

IOT-Based Smart Water Quality Monitoring System

SRI PUJITHA V

UG Student,
Department of CS & IT,
Vels Institute of Science,
Technology And Advanced Studies (VISTAS),
Pallavaram, Chennai-600117,
Tamil Nadu, India.


Dr. V. VISHWA PRIYA^{MCA.,MBA.,M.Phil.,Ph.D., SET.,}

Assistant Professor,
Department of CS & IT,
Vels Institute of Science,
Technology And Advanced Studies (VISTAS),
Pallavaram, Chennai-600117,
Tamil Nadu, India.



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ABSTRACT

Ensuring safe and clean water is a major challenge in today's society. It impacts public health, agriculture, and industry. Traditional water testing methods are often manual, costly, and do not allow for real-time monitoring. To address these issues, this project develops an IoT-based Smart Water Quality Monitoring System. It continuously measures and analyzes water parameters using advanced sensors and cloud integration. The system uses various sensors, including a pH sensor to measure acidity and alkalinity, a turbidity sensor to detect suspended particles, a dissolved oxygen sensor to assess oxygen content, a temperature sensor, and a TDS/conductivity sensor to evaluate salinity and ion concentration. These sensors connect to a microcontroller or processor such as Arduino, ESP32, or Raspberry Pi, which gathers and processes the data. The processed data is sent wirelessly to cloud platforms like ThingSpeak, Firebase, or AWS IoT, allowing for secure storage, visualization, and analysis. Users can access real-time dashboards and receive alerts when water quality parameters exceed safe levels, enabling timely intervention. By combining IoT technology with environmental

monitoring, this project offers a low-cost, scalable, and efficient solution for managing water quality. The system can be applied in domestic water supply, aquaculture, agriculture, and municipal infrastructure, supporting sustainable resource management and smart city efforts.

KEYWORDS

IoT, Smart Water Quality Monitoring, pH Sensor, Turbidity Sensor, Dissolved Oxygen Sensor, Temperature Sensor, TDS/Conductivity Sensor, Arduino.

INTRODUCTION

Water is essential for life, yet contamination and pollution threaten its safety and availability. Industrial discharge, agricultural runoff, and urban waste all contribute to declining water quality, which affects human health and ecosystems. Traditional monitoring methods use laboratory-based testing, which, while accurate, is slow and does not provide continuous insights. Recently, the Internet of Things (IoT) has become a game-changing technology. It allows interconnected devices to collect, send, and analyze data seamlessly. IoT-based monitoring

systems can acquire real-time data, be accessed remotely, and integrate with smart infrastructure.

This paper presents a smart water quality monitoring system that uses IoT technology for continuous, multi-parameter analysis of water conditions. Unlike current solutions that often focus on a single parameter or lack real-time visualization, the proposed system integrates multiple sensors and cloud-based dashboards for thorough monitoring. This work includes designing a low-cost, scalable prototype, demonstrating real-time visualization through cloud platforms, and verifying sensor accuracy against recognized standards. Water is essential for life, yet contamination and pollution threaten its safety and availability. Industrial discharge, agricultural runoff, and urban waste all contribute to declining water quality, which affects human health and ecosystems. Traditional monitoring methods use laboratory-based testing, which, while accurate, is slow and does not provide continuous insights. Recently, the Internet of Things (IoT) has become a game-changing technology. It allows interconnected devices to collect, send, and analyze data seamlessly. IoT-based monitoring systems can acquire real-time data, be accessed remotely, and integrate with smart infrastructure.

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II. LITERATURE REVIEW

Several researchers have investigated IoT-based methods for water monitoring. Early systems focused only on measuring pH or turbidity, limiting their usefulness in various situations. Other studies used wireless sensor networks but

did not integrate with cloud-based dashboards, which restricted accessibility and scalability. Some projects utilized expensive equipment, making them impractical for widespread use. A few recent projects attempted to integrate multiple sensors but often lacked real-time visualization or user-friendly interfaces.

The proposed system fills these gaps by combining low-cost sensors with a microcontroller platform, ensuring it is affordable and easy to deploy. Additionally, integrating cloud services provides real-time visualization and alerts based on threshold levels, improving usability for everyone involved. By placing this work within the larger context of IoT applications in environmental monitoring, the paper highlights its uniqueness and practical importance.

III. PROBLEM IDENTIFICATION

Water quality monitoring is essential for protecting public health, supporting the environment, and ensuring safe water distribution. Traditional methods depend on manual sampling and lab analysis, which take a lot of time and effort and do not offer real-time information. This often results in delayed detection of contamination, raising the risk of waterborne diseases and ecological harm. Additionally, current monitoring systems have drawbacks, such as problems with sensor calibration, limited scalability, reliance on constant internet access, and poor integration with modern cloud platforms. The lack of automated, affordable, and scalable options shows the need for an IoT-enabled smart water quality monitoring system. Such a system can deliver real-time data, proactive alerts, and smooth integration with decision-making tools.

IV. SYSTEM DESIGN AND METHODOLOGY

The system architecture consists of hardware and software components that work together. On the hardware side, sensors for pH, turbidity, dissolved oxygen, total dissolved solids, and temperature connect to an ESP32 or Arduino microcontroller. These sensors deliver

continuous readings, processed locally before being transmitted via Wi-Fi. The microcontroller serves as the central node, handling sensor calibration, data collection, and communication.

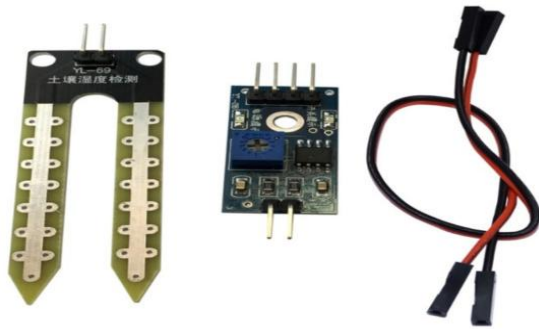


Figure 1. A typical YL-69 sensor, with necessary parts

On the software side, the firmware is written in C/C++, with routines for sensor calibration and error handling. Data is sent using standard communication protocols like MQTT or HTTP. The cloud platform, set up through ThingSpeak, Firebase, or AWS IoT, stores incoming data and provides visualization through dashboards. Users can access these dashboards through web or mobile applications for remote monitoring. The workflow includes collecting sensor data, sending it to the cloud, storing it, and visualizing it. A block diagram illustrates how information flows from sensors to the user interface.

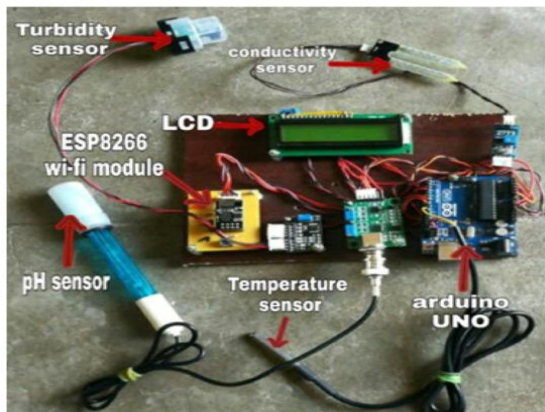


Figure 2. Image of system proposed

V. EXPERIMENTAL SETUPS

To test the system, water samples were collected from tap water, pond water, and packaged drinking water. Each sample was analyzed using the integrated sensors, and the results were compared to WHO standards. The pH sensor effectively identified acidic, neutral, and alkaline samples. The turbidity sensor detected suspended particles in pond water, while the dissolved oxygen sensor indicated variations across the different sources. The TDS sensor measured impurities, confirming the presence of dissolved solids in untreated water.

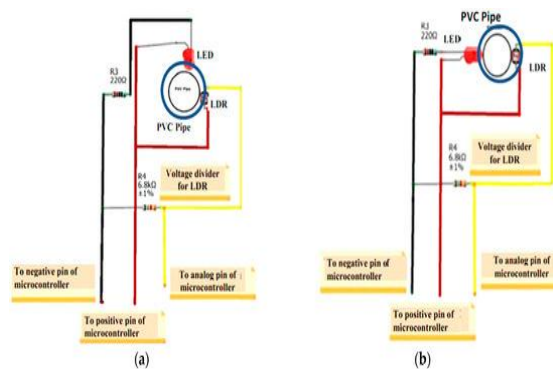


Figure 3. (a) Turbidity unit proposed for scenario 1 (180°); (b) Turbidity unit proposed for scenario 2 (90°)

The results were shown on the cloud dashboard, which displayed real-time graphs and allowed for alerts based on thresholds. For example, when turbidity exceeded acceptable limits, the system generated a warning notification. The findings confirm that the system can reliably monitor water quality. However, challenges such as sensor calibration drift and dependence on internet connectivity were noted. Despite these issues, the system showed scalability, cost-effectiveness, and ease of deployment.

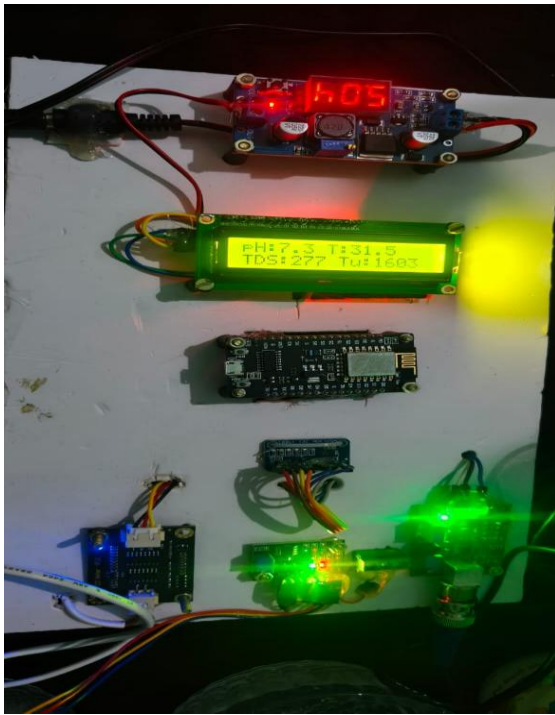


Fig 4

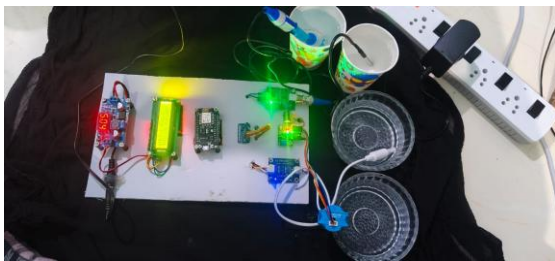


Fig 5

Figure 4 & 5 : Experimental Setup

VI. RESULTS

The figure below shows the real-time use of the IoT-based smart water quality monitoring system developed in this work. The setup includes multiple sensors for measuring pH, turbidity, dissolved oxygen, and temperature. These sensors connect to an ESP32 microcontroller for collecting data. The data is sent wirelessly to cloud platforms for visualization and analysis. This allows for continuous monitoring and timely alerts. This practical setup proves that the proposed system works and effectively provides real-time insights into water quality.



Figure 5: Experimental Real Output

My Dashboards	
Dashboard Name	WaterQualityTester
My Feeds	
Feed Name	Last Value
ph	7122938
tds	344.531250
temperature	31.500000
turbidity	1699.000000
Welcome Feed	57

Figure 6: Feed and Dashboard at Adafruit.io

VII. FUTURE ENHANCEMENT

While the system has produced encouraging results, several improvements can enhance its effectiveness and usability. Future work will focus on integrating machine learning algorithms to provide predictive analysis of water quality trends, offering early warnings about potential contamination. Developing a mobile application will be prioritized to enhance accessibility for end-users, allowing households and municipal authorities to monitor water quality conveniently. Additionally, large-scale deployment across urban and rural water distribution networks will be explored to test

scalability. To improve sustainability, solar-powered sensor nodes will be added to lessen reliance on traditional power sources. Finally, further research will tackle sensor calibration issues and investigate advanced communication protocols to boost reliability in areas with limited internet connectivity.

VIII. SIGNIFICANCE OF THE STUDY

Providing safe drinking water is a global challenge, especially in developing areas where contamination often goes unnoticed. The proposed IoT-based monitoring system presents a scalable solution that can be used in households, industries, and municipal pipelines. By offering continuous monitoring and real-time alerts, the system empowers communities to take action against waterborne diseases. The integration of cloud platforms also ensures that data can be shared with authorities and researchers, contributing to public health initiatives and smart city growth.

IX. COST ANALYSIS

One of the main benefits of the proposed system is its low cost. The hardware components, including sensors and microcontroller, are inexpensive and easily obtainable. A detailed cost analysis shows that the system can be put together for a fraction of the price of traditional lab equipment. This makes it suitable for use in resource-limited areas like rural communities. Additionally, the design's scalability allows multiple units to be implemented across a network without significant financial strain, making it a practical choice for large-scale monitoring.

X. CONCLUSION

This paper detailed the design and implementation of an IoT-based Smart Water Quality Monitoring System that can measure multiple parameters such as pH, turbidity, dissolved oxygen, total dissolved solids, and temperature. By integrating low-cost sensors with a microcontroller and cloud platform, the system enables ongoing monitoring and real-time visualization of water quality data. Experimental evaluations showed that the

system yields reliable readings compared to established thresholds while also being scalable and affordable. The proposed solution addresses the shortcomings of traditional lab-based methods by offering a practical, accessible, and automated way to assess water quality. Overall, the system contributes to the progress of smart city infrastructure and environmental monitoring technologies.

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