SMART WATER QUALITY MONITORING BOTTLE

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ABSTRACT:
The project "Smart water quality monitoring bottle", designed to access clean drinking water in real time. The bottle continuously monitors the water quality parameters through integrated sensors like TDS (total dissolved solids), pH, Temperature. Data is processed by a microcontroller and it displays on the bottle itself, These readings give users quick insights into whether the water is potentially safe to drink or not. This project promotes health and hygiene by enabling water testing, especially useful in remote or uncertain environments. This system provides transparent, sensor-based water quality monitoring. It is a simple, portable, and affordable solution that encourages users to make decisions about the water that they consume. The design is simple, efficient, and sustainable, offering a low-power, low-maintenance tool to support public health and environmental safety.

Keywords: Water quality, monitoring, TDS, pH, Temperature, hygiene, safety.

I. INTRODUCTION:
Access to clean and safe drinking water is one of the most critical necessities for maintaining human health. However, despite the widespread availability of bottled or tap water in urban and semi-urban areas, the quality of drinking water is not always guaranteed. Factors such as aging pipelines, industrial pollution, chemical contamination, and improper storage can significantly degrade water quality even before it reaches the end-user. In rural or underdeveloped regions, this problem is even more pronounced due to the lack of real-time water testing infrastructure. Drinking contaminated water can lead to serious health issues including gastrointestinal infections, heavy metal poisoning, and long-term chronic diseases.

To address this growing concern, there is a pressing need for portable, user-friendly devices that allow individuals to assess the quality of their drinking water in real-time. The Smart Water Quality Monitoring Bottle is an innovative solution designed to meet this need. It combines the portability of a traditional water bottle with the intelligence of an embedded monitoring system, enabling users to assess water safety instantly, anytime and anywhere.

This smart bottle integrates multiple water quality sensors, including a TDS (Total Dissolved Solids) sensor, a pH sensor, and a temperature sensor, to evaluate the potability of the water it contains. These sensors are controlled and managed by a low-power microcontroller, such as the ESP32 or Arduino, which processes the sensor data and displays the results on a compact OLED screen or transmits them wirelessly to a smartphone application. This allows users to receive instant feedback on whether the water is safe to drink, along with parameters like pH value, mineral content, and temperature.

The system is designed to be lightweight, compact, and battery-operated, making it ideal for outdoor activities such as hiking, camping, and traveling in areas with uncertain water sources. It is also highly useful in domestic environments to double-check tap water or stored water before consumption. By integrating real-time alerts, the system warns the user when water falls outside the safe limits, helping prevent potential health risks.

What sets this project apart is its potential for everyday usability and real-world impact. While water quality monitoring is commonly done in centralized laboratories or municipal systems, this project decentralizes the process, placing the power of water testing directly into the hands of the individual. The smart water bottle not only improves safety and awareness but also promotes better hydration habits and environmental consciousness.

II. RELATED WORK:

Several studies have explored the integration of IoT sensors with wireless communication technologies to create intelligent environmental sensing networks [1]. These networks have been deployed for applications such as air quality monitoring, water level detection, weather observation, and pollution control [2]. For example, IoT-enabled air quality monitoring systems have been implemented using gas sensors and microcontrollers to continuously evaluate pollutants and alert users through connected applications [3]. Water quality monitoring is another critical area where IoT plays a vital role. Traditional laboratory-based testing methods are often time-consuming and inaccessible in remote locations. In contrast, IoT-based systems enable continuous, real-time assessment of water parameters such as pH, turbidity, Total Dissolved Solids (TDS), and temperature [4]. These systems typically employ microcontrollers like Arduino or ESP32, along with GSM, Wi-Fi, or Bluetooth modules for data transmission to cloud platforms or mobile applications. The concept of smart bottles or portable water testing devices has emerged as a practical implementation of IoT in the context of public health. One such development is the Smart Water Quality Monitoring Bottle, which combines the portability of a regular water container with an embedded sensor system. It integrates pH, TDS, and temperature sensors connected to a low-power microcontroller [5]. This system allows real-time analysis of drinking water quality, displaying results on an OLED screen or sending them to a smartphone via Bluetooth or Wi-Fi. This type of solution is particularly valuable in rural or disaster-affected areas where centralized water testing infrastructure is unavailable [6]. Furthermore, research has demonstrated how IoT can support predictive maintenance and real-time alerts in water distribution systems by analyzing data collected from sensors installed in pipelines and reservoirs [7]. Data collected from IoT nodes can also be stored in the cloud for long-term analysis, helping policymakers and public health officials make informed decisions [8].

III. EXISTING SYSTEM:

A. Smart Water Bottles (No Quality Monitoring):

These bottles are enhanced with technology to encourage proper hydration but do not analyze the water's quality.

- Purpose: Track hydration and remind users to drink.
- Features: App connectivity, reminders, intake tracking.
- Examples: Hidrate Spark, Thermos Smart Lid, Ozmo Active.

B. Portable Water Quality Monitors:

These standalone tools are designed to analyze water quality, often used for safety and testing rather than hydration tracking.

- Purpose: Test water for safety and contaminants.
- Features: Handheld, digital readouts, reusable.

- Examples: TDS meters, pH meters, digital test kits.

C. High-End Integrated Systems (Limited Availability):

- Purpose: Combine hydration tracking and water quality sensing.
- Status: Mostly prototypes or niche products.
- Examples: Ecomo (Prototype)Claimed to detect contaminants in water, LARQ (Uses UV- C light to self-clean and sanitize water but does not measure contaminants in real time.)

IV. PROPOSED SYSTEM:

A. Overview of the Proposed System:

The proposed solution is to develop a Smart Water Bottle that not only tracks hydration but also monitors the quality of the water in real-time. This bottle will integrate sensors, a microcontroller, and connectivity features to provide users with live feedback on water safety, ensuring both adequate hydration and health protection from contaminants.

B. Overall System Architecture:

The system continuously monitor the water quality parameters through sensors, such as TDS sensor which measures the total dissolved solids in the water. pH sensor determines the acidity or alkalinity of the water. Temperature sensor monitors the water temperature. The data collected is then sent to the microcontroller, which processes it and displays the results on the digital display. This allows users to instantly assess the safety and quality of the water. The system is powered by a battery, making it suitable for portable smart water bottle.

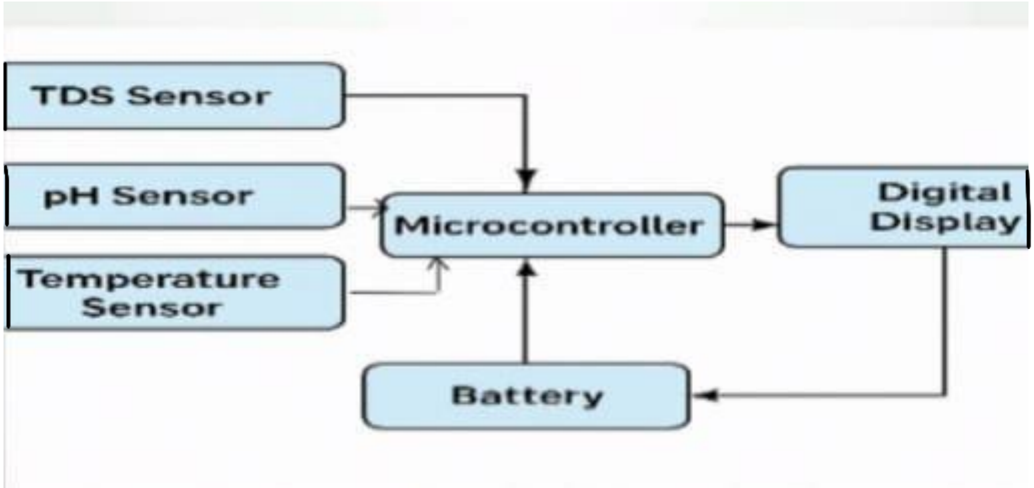


Figure. 1. System Architecture

V. IMPLEMENTATION DETAILS:

A. Development Framework:

The Smart Water Quality Monitoring Bottle is designed by integrating embedded systems with real-time sensing technology to evaluate drinking water safety. The hardware includes essential sensors such as a TDS sensor, pH sensor, and temperature sensor, embedded within a portable water bottle casing. A low-power microcontroller—such as the ESP32 or Arduino Nano—serves as the processing unit, interfacing with the sensors and managing data collection. The system outputs readings to either a built-in OLED display for immediate visualization or wirelessly transmits data to a smartphone application via Bluetooth or Wi-Fi, depending on the configuration.

B. Sensor Integration and Data Processing:

Each water quality parameter is monitored using dedicated sensors: The TDS sensor estimates the total dissolved solids, indicating the presence of minerals and contaminants. The pH sensor evaluates the water's acidity or alkalinity, crucial for assessing potability. The temperature sensor ensures the water is within a safe and comfortable range. Sensor data is collected and processed in real-time by the microcontroller. Threshold values for safe drinking water are predefined and embedded into the firmware. When values exceed these thresholds, visual or digital alerts notify the user.

C. Real-Time Feedback and User Interaction:

The system provides real-time user feedback through: A compact OLED display that shows current readings (TDS, pH, temperature) and a potability status (e.g., "Safe to Drink" or "Contaminated"). A mobile application interface where historical data, alerts, and recommendations are accessible. The app also supports calibration settings and firmware updates.

D. Power Efficiency and Portability:

The device is powered by a rechargeable lithium-ion battery, optimized for low-power consumption through efficient microcontroller sleep-wake cycles and sensor polling intervals. The bottle's compact form factor and sealed electronics ensure portability, durability, and usability in both urban and rural settings.

E. Data Security and Wireless Communication:

When paired with a mobile app, the system uses secure Bluetooth LE or encrypted Wi-Fi protocols to transmit data, ensuring user privacy. Data logs stored on the smartphone can be protected via user authentication. Local data on the device is not retained permanently, mitigating risk in the event of device loss.

F. Testing and Calibration:

The sensors are calibrated using known buffer solutions and test samples during the manufacturing phase. Field testing includes: Comparing sensor accuracy with certified lab equipment. Environmental tests for ruggedness in diverse conditions (temperature, contamination levels).
User feedback is collected during field trials to refine sensor calibration curves and optimize the mobile interface for usability and clarity.

VI. ALGORITHM:

Step 1: System Initialization

1. Initialize microcontroller (e.g., arduino).
2. Initialize sensors: TDS, pH, temperature.
3. Initialize display (OLED/LCD).
4. Load threshold values for each water quality parameter.

Step 2: Sensor Data Acquisition

1. Start a timer or loop for periodic sampling (e.g., every 10 seconds).
2. Read values from:
    - TDS sensor (in ppm)
    - pH sensor (0–14 scale)
    - Temperature sensor (°C)

Step 3: Data Validation and Preprocessing

1. Check if sensor values are within measurable range.
2. Convert analog sensor outputs to meaningful units.

Step 4: Water Quality Evaluation Logic

Compare sensor readings to safety thresholds:

- TDS: Acceptable range ~0–500 ppm
- pH: Safe range 6.5–8.5
- Temperature: Optimal for drinking ~15–30°C

Step 5: Loop or Sleep

1. Wait for the next sampling interval.
2. Enter low-power sleep mode (if battery-saving is enabled).
3. Repeat from Step 2.

VII. EXPERIMENTAL RESULTS AND ANALYSIS:

A Smart Water Quality Monitoring Bottle is a device designed to assess and display the quality of water in real time, often using sensors and microcontrollers. It typically checks parameters like pH, temperature, turbidity, total dissolved solids (TDS), and sometimes chemical contaminants like chlorine or heavy metals.

Expected Results and Analysis

Here's a breakdown of typical results from such a project and how they might be analyzed:

Parameters Monitored

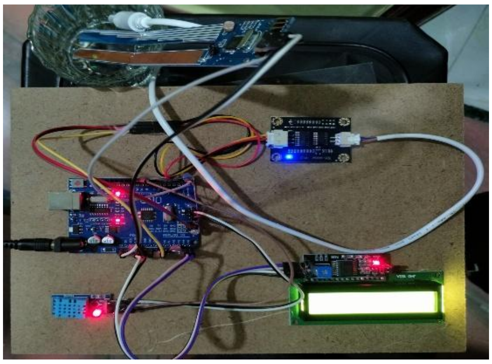
Parameter	**Ideal Range**	**Observed Range**	**Status**
pH	6.5 – 8.5	7.0	Normal
TDS (ppm)	< 250	150	Safe
Temperature (°C)	25 – 35	27.5	Acceptable

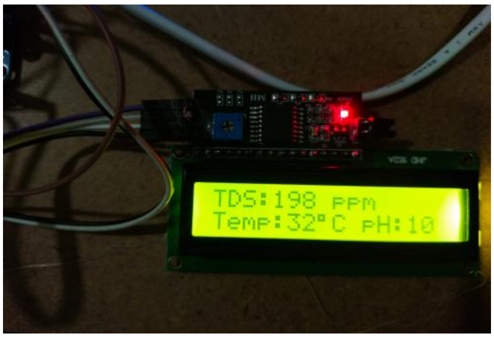
Data Analysis

PH Stability: The water remained within the neutral range, which is good for drinking purposes.

TDS Levels: TDS under 500 ppm suggests the water is free from excess salts and minerals.

Temperature: Readings are consistent with normal room temperature, indicating no heating or microbial activity.





VIII. DISCUSSION:

A. Importance of Real-Time Water Quality Monitoring

Access to clean and safe drinking water is a critical requirement for human health. However, despite the availability of bottled and tap water in urban and semi-urban areas, water quality is not always assured. Factors such as aging pipelines, industrial discharges, chemical contaminants, and inadequate storage conditions can compromise water quality before it reaches the end-user. The situation is even more critical in rural or underdeveloped regions, where real-time water testing infrastructure is often lacking or completely absent. Contaminated drinking water is directly linked to serious health issues, including gastrointestinal infections, heavy metal poisoning, and chronic illnesses. This highlights an urgent need for portable, accessible, and user-friendly solutions that empower individuals to assess water quality independently and in real-time.

B. Proposed Solution: Smart Water Quality Monitoring Bottle

To address this pressing issue, a novel solution—the Smart Water Quality Monitoring Bottle—has been proposed. This innovative device combines the portability of a traditional water bottle with an integrated water monitoring system. It enables users to assess the safety of their drinking water instantly, regardless of location. The smart bottle incorporates a suite of sensors, including a TDS (Total Dissolved Solids) sensor, pH sensor, and temperature sensor, to comprehensively evaluate water potability. These sensors are managed by a low-power microcontroller such as the ESP32 or Arduino, which processes real-time data and communicates the results via a built-in OLED screen or a connected mobile application. The immediate feedback on water safety—along with key parameters like mineral content, pH levels, and temperature—enhances user confidence and promotes proactive health behavior.

C. Challenges and Future Scope

While the Smart Water Quality Monitoring Bottle offers a promising solution, certain challenges must be considered. Sensor calibration and long-term accuracy in varied environmental conditions can affect reliability. Battery life and power management are also important, especially for users in remote areas with limited access to charging facilities. Additionally, while the integration of wireless data transmission enhances usability, it may introduce concerns related to data privacy and app security. From a production standpoint, ensuring affordability while maintaining sensor accuracy and durability is critical to achieving widespread adoption, especially in low-resource settings. Future enhancements could include advanced data analytics for water quality trends, solar-powered charging systems, and AI-based contamination prediction features. With these improvements, the smart bottle could become a key tool in public health monitoring and disaster response situations where clean water access is uncertain

IX. CONCLUSION

The Smart Water Quality Monitoring Bottle project provides an innovative and practical solution for real-time assessment of drinking water safety using embedded sensors and microcontroller-based technology. By measuring key parameters such as TDS, pH, and temperature, the system enables users to quickly determine water quality, reducing the risk of consuming contaminated water. Its portable design makes it ideal for everyday use, travel, and remote areas with unreliable water sources. The integration of display modules or mobile connectivity enhances user interaction and accessibility. Overall, this project demonstrates how smart technology can be effectively utilized to address essential health and environmental concerns, promoting safer water consumption and greater public awareness.

X. References:

1. Barabde, M.N. · Danve, S.R. “**Continuous water quality monitoring system for Water resources at remote places”.** *IJIRCEE.* 2015

2. Moparthi, Nageswara Rao · Mukesh, Ch · Vidya Sagar, P. **“Water quality monitoring system using IoT”** *4th International Conference on Advances in Electrical, Electronics, Information, Communication, and Bio-Informatics.* 2018

3. J. Vithanage et al., "**Smart One: IoT-based smart platform to manage personal water usage"**, *2019 International Conference on Advancements in Computing (ICAC)*, 2019.

4. Rahul krishnan Ravindran, Radhika Ravindran and T. Anjali, **"Hydration Check: An IOT based smart water bottle",** *2022 13th International Conference on Computing Communication and Networking Technologies (ICCCNT)*, 2022.

5. Sumit Kor, Rohit Shinde, Amol Bhosale and Vijay R. Sonawane, "**IOT BASED SMART WATER BOTTLE".**