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IoT-based Aquaculture Monitoring System

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***Abstract*— Water quality management plays an important role in the use of aquaculture and sustainable water. This article presents automatic monitoring and control systems based on the IoT generated on the ESP32 platform to integrate several sensors for tracking real -time and automatic water quality control. This system continues to control the parameters of the water key using the turbidity, temperature (DS18b20), TDS, PH and Ultrasonic sensor. When the water quality decreases outside the critical value determined, the automated pump discharges contaminated water. After the tank empties 75%, the secondary pump is replenished with freshwater to maintain the optimal conditions for life. The ultrasound sensor provides the correct water level to prevent overflow or shortage. Data is sent to the cloud for storage and processing. Safe web interface with user authentication provides the system's remote monitoring and management to ensure data safety. This study emphasizes the effects of IoT, reduces manual efforts and increases work efficiency in automation of water quality.**

***Index Terms*— IoT-based aquaculture, ESP32 platform, Sensor integration, Temperature sensor (DS18B20), pH sensor, Ultrasonic sensor, Turbidity sensor, TDS sensor, Automation, Water quality monitoring, Cloud data storage, ThingSpeak, Web interface, User authentication, Data visualization, Water pump control, Remote monitoring, Aquaculture management.**

I. INTRODUCTION

Monitoring and management of water quality is an important issue in which the community faces the world, especially in the area facing rapid urbanization and industrial growth. Clean and safe approaches are a fundamental right for people, but pollution of various sources continues to threaten water resources, affecting human health and environment. Traditional methods that assess the quality of water often include manual samples and laboratory analysis, which cannot be provided in real time to change the conditions, expensive, expensive, and change conditions. This requires the development of innovative and economically effective solutions for continuous remote water quality monitoring. The Internet of Things (IoT) provides a promising path to solve this problem, so you can distribute an interconnected sensory network that can collect and transmit data in real time according to a variety of water quality parameters.

This researcher presents the design and implementation of the intellectual water management system based on IoT for automatic monitoring and water quality management. This system uses the features of the ESP32 microcontroller platform, an ideal universal and cheap solution for IoT applications.

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By integrating several sensors, including turbidity, temperature, total dissolved hard parts (TDS) and pH, the system provides a comprehensive evaluation of water quality. This parameter is a decisive indicator of water pollution and is necessary to maintain safe and healthy water supply. The turbidity measures cloudy or inappropriate water due to floating particles, while the temperature affects the various chemicals and biological processes of the reservoir. The TDS represents the total amount of the material dissolved in water, and the pH measures the acidity or alkaline diagram. Continuous monitoring of these parameters ensures early detection of potential pollution events and facilitates timely intervention.

In addition to monitoring, the suggested system includes an automatic control mechanism for maintaining the optimal water quality in the tank. Two pumps are strategically used to manage water levels and quality. The output pump is activated when the read value of the sensor indicating contaminated water exceeds the preliminary critical value. This automatic emission mechanism prevents the contaminated water from being removed from the tank to prevent further deterioration of the water quality. Then, after reaching a low point (about 75% empty) with a predetermined tank level, the entrance pump is activated to replenish the reservoir with freshwater. This automatic supplement process provides continuous water while maintaining a safe work level. Ultrasound sensors are included to ensure accurate and non -contact monitoring of the water level determined to control pump operation and to prevent overflow or dry learning.

The data collected by the sensor is transmitted to the cloud platform by wireless communication, which provides remote access and visualization of water quality parameters. This data flow provides valuable information on dynamic changes in water in real time, allowing users to make reasonable decisions in relation to water resource management. The selected website is designed to extract and display sensor data in a convenient format. To ensure the security and confidentiality of the collected data, the website is protected by user authentication to limit access to the official employee. This security measure is needed to prevent unauthorized access to confidential data and maintain the integrity of the system. This study shows practical and economically effective solutions for automatic monitoring and control as knowledge of water quality monitoring and management increases based on IoT. Integrated systems, including such sensors, automatic control mechanisms, cloud connections and safe access to websites, provide a complex platform that can ensure safe and reliable water supply. The following section of this article emphasizes the potential of this approach to solve the actual water resource management problem by detailing the architecture of the system, hardware and software, experimental settings, results and results. This document also describes the potential future improvements of the system, including the integration, expansion data analysis and prediction modelling for leading water quality management.

II. Architecture

The below Image shows the architecture used for the management of pond water quality. Let's dive into the details:

A. ESP32 Microcontroller

This system is based on the ESP32 microcontroller. This powerful and universal system of the chip (SOC) is ideal for IoT applications by combining dual-core processors, Wi-Fi connections and rich peripherals. ESP32 is used as a central processing to obtain these sensors, perform control logic for pumps, manage communication with cloud platforms, and handle all other system work. Low energy consumption and economic efficiency are suitable choices for this application.

B. Turbidity Sensor

This sensor measures the relative clarity of the water and detects the amount of light scattered by floating particles. The higher the turbidity, the higher the concentration of the discontinued solid material that can negatively affect the quality of the water. The turbidity sensor produces an analog voltage in proportion to the turbidity level and then read by the analog ESP32 (ADC) converter.

C. Temperature Sensor

Temperature sensors are used to measure water temperature. Temperature is an important parameter. This is because it affects various physical, chemical and biological processes of water. The sensor used in this system understands the dynamics of water quality and provides the exact temperature display required for specific water quality calculation. The output of the temperature sensor reads ESP32.

D. Total Dissolved Solids (TDS) Sensor

The TDS sensor measures the total amount of dissolved substances, including minerals, salt and organic materials present in water. High TDS levels can affect the taste and suitability of water and can indicate the presence of contaminants. The TDS sensor is marked with an analog signal corresponding to the TDS concentration and then processed by ESP32.

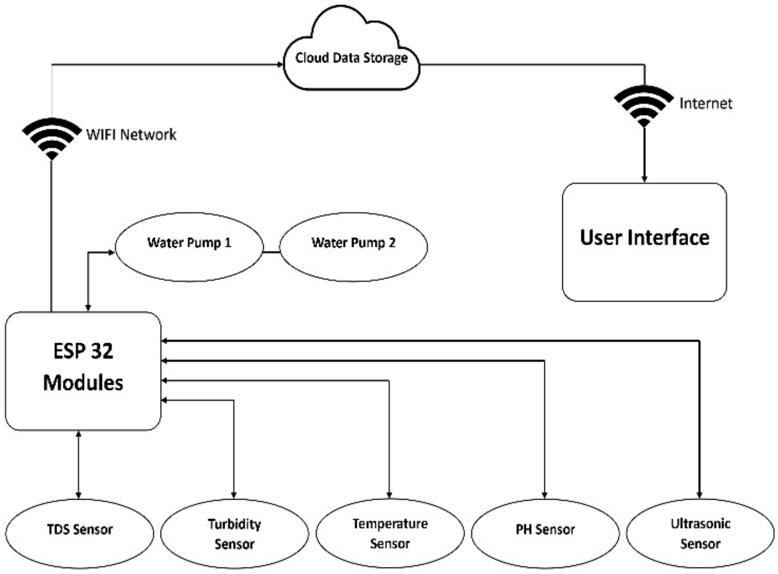

Figure 1. System Architecture

E. pH Sensor

The pH sensor measures the acidity or alkaline diameter of the water. PH is an important parameter in determining the quality of water because it affects the solubility and bioavailability of various substances. The pH sensor usually removes the voltage proportional to the pH level. This voltage reads and processes ESP32 to determine the value of the pH.

F. Ultrasonic Sensor

This sensor uses ultrasonic waves to measure the distance to the water surface of the tank. It provides non - contact monitoring for the water level and is important for pump control. Ultrasound sensors are used to release the distance to the water level. This data is then used to determine the water level and appropriate control of the pump by ESP32.

G. Cloud Data Storage

The data collected by the sensor in the intellectual supply and demand management system is transmitted through wireless communication through wireless communication for storage, visualization and basic analysis. ThingSpeak, an open source IoT platform provided by MathWorks, offers a convenient interface and a tool that can easily access data logs and visualization. This section describes the integration of things of the system in detail.

H. User Interface

The user interface available through the web browser provides a sign that can be clear and intuitively understanding the water quality data in real time. It shows the indications of each sensor (turbidity, temperature, TDS, pH and level) of the format that can be easily read and often uses graphics such as diagram and sensors for a quick understanding. The interface also includes user authentication to provide safe access to data to protect it from unauthorized or manipulation. Depending on the implementation, the interface can provide additional features such as the viewing data view, allowing users to analyze trends and models over time. You can also inform the user about potential water quality issues, including notifications or notifications based on preliminary critical values. The general design gives priority to the user's convenience, ensuring that even people who do not have technical tests can easily understand and interpret the displayed information.

III. METHODOLOGY

The proposed intellectual water supply management system operates through continuous environmental monitoring cycles, data processing and automatic control to provide real -time evaluation and water quality control.

Below Given is the workflow diagram of the proposed system.

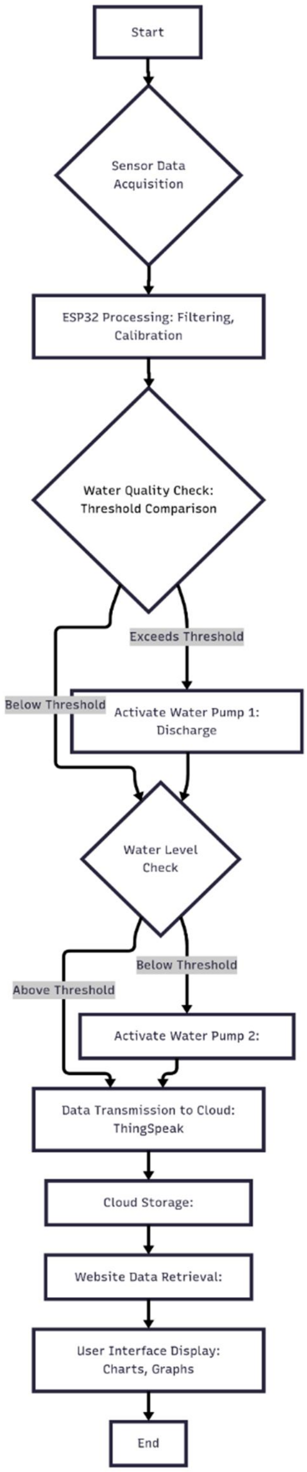

Figure 2: Workflow Diagram of the proposed system

A. Monitoring and Data Acquisition

Initially, the sensor arrangement strategically placed in the source continues to control the important parameters of the water quality, including the turbidity, temperature, TDS, pH and water level, and transmits these physical parameters to analog or digital electrical signals.

B. Microcontroller Processing

The ESP32 Micro Controller module is a pre -processing data that acts as a central processing device, receives these signals, converts analog signals to digital data, and can include noise adjustment or calibration filtering adjustment. The ESP32 performs a control logic that regulates the operation of the water pump based on the processed read value of the sensor and the preliminary critical threshold. For example, if the sagging level or TDS exceeds the allowable limit, the ESP32 activates "Water Pump 1" to lower the contaminated water. On the contrary, when the water level falls below the specific threshold value, "Water Pump 2" is activated to supplement the source. The ESP32 then usually uses communication protocols such as MQTT or HTTP to transmit the processed data of the sensor to the cloud server through the Wi-Fi network connection.

C. Cloud Data Storage and Management

The cloud platform provides a stable infrastructure for data storage and management and receives storage from ESP32 and in the database presented. Depending on the function of the cloud platform, you can perform additional processing or data analysis, including statistical calculation, trend analysis, or mechanical learning.

D. User Interface and Remote Monitoring

The user interface that can be used through a web browser or selected mobile applications facilitates the remote monitoring and control of the system, receives data from the cloud server and expresses it in convenient formats such as graphic visualization. This system can also be configured to create notifications or notifications based on pre -defined thresholds.

IV. Components used in the Automation System

A. ESP 32 DevKit V1

The core of the intellectual water management system is the ESP32 DevKit V1. The developer's fee is based on the ESP32 microcontroller, a powerful and universal system of chip (SOC) suitable for IoT applications. ESP32 is equipped with a dual -core 32 -bit microprocessor LX6, providing excellent processing opportunities to process sensor data, and performing logic of management and communication management on a cloud platform. DevKit V1 can conveniently access various ESP32 peripherals, including an analog digital converter (ADC) for read sensors. Digital inlet/output includes a built-in Wi-Fi connection for smooth transmission of digital inlet/output and data for pump and relay control. In a compact field, the form factor and convenience are suitable for prototyping and development in this project. Low energy consumption of ESP32 is also an important factor in long -term layout.

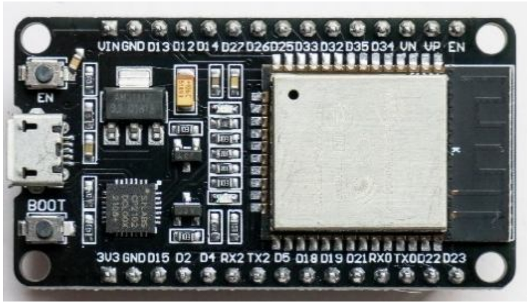

Figure 3: ESP 32 DevKit V1

B. Turbidity Sensor

This system uses the TS-300B water turbidity sensor to measure clouds or unexpected water. This sensor acts on the scattering principles of light in which the amount of light scattered by floating particles is measured by floating particles. The TS-300B removes the analog voltage proportional to the turbidity level. The analog signal is then read by ADC ESP32, and the system can quantify the turbidity and control the changes in the clarity of water. You can measure the turbidity of the range of 0 to 4095 NTU (Nephelometric Turbidity Units).

Figure 4: TS-300B Turbidity Sensor

C. TDS Sensor

This system uses analog TDS sensors (Total Dissolved Solids) to measure the concentration of the dissolved substances in water. This module measures the conductivity of the water, which is directly related to the number of solid solids in existence. The sensor displays an analog voltage proportional to 0 to 1000 ppm (parts per million) in proportion to the TDS concentration. This analog signal is read by ESP32 ADC. This module operates from 3.3V to 5V in the voltage range, so it is compatible with the operating voltage ESP32. This sensor allows you to control the entire level of the solids in which the system is dissolved, which is an important indicator of water quality.

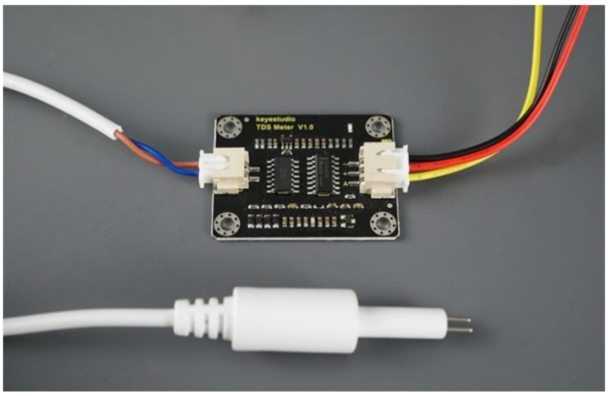

Figure 5: Analog TDS Sensor Module

D. Temperature Sensor

This system includes a digital temperature sensor DS18B20 for accurately measuring the temperature of the water. This sensor uses a single pass interface to simplify the connection with ESP32. DS18B20 provides a digital temperature indicator with a resolution of up to 0.0625 ° C, so there is no need to convert the analogy to a digital cycle. Wide temperature range and high accuracy are suitable for monitoring water temperature under various environmental conditions. Digital termination of DS18B20 reads ESP32 directly and provides accurate and reliable temperature monitoring.

Figure 6: DS18B20 Temperature Sensor

E. PH Sensor

The system employs an ELECROW Crowtail- pH sensor to measure the acidity or alkalinity of the water. This sensor provides an analog voltage output that corresponds to the pH level of the water. The analog signal from the pH sensor is read by the ESP32's ADC, enabling the system to determine the pH value. The Crowtail interface simplifies the connection to the ESP32. This pH sensor allows for monitoring the pH balance of the water, a crucial parameter for assessing water quality and ensuring its suitability for various applications

Figure 7: Crowtail PH Sensor Module

F. Ultrasonic Sensor

The system uses an HC-SR04 ultrasonic distance sensing module to monitor the water level in the tank. This sensor works by emitting ultrasonic pulses and measuring the time it takes for the reflected pulses to return. This time is then used to calculate the distance to the water surface. The HC-SR04 provides a non-contact method for water level measurement, which is advantageous for avoiding contamination or interference with the water. The module provides a digital output that is processed by the ESP32 to determine the water level and control the pumps accordingly. Its accuracy and relatively low cost make it a suitable choice for this application

Figure 8: HC-SR04 Ultrasonic Sensor Module

G. Water Pumps

The system utilizes two 5V DC submersible water pumps, each with a flow rate of 120 liters per hour (LPH). One pump serves as the discharge pump (Water Pump 1), responsible for removing contaminated water from the tank when the water quality parameters exceed predefined thresholds. The other pump acts as the inlet pump (Water Pump 2), replenishing the tank with fresh water when the water level falls below a certain point. These submersible pumps were chosen for their compact size, ability to operate while submerged in water, and their appropriate flow rate for the scale of this water management system. Their 5V DC operation makes them compatible with the power system used in the project.

Figure 9: 5V DC Submersible Motor (120LPH)

H. L298 Motor Driver

The L298 Motor Driver Module is a dual H-Bridge driver capable of controlling two DC motors, making it suitable for operating the 5V submersible water pumps used in the system. It supports motor voltages from 5V to 35V and can handle up to 2A per channel, ensuring reliable performance for small water pumps. The module receives control signals from the ESP32, allowing bidirectional control (forward and reverse) of the pumps based on sensor data. Its built-in heat sink provides thermal protection, ensuring stable operation during continuous usage. The logic control voltage of 5V is compatible with the ESP32's GPIO pins, enabling seamless integration. By isolating the low-power ESP32 from the higher-current motor circuits, the L298 protects the microcontroller while ensuring efficient pump control, crucial for maintaining optimal water quality in the aquaculture system.

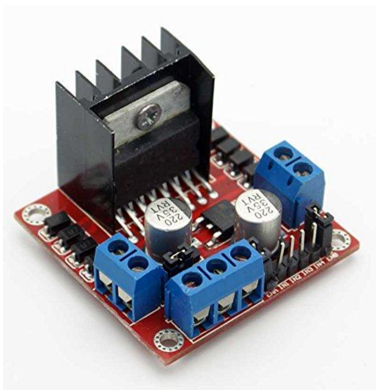

Figure 10: L298 Motor Driver

I. Wiring and Connections

For prototyping and development, all the components were connected using a breadboard. The breadboard provided a convenient and flexible platform for establishing temporary electrical connections between the various components. Jumper wires were used to connect the sensors, pumps, relays, and the ESP32 to the breadboard.

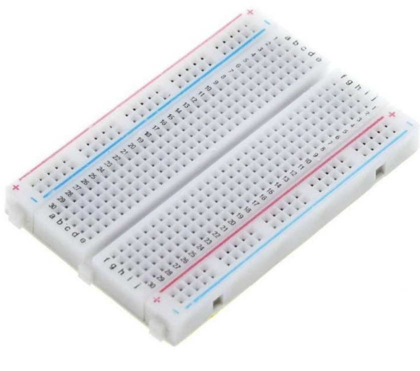

Figure 11: Bread Board

V. BACKGROUND

Water is the basic resource necessary for all life. Accessibility and quality have a direct impact on human health, ecosystems and economic development. Nevertheless, global water pollution has increased due to rapid urbanization, industrialization and agricultural practices. This contamination can appear in various forms that can be harmful to water resources without safe consumption, including increasing the turbidity of suspended particles, increasing solid levels, temperature fluctuations and pH levels. Traditional methods of monitoring the quality of water often include manual samples and laboratory analysis, which takes a lot of time, expensive, and cannot give ideas about dynamic changes in water quality. These limitations emphasize the need for more effective and economical solutions for persistent and remote water quality monitoring.

With the emergence of the Internet of Things (IoT), revolutionary in various fields allowed the relationship of physical devices to collect and exchange data. In the context of water management, IoT provides a powerful tool for the development of an intelligent system that can monitor and automatically manage water in real time. By distributing an interconnected sensor network, you can collect continuous data on various water quality parameters to provide a comprehensive and dynamic picture of water conditions. Then you can send these data to the cloud platform in real time to store, process and visualize, so that the stakeholder can access anywhere connected to the Internet.

Several studies have shown the potential of the IoT system for monitoring water quality. These systems generally create a network that can collect and transmit data, including the integration of various sensors, microcontrollers and communication technologies. For example, the study studied the use of the turbidity sensor and evaluated the electrochemical sensor for measuring the temperature sensor and pH and other chemical parameters for monitoring the sharpness of water and heat pollution.

The read value of the sensor then is processed by a microcontroller such as ESP32, which can handle communication with data rates, local processing and cloud platforms. Cloud calculations play a decisive role in IoT -based water management systems. The cloud platform provides infrastructure for storage, processing and visualization of data. They offer extended storage solutions, so you can accumulate large data sets over time. It also provides a powerful tool for data analysis to identify the trends, models and abnormalities of these water quality. The cloud platform also facilitates remote access to data through a convenient interface, allowing stakeholders to control the quality of water anywhere. Automated control mechanisms can be integrated into these systems to ensure aggressive water control.

For example, if the sensor shows that the water quality parameters are out of the acceptable level, the control system can cause operations such as the addition of chemicals for pumping for discharge of contaminated water or adjusting the pH level. This automation helps to minimize the risk of human health and the environment by ensuring that water quality is maintained within a safe limit. This study is based on the existing tasks that develop an intelligent water management system that integrates a cloud platform for multiple sensors, ESP32 microcontrollers and real -time monitoring and automatic water quality control, and monitoring and managing water quality based on IoT. On -site storage for on -site storage is instructed to solve the problem of traditional water quality monitor methods by providing more effective, economically effective and inexpensive solutions. In the following sections, the design, implementation, testing, and results of the system are described in detail, showing the actual possibility of use in various water resource management scenarios.

Clean and safe approaches are a fundamental right for people, but this major resource is increasingly threatening to contamination caused by industrial emissions, agricultural drainage and inappropriate wastewater treatment. Fast urbanization and population growth worsen these problems, requiring innovative solutions for effective water quality management and effective water quality management. Traditional methods of monitoring the quality of water often dependent on manual samples and laboratory analysis are inappropriate in the face of this increasing pressure. This method takes a lot of time and expensive and often cannot deal with the dynamic characteristics of the change of matter, and the community is vulnerable to an unexpected event of unexpected pollution.

The Internet of Things (IoT) provides a changing approach to solve this problem. If you connect the physical device, including sensors and drives on the Internet, you can use IoT to create an intellectual system that allows you to monitor the environment with real -time and automatic control. In the context of water resource control, the IoT system can collect continuous data on important water quality parameters to provide a comprehensive and dynamic understanding of water conditions. This data, which is transmitted to a cloud platform wirelessly, can be used for the parties interested in facilitating the adoption of appropriate arbitration.

Many studies have proven the potential of IoT to monitor the quality of water. The researchers have studied the use of various sensors, including turbidity, temperature, pH and microcontrollers and communication models

that are dissolved solids for creating reliable monitoring networks. This system provides advantages compared to existing methods, including increased data collection, cost savings and improved space coverage. In addition, the characteristics of the data can be allowed initially to reduce the potential risk of human health and the environment by quickly allowing real -time contamination events.
Cloud calculations play an important role in water resource management based on IoT. The cloud platform provides extended infrastructure for storing and processing enormous amounts of data generated in the sensory network. It also provides powerful information to manage active water resources by providing powerful analysis tools that can be used to determine the trends, models and ideals of the data. In addition, the cloud platform can facilitate remote access to the data through a convenient interface, allowing the stakeholders to control the quality of the water quality and control system anywhere.
Automated control mechanisms with IoT and Cloud Technologies can further improve the water management system. Integrating sensory networks and control algorithms and drives such as pumps and valves can automate answers to changes in water quality conditions.
For example, when the contaminated event is displayed in the sensor readings, the system can automatically run the pump to restore the water quality by distracting the contaminated water or activating the processing process. This level of automation minimizes the necessity of human intervention to improve the efficiency and response of the water management system.

VI. RELATED WORK

Integrating the Internet of Things (IoT) into material monitoring has attracted considerable attention in recent years. Various systems have been proposed in various environmental applications, sensors settings and automation levels.
Singh and Sharm [1] have developed an intellectual system for monitoring forms using IoT and cloud computing. Their research visualized data through the cloud interface and was revealed by the pH in real time and temperature monitoring. However, there was no automatic control function such as pump operation based on the critical value of the sensor.
Kumar and GUPA [2] proposed a real -time water quality system with predictive analysis. The system predicted the level of contamination using a machine learning model, but it was suitable for distribution systems in the city area, which is important for the form, and excluded parameters such as cloud covers and TDs.
KAUR and KAUR [3] used the ESP8266 microcontroller to suggest sensitive to the cloud platform of water quality monitoring. Their design focused on low cost and simple support, but only controlled three parameters (temperature, pH values, evangelism) and did not provide automation of water level or quality control.
SHUCLA and PATEL [4] have developed IoT and machinery water resources monitoring agents to detect industrial waste. We are effective in detecting abnormalities, but the system is not for the aquaculture environment, and there was no mechanism to fill water.
Wu and Lee [5] have studied the use of several sensors to manage the form. This system includes an oxygen sensor dissolved in addition to the pH and temperature sensors, improving the quality of the water quality. However, the user interface did not have remote control of real -time and security mechanisms.
Compared to these existing works, the proposed system distinguishes itself by:

- Integrating five essential sensors (pH, TDS, turbidity, temperature, and ultrasonic) to provide a holistic water quality evaluation.
- Enabling automated pump control for water replacement, based on real-time threshold values.
- Implementing a secure web interface for real-time data monitoring, historical trend analysis, and user authentication.
- Utilizing ThingSpeak for cloud data storage and visualization with scalability for future integration of advanced analytics.

This work bridges the gap between actual monitoring and autonomous management in aquaculture systems and provides a practical and scalable solution for efficient control of water resources.

VII. USER INTERFACE

The user interface that can be used through the standard web browser is designed to provide convenient and beneficial data display for the quality and status of the system. Safety priority user authentication systems guarantee that only the approved employees can access confidential data and manage the system. The interface consists of a key of several pages.

A. Dashboard

This toolbar serves as a major interaction point of the user and provides an overview of the system status in real time. It indicates the live reading value of all sensors, including the current water level (obtained from the ultrasound sensor) of the turbidity, temperature, TDS, pH and pond. These markings can be easily interpreted in a clear and simple manner, often using visual expressions such as sensors or numerical displays. The toolbar also includes a recent sensor journal, providing a quick record of water -quality parameters. This page allows users to immediately evaluate the current water quality and system status.

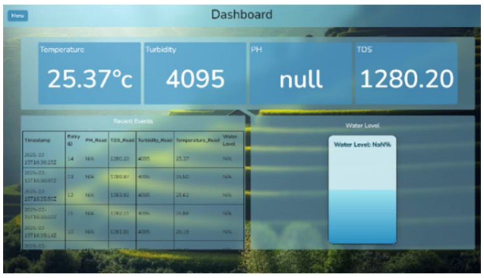

Figure 12: Dashboard

B. Historical Data Graphs

This page enables users to visualize trends in the sensor data over time. Users can select from a dropdown menu the specific sensor parameter they wish to graph (turbidity, temperature, TDS, or pH). The page then displays a graph of the selected parameter's readings over the past 15 readings. This feature allows users to analyze patterns and identify any potential anomalies or trends in the water quality data. Visualizing the data in graphical form provides valuable insights into the dynamic changes in water quality, aiding in proactive management decisions.

Figure 13: Historical Graph Data

C. Logs Page

The dedicated logs page provides a comprehensive record of all sensor readings and system events. This page displays a detailed log of all sensor readings, timestamped for accurate tracking. It also records any system events, such as pump activation or deactivation, along with the reasons for these actions (e.g., exceeding a threshold, water level dropping below a setpoint). The logs page serves as an audit trail, providing a complete history of the system's operation and enabling users to investigate past events or analyze long-term trends in water quality.

Figure 14: Logs Page

D. User Authentication

Access to the user interface is protected by a user authentication system. Users are required to log in with valid credentials (username and password) before they can access any of the system's data or functionalities. This security measure prevents unauthorized access to the system, ensuring the privacy and integrity of the water quality data and preventing malicious control of the system's operations.

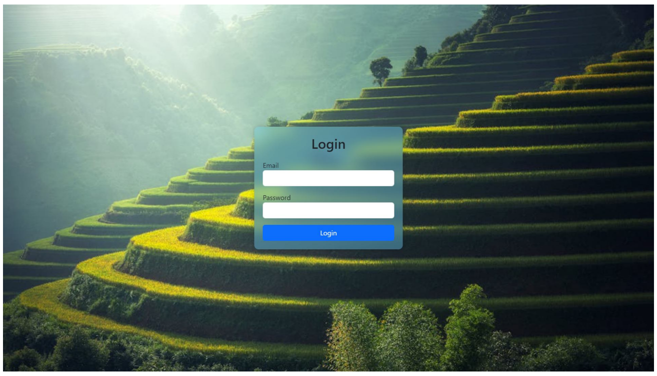

Figure 15: Login Page

The user interface is designed with ease of use in mind. The layout is intuitive, and the information is presented in a clear and concise manner. The use of visual representations and interactive elements makes it easy for users to quickly understand the data and interact with the system. The combination of real-time monitoring, historical data analysis, and detailed logging provides a comprehensive tool for effective water management.

VIII. Results and Discussion

The IoT-Based Aquaculture Management System was tested extensively, and 100 samples were collected with timestamped readings for key water quality parameters including pH, TDS, turbidity, temperature, and water level. The statistical analysis of the collected data is summarized in Table 1.

TABLE I: SUMMARY STATISTICS OF COLLECTED SENSOR DATA

Parameter	Mean	Min	Max	Std. Deviation
pH	7.3501	6.91	9.79	0.4771
TDS (ppm)	180.46	89	221	19.2065
Turbidity (NTU)	4095	4095	4095	0
Temperature (°C)	28.9302	28.87	29.06	0.0502
Water Level (cm)	88	88	88	0

The pH values recorded during the data collection phase ranged from 6.91 to 9.79, with a mean value of 7.35, indicating slightly alkaline conditions which are within the acceptable range for most freshwater aquaculture species. TDS values had a mean of 180.46 ppm, suggesting moderate mineral concentration in the water. A standard deviation of 19.21 indicates some variation, likely influenced by feed residue and environmental factors.

Turbidity readings were consistently recorded at the sensor's maximum limit of 4095 NTU. This may be due to sensor limitations or consistently high turbidity levels in the test environment. The temperature remained very stable, ranging narrowly between 28.87°C and 29.06°C, with a very low standard deviation of 0.0502°C, suggesting a controlled and thermally stable environment.

Interestingly, the water level remained constant at 88 cm throughout the measurement period, indicating successful automation and control of the water pump system based on ultrasonic sensor readings.

These results validate the functionality and reliability of the proposed system under real-world aquaculture conditions. The system successfully monitored and maintained key parameters within acceptable thresholds, demonstrating its potential for practical deployment in fish farming operations.

IX. Conclusion

This study developed an intelligent water management system using the ESP32 Devkit V1, integrating turbidity, temperature, TDS, pH, and ultrasonic sensors with ThingSpeak for real-time monitoring. The system automates water quality control through the ESP32, relays, and DC 5V underwater pumps, which drain contaminated water and refill fresh water based on critical thresholds. ThingSpeak facilitates data storage, visualization, and remote access, enhancing management efficiency. The system is cost-effective, suitable for small communities, and reduces manual intervention. Future improvements include refining data accuracy and incorporating machine learning for predictive modeling. Additional sensors, such as dissolved oxygen, can further enhance system evaluation. Replacing prototype layouts with printed circuit boards and exploring alternative cloud platforms can improve durability and scalability. Ensuring system reliability in various environmental conditions is essential for real-world deployment. This IoT-based system offers a sustainable and real-time solution for efficient water resource management.

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