A Prototype Web-Based Water Quality Monitoring System for Improved Aquaculture Management using Arduino Nano

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A Prototype Web-Based Water Quality Monitoring System for Improved Aquaculture Management using Arduino Nano

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Abstract: *The Prototype Web Base Water Quality Monitoring System is the solution to the problems faced by the fishpond owners in manual checking of water conditions. The objective of the system is to support viable aquaculture by providing convenient automated methods of monitoring the water parameters. The prototype is using Arduino Nano integrated with turbidity, pH, and temperature sensors to measure water quality in real time. The collected data is then transmitted to a Database then is displayed to our web application, enabling remote access through our user-friendly interface. Which is designed for freshwater fishponds, the system replaces manual observation with accurate and continual monitoring. It offers a cost-effective solution for local fish farmers while promoting better aquatic health management. The system operates through a web platform and requires a stable internet connection to transmit and access data remotely.*

Keywords: Arduino Nano; Water Quality Monitoring; Web Application; Fishpond; ESP

1. INTRODUCTION

Water is fundamental to sustaining life, comprising approximately 70% of the Earth's surface and playing a vital role in human health, agriculture, ecosystems, and industrial processes [1]. As global pressures from pollution, climate change, and population growth continue to mount, ensuring the availability of clean and safe water has become an urgent concern [2]. This is not only a global issue but also a regional challenge. For instance, a study in Kohima, Nagaland, found elevated aluminum levels in drinking water, which posed potential long-term health risks despite most parameters falling within acceptable limits [3]. These findings emphasize the need for continuous and localized water monitoring, particularly in underserved or rural communities.

Effective water quality monitoring is essential for understanding the condition of aquatic systems, identifying pollution sources, and supporting sustainable management practices [4]. However, traditional monitoring methods often involve manual sampling and laboratory analysis, which can be slow, resource-intensive, and unable to provide real-time feedback. As a result, they offer only periodic snapshots of water quality, limiting the ability to respond promptly to contamination events [5].

In response to these limitations, there is growing interest in real-time, sensor-based water monitoring systems. Key indicators such as turbidity, pH, and temperature serve as critical measures of water health. High turbidity, for example, can signal the presence of suspended solids, bacteria, or other pollutants that may threaten aquatic life and human safety [6]. Seasonal changes in water quality have also been documented, such as significant fluctuations in turbidity, conductivity, and TDS between monsoon and dry seasons [7]. These findings reinforce the need for continuous, adaptive monitoring tools that can respond to environmental shifts.

A similar study in the Sambunotan Watershed of Dinagat Islands reported that human activities—such as quarrying and livestock farming—substantially influenced water quality indicators like TDS and dissolved oxygen [8]. Such findings support the integration of localized environmental data into the design of water monitoring systems.

This study proposes the development of a low-cost, real-time water quality monitoring system using Arduino Nano and sensors for turbidity, pH, and temperature. The system is intended to provide continuous feedback on water conditions, enabling early detection of contamination and supporting timely interventions—particularly in aquaculture settings.

In fish farming, water quality directly influences fish health, growth, and yield. Many fishpond operators, however, still rely on traditional visual inspection methods, which are often unreliable. Decisions are frequently based on how the water looks rather than measured data, leading to either premature or delayed corrective actions. The lack of accessible monitoring tools further limits farmers' ability to manage their ponds effectively.

The main objective of this study is to design and develop a real-time water quality monitoring system for small-scale aquaculture. Specifically, the study aims to:

1. Build an Arduino-based device integrating turbidity, pH, and temperature sensors for continuous water assessment;
2. Develop a web-based interface to display and manage sensor data for aquaculture applications;
3. Evaluate the system's accuracy, reliability, and performance under actual fishpond conditions.

2. REVIEW OF RELATED WORK

2.1Water Quality Monitoring:

Aquaculture is one of the most promising industries in the agricultural sector. Fish, as one of aquaculture's contributions, is considered a substantial source of protein for people around the world [9]. However, one issue confronting small-scale aqua farmers is the current practice of conventional water quality monitoring, which is tedious and time-consuming. These current methods for water quality evaluation rely on laboratory-based tests that require fresh supplies of chemicals, qualified staff, and water samples [5].

A water quality monitoring system using IoT technology with Arduino UNO and NodeMCU boards was developed in a previous study [10]. The system uses two sensors to measure parameters such as pH and temperature in the water. According to the study, it was effective for real-time water quality tracking and enabled better control.

Another study developed a smart water monitoring system using IoT and machine learning with an Arduino Uno and a turbidity sensor [11]. The system analyzed water data and predicted possible changes in water quality. It demonstrated strong performance in both monitoring and forecasting applications.

2.2Arduino-based Water Quality Monitoring:

Arduino is an open-source platform used to create small computer boards and kits for building digital devices [12]. The Arduino Uno is especially popular because it is affordable and flexible. It can connect to various sensors and components, making it a practical tool for monitoring water quality in fish farms. Arduino-based systems are commonly applied in aquaculture for checking water conditions in ponds, tanks, and similar aquatic environments [13]. These systems typically involve connecting multiple sensors to an Arduino microcontroller, which can be programmed to collect and process data. The collected data is then displayed on a webpage once the system is connected to the internet [14].

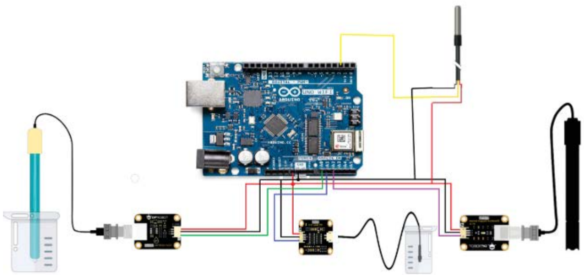

Figure 1. Aqua Quality Monitoring System

Figure 1. The hardware implementation of the system consists of an Arduino microcontroller, a pH sensor, a TDS sensor, and a dissolved oxygen meter. Before assembling the sensors, they should be calibrated, and each sensor should be precisely checked using standard techniques such as testing the pH sensor in buffer solution, dipping the dissolved oxygen meter in a zero dissolved oxygen solution, and testing the TDS sensor in an electrolytic solution of known electric conductivity with a standard Total Suspended Solids (TSS) value [13]. This is a circuit diagram illustrating the connections of various sensors to a microcontroller board.

2.3 Turbidity Sensors in Water Quality Monitoring

Turbidity originates from living organisms such as algae and zooplankton, as well as from nonliving materials like clay or mud. The lower the turbidity reading, the cloudier the water. A certain level of turbidity is considered beneficial in dams and ponds because some fish seek cover in less transparent water during the day, and overly clear water can increase the risk of bird predation. However, excessive turbidity can also cause problems, so maintaining an optimal turbidity level is essential. Continuous monitoring of turbidity levels is necessary to prevent issues for fish farmers [15].

Turbidity in water results from suspended solids that block incident and scattered light. It is defined as the amount of scattered light caused by these suspended particles [16]. The DFROBOT turbidity sensor, used in this system, operates at 5V DC with a response time of less than 500 ms. According to standards, a turbidity reading of less than 1 NTU (Nephelometric Turbidity Unit) indicates good water quality, 1–5 NTU indicates fair quality, and values greater than 5 NTU reflect poor water quality.

2.4 Theoretical Framework

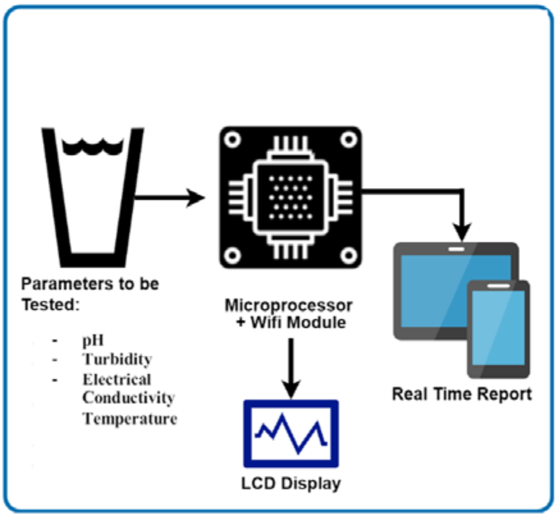

Figure 2. Design of an Arduino-Based Water Quality Monitoring System [17]

Figure 2. The Arduino-based water monitoring system is fully functional and capable of detecting sensor readings from four parameters: temperature, pH, turbidity, and electrical conductivity [17]. These sensors are submerged in the water being analyzed, which may be either flowing or stored. To transmit data to controllers—optionally via wireless communication—sensors convert physical parameters into measurable electrical signals. The controller reads, processes, and forwards this data to the application layer, which handles data management, analysis, and generates alerts based on monitored values.

3. METHODOLOGY

The system describes the sequential stages involved in sensor calibration, data collecting, and analysis as well as the reasoning behind the selected technology. By bridging the gap between traditional aquaculture methods and contemporary technology, this methodical approach seeks to provide real-time insights that are essential for making wise management decisions that will increase sustainability and productivity.

3.1 Concept of the Study

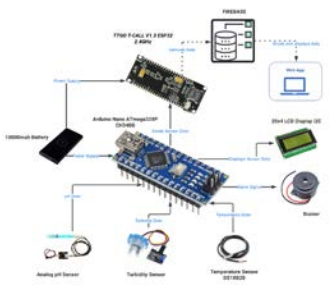

Figure 3. Conceptual Framework of the System

Figure 3. shows the basic setup of the system, where the pH, temperature, and turbidity sensors connect to the Arduino Nano. The Arduino Nano processes the data from these sensors and shows the results on a small LCD screen. The system runs on a power bank, making it easy to carry around and keep running all the time. The Arduino Nano is linked to an ESP32, which sends the data wirelessly to the cloud. The sensor readings are sent regularly to a database, so they can be accessed and checked anytime through a web app from anywhere.

3.2 Inputs, Processes, and Outputs

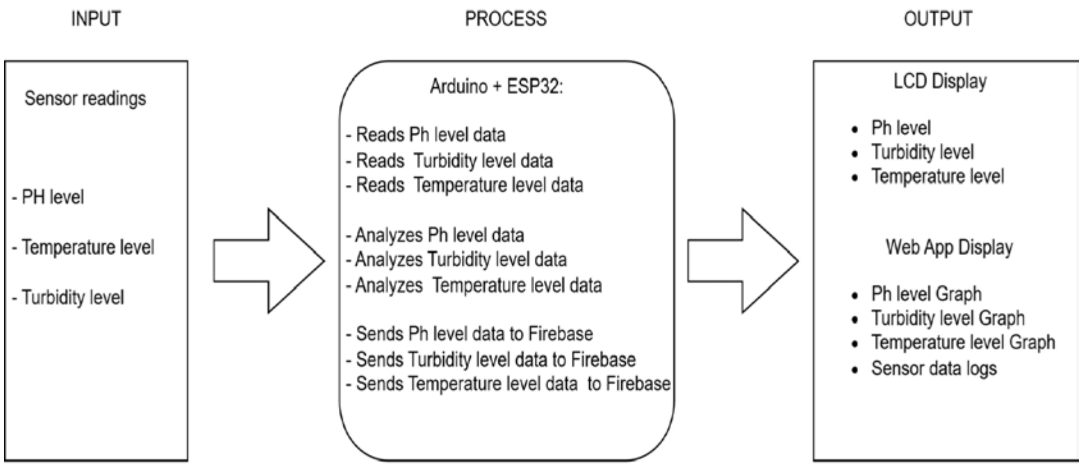

Figure 4. Inputs, Processes, and Outputs (IPO) Model

Figure 4. shows the water quality monitoring system using the input-processing-output (IPO) model. The input part has sensors (pH, temperature, and turbidity) that collect real-time water data. The Arduino Nano and ESP32 then receive, process, and analyze this data. The ESP32 sends the processed data to the cloud (Firebase) for web app monitoring and remote access. The output part displays the results on the LCD screen and uploads the data for continuous remote monitoring via the web application.

3.3 Research Locale

Figure 5. System Map, Kinamlutan Butuan City Agusan Del Norte

Figure 5. shows a map of the research location in Barangay Kinamlutan, Butuan City. This is where the Water Quality Monitoring System was designed and developed to help improve aquaculture management. This place was chosen because it is important for local fish farming and fits the goal of the project, which is to better check water quality and make sure the conditions are good for aquaculture there.

3.4. Data Collection

Data collection involves setting up the monitoring system in a fishpond in Barangay Kinamlutan, Butuan City. Sensors go directly into the pond water to take live readings of turbidity, pH, and temperature. The readings appear on the LCD screen and are processed by the Arduino Nano. The ESP32 then sends the data wirelessly to the Firebase database. This setup makes it possible to continuously monitor the pond's water quality throughout the study.

3.5. Data Acquisition

The sensors were carefully set up and adjusted to get reliable data. They were calibrated using standard solutions or known temperatures to make sure the readings were correct. The Arduino Nano was programmed to take readings at regular times and turn them into useful information. Then, the ESP32 sent this data straight to the Firebase database in real time, so water quality could be watched all the time and past data could be checked whenever needed.

3.6 Data Analysis

The data collected on turbidity, pH level, and temperature will be organized and studied to find trends, unusual changes, and patterns that affect the fishpond's water quality. The data taken from the Firebase database will be checked using simple math like averages and compared to set limits to see if they stay within the best range for aquaculture. Graphs and tables will show the information clearly and make it easier to understand. This study will help us understand water conditions over time and support smart decisions to keep the fishpond healthy.

3.7 Functional Requirements

Data Collection: The system will collect real-time data on turbidity, pH, and temperature accurately.

Data Transmission: The system will send data securely to the web server using Wi-Fi.

Data Storage: The system will save collected data in a database that can grow to handle more information for future analysis.

Web Interface: The system will provide an easy-to-use interface to show real-time sensor readings and past data in a clear way.

4. RESULTS AND DISCUSSION

This provides the result and discussion of the Water Quality Monitoring System, including the Arduino-based device, the water quality monitoring system, and for the testing performed to determine its performance and effectiveness in real-world conditions.

4.1 Arduino-Based Device

the Arduino device used in the Water Quality Monitoring System, such as its system design, components, and sensor and module integration. This section also provides the cost analysis and programming requirement needed for the device to operate and connect.

4.2 System Design

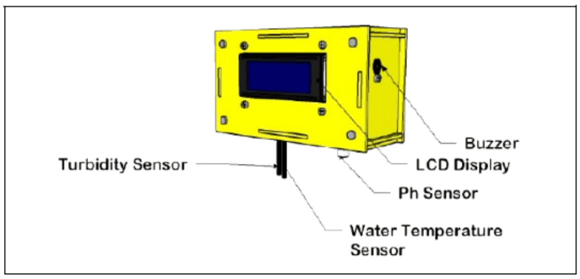

Figure 6. System Hardware Design

Figure 6. shows a prototype water quality monitoring system made to check conditions in aquaculture settings. The device is housed in a casing and includes three main sensors: a turbidity sensor to measure how clear the water is, a pH sensor to monitor the water's acidity or alkalinity, and a water temperature sensor to track temperature all placed at the bottom of the unit. A front display shows the data clearly as it happens, and a buzzer sounds if any of the readings go outside safe limits. This small, handy setup makes it easy to keep an eye on the water quality all the time, helping to protect the health of the aquatic environment.

4.3 Water Quality Monitoring Web Application

This section provides an overview of the Water Quality Monitoring Web Application, highlighting its interface design, functionality, and performance. It focuses on the system's ability to deliver real-time water quality data through a user-friendly platform integrated with Firebase for efficient monitoring and data storage.

4.3.1 Web Application Interface

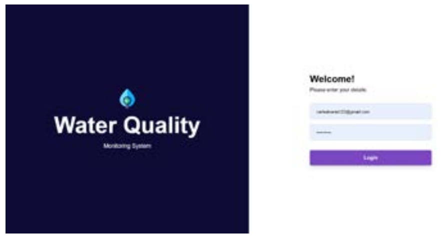

Figure 7. Login Page of Water Quality Monitoring System (WQS)

Figure 7. shows the login interface of the Water Quality Monitoring System, which allows users to access the web application using their registered Gmail accounts through Firebase. This login page ensures that only authorized users can access the system by validating email and password credentials stored in Firebase Authentication. The interface provides a simple and modern design, with a clear layout separating the branding on the left and the login form on the right. This setup enhances user experience while maintaining secure access to the system's real-time water quality data.

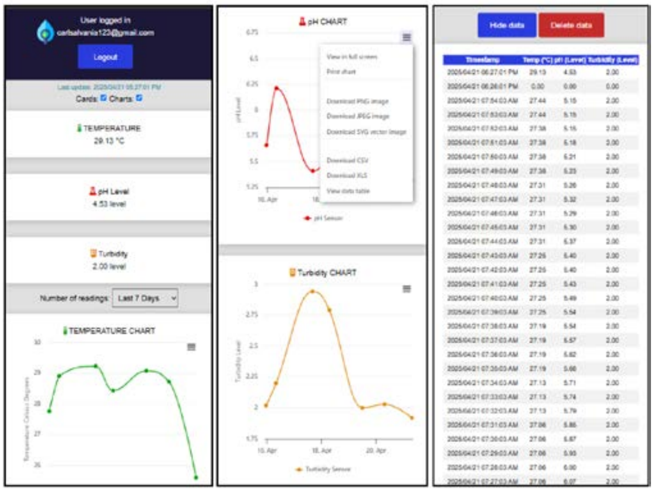

Figure 8. Water Quality Monitoring (WQS) Dashboard

Figure 8. shows the main screen of the easy-to-use web-based Water Quality Monitoring System that provides real-time feedback. The app communicates with Firebase, which updates the sensor data in real time and always stores it. It gives significant water quality information such as pH, turbidity, and temperature in interactive graphs so users can easily identify trends and spot any abnormal change. The device maintains a log that includes every reading together with the precise time it was recorded so users can easily identify when the data were recorded. It also contains a delete function, where users can erase old or unnecessary data at their discretion. The system is easy to use and efficient for monitoring water quality in fish farms using these user-friendly tools, enabling users to make better choices to maintain their fish safe and healthy.

4.3.2 Web Application Performance

The system's web application was evaluated based on load time, responsiveness, and how well it worked across different devices. Users accessed the platform in both desktop and mobile devices and the site demonstrated the following:

1. Load Time: < 60 seconds on average
2. Compatibility: 100% functional on Android, iOS, Windows, and macOS devices

3. Responsiveness: Adjusts layout based on screen size

4.4 Testing and Evaluation

4.4.1 Water Sensor Test

These factors are very important for ideal water condition in freshwater tilapia fishpond:

1. pH Level: As tilapia are sensitive to peak changes in pH, the ideal levels are to be in the 6.5 to 7.5 range.

2. Water Temperature: This is the ideal range of temperatures for tilapia, ranging from 21°C to 27°C.

3. Turbidity: Less than 25 NTU is the turbidity that qualifies waters to be good quality above 80 NTU can cause stress to fish and deteriorates water.

Table 1. Comparison of Sensor Test and Commercial Sensor Result

Parameter	Sensor Measurement	Commercial Sensor
pH Level	6.6	6.2
Water Temp	25.61ºC	24.5ºC
Turbidity	Clear water = 2NTU Muddy water = 223NTU	

Figure 9. Turbidity Measurement

The readings from our sensor and a commercial sensor have been contrasted in a table. The accuracy is affi rmed with close readings of temperature and pH value. It gives perfect readings for turbidity: muddy water gives a reading of 223 NTU, while clear water gives a mere 2 NTU. It demonstrates how eff ectively the sensor could discriminate diff erent levels of water in the clarity of aquaculture application.

4.4.2 Sensor Accuracy

Table 2. Sensor Accuracy

Sensor Type	Calibration Method	Purpose	Expected Accuracy
pH	Manual calibration using a linear equation: pH = -5.70 * voltage + calibration_value. The calibration_value was set to 24.15 based on pH buff er solutions.	Converts raw voltage to accurate pH levels based on known standards.	±0.1 pH (depending on probe quality).
Turbidity	Analog value scaled using: turbidity = map(sensorValue, 0, 977, 300, 0). Mapping values were set based on clean and dirty water samples.	Translates raw analog sensor output to approximate NTU values.	Approximate; good for trend detection, not lab-grade.
Temperature	No manual formula, uses DallasTemperature library for automatic conversion to Celsius. Calibration was confi rmed by comparing with a trusted thermometer.	Ensures temperature readings are accurate for real-world water conditions.	±0.5°C (as per DS18B20 datasheet).

According to the nature of installation, embedded formulae were used to calibrate all sensors used in the system. With a calibrated value of 24.15, the PH sensor can derive the pH values by using the formula pH=-5.70*voltage+calibration_value. The Turbidity sensor converted its raw analog input into NTU estimation using the formula turbidity=map(sensorValue,0,977,300,0). Lastly, the temperature DS18B20 sensor used a library function getTempCByIndex(0) to output results in Celsius automatically and accurately. These formulations now provide real-time monitoring very accurately from the fishpond.

4.4.3 Data Collected by the WQMS

The outcome of the water sensor trial, done over a period of six days, indicated the performance and accuracy of the temperature, pH, and turbidity sensors as tested. This piece of information adds valuable insight into water quality shift detection and proves the system's capabilities of monitoring environmental changes in a freshwater tilapia fishpond. The following graphs portray the results.

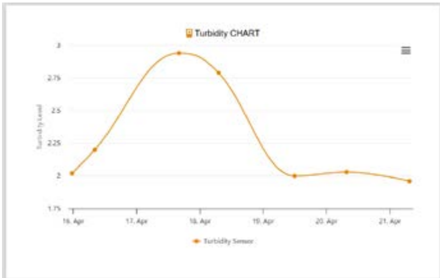

Figure 10. Turbidity Chart collected by the WQMS

Figure 10. depicts how the turbidity level started out at 2.0 on April 16 and steadily increased across the six days of testing, peaking at 2.9 on April 17. Then, it decreased gradually from April 19 to April 21 to settle around 2.0, which could be interpreted that the water became murkier towards the center of the testing period due to disturbances such as rains or change in flow, only to become clearer again back to the normal condition.

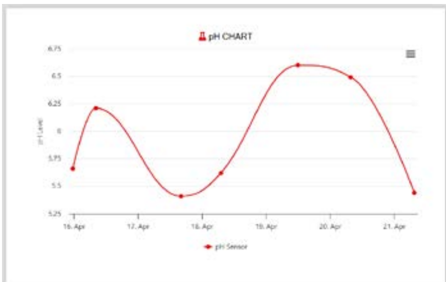

Figure 11. pH Chart collected by the WQMS

Figure 11. shows two graphical representations; the pH fluctuations were quite visible during the six days of testing: It started with a maximum of 5.7 on April 16 and peaked at 6.65 on April 19. Then it dropped slightly at 5.4 on 18 April, which later started increasing again; this really displays how water acids and alkaline characteristics change features, environment, or sources. The level of pH returned to 5.4 again on April 21, which indicated a return to the acidic condition. The changes were common, though unstable; however, the pH values remained within the normal limits of natural water.

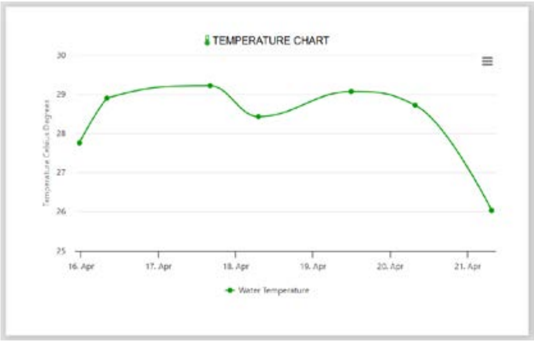

Figure 12. Temperature Chart Collected by WQMS

The whole six-day course of the water temperature was examined from April 16 to April 21. The results show that from Figure 12. the temperature readings ranged from 26.0°C to 29.2°C. The overall process indicates a time of persistent and warm weather, with the temperature gradually increasing from 27.7°C on the first day up to a peak of 29.2°C on April 18. The following day, April 19, saw an insignificant drop in temperature and the temperature further rose again up to 29.1°C on April 20. However, a sudden drop to 26.0°C on the very last day (April 21) gave the indication of a serious weather shift or water influx. In general, the results indicate that although the water temperature stayed rather constant during the middle days, weather conditions intervened toward the end.

4.5 Findings of the Study

Based on the system testing results, the Water Quality Monitoring System (WQMS) was able to accurately capture real-time data on the temperature, turbidity, and pH levels of water needed in aquaculture. The data collection period was six days during which the sensors and components of the system were observed and the components recorded operability. All environmental changes like rainfall and water current were registered using time stamps providing a basis for water turbidity and temperature levels confirming the system's effectiveness to capture real time data.

The web app worked well, loading quickly and running smoothly on different devices and platforms. The hardware costs just Php 4,133.00, so even small fishpond owners can afford it. Finally, the study showed that the WQMS is both budget-friendly and reliable for checking water quality in fish farming. This makes it a useful tool for keeping fish healthy without breaking the bank

5. CONCLUSION AND RECOMMENDATION

This study successfully completes the design and development as well as the assessment of an automated user friendly WQMS tailored for efficient water quality management for fishpond owners. Based on the results of the study, the system was successful in the real time monitoring of the vital water quality parameters which include temperature, PH and turbidity. The calibration of the sensors in the system was appropriate as the sensors were responsive to environmental factors like rainfall and changes in water flow, particularly with respect to the temperature and turbidity.

The web application fulfilled its purpose as it did not lag during the loading process and could be opened on multiple devices and platforms at the same time. It was responsive to different resolutions which meant that the water quality data
could be accessed by both mobile phone and desktop computer users. Effective adjustment of screen size favors easier access to water quality data via desktop computer or mobile phone. Furthermore, the fact that the hardware costs only Php 4,133.00 makes the system a cheap option for small-scale owners of fishponds.

Fishpond operators, based on survey results, show a keen interest in application of such technology. This means that rational monitoring and systematic maintenance of aquatically healthier environments by the WQMS may greatly improve on fishpond management practices and help embrace more sustainable aquaculture.

Following are the recommendations that would help in further improvements of the Water Quality Monitoring System (WQMS):

1. Power Supply: It can be changed from battery to mains for more reliability and consistency in power source.

2. Additional Sensors: More sensors could be installed to get proper readings on the water quality, for instance, installation of the ammonia or dissolved oxygen sensors.

3. Arduino housing: The Arduino setup may be given some roof or protective housing so that it is completely protected from the elements.

4. Mobile App: Instead of browsers-based platforms, maybe a mobile app should be developed so that it is easier for monitoring.

These upgrades would help improve the WQMS and develop a sustainable and efficient means for fishpond owners.

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