An IoT Based Water Quality Monitoring System

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ABSTRACT

Water pollution has become a critical environmental and public health challenge due to rapid industrialization, urban expansion, and improper waste disposal. Conventional water quality monitoring methods rely on manual sampling and laboratory testing, which are time consuming and unsuitable for continuous monitoring. Although IoT-based systems allow realtime data collection, they often present only raw sensor values, making it difficult for users to understand pollution severity or take appropriate action. This paper presents an AIoT Based Water Quality Monitoring System that integrates IoT, Machine Learning, and location awareness to provide meaningful interpretation of water quality data. Sensors connected to an ESP32 microcontroller measure temperature, pH, turbidity, and total dissolved solids (TDS), and the data is transmitted to the cloud along with GPS-based location information of the water source. A Machine Learning model predicts the Water Quality Index (WQI), which represents overall water quality in a single score. The system further supports context-aware water usage classification, anomaly detection for sudden abnormal changes, and trend status indication to analyse long-term water quality behaviour. By combining real-time monitoring with intelligent analysis and location tracking, the system provides effective decision support for water pollution management.

.**Keywords:** Artificial Intelligence of Things (AIoT), Water Quality Monitoring, Internet of Things (IoT), Water Quality Index (WQI), Machine Learning, ESP32, ThingSpeak Cloud, Decision Support System, Anomaly Detection.

I. INTRODUCTION

Water from ponds, lakes, and other small water bodies is commonly used by rural communities for drinking, domestic, and agricultural purposes. Due to lack of proper monitoring, contaminated water from these sources often leads to various chronic waterborne diseases in nearby villages. The goal of this project is to develop an **AIoT-Based Water Quality Monitoring System** that helps monitor the condition of such water bodies and create awareness about unsafe water usage. The system does not cure or prevent diseases directly, but it provides useful information that helps communities and authorities identify unsafe water conditions and take necessary precautions to protect public health.

II. LITERATURE REVIEW & BASE PAPER DIFFERENTIATION

Several research works have been proposed in the literature to address the problem of water quality monitoring using IoT and sensor-based technologies. Studies by Chowdury et al., Das and Jain, Koditala and Pandey, and Saravanan et al. demonstrate the effectiveness of IoT and wireless sensor networks in enabling real-time monitoring of water quality parameters such as pH, turbidity, temperature, and dissolved solids. These systems significantly reduce manual intervention and allow remote visualization of water quality data through web or mobile platforms. However, most of these approaches rely on static threshold-based evaluation and present raw sensor readings, requiring manual interpretation by users. The base IEEE paper titled "IoT-Enabled Advanced Water Quality Monitoring System for Pond Management and Environmental Conservation" (2024) further improves upon earlier systems by incorporating cloud connectivity and a mobile application for monitoring parameters such as pH, turbidity, and total dissolved solids (TDS). While the base paper provides an effective IoT-based real-time monitoring solution, the analysis is limited to threshold comparisons and basic drinkable or non-drinkable classification. The system does not incorporate intelligent data analysis, Water Quality Index computation, explainable decision support, or anomaly analysis. From the comparison, it is evident that existing systems primarily focus on data acquisition and visualization, whereas the proposed system extends these works by integrating machine learning for Water Quality Index prediction, combined parameter analysis, decision support, and time-aware Intelligent Water Quality Analysis. This extension transforms conventional IoT-based monitoring into an intelligent AIoT-based decision support system suitable for practical and scalable water pollution monitoring .

III. PROPOSED SYSTEM

The proposed AIoT-Based Water Quality Monitoring System is designed as a modular pipeline integrating sensing, communication, cloud processing, and machine learning analysis. The architecture ensures continuous data acquisition and intelligent interpretation of water quality conditions.

A. Data Acquisition Layer

The system utilizes multiple sensors to measure key water quality parameters, including pH, turbidity, temperature, and total dissolved solids (TDS). These parameters represent the chemical and physical characteristics of water sources such as ponds, lakes, and canals.

B. IoT Communication Layer

The collected sensor data is processed by an ESP32 microcontroller, which acts as the IoT edge device. The ESP32 transmits the data to the cloud platform using Wi-Fi communication, enabling real-time data transfer and remote accessibility.

C. Cloud Storage Layer

The cloud platform receives and stores incoming sensor data, maintaining a continuous data stream. It provides centralized storage and supports real-time data retrieval for further processing and analysis.

D. Machine Learning Layer

The stored data is processed using a machine learning model that analyzes multiple parameters simultaneously. The model performs multi-class classification of water quality into three categories: safe for drinking, moderate (suitable for agriculture), and unsafe (dangerous). Additionally, the system generates context-aware insights based on the classification results.

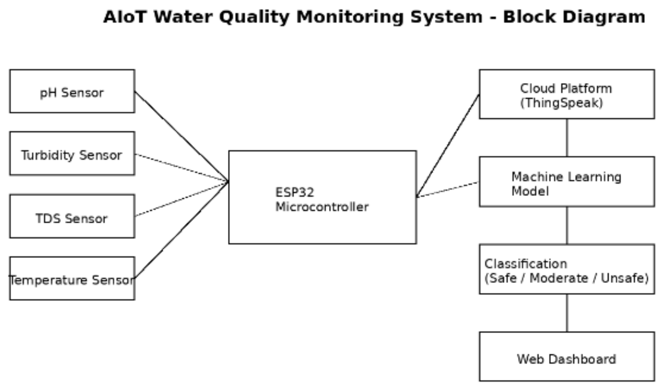
E. Classification Model:

A machine learning model classifies water into three categories:

- **Safe for drinking**
- **Moderate (suitable for agriculture)**
- **Unsafe (dangerous)**

F. Visualization Layer

The final output is presented through a web-based dashboard, which displays real-time sensor values along with classification results and context-aware information. This layer enables users to easily understand water quality conditions without interpreting raw data.



IV. METHODOLOGY

The proposed AIoT-Based Water Quality Monitoring System follows a structured pipeline to continuously monitor and analyze water conditions in small water bodies. The methodology integrates IoT-based sensing, cloud communication, and machine learning to provide meaningful interpretation of water quality.

Data Acquisition: Water quality parameters such as pH, turbidity, temperature, and total dissolved solids (TDS) are collected from the source using sensors deployed in ponds, lakes, and canals.

Data Processing: The collected sensor data is captured by the ESP32 microcontroller and converted into a structured digital format suitable for transmission.

Data Transmission: The processed data is transmitted to the cloud platform using Wi-Fi communication, enabling real-time data availability and remote access.

Cloud Integration: The cloud platform stores incoming data and provides a centralized environment for data retrieval and further analysis.

Machine Learning Analysis: The collected data is provided to the machine learning model, where multiple parameters are evaluated together. The model performs multi-class classification of water quality into three categories: safe, moderate, and unsafe.

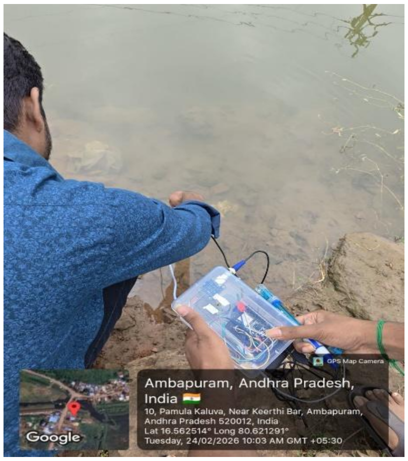
Context-Aware Output: Based on classification results, the system generates context-aware insights indicating the usability of water for drinking, agriculture, or warning conditions.

Visualization: The final results are displayed on a web-based dashboard, presenting real-time sensor values along with classification outputs and contextual information.

V. Proposed System Hardware And Software Results

I. Hardware Device Set Up

The hardware setup is deployed near a natural water source, where sensors are immersed to collect real-time parameters like pH, turbidity, and temperature.A microcontroller-based unit inside a protective enclosure processes the data and enables transmission for continuous AIoT-based water quality monitoring.



II. Login + Create Account

The system provides a secure authentication mechanism through login and registration interfaces. This ensures controlled access to the platform and allows users to securely interact with real-time monitoring and prediction features.

Fig. 6: User Authentication Interface

III. ThingSpeak Graphs

The system displays real-time sensor data retrieved from the cloud platform. Parameters such as pH, turbidity, temperature, and TDS are continuously updated and visualized using graphical representations for easy monitoring.

Fig. 7: Real-Time Sensor Data Visualization

IV. Dashboard (Live Values)

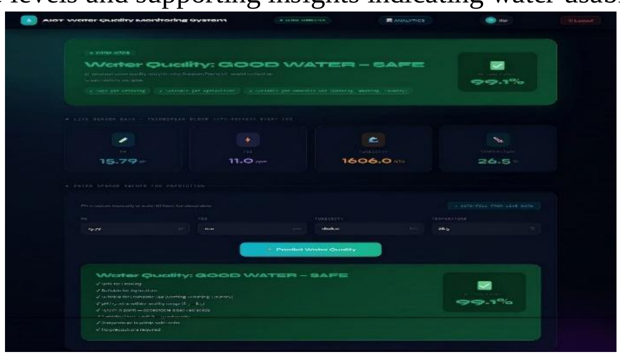
The dashboard presents real-time sensor readings in a structured format. It allows users to quickly observe water quality conditions without analyzing raw data, improving usability and decision-making.

Fig. 8: Dashboard Showing Real-Time Sensor Values

The system allows users to input sensor values manually or auto-fill them from live data. This input is used by the machine learning model to perform water quality classification.

V. SAFE Output (Green Screen)

When all parameters fall within acceptable limits, the system classifies the water as safe for drinking. The output includes confidence levels and supporting insights indicating water usability.



VI. MODERATE Output (Orange Screen)

If the water is not suitable for drinking but can be used for agricultural purposes, the system provides a moderate classification. It also includes recommendations for safe usage.

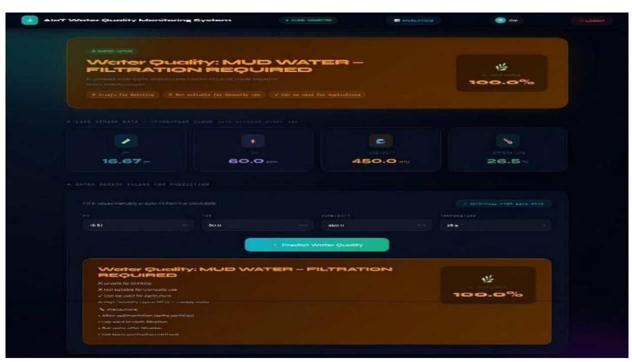


Fig. 11: Moderate Water Quality Classification

VII. DANGEROUS Output (Red Screen)

When the water quality parameters exceed safe thresholds, the system classifies it as unsafe. It generates warning messages along with context-aware insights to alert users and prevent harmful usage.

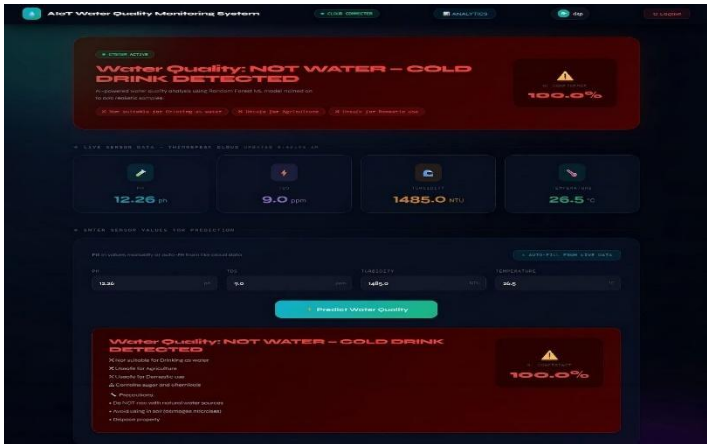


Fig. 12: Unsafe Water Detection and Warning

VI. CONCLUSION

The proposed AIoT-Based Water Quality Monitoring System successfully integrates IoT sensing, cloud communication, and machine learning to monitor water quality in real time. The system collects parameters such as pH, turbidity, temperature, and TDS from small water bodies and transmits the data to the cloud for analysis.

Unlike traditional monitoring methods that only display raw values, the proposed system performs multi-class classification of water quality into safe, moderate, and unsafe categories. In addition, the system provides context-aware insights, enabling users to understand whether the water can be used for drinking, agriculture, or should be avoided.

The developed system is simple, cost-effective, and suitable for deployment in rural areas where continuous monitoring is lacking. By providing clear interpretation instead of raw data, the system helps in improving awareness and supports better decision-making regarding water usage.

Overall, the proposed solution demonstrates an effective approach for real-time monitoring and intelligent analysis of water quality, contributing towards safer and more informed utilization of water resources.

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