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IOT-Based Smart Drinking Water Safety Monitoring System with On-Demand User Display

Akshya Sri S, UG Scholar,
Vels Institute of Science,
Technology And Advanced Studies (VISTAS), Pallavaram,
Chennai-600117,
Tamil Nadu, India.

Dr. R.Parameswari, Head & Professor,
Vels Institute of Science,
Technology And Advanced Studies (VISTAS), Pallavaram,
Chennai-600117,
Tamil Nadu, India.

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Abstract: Water quality monitoring is es-sential for ensuring safe drinking water and protecting public health. With in-creasing pollution and improper waste management, the quality of drinking wa-ter is being affected in many regions. Tra-ditional methods of water testing rely on manual sampling and laboratory analy-sis, which are time-consuming, labor-in-tensive, and not suitable for quick deci-sion-making. Therefore, there is a need for an efficient and user-friendly system to monitor water quality effectively.This project proposes an IoT-Based Smart Drinking Water Safety Monitoring Sys-tem with On-Demand User Display. The system uses a turbidity sensor to measure the clarity of water, which is an im-portant indicator of water quality. A NodeMCU (ESP8266) microcontroller is used to process the collected sensor data and enable wireless communication through Wi-Fi. The system is designed as an on-demand monitoring solution, where the user can check the water qual-ity by clicking a "Check Water Status" button on the web interface. Upon user request, the system processes the data and displays the result on an LCD, while also updating the status on the web page. The system classifies water quality into categories such as 'Clean', 'Moderate', and 'Contaminated' based on predefined threshold values. This approach reduces unnecessary continuous monitoring and provides efficient resource usage. It also improves accuracy, reduces manual ef-fort, and ensures user convenience. Over-all, the proposed system offers a cost-ef-fective, reliable, and scalable solution for modern drinking water safety monitor-ing.

Keywords: Internet of Things (IoT), NodeMCU (ESP8266), Turbidity Sensor, Water Quality Monitoring, Real-Time Monitoring, Wireless Communication, Embedded Systems, Web Interface.

I.INTRODUCTION

An A smart water quality monitoring sys-tem is an IoT-based platform designed to measure and display water turbidity levels using an embedded system and web inter-face. The system is developed to provide real-time monitoring using NodeMCU, which acts as the main controller and com-munication unit. With the help of this sys-tem, water quality can be assessed, ana-lyzed, and displayed efficiently through both hardware and software interfaces. The project focuses on integrating sensor data acquisition, processing, and user interaction to create a reliable and practical monitoring solution.

The system is primarily designed to simu-late and demonstrate real-time water quality analysis, data processing, and web-based visualization. It provides an interface for users to check water status through a browser, while also displaying results on an LCD screen for immediate feedback. The NodeMCU connects to a wireless network and hosts a local web server, allowing users to access the system using an IP address. This enables remote monitoring and en-hances usability. The system is also useful for understanding basic IoT concepts, em-bedded programming, and web integration.

The platform continuously processes tur-bidity values and categorizes water quality into SAFE, MODERATE, and UNSAFE
levels based on predefined thresholds. These values are displayed on the LCD and web interface with proper formatting and color indication. The system also stores re-cent readings in memory and presents them in a structured table format on the webpage. This feature helps in analyzing trends and improves the overall functionality of the system. The implementation includes both hardware integration and software develop-ment using Arduino IDE and embedded C programming.

The system architecture consists of NodeMCU, LCD display with I2C module, and a turbidity sensor module. Due to hard-ware calibration limitations, simulated tur-bidity values are used for demonstration purposes while maintaining the full logic and functionality of the system. The web in-terface is designed using simple HTML and styling to provide a user-friendly experi-ence. The interface includes a button to trig-ger water quality checks and dynamically updates results along with stored data.

The project is structured to provide an ef-fective learning and demonstration plat-form for IoT-based environmental monitor-ing systems. It allows users to understand system design, data handling, and real-time interaction without complexity. The inte-gration of hardware and software components ensures smooth operation and reliability. Overall, the system serves as a practical solution for monitoring water quality and can be further enhanced with real-time sensor integration and cloud stor-age capabilities for advanced applications.

Types of Coding Challenges

The three main types of water quality levels based on turbidity values are:

- **Safe Water**

Safe water has low turbidity levels indicat-ing clear and clean conditions. These are typically observed in normal drinking water where there is minimal presence of sus-pended particles. The safe category is iden-tified when the turbidity value falls within a lower range and confirms that the water is suitable for basic usage and consumption.

- **Moderate Water**

Moderate water represents a medium level of turbidity with a noticeable presence of impurities. It requires attention as it may not be fully safe for direct consumption without treatment. Moderate levels occur when turbidity values lie within an interme-diate range and reflect partially contami-nated water conditions.

- **Unsafe Water**

Unsafe water has high turbidity levels indi-cating heavy contamination and poor qual-ity. This condition occurs when a large number of suspended particles are present, making the water unsuitable for use. It re-quires filtration or purification before any application, as the turbidity values exceed safe limits and indicate serious quality is-sues.

II.LITERATURE REVIEW

The conceptualization of the smart water quality monitoring system is based on ex-isting research in Internet of Things (IoT), embedded systems, and environmental monitoring technologies. This section dis-cusses the foundational concepts and technological approaches that support the design and implementation of the proposed system.

1. IoT-Based System Architecture

Recent studies highlight the use of IoT ar-chitectures for real-time monitoring appli-cations. The integration of microcontrollers with wireless communication enables effi-cient data collection and remote access. Such systems ensure continuous monitor-ing and improved decision-making through connected devices.

2. Water Quality Monitoring Systems

Research indicates that turbidity is a key pa-rameter for assessing water quality. Various systems utilize turbidity sensors to detect suspended particles and impurities in water. These monitoring systems are widely ap-plied in environmental studies and smart water management solutions.

3. Embedded Systems and Microcontrol-lers

Embedded platforms such as NodeMCU are commonly used for developing low-cost and efficient monitoring systems. Their ability to interface with sensors and com-municate over Wi-Fi makes them suitable for real-time applications. These systems provide reliable performance with minimal power consumption.

4. Wireless Communication and Web In-terfaces

Modern systems integrate wireless commu-nication to enable remote monitoring through web-based platforms. Web inter-faces provide user-friendly access to real-time data and system status. This improves accessibility and allows users to monitor environmental conditions from any loca-tion.

5. Data Processing and Visualization

Data visualization plays a vital role in un-derstanding system outputs. Structured rep-resentation of sensor data using tables and visual indicators enhances clarity. Real-time data processing helps in classifying and presenting results effectively for user interpretation.

6. Innovations in Smart Water Monitor-ing System

Unlike traditional monitoring methods, the proposed system integrates sensing, pro-cessing, and web-based display into a single platform. It provides real-time feedback through both LCD and web interfaces. The system also includes simulated data han-dling for demonstration, ensuring con-sistent functionality and improved usability in practical applications.

III.METHODLOGY

The architecture of the smart water quality monitoring system follows a structured and modular approach integrating hardware components, embedded programming, and web-based communication systems.

1. Hardware Architecture (NodeMCU & Sensor Interface)

- The system hardware is designed using NodeMCU, which facilitates:
- Real-time data acquisition from tur-bidity sensor
- Interface with LCD display using I2C protocol
- Efficient control and processing of input signals

2. Embedded Programming (Arduino IDE)

The software logic is implemented using embedded C/C++, which manages:

- Sensor data reading and processing
- Classification of water quality lev-els
- Control of LCD output and display updates

3. Data Handling and Processing

The system processes turbidity values using predefined logic to determine:

- Safe water conditions
- Moderate contamination levels
- Unsafe water quality states

4. Wireless Communication (Wi-Fi Mod-ule)

The NodeMCU uses built-in Wi-Fi capabil-ities to ensure:

- Connection to local wireless net-work
- Hosting of a local web server
- Remote access to system data through IP address

5. Web Interface Module

The web-based platform enables users to:

- Request water quality status through a browser
- View results with clear visual repre-sentation
- Access stored readings in tabular format

6. Comprehensive System Integration

All system components are integrated to en-sure smooth communication between hard-ware, software, and user interface. The final system operates efficiently by combining real-time monitoring, data processing, and user interaction into a single unified plat-form.

IV. IMPLEMENTATION

The implementation phase involves con-verting the system design into a fully func-tional smart water monitoring platform. The hardware components are assembled to ensure proper communication between the NodeMCU, turbidity sensor, and LCD dis-play. The system is designed to provide smooth operation and real-time interaction through both hardware and web interfaces.

Users can easily access the system through a browser to check water quality status. The NodeMCU is programmed using the Ar-duino IDE, where embedded C/C++ code is used to handle sensor data processing and system control. The built-in Wi-Fi module enables communication between the device and the web interface by hosting a local server. This allows efficient data exchange and remote access using an IP address. The LCD display is integrated using I2C com-munication to provide immediate visual output. The system processes turbidity val-ues (simulated for demonstration due to hardware limitations) and classifies water quality into SAFE, MODERATE, and UN-SAFE categories. The results are displayed on both the LCD and the web page with proper formatting and color indication. The web interface is designed to be simple and user-friendly, allowing users to request and view results easily. Key features imple-mented include a real-time monitoring sys-tem, LCD display output, a web-based in-terface, and a structured table to store recent readings. The system also supports contin-uous updates and user interaction through a button-based request mechanism. The en-tire setup is tested under different condi-tions to ensure consistent performance, re-liability, and responsiveness.

V. WORKING PRINCIPLE

The smart water quality monitoring system operates on an embedded and web-based ar-chitecture utilizing NodeMCU, sensor inte-gration, and wireless communication. The framework is designed to enable seamless interaction between hardware components and users through efficient data processing and real-time monitoring mechanisms.

1. User Interaction Layer (Web Inter-face)

The operational workflow begins at the web interface, which is accessed through a browser using the NodeMCU IP address. Users interact with the system through a simple and responsive webpage where they can request water quality status. The interface dynamically displays results and updates based on user actions and system responses.

2. Request Handling and Communica-tion

When a user initiates a request (e.g., click-ing the "Check Water Status" button), the browser sends an HTTP request to the NodeMCU server. The request is received and processed by predefined routes within the embedded web server. The system inter-prets the request and prepares the appropri-ate response.

3. Core Processing Layer (NodeMCU)

The NodeMCU acts as the central pro-cessing unit of the system. It performs the following functions:

- Reads turbidity values (simulated for demonstration)
- Processes data based on predefined thresholds
- Controls LCD display output
- Manages communication with the web interface
- This ensures efficient and continu-ous system operation.

4. Data Handling and Storage

The system temporarily stores recent tur-bidity readings in memory, including:

- Turbidity values
- Water quality status (SAFE, MOD-ERATE, UNSAFE)
- Sequential reading records

These records are used to generate a struc-tured table on the web interface for easy vis-ualization and tracking.

5. Water Quality Evaluation Mechanism

A key component of the system is the clas-sification process. When a reading is gener-ated:

- The turbidity value is obtained (or simulated)
- The value is compared against pre-defined limits
- The system categorizes the water as SAFE, MODERATE, or UNSAFE
- The result is formatted for display
- This mechanism ensures quick and accurate interpretation of water quality.

6. Response Generation and Display Up-dating

After processing, the NodeMCU sends the response back to the browser. The web in-terface updates to display:

- Water quality status with color indi-cation
- Latest turbidity reading
- Stored data in tabular format
- Simultaneously, the LCD display is updated to show the current status, providing immediate feedback.

7. Continuous Monitoring and Interac-tion

The system continuously supports user in-teraction by allowing repeated requests. Each interaction updates the stored data and display output, enabling:

- Multiple reading comparisons
- Real-time monitoring experience
- Improved user engagement

8. System Reliability and Communica-tion

The system ensures stable communication through Wi-Fi connectivity and proper data handling. It maintains:

- Consistent network connection
- Accurate data processing
- Reliable display updates
- This guarantees smooth operation across all system components.

9. Consolidated System Workflow

The complete system workflow can be summarized as follows:

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- User accesses the web interface using IP address
- User clicks the water status request button
- NodeMCU receives and processes the request
- Turbidity value is generated and evaluated
- Water quality status is determined
- Results are displayed on LCD and web page
- Data is stored and updated for future reference

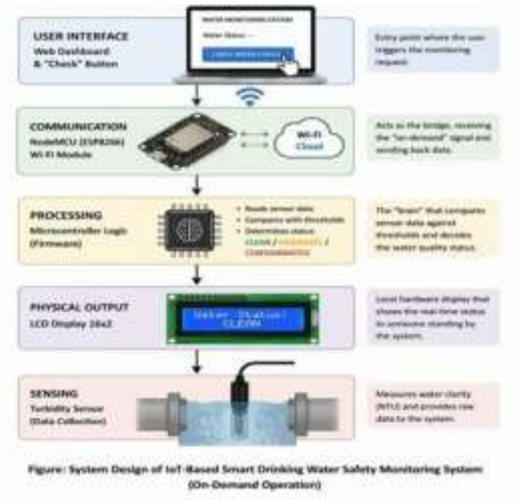

Figure: System Design of IoT-Based Smart Drinking Water Safety Monitoring System (On-Demand Operation)

VI. RESULT

The smart water quality monitoring system was successfully developed and tested us-ing NodeMCU and IoT-based technologies, demonstrating its effectiveness in providing a reliable solution for real-time water qual-ity analysis. The system integrates sensor-based data acquisition, processing, and web-based visualization into a unified plat-form, ensuring a smooth and interactive user experience. The implementation was evaluated based on system functionality, re-sponse time, and usability. Users were able to access the web interface and retrieve wa-ter quality status without delays. The client-side web interface delivered a simple and responsive experience across different de-vices. The integrated monitoring module operated efficiently, allowing users to re-quest water quality status instantly. The NodeMCU processed turbidity values (sim-ulated for demonstration) and classified them accurately based on predefined thresholds. The results were displayed sim-ultaneously on the LCD and web interface, ensuring consistency and reliability. This mechanism enabled effective visualization of water conditions. The data handling sub-system stored recent readings and presented them in a structured table format, allowing users to observe variations and trends. The system maintained stable wireless commu-nication, ensuring continuous connectivity and data exchange. Furthermore, the system ensured operational reliability through proper power management and stable per-formance. Overall, the integration of hard-ware and software components resulted in a functional and efficient monitoring system.

The smart water quality monitoring system successfully achieves the following tech-nical objectives:

- Provides real-time water quality monitoring
- Enables wireless data access through web interface
- Displays output on both LCD and browser
- Stores and visualizes recent read-ings
- Offers a simple and user-friendly design

Ultimately, the system improves accessibil-ity to water quality information and demon-strates an effective IoT-based environmen-tal monitoring solution.

Fig 1 Hardware Setup

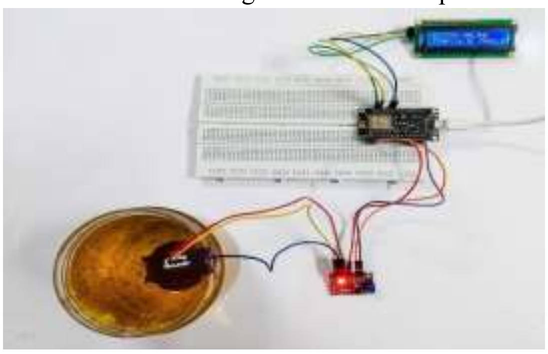

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Fig 2 Water Sample

Fig 3 LCD Output

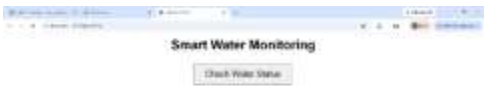

Fig 4 Login Page

Fig 5 Web Result Page

VII. CONCLUSION

The smart water quality monitoring system successfully demonstrates the effective application of IoT and embedded system technologies in developing a reliable, effi-cient, and-user-friendly-environmental monitoring solution. The system seamlessly integrates multiple functionalities—includ-ing real-time turbidity monitoring, LCD-based output display, web-based interac-tion, and structured data visualization—into a single cohesive platform. Users can easily observe water quality status, understand variations in turbidity levels, and monitor system outputs through both hardware and web interfaces. The implementation of wireless communication ensures remote ac-cessibility and enhances overall usability. The use of NodeMCU enables efficient data processing and system control, while the web interface provides a responsive and in-teractive user experience. Additionally, the system incorporates simulated data han-dling to maintain consistent functionality in the presence of hardware limitations. The integration of data storage and tabular visu-alization allows users to track recent read-ings and analyze trends effectively. Overall, the system fulfills its primary objective of providing a practical and accessible solu-tion for water quality monitoring. It not only improves awareness of environmental conditions but also serves as a foundational platform for future enhancements such as real-time sensor calibration, cloud integra-tion, and large-scale monitoring applica-tions.

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