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Smart Water Pollution Management: IoT for Automatic Detection and Prevention

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Abstract: *Water quality monitoring is vital for public health and environmental sustainability, but traditional methods face challenges such as high costs, lack of portability, and limited real-time data access. This paper presents a solution using Arduino-based sensors integrated with IoT technology to enhance water quality monitoring. The system employs various sensors to measure parameters like Total Dissolved Solids (TDS), turbidity, water transparency, methane gas, and alcohol gas. Data from these sensors is transmitted to a NodeMCU microcontroller and uploaded to the Blynk cloud platform, allowing real-time monitoring and remote access via customizable dashboards. The proposed system is cost-effective, portable, and provides immediate data access, addressing the limitations of traditional methods. It enables timely detection of water quality issues, facilitating prompt responses to health and environmental threats. This innovative approach significantly advances water quality monitoring by leveraging IoT technologies to improve environmental management practices.*

Keywords: Water quality monitoring

I. INTRODUCTION

Water quality monitoring is essential for safeguarding public health and ensuring environmental sustainability. Contaminated water can lead to severe health issues such as gastrointestinal diseases, reproductive problems, and neurological disorders. Furthermore, environmental degradation due to polluted water bodies affects biodiversity and disrupts ecosystems, making the accurate and timely monitoring of water quality a critical task. Traditional water quality monitoring methods, while reliable, often face significant challenges related to high costs, lack of portability, and limited access to real-time data [1][4]. These limitations can hinder effective water management and delay responses to contamination events, potentially exacerbating health risks and environmental damage.Traditional water quality monitoring typically involves manual sampling and laboratory analysis. While these methods can provide precise measurements, they are labor-intensive, time-consuming, and often not feasible for continuous monitoring. Moreover, the delay between sample collection and result analysis can result in missed opportunities for timely intervention. The need for trained personnel and specialized equipment further adds to the cost and complexity of traditional monitoring approaches [6]. Consequently, there is a pressing need for innovative solutions that can overcome these limitations and offer more efficient and accessible water quality monitoring.

In recent years, advancements in Internet of Things (IoT) technology have provided new opportunities for enhancing water quality monitoring systems. IoT-based solutions offer the potential for real-time data collection, remote monitoring, and integration with cloud-based platforms for data visualization and analysis [8][9]. These systems utilize a variety of sensors to monitor key water quality parameters such as pH, turbidity, temperature, and chemical contaminants. The data collected by these sensors are transmitted wirelessly to centralized platforms where they can be analyzed in real-time, allowing for immediate detection of water quality issues and prompt response measures [3][7].

This paper proposes a comprehensive water quality monitoring solution that leverages Arduino-based sensors integrated with IoT technology. The system employs an array of sensors, including Total Dissolved Solids (TDS), turbidity, water transparency, methane gas, and alcohol gas sensors, to provide a holistic assessment of water quality. TDS sensors measure the concentration of dissolved solids in the water, indicating the overall quality and purity of the water. Turbidity sensors assess the cloudiness or haziness of water, which can be caused by particles and microorganisms, thus indicating potential pollution. Water transparency sensors provide data on the clarity of water, which is essential for determining the presence of contaminants. Methane and alcohol gas sensors detect the presence of hazardous gases that could indicate industrial pollution or contamination from agricultural runoff.

Data collected by these sensors are transmitted to a NodeMCU microcontroller, a low-cost open-source IoT platform. The NodeMCU processes the data and uploads it to the Blynk cloud platform. Blynk is a popular IoT platform that enables remote visualization and control of sensor data through customizable dashboards accessible via web or mobile applications. This integration allows for real-time monitoring and provides users with immediate access to water quality data from anywhere in the world, significantly enhancing the responsiveness and effectiveness of water quality management [2][5].The proposed system offers several advantages over traditional water quality monitoring methods. It is cost-effective, reducing the financial burden associated with frequent and extensive water quality testing. Its portability ensures that the system can be easily deployed in various locations, including remote and underserved areas where traditional monitoring is often impractical. The real-time data access feature allows for immediate detection of water quality issues, facilitating prompt and effective responses to potential health hazards and environmental threats [4][10].

Moreover, the system's ability to continuously monitor water quality parameters provides a more comprehensive understanding of water conditions over time, enabling better trend analysis and long-term planning. This continuous monitoring capability is particularly important for identifying and addressing emerging contaminants and understanding the impact of seasonal variations and human activities on water quality [1][7].

In conclusion, the integration of Arduino-based sensors with IoT technology presents a powerful solution to the limitations of traditional water quality monitoring methods. By providing a cost-effective, portable, and real-time monitoring system, this project aims to enhance the management and protection of water resources, ultimately contributing to better public health outcomes and environmental sustainability. This innovative approach represents a significant step forward in the field of water quality monitoring, demonstrating the potential of IoT technologies to transform environmental management practices [6][9].

By exploring the development and implementation of this IoT-based water quality monitoring system, this paper aims to demonstrate its feasibility and effectiveness in overcoming the challenges associated with traditional monitoring methods. The findings from this study can provide valuable insights for researchers, policymakers, and practitioners working towards improving water quality monitoring and management [3][8].

II. LITERATURE SURVEY TABLE

SL. No	Author /Year	Title	Key techniques	Accomplished Work	Limitations
01	Dr.NageswaraRaoMoparthi, Ch. Mukesh, and Dr. P. VidyaSagar [2018]	Water Quality Monitoring System Using IoT	The key techniques include IoT integration with Arduino, pH sensor and GSM alerts, real-time LED display, cloud data storage, and a cost-effective, automated system for efficient water quality monitoring	Developed an IoT-based system for real-time water quality monitoring. Implemented pH sensors and GSM alerts for timely notifications. Enabled real-time data display and cloud connectivity. Designed a cost-effective, automated, low-maintenance system.	Limited Sensor Range Dependency on GSM Maintenance Power Supply
02	SantoshKonde and Dr. S.B. Deosarkar	IOT Based Water Quality Monitoring	It include sensor integration for real-time data collection,	Developing a sensor-integrated IoT system for real-time monitoring.	Sensor calibration issues may lead to inaccuracies.

	[2020]	System	IoT connectivity for remote monitoring, and data analytics for quality assessment.	ensuring data accuracy, and providing actionable insights for quality management.	Limited data transmission range could affect remote monitoring.
03	Cho ZinMyint, Lenin Gopal, and Yan Lin Aung [2017]	Reconfigurable Smart Water Quality Monitoring System in IoT Environment	The smart water quality monitoring system include FPGA programming in VHDL, sensor integration (ultrasonic, pH, temperature, turbidity, CO2), Zigbee wireless communication, and real-time data processing.	designing a reconfigurable smart water quality monitoring system using FPGA programming, integrating multiple sensors, implementing Zigbee wireless communication, and achieving real-time data processing for remote monitoring of water parameters.	Complexity of FPGA programming. Challenges in sensor calibration and maintenance.
04	Sharifah H. S. Ariffin, M. AriffBaharuddin, M. Husaini M. Fauzi, Nurul M. A. Latiff, Sharifah K. Syed Yusof. [2017]	Wireless Water Quality Cloud Monitoring System with Self-healing Algorithm	Utilized IoT sensors for water quality parameters, Favoriot cloud platform for real-time data storage, and a self-healing algorithm to automate recovery from wireless service connection failures.	Developed a real-time water quality monitoring system integrating IoT sensors, cloud storage (Favoriot), and a self-healing algorithm, ensuring continuous data collection and recovery from wireless service disruptions.	Reliance on GPRS network for data transmission may face connectivity issues. The self-healing algorithm's effectiveness may vary based on the severity of disruptions.
05	Abel KurianOommen, AdarshSaji, Shilpa Joseph, Prof Babu P Kuriakose [2019]	Automated Water Quality Monitoring System for Aquaponics	Internet of Things (IoT) application for real-time monitoring, chemical reagent tests for ion concentration detection, Wi-Fi technology for wireless control and communication, optimization of power usage for water circulation.	Developed an automated system using IoT for monitoring pH, temperature, ammonia, and nitrate levels in aquaponics. Utilized chemical reagent tests for ion concentration measurement, optimizing power usage with Wi-Fi control.	Dependency on chemical reagent tests, Lack of electronic sensors for ammonia Potential complexity in setting up
06	SitiNadhirahZainurin, Wan Zakiah Wan Ismail, SitiNurulImanMahamud, Irneza Ismail,	Advancements in Monitoring Water Quality Based on Various Sensing Methods: A	The review discusses IoT, virtual sensing, CPS, and optical techniques for water quality monitoring. It highlights CPS's integration of physical	The review evaluates conventional and modern water quality monitoring methods worldwide, emphasizing the potential of cyber-physical systems (CPS) for real-time	Costliness of conventional methods. Complexity of modern methods.

	JulizaJamaludin, KhairulNabilahZainulAriffin, and Wan Maryam Wan Ahmad Kamil [2022]	Systematic Review	and computational algorithms, embedded sensors, processors, and actuators for environment interaction and real-time data.	detection and reliability improvement in water quality assessments.	
07	MuhammedSakibHasan, ShahjalalKhandaker, Md. ShahidIqbal, Md. MonirulKabir [2020]	Real-Time Smart Wastewater Monitoring System Using IoT: Perspective of Bangladesh	Utilized Arduino UNO microcontrollers, GSM-GPRS modules, and smart sensors (Temperature, pH, Turbidity, DO, TDS) for real-time water parameter monitoring. Implemented a web-based interface for data visualization and analysis.	Developed a real-time Smart Wastewater Monitoring System (SWMS) in Bangladesh using IoT, incorporating microcontrollers, smart sensors, GSM-GPRS modules, and a web server for continuous online monitoring.	Limited sensor parameters (Temperature, pH, Turbidity, DO, TDS). Reliance on GSM-GPRS network for data transmission.
08	SathishPasika, SaiTejaGandla [2020]	"Smart water quality monitoring system with cost-effective using IoT"	Utilized sensors (pH, turbidity, ultrasonic, DHT-11), Arduino Mega, NodeMCU, and ESP8266 Wi-Fi module for data processing and transmi	Developed a real-time water quality monitoring system using IoT, measuring pH, turbidity, water level, temperature, and humidity. Data processed via MCU and transmitted to the cloud for monitoring.	Limited to monitoring basic water quality parameters. May require frequent maintenance due to sensor calibration needs.
09	MoniraMukta, Surajit Das Barman, MSaddamHossain Khan, Samia Islam, Ahmed Wasif Reza [2019]	IoT based Smart Water Quality Monitoring System	IoT integration, Arduino Uno with sensors, fast forest binary classifier for water quality analysis, .NET platform for desktop application development.	Developed an intelligent IoT system to continuously monitor water quality based on pH, temperature, conductivity, and turbidity, using a fast forest binary classifier for analysis.	Limited to physical parameters doesn't address chemical contaminants. Relies on WHO standards only, may not cover specific regional water quality guidelines.
10	M. B. Kalpana [2016]	Online Monitoring Of Water Quality Using Raspberry Pi3 Model B	Utilized Raspberry Pi3 Model B with sensors for conductivity, turbidity, and pH. Data is processed, stored in text files, and transmitted to a web	Developed a low-cost, automated system for real-time monitoring of water quality parameters like conductivity, turbidity, and pH using Raspberry Pi3 Model B, providing global	Limited to monitoring only a few parameters (conductivity, turbidity, pH). Initial setup and calibration

			server for real-time monitoring via cloud computing.	accessibility.	required.

III. EXISTING SYSTEM

Traditional water quality monitoring systems predominantly rely on manual sampling and laboratory analysis techniques. Water samples are collected at various locations, transported to laboratories, and subjected to chemical and biological analyses to determine parameters such as pH, dissolved oxygen, nutrient levels, and contaminant concentrations. While these methods provide valuable insights into water quality, they have significant drawbacks. Manual sampling is labor-intensive and time-consuming, often resulting in delayed data acquisition and analysis. Additionally, the spatial and temporal resolution of data obtained through periodic sampling may not adequately capture dynamic changes in water quality, particularly in rapidly evolving environmental conditions [6][10].

Automated water quality monitoring systems have been developed to address some of these limitations. These systems typically deploy sensors in situ to continuously measure water quality parameters in real-time. However, many automated systems are costly to implement, require significant infrastructure investments, and may lack compatibility with emerging IoT technologies for data transmission and visualization [4][7]. Furthermore, these systems often lack portability, limiting their deployment in remote or inaccessible areas where water quality issues may be prevalent. This lack of real-time monitoring capabilities hampers timely responses to emerging water quality threats, posing risks to public health and environmental sustainability [4][9].

3.1 PROBLEM IDENTIFICATION

Water quality monitoring plays a crucial role in ensuring public health and environmental sustainability. However, existing monitoring systems encounter several significant challenges that hinder their effectiveness and practicality.

Traditional water quality monitoring methods heavily rely on manual sampling and laboratory analysis. This approach is labor-intensive, time-consuming, and requires substantial resources. The process involves collecting water samples from various locations, transporting them to laboratories, and conducting detailed chemical and biological analyses to assess parameters such as pH levels, dissolved oxygen content, nutrient concentrations, and contaminant levels (6)(10). While these methods can provide accurate data, the time lag between sample collection and analysis results in delayed data acquisition. This delay can be particularly problematic in dynamic water environments where rapid changes occur, impacting the ability to respond swiftly to emerging water quality issues

Automated water quality monitoring systems have been developed to address some of the limitations of traditional methods. These systems utilize in situ sensors to continuously measure water quality parameters in real-time, reducing the need for manual sampling and providing more immediate data (4)(7). However, these automated systems come with their own set of challenges. They often require significant initial investment in infrastructure and technology, making them costly to implement. The complexity of these systems also demands specialized knowledge for installation, maintenance, and operation, further adding to the costs.

Moreover, automated systems may lack portability, limiting their deployment in remote or inaccessible areas where water quality issues may be prevalent. The need for stable power supplies and fixed installations restricts their use in off-grid locations. Additionally, while some systems offer real-time data collection, the lack of comprehensive integration with IoT technologies can limit data transmission and visualization capabilities, hindering effective monitoring and response to water quality issues in real-time.

Furthermore, both traditional and automated systems often focus on a limited set of parameters, potentially overlooking crucial indicators of water quality, such as specific contaminants or changes in biological activity. This narrow focus can lead to incomplete assessments and inadequate responses to water quality challenges.

In summary, the main challenges facing existing water quality monitoring systems include:

1. Cost: Traditional methods and automated systems are often expensive to implement and maintain.
2. Labor Intensity: Manual sampling and complex infrastructure maintenance require significant human resources.

3. Timeliness: Delayed data acquisition and lack of real-time monitoring capabilities impede timely responses to emerging water quality issues.
4. Portability: Limited deployment options in remote or off-grid areas due to infrastructure and power supply requirements.
5. Comprehensiveness: Focus on a limited set of parameters may result in incomplete assessments of water quality.

Addressing these challenges requires the development of a more efficient, cost-effective, and comprehensive water quality monitoring solution that integrates real-time data acquisition, IoT technologies, and enhanced portability capabilities.

3.2. RELATED WORK AND MOTIVATION

The realm of water quality monitoring has witnessed a spectrum of research endeavors aimed at addressing the inherent challenges prevalent in existing monitoring systems. These efforts have encompassed a diverse array of methodologies and technologies, each offering unique insights and solutions to improve the efficacy and practicality of water quality monitoring.

One avenue of exploration in this domain is reflected in the study conducted by Moparthi et al. (2018) (1), which advocated for an IoT-based approach utilizing Arduino and GSM technology for real-time pH monitoring. While this approach showcased effectiveness in pH monitoring, its reliance on GSM networks highlighted certain limitations, particularly regarding network availability and reliability.

Conversely, research endeavors such as that of Konde and Deosarkar (2020) (2) delved into real-time data collection techniques through surveys and interviews to analyze the impact of social media on mental health. While this study may not directly relate to water quality monitoring, it shed light on the advantages and limitations of data collection methodologies, offering valuable insights for improving data acquisition techniques in various domains, including water quality monitoring.

Moreover, studies focusing on technological advancements have also significantly contributed to the discourse on water quality monitoring. For instance, Myint et al. (2017) (3) explored the integration of FPGA programming and Zigbee communication to develop a reconfigurable smart water quality monitoring system in an IoT environment. This study highlighted the potential of advanced sensor integration in addressing global water quality monitoring needs, offering scalability and adaptability to diverse monitoring scenarios.

Similarly, Ariffin et al. (2017) (4) ventured into wireless water quality monitoring systems with self-healing algorithms, leveraging IoT sensors and cloud storage for uninterrupted data collection. While this system provided real-time monitoring benefits, challenges persisted concerning GPRS connectivity and the effectiveness of self-healing algorithms, showcasing the complexities involved in implementing such advanced monitoring solutions.

Furthermore, investigations into specific applications of IoT technology in water quality monitoring, such as the study by Oommen et al. (2019) (5) focusing on automated monitoring systems for aquaponics, have underscored the complexities and challenges associated with integrating IoT technologies into specialized monitoring environments. This study highlighted the need for addressing maintenance issues and system optimization to ensure the reliability and effectiveness of IoT-based monitoring systems.

The motivation underlying this project stems from a comprehensive understanding of the limitations and opportunities presented by existing water quality monitoring systems. Traditional methods, characterized by manual sampling and labor-intensive laboratory analyses, often fall short in terms of real-time data acquisition and scalability. On the other hand, automated systems, while offering real-time capabilities, are often hindered by high implementation costs, technical complexities, and limited portability.

By drawing insights from the diverse body of related work, the motivation is to develop a more efficient, cost-effective, and comprehensive solution for water quality monitoring. This entails leveraging IoT technologies to enable real-time data acquisition, enhancing accessibility and scalability, and addressing the challenges posed by existing monitoring systems. Ultimately, the goal is to contribute to sustainable water resource management by providing reliable and actionable data for addressing water quality challenges and safeguarding public health and environmental well-being.

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3.3.PROPOSED METHOD

The proposed method for water quality monitoring aims to address the limitations observed in existing systems while leveraging the advancements and insights gained from related research endeavors. This method encompasses a comprehensive approach that integrates IoT technologies, real-time data acquisition, and enhanced portability features to create an efficient, cost-effective, and comprehensive water quality monitoring solution.

At the core of the proposed method are IoT-enabled sensors capable of measuring a wide range of water quality parameters. These sensors include but are not limited to Total Dissolved Solids (TDS), turbidity, water transparency, methane gas, and alcohol gas sensors. The selection of these sensors is based on their relevance to assessing water quality and their ability to provide real-time data.

The deployment of these sensors is facilitated by a compact and portable hardware setup, utilizing Arduino-based microcontrollers as the central processing units. Arduino boards are chosen for their versatility, affordability, and ease of integration with various sensors. Additionally, the use of NodeMCU microcontrollers enhances the system's connectivity capabilities, enabling wireless data transmission to central monitoring systems.

The data collected by the sensors is transmitted wirelessly to a central monitoring system, which can be accessed through a user-friendly interface such as a web-based dashboard or a mobile application. The data transmission is facilitated by Wi-Fi or cellular networks, ensuring reliable and real-time data acquisition. This real-time data access is crucial for timely detection of water quality issues and prompt decision-making.

Furthermore, the proposed method incorporates cloud-based storage and analytics capabilities. Data collected from multiple monitoring points are stored securely in the cloud, allowing for centralized data management and analysis. Advanced analytics algorithms are applied to the data to identify trends, anomalies, and potential water quality threats. These analytics insights can aid in proactive decision-making and targeted interventions

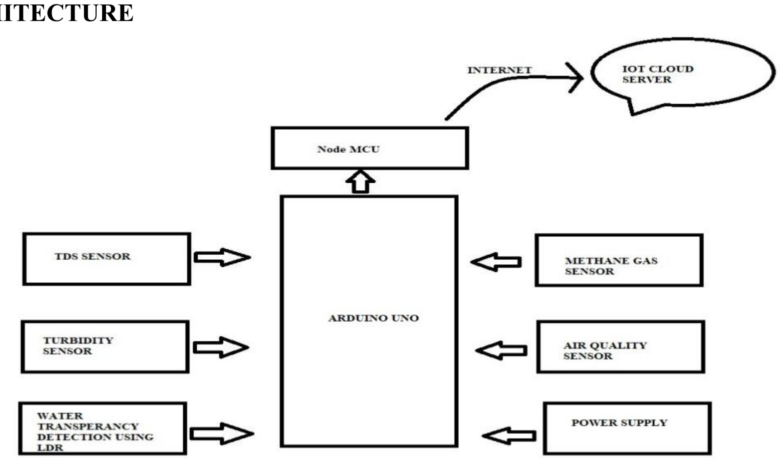
The scalability of the proposed method is another key aspect. The modular design allows for easy integration of additional sensors or monitoring points as needed. This scalability is essential for expanding monitoring networks and adapting to evolving water quality challenges.

Moreover, the proposed method emphasizes energy efficiency and sustainability. Power-saving features are implemented to optimize energy usage, prolonging the operational life of the monitoring system and reducing maintenance requirements. This energy-efficient design is complemented by the use of renewable energy sources where feasible, further enhancing the system's sustainability.

Overall, the proposed method for water quality monitoring represents a holistic and innovative approach that addresses the shortcomings of existing systems. By leveraging IoT technologies, real-time data acquisition, enhanced portability, scalability, and sustainability features, this method aims to provide a reliable and comprehensive solution for monitoring water quality in diverse environments.

IV. SYSTEM DESIGN

4.1 SYSTEM ARCHITECTURE



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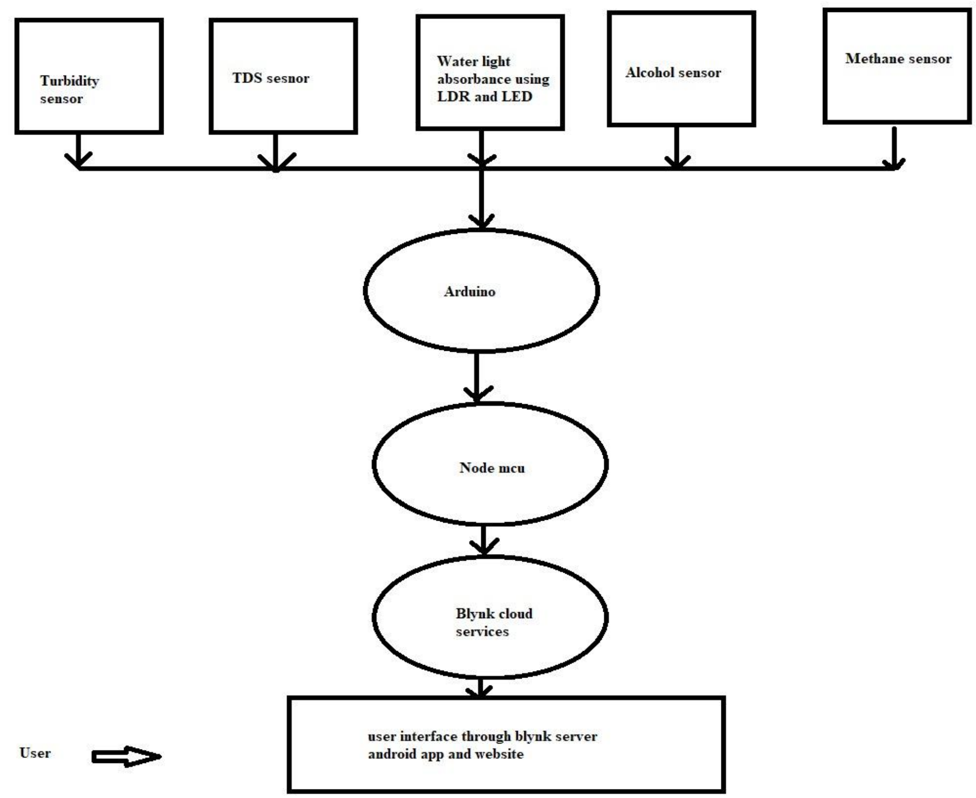
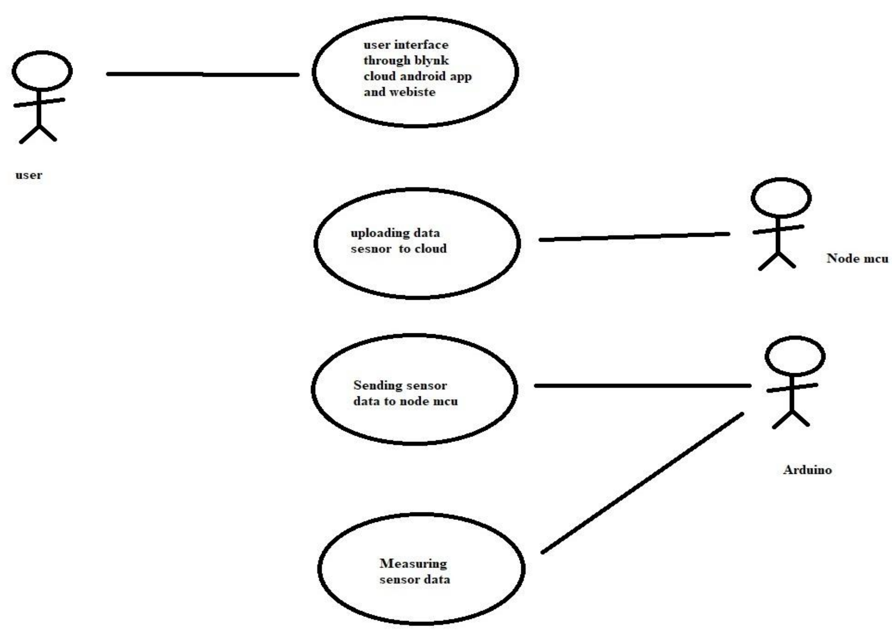
4.2 SYSTEM DATA FLOW DIAGRAMS :



4.3 USE CASE DIAGRAMS :



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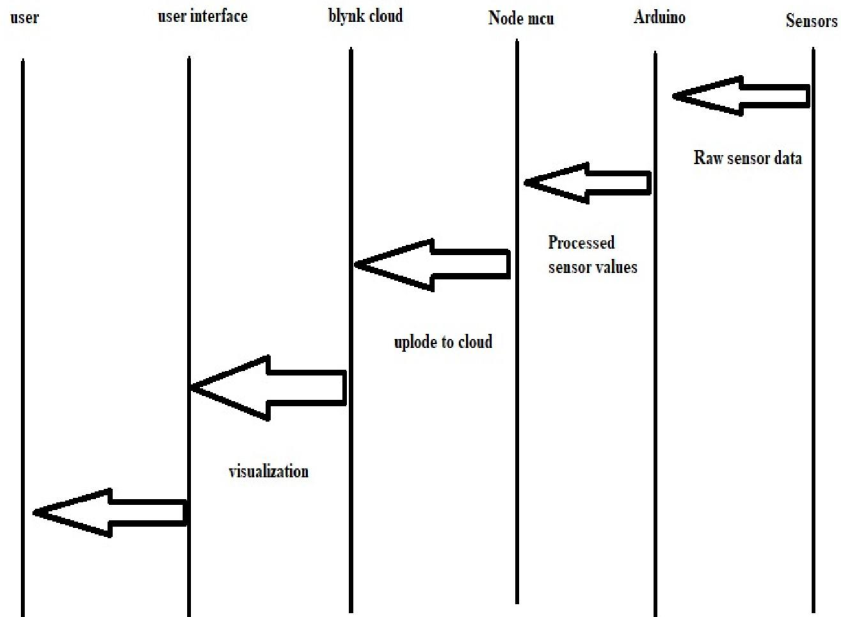
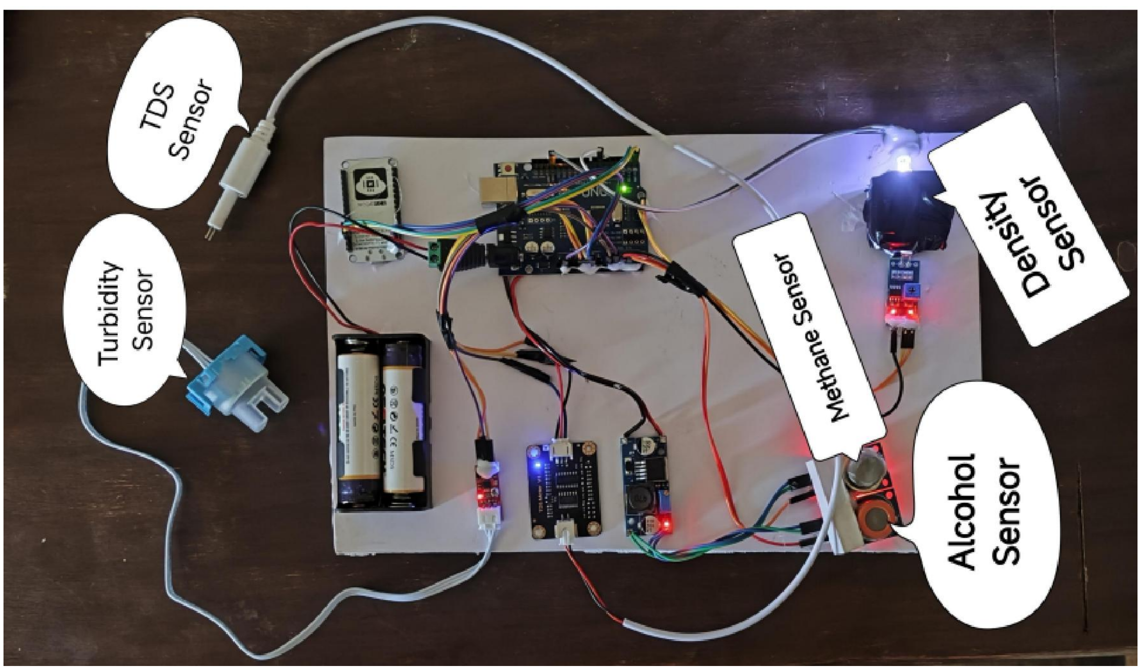
4.4 SEQUENCE DIAGRAMS :



V. RESULTS



In the figure presented below, the integration of various sensors with the Arduino board is depicted. This setup forms the core of the proposed water quality monitoring system, highlighting the interconnected components that facilitate real-time data acquisition and transmission.

TDS Sensor: The Total Dissolved Solids (TDS) sensor is connected to the Arduino board to measure the concentration of dissolved substances in the water. This parameter is crucial for assessing the overall water quality and identifying potential contaminants.

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Turbidity Sensor: The turbidity sensor is linked to the Arduino board to evaluate the clarity of the water by measuring the amount of suspended particles. High turbidity levels can indicate the presence of pollutants and affect the water's aesthetic and biological quality.

Methane Sensor: The methane sensor is integrated into the system to detect the presence of methane gas in the water. Methane contamination can be hazardous and is often associated with industrial discharge or natural seepage, making it an essential parameter to monitor.

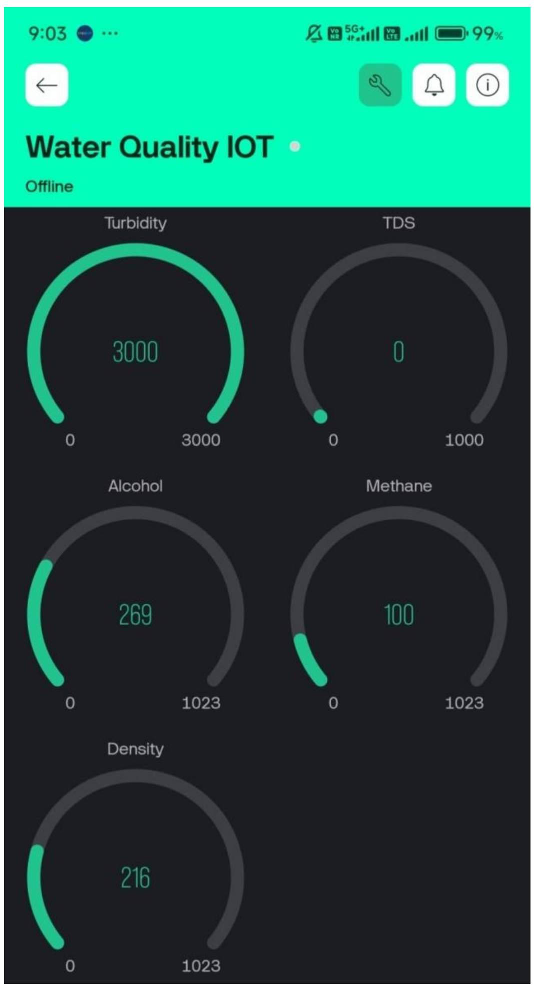
Light Sensor: The light sensor, also known as a water transparency sensor, utilizes an LDR (Light Dependent Resistor) to measure the transparency of the water by detecting the amount of light passing through it. This sensor helps in understanding the level of particulate matter and the water's optical properties.

Alcohol Sensor: The alcohol sensor is incorporated to detect any alcohol contamination in the water. This sensor is particularly useful for monitoring water sources near industrial areas where alcohol might be a pollutant.

The data collected by these sensors are processed by the Arduino board, which serves as the central processing unit. The Arduino board not only manages the sensor data but also facilitates the transmission of this data to the NodeMCU microcontroller for further processing and cloud storage. This integrated sensor setup ensures comprehensive monitoring of multiple water quality parameters, providing a holistic view of the water's condition.

This illustration exemplifies the seamless integration of diverse sensors with the Arduino board, forming a robust and efficient water quality monitoring system that leverages IoT technology for real-time, multi-parameter assessment.

5.1 OUTPUT SCREENSHOTS



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5.1.1 Turbidity:

Figure 5.1.1(a) Turbidity value for sample 1
Figure 5.1.1(b) Turbidity value for sample 2
Figure 5.1.1(c) Turbidity value for sample 3

Water sample	Type of Wastewater	Turbidity Level (out of 3000)	Good for Purpose?
1	Agricultural Wastewater	236	Yes
2	Agricultural Wastewater	250	Yes
3	Agricultural Wastewater	800	No
4	Agricultural Wastewater	1200	No
5	Agricultural Wastewater	220	Yes
1	Municipal Wastewater	1550	No
2	Municipal Wastewater	800	Yes
3	Municipal Wastewater	1200	Yes
4	Municipal Wastewater	500	Yes
5	Municipal Wastewater	1600	No
1	Industrial Wastewater	2242	No
2	Industrial Wastewater	2000	No
3	Industrial Wastewater	1200	Yes
4	Industrial Wastewater	2800	No
5	Industrial Wastewater	1500	Yes

In the following figures, we present the output screenshots of turbidity measurements for different types of wastewater. These measurements highlight the varying levels of turbidity, which indicate the concentration of suspended particles in the water samples from agricultural, municipal, and industrial sources.

Figure a: Agricultural Wastewater

The turbidity level measured for agricultural wastewater is 236 out of 3000. This relatively low turbidity level suggests that the water has a moderate amount of suspended particles, likely due to soil runoff, fertilizers, and organic matter from agricultural activities.

Figure b: Municipal Wastewater

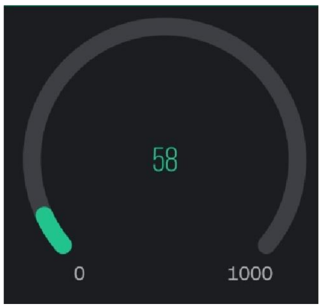
The turbidity level measured for municipal wastewater is 1550 out of 3000. This higher turbidity level indicates a significant presence of suspended particles, which can be attributed to a mix of organic and inorganic matter, including sewage, household waste, and urban runoff.

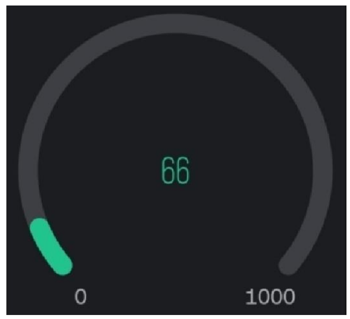
Figure c: Industrial Wastewater

The turbidity level measured for industrial wastewater is 2242 out of 3000. This maximum turbidity level suggests an extremely high concentration of suspended particles, likely due to various industrial effluents, chemicals, and solid waste materials discharged into the water.

These turbidity measurements underscore the significant differences in water quality across different sources of wastewater. Agricultural wastewater shows moderate turbidity, municipal wastewater exhibits higher turbidity, and industrial wastewater reaches the maximum turbidity level, reflecting the varying levels of contamination and the need for targeted water treatment strategies for each type of wastewater

5.1.2 TDS:





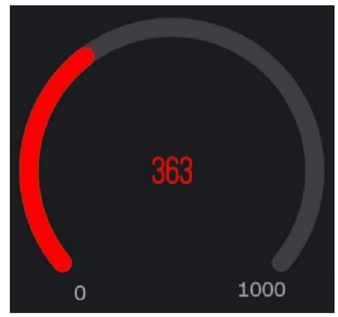


Figure 5.1.2(a) TDS value for sample 1
Figure 5.1.2(b) TDS value for sample 2
Figure 5.1.2(c) TDS value for sample 3

Water sample	Type of Wastewater	TDS Level (out of 1000)	Good for Purpose?
1	Agricultural Wastewater	58	Yes
2	Agricultural Wastewater	250	Yes
3	Agricultural Wastewater	800	No
4	Agricultural Wastewater	1200	No
5	Agricultural Wastewater	220	Yes
1	Municipal Wastewater	66	No
2	Municipal Wastewater	800	Yes
3	Municipal Wastewater	1200	Yes
4	Municipal Wastewater	500	Yes
5	Municipal Wastewater	1600	No
1	Industrial Wastewater	363	No
2	Industrial Wastewater	2000	No
3	Industrial Wastewater	1200	Yes
4	Industrial Wastewater	2800	No
5	Industrial Wastewater	1500	Yes

In the following figures, we present the output screenshots of Total Dissolved Solids (TDS) measurements for different types of wastewater. These measurements highlight the varying levels of dissolved solids in the water samples from agricultural, municipal, and industrial sources.

Figure a: Agricultural Wastewater

The TDS level measured for agricultural wastewater is 58 out of 1000. This relatively low TDS level indicates that the water contains a modest amount of dissolved solids, which could include minerals, salts, and organic matter resulting from agricultural activities such as irrigation and fertilizer use.

Figure b: Municipal Wastewater

The TDS level measured for municipal wastewater is 66 out of 1000. This slightly higher TDS level suggests the presence of various dissolved substances, including household detergents, waste products, and urban runoff, reflecting the diverse sources of contaminants in municipal wastewater.

Figure c: Industrial Wastewater

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The TDS level measured for industrial wastewater is 363 out of 1000. This significantly higher TDS level indicates a considerable amount of dissolved solids, likely due to the presence of industrial chemicals, effluents, and other byproducts from manufacturing processes.

These TDS measurements illustrate the considerable differences in the concentration of dissolved solids across different sources of wastewater. Agricultural wastewater has the lowest TDS level, municipal wastewater has a moderate TDS level, and industrial wastewater shows a substantially higher TDS level. These differences reflect the varying degrees of water contamination and highlight the necessity for tailored water treatment solutions for each type of wastewater

5.1.3 MQ-3 ALCOHOL GAS SENSOR:

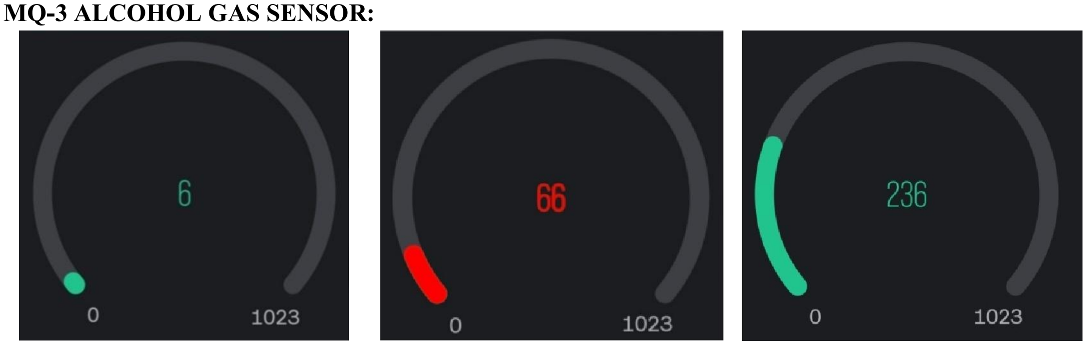

Figure 5.1.3(a) MQ3 value for sample 1
Figure 5.1.3(b) MQ3 value for sample 2
Figure 5.1.3(c) MQ3 value for sample 3

Water sample	Type of Wastewater	MQ3 Alcohol Gas Sensor Reading (out of 1023)	Good for Purpose?
1	Agricultural Wastewater	6	Yes
2	Agricultural Wastewater	250	Yes
3	Agricultural Wastewater	800	No
4	Agricultural Wastewater	1200	No
5	Agricultural Wastewater	220	Yes
1	Municipal Wastewater	66	No
2	Municipal Wastewater	800	Yes
3	Municipal Wastewater	1200	Yes
4	Municipal Wastewater	500	Yes
5	Municipal Wastewater	1600	No
1	Industrial Wastewater	363	No
2	Industrial Wastewater	2000	No
3	Industrial Wastewater	1200	Yes
4	Industrial Wastewater	2800	No
5	Industrial Wastewater	1500	Yes

In the following figures, we present the output screenshots of the MQ3 alcohol gas sensor measurements for different types of wastewater. These measurements highlight the varying levels of alcohol gas detected in water samples from agricultural, municipal, and industrial sources.

Figure a: Agricultural Wastewater

The MQ3 alcohol gas sensor reading for agricultural wastewater is 6 out of 1023. This very low level indicates that there is minimal alcohol gas contamination in the agricultural wastewater, likely due to the nature of agricultural runoff, which typically does not include significant alcohol pollutants.

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Figure b: Municipal Wastewater

The MQ3 alcohol gas sensor reading for municipal wastewater is 66 out of 1023. This moderate level suggests the presence of alcohol gas, which could be attributed to household waste, cleaning agents, or other urban sources of alcohol-containing substances in the municipal wastewater.

Figure c: Industrial Wastewater

The MQ3 alcohol gas sensor reading for industrial wastewater is 236 out of 1023. This higher level indicates a significant presence of alcohol gas, likely due to industrial processes and chemical waste that include alcohols and related compounds, reflecting the more substantial contamination in industrial wastewater.

These measurements of alcohol gas levels underscore the varying degrees of contamination found in different sources of wastewater. Agricultural wastewater shows negligible alcohol gas levels, municipal wastewater exhibits moderate levels, and industrial wastewater shows significantly higher levels. These variations highlight the diverse nature of pollutants present in each type of wastewater, emphasizing the need for specific monitoring and treatment strategies tailored to each source.

5.1.4 MQ-4 METHANE GAS SENSOR:

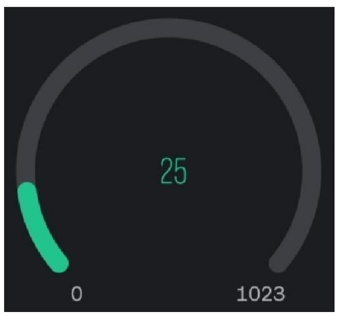

Figure 5.1.4(a) MQ4 value for sample 1

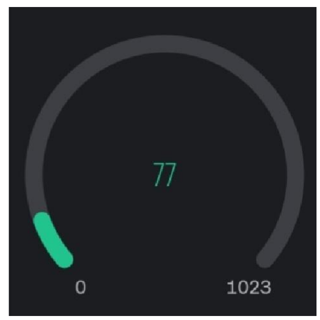

Figure 5.1.4(b) MQ4 value for sample

Water sample	Type of Wastewater	MQ-4 Methane Gas Sensor Reading (out of 1023)	Good for Purpose?
1	Municipal Wastewater	25	Yes
2	Municipal Wastewater	77	No
3	Municipal Wastewater	120	Yes
4	Municipal Wastewater	500	Yes
5	Municipal Wastewater	1600	No
1	Industrial Wastewater	77	No
2	Industrial Wastewater	200	Yes
3	Industrial Wastewater	120	Yes
4	Industrial Wastewater	280	No
5	Industrial Wastewater	150	Yes

In the following figures, we present the output screenshots of the MQ-4 methane gas sensor measurements for municipal and industrial wastewater. These measurements illustrate the varying levels of methane gas detected in these water samples.

Figure A: Municipal Wastewater:

The MQ-4 methane gas sensor reading for municipal wastewater is 25 out of 1023. This relatively low level indicates that there is a small amount of methane gas present in the municipal wastewater. Methane in municipal wastewater can originate from organic matter decomposition and anaerobic conditions in sewage systems.

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Figure B: Industrial Wastewater:

The MQ-4 methane gas sensor reading for industrial wastewater is 77 out of 1023. This higher level suggests a more significant presence of methane gas, likely due to industrial processes that produce methane as a byproduct or from the decomposition of organic industrial waste under anaerobic conditions.

These methane gas measurements highlight the differences in contamination levels between municipal and industrial wastewater. Municipal wastewater shows a lower level of methane gas, while industrial wastewater exhibits a higher level, reflecting the nature and sources of methane pollution in these different types of wastewater. This emphasizes the importance of tailored monitoring and treatment strategies to effectively manage and mitigate methane emissions from various wastewater sources.

5.1.5 LDR DENSITY SENSOR:

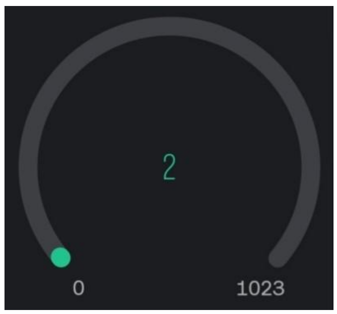

Figure 5.1.5(a) LDR value for sample 1

Figure 5.1.5(b) LDR value for sample 2

Water sample	Type of Wastewater	Density Sensor Reading (out of 1023)	Good for Purpose?
1	Municipal Wastewater	25	Yes
2	Municipal Wastewater	77	No
3	Municipal Wastewater	120	Yes
4	Municipal Wastewater	500	Yes
5	Municipal Wastewater	1600	No
1	Industrial Wastewater	77	No
2	Industrial Wastewater	200	Yes
3	Industrial Wastewater	120	Yes
4	Industrial Wastewater	280	No
5	Industrial Wastewater	150	Yes

In the following figures, we present the output screenshots of the ldr density sensor measurements for municipal and industrial wastewater. These measurements indicate the transparency or clarity of the water, which can be affected by the presence of suspended particles and pollutants.

Figure A: Municipal Wastewater

The light sensor reading for municipal wastewater is 2 out of 1023. This very low reading indicates extremely poor transparency, suggesting that the water is highly turbid and contains a significant amount of suspended particles and pollutants. Such low transparency is common in municipal wastewater due to the mix of organic and inorganic matter from household and urban runoff.

Figure B: Industrial Wastewater

The light sensor reading for industrial wastewater is 156 out of 1023. This higher reading compared to municipal wastewater indicates better transparency, but it still suggests the presence of considerable suspended particles and pollutants. The transparency level in industrial wastewater can vary widely depending on the type and extent of industrial processes and effluents.

These light sensor measurements highlight the differences in water clarity between municipal and industrial wastewater. Municipal wastewater shows extremely low transparency, reflecting a high level of contamination and suspended particles, while industrial wastewater, although better in comparison, still shows reduced clarity due to industrial pollutants. This emphasizes the need for tailored water treatment approaches to address the specific challenges posed by different wastewater sources in terms of particulate matter and overall water quality.

VI. FUTURE SCOPE

• Enhanced Accuracy and Calibration :
o Implement more advanced calibration techniques to improve the accuracy of the turbidity and TDS measurements.
o Consider environmental factors (e.g., temperature compensation) more comprehensively to further enhance measurement accuracy.
• Additional Sensors:
o Integrate a pH sensor to provide a more comprehensive analysis of water quality.
o Include a Dissolved Oxygen (DO) sensor for applications requiring detailed water quality parameters.
• Data Logging and Analysis:
o Implement data logging to SD cards or cloud services for historical data analysis and trend detection.
o Develop a real-time monitoring system with wireless communication (e.g., Wi-Fi, Bluetooth) to remotely monitor water quality.
• Automation and Control:
o Develop automated systems that can adjust water treatment processes based on real-time sensor data.
o Integrate with IoT platforms to enable smart water quality management systems that can be monitored and controlled remotely.
• User Interface and Alerts:
o Develop mobile applications to provide users with easy access to real-time water quality data and alerts.
o Implement alert systems (e.g., SMS, email) to notify users immediately when water quality falls below acceptable levels.
• Robustness and Deployment:
o Design weatherproof enclosures for the sensors and electronics to enable outdoor deployment in various environmental conditions.
o Explore alternative power sources (e.g., solar power) for deployment in remote areas without reliable access to electricity.

6.1 CONCLUSION

In conclusion, the proposed method for water quality monitoring represents a significant step forward in addressing the challenges and limitations faced by existing monitoring systems. By integrating IoT technologies, real-time data acquisition, enhanced portability, scalability, and sustainability features, this method offers a comprehensive and efficient solution for ensuring the safety and sustainability of water resources

One of the key strengths of the proposed method lies in its ability to provide real-time data acquisition and monitoring. The integration of IoT-enabled sensors and wireless connectivity enables continuous data collection, allowing for prompt detection of water quality issues and timely interventions. This real-time monitoring capability is crucial for safeguarding public health, protecting ecosystems, and supporting informed decision-making by stakeholders and authorities.

Moreover, the proposed method emphasizes cost-effectiveness and scalability. The use of Arduino-based microcontrollers and modular sensor integration reduces implementation costs while facilitating easy expansion and adaptation to diverse monitoring scenarios. This scalability is essential for extending monitoring networks to remote or hard-to-reach areas where water quality challenges may be prevalent

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