Journal of IoT in Social, Mobile, Analytics, and Cloud (ISSN: 2582-1369)
www.irojournals.com/iroismac/

IoT-Enabled Portable Water Quality Monitoring System

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Abstract

Clean and safe drinking water is what we all depend on every day. With so many varieties of bottled water available stored in plastic, glass, copper, or even steel containers it's hard to tell whether the drinking water is safe. Most people have no idea that the type of bottle and storing it will actually determine water quality. For example, plastic bottles, when exposed to heat, are able to contaminate water with toxic chemicals, and prolonged use can lead to health issues. Copper bottles are widely utilized because of their health benefits, but if water stays in them for a long time, they are able to alter water pH and cause copper leaching. Glass bottles are normally safe but can easily get contaminated if not properly cleaned. To help people understand what they are drinking better, we developed a smart water quality tester using an Arduino UNO. It uses four sensors pH, TDS (Total Dissolved Solids), turbidity, and temperature to check if the water is clean and safe. Whether it is bottled mineral water, boiling tap water, or rainwater, this tester can analyze them all. The sensor readings are shown in real-time on a web dashboard. It's a simple and affordable method for testing water in our home, stores in shopping malls, or even in water bottling plants. This project aims to make individuals more aware of what is in their water and how the bottles they consume from can help bring about a change. It is a step towards making water safety more accessible, clear, and trustworthy for everyone.

Keywords: Arduino UNO, Drinking Water Safety, pH Sensor, TDS Sensor, Turbidity Sensor, DS18B20 Temperature Sensor, Portable Water Analysis.

DOI: https://doi.org/10.36548/jismac.2025.3.003
Received: 04.06.2025, received in revised form: 07.07.2025, accepted: 24.07.2025, published: 05.08.2025

1. Introduction

Drinking water is a basic human right and a foundation of public health. While great concern has been given to the cleanliness of water at its source, whether from municipal supply, filtration, or packaged water, the containers in which water is held are less frequently scrutinized. Plastic, copper, and glass bottles are routinely used in the home, the workplace, and point-of-sale environments. But these bottles can impact water quality over time, particularly when exposed to heat, sunlight, or extensive storage periods. Plastic bottles, especially non-BPA-free ones, may leach dangerous chemicals such as bisphenol A (BPA) or phthalates if heated. Copper containers, although traditionally used due to their antimicrobial benefits, can raise the pH and total dissolved solids (TDS) of water above safe thresholds if mishandled. Glass bottles, being chemically inert, can nevertheless facilitate biological contamination if not regularly sanitized. In spite of these dangers, real-time consumer-level monitoring devices that assess the impact of storage containers do not exist, to a large extent, on the market and in the literature.

This paper suggests an IoT-based Smart Water Quality Monitoring System developed on an Arduino UNO board, intended to measure major water quality parameters-pH, TDS, turbidity, and temperature in real time for various types of bottles. The system combines a set of low-cost sensors with the Blynk mobile application, offering continuous and remote access to water quality parameters. In contrast to current industrial-scale or water-source-level monitoring systems, this configuration targets the influence of storage material and ambient conditions on stored drinking water. The aim is to develop a practical, cost-effective, and informative solution that enables ordinary users to gain action-oriented insights regarding the safety and usability of their stored drinking water. Through this research, we seek not only to confirm the system's performance for three typical bottles plastic, copper, and glass but also to emphasize the need for awareness regarding container-induced water degradation, especially under warm climatic or extended use conditions.

2. Related Work

Pollutants can be added to the water supply via industrial effluent disposal, agricultural runoff, and poor storage, which can lead to serious health threats when consumed as drinking water in raw or substandard form [1]. The recent evolution of Internet of Things (IoT) technology has opened up new avenues in the form of real-time and remote water quality monitoring. Traditional water quality monitoring is time-consuming, labor-intensive, and requires extensive laboratory space, which is not feasible for continuous or frequent monitoring [2]. Several recent studies highlight the benefits of such systems. Roy et al. [3][4] presented IoT-based frameworks for spring and general water monitoring. Ismail et al. [5] emphasized scalability and future research directions for water management. Mathew et al. [6] and B. G. et al. developed systems for real-time analysis and pollution detection. Solar-powered solutions for remote locations were suggested by S. B. S. et al. [7]. Satya Sai et al. [8] developed multiple similar monitoring systems using Arduino, emphasizing cost-effectiveness. In addition, Baranitharan et al. [9] developed an IoT based smart irrigation water management system, which shows that sensor-based water management can be applied not only to agricultural practices but also to the assessment of drinking water and how it can be sourced and distributed efficiently. What makes this project original is its unique effort in providing an assessment of stored water within households and commercial settings. By comparing water samples across different bottle materials and environmental conditions (e.g., heat exposure), this system creates public awareness about how storage choices directly influence water quality. The Arduino-based platform makes the solution affordable, portable, and scalable, ideal for households, shops, and bottling units. This system represents another aspect of the emerging trend of real-time intelligent water quality monitoring, along with many other recent research examples that have focused on sensors and sensor-based analysis [10], IoT systems-based applications for water safety, and smart sustainable technologies for public and private use [11].

These solutions represent a potential bridge between safe water use practices and technological advancements for environmental monitoring. Mathew et al. [12] developed an intelligent pollution monitoring device that receives sensor-based data in real time and alerts the user to hazardous conditions. These systems can monitor water quality, but most are designed for large bodies of water or fixed-point sources of water supply, such that they do not necessarily address personal use or household water sources [13]. Several other investigations examined water quality monitoring in various settings, including rural spring water [14], urban water pipeline leakage [15], and solar-powered off-grid solutions [16]. Ismail et al compiled an exhaustive survey of IoT-based water management systems, and identified several limitations including lack of scalability, cost efficiency, and integration issues [21]. However, few studies explicitly assess the effect of storage materials (e.g. plastic, glass, copper) or environmental factors (e.g. temperature) on drinking water quality, which is pertinent to real-life drinking scenarios [22]. Recent research has been done related to IoT in water quality monitoring systems. Vo Luong et al. [16] developed an IoT water quality monitoring system with pH, turbidity, and temperature sensors for real-time monitoring. However, their system was limited to fixed water sources, did not consider the material used to store the monitored water, and did not develop a way to test the water for post-storage differentiation of health risk. Bagal [17] developed a smart water meter that combines quality monitoring and alerts for users. However, while their smart water meter benefited from direct quality readings, it did not evaluate the storage medium (plastic or copper) and the potential impact it may have on water safety after storage. Rai et al. [18] introduced the merging of the Internet of Things (IoT) and machine learning for querying pollution predictions based on contamination levels and laboratory analysis methods. Their research acknowledged that IoT monitoring systems will achieve greater scales than personal users and smaller bottle sized monitoring systems. This method allows people to not only assess water quality in real-time, but also fosters greater awareness regarding how people are affected by different bottles or environmental factors in relation to water safety; [19] it is usable at multiple scales, including home, retail, and field environments, while contributing to public health and supporting safer behaviors around water consumption [20].

3. Methodology

3.1 Sensor Initialization

The system monitor's the quality of drinking water in a variety of storage materials, such as plastic, glass, and copper bottles.[23] The system comprises sensor nodes communicating with an Arduino UNO microcontroller that measures real-time water quality and sends it to a web-based dashboard [24][25]. The system architecture helps establish how different storage materials and environmental in the larger sense

3.2 Hardware Components and Configuration

The Arduino UNO serves as the main microcontroller for the water quality monitoring system, handling data communication and reading analog and digital signals from multiple sensors. A pH sensor, which measures the acidity or alkalinity of water particularly crucial for identifying alterations brought on by leaching in copper bottles a TDS (Total Dissolved Solids) sensor, which measures the amount of dissolved minerals or contaminants that may have come from the container materials, and a turbidity sensor, which evaluates the clarity of the water by identifying suspended particles, are some of the key sensors built into the setup. Furthermore, the water temperature is measured using a DS18B20 temperature sensor, which facilitates the examination of chemical leaching behavior in plastic containers at high temperatures. Analog and digital pins are used to connect each sensor to the Arduino UNO, and the parts are put together on a breadboard to enable flexible configuration and testing.

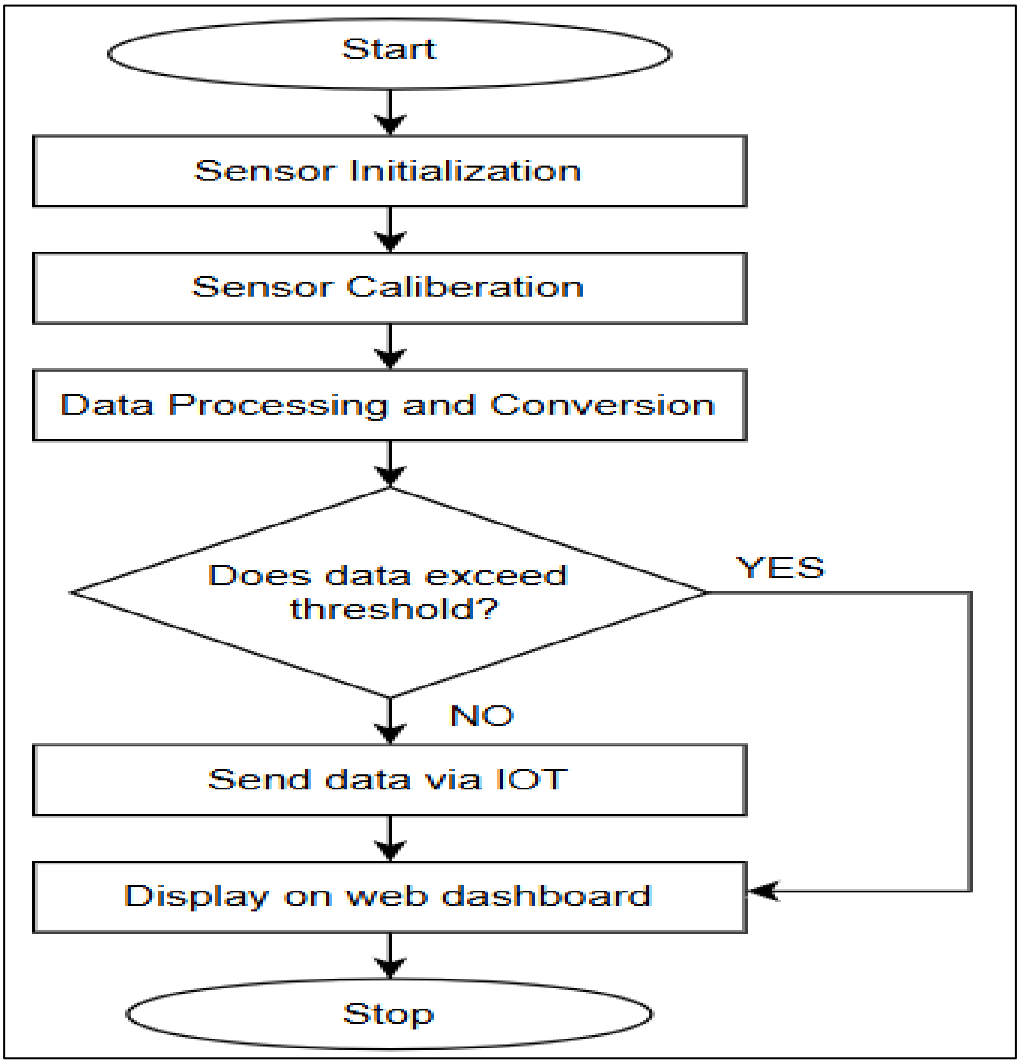

Figure 1. Workflow of the Proposed System

This method was rolled out in systematic stages, integrating physical/digital hardware and software components with IoT as shown in figure 1

3.3 Software Development

The system is programmed using Arduino IDE. Code is developed to read sensor values in real-time, convert raw data into standard units (°C, NTU, ppm, pH), and send this information through serial or wireless communication (e.g., ESP8266 module) to a web interface or mobile app like Blynk [20]. Calibration steps ensure the accuracy of each sensor module [21].

3.4 Experimental Setup

Water sourced from the same origin is stored in plastic, glass, and copper bottles under two conditions:

1. Room temperature
2. High temperature (exposed to sunlight or an artificially heated environment)
3. Sensor readings (pH, turbidity, TDS, and temperature) are recorded at set intervals. The data is visualized in real-time through a web dashboard, allowing for immediate comparison across materials and environmental conditions [3][5][6][9].

Table 1. Measured Water Quality as Per WHO Standard

Water Quality parameter	WHO standard (for drinking water)
pH	7-8.5 pH
Turbidity	7-5 NTU
Temperature	15ºC (Drinking Water)
Chlorine Level	2-3 mg/l
Conductivity	400 µS/cm
Dissolved Oxygen (DO)	5-6 mg/l

4. Proposed System

The proposed system is low-cost, real-time IoT-based water quality monitoring system designed to ascertain the safety of drinking water stored in various types of containers, such as plastic, copper, and glass bottles. The system will address rising issues of chemical leaching, pH level alteration, and microbial contamination resulting from long storage and exposure to high temperatures. Figure 2 shows the proposed system architecture.

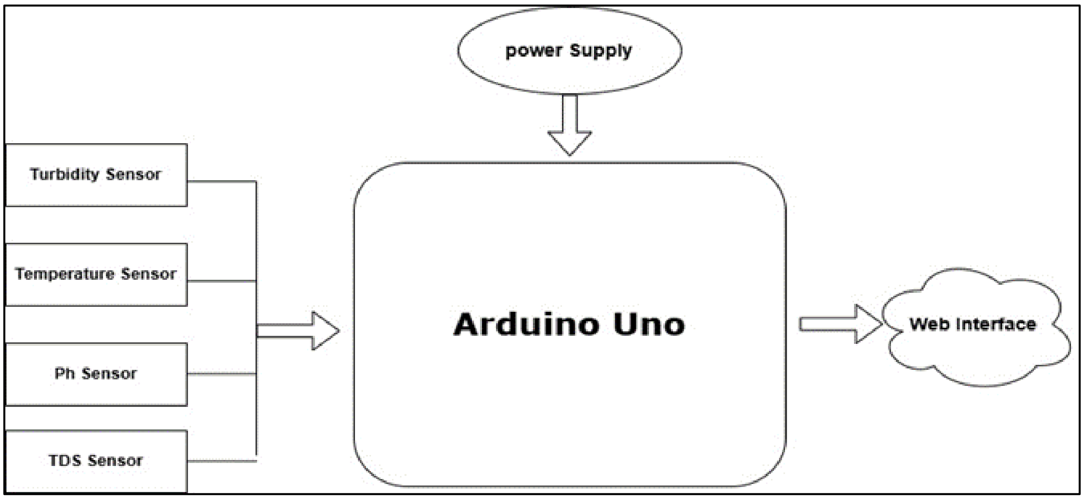

Figure 2. System Architecture

The core of the system lies in the Arduino UNO microcontroller, which interacts with a set of sensors that measure critical water quality parameters in real-time:

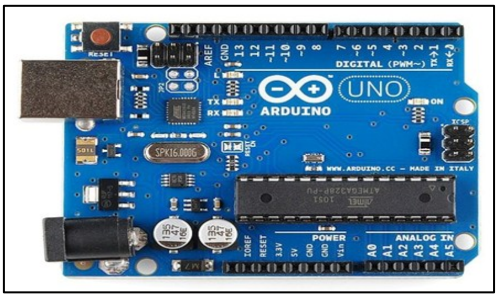

Figure 3. Arduino UNO

pH Sensor: Detects changes in water acidity or alkalinity, which is particularly important for monitoring copper leaching or acidification in plastic bottles.

Figure 4. pH Sensor

TDS Sensor: Measures the concentration of dissolved solids, providing insight into water purity and contamination from mineral leaching.

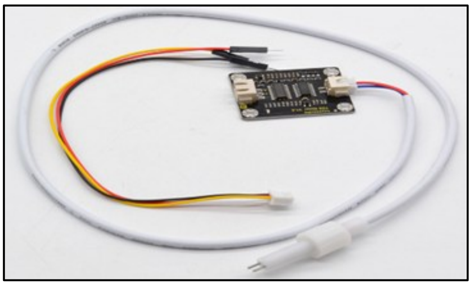

Figure 5. TDS Sensor

Turbidity Sensor: Evaluates water clarity by measuring suspended particles that may indicate microbial or chemical contamination.

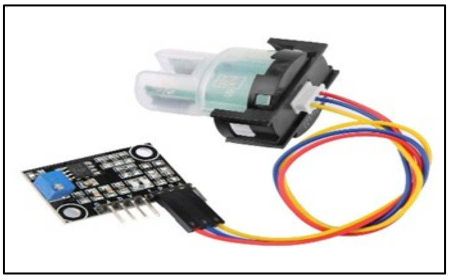

Figure 6. Turbidity Sensor

Temperature Sensor (DS18B20): Monitors the temperature of stored water, which is critical for identifying conditions that may accelerate chemical leaching in plastic bottles.

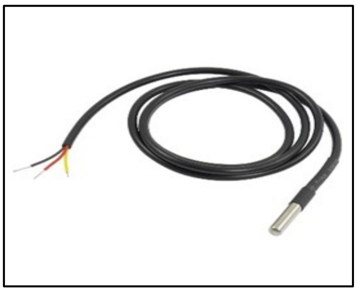

Figure 7. Temperature Sensor

The system of water quality monitoring employs the Arduino UNO as its central microcontroller responsible for detecting analog and digital inputs from a sequence of sensors and managing data communications. Key sensors included in the configuration are a pH sensor, measuring the alkalinity or acidity of water, which is most important for detecting changes that can occur as a result of leaching in copper-made bottles; a TDS (Total Dissolved Solids) sensor, measuring the concentration of dissolved contaminants or minerals that could come from the material used in the containers; and a turbidity sensor, measuring water clarity by suspended solids. An additional DS18B20 temperature sensor is used to read water temperature to facilitate the analysis of chemical leaching behavior of plastic containers under high temperatures. Sensors are connected to the Arduino UNO through analog and digital pins, and components are placed on a breadboard for ease of reconfiguration and experimental validation.

5. Results and Discussion

The proposed System was calibrated on various kinds of bottled water packaged in varying materials: plastic, glass, and copper and stored at room temperature and heat. The system monitored some of the most critical water quality parameters such as pH, TDS (Total Dissolved Solids), turbidity, and temperature with respective sensors interfaced with an Arduino UNO. The sensor readings in real time were displayed via the web application on mobile phones, as illustrated in figure 8.

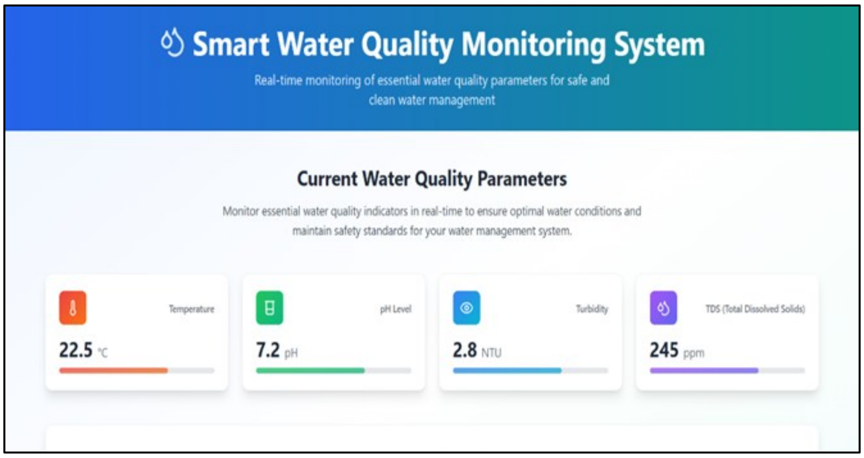

Figure 8. Web Interface

Plastic Bottles: Plastic bottles continuously displayed a decreasing pH at higher temperatures (>35°C), sometimes falling below 6.5, indicating increasing acidity. Though this pattern was not seen in all of the samples tested at room temperature, it is noteworthy that the TDS levels were also elevated, indicating potential chemical leaching (of BPA or over time microplastics). Without a doubt, temperature causes plastic to leach, which in turn impacts the general quality of the water.

Copper Bottles: Copper's initial alkalizing effects were supported by the experiment's slight pH increases (7.8–8.1) in water stored in copper receptacles. But even at higher temperatures, TDS rose over time, lowering pH levels. Leached copper ion levels can even be harmful if consumed for an extended period.

Glass Bottles: When water was tested in glass bottles under various cycles, the pH levels (6.9-7.1 pH) and TDS levels (~90-120 ppm) showed little variation, even when the temperature was changed. This suggests that the water is chemically inert and safe for long-term storage. For the majority of tests, the turbidity was less than 1 NTU. Rainwater in plastic containers had turbidity levels of up to 2.5–3.2 NTU, which is typical of boiled water.

Temperature Sensor Results: The DS18B20 sensor successfully recorded temperature variations, showing the different types of bottles' levels of heat absorption. As seen in figure 9, plastic bottles were found to have the highest degree of heat transfer, enabling temperatures to rise quickly and possibly quickening internal chemical reactions.

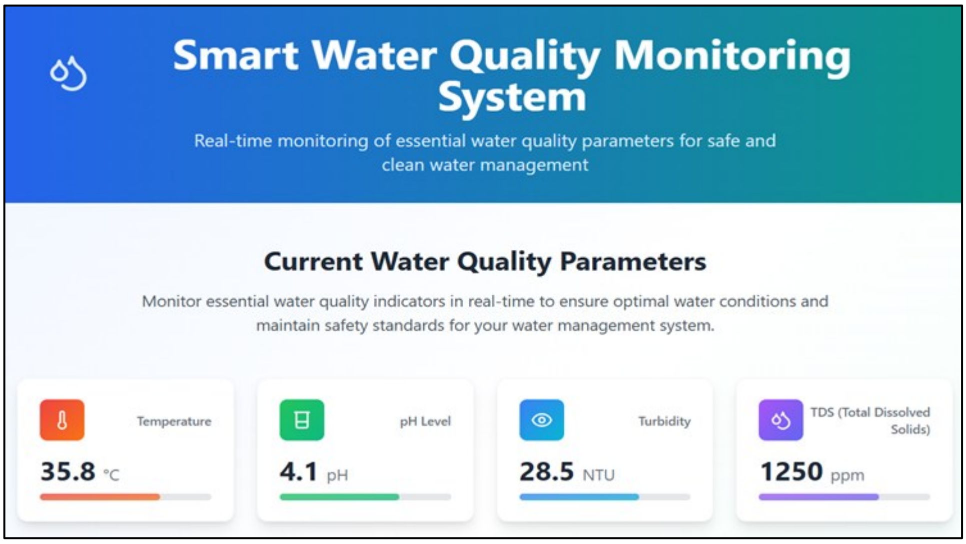

Figure 9. Dashboard Showing Real-Time Water Quality Data

Alerts & Real-Time Feedback: The system was designed to notify the user when values surpassed WHO guidelines (turbidity > 5 NTU or TDS > 500 ppm). It was also responsive enough to enable early warning and decision-making so the user could react to daily use.

This system focuses on consumer-facing use cases, like home use, retail water packaging, and impermeable storage awareness, as opposed to previous studies that targeted industrial pipelines [4][5] or environmental bodies like lakes [8]. The majority of earlier environmental studies lacked comparative material studies, which is crucial given that millions of people worldwide drink bottled water, frequently under the mistaken impression that the type of bottle and/or storage temperature could jeopardize their safety.

All things considered, the system was effective in providing real-time feedback on the quality of the water for various bottle types and storage settings. It promoted awareness of the effects of environmental factors and container materials on water safety and was a dependable and user-friendly method for identifying dangerous drinking conditions.

Table 2. Water Quality Analysis of the Different Water

Water Sample	Std. pH Range	pH	Std. Turbidity (NTU)	Turbidity (NTU)	Std. Temperature (ºC)	Temperature (ºC)
Borewell Water	6.6-8.5	7.35	1-5	3.2	20-30	24.5
Filtered Wastewater	6.6-7.5	7.12	1-10	1.0	20-35	23.5
Greywater (used water)	6.0-8.0	8.45	10-50	28.9	25-40	23.0
Industrial effluent Water	5.5-9.0	6.24	20-500	152.3	30-50	26.0
Filtered Water	6.5-8.5	7.85	<1	1.0	20-30	23.8

5. Conclusion

The availability of safe and clean drinking water is vital for healthy living. Water safety can be based on the actual source, but it can also depend on the storage method. The project is based on a real-time problem for evaluating and monitoring drinking water quality using an IoT based system using Arduino UNO microcontroller. The system utilizes four sensors: pH, Total Dissolved Solids (TDS), turbidity, and temperature to measure the water quality parameters of different types of water stored in plastic bottles, copper bottles, and glass bottles at different temperatures. The data from the sensors will be processed by the Arduino and displayed, in real-time, in the Blynk mobile app providing users with direct access to the information affecting their drinking water. One of the critical observations in the project was the impact of different bottles on the water quality. For instance, the plastic bottles heated at higher temperatures showed a low pH and higher TDS which suggest there may have been leaching from the chemicals in the plastic. Copper bottles, though health-positive, registered higher TDS and changed pH over time due to probable copper ion release. In terms of stability, glass bottles appeared to do the best, producing water quality that was relatively the same overall, as long as the bottles were well cleaned! This structure is low cost, low-profile and very effective at promoting water safety awareness. It acts as a convenient device at home, in a shop, in a school, or even on-the-go in a small pack of bottles when a requisite level of quality assurance for drinking water is desired. That said, real-time alerts when any parameter exceeded a safety/shared limit, gave the user the power to take action. Overall, the structure achieved aspects of real-time feedback of water quality across varied types of bottles, and variations in storage environments. Moreover, it may act as a valid and user-friendly system to determine drinking conditions that are hazardous, and raise awareness around container materials and the ambient conditions in which the water will be used.

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