DESIGN AND ANALYSIS OF THE PERFORMANCE OF THE IOT-BASED WATER PURITY IDENTIFICATION SYSTEM

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ABSTRACT

In recent years, millions of tourists have visited Bangladesh to experience its natural beauty, underscoring the critical need for access to potable water. Contamination of water sources poses significant risks to human health, particularly in high-traffic tourist regions. This study proposes an Internet of Things (IoT) based water quality monitoring system designed to assess drinking water safety in Bangladesh's tourist areas. The system is integrated with a Wi-Fi-capable ESP32 microcontroller and four sensors to collect four water parameter values such as pH, turbidity, total dissolved solids (TDS), and temperature with a. Data from 1,000 water samples collected across diverse tourist locations are transmitted wirelessly to a dedicated IoT server for real-time analysis, aligning with water quality thresholds established by the World Health Organization (WHO) and Bangladesh standards. Results indicate that 36% of samples fully complied with safety standards, 58% were moderately pure (posing minimal risk to vulnerable populations), and 6% were polluted. These findings highlight the system's potential to identify unsafe water sources, safeguard public health, and promote environmental sustainability. By offering scalable, cost-effective monitoring, this IoT framework addresses regional challenges while contributing to global efforts for clean water access.

KEYWORDS

IoT, water purity, EPS32,TDS sensor, pH sensor, Turbidity sensor

1. INTRODUCTION

Access to clean and safe drinking water is a fundamental human right, yet billions of people worldwide still lack access to potable water. According to the World Health Organization (WHO), over 2 billion people globally rely on water sources contaminated with feces, leading to severe health risks such as cholera, diarrhea, dysentery, and other waterborne diseases [1]. In Bangladesh, a country known for its rich natural beauty and cultural heritage, the issue of water pollution is particularly acute. Millions of tourists visit Bangladesh annually, drawn to its scenic landscapes, rivers, and historical sites.

However, the availability of safe drinking water remains a critical concern for both locals and tourists, as water sources are increasingly contaminated due to industrial waste, agricultural runoff, and inadequate sanitation infrastructure [2]. For tourists, who often rely on natural water sources or local supplies, the risk of consuming contaminated water is high, leading to potential health hazards. This situation underscores the urgent need for effective water quality monitoring systems that can provide real-time data to ensure drinking water safety, particularly in tourist areas [3-4].

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In recent years, Internet of Things (IoT) technologies have revolutionized water quality monitoring by enabling real-time data collection, remote sensing, and automated analysis [5-6]. IoT-based systems offer a cost-effective and scalable solution for continuous water quality monitoring, making them particularly suitable for developing countries like Bangladesh, where resources are limited and the need for efficient water management is critical. Intelligent systems models are now being developed to predict water safety and enhance water quality, significantly advancing over traditional methods [7-8]. Water purity level is determined by the value of the parameters based on the water quality requirements specified by Bangladesh and the guidelines supplied by the WHO [9-10] that are safe for drinking. Several studies have explored the use of IoT for water quality monitoring, but many of these systems have significant limitations. For instance, [11] proposed a GSM-based system for monitoring water purity parameters such as pH, temperature, and conductivity. However, it was limited by its inability to store large amounts of data for further analysis. Similarly, [12] developed an automated water quality monitoring system that only measured two parameters, which is insufficient for a comprehensive assessment of water safety.

In [13], the authors survey the tools and techniques used in existing water quality monitoring systems. Other systems, such as those proposed by [14], relied on proprietary applications like BLYNK, which restricted their usability to specific users and limited their scalability. Similarly, [15] highlighted the challenges of IoT-based water quality monitoring in domestic applications but did not provide a solution tailored to the needs of tourists or rural communities. While these systems [16] have demonstrated the potential of IoT for water quality monitoring, they often lack the flexibility and scalability needed for broader applications, such as monitoring water quality in tourist areas. For example, [17] proposed an IoT-based system for monitoring water quality in rivers, but it was limited by its reliance on expensive sensors and complex data processing algorithms.

Moreover, many existing systems focus on monitoring water quality in controlled environments, such as laboratories or industrial settings, and do not address the specific challenges of monitoring water in natural or tourist areas, where water quality can vary significantly due to environmental factors.

To address these gaps, this paper proposes an IoT-based water purity identification system tailored for tourist areas in Bangladesh. The system integrates with Wi-Fi-capable ESP32 microcontroller and four sensors for measuring water parameters such as pH, TDS, turbidity, and temperature. Data is transmitted wirelessly to an IoT server, enabling real-time monitoring without proprietary software. Unlike prior systems, ours prioritizes usability in resource-limited settings: it stores data locally to mitigate connectivity issues. It classifies water safety into three categories (fully pure, average pure, and polluted) based on WHO and national standards. This empowers tourists and communities to make informed decisions, reducing risks of waterborne diseases. By combining affordability, flexibility, and comprehensive parameter analysis, this system advances IoT applications in water quality monitoring, offering a practical solution to Bangladesh’s urgent public health challenges.

The remainder of this paper is organized as follows: Section 2 describes the methodology used in this study. Section 3 presents the proposed IoT-based water purity identification system, its hardware components, and IoT server configuration. Sections 4 and 5 discuss the results and discussion of the water quality analysis and their implications for public health and environmental sustainability. Finally, Section 6 concludes the paper with a summary of the findings and recommendations for future research.

2. METHODOLOGY

This paper proposes a real-time IoT-based water quality identification system that integrates sensors to collect and analyse water purity data. The methodology comprises three core components: water purity evaluation parameters, data collection protocols, and water purity classification criteria.

2.1. Data Collection Area

Figure 1 indicates the study area map of Bangladesh, showing the numerous tourist areas where the water samples were collected. The wide range of geographical features is shown in this visual representation. We collected data from five tourist regions labeled from G-1 to G-5 in Bangladesh, as shown in Table 1. This study, 1,000 water samples were collected from several sources such as natural water (rivers, tube wells), tap water, bottled water, and hotel/restaurant supplies. The proposed system continuously tracks water quality indicators, including temperature, pH levels, cloudiness (turbidity), and TDS. The collected information is transmitted wirelessly to a central processing hub, enabling immediate analysis and indicating the water purity level in real-time.

Table 1. Sample distribution across tourist region

Group	Tourist Regions	Samples
G-1	Cox's Bazar and Chittagong	200
G-2	Dhaka and Comilla	300
G-3	Rajshahi	100
G-4	Bogra and Rangpur	200
G-5	Kustia and Mujibnagar	200

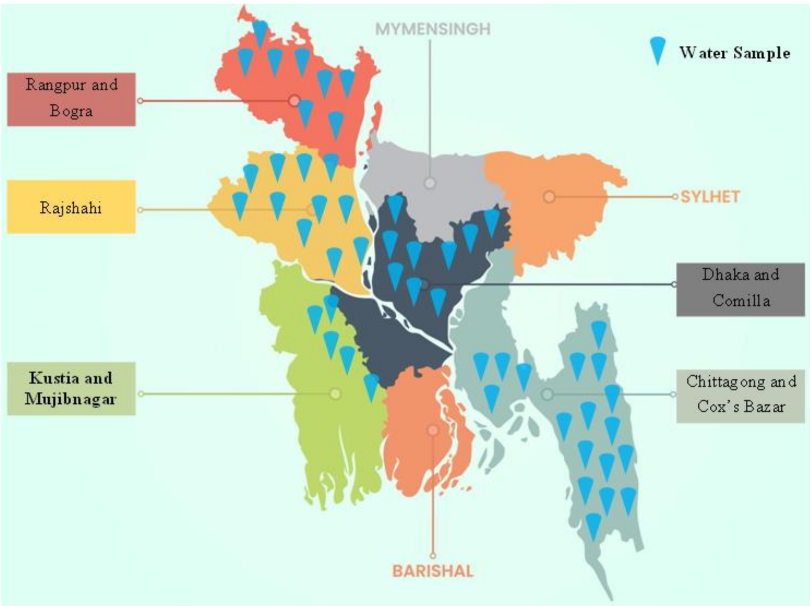

Figure 1. Geographical locations of the study area

2.2. Water Purity Classification

The following three different conditions are considered to classify the water purity level such as "Fully pure water", "Average pure water" and "Polluted water". According to WHO's specified range, Table 2 categorizes the value of different water parameters based on the above classification. A "Fully pure water" is considered when all parameters of the collected water sample are within the acceptable safe range, as shown in Table 2. This water is fully pure and safe for drinking. In the "Average pure water" level, the range of all parameters may not be within the acceptable safe range. In this case, one or two parameters of some samples may have the acceptable safe range, but the remaining parameter values are felt around the acceptable safe range, as shown in Table 2. Finally, in "Polluted water," all parameters of the water sample are not in the acceptable safe range. This water is not safe for us and causes serious diseases. We should avoid it.

Table 2. Water purity classification criteria

Category	pH	TDS (ppm)	Turbidity (NTU)
Fully pure water	6.5-7.2	50-300	Turbidity<10
Average pure water	5.5-6.5 &7.2-8.5	300-500	11-35
Polluted water	pH>8.5	TDS>500	Turbidity>35

3. Proposed IoT-Based Water Purity Identification System

The proposed IoT-based water purity identification system is depicted in the block diagram shown in Figure 2. This illustration effectively outlines the operational sequence involved in evaluating water purity through the use of IoT-enabled sensors and data processing techniques. In this system, the ESP32 microcontroller unit (MCU) acts as the central processing hub, adeptly converting analog sensor data into a digital format and transmitting the readings to a dedicated IoT server.

The control unit is designed for real-time data acquisition, capturing sensor readings every second and sending this information to the IoT server. Outliers such as sensor errors, extreme values, were removed to ensure dataset integrity. Configured to process a set of four sensor readings every four seconds, the IoT server conducts real-time analysis of the collected data using statistical methods for further assessment. Based on the categorized outcomes, customers receive prompt notifications regarding the status of water quality, clearly indicating whether the sample complies with established safety standards for drinking water.

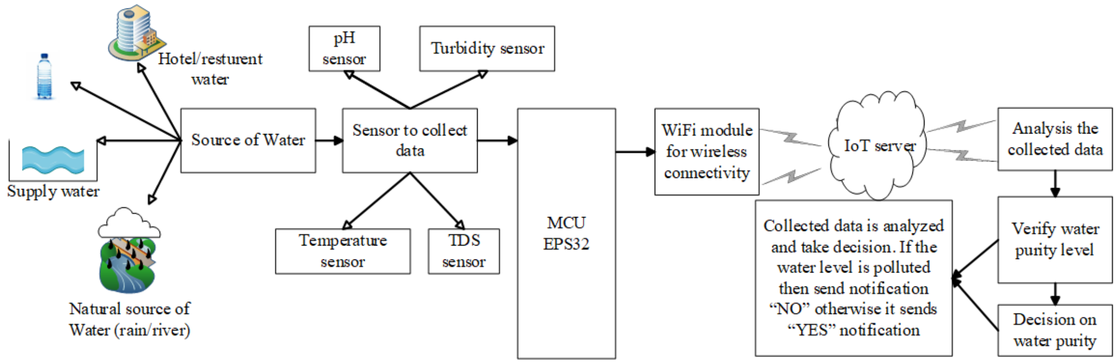

Figure 2. IoT-based water purity identification system

3.1. IoT Server Configuration

Figure 3 illustrates the configuration of the IoT server, which wirelessly acquires data from sensors as previously outlined. The IoT server, operated on a personal computer, is tasked with receiving, storing, and processing the data collected from these sensors. The established system gathers sensor data at one-second intervals, automatically logging the information into a CSV file on the server's PC. Once the necessary data points have been accumulated, the system ceases further data collection, and the dataset is then fed into a statistical model for classification. A "NO" designation signifies that the water is contaminated and deemed unsafe for consumption. Conversely, water that is classified as safe can either be completely pure or moderately pure. Utilizing a dedicated IoT server enhances data security, as sensitive information remains confined within the local network. Moreover, hosting data locally reduces transmission delays, boosts real-time processing efficiency, and contributes to a seamless operating experience for the system.

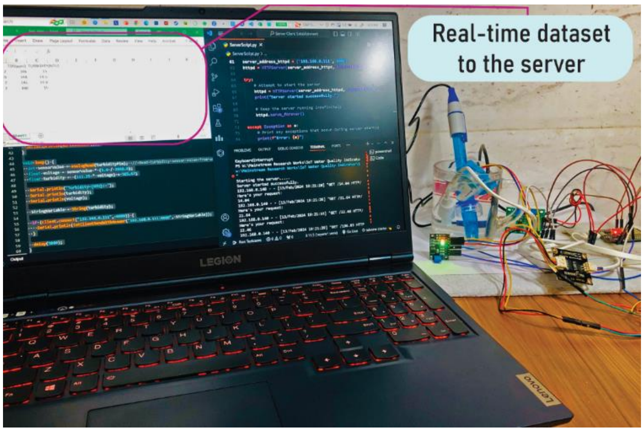

Figure 3. Real-time data transfer to the IoT server

3.2. Hardware Equipment

The main hardware equipment in this experiment is the EPS32 microcontroller. The ESP32 is a multifunctional, inexpensive microcontroller with integrated Wi-Fi and Bluetooth capabilities, has made it highly popular in the field of IoT and embedded systems. The ESP32 features a dual-core Xtensa LX6 microprocessor, capable of running at up to 240 MHz, with an integrated Tensilica Xtensa LX6 dual-core or single-core processor. This provides substantial computational power for a wide range of applications. It comes with 520 KB of SRAM and typically includes up to 4 MB of flash memory. Some variants also offer external SPI flash support. The ESP32 supports Wi-Fi (802.11 b/g/n) and Bluetooth 4.2 (both Classic Bluetooth and BLE), making it ideal for IoT applications [18].

The proposed system utilizes four advanced sensors for water quality assessment. The Analog pH sensor measures acidity or alkalinity, ensuring water safety for consumption and environmental monitoring. The Turbidity sensor evaluates water clarity by analyzing light transmittance, aiding in drinking water monitoring, river assessments, and wastewater treatment. The Analog TDS sensor detects dissolved ion concentrations, providing insights into water purity and requiring calibration for accuracy. Lastly, the DS18B20 temperature sensor offers precise temperature readings, which is essential for environmental and industrial water quality management. These sensors collectively enhance real-time monitoring and informed decision-making.

4. RESULT

The results of the water purity analysis, based on data collected from 1,000 water samples across various tourist locations in Bangladesh, provide valuable insights into the safety of drinking water in these areas. The statistical analysis revealed that the majority of the water samples fell within acceptable ranges, as per WHO and Bangladesh standards. However, a small percentage of samples exhibited unsafe levels of contamination, highlighting the need for continuous monitoring and intervention.

4.1. pH Analysis

Figure 5 presents pH analysis results across tourist locations. For G-1 (Figure 5(a)), 42% of samples fell within the acceptable pH range (safe for drinking), 56% were moderately pure (non-harmful but not ideal), and 2% were highly contaminated (unsafe). Similar trends were observed for G-2 to G-5 (Figures 5(b)–5(e)). Aggregated results (Figure 5(f)) show 48% fully compliant, 50% moderately pure, and 2% contaminated. While pH levels suggest most water is safe, this parameter alone does not guarantee overall purity.

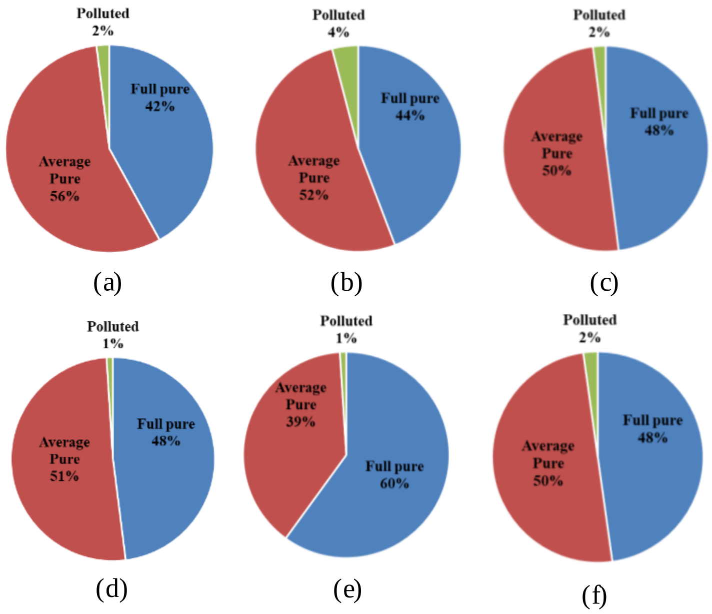

Figure 5. pH analysis for water purity identification; (a) pH analysis for G-1 data, (b) pH analysis for G-2 data, (c) pH analysis for G-3 data, (d) pH analysis for G-4 data, (e) pH analysis for G-5 data, (f) pH analysis for all data sample

4.2. TDS Analysis

Figure 8 presents the findings for TDS. In G-1 (Figure 6(a)), 45% of samples met the safe TDS thresholds, while 52% showed elevated levels that could affect taste and odor, and 3% were polluted (posing health risks). Figures 8b–8e, representing G-2 through G-5, displayed similar trends. Overall results indicate that 44% of samples were safe, 52% were moderately pure, and 4% were polluted (Figure 6(f)). The TDS results support the pH findings, suggesting that water is generally safe, albeit with localized risks.

4.3. Turbidity Analysis

The turbidity analysis results (Figure 7) indicate that 26% of samples were fully compliant, 70% were moderately pure, and 4% were polluted (as shown in Figure 7(f)). While the majority of the water posed no immediate health threats, the 4% deemed polluted (exceeding turbidity limits) underscores contamination risks, particularly for vulnerable populations.

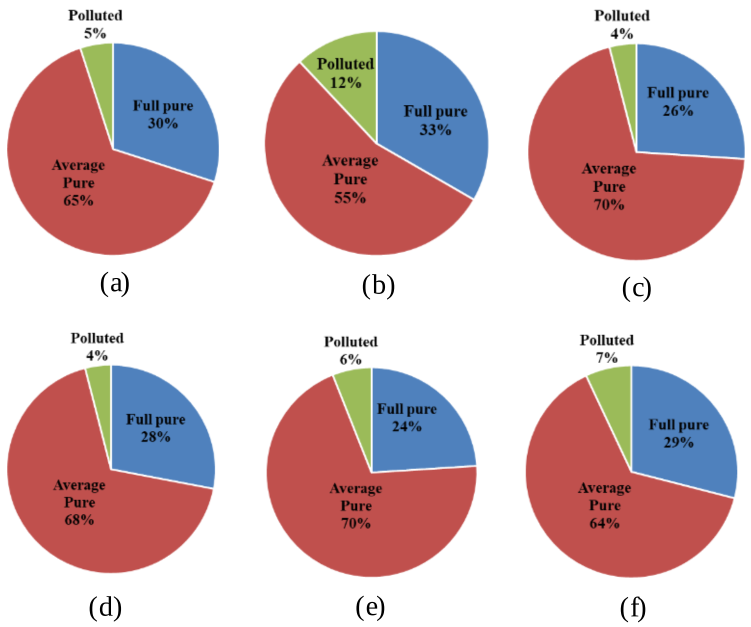

Figure 6. TDS analysis for water purity identification; (a) Turbidity analysis for G-1 data, (b) Turbidity analysis for G-2 data, (c) Turbidity analysis for G-3 data, (d) Turbidity analysis for G-4 data, (e) Turbidity analysis for G-5 data, (f) Turbidity analysis for all data sample

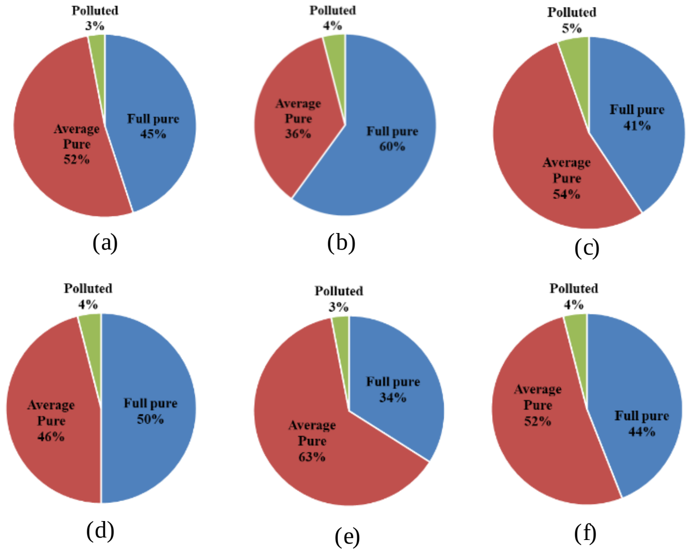

Figure 7. Turbidity analysis for water purity identification; (a) Turbidity analysis for G-1 data, (b) Turbidity analysis for G-2 data, (c) Turbidity analysis for G-3 data, (d) Turbidity analysis for G-4 data, (e) Turbidity analysis for G-5 data, (f) Turbidity analysis for all data sample

5. DISCUSSION

Figure 8 shows the statistical result for water purity levels at tourist places in Bangladesh based on the combined values of pH, TDS, Turbidity, and temperature of each water sample. The results indicate that 36% of samples are fully pure and safe for drinking, while 58% fall into the average purity category, meaning they may be safe but do not fully meet ideal standards. Only 6% of samples are classified as polluted, posing potential health risks. The predominance of moderately pure water highlights the need for cautious consumption. This IoT-based system provides a valuable tool for tourists to identify safe drinking water sources. Table 3 summarizes the overall water purity classification.

Table 3.Result summary of overall water quality

Parameter	**Fully pure water**	**Average pure water**	**Polluted water**
pH	49 %	50%	1%
TDS (PPM)	45%	53%	2%
Turbidity (NTU)	26%	70%	4%
Combine all parameters	36%	58%	6%

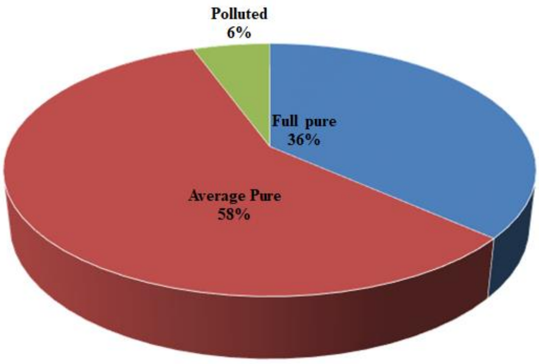

Figure 8. Overall purity level of drinking water

6. CONCLUSIONS

This study developed an IoT-based water purity identification system to monitor drinking water quality in tourist areas of Bangladesh. Using sensors to measure pH, TDS, turbidity, and temperature, the system wirelessly transmits data for real-time analysis. Results from 1,000 water samples showed that 36% were fully pure, 58% were moderately pure, and 6% were polluted, emphasizing the need for continuous monitoring and intervention to ensure safe drinking water. Compared to traditional methods, the system offers real-time data collection, remote monitoring, and proactive decision-making to prevent health risks. By providing timely water quality updates, it enhances tourist safety and environmental sustainability. Additionally, IoT integration allows for scalable and efficient water management.

However, the current system lacks predictive capabilities. Future enhancements include integrating AI and machine learning to forecast water quality trends and expanding monitored parameters to include BOD and heavy metals for a more comprehensive assessment. This research contributes to IoT-based water monitoring, offering a scalable solution for sustainable water management. Future studies should focus on improving predictive capabilities, increasing monitored parameters, and addressing implementation challenges like cost and maintenance to maximize its impact.

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