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WATER QUALITY MONITORING USING EMBEDDED CONTROLLER ESP32

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Abstract- **Water is one of the most essential resources for sustaining life, playing a vital role in human health, agriculture, industry, and ecosystem balance. Despite its importance, water pollution is a growing crisis, making it the most contaminated natural resource compared to air and soil. For instance, industrial waste, agricultural runoff, sewage discharge, and plastic pollution contribute to water contamination, with over 80% of waste water worldwide being released untreated into water bodies. In addition, heavy metals, pesticides, micro plastics, and pathogens further degrade water quality, posing severe risks to human health and biodiversity. This paper proposes a water quality monitoring system using Embedded Controller ESP32. This system helps in ensuring safe drinking water, regulatory compliance, and ecosystem protection.**

Keywords: **Cloud Interface, Water Samples, Wireless**

I. INTRODUCTION:

Water is an essential resource for human survival, agriculture, industry, and environmental sustainability. However, increase in pollution due to industrial discharge, agricultural runoff, and domestic waste has severely degraded water quality, posing risks to public health and aquatic ecosystems. To ensure safe and clean water, continuous monitoring of key parameters such as Potential of Hydrogen (pH), Total Dissolved Solids (TDS), and Turbidity is necessary.

This project focuses on developing a real-time water quality monitoring system using an ESP32 microcontroller integrated with pH, TDS, and turbidity sensors. The ESP32, with its built-in Wi-Fi capability, collects data from these sensors and transmits it wirelessly to a web-based interface that can be accessed via an IP address. This allows users to remotely monitor water quality parameters in real time without the need for complex hardware setups. The pH sensor measures the acidity or alkalinity of water, the TDS sensor detects the concentration of dissolved solids indicating purity levels, and the turbidity sensor assesses water clarity by detecting suspended particles.

By leveraging IoT-based technology, this system provides a cost-effective and efficient solution for continuous water quality monitoring, making it suitable for applications in households, industries, agriculture, and environmental agencies. The ability to remotely access sensor readings enhances decision-making and ensures timely intervention to prevent contamination. This project contributes to sustainable water management and aligns with global efforts to ensure access to clean and safe water.

II. LITERATURE REVIEW:

H. Sui (2020) described a data capture and trans mission system using NB-IoT as the wireless service and no edge processing nor a description of a pollution event detection algorithm [1]. Currently, NB-IoT as service is not ubiquitous in rural areas. Real-Time Water Quality Monitoring in the Winnipeg River Watershed (2023) designed by International Institute for Sustainable Development is an IoT-based real-time sensors with cloud computing and data analytics platforms but it has disadvantage of Continuous real-time monitoring relies on sensor accuracy, which can be affected by biofouling, calibration drift, and environmental conditions [2].

Cheniti Mohamed (2021) proposed an Arduino-Based Smart Water Quality Monitoring System to build a low-cost water quality monitoring system using Arduino, pH sensors, and turbidity sensors and display real-time readings on an LCD and send alerts for poor water quality but Arduino has limited processing power, restricting advanced data analytics, basic sensors may not detect micro-level contaminants like pesticides or pharmaceuticals and the system is only suitable for small-scale water sources, not large water bodies [3].

S. Lerios (2021) proposed a Machine Learning-Based Water Contamination Prediction System, a predictive model that analyzes past water quality data to predict potential contamination. It requires a large dataset for accurate predictions, which may not always be available and cannot provide real-time data; works mainly as a predictive tool [4].

Satish M.Tin (2013) proposed a Solar-Powered Autonomous Water Quality Monitoring System, a self-sustaining floating device powered by solar panels to continuously monitor water parameters and deploy in lakes or reservoirs for long-term water quality assessment. Solar efficiency depends on weather conditions, limiting power availability [5].

S. Geetha (2024) proposed a mobile application for water quality monitoring and reporting to create a mobile app that allows users to manually enter water quality test results from low-cost test kits and develop a crowd sourced database for tracking water pollution trends in different regions. It relies on user-reported data, which may be inconsistent or inaccurate. It cannot provide real-time automated monitoring like sensor-based systems [6].

Evaluation and analysis of goodness of fit for water quality parameters using linear regression through the Internet of Things (IoT) based water quality monitoring system concentrated on the application of postprocessing ANOVA analysis to detect abnormalities without an edge processing for near-real-time event detection [7].

Micaela Jara Ten Kathen (2022) proposed an Autonomous Surface Vehicles for Water Monitoring using Raspberry Pi and NVIDIA Jetson Nano for AI-based water quality analysis that collect and analyze water quality data using federated learning and AI optimization. However, it is affected by weather conditions and is also more expensive [8].

N. Vijayakumar (2015) proposed a real time monitoring of water quality in IoT environment using Raspberry Pi data acquisition system, but it has no edge processing nor a specific event detection algorithm and uses only 802.11 [9].

B. A Aderemi (2022) proposed some of the groundwater management models with a focus on IoT based systems, but they do not implement edge processing for pollution event detection [10].

Christian Correa (2023) proposed an Embedded Edge-Processing Water Quality Monitoring System for Underground Waters with event detections algorithm and it is limited to underground water only [11].

III.SYSTEM DESIGN AND IMPLEMENTATION

The Water Quality Monitoring System is designed to measure key water parameters, ensuring real-time monitoring and analysis. This system is implemented using an ESP32 microcontroller, which serves as the central processing unit for collecting and transmitting data from various sensors. The primary sensors used in this project include a pH sensor, a turbidity sensor, and a Total Dissolved Solids (TDS) sensor. These sensors help evaluate essential water quality indicators, including acidity levels, clarity, and the concentration of dissolved particles. By integrating these sensors, the system provides a cost-effective and efficient solution for water quality assessment in environmental and industrial applications. Figure 1 presents the block diagram of water quality monitoring system.

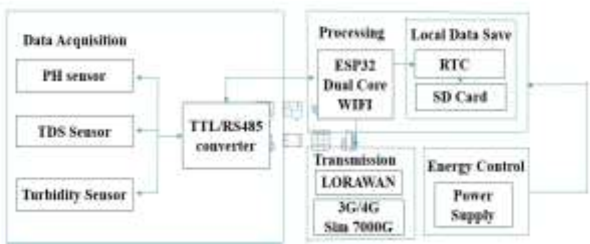

Fig.1. Block diagram water quality monitoring system

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The hardware implementation involves interfacing the pH, turbidity, and TDS sensors with the ESP32. The ESP32 is selected due to its Wi-Fi connectivity, allowing seamless transmission of data to a cloud server for remote access. The pH sensor is used to determine the acidity or alkalinity of the water, which is crucial for monitoring drinking water quality and aquatic environments. The turbidity sensor measures water clarity by detecting suspended particles, which is essential for identifying pollution levels. The TDS sensor evaluates the concentration of dissolved solids, indicating the purity of water and detecting contamination. These sensors provide analog outputs, which are processed by the ESP32's ADC (Analog-to-Digital Converter) to convert raw data into meaningful values. Figure 2 shows the Circuit level implementation of water quality monitoring system

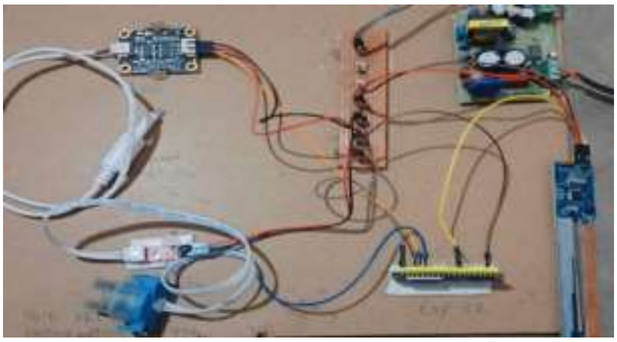

Fig.2. Circuit implementation of water quality monitoring system

For software development, the Arduino IDE is used to program the ESP32. The code is written in C/C++, utilizing essential libraries such as Wi-Fi for internet connectivity and sensor-specific libraries to read and process data efficiently. The ESP32 continuously collects data from the sensors, processes it, and transmits it to a cloud server. The cloud-based platform enables real-time monitoring, allowing users to access water quality data from any location. Additionally, threshold values can be set, triggering alerts if water parameters exceed safe limits.

IV. RESULT

Before deployment, the system undergoes calibration and testing to ensure accurate sensor readings. Calibration is performed using standard buffer solutions for pH measurement, clean water for TDS validation, and controlled turbidity samples. The system is tested under different environmental conditions to evaluate its reliability. Once deployed, it continuously monitors water quality, providing automated and real-time updates to users via the cloud interface. Figure 3, 4,5 shows the sensor values for different solutions.

Fig 3: Sensor readings when sensors are open

Fig.4: Sensor values for pure water, dirty water and normal water samples

Fig.5: Sensor values for tap water, pure water and lemon water

Table 1: Readings of pH, Turbidity and TDS sensors for the above samples

Water Sample Type	PH value	Turbidity value	TDS value
Lemon water	6	1	300
Underground water	7	3	600
Mineral water	8	2	120
Mud water	8	5	900

Table 1 tabulates the pH sensor readings for lemon water, groundwater, mineral water, and mud water typically show acidic, neutral, alkaline and slightly alkaline values, respectively. TDS (Total Dissolved Solids) readings are high in mineral water due to added minerals, moderate in groundwater due to natural salts, lowest in lemon water, and highest in mud water.

Turbidity sensor readings for lemon water may show slight cloudiness due to pulp, while groundwater may have moderate turbidity due to suspended particles, and mineral water generally has the lowest turbidity. Mud water having the more turbidity levels compared other samples, to decrease the turbidity levels some filtration methods are used.These readings help assess water quality for various applications.

V. CONCLUSION

The water quality monitoring system developed in this project provides a real-time, cost-effective, and efficient solution for assessing water purity using IoT-based technology. By integrating the ESP32 microcontroller with pH, TDS, and turbidity sensors, the system successfully monitors essential water parameters and transmits the data wirelessly to a web-based interface accessible via an IP address. This allows users to remotely track water quality, ensuring timely detection of contamination and enabling proactive measures to maintain safe and clean water.

The system's ability to provide continuous, remote monitoring makes it highly suitable for applications in households, industries, agriculture, and environmental protection agencies. Compared to traditional methods, this approach enhances accuracy, reduces manual labor, and offers a scalable solution for large-scale water quality assessment. Moreover, by leveraging IoT technology, this project aligns with sustainable development goals (SDG 6 - Clean Water and Sanitation), contributing to global efforts in water conservation and pollution prevention.

In conclusion, this project demonstrates a practical and innovative approach to water quality monitoring, emphasizing the importance of technological advancements in environmental sustainability. Future improvements can include additional sensors, cloud-based data storage, and AI-driven analytics for predictive water quality assessment, further enhancing its usability and impact.

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