IOT Based Water Quality Monitoring System

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Abstract- Water quality is essential for human health and environmental safety, but traditional monitoring methods are manual, time-consuming, and lack real-time data. To overcome these issues, an IoT-based system using the ESP8266 nodeMCU and Arduino IDE is developed to continuously monitor parameters such as TDS, temperature, pH, and turbidity, enabling timely detection of water contamination.
This project involves the development of a comprehensive water quality monitoring system based on the ESP8266 nodeMCU microcontroller and the Arduino IDE. The system is designed to measure key water quality parameters, including Total Dissolved Solids (TDS), temperature, pH, and turbidity. The ESP8266 nodeMCU processes data from various sensors that monitor these parameters, and the information is transmitted to the Arduino IDE for real-time visualization and analysis. This integration allows users to access detailed insights into water quality from any location, facilitating timely interventions, ensuring safe and clean water management. The system enhances environmental monitoring, supports water treatment processes, and provides valuable data for maintaining optimal water quality standards.

Keywords: Water Quality Monitoring, Total Dissolved Solids (TDS), pH Measurement, Turbidity Analysis, Temperature Monitoring, Real-Time Data Acquisition

I.INTRODUCTION

Water is one of the most critical resources for sustaining life, and its quality plays a vital role in ensuring human health, environmental safety, and socio-economic development. However, traditional water quality monitoring methods are largely dependent on manual sampling and laboratory analysis, which are time-consuming, labour-intensive and incapable of providing real-time insights. As industrialization, urbanization, and climate change continue to exert pressure on water resources, the risk of contamination has increased significantly, making timely detection and intervention essential. To address these challenges, modern technologies such as the Internet of Things (IoT) offer innovative solutions by enabling continuous monitoring, automated data collection, and remote accessibility. IoT-based systems integrate sensors with microcontrollers to measure key parameters such as Total Dissolved Solids (TDS), pH, turbidity, and temperature, providing accurate and real-time information about water quality. The ESP8266 nodeMCU microcontroller, combined with the Arduino IDE, offers a cost-effective and efficient platform for processing sensor data and transmitting it for visualization and analysis. This integration not only enhances environmental monitoring but also supports water treatment processes and ensures compliance with quality standards. By leveraging IoT technologies, water quality management can be transformed into a proactive, data-driven process that safeguards public health and promotes sustainable resource utilization.

II.SYSTEM OVERVIEW

The proposed system is an IoT-based Water Quality Monitoring System developed using the ESP32 microcontroller to monitor essential water quality parameters such as pH, Total Dissolved Solids (TDS), turbidity, and temperature. The respective sensors are placed in the water source to continuously collect real-time data, which is then processed by the ESP32. With its built-in Wi-Fi capability, the processed data is transmitted wirelessly to a cloud-based dashboard for visualization and analysis. The system allows users to remotely monitor water quality through a smartphone or computer, enabling timely detection of contamination or abnormal parameter levels. This automated approach reduces manual testing, enhances accuracy, supports environmental monitoring, and ensures safe and efficient water management.

III. PROPOSED SYSTEM DESIGN

The IoT-enabled water quality analysis is designed to continuously measure and monitor important water quality parameters in real time. The system uses multiple sensors to detect key parameters such as pH, Total Dissolved Solids (TDS), temperature, and turbidity. These sensors are connected to the ESP8266 node MCU microcontroller, which acts as the central processing unit. The ESP8266 node

MCU collects data from the sensors, converts analogy signals into digital values, and processes them for accuracy. The program for the system is developed using the Arduino IDE, which allows easy coding, compilation, and uploading of the program to the microcontroller. The ESP8266 has built-in Wi-Fi capability, which enables the system to send the collected data to a cloud server or IoT platform. Users can monitor the water quality remotely through a web or mobile application.

IV. RELATED WORKS

Recent research in the field of environmental monitoring has seen a significant shift toward the integration of Internet of Things (IoT) technologies to replace manual sampling. Below are key studies and developments from 2024–2025 that align with the objectives of this project:

1. IoT-Based Smart Surveillance and River Monitoring (2025)

Studies published in the International Journal of Emerging Trends in Engineering and Development (2025) highlight the application of the ESP32 microcontroller in IoT-based smart surveillance and river water monitoring systems. These systems integrate multiple sensors, including pH, temperature, turbidity, and Total Dissolved Solids (TDS), to enable continuous real-time data acquisition and analysis of water quality parameters. The ESP32 processes the collected sensor data and utilizes its built-in Wi-Fi capability to transmit the information directly to cloud-based platforms, eliminating the need for additional communication modules and reducing overall system cost and complexity. This seamless connectivity enables remote monitoring through web or mobile interfaces, allowing environmental authorities to quickly detect contamination levels and take timely corrective actions. Such systems significantly enhance environmental protection, particularly in rural and remote areas where conventional laboratory-based monitoring methods are limited.

2. Low-Cost Automated Monitoring for Drinking Water (2024–2025)

Research published in IEEE Xplore (2024) and the International Journal of Computer Systems and Publications (2026, Early Access) highlights the development of low-cost, automated drinking water monitoring systems designed for urban and residential applications. These studies emphasize the use of cloud-based IoT dashboards such as Adafruit IO or Blynk for real-time data visualization and remote monitoring. A notable 2024 implementation introduced signal-conditioning converters for pH and TDS sensors to enhance measurement accuracy and stability before data processing by the ESP32, significantly reducing noise and improving the reliability of low-cost sensor nodes.

3. Performance and Reliability Analysis (2025)

Recent work documented on ResearchGate (November 2025) evaluated the technical robustness of IoT systems for early detection of water pollution. This study measured critical performance metrics: Energy Efficiency: The systems were found to consume approximately 0.18W during active transmission, proving their suitability for solar-powered or battery-operated remote deployment. Latency: Data latency (the time between sensor reading and cloud upload) averaged 1.25 seconds, which is well within the acceptable threshold for real-time environmental monitoring.

4. Advanced Integration: Machine Learning and AI (2025)

Emerging research from the International Journal of Advanced Research in Science, Communication, and Technology (2025) has begun integrating Machine Learning (ML) with the ESP32. These systems not only monitor real-time data but also use algorithms like Random Forest or Decision Trees to classify water as "Potable" or "Non-Potable" with an accuracy exceeding 90%. While this project focuses on real-time analysis, these works establish a future path for automated hazard prediction.

5.Comparative Analysis of Microcontrollers

Recent literature surveys comparing widely used microcontrollers such as Arduino, Node MCU, and ESP8266 consistently conclude that the ESP8266 is the most efficient and reliable platform for water quality monitoring systems. This superiority is largely attributed to its dual-core processor architecture, which allows the system to handle multiple tasks simultaneously, such as real-time sensor data acquisition and continuous Wi-Fi communication, without causing delays or data loss. In contrast, single-core controllers like traditional Arduino boards may experience performance limitations when managing both sensing and networking operations together. Furthermore, the ESP8266 offers a higher 12-bit Analog-to-Digital

Converter (ADC) resolution, which provides greater measurement accuracy and finer signal differentiation for analog sensors such as pH and turbidity. This improved resolution ensures more precise monitoring of water parameters compared to the 10-bit ADC resolution typically available in older Arduino platforms. Additionally, the ESP32 includes built-in Wi-Fi and Bluetooth capabilities, reducing the need for external communication modules and lowering overall system cost and complexity, making it a highly suitable choice for modern IoT-based water monitoring applications.

V.METHODOLOGY

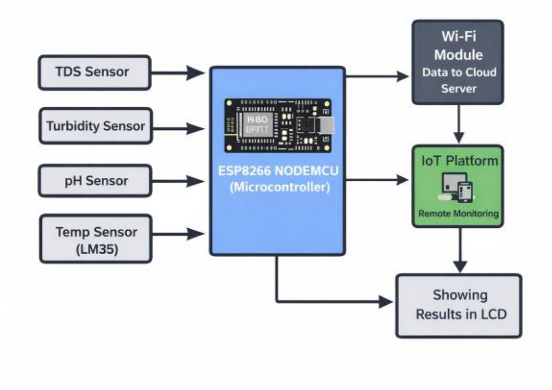

Fig.1 Block Diagram of Proposed system

The proposed IoT-based Water Quality Monitoring System as shown in Fig. 1 is designed to measure important water parameters and provide real-time monitoring using the ESP8266 Node MCU microcontroller. The system consists of several sensors such as the pH sensor, TDS sensor, turbidity sensor, and the LM35 Temperature Sensor, which are connected to the microcontroller.

The pH sensor measures the acidity or alkalinity of the water, which indicates whether the water is suitable for drinking or other purposes. The TDS (Total Dissolved Solids) sensor measures the concentration of dissolved substances such as minerals and salts in the water. The turbidity sensor detects the level of suspended particles and determines the clarity of the water. The LM35 temperature sensor measures the temperature of the water, which is an important factor affecting water quality.

All these sensors send analog or digital signals to the ESP8266 Node MCU, which acts as the central processing unit of the system. The microcontroller processes the collected sensor data and converts it into meaningful values. The program for the system is developed and uploaded using the Arduino IDE.

The ESP8266 also has an inbuilt Wi-Fi module that enables the system to transmit the measured data to an IoT platform or cloud server for remote monitoring. Additionally, the measured parameters are displayed locally using an LCD display for immediate observation. This system enables continuous monitoring of water quality, reduces manual testing, and provides efficient and real-time data analysis for water management.

VI.PARAMETER USED TO DETECT THE QUALITY OF WATER

PH Parameter:

The pH parameter is crucial, as it serves as an indicator of the concentration of hydrogen ions in water. It determines the acidity or alkalinity of water by measuring its pH value. Pure water has a pH value of 7, whereas values below 7 indicate acidity and values above 7 indicate alkalinity. The pH scale ranges from 0 to 14. The pH of drinking water should fall in the range of 6.5 to 8.5, according to WHO standards.

Turbidity:

Turbidity measurement quantifies the presence of imperceptible suspended particles in water. A lower level of turbidity is indicative of cleaner water since it indicates that there is less sediment suspended in the water. Higher levels of turbidity are associated with an increased risk of waterborne infections such as cholera and diarrheal.

Total Dissolved Solids (TDS):

TDS measures water’s total dissolved solids. These include minerals, salts, metals, cations, anions, and organic and inorganic compounds. TDS is usually measured in ppm or mg/L. Monitor TDS levels in water to monitor water quality because elevated TDS levels can suggest pollutants and affect taste, Odor and appropriateness for drinking and industrial use.

Temperature:

Temperature is an important parameter in water quality analysis because it affects the physical and chemical properties of water. It influences the level of dissolved oxygen and the survival of aquatic organisms. Changes in temperature can also affect chemical reactions and biological activities in water. Therefore, monitoring temperature helps in understanding the overall condition and quality of the water.

Standard values in water quality analysis:

Parameters	Unit	Range
pH	Ph unit	6.5-8.5
Turbidity	NTU	0-5
Temperature	C	10-25
TDS	Mg/l	4-6

VII. OUTPUT

The measured water quality parameters obtained from the IoT monitoring system are compared with the standard limits recommended by the World Health Organization and Bureau of Indian Standards. The recorded pH value of 9.44 exceeds the acceptable range of 6.5–8.5, indicating alkaline water. The TDS value of 608 mg/L is higher than the desirable limit of 500 mg/L, while the turbidity value of 615 NTU greatly exceeds the permissible level. However, the temperature of 20.9 °C falls within the normal range. Overall, the results indicate that the water quality is unsuitable for drinking.

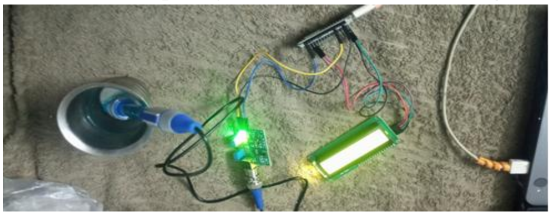

Fig 2 pH

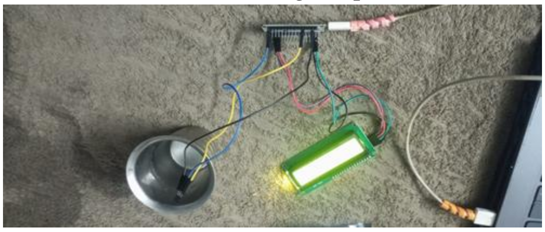

Fig 3 Temperature

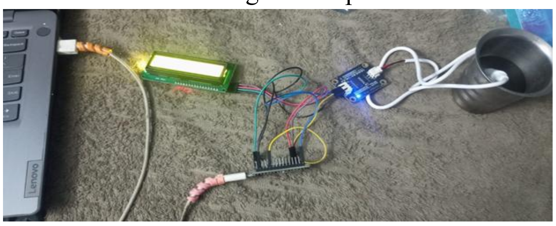

Fig 4 TDS

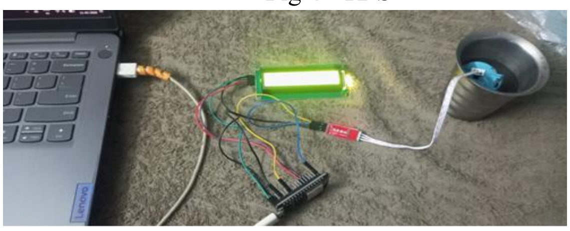

Fig 5 Turbidity

Fig 6 Output in LCD

Comparison of standard value and Measured value output:

Parameter	Unit	Measured Value	Standard Value (Drinking Water)
pH	pH scale	9.44	6.5 – 8.5
Total Dissolved Solids (TDS)	mg/L	608	≤ 500 mg/L
Turbidity	NTU	615	≤ 5 NTU
Temperature	°C	20.9	20 – 30 °C (normal range)

VIII.FUTURE SCOPE

The proposed IoT-Based Water Quality Monitoring System can be further enhanced by integrating advanced technologies and additional features to improve its performance and scalability. In the future, the system can incorporate Artificial Intelligence and Machine Learning algorithms to predict water contamination trends and detect anomalies automatically. Integration of GSM or SMS alert systems can enable instant notifications to authorities when water parameters exceed safe limits.

The system can also be expanded by adding more sensors to measure parameters such as dissolved oxygen, conductivity, and biological contaminants for comprehensive water analysis. Development of a dedicated mobile application with user authentication and data analytics features can improve user accessibility and security. Furthermore, the system can be deployed on a large scale for smart city water management, industrial water treatment plants, and rural water supply monitoring, contributing to sustainable environmental protection and efficient water resource management.

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