



Design and Development of Drinking Water Quality Alert System with Voice Announcement for Remote Areas

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Abstract: Due to rising levels of water contamination and pollution, ensuring safe drinking water is an essential public health necessity. Traditional techniques for testing the quality of water are labor-intensive, manual, and do not yield data in real time. The development of a drinking water quality monitoring and alert system that allows for ongoing, real-time water quality parameter monitoring is presented in this project. Essential parameters like pH, turbidity, total dissolved solids (TDS), and drinking water temperature are measured by the system using a variety of sensors. These sensors are connected to a Wi-Fi-capable microcontroller, which gathers and sends sensor data to a cloud platform for processing and archiving. When anomalous conditions are found, users or relevant authorities receive immediate alerts that compare the monitored values with accepted safe drinking water limits. This system helps prevent water-borne illnesses, minimizes human labor, and guarantees prompt detection of water contamination. The suggested solution is affordable, scalable, and appropriate for applications involving rural water supplies and smart cities. By making sure that everyone, even those with low literacy levels, receives important warnings, the voice alert feature increases community awareness and response times. This device can be employed in rural and remote areas for long period since the system is made to work 24/7 with little or no human intervention. IoT makes the data to be visually represent to view live data through a dashboard or mobile applications so that authorities and residents can have water quality data with them no matter what location they are in. It logs historical water quality data, used for further analysis and management purposes.

Keywords: IoT for Water Quality Monitoring using ESP32 with pH, TDS, and Turbidity sensors, coupled with an Alert System that is voice controlled and also pushes notificataions on Blynk.

I. INTRODUCTION

In the home, agricultural, and industrial sectors, water contamination and inadequate quality monitoring continue to be significant problems that frequently result in health hazards and environmental deterioration. Manual sampling and laboratory analysis are the mainstays of traditional water testing techniques, which are laborious and do not allow for real-time monitoring [1]. Modern Internet of Things (IoT) technology places a strong emphasis on ongoing remote monitoring through the use of cloud platforms and smart sensors, greatly increasing productivity and reaction time [2]. Research has indicated that the integration of wireless communication modules with microcontrollers facilitates automated data collection and real-time transmission to cloud dashboards for analysis and visualization [3][4]. Numerous studies have examined Internet of Things (IoT)-based water quality monitoring systems, emphasizing automation's ability to increase accuracy, scalability, and minimize human intervention [5, 6, 7]. The proposed system fills a clear research gap because, despite these advancements, many existing systems mainly concentrate on parameter monitoring and cloud visualization, with little attention paid to integrated multi-parameter analysis, real-time SMS alerts, and low-cost scalable deployment for rural areas. Many existing systems do not provide proper user-friendly alert features to the non-technical rural community users. The most common solutions are built on mobile applications or internet connection which can be an unreliable factor in most of the remote areas. Thus to remove such drawbacks of existing solutions a Low-Cost real-time monitoring with a voice announcement feature and decision-making based alert mechanism system to check multiple parameters (pH, turbidity and TDS) has been proposed. The system is capable to simultaneously monitor the multiple parameters, do real time analysis based on the given safe limit and do automatic decision and generates local real-time alert with a voice announcement system.

II. LITERATURE SURVEY

IoT-based automation of environmental monitoring systems has been the subject of much recent research, especially in the area of water quality evaluation. A fundamental strategy for the real-time measurement of water parameters like



pH, turbidity, and Total Dissolved Solids (TDS) is the combination of microcontrollers and smart sensors, which greatly lessens reliance on manual sampling techniques [1]. According to studies, wirelessly enabled controllers, such as the ESP32, facilitate smooth data transfer to cloud platforms, allowing for ongoing remote monitoring in both residential and commercial settings [2]. A number of studies concentrate on intelligent cloud-based visualization and alert systems that go beyond simple monitoring. Web dashboards and IoT platforms have been used to provide automated alerts when safety thresholds are exceeded as well as graphical representation of water parameters [3][4]. When compared to conventional laboratory-based testing systems, these methods show increased efficiency, quicker reaction times, and improved reliability. Additional research suggests that automated alert systems enhance public health safety by offering immediate notifications during contamination incidents [5][6].

In water monitoring systems, sensor calibration and accuracy enhancement have also become important research topics. Numerous studies look at filtering algorithms and signal conditioning strategies to improve measurement accuracy in a range of environmental circumstances [7][8]. Low-cost embedded solutions that can achieve acceptable accuracy levels for real-world deployment—even in rural and resource-constrained areas—are presented in existing literature. It has been demonstrated that incorporating several sensors into a single monitoring framework increases the system's overall robustness and capacity for multi-parameter analysis [9]. Despite these developments, existing systems mainly concentrate on isolated parameter monitoring or simple cloud visualization, providing little assistance for SMS-based alert systems, scalable low-cost deployment models, and integrated multi-parameter analytics. Furthermore, many studies pay relatively little attention to quantitative evaluation metrics like performance validation, threshold optimization, and long-term data logging [10]. The foundation of the proposed research is the need for an integrated smart water quality monitoring system that integrates real-time sensing, cloud integration, automated alert mechanisms, and workable deployment strategies.

III. SYSTEM ANALYSIS

A. EXISTING SYSTEM

Fig.1: Shows Our current approach consists of manual water sampling and analysis in the laboratory. Water samples from various sources are manually drawn and laboratory analyzed to determine the quality parameters. The process is not only laborious but it does not involve real-time analysis, there is no alert system.

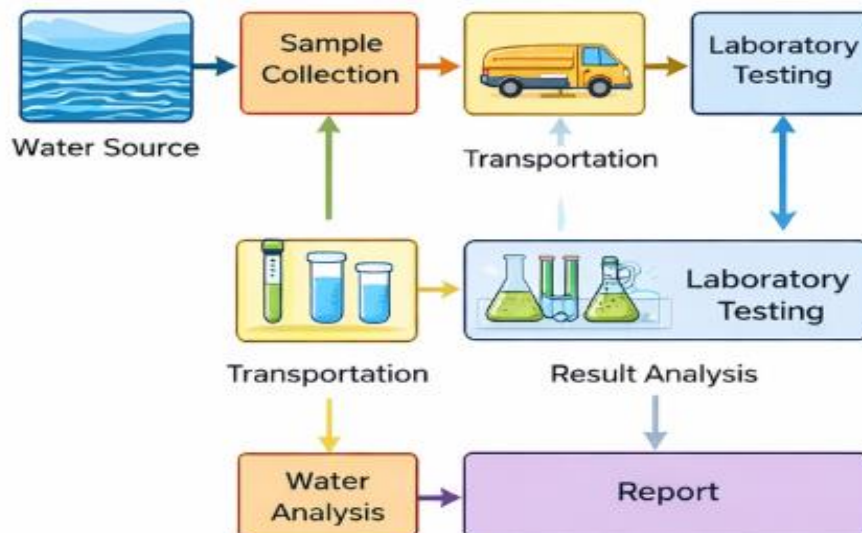


Fig.1: Water Quality Testing Process Flow

The present water quality monitoring process mainly rely on manual sampling method and laboratory testing method. Water samples are collected from river, lake, well, borehole and tank in accordance to the procedure and then are brought to laboratory to test water parameters like pH, turbidity, temperature, and total dissolved solid (TDS). This system can bring accurate result. However, manual sampling is time consuming and laborsome work including: taking the sample, transporting, analyzing the water sample and then making the report. The time gap from the time of sample taking till getting the results makes water quality information non-reliable as the water quality itself can vary over this time and the taken water sample is not suitable for real-time analysis. Another problem associated with this approach is lack of real-time process. This traditional manual system only collected samples at a given time, therefore,



it can not detect unexpected contamination or unexpected water pollution. It demands the involvement of skilled people, the collected samples can only be carefully processed and handled manually to minimize potential human error or risk, and the operational cost is higher. Moreover, the system has no intelligent automation and analysis on its own, for example, no automated system compares water results with safety limits, and no trends are analysed based on accumulated history data.

B. PROPOSED SYSTEM

Fig.2: Shows the present system, we are using different sensors with ESP32, which can sense the water parameters like pH, turbidity and TDS values constantly to check quality of water in real-time. When any value crosses safe range we create alerts and alerts on buzzer, voice and we send this data to the Blynk IoT.

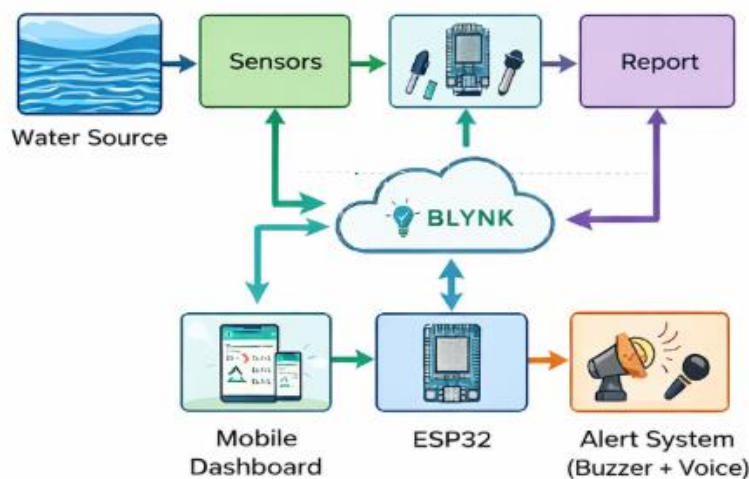


Fig.2: IoT-Based Drinking Water Quality Monitoring and Alert System

The proposed system enhances public safety and response time by coupling an Internet of Things (IoT)-based smart water quality monitoring system with a real-time voice alert mechanism. The system uses an ESP32 microcontroller to manage embedded sensors that continuously collect water quality data (such as pH, turbidity, temperature, and total dissolved solids - TDS) for the source and points of delivery. As opposed to conventional measurement methods, the monitored data is pushed into a cloud platform for long-distance data retrieval and management, analysis, storage, and usage. In case any parameter exceeds defined safety margins, the system will instantly trigger a buzzer, broadcast a voice announcement for local warning, and simultaneously notify the users via an Internet-connected mobile application; thereby the alerts can also be perceived in areas lacking internet service. Additionally, it permits for sustained storage of the data from all the sensor readings to perform historically data analysis. Moreover, through the integration of elementary data analytical methods and an anomaly detection approach, uncommon water quality variations and sudden change can also be detected by identifying patterns, anomalies and unexpected patterns and alerting to any imminent threat. It has a flexible and extendable system architecture so that further sensors and sophisticated techniques (such as machine learning for prediction of potential contamination events in the future) may be further appended in the coming days to achieve better results in the process. As the cost of system is minimal, energy effective and user friendly it is also ideally fit for remote and rural area; so, the system can implement affordable hardware elements (e.g. ESP32 micro-controller) to minimize device costs, thereby the most suitable options in such remote locations for providing warnings at reasonable cost and for ease to operation and maintenance even among low literacy level peoples by virtue of its voiced alerts .

IV. METHODOLOGY

Module 1: Sensor Data Collection Module

It employs the use of various water quality sensors located at the water source to determine the essential parameters of drinking water, which include pH, Turbidity, and Total Dissolved Solids (TDS).

- The system initializes all sensors during the startup process and continuously reads the analog signals produced by the sensors.
- The raw analog data is then converted to measurable units (pH value, NTU, ppm) using calibration formulas.



Module 2: Data Processing & Calibration Module

The raw sensor output may include fluctuations and noise based on environmental factors.

- This module involves analog-to-digital conversion and the use of calibration equations to transform voltage measurements into normalized water quality data.
- The processed data is compared to pre-defined safe limits based on WHO guidelines for drinking water quality.
- The validated data is transmitted for cloud transmission and alert evaluation.

Module 3: IoT Communication Module

- To enable remote monitoring of water quality in real time.
- The Node MCU connects to Wi-Fi and establishes communication with the Blynk IoT cloud platform.
- Sensor values are transmitted using virtual pins to the mobile dashboard.
- The system ensures continuous data updates at fixed intervals (e.g., every 3 seconds).
- In case of unsafe water detection, an event notification is triggered on the Blynk mobile application.

Module 4 : Threshold Evaluation & Decision Module

This module checks whether the water is safe or contaminated.

- The processed sensor values are compared with the threshold values:
pH level: 6.5 – 8.5 TDS: ≤ 500 ppm Turbidity: ≤ 5 NTU
- If any of the values go beyond the safe limits, the water is declared “Unsafe.”
- The result is transmitted to the alert module for further processing.

Module 5: Voice Alert & Buzzer Notification Module

- To issue immediate local warnings at the water source point.
- Upon detection of unsafe water, the DFPlayer Mini module is responsible for playing a voice message through a speaker.
- A buzzer is also activated at the same time.
- This is to ensure that even the illiterate or elderly are able to comprehend the warning without the need for a smartphone

Module 6 Monitoring & User Interface Module

- Offers real-time graphical representation of water quality values on the Blynk mobile app.
- Offers real-time graphical and numeric representation of pH, turbidity, and TDS values.
- Allows for remote monitoring from anywhere with internet access.

Allows for storage of data logs in the cloud for future analysis

V. RESULTS

Fig 3 shows the complete architecture of an IoT-enabled water monitoring system

The entire water monitoring system is built using an ESP32 which takes pH, turbidity and TDS sensors as its inputs. These sensors are used to measure the amount of water in real-time. The collected data is transmitted to the ESP32 micro-controller and later to cloud server through transmission and power supplies as presented. This prototype provides a real and useful insight into designing such systems.

Each sensor helps find the water quality in this application setup pH sensors indicate whether water is acid or alkaline; turbidity sensors assess water clearness and TDS sensor measures dissolved solids to make sure the quality is suitable for drinking. These sensors have been fully submerged in water samples.

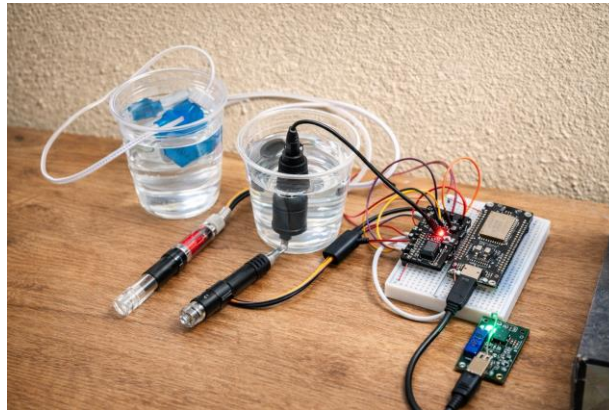


Fig.3: IoT-based Prototype for Monitoring Water Quality

Fig. 4 shows the IoT-based water quality monitoring dashboard implemented in the Blynk mobile application. On the dashboard, we can visualize the key parameters of water like pH, turbidity, and total dissolved solids (TDS) in real-time.



Fig.4: Blynk Dashboard Showing Parameters Of Water Quality

Fig. 5 shows the serial monitor output for safe limits of water quality parameters. The water quality system real time shows the values of pH, TDS and Turbidity from the sensors and based on the parameters they fall in safe range the output is SAFE which means the water is safe to drink and use.

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Output Serial Monitor X
Message (Enter to send message to 'ESP32 Dev Module' on 'COM6')
TDS: 450 ppm
Turbidity: 0.0 NTU
Status: ✓ SAFE
-----
--- MONITORING STATUS ---
pH: 7.17 (2.45V)
TDS: 450 ppm
Turbidity: 0.0 NTU
Status: ✓ SAFE
    
```

Fig.5: Safe water condition



Fig.6 shows about the serial monitor output when the water quality exceeds safe limits. The system displays real-time values of pH, TDS, and turbidity, where the turbidity level is high, indicating contamination. As a result, the system marks the water status as UNSAFE.

This output confirms that the system can effectively detect abnormal conditions and alert users immediately. The serial monitor helps in monitoring sensor readings and verifying the system's response during unsafe situations

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Output Serial Monitor X
Message (Enter to send message to 'ESP32 Dev Module' on 'COM6')

Turbidity: 356.0 NTU
Status: ⚠ UNSAFE
-----

--- MONITORING STATUS ---
pH: 7.70 (2.30V)
TDS: 584 ppm
Turbidity: 108.7 NTU
Status: ⚠ UNSAFE

```

Fig.6: Unsafe water condition

Fig.7 shows the serial monitor output displaying continuous water quality readings over time. The system records parameters such as pH, turbidity, and TDS at regular intervals. The values indicate abnormal conditions, where pH is low and turbidity and TDS levels are high, suggesting poor water quality.

This output demonstrates the system's ability to perform continuous monitoring and log real-time data, helping in identifying changes in water quality and detecting contamination effectively

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Output Serial Monitor X
Message (Enter to send message to 'ESP32 Dev Module' on 'COM7')

12:53:09.467 -> -----
12:53:14.487 -> ---- Water Quality ----
12:53:14.487 -> pH: 3.74
12:53:14.487 -> Turbidity (NTU approx): 147.75
12:53:14.487 -> TDS (ppm): 717.39
12:53:14.487 -> -----
12:53:19.506 -> ---- Water Quality ----
12:53:19.506 -> pH: 3.42
12:53:19.506 -> Turbidity (NTU approx): 148.72
12:53:19.506 -> TDS (ppm): 717.39
12:53:19.506 -> -----

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Fig.7: Water Quality Parameters Serial Monitor

VI. CONCLUSION

In this project, an IoT-Based Drinking Water Quality Monitoring and Alert System with Voice Announcement has been successfully designed and implemented. The system uses sensors such as pH sensor, TDS sensor, and turbidity sensor to continuously monitor important water quality parameters. The collected data is processed by the ESP32 microcontroller, which evaluates whether the water quality falls within safe drinking limits.

The system also integrates IoT technology using the Blynk platform, allowing real-time monitoring of water quality through a mobile application or dashboard. Whenever the water quality parameters exceed the predefined safe limits, the system generates alerts using a buzzer and status notification, ensuring that users are immediately informed about unsafe water conditions.



The implementation results show that the system can accurately detect both safe and unsafe water conditions and display the results on the serial monitor and IoT dashboard. This system provides a low-cost, efficient, and reliable solution for monitoring drinking water quality, especially in rural and remote areas where regular water testing facilities may not be available.

Overall, the developed system helps ensure safe drinking water and supports better health and environmental safety. Moreover, the system is highly dependable and capable to regularly survey parameters like water quality along with negligible human interruption. It enables fast tracing out of any anomaly using the obtained and processed data as and when there is occurrence of anything unusual.

VII. FUTURE SCOPE

Additional sensors can be integrated into the proposed IoT-based water quality monitoring system to detect water quality more Parameters including Dissolved Oxygen (DO), Temperature, Biological Contaminants can be additionally incorporated to provide the comprehensive water quality status with great efficiency and accuracy. Features like ML to forecast water quality; predict water contamination; providing solar power as supply for the system .SMS,mobile app based water quality reports, government monitoring; smart city infrastructure based on water quality information can also be introduced in the future to improve the overall system and provide more benefits. Furthermore, by using web based advanced monitoring dashboard, the decision can be taken based on data analysis and historical information and also by improving the voice indication system in multilingual format helps a diverse range of public users. By implementing those, the system would more effective, reliable, scalable, intellectual, and user friendly.

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