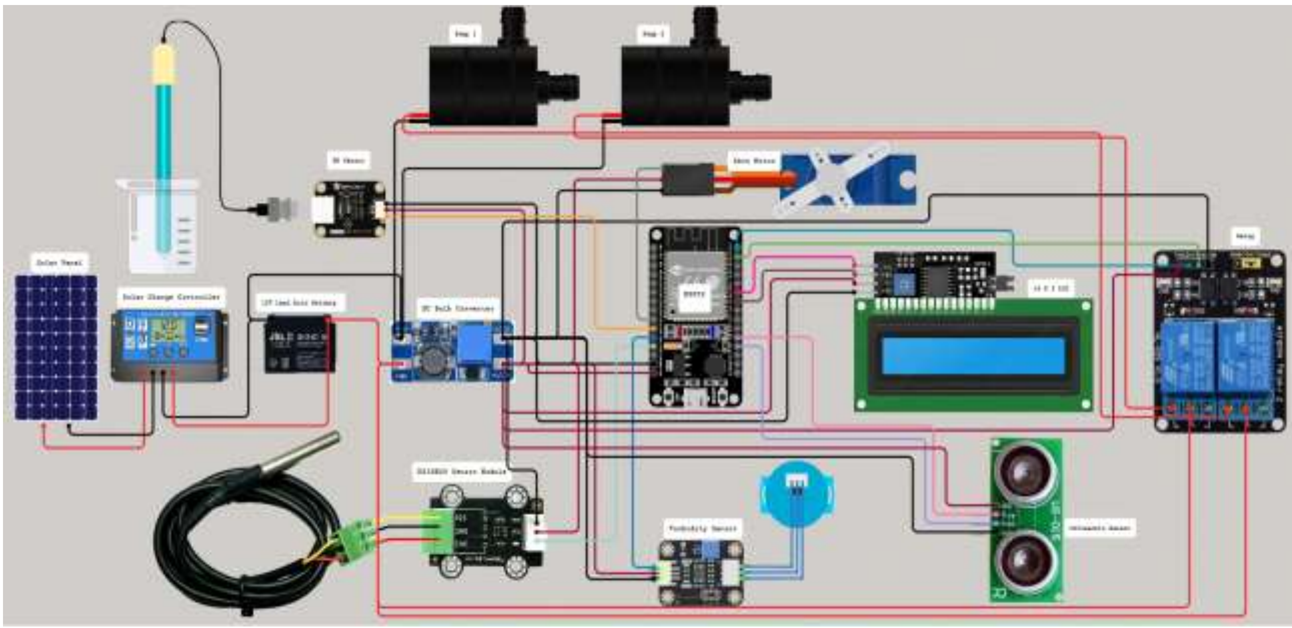


Figure 2: System circuit diagram

2.2.3 System flowchart

The system flowchart, illustrated in Figure 3, provides a structured visual representation of the operational workflow of the automated fish pond system. It serves as a foundational blueprint for the development of the microcontroller program, which was implemented using C++. The process begins with the initialization of the input and output ports, followed by the establishment of a Wi-Fi connection to facilitate remote data transmission. The system then continuously acquires sensor readings, including water temperature, pH, and turbidity, which are displayed on an LCD screen for real-time monitoring. Based on the sensor data, the microcontroller executes automated control of the actuators activating the fish feeder via a servo motor and triggering the water pumps when poor water quality is detected. Additionally, the system is programmed to upload collected sensor data to a Google Sheet at six-hour intervals, enabling remote access and analysis. This structured flow ensures a seamless integration of IoT-based automation, enhancing efficiency, reliability, and sustainability in aquaculture management.

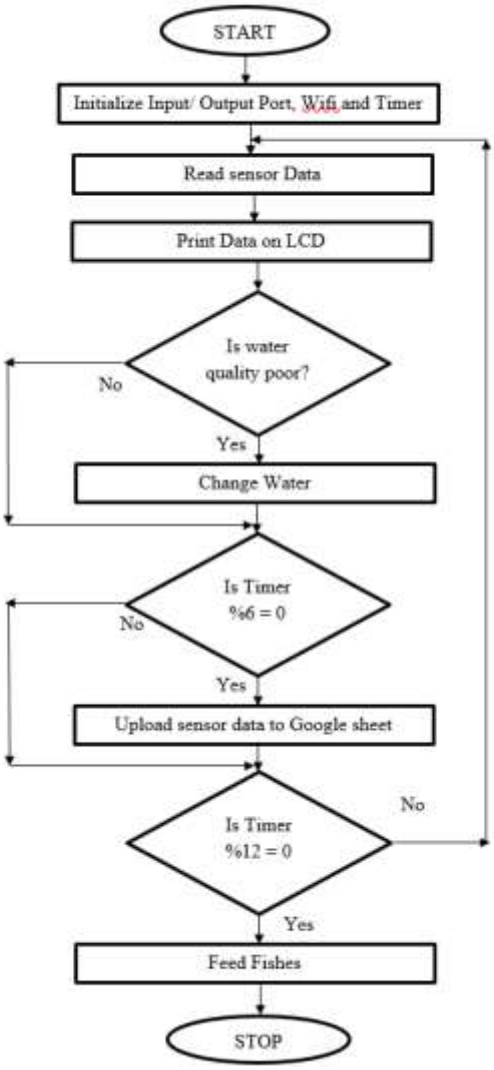


Figure 3: System flowchart

2.2.4 System implementation

The implementation of the automated fish pond system involved integrating both hardware and software components to create a functional IoT-based monitoring and control system. The ESP32 microcontroller served as the central processing unit, managing data acquisition from the pH, temperature, and turbidity sensors. The sensors continuously monitored water quality parameters, and the collected data was displayed on an LCD screen for on-site monitoring while being transmitted via Wi-Fi to a cloud-based Google Sheet on 6 hours interval for remote access.

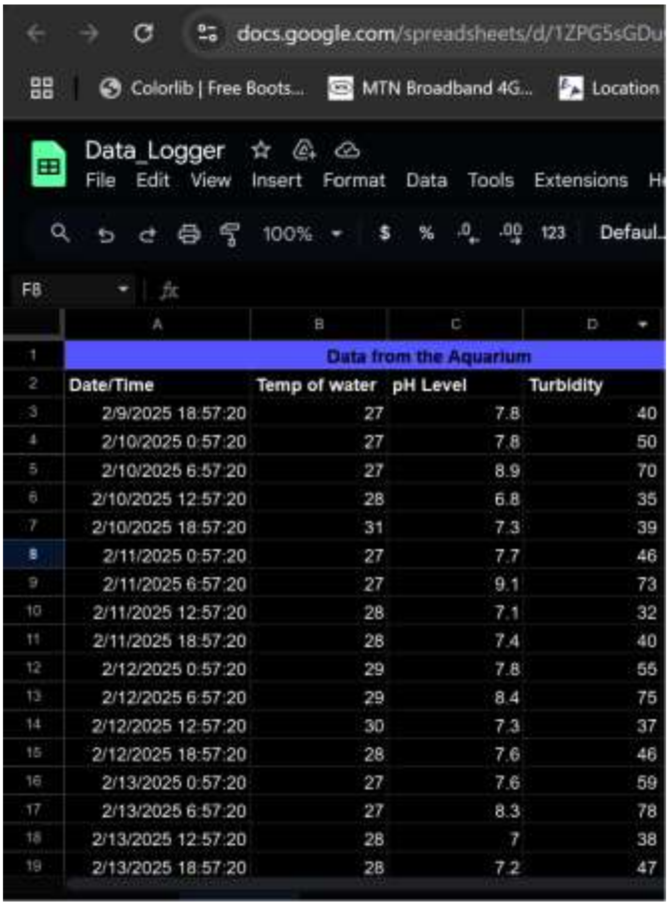
The fish feeding mechanism was automated using a servo motor, which controlled the release of feed at preprogrammed intervals. An ultrasonic sensor is positioned over the feed hopper to monitor and give feedback on the amount of feed in the hopper hence ensuring consistent feeding. Additionally, two 12V DC mini water pumps were incorporated to automate water replacement when sensor readings indicated deteriorating water conditions. An ultrasonic level sensor also monitors the water level during the water change process to ensure the water level is controlled. A solar power system, consisting of a 30W solar panel, a 12V lead-acid battery, and a 30A charge controller, provided a sustainable power supply to ensure uninterrupted system operation.

The system was tested in a real-world environment to evaluate its performance and reliability. Adjustments were made based on observed discrepancies, optimizing sensor accuracy, feeding schedules, and water replacement cycles. The integration of IoT allowed fish farmers to remotely monitor water conditions and system status via Google Sheets, improving efficiency and reducing manual labour. This implementation showcases the potential of IoT in enhancing aquaculture management by providing real-time insights and automated interventions. The software development interface comprising of Arduino IDE where the code integration for the system is implemented in shown in Figure 4. Additionally, Figures 5a and b depict the designed system while figure 6 shows the screenshot of the data logged on the google sheets.

Figure 4: System software development interface

Figure 5a: The designed system

Figure 5b: The designed system



	A	B	C	D
1	Data from the Aquarium			
2	Date/Time	Temp of water	pH Level	Turbidity
3	2/9/2025 18:57:20	27	7.8	40
4	2/10/2025 0:57:20	27	7.8	50
5	2/10/2025 6:57:20	27	8.9	70
6	2/10/2025 12:57:20	28	6.8	35
7	2/10/2025 18:57:20	31	7.3	39
8	2/11/2025 0:57:20	27	7.7	46
9	2/11/2025 6:57:20	27	9.1	73
10	2/11/2025 12:57:20	28	7.1	32
11	2/11/2025 18:57:20	28	7.4	40
12	2/12/2025 0:57:20	29	7.8	55
13	2/12/2025 6:57:20	29	8.4	75
14	2/12/2025 12:57:20	30	7.3	37
15	2/12/2025 18:57:20	28	7.6	46
16	2/13/2025 0:57:20	27	7.6	59
17	2/13/2025 6:57:20	27	8.3	78
18	2/13/2025 12:57:20	28	7	38
19	2/13/2025 18:57:20	28	7.2	47

Figure 6: Data logged in google sheet.

3. RESULT AND DISCUSSION

The designed system effectively monitored the catfish aquarium water parameters, including temperature, pH level, and turbidity and successfully logged the data on the google sheet. Over 5 days of testing, the water temperature ranged from 27°C to 31°C, the pH values fluctuated between 6.8 and 9.1, reflecting natural variations in water chemistry. Harun et al. (2018) recorded similar fluctuations in water PH level with peak reading of up to 9 using a non-IoT-based system but lacked real-time monitoring capabilities. Turbidity levels varied, with a peak value of 50 NTU, indicating temporary decreases in water clarity and was automatically addressed by the water pump activation feature. Figures 4 and 5 shows the designed system and the screen shoot of the data logged on the google sheet respectively.

To further evaluate the result of the designed system, we have also collected corresponding manual measurements for water temperature, pH level, and turbidity using conventional instruments such as a thermometer, handheld pH meter, and turbidity tube over the period of five days. These values were recorded and presented in Table 1 alongside the sensor-generated data to assess the system's accuracy and reliability in real-world conditions. By calculating the percentage variation between the average sensor readings and manual measurements, we determined that the temperature readings varied by an average of 1.95%, pH by 2.09%, and turbidity by 1.96%. This minimal deviation confirms that the sensors used in the system are not only consistent but also accurate enough for practical aquaculture applications. To visually assess the measurement accuracy of the data presented in Table 1, evaluation charts Figures 7, 8 and 9 which shows the plot of sensor data against manual readings for temperature, pH, and turbidity respectively, has been presented to further illustrate the strong linear correlations and negligible systematic bias across all parameters.

In addition to the system's precise water-quality monitoring, the system proved highly reliable in its automated interventions. Over the five-day test period, the servo-driven feeder consistently dispensed the feed at 12-hour intervals, with zero missed or mistimed feedings. This regularity not only ensures optimal growth rates by maintaining a consistent feeding schedule but also eliminates the variability and labour demands of manual feeding.

Equally robust was the water-replacement mechanism: whenever turbidity readings reached or exceeded the 50 NTU threshold, the ESP32 immediately activated Pump 1 to drain the turbid water and then engaged Pump 2 to refill the tank with fresh water. Across seven turbidity-triggered events, the pumps responded accordingly with only about 2 seconds, achieving a 100% success rate in restoring water clarity. Together, these results demonstrate that the system not only delivers highly accurate sensor readings (with average deviations under 2% for temperature, pH, and turbidity), but also flawlessly executes its automated feeding and water-change routines validating its efficacy as a fully autonomous solution for sustainable, low-labour aquaculture management.

Table 1: Timestamped system reading of the aquarium water system

Date/Time	Sensor Temp (°C)	Thermometer Temp (°C)	Sensor pH	Manual pH	Sensor Turbidity (NTU)	Manual Turbidity (NTU)
2/9/2025 18:57:20	27	27.5	7.8	7.7	24	24.9
2/10/2025 0:57:20	27	26.4	7.8	7.6	50	48.4
2/10/2025 6:57:20	27	27.7	8.9	9.1	10	10.8
2/10/2025 12:57:20	28	28.4	6.8	7.7	18	17.0
2/10/2025 18:57:20	31	30.6	7.3	7.1	39	40.5
2/11/2025 0:57:20	27	26.9	7.7	7.5	46	44.2
2/11/2025 6:57:20	27	27.4	9.1	9.9	16	18.2
2/11/2025 12:57:20	28	27.4	7.1	7.6	22	21.0
2/11/2025 18:57:20	28	27.1	7.4	7.6	40	40.8
2/12/2025 0:57:20	29	30.5	7.8	8.0	50	48.4
2/12/2025 6:57:20	29	28.2	8.4	8.1	24	22.2
2/12/2025 12:57:20	30	30.5	7.3	7.5	37	36.7
2/12/2025 18:57:20	28	27.5	7.6	7.4	43	42.2
2/13/2025 0:57:20	26	25.4	7.6	7.8	12	13.2
2/13/2025 6:57:20	27	26.2	8.3	8.4	24	23.4
2/13/2025 12:57:20	28	27.4	7.0	7.6	38	37.2
2/13/2025 18:57:20	28	27.2	7.2	7.0	47	45.4

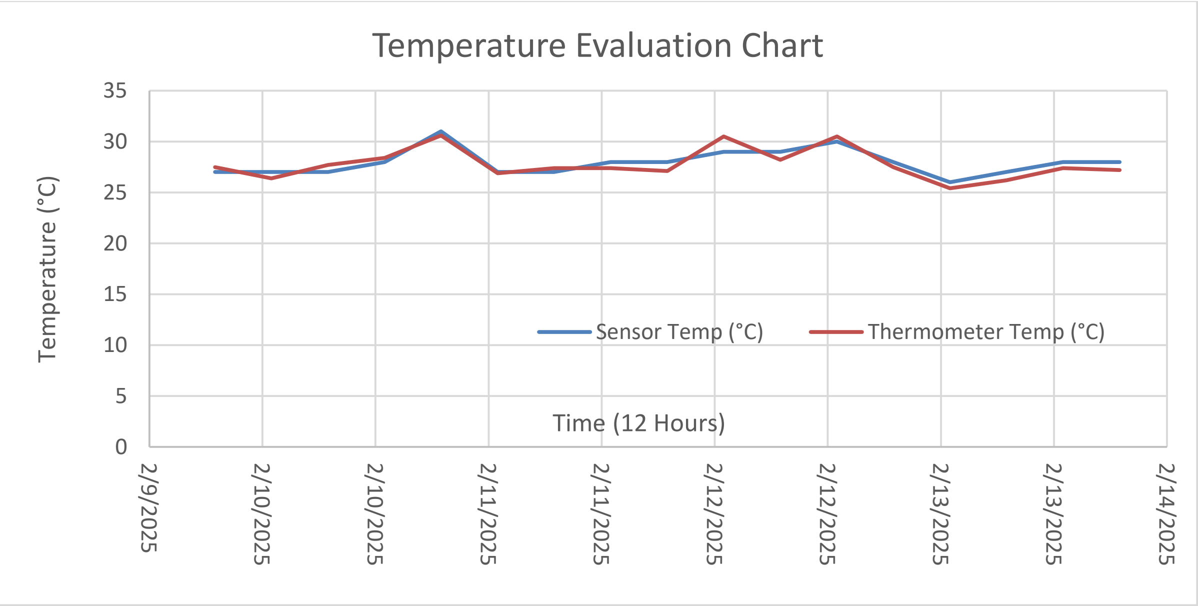


Figure 7: Aquarium water temperature evaluation

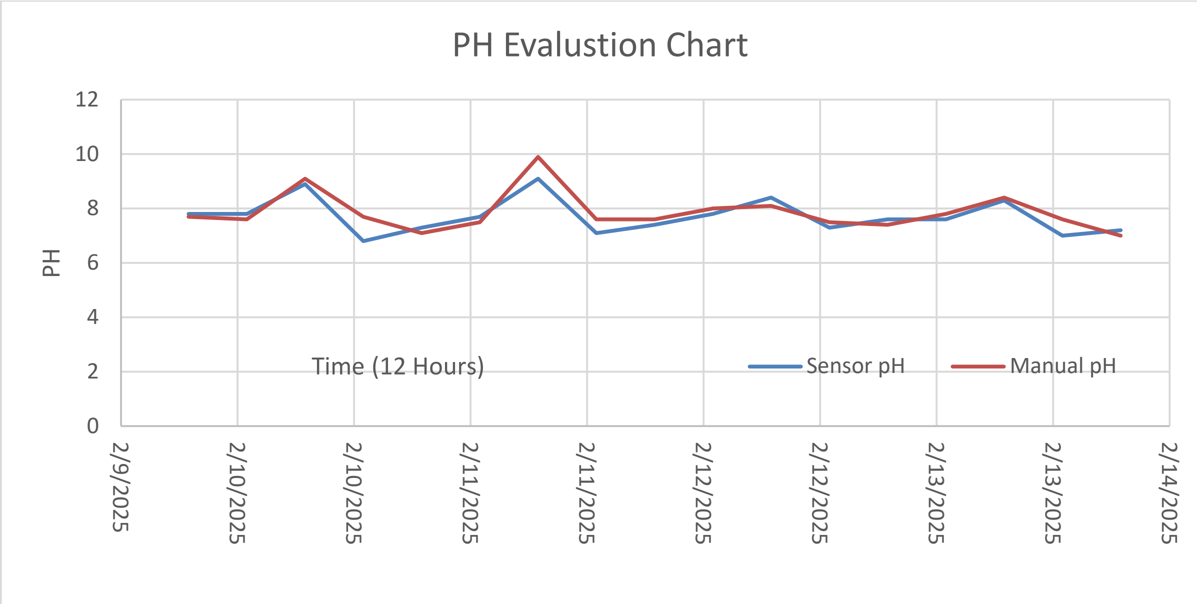


Figure 8: Aquarium water PH evaluation chart

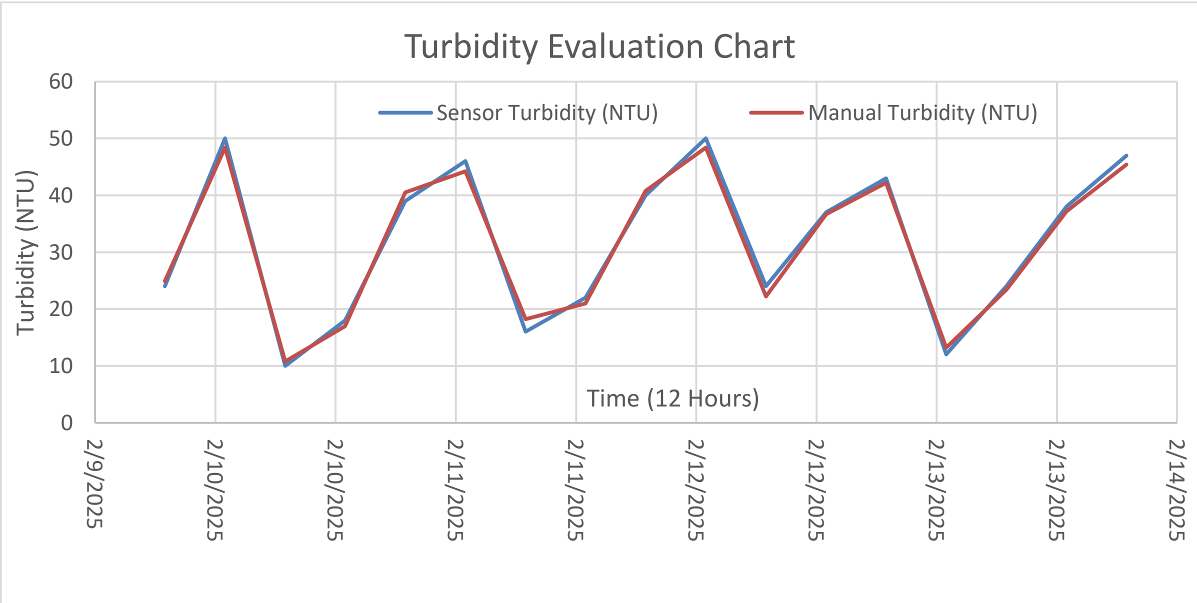


Figure 9: Aquarium water turbidity evaluation chart

4. CONCLUSION

The automated aquarium monitoring system developed in this work successfully meets the primary objectives of the paper which includes designing and implementing a cost effective, IoT-based solution for real-time monitoring and autonomous management of water quality and feeding in small-scale aquaculture environments. By integrating reliable sensors for temperature, pH, and turbidity, the system continuously tracks the aquatic conditions and leverages cloud connectivity via Google Sheets to enable remote monitoring and data logging. The servo-controlled feeder demonstrated accurate performance by its ability to dispense feed every 12 hours as expected, while the dual-pump water management mechanism effectively responded to turbidity thresholds, automatically replacing water whenever readings exceeded 50 NTU. Experimental evaluation revealed that the system's sensor data deviated by an average of just 1.95% for temperature, 2.09% for pH, and 1.96% for turbidity when compared to results obtained from manual testing instruments. When compared with existing systems, such as those developed by [3] and [6], which lacked either real-time cloud integration or automated water quality control mechanisms, the proposed system offers a more robust and comprehensive solution. Furthermore, compared to the IoT-based system developed by [8] which reported average deviations of 2.3% for temperature and 2.7% for pH without statistical validation for turbidity this work exhibits superior accuracy and greater measurement transparency across all key parameters.

Despite the strong performance of the designed system, the system has certain limitations as it currently monitors only three water quality parameters and does not incorporate dissolved oxygen or ammonia levels, which are critical for more advanced aquaculture systems. To enhance future iterations, it is recommended that the system be expanded to include more comprehensive water quality sensors, such as those for dissolved oxygen and nitrate detection. Additionally, predictive analytics powered by machine learning could be incorporated to forecast changes in water conditions and adapt system behaviour proactively.

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