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DEVELOPMENT OF WATER POLLUTANTS MONITORING SYSTEM IN RESIDENTIAL WATER SUPPLY WITH GSM FEEDBACK ALERT

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ABSTRACT

Safe and clean water is essential for human life. For this reason, access to clean and safe water is enshrined in the universal fundamental human rights. However, total dissolved solids (TDS) in water could be hazardous and fatal to human health due to pollutants and toxins. Work aims to ensure that drinking water is safe and of the highest possible quality. To achieve this, a comprehensive real-time solution for monitoring TDS in residential water supply through a feedback alert system that delivers real-time short message (SMS) to the user's mobile phone was developed. The following are the contributions of this project: real-time TDS monitoring was achieved using real-time data from sensors to measure the TDS levels in the incoming water supply continuously. A central database uses logged and stored TDS data to historically analyse water quality trends over time. A cost-efficient, accessible and scalable device suitable for various residential situations was developed. By giving users access to real-time TDS data and alerts, this system enables quick response to water quality issues, like filter replacements or maintenance, which helps to enhance water quality and general health. A performance evaluation showed that the system executes the objectives as intended.

Keywords: Water pollutant, GSM; Microcontroller, Arduino, SMS alert, water quality, Total dissolved solids

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INTRODUCTION

Accessing clean and safe drinking water is essential for maintaining human well-being. However, keeping the quality of home water supplies is a constant struggle notably, in places where pollutants and contaminants can contaminate the water's purity (Wang, 2021). Total dissolved solids (TDS) are an essential indicator for evaluating water quality because they show the presence of dissolved minerals and contaminants. Therefore, to ensure that the water satisfies the necessary safety standards, TDS levels in the household water supply must be monitored (Thirumalini and Joseph, 2009). This research acknowledges that conventional approaches for water quality monitoring frequently fail to provide households with real-time information. This often leads to protracted exposure to substandard water quality (Ahmed, Mumtaz, Anwar, Mumtaz, and Qamar, 2020).

However, with cutting-edge technology, this project proffers an original solution to this urgent problem. The developed monitoring device will be attached to water supply inlets so that the sensors have contact with the water going into the storage tanks or directly into residential buildings. The water source could be from the public water supply corporation or private boreholes. This approach ensures that the water supplied to the homes for drinking and other domestic use is constantly monitored for TDS pollutants and therefore safe and clean for human consumption. The uniqueness of this project is the real-time alert system that sends short message service (SMS) alerts to the user's phone for daily monitoring of the safety level of the daily water supply. Similarly, a central database logs and stores the TDS data sensed and transmitted to the database. This database enables historical analysis of water quality trends over time.

LITERATURE REVIEW

Historically, humans have always been concerned about the quality of water they consume. However, the techniques of monitoring water quality have evolved. In Khurana *et al.* 2022, a water quality monitoring system based on the Internet of Things (IoT) is designed to continuously assess water quality in real time through a wireless automated setup (Khurana, Choudhary, Gupta, Dutta, and Patwal, 2022). This system comprises essential components such as a microcontroller, a pH sensor, and a Wi-Fi module. The pH sensor collects water quality data, which is then transmitted to the microcontroller for processing. Subsequently, the processed data is wirelessly transmitted to a mobile device via the Wi-Fi module. In the event of an unsuitable pH level, the system triggers an alarm using a buzzer. However, the limitation of this system lies in its ability to measure only one water quality parameter. While the existing prototype employs a pH sensor to gauge water quality, the potential exists to integrate additional sensors to assess water quality comprehensively. In Vijayakumar *et al.*2015, real-time water quality monitoring within an IoT environment was developed. The system performs continuous, up-to-the-minute updates on water conditions. This comprehensive system assesses various parameters, including water temperature, pH level, turbidity, conductivity, and dissolved oxygen content. The core of this system relies on a Raspberry Pi as its central controller, facilitating seamless data transmission to the cloud. A specialised IoT module is integrated to enable this data transfer, ensuring efficient sensor data retrieval from the primary controller to the cloud. Users can conveniently access and view this sensor data via a designated web address on the cloud. Furthermore, the IoT module extends Wi-Fi connectivity, allowing data visualisation on mobile devices. However, it is worth noting that this approach can be very costly and demands a robust network infrastructure and internet for optimal functionality (Vijayakumar and Ramya, 2015).

Similarly, a novel approach for monitoring water quality utilising intelligent sensor technology has been introduced. Researchers have conceived and executed a water quality monitoring system to provide users with real-time parameter notifications. This system effectively measures key physicochemical parameters of water quality, including flow rate, pH level, conductivity, and oxidation-reduction potential, serving as indicators of water contamination. Custom-designed sensors, complemented by signal conditioning circuits, are integrated into a microcontroller-based measurement node responsible for data processing and analysis. ZigBee receiver and transmitter modules were incorporated into the system design to enable seamless communication between the measurement and notification nodes. The notification node facilitates the presentation of sensor readings and emits audio alerts when water quality parameters breach predetermined safety thresholds. Data transmission between the measurement node and the notification node is achieved through ZigBee technology, enabling audio and visual display of real-time parameters. However, it is important to note that this project has a limitation, as it lacks a feature to retain historical readings (Cloete, Malekian, and Nair, 2016).

METHODOLOGY

This system has two primary segments: the hardware and software components. The hardware section focuses primarily on circuit design and elucidating the operational principles governing the various system components. Conversely, the software section delves into programming aspects, encompassing code development and, ultimately, the seamless integration of both hardware and software components.

SYSTEM OVERVIEW

The overall system is achieved by building an automated TDS monitoring system that continuously monitors the water
quality. This is how the system works: the system keeps the quality of water in check by monitoring the total amount of TDS in the water continuously to see that these parameters are at safe level for consumption. There will be a display unit that will keep displaying the level and readings of the water parameter and an SMS alert that will notify the user when these qualities are not up to required standard for example in a residential water supply Tank/water supply inlet from a water corporation.

Hardware Module Description

Microcontroller (Arduino board)

The microcontroller used to achieve the project's objectives, including cost-effectiveness, is Arduino. Arduino is a single-board microcontroller designed to simplify the creation of interactive objects or environments. Its hardware comprises an open-source board built around either an 8-bit Atmel AVK microcontroller or a 32-bit Atmel ARM microcontroller. The current modules come equipped with essential features, including a USB interface, six analog input pins, and 14 digital pins for connecting various expansion boards. Arduino was initially introduced in 2005 with the primary goal of providing engineers with a user-friendly and extensive platform for programming interactive objects. It comes with an integrated development environment (IDE) that can be run on standard personal computers, enabling users to write programs for Arduino using C or C++.

Arduino is the heart of this project it will process information from the sensors and, based on this, trigger an action that initiates the sending of SMS to the phones of the users and logging of data to

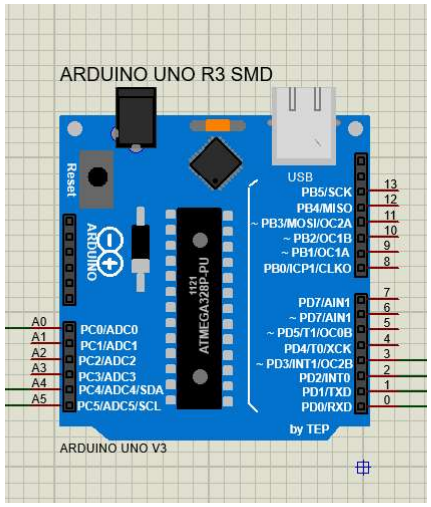

Figure 1: Schematic diagram of Arduino microcontroller

the database. Figure 1 shows the diagram of the Arduino (Kumar, Roopa, and Sathiya, 2015)
The Arduino Uno is configured to send the measured parameters to the communication unit for transmission to the cloud application. It is also configured to display the measured TDS values on the OLED display module.

Liquid Crystal Display (LCD)

A liquid crystal display (LCD) is a type of flat-panel display that relies on the optical properties of liquid crystals to modulate light. Unlike traditional light-emitting displays, liquid crystals do not emit light; instead, they utilise a backlight or reflector to create images in either colour or monochrome. LCDs are versatile and can present various images, making them suitable for various applications, including general-purpose computer displays. In addition, LCD technology is prevalent in portable consumer electronics, with small LCD screens commonly found in devices such as DVD players, video game consoles, and clocks. In this project, the LCD displays the value of the measured TDS and other important information. Figure 2 presents a schematic diagram of the LCD (Kim, Berkeley, Kim, and Song, 2004).

Network/Communication Unit

The communication unit in the system utilises an ESP8266 Wi-Fi module for the Arduino microcontroller to enable wireless data transmission to the database. At the same time, the GSM Module (SIM 900) allows connection to the mobile network and uses various services, such as sending and receiving SMS messages. GSM modules are widely used in multiple applications, such as IoT (Internet of Things) projects, home automation, security systems, vehicle tracking, and remote monitoring. The ESP8266 module is configured to establish a Wi-Fi connection with a Local Area Network (LAN), allowing the Arduino to send real-time TDS values to a central monitoring system (Zinkevich, 2021).

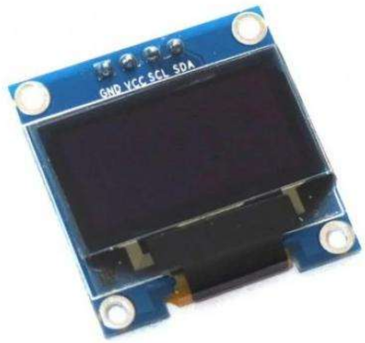

Figure 2: Schematic diagram of LCD display

Data is transmitted using the Message Queuing Telemetry Transport (MQTT) protocol, which is lightweight and suitable for IoT applications, ensuring efficient and reliable communication. The Arduino collects the processed data from the sensors and publishes it to the Azure IoT Central Application using the ESP8266, which can be accessed via a web or mobile application for real-time monitoring and alerts. Additionally, the ESP8266 is programmed to reconnect automatically if the Wi-Fi connection is lost, ensuring continuous data transmission without manual intervention. Figure 3 shows the diagram of the communication unit as implemented in this project.

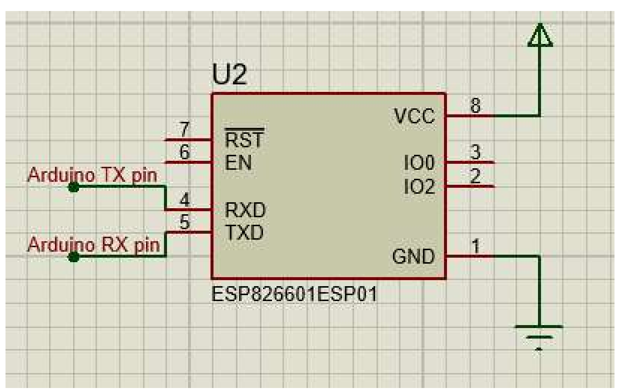

Figure 3: Schematic diagram of ESP8266 Wi-Fi module

TDS Sensor

A TDS sensor quantifies the concentration of dissolved substances such as salts, minerals, and metals within water. With an increase in the concentration of dissolved solids in the water, there is a corresponding rise in its electrical conductivity. This increased conductivity lets the system determine the TDS in parts per million (ppm) or milligrams per litre (mg/L). Figure 4 shows the TDS sensor used in the implementation of the project (Setyobudi, 2023).

Figure 4: TDS sensor

The system block diagram shows the schematic arrangement of the project's components, as shown in Figure 5. It provides a functional view of a system and the interconnections of various units.

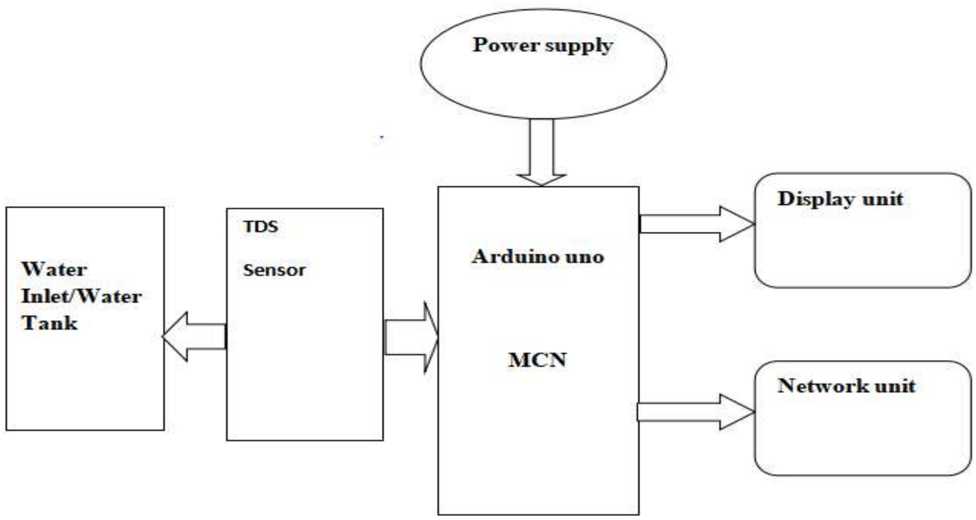

Figure 5: Block diagram of TDS monitoring for safe residential water supply with GSM feedback alert system

Software Module Description

Software coding

The Arduino IDE (Integrated Development Environment) software application for writing, compiling, and uploading code to Arduino microcontroller boards. It is used to write code for the Arduino Uno and the ESP-8266 Wi-Fi module. After the code is written, it compiles and then uploads it to the modules. The software code used to program the Arduino Uno Microcontroller and the ESP8266 is written in the embedded C programming language. Figure 6 shows the snapshot of the Arduino IDE when programming the microcontroller to accept data from the sensor modules. The following was the algorithm of the coding process of the Arduino Uno microcontroller

Figure 6: Snapshot of Arduino IDEsystem

Initialise the TDS sensor

Initialise the LCD

Read sensor values

Display values on display

Send values to the Wi-Fi module

Repeat steps iii, iv and v

The following was the algorithm of the coding process of the ESP8266 Wi-Fi module:

Connect to the Local Area Network (LAN)

Connect to the Azure IoT Central database

Receive sensor values from Arduino

Send sensor values to the Azure IoT Central database

Repeat steps iii and iv

Web Interface Unit

This unit uses the Microsoft Azure IoT Central database depicted in Figure 7, the cloud platform used to log and store the measured TDS values. The application is created and set to receive data from the water quality monitoring system. The communication unit connectedto the Arduino Uno sends the data from the microcontroller to the web application through the internet. The application is designed to provide instant visualizations of the data obtained on a user-friendly dashboard, making it easier for historical water quality analysis and processing..

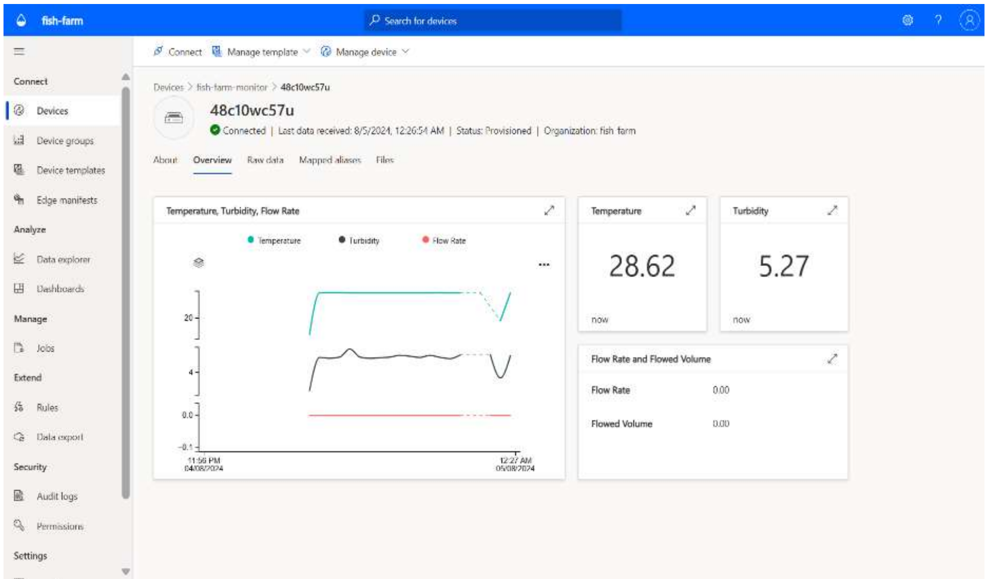

Figure 7: Snapshot of Azure IoT Central application dashboard

Circuit Description

The circuit diagram of the water quality monitoring system in Figure 8 represents the schematic diagram of all the components used to implement this system. Also, a flowchart that visually show a sequence of steps that is implemented in achieving this project is represented in Figure 9

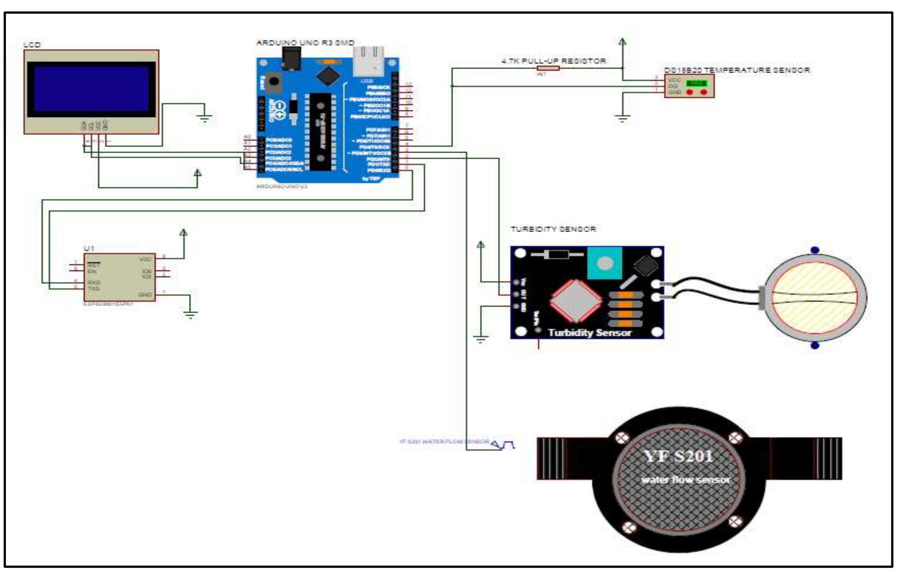

Figure 8: Circuit Diagram of Water Quality Monitoring

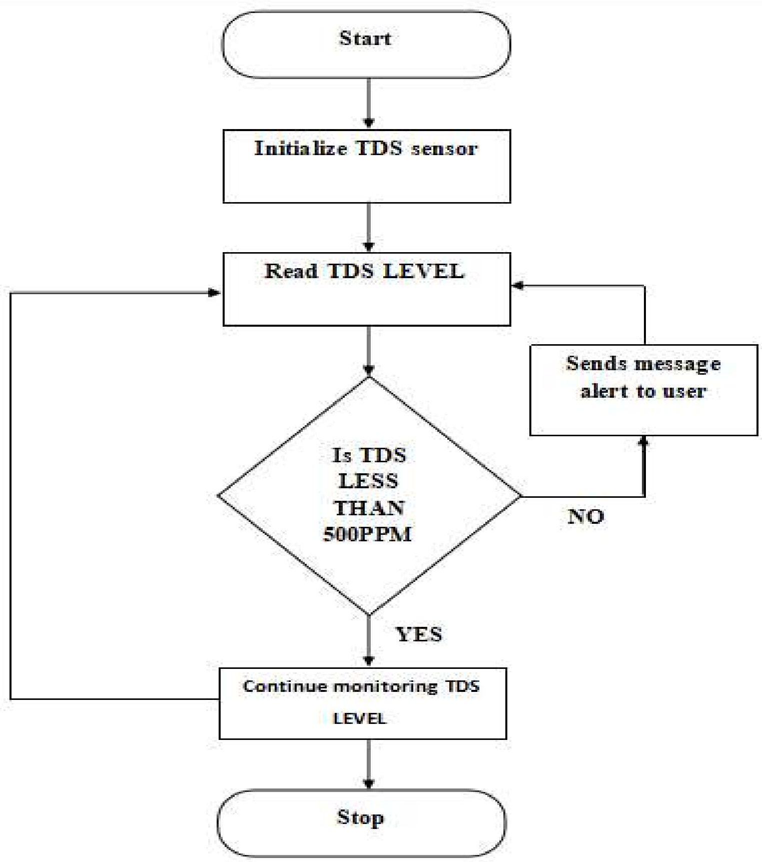

Figure 9: flow chart diagram for TDS monitoring for residential water supply with GSM feedback alert system

RESULTS AND DISCUSSION

Construction

This section shows the system's finished construction, which involved multiple steps, from hardware assembly to software programming. The hardware components were meticulously assembled and connected. A storage tank setup was simulated using a plastic tank, and the sensors were placed in the correct locations to ensure high levels of accuracy in the measurements, as shown in Figure 10. Other components and their connections were placed in a plastic junction box, which is supposed to shield the components from harsh weather conditions.

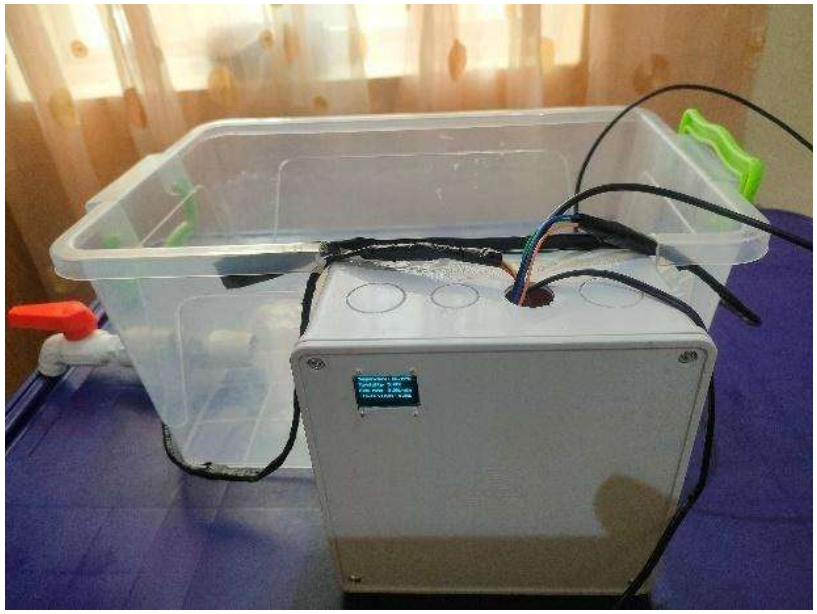

Figure 10: flow chart diagram for TDS monitoring for residential water supply with GSM feedback alert system

DISCUSSION

The results from the developed TDS quality monitoring system show that it depends on the TDS sensor to sense the water for dissolved particles, which leads the microcontroller to decide whether to send an SMS warning through the GSM module. Suppose the water is not safe for consumption. In that case, it sends an alert to the residents, warning that the required water quality is not supplied, or it continues to monitor the quality continuously, as shown in Table 1. The results from testing the different units indicate a well-designed and functioning system that successfully monitors water quality parameters and visualises data effectively locally and on the cloud application.

The alert response test was also conducted on the system using five (5) different water samples to simulate the system's response to various water conditions. The system's overall performance was evaluated by calculating the average delay time for sending alerts across the different water samples. This value ranged from 6.0 to 10.85 seconds, and the average was 9.28 seconds, implying that the water quality monitoring system is reliable and offers quick alert response time for non-optimal water conditions

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Table 1: Results of performance of the water quality monitoring system

Conditions of measured parameters	Action taken by system	Level of TDD
When TDS(Total dissolved solids) level falls between 50-500PPM	Continues to monitor water quality	Less than 500PPM
When TDS(Total dissolved solids) falls above 500-1000PPM	Sends warning alerts to residents	Greater than 500PPM

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