Embedded Based Realtime Monitoring and Detection of Bacterial Contamination in Drinking Water Using ORP Measurement

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***Abstract*— This project proposes an embedded real time bacterial contamination monitoring and detection system using the Arduino Uno microcontroller. This system uses an oxidation reduction potential (ORP) sensor to detect the presence of bacteria in water or other liquid environments which indicates microbial activity. The detected values are processed by the Arduino and displayed on an LCD with an 12c interface for easy monitoring. A GSM module has been integrated to send instant alerts SMS to the concerned personnel when pollution levels cross predetermined limits. A buzzer provides as immediate audible warning on site while a relay module can be used to trigger additional safety mechanisms such as shutting off the water supply or activating filtration system. This low-cost portable and energy efficient system is suitable for use in rural and industrial settings. It provides a practical alternative to traditional laboratory testing to bacterial threats in real-time environmental conditions.**

***Keywords*—Real-time Monitoring, Bacterial Contamination Detection, GSM Alert System, Water Quality Monitoring, LCD Display with I2C Interface**

I.INTRODUCTION

A plentiful supply of clean water is essential for sustaining all living forms in the environment, irrigating farms, and quenching thirst since it is a vital natural resource for human activity and life on Earth. Numerous factors primarily human Water quality deterioration is caused by a number of activities, including population growth, industry, urbanization, agriculture, household waste, and poor management. Water and basic sanitation must be accessible and managed sustainably for everyone, according to the Agenda for Sustainable Development. Water quality may be enhanced by pollution reduction and the removal of dangerous pollutants. Water quality monitoring allows for the measurement and identification of harmful constituents that can be compared to permitted levels, making it a strategic management tool for decision-making and water quality improvement [1]. Conventional online water quality monitors measure parameters including pH, conductivity, turbidity, and chlorine content. They are used in process monitoring of water treatment plants and are also taken into account for regular DS monitoring. Many of these sensors, including those that measure conductivity and pH, are more likely to pick up dissolved pollutants than particle ones. Furthermore, traditional online water quality monitors are unable to identify the features of particle matter [2]. By educating customers about their usage habits and offering incentives for efficient use, residential areas may make quality improvements in water consumption levels. Aside from the monitoring process, public areas like shopping centres, workplaces, and public bodies can have little to no effect on the behavioural components of consuming. In addition to laying the groundwork for smart living, integrating smart water metering systems into individual homes or entire districts can encourage customers to alter their use patterns. Furthermore, leaks and infrastructure failures can be reduced by strategically integrating smart sensors into main distribution water networks [3]. Water is necessary for life as we know it. However, freshwater shortages remain a problem in many nations. This concerning matter really encouraged people to choose other resources. Gulf nations are obtaining freshwater, for instance, for Water is necessary for life as we know it. However, there are freshwater shortages in many nations. This concerning matter really encouraged people to choose other resources. For instance, the Gulf nations use a laborious desalination process to get freshwater from the ocean. However, this procedure is becoming increasingly difficult due to the increasing construction along the beach and the resultant contamination of the water. In some nations, rainwater is processed to produce freshwater. However, this procedure is becoming increasingly difficult due to the increasing construction along the beach and the resultant contamination of the water.In other countries, freshwater is created by processing rainfall [4]. water quality monitoring system that evaluates irrigation water sources like lakes, rivers, taps, and filters by fusing a sensor framework with an intelligent decision-making method. Four sensors were used to monitor the water quality parameters: electrical conductivity (EC), pH, temperature, and oxidation-reduction potential (ORP). At the end of the procedure, the system conducted a scientific examination to determine the water quality using the water quality index technique.Our method uses fuzzy logic, which is advantageous since it requires less mathematical computation than evolutionary algorithms and neural networks. The suggested system can offer simplicity and flexibility while yet producing dependable results.

A. Objectives

- To develop a real-time bacterial contamination monitoring system using Arduino Uno.
- To detect microbial activity in liquids through an Oxidation Reduction Potential (ORP) sensor.
- To alert users instantly via GSM module when contamination levels exceed safe limits.
- To provide on-site audio alerts and activate safety mechanisms through a buzzer and relay module.
- To create a cost-effective, portable, and energy-efficient solution suitable for rural and industrial environments.

The following is a description of the main sections that make up the remainder of the article Section 2 covers studies on Embedded Based Realtime Monitoring and Detection of Bacterial Contamination models, as presented by various authors. The proposed methodology with different techniques is outlined in Section 3. The outcomes of the suggested model are examined and a performance comparison with alternative optimizers is shown in Section 4. In Section 5, the report comes to a close with a review of the results and recommendations for the future.

II.RELATED WORK

Amit Bhati et.al, (2024) In rural locations where central water delivery is prevalent, this article suggests a low-cost, low-power method for water quality monitoring. The system uses sensor nodes integrated with existing distribution networks to measure the electrochemical properties of water. Using Decision Tree and Naive Bayes algorithms, the system predicts safe drinking water and alerts users when parameters fall outside WHO-specified safe ranges. The results show an efficient performance with an F1-Score of 0.56.

Wibowo Harry Sugiharto et.al., (2024) This study reviews existing literature on IoT-based physicochemical biological sensors to measure the quality of water. Real-time monitoring is not appropriate for biological sensors, such as those that detect the study recommends future research into developing comprehensive water quality indexes (WQI) based on the identified parameters for more reliable water quality management.

Damir B. Krkljes et.al, (2024) This article presents a multiparameter water quality monitoring device intended for ongoing freshwater monitoring. The system employs a small spectrophotometer to identify coliforms and sensors to measure temperature, conductivity, and turbidity. To lessen measurement errors brought on by water contaminants, a heuristic approach is presented. The device functions as an early warning system for pollution occurrences, is submersible, and is appropriate for long-term field operation.

Mahmood Hassan Akhtar et.al., (2024) This paper discusses advancements in pH sensing technologies, emphasizing electrochemical and optical sensors. It highlights their potential applications in biomedical fields, such as wearable pH sensors for real-time healthcare monitoring. The paper explores recent developments in biosensors, presenting opportunities for real-time biological applications, especially in personalized medicine.

Waheb A. Jabbar et.al., (2024) This paper discusses the development of a solar-powered, portable IoT-based water quality monitoring system designed for rural areas. Using LoRaWAN technology, the system measures real-time parameters such as pH and turbidity, transmitting data to an IoT server for analysis. The system was tested and compared with laboratory instruments, demonstrating its reliability.

Titus Mutunga et.al., (2024) This study explores the use of wireless remote sensing and sensors to monitor pesticide pollution in surface and groundwater. It integrates wireless technologies with sensor networks to track pesticide levels in water, providing real-time monitoring capabilities. The proposed system aims to improve water quality monitoring, ensuring timely detection of contaminants.

Zahra Parsa and et.al., (2024) The goal is to minimize operating expenses while ensuring that the effluent quality consistently complies with environmental laws. The study emphasizes how important it is to comprehend the dynamic behaviour of processes in order to create efficient control strategies. The problems of managing wastewater treatment processes are also covered, including the shortcomings of existing models, the restrictions of control techniques, the requirement for real-time data, and the technical and financial hurdles of putting improved controller hardware into practice.

Suresh Kunjiraman et.al., (2024) The paper discusses how the release of Significant production losses may result from the release of harmful gases from aquaculture waste, such as hydrogen sulfide and ammonia. It draws attention to the possibility of immobilized microbial consortia (IMC) as an inexpensive, environmentally acceptable method of managing aquaculture waste, namely Bacillus MCCB 101 for the breakdown of organic matter and Julia MCCB 147 for the reduction of hydrogen sulfide.

Honggui Han et.al., (2024) This research introduces a data-knowledge-driven inductive learning (DKIL) method for modelling wastewater treatment processes (WWTPs). It utilizes fuzzy-based strategies and a collaborative optimization algorithm to efficiently model WWTPs by integrating data and knowledge, enhancing the modelling performance and operational feature extraction of WWTPs. The study verifies the effectiveness of DKIL through experimental results.

Khaya Pearlman Shabangu et.al., (2024) This study optimizes microbial fuel cells with the Box–Behnken design technique for industrial wastewater treatment and bioelectricity generation. By determining ideal values for variables like voltage production and COD elimination, the study emphasizes MFCs' potential as a sustainable bioenergy source. The findings of validation demonstrate that industrial wastewater may be used as an anolyte to generate bioelectricity, providing a scalable approach to energy production and wastewater treatment.

III.PROPOSED METHODOLOGY

In order to guarantee continuous, precise, and prompt detection of microbial threats in liquid settings, the suggested technique for the real-time bacterial contamination monitoring and detection system is focused on the integration of numerous embedded components shown in figure 1. The core of the system is the Arduino Uno microcontroller, which handles control logic and sensor data processing. This redox potential of the liquid medium is measured using an Oxidation-Reduction Potential (ORP) sensor. Variations in ORP levels are accurate markers of the presence of bacteria because microbial activity modifies the oxidation-reduction balance. The Arduino receives these measurements continually from the ORP sensor and analyses them based on predetermined contamination limits. Water quality parameters are visible in real time thanks to an I2C module that connects the Arduino to an LCD display for simple monitoring. The system initiates many alarm mechanisms when the level of contamination exceeds the safety threshold. A GSM module is turned on to send an SMS alert to selected persons, allowing for remote reaction and intervention, while a buzzer instantly sounds an audible warning to alert those present. Furthermore, a relay module is incorporated to automate safety precautions like turning off the water supply or activating a filter system, improving the system's ability to stop contamination from spreading.

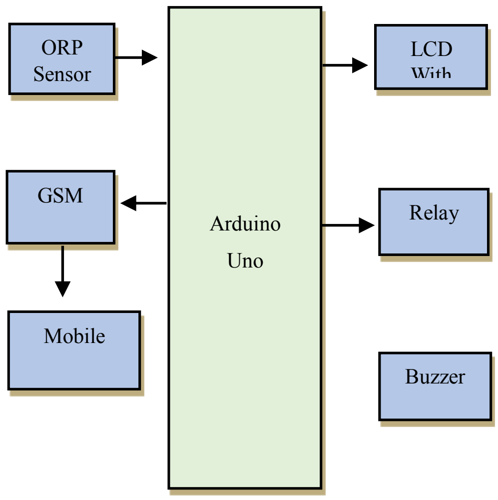

Fig. 1 Proposed Block Diagram

A. Arduino uno microcontroller

This investigates the Arduino board's functionality and uses. This also looks at how it may be utilized as a research and study tool shown in figure 2. An

Arduino board may be a useful tool for developing test benches, particularly for sensors. Fast processing and an intuitive UI are the primary benefits. These days, as more and more people use open-source gear and software, technology is taking on a new dimension by making complex tasks seem simple and engaging.

Fig. 2 Arduino Uno Microcontroller

Additionally new code can be burned (uploaded)to this development board by connecting it a USB wire. With Arduino IDE users can develop C++ applications for Arduino on a simple integrated platform that runs on standard personal computers.

B. Relay

Relays are electrical switches that use electromagnets to control the current flowing through electrical circuits. It is essential for using low-voltage or low-current signals to control high-voltage or high-current devices. Relays are often utilized in home, automobile, and industrial settings as interface devices between various electrical systems. A coil, an armature, and one or more sets of contacts make up a relay's fundamental construction. A magnetic field pulls the armature when an electric current passes through the coil, moving the contacts, which function as switches shown in figure 3. There are several types of relays, such as reed, solid-state, and electromechanical relays with its own advantages and applications.

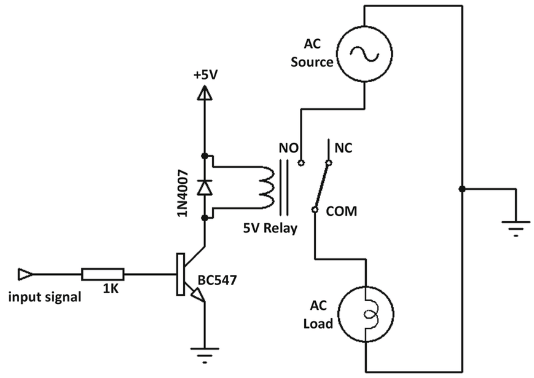

Fig. 3 Relay Circuit Diagram

The power supply supplies electricity to the electromagnet through a control switch and connections to the load. When current begins to flow through the control coil the electromagnet intensifies the magnetic field pulling the upper contact arm to the lower fixed arm. As a result, the contacts close creating a short circuit that powers the load.

C. Buzzer

The user and a product can interact in a variety of ways. Using a buzzer IC for audio communication is one of the greatest methods. Therefore, it is highly beneficial to comprehend certain technologies with setups throughout the design process shown in figure 4. Thus, an overview of an audio signalling device, such as a buzzer or beeper, and how it functions with applications are covered in this article. One type of mechanical, piezoelectric, or electromechanical auditory signalling device is a buzzer or beeper.

Fig. 4 Buzzer

D. *Gsm Module*

GSM, or Global System for Mobile Communications, is a digital cellular communications system that has gained global acceptance and market share. Initially developed in Europe, it offers advanced services like ISDN compatibility and worldwide roaming. GSM's advanced architecture has made it a model for future third-generation cellular systems like UMTS.

Fig. 5 GSM Module

GSM offers a secure network, extensive coverage, and compatibility with various accessories and handsets. However, its disadvantage is the common bandwidth sharing among users, potentially leading to bandwidth limitations and interference. The chips that enable communication between a computer or mobile devices and a GSM system are called GSM modules shown in figure 5.

E. Orp Sensor

An Oxidation-Reduction Potential (ORP) sensor is a device used to gauge a solution's capacity to function as a reducing or oxidizing agent. The ORP value, which is commonly expressed in mill volts (mV), shows how likely a solution is to gain or lose electrons. This value is crucial in many fields, including water treatment, aquariums, and industrial processes shown in figure 6.

Fig. 6 ORP Sensor

IV. RESULT AND DISCUSSION

The proposed system effectively monitors bacterial contamination in real-time using an ORP sensor integrated with an Arduino Uno. It provides instant alerts via SMS and audible warnings through a buzzer when contamination levels exceed preset thresholds. The system's user-friendly LCD display and GSM module ensure that personnel are promptly notified of any contamination, enhancing water quality management. The inclusion of a relay module allows for automated safety responses, such as shutting off water supplies or activating filtration systems. With its low cost and portability, the system is an ideal solution for rural and industrial applications. This system serves as an efficient, real-time alternative to traditional laboratory testing. It offers immediate detection and response to bacterial threats in environmental settings. The integration of these components ensures a proactive approach to maintaining safe water quality standards.

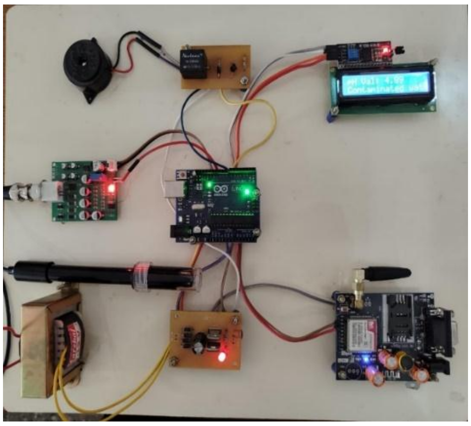

Fig. 7 Full measurement setup of ORP

The complete test configuration and schematic circuitry for ORP measurements are shown in figure 7. The Arduino microcontroller was powered on by a 3.3V power supply. The SIM 900 GSM module must be registered in the network before the measurement may begin. Will begin receiving ORP values continually as soon as the modem initialization instruction is received by the registered mobile. These values are then compared to predetermined acceptable limits, and the results are shown both locally (LCD) and remotely. Customers, water board officials, and water corporations get a caution message (SMS) if the values are determined to be abnormal.

Fig. 8 Output of contaminated drinking water

Figure 8 illustrates the output of the contaminated drinking water detection system, showing the real-time reading of the ORP sensor displayed on the LCD. The sensor detects bacterial contamination levels, triggering the GSM module to send an alert if the pollution exceeds predefined limits. The buzzer emits an audible warning, notifying users of the contamination. Additionally, the relay module can activate safety mechanisms, such as shutting off the water supply or initiating filtration, ensuring immediate action is taken.

V.CONCLUSION

The project goal was to install a real-time monitoring and bacterial contamination detection system in order to guarantee the safety of drinking water. In order to evaluate water's capacity to prevent bacterial development and function as a trustworthy signal of contamination, an embedded system was created that uses Oxidation-Reduction Potential (ORP) assessment. The system included a relay-driven buzzer for alarms, an Arduino Uno, an ORP sensor, an LCD with I2C for data display, and a GSM module for remote notifications. The system identified contamination incidents by continually monitoring ORP readings, set off local alarms, and provided users SMS warnings so they could take prompt action. Through proactive water quality control, the approach offered an affordable and easily accessible way to protect public health. There were serious health dangers to the general public when drinking water was contaminated by microorganisms. Water quality analysis using traditional laboratory-based techniques was accurate, but sometimes costly, time-consuming, and inappropriate for real-time applications. Using Oxidation-Reduction Potential (ORP) measurements, this study suggested an embedded system for real-time monitoring and drinking water bacterial contamination detection. Because it reflected the equilibrium between oxidizing and reducing agents, ORP was a trustworthy indication of water quality and may be related to microbial activity.

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