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IoT Driven Water Intelligence System

Mohanthi K[1], Akash V[2], Kishore V[3], Chandan M, Jayanth SN
Department of Electronics and Communication Engineering,
Sri Sairam College of Engineering, Bengaluru,India.
https://orcid.org/0009-0004-0901-668X

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Abstract : Water is one of the most valuable natural resources, and maintaining its quality is essential for both human health and environmental balance. Conventional water testing methods are mostly manual, time-consuming, and cannot provide real-time updates. To overcome these limitations, this paper proposes an IoT Driven Water Intelligence System that continuously monitors and controls water quality using smart sensors and an embedded microcontroller. The system utilizes pH, TDS, turbidity, and temperature sensors to collect data, which is processed by an ESP32 microcontroller and displayed on an OLED screen. The collected readings can also be sent wirelessly to a cloud dashboard for online observation. When unsafe water parameters are detected, the system automatically activates a relay-based purification control unit to improve water quality. This intelligent and low-cost IoT model ensures real-time monitoring, faster response, and efficient purification control, making it suitable for domestic, industrial, and environmental applications.
Keywords: Internet of Things (IoT), Water Quality Monitoring, ESP32 Microcontroller, Smart Sensors, Automation, Real-Time Data, Water Purification System, Intelligent Water Management

1. INTRODUCTION

Water quality plays a crucial role in maintaining the health and well-being of living organisms. With the rise of industrial activities, population growth, and pollution, access to clean and safe water has become a serious global challenge. Traditional methods used for testing water quality require manual sampling and laboratory analysis, which are not only time-consuming but also fail to provide real-time information. In recent years, the Internet of Things (IoT) has emerged as a promising technology for remote and continuous environmental monitoring. By integrating sensors, microcontrollers, and communication modules, IoT systems can collect, analyze, and share data instantly. These smart systems enable quick detection of unsafe conditions and support automated responses without human intervention. The proposed IoT Driven Water Intelligence System aims to provide an affordable and efficient solution for real-time water quality assessment and control. It uses pH, TDS, turbidity, and temperature sensors connected to an ESP32 microcontroller to measure key water parameters. The data is displayed on an OLED screen and can also be uploaded to an online platform for remote monitoring. If the readings go beyond the safe range, a relay-controlled purification unit is automatically activated to maintain water safety. This project demonstrates how IoT technology can be applied to smart water management and environmental sustainability by ensuring reliable, automated, and continuous quality control.

2. LITERATURE REVIEW

Researchers around the world have worked on developing IoT-based systems for continuous water quality monitoring. Several studies have focused on improving data accuracy, wireless transmission, and system automation, but most lack integrated control mechanisms for purification.

Kumar et al. (2021) designed an IoT-based monitoring system that measured pH and turbidity levels using Arduino and displayed the results on a web platform. Their model successfully demonstrated real-time monitoring but required manual purification control.

Sharma and Mehta (2020) developed a wireless sensor network to detect contamination in water distribution systems. While effective for data collection, it required frequent recalibration and did not support automated actions.

Gupta et al. (2022) proposed a low-cost monitoring system using Raspberry Pi and various sensors. The system achieved high accuracy but involved complex setup and higher power consumption.

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Patel and Singh (2023) presented an intelligent IoT model capable of monitoring temperature and pH levels. Although the system offered precise readings, it lacked an automatic response to restore water quality when unsafe conditions occurred. From the above studies, it is evident that existing systems primarily focus on observation and data transmission rather than automatic intervention. The proposed IoT Driven Water Intelligence Systemaddresses this limitation by integrating real-time monitoring and automated purification control within a single low-cost framework.

3. METHODOLOGY / SYSTEM DESIGN

The proposed IoT Driven Water Intelligence System is designed to continuously monitor and automatically control water quality based on sensor feedback. The methodology focuses on real-time data collection, intelligent processing, and purification activation through a relay mechanism.

3.1 Block Diagram

The overall system architecture of the proposed IoT Driven Water Intelligence System is illustrated in **Figure 1**. The setup consists of an ESP32 microcontroller connected to various sensors (pH, TDS, turbidity, and temperature), a display unit, and a relay-controlled motorized valve. Each component plays a vital role in continuous water quality assessment and automated purification control.

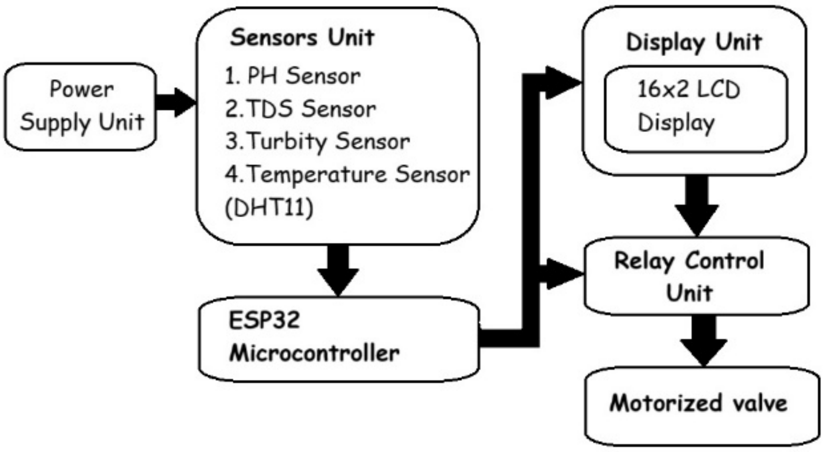

Fig 1. Block Diagram of IoT Driven Water Intelligence System

The sensors collect real-time data and send it to the ESP32 for analysis. The processed results are displayed on the 16x2 LCD display, while the relay module activates the motorized valve whenever water quality parameters exceed the preset safety limits. The system is powered by a regulated supply and operates automatically without user intervention.

3.3 Hardware Components

- **ESP32 Microcontroller:** Acts as the main controller for data acquisition, processing, and communication.
- **pH Sensor:** Measures the acidity or alkalinity of water.
- **TDS Sensor:** Detects the total dissolved solids to determine the purity of water.
- **Turbidity Sensor:** Evaluates the clarity of water by measuring light scattering.
- **Temperature Sensor:** Monitors temperature, which affects pH and TDS values.
- **Relay Module:** Controls the purification system based on the microcontroller's output.
- **OLED Display:** Shows real-time readings for user visibility.
- **Power Supply Unit:** Provides regulated power to all components.

3.4 Software Overview

The system is programmed using Arduino IDE with the ESP32 board configuration.

- Sensor libraries are used for calibration and data conversion.
- The code includes threshold-based decision logic to trigger the relay.
- Real-time values are updated on the OLED display and can be sent to a ThingSpeak or Blynk IoT dashboard for cloud visualization.

This combination of hardware and software provides a reliable, responsive, and scalable platform for intelligent water management.

4. IMPLEMENTATION

The implementation of the IoT Driven Water Intelligence System involves both hardware assembly and software programming to achieve continuous water quality monitoring and control. The system integrates sensors, a microcontroller, and output devices to function as an automated purification controller.

4.1 Circuit Description

The circuit is built around the ESP32 microcontroller, which acts as the central control unit. The sensors pH, TDS, turbidity, and DHT11 (temperature) are connected to the analog and digital input pins of the ESP32. Each sensor provides a voltage signal proportional to its respective measurement, which is then processed by the microcontroller.

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A 16x2 LCD display is connected to show the live values of water parameters, allowing users to view real-time conditions. The relay module is interfaced with the ESP32 to control the motorized valve. When unsafe conditions (such as high TDS or abnormal pH) are detected, the relay is energized, turning ON the motorized valve to start the purification cycle. Once the water quality reaches acceptable limits, the relay is automatically turned OFF. The power supply unit provides stable 5V and 3.3V DC outputs for all components. Proper isolation is maintained between the low-voltage control circuit and the high-voltage relay to ensure system safety.

4.2 Code Explanation

The software for this project is developed using Arduino IDE with the ESP32 board configuration. The program includes the following major sections:

1. Sensor Initialization: All sensors are calibrated and initialized for accurate readings.
2. Data Acquisition: The microcontroller reads the analog and digital signals from each sensor at fixed intervals.
3. Threshold Comparison: Predefined threshold values are stored for each parameter (e.g., pH: 6.5–8.5, TDS: <500 ppm).
4. Display Output: The sensor readings are displayed on the LCD in real time.
5. Relay Control: If any value goes beyond the threshold, the relay is activated to open the motorized valve.
6. Re-Check Routine: After purification, the system waits for a defined time (15 or 30 minutes) and rechecks the water parameters automatically. The program ensures automatic operation, real-time feedback, and efficient control without requiring manual intervention.

4.3 Testing and Calibration

Each sensor was tested under different water conditions to ensure accuracy and consistency.

- The pH sensor was calibrated using standard buffer solutions (pH 4, 7, and 9).
- The TDS sensor was verified using samples of known concentration.
- The turbidity sensor was tested with clear and cloudy water to observe variation in voltage output.
- The temperature sensor (DHT11) was checked under room and warm water conditions.

The system successfully detected unsafe water levels and activated the purification unit automatically. The data displayed on the LCD and recorded online closely matched the reference measurements, confirming system reliability.

5. RESULTS AND DISCUSSION

The proposed IoT Driven Water Intelligence System was successfully developed and tested under different water conditions to evaluate its performance. The system accurately measured multiple water quality parameters in real time and responded automatically when the readings exceeded the predefined limits. The readings for pH, TDS, turbidity, and temperature were displayed on the 16×2 LCD and simultaneously transmitted to the IoT dashboard. The relay control mechanism efficiently activated the motorized valve during unsafe conditions and deactivated it once the water quality stabilized.

5.1 Output Screenshots

The developed prototype of the IoT Driven Water Intelligence System is shown in Figure 2. It includes the ESP32 microcontroller, pH, TDS, turbidity, and temperature sensors connected to a 16×2 LCD display an relay control unit.

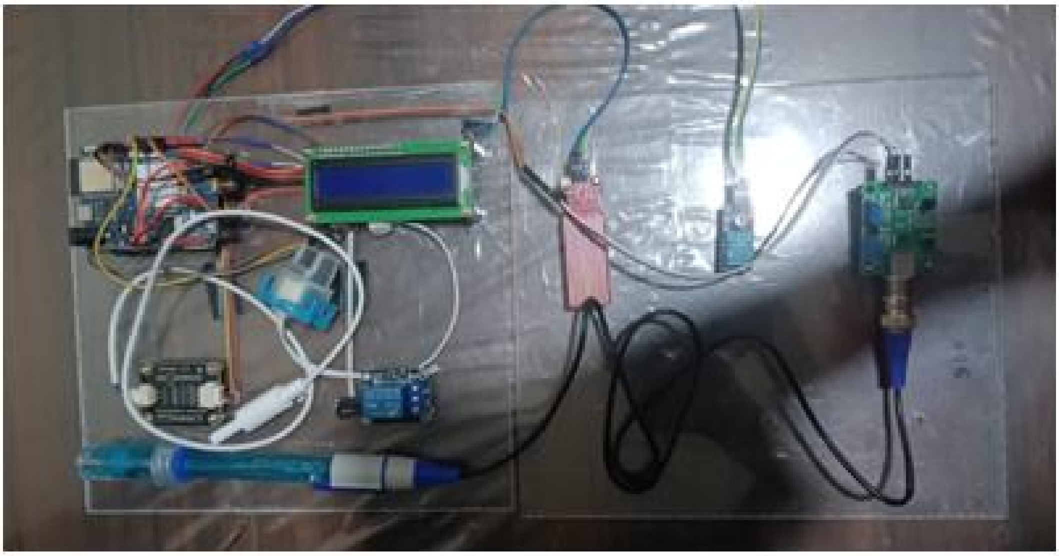

Fig 2. Hardware setup of IoT Driven Water Intelligence System

During testing, various sensor readings were displayed on the LCD, as shown in **Figures 3–5**. The system measured temperature, turbidity, pH, and TDS values in real time and activated the purification control when unsafe water conditions were detected.

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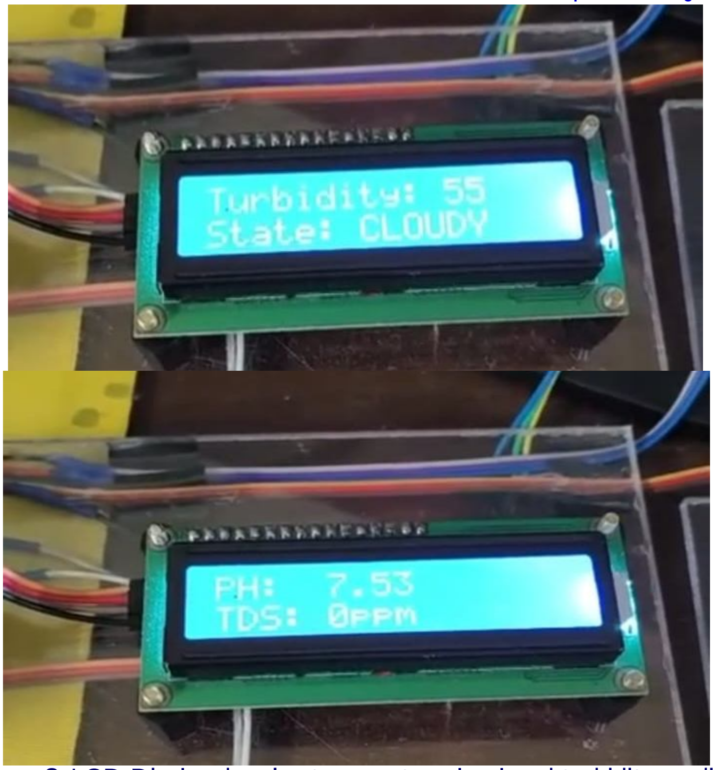

Figure 3. LCD Display showing temperature, level, and turbidity readings

Figure 4. LCD Display showing pH and TDS readings

Figure 5. LCD Display showing purifier activation status

5.2 Data Analysis

Table 1 summarizes the experimental readings recorded during the testing phase:

Parameter	Safe Range	Sample Reading	System Response
pH	6.5 – 8.5	7.2	Safe (No action)
TDS (ppm)	< 500	580	Purifer ON
Turbidity (NTU)	< 5	2.4	Safe (No action)
Temperature (°C)	25 – 35	31	Normal

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The results confirm that the system reacts accurately to parameter changes and ensures timely corrective action. The ESP32 processed all sensor inputs efficiently, and the relay response time was observed to be under 2 seconds.

5.3 Discussion

The implemented system proved to be reliable and effective for small- to medium-scale water management setups. Compared with traditional manual testing, the proposed IoT system offers:

- **Faster detection** of unsafe conditions
- **Automatic control** without human involvement
- **Accurate, real-time readings** displayed locally and online
- **Scalability** for integration with industrial or community purification systems

These results validate the concept of a smart, self-regulating water monitoring system that can enhance water safety and sustainability.

6. CONCLUSION

The IoT Driven Water Intelligence System provides an efficient and automated method for continuous water quality monitoring and control. By integrating multiple sensors with an ESP32 microcontroller, the system effectively measures key parameters such as pH, TDS, turbidity, and temperature in real time. The relay control mechanism ensures that corrective action, such as activating the motorized valve or purification unit, occurs automatically whenever water quality deviates from the safe range. The prototype successfully demonstrated accurate readings, quick response, and reliable automation in various test conditions. Compared to conventional water testing methods, this IoT-based approach offers greater efficiency, lower maintenance, and real-time data access, making it highly suitable for domestic, industrial, and environmental applications. Overall, the project highlights how IoT technology can be leveraged for smart environmental management, promoting safe water consumption and sustainable resource utilization.

7. FUTURE SCOPE

The current system demonstrates a reliable approach to automated water quality monitoring and purification control. However, there are several possibilities for further enhancement and scalability in future implementations:

1. Cloud and Mobile Integration:
   The system can be connected to a cloud platform with mobile app support to provide real-time alerts, historical data visualization, and remote system control.
2. AI-Based Prediction:
   Machine learning algorithms can be applied to predict future water quality trends and detect anomalies based on continuous data collection.
3. Advanced Sensor Calibration:
   Incorporating self-calibrating sensors can improve accuracy and reduce the need for manual maintenance.
4. Solar Power Operation:
   Using solar panels can make the system energy-efficient and suitable for deployment in remote or rural areas.
5. Expanded Industrial Applications:
   The same setup can be adapted for industries such as food processing, aquaculture, and wastewater management to ensure compliance with safety standards. Future developments focusing on these areas can transform the proposed model into a fully intelligent and autonomous water management solution.

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