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Article

Water Quality Control and Aquaculture Pond Feeding System with Internet of Things Technology

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Abstract. This research explores a water quality control and feeding system for aquaculture ponds using Internet of Things technology. Aquaculture is a major economic activity in Thailand, but maintaining optimal water quality is crucial for the health and growth of aquatic animals. The system consists of three key components: sensors for monitoring water parameters (temperature, pH, turbidity, and dissolved oxygen), a NodeMCU ESP32 microcontroller for data processing, and a web application for user interaction. Water quality is regulated through automatic control of pumps that manage water exchange when parameters exceed safe thresholds, while an automated feeding system dispenses food based on user-set schedules or manual controls. Real-time data is displayed on the web application, which allows users to monitor sensor readings, control operations, and generate reports. The system supports both automatic and manual modes and includes features for user authentication, data logging, and export options. Performance evaluations demonstrated the system's effectiveness in maintaining water quality and automating feeding processes, meeting the needs of aquaculture farmers efficiently.

Keywords: IoT technology, water quality control, aquaculture ponds, automated feeding system.

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1. Introduction

Water quality for aquaculture is essential for the growth, strength, disease resistance, reproduction, breeding, and survival of aquatic animals. Water serves as a medium for respiration, maintaining balance, and biochemical processes in aquatic animals [1]. If the water quality is good and suitable for the type of aquatic animals, they will grow well, have good quality, and can be sold at high prices [2, 3]. Maintaining water quality at an appropriate level helps increase the growth rate of aquatic animals and reduce the likelihood of disease [4]. The essential water parameters to monitor and maintain include water temperature (T), Potential of Hydrogen ion (pH), turbidity (Tu), and dissolved oxygen (DO). Chemical and physical water quality factors suitable for aquaculture should be kept at optimal levels at all time [5, 6]. Oxygen gas from the atmosphere can dissolve better in cold water than in warm water [7, 8]. High water Tu can absorb more heat from sunlight, raising the temperature above normal levels [9]. Higher water temperatures reduce dissolved oxygen, making summer a critical period for aquatic animals [10]. During low light intensity periods, such as at night or during stormy seasons with prolonged cloudy weather, plankton photosynthesis decreases, reducing dissolved oxygen in the water, which might be insufficient for aquatic life, requiring close monitoring by farmers [11, 12]. Overfeeding aquatic animals is another issue to avoid, as 80% of water quality problems stem from the feed used in aquaculture, leading to spoilage and bad odors [13-15]. The key to successful aquaculture is maintaining water quality suitable for the aquatic animals through measuring water parameters in the ponds, including: 1) Water Temperature: It directly and indirectly influences aquatic life, making regular monitoring necessary. The optimal temperature range for aquaculture is 25-32 degrees Celsius [16-18]. 2) pH Level: It indicates the concentration of hydrogen ions in water. Extremely high or low pH levels are unsuitable for aquaculture. The ideal pH range is 6.5-9.0 [18-21]. 3) Tu: It indicates the presence of suspended and colloidal matter in the water. High Tu blocks light penetration and suspended sediments can clog gills, hindering respiration and growth, and reducing disease resistance. The ideal Tu range for aquatic growth is 0-100 Nephelometric Tu unit (NTU) [18, 22, 23]. 4) Dissolved Oxygen (DO): It indicates water quality. Polluted water usually has low DO levels. Water suitable for aquatic life should have a DO level of at least 5 mg/L [24-26]. However, manual water quality monitoring is time-consuming and inaccurate, as water quality constantly changes. Literature reviews show that many researchers have applied Internet of Things (IoT) and Remote Sensing (RS) technologies [26-28]. Prasad et al. (2015) developed an intelligent water quality measurement system to analyze pH, conductivity, and temperature using remote sensing technology. Continuous water pollution monitoring provides alerts for abnormalities. The system stores backup data on an SD card for retrospective analysis and uses a GSM module to transmit data to a web application [29]. Lean Karlo et al. (2020) developed an aquaculture system that automatically monitors and adjusts water quality parameters, including temperature, pH, Tu, salinity, and dissolved oxygen, using a web application for automatic device control [30]. Recent advancements in IoT-based aquaculture monitoring have increasingly integrated Artificial Intelligence (AI) to enhance predictive analytics and proactive decision-making. Studies have demonstrated that AIoT systems utilize machine learning (ML) models, such as Random Forests, Support Vector Machines (SVMs), and Neural Networks, to analyze real-time data from IoT sensors monitoring critical water quality parameters like T, pH, DO, and Tu [28, 30, 31]. These systems provide actionable insights for water quality management, feeding optimization, and early disease detection, enabling farmers to take preventive measures before issues arise [29]. The integration of AI-driven predictive analytics can improve operational efficiency, reduce resource waste, and enhance sustainability in aquaculture operations by ensuring optimal conditions for aquatic life [4, 32]. Additionally, smart feeding systems using AI algorithms analyze fish behavior and optimize feeding schedules to minimize feed waste and improve fish growth rates [33]. These advancements highlight the growing importance of AIoT in promoting smart farming practices that improve productivity and reduce risks in aquaculture [26, 34].

The problem with manual water quality monitoring is that it is time-consuming and inaccurate. Water quality changes all the time, so modern technology has been applied to overcome this problem in aquaculture. This research therefore developed a system to monitor the water quality in the pond and control the amount of food fed through the IoT technology. This system can monitor water parameters using sensors installed in the pond and send the parameter values to be displayed on a web application. It can also set the feeding rate for aquatic animals to reduce the problem of overfeeding, which causes water spoilage. This is another way to control water quality.

2. Materials and Methods

2.1. Overview Process

The diagram of the water quality control and feeding system in aquaculture ponds using IoT technology consists of 3 main parts: 1) Electronic devices used in the system: These devices collect data through sensors, process data, and control the various output devices of the aquaculture pond. 2) Database: The database stores and records data values from the electronic devices used in the system and the web application. The system can retrieve data from the sensors to display results or control various devices. 3) Web application: The web application allows users to check parameter values from the sensors and control the output devices in the aquaculture pond. Users can also generate reports or download data. See Fig.1 for a diagram of the system.

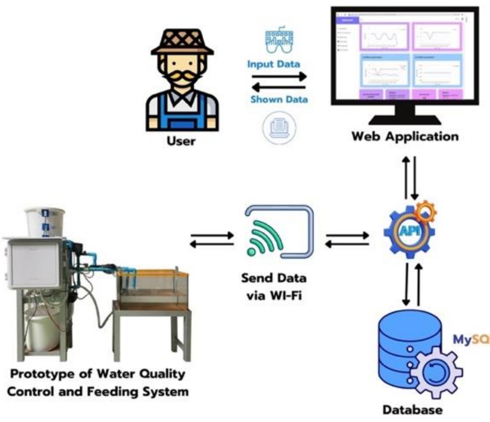


Fig. 1. The overview process of methodology in this work.

2.2. Th Prototype of Water Quality Control and Feeding in Aquaculture Ponds using IoT

The design and development of the water quality control and feeding system in aquaculture ponds using IoT technology is shown in Fig. 2. An aquaculture pond was simulated using a 23x46x29 cm^3 tank. Three tanks were installed: a feed tank, a water storage tank, and a wastewater tank as shown in Fig. 2. The automatic water quality monitoring and feeding system using IoT technology can measure water quality parameters through various sensors in the aquaculture pond. The data is then processed by the NodeMCU ESP32 microcontroller board. The system can operate in two modes: automatic and manual. The system can measure T, pH, Tu, and DO in the water as required by the user through a smartphone using a web application developed for this purpose. In addition, the water quality measurement data is displayed on a 20x4 character LCD display and on the web application. The main components of the prototype system are as follows:

- The water quality control system in the aquaculture pond has been equipped with T sensors, Model DS18B20 (accuracy ± 0.5°C), pH sensors, Model H-101 pH electrode (accuracy ± 0.1pH), Tu sensors, Model SEN0189, and DO sensors kit SKU: SEN0237, Model Gravity, within the aquaculture pond to read water quality data in real-time.
- The water replenishment and drainage system of the aquaculture pond, equipped with a 12 liters tank for each system, if the water quality exceeds the dangerous standards for aquatic animals, will command the microcontroller to control the 12 V_{DC} water pumps to drain the water out and introduce new water into the pond with a pump to maintain standards. The water level in the aquaculture pond is controlled by installing an ultrasonic (Ul) sensor, Model HC-SR04, at the top of the pond to not exceed the specified level. Additionally, a water flow rate (Wf) sensor, Model FS300A G3/4", has been installed to inform the user about the daily water usage.
- The feeding system for aquatic animals has been equipped with three on-contact (NC) level sensors, Model XKC-Y26-V, located next to the 12 liters feed storage tank, to indicate the feed level remaining in the tank to the farmer at three levels: 25%, 50%, and 100%. A 12 V_{DC} solenoid valve was equipped to dispense the feed, the system was set to operate for a duration of 1 second (0.10 liters) for the feeding. The user can choose the feeding method through a developed web application in two ways: 1) automatically by specifying the time and amount of feed in second, and 2) manually controlling the feed amount in second through the solenoid valve to open/close.
- The control system consists of four main components: 1) Power Supply Section: This part involves a 220 V_{AC} power supply connected to a 15 A breaker, which controls the on/off function of the entire control system. It includes a switching power supply that converts the voltage to 12 V_{DC}, which powers the water inlet pump, water outlet pump, and solenoid valve for the feeding system. Additionally, a portion of the 12 V_{DC} switching power supply is converted to 5 V_{DC} using a DC to DC converter, supplying power to the NodeMCU ESP32 microcontroller, all sensors in the system, the display, the RTC module, and relays. 2) Processing Unit: This section uses a NodeMCU ESP32 microcontroller to control the operation of monitoring and managing the water quality of all the aquaculture ponds. 3) Input Section (Sensors): The sensors send signals to the NodeMCU ESP32 microcontroller, which processes the input signals to control the output devices (water inlet pump, water outlet pump, and solenoid valve). 4) Output Section: The devices in this section operate upon receiving commands from the NodeMCU ESP32 microcontroller, sending signals to the NodeMCU ESP32 as illustrated in Fig. 3.

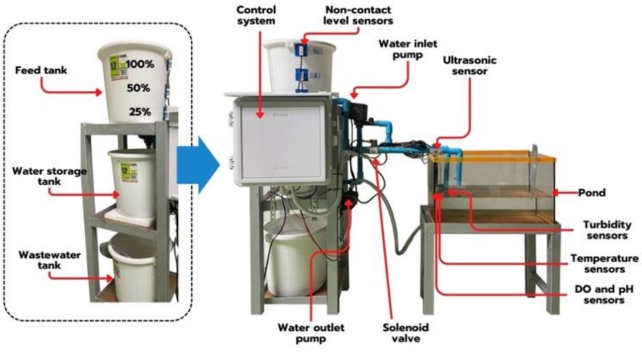


Fig. 2. Prototype of the system.

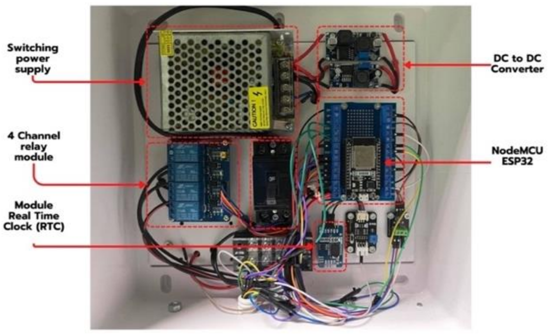


Fig. 3. The control circuit of the automatic water quality monitoring and feeding system

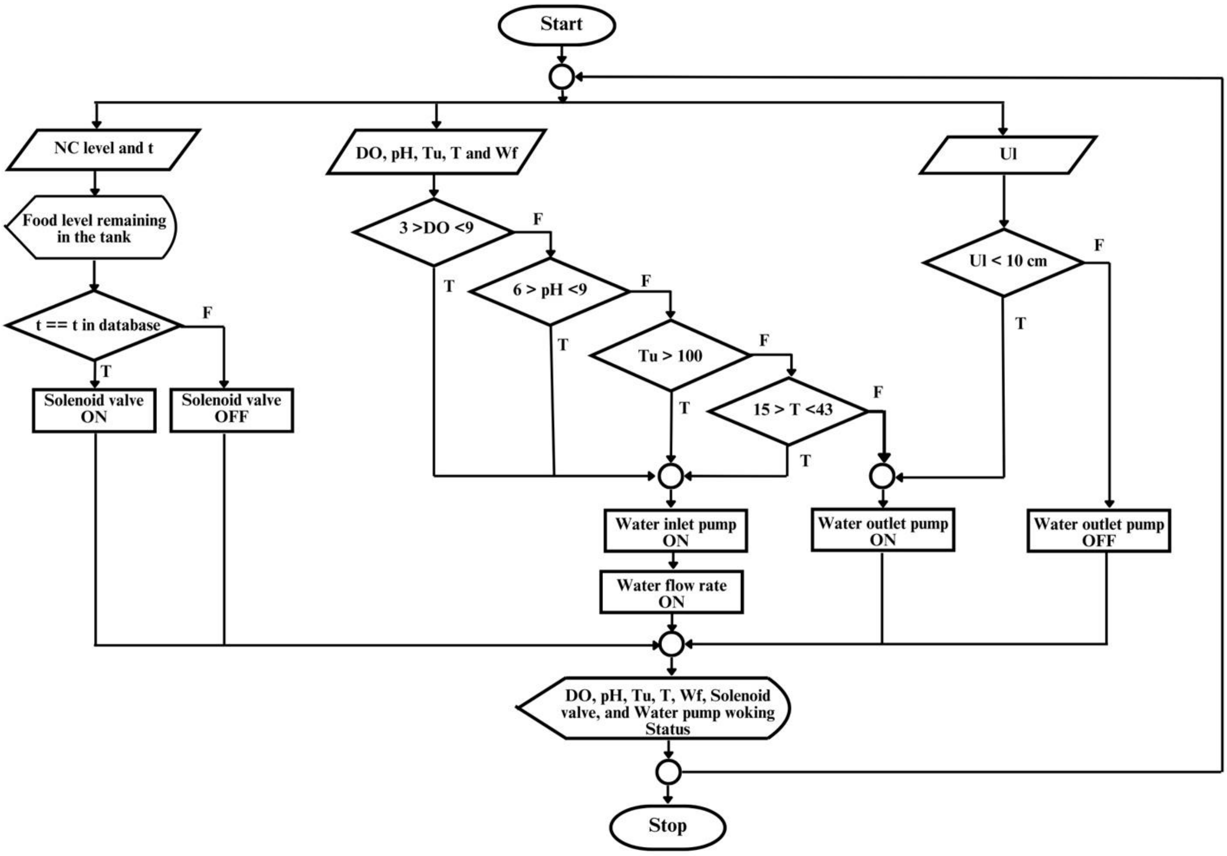


Fig. 4. System flowchart.

The operating principle of the automatic water quality measurement and feeding system as shown in Fig. 4 begins with measuring the water quality in the aquaculture pond through sensor data readings for DO levels between 3-9 mg/L, pH levels between 6-9, and Tu levels above 100 NTU. If the water quality sensor readings do not meet the specified conditions, the microcontroller processes will command the water replenishment (water inlet pump) and drainage (water outlet pump) systems to activate immediately. Additionally, the water replenishment system will operate when the water T sensor readings are not within the range of 15-43 °C to adjust the water quality in the pond to be suitable for aquaculture [16-18]. The water outlet pump will operate when the surface water level in the pond is less than 10 centimeters, the distance between the Ul sensor to the water surface, as determined through Ul sensor readings, to prevent overflow within the aquaculture pond. For the feeding system, the time is checked against the database that the user has set to match the standard time of Thailand; it will control the operation of the solenoid valve for a duration of 1 seconds (0.10 liters) to dispense feed into the aquaculture pond.

2.3. Web Application

The analysis of the main functions of the water quality control and feeding system in aquaculture ponds using IoT technology, involving two types of users: 1) User and 2) Admin.

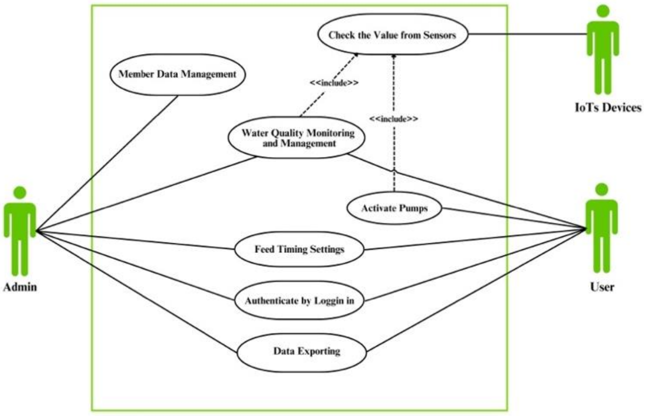


Fig. 5. Use case diagram.

Fig. 5 explains the workflow diagram of user interactions with the water quality control and feeding system in aquaculture ponds using IoT technology, consisting of 6 tasks.

1. User Login: Upon entering their username and password, the system verifies the user's status before granting access.
2. Feed Timing Settings (User): Users can access the feed timing settings, allowing them to input and save feeding times in the database. Consequently, the feed

dispensing unit installed near the aquaculture pond operates automatically according to the scheduled times.

3. Water Quality Data Access (User): Users can access water quality data through a developed web application. This system retrieves water quality data from various sensors installed in the aquaculture pond and displays it in real-time line graphs on the web application.

4. Member Data Management (Admin): Administrators have the ability to access and modify member information, including adding, deleting, and editing user data, as well as setting user statuses.

5. Water Quality Sensor Data Logging: Sensors (IoT Devices) installed in the aquaculture pond can send water quality data to be saved in the database, which then can be displayed through the web application.

6. Water Quality Monitoring and Management: Sensors (IoT Devices) can measure water quality parameters and compare them against standard aquaculture criteria. If water quality does not meet the set standards, the system automatically activates water pumps to exchange water in the pond.

7. Data Exporting: The system is capable of exporting data into files, summarizing sensor data from nodes in formats such as CSV, PDF, Excel, etc., and allows for printing.

2.4. Activity Diagram

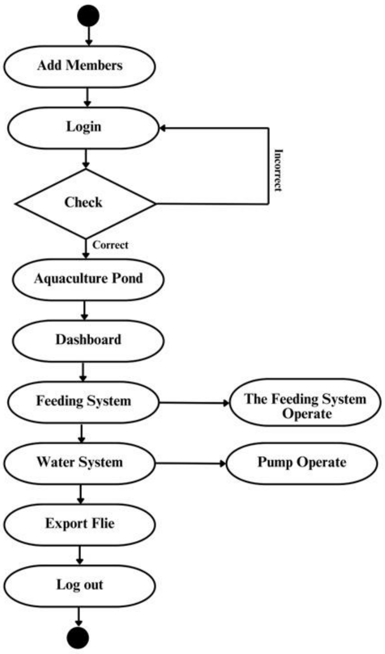


Fig. 6. The operations in the user's part of the system.

The operation of the water quality control and feeding system in aquaculture ponds using IoT technology is as illustrated in Fig. 6. The use of the system begins when the system admin adds a user and records the user's information into the database. When a user logs into the system by entering a Username and Password on the developed web application, the system checks the information in the user database. If there is no matching user information, access to the main web application page of the system will not be allowed. However, if the entered Username and Password are correct, the main web application page of the system will be displayed, divided according to the user's status as set. Upon accessing the main web application page of the system, there will be six sub-system operation commands: 1) Displaying water quality data in the aquaculture pond in real-time line graph format. The displayed data is pulled from the database, which stores water quality data from various sensors installed around the aquaculture pond. 2) Setting the timing for feeding the aquatic animals in the pond. When a user enters the feeding time and saves the information, the system will store the data in the database and activate the feeding unit at the set time. 3) Activating the water pump when the water quality data in the aquaculture pond does not meet the set standards. The system will automatically operate the water replenishing and discharge unit and display the operating status on the web application. Users can also manually activate the water pump in emergency cases. 4) Managing user data and setting user statuses, which is managed by the system admin who records the information in the user database. 5) Exporting data files and displaying information from various sensors in each aquaculture pond. 6) Logging out, which ends the session on the web application after completing all operations.

Figure 7 describes the system's diagram, dividing users into two types: Admin and user. Both Admin and User must log in to access the system before they can manage various data within the database. The functionalities shared between Admin and User include the data display page, the feed scheduling page, the water pump status check page, and the data export page. Additionally, the Admin has exclusive access to the user management page to add, delete, edit member information, and set user statuses.

2.5. Evaluation of the System’s Performance

Experiments to evaluate the performance of the water quality control and feeding system in aquaculture using IoT technology involve 5 conditions: 1) pH levels in water, 2) Tu, 3) pH levels and Tu, 4) Feeding, and 5) Water pump control through a web application. The evaluation process is initiated by filling an experimental tank with 15 liters of water and the following scenario was performed as follows:

Case 1: pH Level in Water. The initial pH reading from the water quality sensor in the tank is 4.0. Add a pH adjuster to the water in increments of 10 mL stirring well each time.

Case 2: Water Tu. The initial Tu reading from the water quality sensor in the tank is 1 NTU. Add soil to the tank in increments of 0.25 grams, stirring well each time.

Case 3: Combined pH Level and Tu in Water. Test simultaneously for pH levels and Tu. Increase the pH level in increments of 2 and add soil in increments of 0.25 grams to the water.

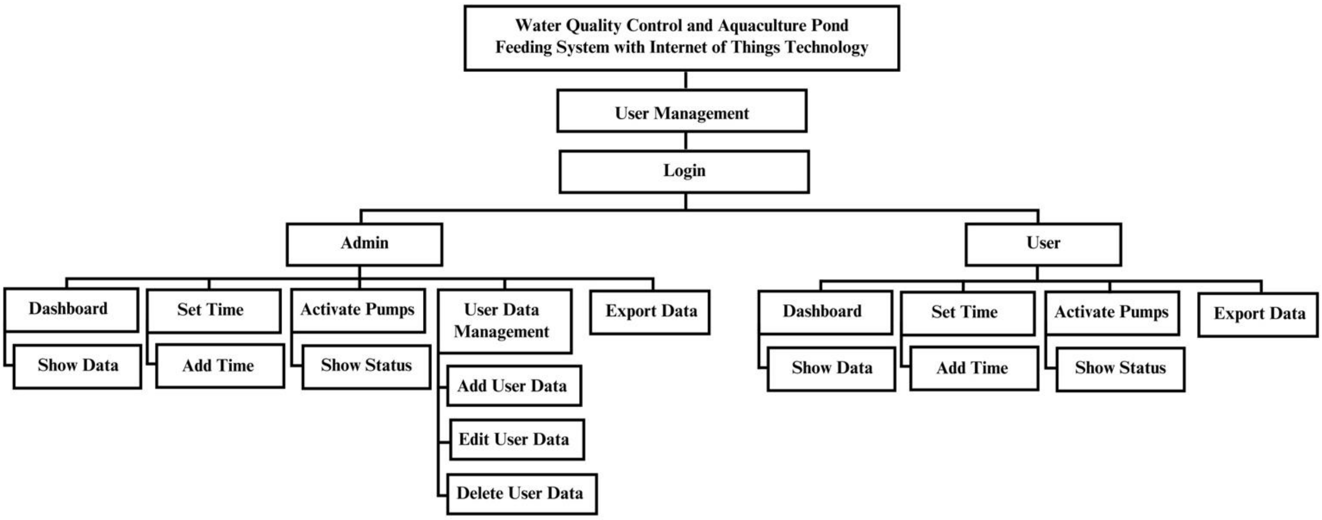
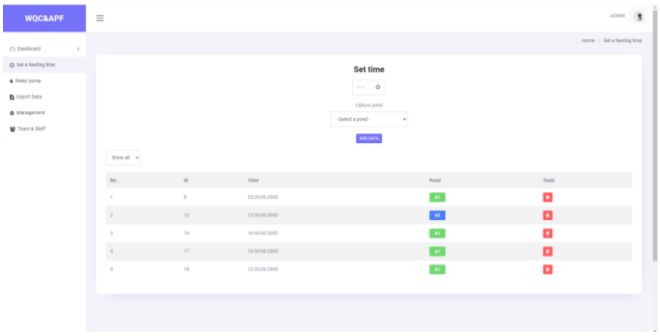


Fig. 7. Menu structure for administrators.



No.	ID	Time	Pond	Tools
1	8	23:26:00.0000	A1	🟥
2	13	13:35:00.0000	A2	🟥
3	16	16:44:00.0000	A1	🟥
4	17	16:50:00.0000	A1	🟥
5	18	12:30:00.0000	A1	🟥

Fig. 8. Evaluation of time setting and pond selection for automatically feeding.

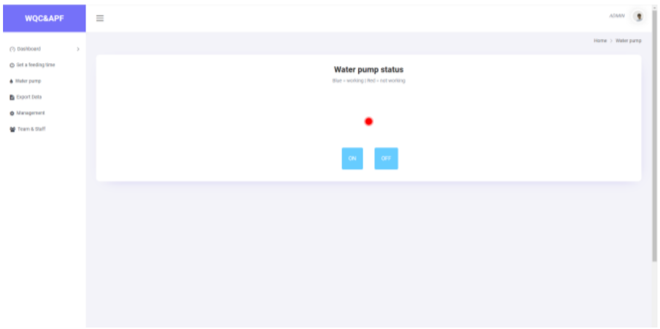


Fig. 9. Water pump control in the web application.

Case 4: Feeding time can be set via the web application. Admin and user can select time and pond for automatically feeding system, Various times were set for pond A1 and for pond A2. Moreover, color of each pond was shown differently to distinguish the pond and reduce confusion for admin and user, as shown in Fig 8.

Case 5: The water pump was automatically via the system; however, admin and user can manually control the water pump in case of emergency. Admin and user can select 'ON' and 'OFF' in the web application for manually control the water pump. There is a color symbol to indicate the status of water pump, blue symbol indicates the water pump is operated while red symbol indicates the water pump is unoperated, as shown in Fig. 9

For all three cases, three repetitions have been performed to verify the water quality in the pond. The data from the water quality sensors will be read and processed by the NodeMCU ESP32 microcontroller board to control the water inflow and outflow systems.

2.6 Scalability and Adaptability of the System

The scalability of the IoT-based aquaculture system is facilitated by its modular architecture, allowing the integration of additional sensors and NodeMCU ESP32 microcontrollers to accommodate various pond sizes and configurations. The system's web application supports multi-pond management, enabling real-time monitoring and control of multiple ponds concurrently. Sensor deployment can be optimized based on pond dimensions, ensuring comprehensive water quality assessment. Furthermore, the system's automated control logic can adapt to varying environmental conditions by dynamically adjusting water exchange rates and feeding schedules, promoting flexibility and scalability across diverse aquaculture operations.

3. Results and Discussion

3.1. Web application

The homepage of the water quality control and feed distribution system for aquaculture using IoT technology displays various types of aquaculture species being bred in the ponds after logging into the system as shown in Fig. 10. Users can select aquatic type and the web application will show pond that have this aquatic type as show in Fig. 11.

Fig. 10. Homepage of the web application.

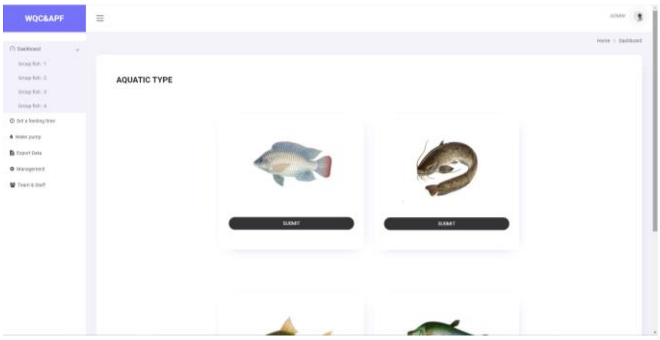


Fig. 11. Aquatic type selection.

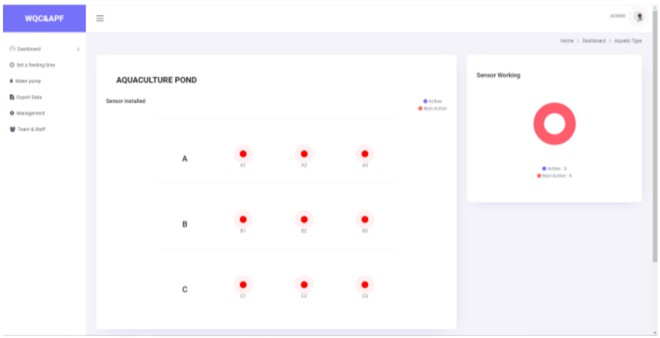


Fig. 12. Dashboard web page display.

Dissolved oxygen 8 mg/L

pH 9

Turbidity 37.5 NTU

Temperature 28 °C

Water flow rate 0 L/s

Water Level 25 %

Current dissolved oxygen 8 mg/L

Notice
Dangerous : Less than 9.0 mg/l or more than 3.2 mg/L
Suggestion : 6.5-8.3 mg/L

Current pH 9

Notice
Dangerous : 4.0-6.0 or 9.0-11.0
Suggestion : 6.5-9.0

Current Turbidity 37.5 NTU

Notice
Dangerous : More than 100 NTU
Suggestion : 0 - 50 NTU

Current temperature 28 °C

Notice
Dangerous : Less than 15 °C or more than 43 °C
Suggestion : 25-32 °C

Fig. 13. Real-time water quality data from various sensors in aquaculture ponds.

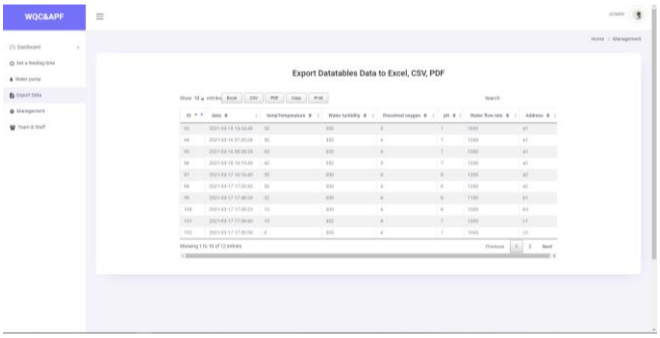


Fig. 14. Data export web page section.

Users wanting to check different water parameters of a specific species can click the 'Submit' button, and the system will present the water parameters for user review. This leads to a page for selecting the desired aquaculture pond to inspect the current operational status of various water quality sensors installed in ponds A, B or C. Sensors operating normally are represented by blue nodes, while red nodes indicate sensors that are malfunctioning or have issues, as shown in Fig. 12. Clicking into each pond displays all the data from the water quality sensors in real-time through the web application, consisting of 7 parts as follows: 1) DO level, 2) Water pH level, 3) Water Tu, 4) Water T, 5) Water Wf, 6) Feed level in the storage tank, and 7) A graph of water quality data, as shown in Fig. 13. For the scheduling of feeding times for the aquatic animals within the ponds, both Admins and Users can enter feeding times and save these settings in the database to command the feed distribution units to operate at specified times. Additionally, the feeding times for each pond can be adjusted through 'Add Data' button, and time settings can be deleted as shown in Fig. 8. If water quality does not meet specified standards, the system automatically initiates water replenishment and disposal for the pond, with the current operational situation displayed on the web application using two-colored nodes: blue indicates the water pump is operating, and red indicates the water pump is not operating. Moreover, users can manually control the water pumps in emergency situations, as shown in Fig. 9. Users can also export data files in various formats such as Excel, CSV, PDF, or print them out, as shown in Fig. 14. The management of user data and assignment of user statuses are handled by the system administrator.

3.2. Evaluation Results of the System

Evaluation of the control system for water quality and feeding in aquaculture ponds using IoT technology involved filling an experimental tank of size 23x46x29 cm^3 with 15 liters of water. The results of the evaluation for the water intake and discharge system are shown in Tables 1 to 3. The results of each scenario were indicated as follows:

Case 1: pH Level of Water. Starting with a pH level of 4, the pH was adjusted by adding 10 mL of a pH-adjusting solution to the tank and stirring it evenly. The first addition of the solution resulted in a pH reading of 5.6 from the sensor in the tank. The microcontroller board processed this data and activated the water inlet pump and water outlet pump via their respective relay modules. Subsequent additions of the solution resulted in pH readings of 7.2 ± 0.12 and 8.7 ± 0.17. Since these values were outside the preset standard range, the microcontroller deactivated the relay modules for both the intake and discharge systems.

Table 1. pH levels in water

pH Adjuster (mL)	pH levels in water (pH ± SD)	water replenishment system	Water drainage system
10	5.6 ± 0.18	/	/
20	7.2 ± 0.12	X	X
30	8.7 ± 0.17	X	X
40	10.2 ± 0.19	/	/
50	11.3 ± 0.21	/	/

Note: '/' indicates that the system is operational, and 'X' indicates that it is not operational.

Case 2: Water Tu. As shown in Table 2, starting with an initial Tu level of 1 NTU, soil was added to the tank in increments of 0.25 g, followed by stirring. The first addition increased the Tu to 34 ± 2.83 NTU. Further additions continued to significantly raise the Tu until it exceeded the standard threshold of 100 NTU. This triggered the microcontroller to activate the water intake and discharge systems via the relay modules.

Table 2. Water Tu

Soil (g)	Water Tu (NTU ± SD)	Water replenishment system	Water drainage system
0.25	34 ± 2.83	X	X
0.50	68 ± 3.52	X	X
0.75	108 ± 3.23	/	/
1.00	138 ± 3.12	/	/
1.25	175 ± 2.84	/	/

Note: '/' indicates that the system is operational, and 'X' indicates that it is not operational.

Case 3: Combined pH Level and Tu. As shown in Table 3, pH levels were adjusted by increments of 2, and soil was added in increments of 0.25 g to adjust Tu. Stirring the water evenly, the initial Tu was 1 NTU. The pH level remained constant at 4 regardless of changes in Tu, causing the sensor readings to fall outside the standard range. Consequently, the microcontroller activated the water intake and discharge systems. When the pH level was adjusted to 6 and 8, both fell within the acceptable range for water quality. However, continuous additions of soil increased the Tu significantly, eventually surpassing the threshold of 100 NTU, leading to activation of the water systems by the microcontroller.

Table 3. Combined pH levels and Tu in water

pH	Soil (g)	Water Tu (NTU ± SD)	Water replenishment system	Water drainage system
4	0.25	32 ± 2.62	/	/
	0.50	70 ± 2.35	/	/
	0.75	110 ± 2.62	/	/
6	0.25	33 ± 2.43	X	X
	0.50	67 ± 2.87	X	X
	0.75	107 ± 3.12	/	/
8	0.25	34 ± 3.01	X	X
	0.50	68 ± 2.94	X	X
	0.75	109 ± 2.73	/	/

Note: '/' indicates that the system is operational, and 'X' indicates that it is not operational.

Case 4: Feeding evaluation by setting feeding time at desired time and when the system operates, the relay (red light indicate) will ticker the solenoid value to distribute the feed to the pond for a duration of 1 second (0.10 liters) as show in Fig. 15.

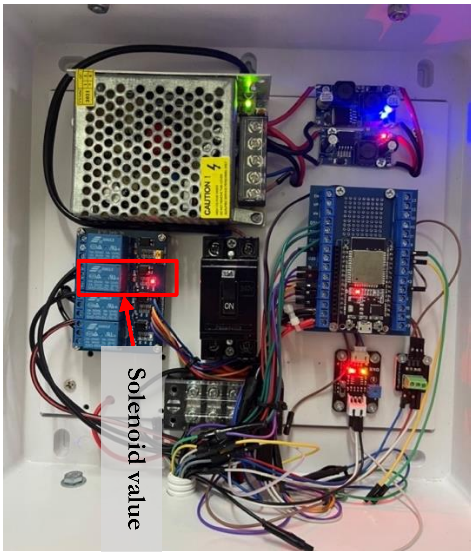


Fig. 15. Relay operate to initiate solenoid for feed distribution to the pond.

Case 5: Water pump control through a web application. Evaluation of manually control of water pump, when user select 'ON' and 'OFF' for the water pump to operate. The water replenishment and drainage system of the aquaculture pond, equipped with a 12 liters tank for each system, if the water quality exceeds the dangerous standards for aquatic animals, will command the microcontroller to control the 12 V_{DC} water pumps to drain the water out and introduce new water into the pond with a pump to maintain standards. The water level in the aquaculture pond is controlled by installing an Ul sensor, Model HC-SR04, at the top of the pond to not exceed the specified level. Additionally, a Wf sensor, Model FS300A G3/4", has been installed to inform the user about the daily water usage as show in Fig. 16. replenishment (water inlet pump) and drainage (water outlet pump) systems

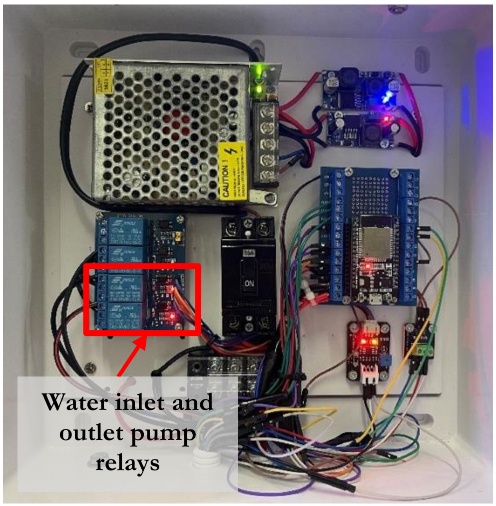


Fig. 16. Relay operate to initiate water pumps of the pond.

In summary, the evaluation demonstrated that the water quality control system for aquaculture ponds using IoT technology met the system requirements and fulfilled the users' needs as specified.

3.3 Enhancing Data Analytics for Actionable Insights

While the current web application allows for data export in formats such as CSV, PDF, and Excel, integrating advanced data analytics tools could significantly enhance the system's utility. By incorporating trend analysis algorithms, the system could detect long-term variations in water quality parameters, such as pH, turbidity, temperature, and dissolved oxygen levels. These insights would allow farmers to predict adverse conditions and implement corrective measures proactively. Furthermore, feeding efficiency metrics could be developed by analyzing correlations between feed input, water quality, and growth rates of aquatic species. This would enable the system to provide optimized feeding schedules, minimizing feed waste and improving overall productivity. The addition of visual dashboards to display predictive analytics and real-time trends would further promote data-driven decision-making in aquaculture management, ultimately contributing to more sustainable and efficient farming practices.

4. Conclusions

This research developed a water quality control and feeding system for aquaculture ponds using IoT technology, which facilitates aquaculture farmers in monitoring water quality, changing water, and feeding automatically. The system consists of three parts: 1) electronic devices or water quality sensors installed in the ponds, 2) a database that stores the water quality sensor data from the ponds, and 3) a web application developed for users to view data from the sensors and control the water quality in each pond in real-time on a dashboard. Additionally, the system can export data in various file formats, enabling users to analyze the data in-depth for planning or managing the aquaculture ponds to achieve higher quality yields.

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