Personalized Testing Kit for Testing Bacterial Contamination in Water

Mr .G. Ashok(Ph .D)
Dean of Academic
Biomedical department
JNN institute of engineering
Kannigaipair, India
ashokg@jnn.edu.in

Indumathi. G
Biomedical Engineering
JNN institute of Engineering
Kannigaipair, India
Indumathig77@jnn.edu.in

Arthi. S
Biomedical Engineering
JNN institute of Engineering
Kannigaipair, India
Arthis69@jnn.edu.in

Dhana Lakshmi. A
Biomedical Engineering
JNN institute of Engineering
Kannigaipair, India
Dhanalakshmik49@jnn.edu.in

Jagannathan. V
Biomedical Engineering
JNN institute of Engineering
Kannigaipair, India

Abstract

Water contamination due to bacterial pathogens is a significant global health concern, contributing to diseases such as cholera, typhoid, and dysentery. Existing bacterial detection methods involve laboratory-based techniques, which are often time-consuming, expensive, and inaccessible in remote locations. This paper presents a personalized testing kit designed to provide a rapid and cost- effective solution for detecting bacterial contamination in water. The system utilizes an Arduino programming using Embedded C. The pH electrode detects changes in water acidity caused by bacterial metabolic activity, allowing real-time analysis of contamination levels. This kit offers an affordable and user-friendly alternative to conventional microbiological methods, making it highly suitable for use in households, rural areas, and emergency situations. The proposed system aims to bridge the gap between accessibility and efficiency in water quality monitoring, ensuring public health safety and promoting widespread adoption of real-time bacterial detection technologies.

Keywords: Arduino programming, Water contamination, cholera, typhoid, Dysentery, Bacterial detection, Embedded C, Metabolic activity, PH electrode

Introduction

Water is most important life sustaining force for the inhabitants of this world. In Developing countries, the lack of sanitation in water is a critical problem in all over the world, Hence the detecting pathogens in water is mandatory for saving Millions of people's life. In india only 2.5% of water is safe fresh water and 20% of population have drinking un purified water and effect is ruin the people's life. [1] However, bacterial contamination of water remains a widespread issue, particularly in developing regions where sanitation infrastructure is inadequate. Contaminated water is a primary vector for waterborne diseases, leading to significant morbidity and mortality worldwide [2].

Ensuring real-time water quality assessment is crucial for preventing outbreaks and safeguarding public health. The consumption of bacterially contaminated water can lead to severe gastrointestinal

infections and other systemic illnesses. Vulnerable populations, such as children, the elderly, and immunocompromised individuals, are particularly at risk. The World Health Organization (WHO) has emphasized the importance of early detection of bacterial contamination to prevent large-scale health crises [2].

Conventional microbiological techniques such as colony-forming unit (CFU) counting, membrane filtration, and polymerase chain reaction (PCR**)** are widely used for bacterial detection. Although these methods provide accurate results, they require specialized equipment, skilled personnel, and extended processing times, making them impractical for routine or emergency testing in low-resource settings [3].Considering the inefficiencies of traditional methods, there is a growing demand for portable, low-cost, and rapid water testing solutions that can be used by individuals without technical expertise. A compact device that can detect bacterial contamination instantly would empower communities and individuals to ensure water safety before consumption [4].

Bacterial metabolic activity alters the chemical composition of water, affecting pH, turbidity, and conductivity. The use of pH electrodes for bacterial contamination detection is based on these principles. By continuously monitoring pH fluctuations, it is possible to determine bacterial presence without direct culture-based analysis, offering a real-time, cost-effective, and non-invasive alternative [5].Advancements in embedded systems and sensor

technology have enabled the development of automated water quality monitoring solutions. The Arduino microcontroller facilitates real-time data acquisition, processing, and display on an LCD screen, allowing users to assess water safety without technical expertise [6]. The integration of a buzzer ensures immediate alerts, enhancing the system's usability for non-specialists.

This research focuses on designing and implementing a personalized water testing kit that can efficiently detect bacterial contamination through pH sensing and microcontroller automation**.** The study evaluates its performance, affordability, and practical applicability compared to existing bacterial detection technologies. The paper also explores potential improvements, such as wireless connectivity and AI-based contamination prediction models, for future enhancements.

Literature Survey

Traditional Methods for Bacterial Contamination Detection

Microbiological methods such as CFU counting, multiple-tube fermentation, and membrane filtration have been widely used for bacterial identification. These approaches provide high specificity and accuracy, but their reliance on incubation periods (typically 24-48 hours**)** and controlled laboratory environments makes them unsuitable for real-time, field-based applications [7].

pH-Based Electrochemical Sensing Techniques

Recent studies have explored pH sensing as an indirect method for bacterial detection. Bacterial metabolism often produces acidic or basic by products, leading to pH shifts in the water sample. Researchers have demonstrated that pH sensors can provide an effective early warning system for bacterial contamination, especially when combined with automated data logging and processing systems [8].

Arduino-Based Water Quality Monitoring Systems

Arduino microcontrollers have gained popularity in low-cost water testing solutions. Several research projects have integrated pH sensors, turbidity meters, and temperature probes with Arduino platforms to create portable, real-time water monitoring devices. These systems have been validated in both laboratory and field conditions, proving their effectiveness in detecting microbial contamination [9].

Embedded Systems and IoT in Water Safety Applications

Embedded systems combined with wireless connectivity and IoT technologies have further improved water testing capabilities. Modern water monitoring solutions use cloud-based data analysis, remote sensing, and AI-driven contamination prediction models to enhance accuracy and reliability. However, many IoT-based solutions require internet connectivity and additional hardware, increasing costs and limiting their deployment in resource-constrained areas. This study aims to bridge this gap by offering a standalone, cost-effective bacterial detection system [10].

METHODOLOGY:

SYSTEM OVERVIEW:

The proposed system consists of a pH electrode for bacterial detection, an Arduino microcontroller for data processing, an LCD display for result visualization, and a buzzer for contamination alerts. The components are

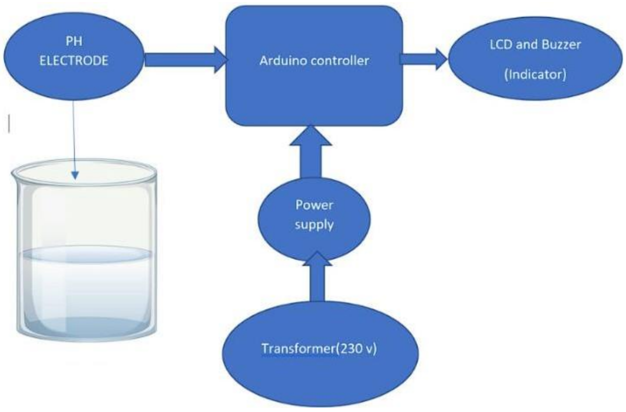

Fig 1: System Architecture

mounted on a PCB board, powered by a 12V step-down transformer, ensuring low power consumption and efficient operation. The pH sensor detects changes in water acidity, correlating these fluctuations with bacterial activity. The Arduino processes the pH data and triggers an alert if contamination exceeds safe thresholds. The results are displayed on the LCD screen, and a buzzer sounds to notify users instantly. The system is programmed using Embedded C, ensuring real-time processing. Various water samples are tested to validate the accuracy and reliability of contamination detection.

There are many other microcontrollers and microcontroller platforms available for physical computing. Parallax Basic Stamp, Netmedia's BX-24, Phidgets, MIT's Handyboard, and many others offer similar functionality. All of these tools take the messy details of microcontroller programming and wrap it up in an easy-to- use package. Arduino also simplifies the process of working with microcontrollers, but it offers some advantage for teachers, students, and interested amateurs over other systems.

COMPONENTS USEDIN THIS SYSTEM:

1) **PH Electrode sensor:**

The bacterial electrode device or pH electrode is a key sensor used to measure the pH level of the water sample. Since bacterial contamination often leads to changes in pH due to metabolic by- products, monitoring pH variations can provide insights into water quality. The pH electrode consists of a glass probe that detects hydrogen ion concentration, producing a voltage output that corresponds to the acidity or alkalinity of the water. It helps in determining bacterial presence based on the variation of pH values.

This sensor detects the PH values based on different samples. if the samples are below and above 6.5it indicates Unpure water means not suitable for drinking. The drinking water PH is 6.5 to 8.5.

Fig2:PH Electrode sensor

2) Arduino controller:

The Arduino Uno is a microcontroller board based on the ATmega328 (datasheet). It has 14 digital input/output pins (of which 6 can be used as PWM outputs), 6 analog inputs, a 16 MHz crystal oscillator, a USB connection, a power jack, an ICSP header, and a reset button. It contains everything needed to support the microcontroller; simply connect it to a computer with a USB cable or power it with a AC-to-DC adapter or battery to get started. The Uno differs from all preceding boards in that it does not use the FTDI USB- to-serial driver chip. Instead, it features the Atmega8U2 programmed as a USB-to- serial converter.

Fig3; Arduino Uno

3) LCD display:

LCD have 16 pins, eight of the pins are data lines (pins 7-14), two are for power and ground (pins 1 and 16), three are used to control the operation of LCD (pins 4-6), and one is used to adjust the LCD screen brightness (pin 3). The remaining two pins (15 and 16) power the backlight.

Liquid crystal displays (LCDs) have materials which combine the properties of both liquids and crystals.An LCD consists of two glass panels, with the liquid crystal material sand witched in between them. The inner surface of the glass plates is coated with transparent electrodes which define the character, symbols or patterns to be displayed polymeric layers are present in between the electrodes and the liquid crystal, which makes the liquid crystal molecules to maintain a defined orientation angle.

Fig4:LCD display

4) BUZZER:

A **buzzer** is a small audio signaling device that generates sound when activated. It plays a crucial role in alerting users when bacterial contamination is detected in the water sample. The buzzer converts electrical signals into sound waves. When bacterial contamination is detected (pH value outside safe limits), the Arduino sends a HIGH signal to the buzzer. The buzzer then emits an alarm sound to notify the user. The duration and frequency of the beep can be controlled through Embedded C programming in Arduino.

Fig5:Buzzer

5) TRANSFORMERS AND POWER SUPPLY:

A transformer is a static piece of which electric power in one circuit is transformed into electric power of same frequency in another circuit. It can raise or lower the voltage in the circuit, but with a corresponding decrease or increase in current. It works with the principle of mutual induction. In our project we are using a step down transformer to providing a necessary supply for the electronic circuits.

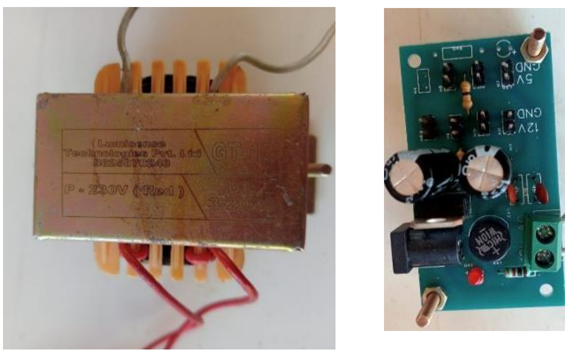

Fig6 ; transformer and power supply

RESULTS AND DISCUSSION:

The Personalized Testing Kit for Testing Bacterial Contamination in Water was successfully developed and tested. The device efficiently detects bacterial contamination by analysing the pH levels of the water sample using a bacterial electrode device (pH electrode). The results were displayed on a 16×2 LCD screen, and an alert system (buzzer) was integrated to notify the user when contamination was detected beyond a safe threshold.

Fig7 ; Different Water samples

Various water samples (tap water, lake water distilled water, Rain water, Mineral water and Dam water) were tested. The system successfully detected bacterial contamination in samples with pH deviations from the neutral range (6.5–7.5). Highly contaminated samples (e.g., rain water) showed lower pH values, triggering the alert system.

S.no	Sample type	Standard PH	Tested PH
1.	Well water	6.5-8.5	7.13-6.63
2.	Dam water	6.5-8.5	6.90-7.44
3.	Rain water	5.0-6.0	5.82-6.31
4.	Lake water	6.5-8.5	7.53-7.71
5.	Mineral water	7.0-8.5	8.30-8.27
6.	Distilled water	5.8-7.0	7.53-7.58
7.	Stagnant water	6.5-9.0	7.23-9.2
8.	Tap water	6.5-8.5	6.86-7.17

Fig8 : result table

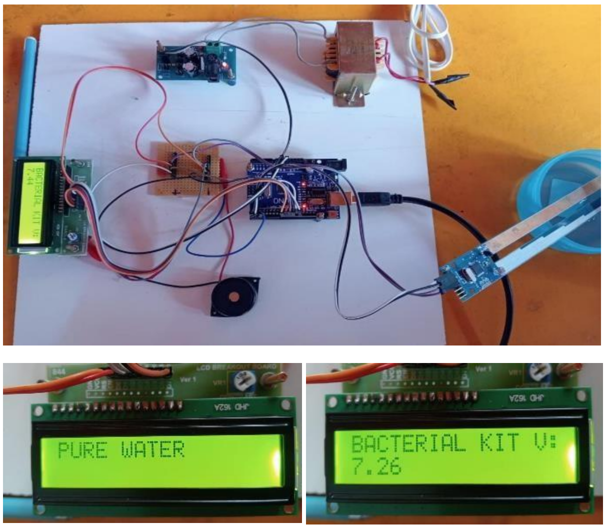

Fig9: Bacterial contamination testing kit

CONCLUSION AND FUTURE IMPROVEMENTS:

The developed bacterial contamination testing kit demonstrated significant potential as an affordable and portable solution for detecting unsafe water conditions. The integration of the pH electrode with an Arduino-based system provided an efficient and real-time method to assess contamination levels. The pH electrode effectively detected pH variations caused by bacterial activity. However, additional sensors (such as turbidity or conductivity sensors) could further enhance the system's sensitivity.
Integrating additional sensors (e.g., turbidity, conductivity, or biosensors) to improve detection accuracy. Implementing wireless communication (IoT**)** to send real- time data to a smartphone or cloud-based system for remote monitoring. Improving the calibration algorithm for better accuracy across different water sources.

References

[1] Suresh, Kasyap, et al. "Simultaneous detection of multiple surface acoustic wave sensor tags for water quality monitoring utilizing cellular code-reuse approach." *IEEE Internet of Things Journal* 9.16 (2021): 14385-14399..

[2] WHO, "Waterborne Diseases and Health Risks," World Health Organization, 2023.

[3] Jones, R. et al., "Global Water Contamination and Health Implications," Journal of Environmental Health, vol. 52, no. 1, pp. 45-60, 2022.

[4] Smith, J. et al., "Advancements in Water Quality Testing Methods," Environmental Science Journal, vol. 45, no. 3, pp. 221-235, 2022.

[5] Brown, P. & Green, T., "Real-Time Water Testing with Sensor-Based Approaches," Sensors and Actuators B: Chemical, vol. 298, 2021.

[6] Johnson, M., "Microbiological Techniques for Water Testing," Journal of Microbial Research, vol. 58, no. 2, pp. 112-
125, 2020.

[7] Lee, C. & Kim, H., "pH Sensing for Bacterial Contamination Detection," IEEE Transactions on Sensors, vol. 67, no. 4, pp. 299-308, 2019.

[8] Patel, R. & Sharma, D., "Arduino- Based Smart Water Quality Monitoring Systems," International Journal of Embedded Systems, vol. 12, no. 5, pp. 85-
97, 2021.

[9] Wang, X. et al., "IoT-Based Water Contamination Detection," Smart Sensors and Systems, vol. 30, pp. 110-123, 2020.

[10] Kumar, A. & Singh, R., "Advances in Electrochemical Sensors for Water Testing," Journal of Applied Electronics, vol. 33, no. 6, pp. 142-156, 2021.

[11] Zhao, L. et al., "Smart Water Quality Monitoring Systems: Challenges and Future Directions," International Conference on Environmental Engineering, 2022.