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SMART WATER QUALITY MONITORING BOTTLE

[1]Ms. Ponnam Shilpa Sri, [2]M. Prasanna, [3]KarrePranathi, [4]Thodeti Ashwitha, [5]Kalawadiya Shveni, [6]Ramanaboina Prathyusha [7.]Dr.D.Shanthi
[1] Assistant Professor, Dept. of CSE(AI&ML), [2]PG Student, [3,4,5,6] B. Tech 3rd Year Student, CSE (AI&ML)
[7.]Professor & HOD, Dept. of CSE(AI&ML)
Vignan's Institute of Management and Technology for Women, Kondapur, Ghatkesar, India.
[1] shilpasri005@gmail.com, [2] pmekala375@gmail.com, [3]karre.pranathi04@gmail.com,
[4] ashwithathodeti@gmail.com, [5] shvenikalawadiya76@gmail.com,[6] prathyusha.r7793@gmail.com,
[7.]drshanthicse@gmail.com

ABSTRACT:
The goal of the "Smart water quality monitoring bottle" project is to make safe drinking water available in real time. The bottle is equipped with integrated sensors, and continuously monitors water quality parameters including TDS (total dissolved solids), Temperature, and pH. A microcontroller processes the data, which is then shown on the bottle. Users can quickly determine whether the water is safe to drink based on these readings. This project promotes health and hygiene by enabling water testing, especially useful in remote or uncertain environments. This system monitors water quality transparently using sensors. It is a simple, portable, and affordable solution that encourages users to make decisions about the water that they consume. The design is straightforward, effective, and sustainable, providing a low-maintenance, low-power instrument to promote environmental safety and public health.

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. Water quality can deteriorate even before it is consumed due to a variety of factors, such as chemical pollution, aging infrastructure, industrial environmental contamination, and inappropriate storage. 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 a product designed to fulfill 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. A low-power microcontroller, like the ESP32 or Arduino, controls and manages these sensors. It processes sensor data and then wirelessly sends the results to a smartphone app or shows them on a small OLED screen. Along with information about temperature, pH, and mineral content, this enables users to get immediate feedback on whether the water is safe to drink.

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's also very helpful to check stored water or tap water before drinking at home. By integrating real-time alerts, the system warns the user when water falls outside the safe limits, helping prevent potential health risks.

This project's potential for everyday usability and practical impact is what makes it unique. Although centralized laboratories or municipal systems are typically used for water quality monitoring, this project decentralizes the procedure and gives the individual direct control over water testing. 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 high-tech bottles encourage proper hydration without sacrificing water quality.

• Objective: Keep track of users' hydration levels and remind them to drink.

• Among the features are intake tracking, app connectivity, and reminders.

• Examples include Ozmo Active, Thermos Smart Lid, and Hidrate Spark.

B. Portable Water Quality Monitors:

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

• Goal: Verify the safety and impurity of the water.

• Features: include reusable, digital readouts, and portability.

• 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 suggested solution is to create a Smart Water Bottle that tracks hydration and provides real time analysis of the hazardous. 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 TDS sensor, which measures the total dissolved solids in the water, is one of the sensors that the system uses to continuously monitor the water quality parameters. The water's acidity or alkalinity is determined by a pH sensor. A temperature sensor measures the water's temperature. The microcontroller receives the collected data, processes it, and outputs the results on the digital display. This allows users to instantly assess the safety and quality of the water. Because the system is battery-operated, it can be used with a portable smart water bottle.

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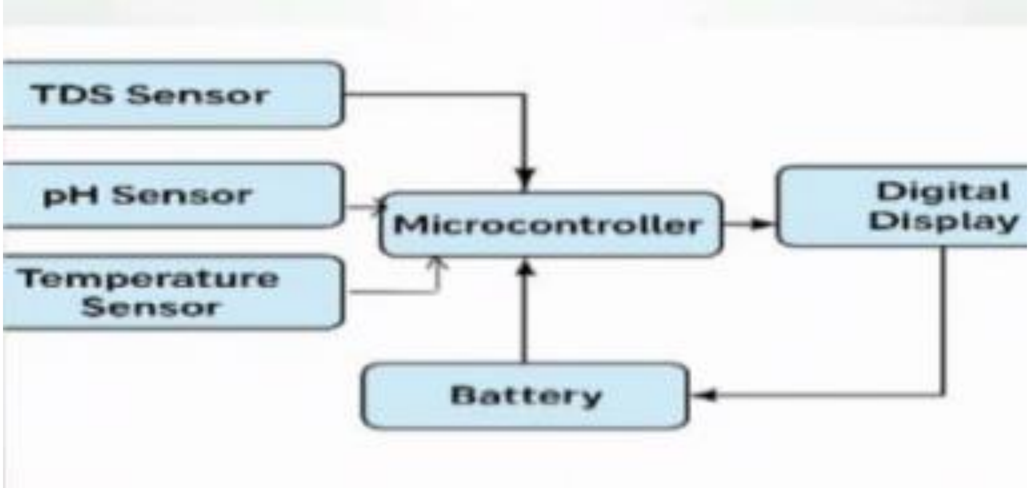

Fig. 1: System Architecture

V. IMPLEMENTATION DETAILS:

A. Development Framework:

The Smart Water Quality Monitoring Bottle uses embedded systems and real-time sensing technology to evaluate the safety of drinking water. 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. The firmware contains predefined threshold values for safe drinking water. 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"). an interface for a mobile application that provides access to alerts, recommendations, and historical data. Firmware updates and calibration settings are also supported by the app.

D. Power Efficiency and Portability:

The device, which has been optimized for low power consumption through efficient microcontroller sleep-wake cycles and sensor polling intervals, is powered by a rechargeable lithium-ion battery. 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:

The system transmits data securely via encrypted Wi-Fi protocols or secure Bluetooth LE in a mobile app pairing and ensures user privacy. Data logs stored on the smartphone can be protected via user authentication. By not permanently storing local data on the device, the risk of device loss is reduced.

F. Testing and Calibration:

The sensors are calibrated using known buffer solutions and test samples during the manufacturing phase. Comparing sensor accuracy with approved lab equipment is one aspect of field testing. Environmental tests for durability under various circumstances (contamination levels, temperature).. 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)

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Step 3: Data Validation and Pre-processing

1. Check if sensor values are within measurable range.
2. Convert analogue 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 device that measures and displays the water's quality in real time using sensors and microcontrollers is called a smart water quality monitoring bottle. pH, temperature, turbidity, total dissolved solids (TDS), and occasionally chemical contaminants like chlorine or heavy metals are among the parameters it usually checks.

Expected Results and Analysis

The typical outcomes of such a project are broken down here, along with possible analysis methods: Monitored Parameters

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

Fig.2: Expected Results and Analysis

Data Analysis

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

TDS Levels: If the TDS is less than 500 ppm, the water is most likely free of excess salts and minerals.

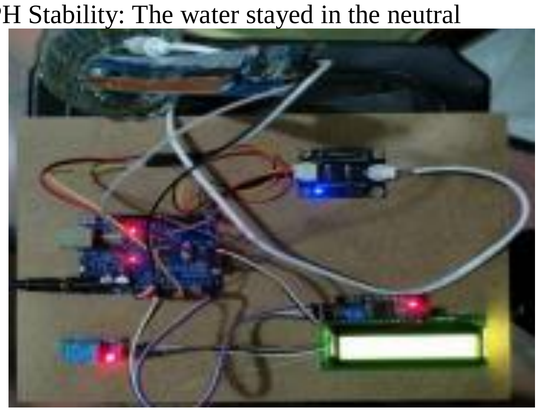

Fig.3: PH Stability

Fig.4: TDS Levels

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 demonstrates the pressing need for portable, easily accessible, and user-friendly solutions that enable people to evaluate the quality of water on their own, 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 allows the user to quickly determine if their drinking water is safe, no matter where they are. The smart bottle incorporates a suite of sensors, including a TDS (Total Dissolved Solids) sensor, pH sensor, and temperature sensor, to comprehensively evaluate water portability. These sensors are controlled by a low-power microcontroller, such as the Arduino or ESP32. It processes data in real time and displays the findings on an integrated OLED screen or through a 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. Affordability must be guaranteed while maintaining sensor accuracy and durability from a production standpoint in order to achieve widespread adoption, especially in low-resource environments. Future enhancements could include solar-powered charging stations, AI-based contamination prediction features, and advanced data analytics for trends in water quality. 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

Using embedded sensors and microcontroller-based technology, the Smart Water Quality Monitoring Bottle project offers a creative and useful way to evaluate the safety of drinking water in real time. 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 shows how intelligent technology can be used to effectively address important environmental and health issues, encouraging safer water use and increased public awareness.

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