# IOT Based Intelligent Monitoring and Analytics Systems for Sustainable Aquaculture

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***Abstract—*** Implementing innovative farming practices becomes imperative for a country whose economy relies heavily on agricultural products. Over recent years, the swift process of urbanization and the depletion of forests have influenced farmers. Due to the lack of rainwater harvesting and changing weather patterns, many crop failure cases have been registered in the last few years. To prevent loss of annual crop production, many researchers propose the technology-driven smart farming method. Smart agriculture involves utilizing technology to create a controlled environment for the management of the crops. Smart farming increases crop production and provides small farmers with an alternative income source. The government initiated many pilot projects to promote smart agriculture in India. Yet, the absence of technological assistance and skilled procedures poses a challenge for most farmers aiming to thrive in this industry. This paper introduces a smart freshwater recirculating aquaculture system based on IoT technology. The proposed system has integrated sensors and actuators.

*KEYWORDS: Aquacalture, edge computing, fog computing, Internet of Things (IoT), recirculating aquaculture system (RAS) .*

## I. Introduction

Aquaculture, the farming of aquatic organisms such as fish and algae, plays a key role in global food production and economic growth. However, traditional aquaculture practices often face challenges like poor water quality management, high mortality rates, and inefficient resource utilization due to the lack of real time monitoring. With the rise of the Internet of Things (IoT), automation and intelligent data analysis have become practical solutions for modernizing aquaculture systems. IoT technology enables continuous monitoring of vital parameters such as temperature, pH, dissolved oxygen, turbidity, and ammonia levels. This project, IoT-Based Intelligent Monitoring and Analytics System for Sustainable Aquaculture, aims to design a smart system using an ESP32 NodeMCU connected with multiple sensors to collect and analyze real-time water quality data. The information is transmitted to a cloud platform (ThingSpeak) for visualization and decision-making, with alert notifications provided through a Telegram bot. The system enhances fish health, minimizes manual effort, and promotes sustainable aquaculture practices by integrating IoT, data analytics, and automation for efficient and eco-friendly operations.

## II. Objectives

The primary objectives of this project are as follows:

1. Real-Time Monitoring: Continuously monitor key water quality parameters such as temperature, pH, dissolved oxygen, turbidity, and ammonia levels.

2. Data-Driven Decision Making: Use analytics and cloud platforms to support smart decisions for feeding, harvesting, and water management.

3. Resource Optimization: Reduce wastage of feed, water, and energy through automation based on sensor data.

4. Early Warning and Alerts: Detect abnormal water conditions early and notify users via the Telegram bot to prevent fish mortality.

5. Sustainability: Promote eco-friendly aquaculture by maintaining balanced water quality and minimizing environmental impact.

## III. Methodology

The IoT-Based Intelligent Monitoring and Analytics System for Sustainable Aquaculture is designed to continuously monitor essential water quality parameters and provide intelligent analysis through cloud based platforms. The system integrates multiple sensors, a microcontroller, and IoT communication technologies to ensure real-time data collection and decision-making. The methodology involves the following key stages:

Step 1: Sensor Data Acquisition Various sensors such as pH, temperature, turbidity, LDR, PIR, and UV are deployed in the aquaculture setup. These sensors continuously measure environmental parameters — pH for acidity, turbidity for water clarity, temperature for thermal balance, and LDR/UV for light conditions. Each sensor sends its analog or digital signals to the ESP32 controller for processing.

Step 2: Data Processing and Transmission The ESP32 NodeMCU serves as the core control unit, which collects and processes the sensor data. It converts the sensor readings into meaningful digital values and prepares them for wireless transmission. The ESP32, equipped with built-in Wi-Fi, transmits the data securely to the ThingSpeak Cloud Platform for storage and analysis.

Step 3: Cloud Data Analytics and Visualization The ThingSpeak Cloud receives real-time data from the ESP32 and displays it on a web-based dashboard. ThingSpeak provides data visualization through graphs and charts, helping users understand trends and variations in water quality. It also enables users to monitor and analyze long-term patterns for sustainable aquaculture management.

Step 4: Alert and Notification System A Telegram Bot is integrated into the system to provide instant alerts. When any sensor detects a parameter that exceeds the pre-defined threshold (e.g., low dissolved oxygen, high turbidity, or abnormal pH), the system automatically sends a real-time alert to the user's Telegram account. This helps the farmer take timely corrective action to prevent fish mortality or ecosystem imbalance.

Step 5: Local Display and Power Supply An LCD display connected to the ESP32 provides local, real-time monitoring of sensor readings without requiring internet access. The system is powered through a regulated power supply, ensuring stable and continuous operation even in variable environmental conditions.

Step 6: Decision Support and Automation The data collected and analyzed through the cloud can be used to make data-driven decisions or to automate future aquaculture systems (e.g., controlling aeration or feeding systems). This establishes the foundation for an intelligent, sustainable, and low-maintenance aquaculture ecosystem.

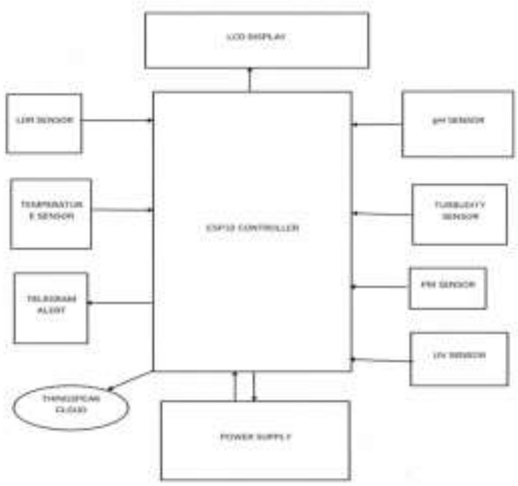


**Fig 1: Block diagram**

## IV. IMPLEMENTATION

Implementation of the multi-parameter monitoring system using the ESP32 controller requires integrating different sensors with the ESP32, a cloud monitoring platform, and a warning mechanism to assure continuous and accurate analysis of the environment. Starting with the hardware, all the sensors should be interfaced with the ESP32. The LDR, pH, turbidity, and UV sensors-which are analog sensors-are connected to the ADC pins of the microcontroller for taking the analog reading. Similarly, other sensors, such as the PIR motion sensor and the temperature sensor (DHT series), which are digital sensors, must be interfaced via any selected digital I/O pin. Further, an LCD display based on the I2C protocol is added to provide local, real-time visualization for sensor data.First, the components are hooked together and the ESP32 is programmed using the Arduino IDE. Inclusion of necessary libraries such as WiFi.h, HTTPClient.h, LiquidCrystal_I2C.h, and DHT.h has been done for making it supportive of WiFi connectivity, communication with the cloud, sensor operation, and display handling. The program configures WiFi credentials on it, allowing the ESP32 to connect to the network automatically at boot time. Right after establishing a successful connection, the controller then initializes and verifies all sensors.

All the major control operations are done in the loop function, where the ESP32 continuously reads data at fixed intervals from all sensors: light intensity from the LDR, temperature and humidity from the DHT sensor, water clarity from the turbidity sensor, pH value, UV intensity, and motion detection from the PIR sensor. The data collected is processed and instantly displayed on the LCD screen, on-site, for monitoring purposes.

The ESP32 will send all sensor readings to the ThingSpeak cloud platform in this case for remote monitoring. The data are formatted into an HTTP GET request and transmitted to the ThingSpeak API, where it gets stored and presented in the form of real-time graphs. Therefore, one can track and analyze environmental conditions from anywhere.

Moreover, the system includes a device for sending alerts through Telegram. Using a Telegram bot API, the ESP32 sends automated notifications in case any sensor reading exceeds preset safety thresholds, such as high temperature, unsafe turbidity levels, or detected motion. The ESP32 efficiently manages sensing, processing, cloud communication, and alerting, powered by a stable power supply. In this way, this implementation gives rise to an efficient and intensive monitoring system for safety, surveillance, and environmental applications.

**Algorithm**

Steps

Step 1: Start the system and power ON the ESP32 controller.

**Step 2: Initialize all required libraries and sensor modules.**

Step 3: Establish WiFi connection for cloud and Telegram communication.

Step 4: Initialize the LCD display using I2C protocol.

Step 5: Configure input pins for LDR, pH, turbidity, UV, PIR, and temperature sensors.

Step 6: Begin continuous monitoring loop.

Step 7: Read light intensity value from the LDR sensor.

Step 8: Read temperature and humidity data from the temperature sensor.

Step 9: Read pH value from the pH sensor.

Step 10: Read turbidity level to check water clarity.

Step 11: Read UV intensity from the UV sensor.

Step 12: Read motion detection status from the PIR sensor.

Step 13: Process and analyze sensor readings against predefined threshold values.

Step 14: Display all important readings on the LCD screen.

Step 15: Format the sensor data for transmission to ThingSpeak cloud.

Step 16: Send the processed data to ThingSpeak for online monitoring.

Step 17: Check for abnormal or critical sensor values.

Step 18: If any reading exceeds limits, generate and send a Telegram alert message.

Step 19: Wait for a short delay to stabilize readings.

Step 20: Repeat the monitoring loop continuously.

## V. RESULT

This image shows a functional prototype of a **water-quality monitoring system** using multiple sensors and a microcontroller. The setup includes an **ESP32 module**, power supply boards, and an **LCD display** mounted on a wooden base for stable operation. Various sensors such as a **pH probe**, **turbidity sensor**, and **temperature sensor** are placed inside a plastic container filled with water to measure real-time water parameters. The sensors are connected through color-coded wiring to ensure proper signal flow and power distribution. The LCD on the left displays live readings collected from the sensors, while indicator LEDs on each module confirm active operation. This prototype demonstrates how environmental parameters can be continuously monitored using IoT-based sensing technology for laboratory, industrial, or field applications.

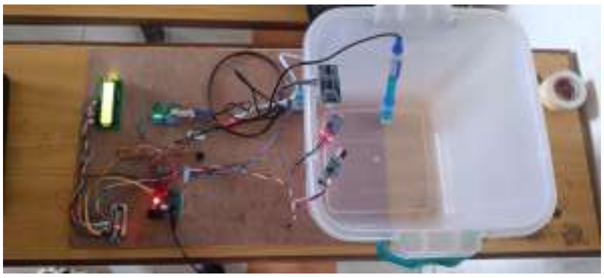

**Fig 1 : Model**


**Fig 2: output in telegram**

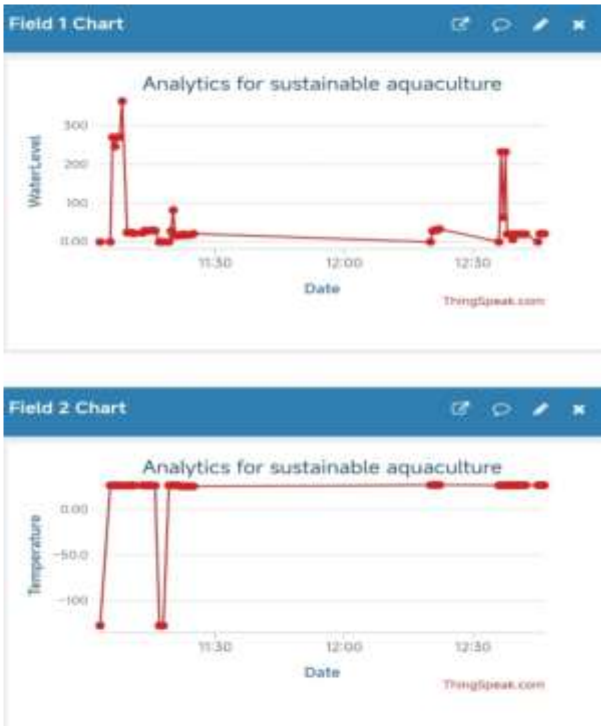


**Fig 3 : analytics for sustainable aquaculture**


**Fig 5: analytics for sustainable aquaculture**

## VI CONCLUSION

The IoT-based intelligent monitoring and analytics system plays a crucial role in transforming traditional aquaculture into a smarter, more efficient, and sustainable process. By continuously tracking key water quality parameters in real time, it helps farmers detect fluctuations early and take timely corrective actions. This leads to healthier fish, reduced mortality rates, and more stable pond conditions. The system also automates routine monitoring tasks, significantly reducing manual labor and human error. With data-driven insights and predictive analytics, farmers can optimize feeding schedules, resource usage, and overall farm operations. As a result, operational costs decrease while productivity and profitability increase. Overall, this technology supports long-term sustainability and modern aquaculture growth.

## VII. REFERENCES

[1] C. E. Boyd, J. W. Clay, A. Hulata, D. J. MacMillan, P. J. Prein, A. H. Verdegem, and M. C. Beveridge, "Achieving sustainable aquaculture: Historical and current perspectives and future needs and challenges," Journal of the World Aquaculture Society, vol. 51, no. 3, pp. 578–633, 2020.

[2] V. Saiz-Rubio and F. Rovira-Más, "From smart farming towards agriculture 5.0: A review on crop data management," Agronomy, vol. 10, no. 2, p. 207, 2020.

[3] P. K. Paul, D. Chatterjee, M. Ghosh, and J. Ganguly, "Agricultural problems in India requiring solution through agricultural information systems: Problems and prospects in developing countries," International Journal of Information Sciences and Computing, vol. 2, no. 1, pp. 33–40, 2015.

[4] K. E. Psannis, C. Stergiou, and B. B. Gupta, "Advanced media-based smart big data on intelligent cloud systems," IEEE Transactions on Sustainable Computing, vol. 4, no. 1, pp. 77–87, Jan.–Mar. 2018.

[5] V. A. Memos, K. E. Psannis, Y. Ishibashi, B. G. Kim, and B. B. Gupta, "An efficient algorithm for media-based surveillance system (EAMSuS) in IoT smart city framework," Future Generation Computer Systems, vol. 83, pp. 619–628, Jun. 2018.

[6] R. Bhattacharjee and S. Chakraborty, "IoT-based smart aquaculture system for real-time water quality monitoring," International Journal of Advanced Research in Electronics and Communication Engineering (IJARECE), vol. 9, no. 4, pp. 45–50, 2020.

[7] A. Singh and M. Gupta, "Design and development of IoT-based water quality monitoring system," International Journal of Innovative Research in Science, Engineering and Technology (IJIRSET), vol. 8, no. 6, pp. 6804–6810, 2019.