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Design of Wireless Based Sensor for Realtime Monitoring pH and TDS in Surface and Groundwater using IoT

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Abstract

In the past, assessing water quality has typically involved labor-intensive and costly processes such as laboratory analysis and manual sampling, which do not provide real-time data. In addition to tasting bad, drinking acidic water on a regular basis can result in acid reflux and recurrent heartburn while high total dissolved solids water can cause kidney stones, especially when the hard water content is more than 500ppm. With growing concerns about water quality, there is a need for continuous monitoring of pH and TDS levels in surface and groundwater sources. To address this, a cutting-edge wireless sensor system leveraging on Internet of Things (IoT) technology has been developed. This system incorporates top-notch pH and TDS sensors known for their accuracy, durability, and environmental compatibility. Integrated with microcontrollers featuring wireless communication capabilities, these sensors enable seamless data transmission to a central server through IoT protocols like cellular networks. The collected data is processed and calibrated to ensure reliability and precision. The IoT platform connected to the central server manages device connectivity, data storage, and analysis, making real-time data accessible via user-friendly web or mobile applications with interactive graphs and dashboards. Power-saving features are implemented to optimize battery life in remote and off-grid locations, and weather-resistant enclosures protect the sensor nodes from harsh environmental conditions. By deploying this wireless-based sensor system, users can gain valuable real-time insights into water quality in surface and groundwater monitoring locations.

1. Introduction

The availability of safe water is increasingly scarce due to pollution, contamination, and climate change, posing one of the greatest challenges to our planet today. Given that marine life is particularly vulnerable to pollutants and ultimately consumes them, it is imperative to continually monitor water quality [1]. Nevertheless, traditional methods for assessing water quality consume significant energy as they involve the collection of water samples from different locations for testing in laboratories. The emerging technology of the Internet of Things (IoT) holds great potential in this area [2,3] and can enable real-time monitoring of pollution. The need for ongoing assessment of environmental water quality has become a vital area of research. The current traditional approaches are insufficient to meet the increasing demand for sensitive, cost-effective, rapid, real-time, and reliable water quality monitoring (WQM). Many experts have proposed using wireless sensor networks (WSN) as a sustainable alternative to traditional water quality monitoring methods [4].

The use of physico-chemical parameters can significantly improve the real-time detection of human activities, which in turn affects the life cycle of ecosystems. Early detection of water contamination allows for the implementation of appropriate controls and the prevention of hazardous circumstances [5]. Assessing the quality of water is crucial to ensure a sustainable supply of clean, portable water, as pollutants are

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often released into bodies of water without undergoing necessary treatment to remove hazardous materials [6]. Water Quality Indicators (WQIs) can be used to determine the suitability of water for its intended purpose, despite potential limitations[7].

The monitoring of water quality is becoming more effective and efficient as a result of increasing global water pollution, as well as advancements in wireless sensor network (WSN) technology in the IoT environment [8,9](table 1). Remote water quality monitoring involves real-time data acquisition, transmission, and processing [10]. In response to the Fourth Industrial Revolution's advancements in automation, the IoT, big data, artificial intelligence, and cloud computing, the Chinese Academy of Engineering has recommended Intelligence Mining as a way to achieve the goal of creating an unmanned workforce [11].

Governments can leverage on IoT for a wide range of public services. Sensor-equipped devices are capable of collecting data on waste management, sewage systems, air quality, and the impact of urban areas on the environment [12,13]. Furthermore, these tools can be used to monitor the condition of lakes, rivers, forests, and oceans. The combination of IoT and big data analytics can form the basis for a sustainable water management strategy in a smart city. Big data analysis involves gathering large volumes of relevant data from deployed IoT sensors to monitor the quality, usage, and physical condition of the devices [14]. To implement this big data analysis approach, IoT software can be expanded to encompass the entire water supply system and device utilization [15]. The IoT, along with remote monitoring, enables access to real-time data[16]. A wireless sensor network (WSN) comprising an internal communication system, a data processing microcontroller, and multiple nodes is used in IoT [17]. If the observed value exceeds the threshold, Spark MLlib's in-depth analysis of Spark flow will automatically trigger a warning SMS for the client. What sets this system apart is our focus on creating a low-power, highly mobile, and high-frequency water monitoring system [18].

2. Methodology

The research requires the following materials: pH sensor, TDS sensor, Atmega328p WiFi module development board (2), breadboard (2), 9V DC power supply (2), connecting jumper wires, pH buffer solution, solar panel, SIM800L, resistors, casing, LCD screen, and panel terminal and sockets.

2.1. pH Sensor

Selecting a pH sensor with the model number V1.1 is essential. This sensor provides a response in less than a minute and operates at a 5V voltage [25]. The accuracy of ± 0.1 pH at 25 ºC makes it ideal for this research, considering the significance of water pH and its impact on water quality [26]. The pH of an aqueous solution can be measured between 0 and 14 using its laboratory-grade probe, which includes a glass electrode for pH measurement and a silver chloride reference electrode. When the probe is immersed in water, the exchange of positively charged ions on the glass bulb for hydrogen ions in the water creates an electrochemical potential across the bulb [27]. For analog to digital conversion, the breakout board's electronic amplifier must be connected to the analog pin of the microcontroller. It operates by detecting the difference in electrical potential between the two electrodes and amplifies the output analog signal.

2.2. TDS Sensor

The TDS meter v1.0, also known as the Total Dissolved Solids (TDS) sensor in the study [13], is designed to measure the overall concentration of dissolved materials in water, including organic and inorganic substances. This versatile sensor can be applied in hydroponics, domestic water systems, and other areas where water quality is a concern. Monitoring TDS is crucial as high levels of dissolved solids may indicate the presence of harmful pollutants such as iron, manganese, bromine, arsenic, and sulfide, originating from human activities [28]. The sensor provides an analog voltage output of 0 to 2.3 V and operates within a range of 3.3 to 5.5 V. To extend the probe's lifespan and maintain output stability, the AC signal prevents polarization of the probe. At a liquid temperature of 25 °C, it offers an accuracy of ± 10% for full scale readings and can measure from 0 to 1000 ppm [29].

2.3. Atmega328p Node Development Board

The Atmega328p module uses IEEE 802.11 bgn to connect microcontrollers to 2.4 GHz Wi-Fi. With the ability to run an RTOS-based SDK, it can function as an independent MCU or work in tandem with ESP-AT firmware to facilitate Wi-Fi connectivity to external host MCUsAn affordable WiFi module that seamlessly integrates into IoT devices is the Atmega328p (see Figure 1). Powered by an L106 32-bit RISC microprocessor core, it runs at 80 or 160 MHz and is built on the Tensilica Diamond Standard 106 Micro architecture.

Table 1. A comparison of different research papers about the detection of water quality (Modified after Ahmed et al. [8]

No.	Paper	Methodology	Limitations	Dataset	Parameters	Results	Hardware
1	[19]	LS-SVM estimation of BOD5 and COD	It is not practicable for an IoT system to use nine WQPs.	200 datasets from the River Karoun	EC, pH, turbidity, Ca2+, Na+, Mg2+, NO−2, NO−3, PO3–4.	RMSECOD = 4.461 and RMSEBOD5 = 5.463	N/A
2	[20]	Using MT, EPR, and GET to estimate BOD, COD, and DO	Its application for IoT systems is cumbersome because it still requires nine parameters.	Dataset of River Karoun, Iran	EC, pH, turbidity, Ca2+, Na+, Mg2+, NO−2, NO−3, PO3–4.	RMSECOD= 4.997, RMSEDO= 4.728, and RMSEBOD = 5.388	N/A
3	[21]	Sensor monitoring with DNN, NN, SVM, and KNN water quality classification	Solely distinguishes between two categories for water quality: excellent and poor. No usage of the standard WQI has occurred.	667 sample dataset gathered from PCRWR for analysis	temperature , pH, turbidity,	Precision: DNN 93% SVM 91% 86% NN, 76% kNN	Parameter sensors, LCD, and ATMega328
4	[8]	Sensor and cloud infrastructure monitoring	Not anticipating, just monitoring	N/A	pH, turbidity, water level, and conductivity	N/A	Sensors and controller for the TI CC3200
6	[22]	Monitoring water quality with sensors and SOAP web services	Just observing; no forecast	N/A	pH, dissolved oxygen, and temperature	N/A	ZigBee transceivers, Arduino modules, and parameter sensors
7	[23]	Aqua farms monitoring in real-time through mobile application.	Merely offers observation; does not analyze data for patterns	N/A	Temperature, pH, DO, ammonia, salt, nitrate, and carbonates	N/A	Raspberry Pi 3 with a sensor node, solar panel, and built-in Wi-Fi module
9	[24]	Fuzzy systems and artificial neural networks (ANNs)	Suggests a general-purpose IoT system devoid of any data and outcomes	N/A	Temperature, conductivity, pH, nitrates, chlorine, ORP, and turbidity	N/A	Connectivity and sensors: Bluetooth, 3G, and ZigBee

2.4. Sim800l Arduino

A highly versatile GSM modem for a variety of IoT applications is the SIM800L GSM/GPRS module (Figure 2). This module offers similar functionalities to a standard mobile phone, allowing for tasks such as sending SMS messages, making calls, utilizing GPRS for Internet access, and more[30]. The SIM800L GSM cellular chip, powering the module, operates within a voltage range of 3.4V to 4.4V, making it well-suited for direct LiP battery supply and an excellent choice for integration into projects with limited space.

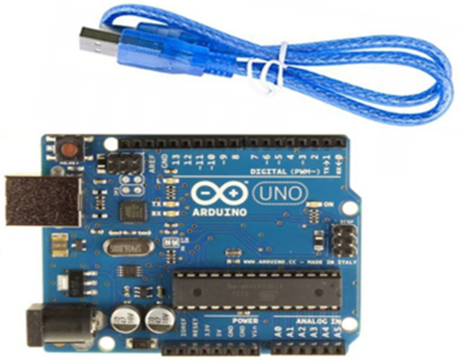


Figure 1. Atmega328p Node development board

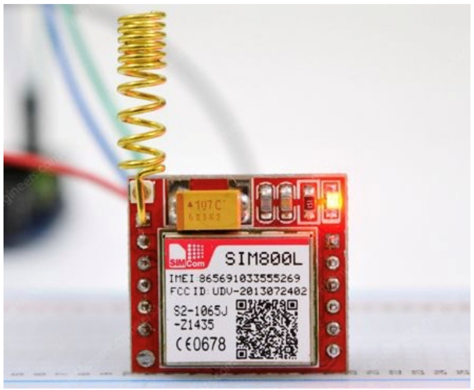


Figure 2. Sim800l Arduino

2.5. Programming the Microcontroller

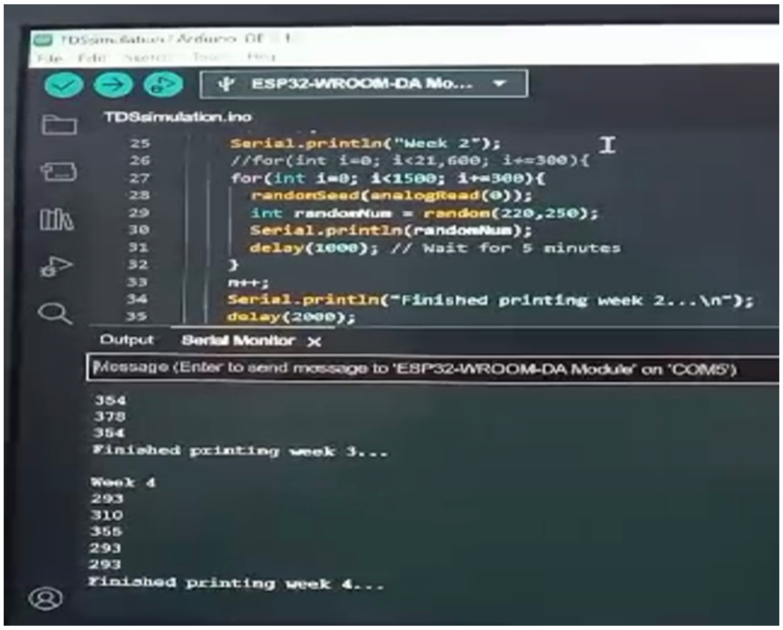
Firmware code for the microcontroller board was created using a programming language compatible with the chosen board (e.g., Arduino IDE for Arduino boards). The code was developed to read pH and TDS values from the sensors, calibrate the readings using the calibration data, and store the data for transmission[31]. The necessary code to establish a wireless connection with the smartphone using the wireless communication module was calibrated to incorporate additional functionalities such as data logging or real-time visualization.

2.6. Solution Selection (Software)

As technology continues to evolve at a rapid pace, the importance of making informed and judicious software selection decisions cannot be overstated. This research sets the stage for delving deeper into the intricacies of Solution Selection, exploring best practices, common pitfalls, and the latest trends that influence the choice of software in modern enterprises.

2.6.1. Arduino IDE

The open-source, cross-platform Arduino Integrated Development Environment (IDE) allows programming in C or C++. This IDE can be used in Windows, Linux, and Mac OS X. By using the IDE, code can be updated, compiled, and uploaded to the microcontroller (Figure 3). When the main code (sketch) is compiled, it produces a Hex file containing all the instructions that the microcontroller can understand. Two distinct sketches need to be created and uploaded for each subsystem: one for the sensor subsystem and one for the receiver subsystem.



```
    Serial.println("Week 2");
    //for(int i=0; i<21,600; i+=300){
    for(int i=0; i<1500; i+=300){
      randomSeed(analogRead(0));
      int randomNum = random(220,250);
      Serial.println(randomNum);
      delay(1000); // Wait for 5 minutes
    }
    n++;
    Serial.println("Finished printing week 2...\n");
    delay(2000);
```

```
354
378
354
Finished printing week 3...

Week 4
293
310
355
293
293
Finished printing week 4...
```

Figure 3. Ardruino IDE snapshot

2.7. Hardware Design

Hardware design involves translating complex theoretical concepts and functional requirements into tangible components and systems. This process includes the design of integrated circuits (ICs), printed circuit boards (PCBs), and various semiconductor devices as discussed below;

2.7.1. Circuit Diagram and Pin Connection

The pin connections for the sensor and receiver subsystems illustrate how the operational voltage and current of each sensor module determine how it is powered. While the nRFL01 runs on 3.3 V, the Arduino Nano, pH, and TDS require 5 V to power the sensor subsystem. Two 3.7 V batteries power an Arduino Nano via a 5 V USB boost converter. An Arduino Mega is powered via a 5 V adaptor for the receiver subsystem using the USB mini-B connector [32].

The sensors are not directly attached to 5V pins because they are not always on in order to preserve battery life and lower power usage. They are activated only when taking a reading of the water quality. This is due to the fact that the maximum 40mA digital output pin on the Arduino Nano cannot support their working currents. TDS sensors are driven by the digital I/O pins of the Arduino Nano and require less current to operate [33]. The schematic does not depict the connection between the Arduino Ethernet shield and Arduino Mega because they are compatible enough for the Ethernet shield to be connected straight onto the Mega board.

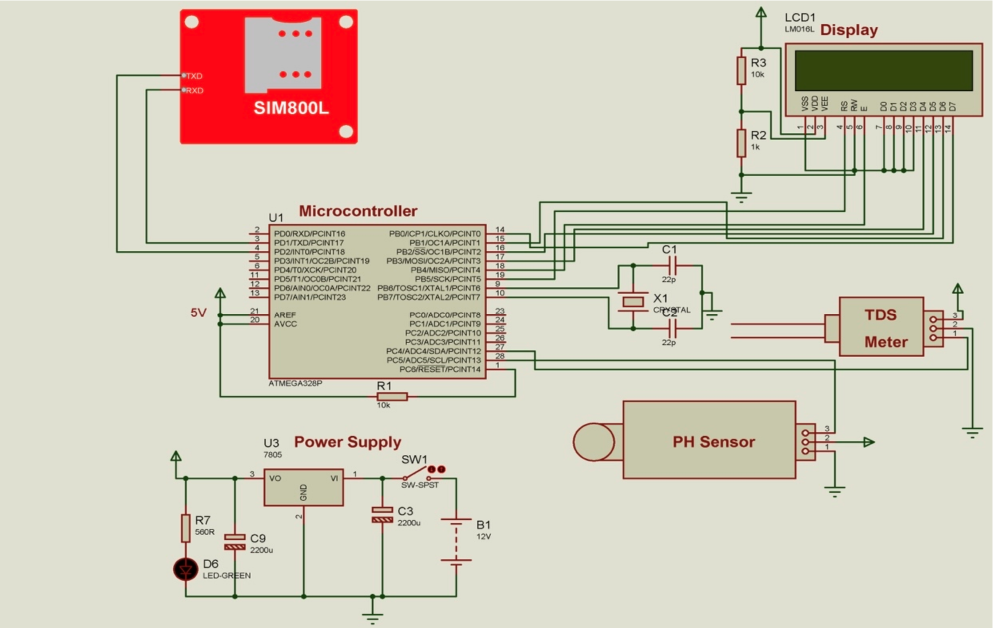


Figure 4. Circuit Diagram

3. Results and Discussion

To ensure the accuracy of the data collected and minimize measurement errors, it was essential to calibrate two sensors utilized in this research: the TDS sensor and the pH sensor. In addition to calibrating these sensors, benchmark tests were carried out simultaneously to validate the sensor readings. This thorough approach aimed to reduce measurement uncertainty and enhance the reliability of the gathered data for the study.

3.1. Benchmark Testing and pH Sensor Calibration

The buffer powder was dissolved in 250 milliliters of distilled water to yield standard solutions with pH values of 4.01, 6.86, and 9.18. The pH measurements were conducted using a pH meter capable of measuring a pH range of 0 to 14, along with the execution of a benchmark test and pH sensor calibration. Following the connection of the pH sensor to the Arduino Nano, the board was programmed with a sample code specific to the sensor. Prior to immersion in the pH 6.86 solution, the probes of the pH sensor and pH meter were cleaned with distilled water and dried with absorbent paper. Upon the display reading of 6.86 appearing and closely aligning with the actual pH value, the "CAL" button was pressed and held. Subsequently, the pH sensor value was monitored using the serial monitor feature of the Arduino IDE, with "Offset" referring to the divergence between the sensor's reading and the meter's reading. During the test, an offset value of 0.37 was observed, replacing the original value of 0.00 in the code. The microcontroller was programmed to incorporate this offset value into the formula when reading the analog signal from the pH electrode. The subsequent step involved the immersion of the cleaned pH sensor and pH meter probes in the pH 4.01 solution (Figure 5). Upon stabilization of the pH value received by the pH sensor, the potentiometer on the breakout board of the pH sensor was adjusted until the reading stabilized at approximately 4.01, signifying the completion of the acidic calibration process. The aforementioned process was then repeated for both solutions. The pH meter yielded a pH reading of 9.18. Accordingly, the potentiometer was adjusted until the pH sensor's reading stabilized at the same value. Subsequent to the completion of the pH sensor's calibration and benchmark test, the yellow part provided a pH threshold detection and alerting circuit.

Adjustment of the potentiometer was conducted to activate the RED LED D1 (changing the digital output from high to low) and notify the user when the pH level reaches a threshold of 5.5 or lower.

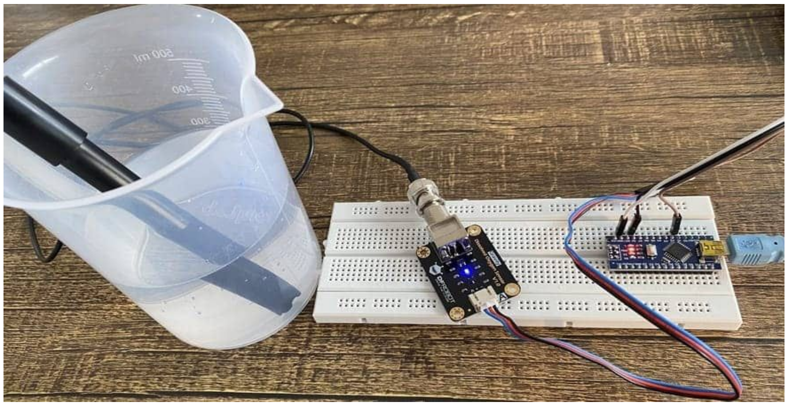


Figure 5. pH calibration test

3.2. Calibration of TDS Sensor and Benchmark Test

The DFRobot-provided code was utilized to calibrate the TDS sensor. By using a conventional buffer solution with an electrical conductivity (EC) of 1413µs/cm, it was determined that the TDS value of the buffer solution is approximately 707 ppm, as the TDS value is half of the EC value, calculated by TDS = EC / 2. The TDS sensor was carefully placed into the buffer solution after being thoroughly cleaned and dried with absorbent paper. Upon uploading the sample code to the Arduino Nano, the serial monitor became accessible. Subsequently, the code entered calibration mode upon receiving the "enter" command. The input command "cal: tds value" was then input; in this case, it was "cal: 774". Following this, the serial monitor displayed a message confirming the successful calibration. The calibration process concluded upon entering the "exit" command. The TDS value of pure water (Elim sachet water) was measured at 72 ppm after the sensor was cleaned (Figure 6). Once the calibration and benchmark test of the TDS sensor was completed, it was noted that it includes a TDS threshold detection/notification circuit in the yellow section. Our adjustments to the potentiometer would activate the RED LED D1 (altering the digital output from low to high) and notify the user when the TDS reading exceeds the threshold value of 400 ppm.

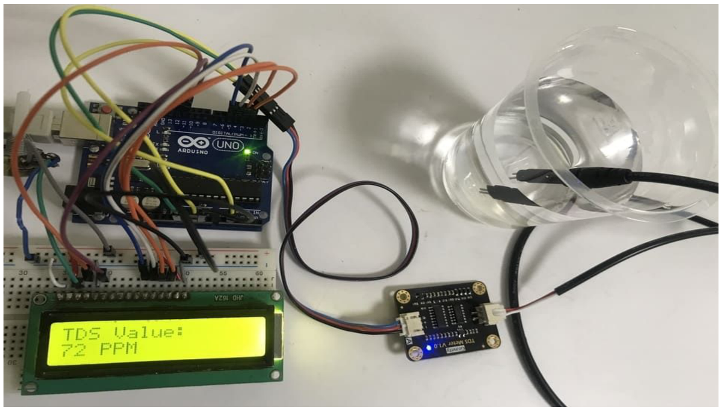


Figure 6. TDS calibration test

3.3. Developed Research Prototype

The hardware prototype comprises two essential subsystems: the sensor subsystem and the receiver subsystem. These two subsystems play a pivotal role in the overall functionality of the prototype, with the sensor subsystem responsible for data acquisition and the receiver subsystem tasked with data reception and processing. This division ensures the efficient and effective operation of the hardware prototype, and is a critical aspect of its design and functionality

3.3.1. Sensor prototype subsystem

All electrical components were enclosed in a waterproof junction box to protect the prototype from water damage. Despite limited space, the junction box was able to accommodate the sensor module breakout board, printed circuit board (PCB), batteries, and sensor modules. Given the project's budget constraints, the selected junction box was deemed the most suitable choice.

3.3.2. Receiver Prototype Subsystem

The receiver subsystem encompasses an Arduino Ethernet shield and an Arduino Mega, both powered by a 5V adaptor, and is installed indoors in close proximity to the router. This system is equipped with an RF module to enable bidirectional communication, and the data received by this subsystem will be subsequently transferred to cloud storage.

3.4. Prototype Performance

Evaluating prototype performance provides invaluable insights into how a product will perform in real-world conditions. This process includes a series of tests and assessments, such as stress tests, usability studies, and performance benchmarks, to determine if the prototype can meet the intended requirements and withstand the anticipated operational demands[34].

3.4.1. Uploading Data and Tracking through Text Messages

The receiver subsystem is designed to upload data and send it as a text message upon receiving input from the sensor subsystem and a network connection (SIM card). The data will be stored in a database and sent to the recipient's phone. Each variable will have its own API key to ensure that the sensor data is appropriately recorded. When the file is uploaded, the date and time will be recorded. The user-facing dashboard provides an interface for users to view and manipulate the data's graphical presentation and temporal range. The dashboard displays both real-time and historical data (Figure 7).

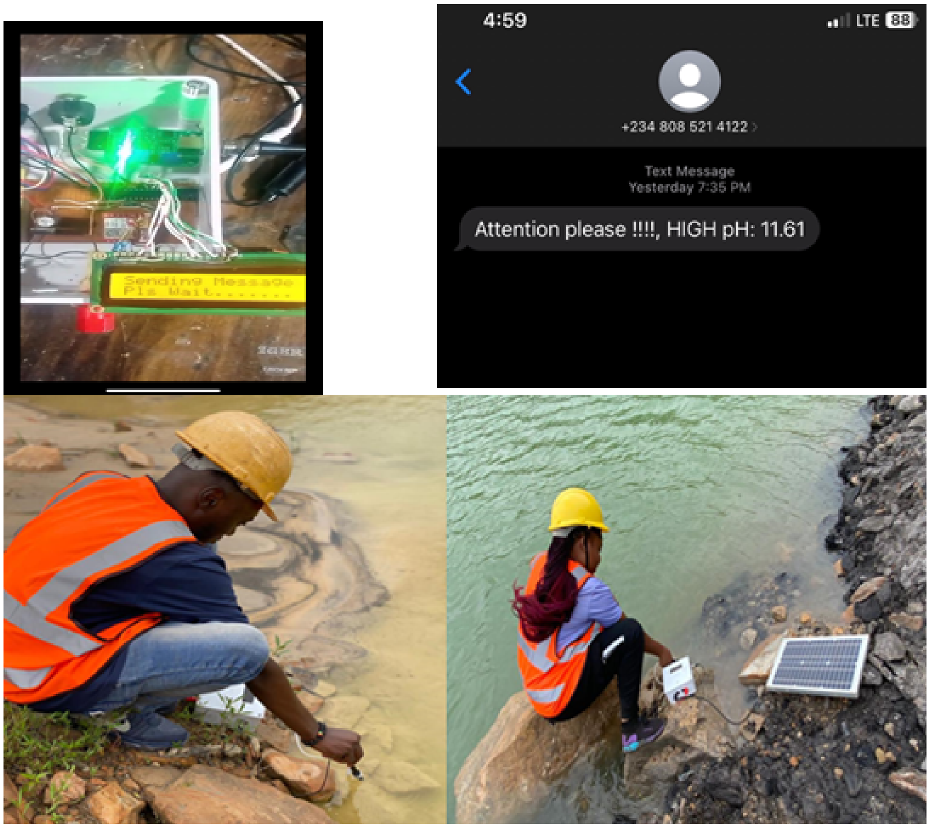
Figure 7. Fully functional Prototype (the red and black nob are provisions for 8watt solar panel).

3.4.2. User Request to Log Real-Time Data or Change Time Interval

A dynamic dashboard has been developed to provide users with a flexible interface. This allows users to modify system settings by adjusting the data logging time period or requesting real-time data logging. By default, the data logging switch is off, and the time interval slider is initially set to 20 minutes. Users can easily adjust the time interval from 0 to 60 minutes by sliding the slider to their preferred setting.

3.4.3. Real-Time Notification

In aquaculture management, it is crucial to monitor water quality parameters to ensure the well-being of aquatic organisms. When the values fall outside the designated safe range, an automated system generates email alerts to notify the responsible parties. To investigate the impact of intentional pH modification using acid pH buffer powder on water quality, results were obtained after raising TDS levels. In the event of parameter deviations beyond the acceptable range, a timely text message notification was sent to prompt the user to inspect the water (refer to Figure 8).



+234 808 521 4122

Text Message
Yesterday 7:35 PM

Attention please !!!!, HIGH pH: 11.61

Figure 8. Prototype sending message and screenshot of data sent via text message

3.5. Data Analysis

Throughout the data collection period, we monitored two critical water quality metrics: pH and TDS. Following the initial day, the subsystem was powered by a 5 V adaptor, leading to a decision to minimize the inconvenience of frequent battery recharging by checking the battery voltage only on the first day.

3.5.1. pH analysis

The pH values of the water within the Mine range from 4.2 to 6.8, and this value increases at the mine pond, indicating that the water sourced directly from the ponds within the mine and the flowing waters around the mine site had minimal influence. The pH of the water along the stream ranged from 6.2 to 8.0 (see table 2). The pH of the mine drainage varied from 6.0 to 6.9, suggesting a slightly acidic state, with no significant change within that range. It is worth noting that the World Health Organization (WHO) recommends a pH range of 6.5 to 8.5 for drinking water, indicating that the water's pH was only marginally within the safe range. It is also important to consider that these measurements were taken during the rainy season, suggesting that surface runoff may have had an impact on the pH level.

Table 2. pH readings at Maiganga mine site in Gombe State Nigeria

Within the Mine		Environs Around the Mine	
Sample code	pH reading	Sample code	pH reading
I1	4.33	J1	6.75
I2	6.47	J2	6.88
I3	6.82	J3	7.95
I4	6.57	J4	6.97
I5	6.44	J5	6.93
I6	6.12	J6	6.29
I7	6.73	J7	7.58
I8	6.28	J8	7.84

3.5.2. TDS Analysis

The mean values for TDS in surface water samples from both the mine site and stream channel ranged from 50ppm to 355ppm (table 3). All water samples fell within the maximum permissible limit of 300ppm, as set by the WHO for good and fair drinking water. TDS consist of small amounts of organic matter that can readily dissolve in water. The slight variation in TDS readings is attributed to temperature fluctuations and evaporation, which can impact ion mobility and concentration. It is worth noting that these readings were obtained during the rainy or wet season.

Table 3. TDS readings at Maiganga mining site in Gombe State, Nigeria

Within the Mine		Environs Around the Mine	
Sample code	TDS reading	Sample code	TDS reading
I1	267	J1	71
I2	82	J2	91
I3	252	J3	59
I4	271	J4	169
I5	355	J5	125
I6	109	J6	121
I7	176	J7	163
I8	271	J8	193

4. Benefits, Challenges and future prospect of IoT in Mining

In conducting a comparative analysis of the existing literature addressing IoT applications in the mining and sustainable development domain, this research provides a comprehensive grasp of the current IoT scenario. The findings demonstrated that IoT-based on mining activities can lower overall costs, depreciation expenses, and operational expenses while increasing productivity, wealth, income, and GDP in the economic index of sustainability [35]. This has the potency to improve workers safety as well as have beneficial effects on culture and knowledge. It is also possible to achieve a notable decrease in emissions and pollution from an environmental perspective.

However, there are a number of obstacles to its implementation and future prospects that must be taken into account, including potential isolated locations and underground mine operations. Data management, interoperability, cost, expertise, and training are some more[36].

Considering its challenges, the potential of the IoT is enormous. It has the ability to continuously monitor and analyze data in real time, as well as continuously assess the impact of regulations and minimize ecological footprints. It can also continuously monitor the environment and structure integrity to prevent accidents.

5. Conclusions

The Internet of Things was used to successfully design a wireless sensor for real-time monitoring of water quality. This sensor generated information in real - time and allow the user to monitor at any time while being far from any location. Other features that have been successfully implemented include real-time notifications in the event that the water quality is declining, graphical previews of previous data, and user requests to modify the time period and regulate data logging. By default, the system logs data from two sensors—two metrics related to water quality and battery voltage—every 20 minutes.

The functionality and performance of this IoT water quality monitoring device can be improved in the future. The first suggestion is to utilize a machine learning system for predictive data analysis. This way, users would receive automatic alerts when to inspect and adopt safety measures to prevent mine pollution of nearby streams and mine water.

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طراحی حسگر مبتنی بر بی‌سیم برای پایش بی‌درنگ pH و TDS در آب‌های سطحی و زیرزمینی با استفاده از اینترنت اشیا

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چکیده:

در گذشته، ارزیابی کیفیت آب معمولاً شامل فرآیندهای کار فشرده و پرهزینه مانند تجزیه و تحلیل آزمایشگاهی و نمونه‌برداری دستی بود که داده‌های بلادرنگ را ارائه نمی‌کردند. علاوه بر طعم بد، نوشیدن آب اسیدی به طور منظم می‌تواند منجر به رفلاکس اسید و سوزش سر دل مکرر شود، در حالی که آب با مواد جامد محلول بالا می‌تواند باعث ایجاد سنگ کلیه شود، به خصوص زمانی که محتوای آب سخت بیش از ppm۵۰۰ باشد. با افزایش نگرانی‌ها در مورد کیفیت آب، نیاز به نظارت مستمر سطوح pH و TDS در منابع آب سطحی و زیرزمینی وجود دارد. برای رفع این مشکل، یک سیستم حسگر بی‌سیم پیشرفته با بهره‌گیری از فناوری اینترنت اشیا (IoT) توسعه یافته است. این سیستم دارای سنسورهای درجه یک pH و TDS است که به دلیل دقت، دوام و سازگاری با محیط زیست شناخته شده است. این حسگرها که با میکروکنترلرهای دارای قابلیت‌های ارتباط بی‌سیم یکپارچه شده‌اند، انتقال یکپارچه داده‌ها را به سرور مرکزی از طریق پروتکل‌های IoT مانند شبکه‌های سلولی امکان‌پذیر می‌سازند. داده‌های جمع آوری شده برای اطمینان از قابلیت اطمینان و دقت پردازش و کالیبره می‌شوند. پلت فرم اینترنت اشیا متصل به سرور مرکزی، اتصال دستگاه، ذخیره سازی داده‌ها و تجزیه و تحلیل را مدیریت می‌کند و داده‌ها را در زمان واقعی از طریق وب کاربر پسند یا برنامه‌های تلفن همراه با نمودارها و داشبوردهای تعاملی در دسترس قرار می‌دهد. ویژگی‌های صرفه‌جویی در مصرف انرژی برای بهینه‌سازی عمر باتری در مکان‌های دور و خارج از شبکه پیاده‌سازی شده‌اند و محفظه‌های مقاوم در برابر آب و هوا از گره‌های حسگر در برابر شرایط محیطی سخت محافظت می‌کنند. با استقرار این سیستم حسگر مبتنی بر بی‌سیم، کاربران می‌توانند در زمان واقعی بینش ارزشمندی در مورد کیفیت آب در مکان‌های نظارت بر آب‌های سطحی و زیرزمینی به دست آورند.

کلمات کلیدی: سنسور، زمان واقعی، کیفیت آب، اینترنت اشیا.