Development of a Low-Cost, IoT-Based Integrated System to Monitor Rural Water Quality

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Abstract— In both rural and urban regions water quality assurance measures are weak. Many research projects have been launched in recent years to develop cellular systems that monitor water quality and respond quickly to maintain acceptable drinking water regulations. Water is inextricably linked to human existence. Not only being a scarce resource but the quality of water potable to drink is also poor. Ingestion of contaminated water could cause the consumer to contract waterborne diseases such as Malaria, Typhoid, and Cholera. Currently, there are lab-based systems, remote sensing systems, and automatic systems with monitoring systems. They are, however, time-consuming, inaccurate, or expensive.

To solve these issues, it is proposed an IoT-based system for monitoring water quality. The incorporation of sensors in these systems makes data collection for parameters like pH, Total Dissolved Solids, and Temperature easier. These sensors collect data by connecting to a microcontroller. The information gathered by these sensors is sent to the cloud and then shown in a smartphone application. If the water quality is below threshold, the system can transmit automatic alerts to the mobile application. As a result, there is an obvious need for a dependable and cost-effective real-time water quality monitoring system, which the proposed system successfully provides.

Keywords—water quality, water quality monitoring, IoT based water quality monitoring, water monitoring, water, IoT

I. INTRODUCTION

Water is utilized for a variety of purposes, including industrial facilities, farming, fishing, and other constructive activities [1]. Water quality (WQ) degradation due to variables like changes in weather patterns, rising temperatures and pollution is a significant global issue. Population expansion, urbanization, and climate change have placed enormous strain on food, energy, and water supplies.[2]. One of the most significant contaminants of water supplies in particular is agricultural runoff. [3]. Pathogenic organisms are microorganisms that live in water and have been a major cause of WQ degradation. Groundwater, rivers, saline water resources, reservoirs, and lakes are all affected by pathogenic pollution. Polluted and contaminated water can cause diseases like fever, malaria etc. Because water quality has such a direct impact on public health and the economy, governments all over the world has made monitoring and analyzing WQ, as well as the reasons of its degradation, a top concern. Conventional methods of WQ control involve manually collecting water samples from various locations and times, followed by laboratory analytical procedures to assess the WQ. These approaches are no longer considered to be efficient. [5]-[9]. Even though the current approaches enables a thorough investigation of chemical and biological agents, it has some shortcomings: a) There is a shortage of real-time water quality data to support key public health choices. b) Spatial and temporal coverage is subpar (only a small number of locations are sampled); and c) It requires a lot of labour and is costly(labour, operation, and equipment). Therefore, continuous, high spatial and temporal resolution on-line water quality monitoring (WQM) is essential. The US Environmental Protection Agency (USEPA) conducted a comprehensive experimental study of water quality sensors to evaluate their efficacy against a variety of contaminants [10]. Among the present systems are autonomous systems with monitoring substations, remote sensing-based monitoring, and laboratory-based WQM. But this is more time consuming. It will be expensive to set up an autonomous water monitoring system with many monitoring substations and control centers [11]. Another approach for sensing parameters related to groundwater is continuous multichannel tubing. A multi-channel flexible tubing mechanism is used [14]. As a result, a reliable and budget friendly real-time water quality monitoring system is clearly required, which IoT-based devices may be able to supply. Temperature, turbidity, pressure, and conductivity are some of the factors that might be used in an IoT-based project. Multiple sensors will be used for sensing, including an ultrasonic sensor, a pressure sensor, and a temperature sensor [12]-[13]. IoT may connect ubiquitous devices and facilities to a variety of networks to provide efficient and secure services for all applications at any time and from any location [15]. Two qualities are necessary for IoT. First, because IoT is a network or Internet extension, it should cohabit with other networks. Interoperability across these networks is essential for data transmission and auxiliary applications. A major IoT framework difficulty is interconnectivity. Second, the Internet of Items allows connected things to integrate information, human behaviors, and other things in addition to devices and objects. As a result, IoT should incorporate mechanisms that handle item connectivity in a broader sense [16]-[18]. The three primary layers of IoT architecture are: (i) application layer，(ii)network layer，and(iii)perception layer. Sensitive devices are used to gather the parameter data needed for WQM. The transmission layer is the network layer. The network layer obtains the perception layer's processed data and chooses the most efficient ways to transmit it through integrated networks to the IoT hub, devices, and applications. The data from the network layer is received by the application layer, which then uses it to perform the appropriate services or processes. As an illustration, the application layer might offer a storage service to backup incoming data to a database or an analysis service to assess data to determine how physical devices will function in the future. The subsequent sections of this paper are structured as follows. Section II examines the design and development of a system for monitoring water quality. The operation of the system for monitoring water quality is shown in Section III. The designed water quality monitoring system is tested in Chapter IV, and Chapter V brings the paper to a close.Design And Development Of Water Quality Monitoring System.

A. *Introduction*

The design and development of the WQM system is presented in this chapter. The block representation gives an idea of the layers of the WQM System and their interaction. There are three sensors in the suggested system to measure temperature, pH and Total Dissolved Solvents (TDS) of the water sample. These three sensors are interfaced with a microcontroller and the data is further processed and transmitted to a cloud platform.

B. *Design of the Water Quality Monitoring System*

The block diagram of the system is as shown in the Fig 1. Three sensors are employed to detect temperature, pH, and TDS in the system. These sensors' job is to acquire information from the water sample. These three sensors are connected to a controlling unit. The controlling unit is the system's brain. A microcontroller serves as the controlling unit. The data is subsequently transferred to the cloud. The cloud facilitates data storage, access, and making data available on demand. The data is then displayed on a mobile application.

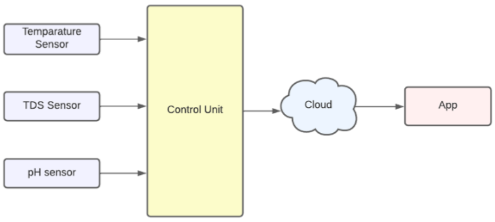


Fig 1. Block representation of the WQM System

The components employed in the proposed WQM system are ESP32, PE-03 pH sensor, Grove TDS Sensor and DS18B20 temperature sensor. ESP32 is a 32-bit microcontroller which is the brain of the WQM system. Its onboard Wi-Fi and Bluetooth features, which come at a low cost, make it more dependable than other microcontrollers. The pH is a crucial metric in determining the WQ. Water quality deteriorates when sediments from pipe corrosion and other sources are present. These sediments are detected by PE-03 sensor. Its level ranges from 0 to 14. The PE-03 pH sensor is reliable, with an accuracy of ±0.01PH and an operating temperature range of 0 °C to 50 °C. It can measure pH levels in a short period of time and is easy to use, making it superior to conventional pH sensors. Grove TDS Sensor is used in this project to measure the TDS in the water sample. There are two forms of solids in water: solutions and suspensions. A glass fiber filter can be used to identify theses two types of solids in water samples. While suspended solids are collected on top of the filter, dissolved solids pass through it with the water. If the filtered portion of the water sample is put in a tiny dish and evaporated, solids will still be present as a residue. Total dissolved solids, or TDS are usually referred to as this material.

$$TS = TDS + TSS \qquad (1)$$

Where TS = Total Solid, TDS = Total Dissolved Solid and TSS = Total Suspension.

Because of its waterproof TDS probe and ability to monitor TDS values up to 70°C, the Grove TDS Sensor was chosen. It is inexpensive, simple to use, and has good compatibility with ESP32. Temperature of water can be used to study the behavior of water and changes in its metrics. The DS18B20 Temperature Sensor was chosen because of its waterproof probe, which enables temperature measurement easy and comfortable in water. It is more dependable because it can measure temperature in a range of -55 °C to 125 °C with an accuracy of ±0.5°C.

C. *Development of the Water Quality Monitoring System*

The proposed system consists of three sensors which are interfaced with ESP32.pH sensor module has three pins which can be connected to the microcontroller. The three pins are used to provide input power to the sensor and also the output of the sensor is transmitted to microcontroller via them. TDS Sensor has 4 pins namely SIG(Output), NC (Not Connected), VCC, GND. The Output pin is connected to any of the input pins of ESP32 and the supply and ground pins are connected to the respective pins ESP32. The DS18B20 Temperature sensor probe has 3 connecting wires GND, VDD (operating voltage), DQ (Output). The VDD and GND pins are connected to input and GND pins of ESP32 respectively while the DQ pin is connected to 3V3 pin of ESP32 via a 4.7k ohm resistor. The circuit diagram of the developed system is as shown in Fig 2.

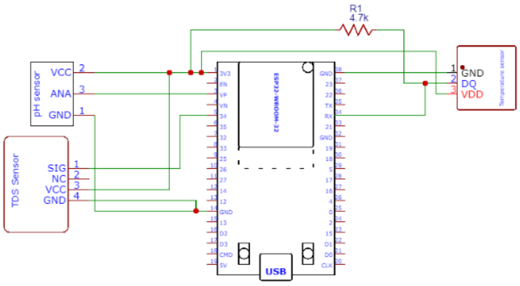


Fig 2 Circuit Diagram of the WQM System

II. WORKING OF WATER QUALITY MONITORING SYSTEM

A. *Introduction*

This section explains how the proposed WQM works. The sensors ‘operation with the Microcontroller is explained below. The data acquired by the sensor is translated into readable form by the microcontroller, which is programmed. For example, each parameter has its own units: Temperatures are commonly expressed in degrees Celsius. The sensor data is converted into its equivalent units by the microcontroller.

B. *Operation of the Water Quality Monitoring System*

The brain of the system is the Microcontroller ESP32, which is employed as the controlling unit. To measure a specific metric, all of the sensors have probes with leads that can be dipped in water. To measure a certain parameter, these leads are dipped in water. When the temperature sensor is immersed in water, it measures the temperature of the sample and transfers the information to the ESP32 through the Rx pin. The information is then read by the microcontroller. The TDS and pH sensors measure pH and TDS levels and transmit the voltages to the ESP32 via 34th and Vp pin respectively. These voltages are converted into pH and TDS readings by the ESP32. The information in ESP32 is then processed and compared with the reference values. The output is categorized as Good, Bad, or Average based on the comparison. The output is then transferred to a cloud built on Google firebase and later displayed in on a mobile application. The app is designed to show temperature, TDS, and pH values as well as the water's status as Good, Bad, or Average.

III. TESTING AND RESULTS WITH THE DEVELOPED WATER QUALITY MONITORING SYSTEM

A. *Introduction*

The following chapter presents the testing of the proposed Water Quality Monitoring System withdifferent water samples collected from various sources. The observations have been comparedwith the reference values obtained from standard sources. The comparison between the reference values and the observed indicates the accuracy of the developed Water Quality Monitoring Systemand its reliability.

B. *Testing of the sample with the developed WQM System*

The three sensors and microcontroller were connected on PCB as shown in Fig 3. This PCB has three sensors connected on it, out of which two sensors have their own modules while the temperature sensor’s connection s made below the PCB. The temperature sensor has a simple probe and doesn’t require any module.

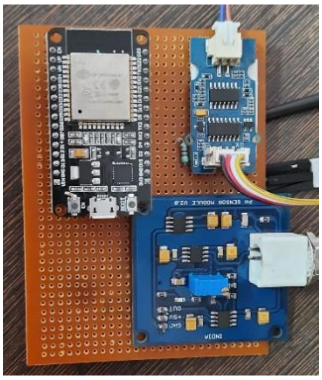


Fig. 3. WQM System on PCB

Classification of water samples is based on the values of pH and TDS. Table 1 depicts the water sample classification. The Microcontroller's processing stage includes the classification of samples. The microcontroller compares the sensor values to the reference values and provides output accordingly after reading them. The water samples are graded as Good, Bad, or Average. If the pH value is between 6.5 and 8.5 and the TDS value is between 0 and 500, the sample is considered "Good." The pH and TDS levels must both be within the acceptable range. The sample is labelled "Average" if the pH is between 5 and 6.5 or 8.5 and 9.5 and the TDS is between 500and 700. Finally, the sample is labelled "Bad" if the pH is less than 5 or larger than 9.5, and the TDS is less than zero or greater than 700. If the TDS value is less than zero, the amount of TDS in the water is larger than the sensor's maximum measurement range.

TABLE 1 CLASSIFICATION OF SAMPLES

Parameter	**Classification**		
	Good	***Average***	***Bad***
pH	6.5-8.5	5-6.5 OR 8.5-9.5	<5 OR >9.5
TDS	0-500	>500	<0 OR > 700

The system has been tested on three water samples Mineral Water, Soap Water and Tap Water. The observations are recorded in Table 2.

TABLE 2 OBSERVATION FOR DIFFERENT WATER SAMPLES

Samples	Referene Values for pH	pH value	Reference value for TDS	TDS value	Remarks
Mineral water	6.5-8.5	7.4	0-500	50	Good
Soap Water	9-10	9.5	Nil	1120	Bad
Tap water	6.5-8.5	7.6	Nil	630	Average
Mud Water	Nil	9.6	Nil	1200	Bad
Acid Water	Nil	4.2	Nil	91	Bad

Based on the observations mentioned in Table 2 graphs were plotted by using the data as shown in fig 4 and fig 5. The graphs are plotted with types of samples on x- axis and pH and TDS(in ppm) values on y-axis.

FIGURE 4 TDS VALUE AGAINST DIFFERENT WATER SAMPLES

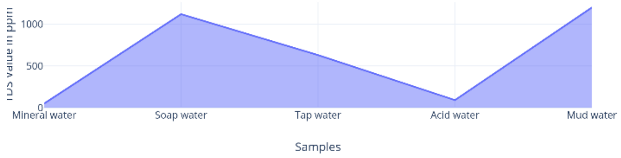
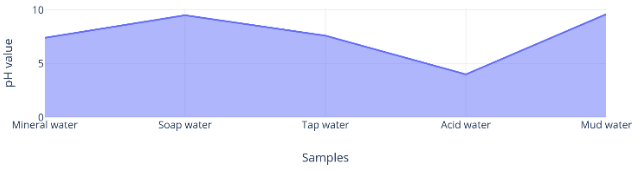


FIGURE 5 PH VALUE AGAINST DIFFERENT WATER SAMPLES



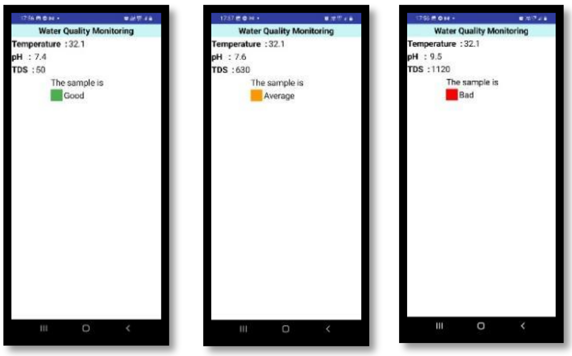
The figure 4 depicts the TDS values of different water samples. The water samples considered for testing i.e., Mineral water, tap water, soap water, Acid water, Mud water are taken on x-axis while TDS values are considered on y-axis. With reference to the data in Table 2 the graph is plotted. The scale of y-axis is considered to be 500ppm per unit. From the graph it is seen that the descending order of TDS values for the samples is as shown below.

Mud Water> Soap Water> Tap Water> Acid Water> Mineral Water

The plot of pH values of water samples considered for testing is as shown in Fig 5. The type of sample is considered on x-axis while the pH value with a scale of 5 per unit is taken on y-axis. The descending order of pH with refernce to fig 5 is as shown below.

Mud Water> Soap Water> Tap Water> Mineral Water> Acid Water

The reference values were extracted from the Bureau of Indian Standards (BIS) Website and arementioned in the reference's column of Table 2. The remarks for the water sample are basedupon the TDS and pH values as mentioned in Table 4.2.1 The remark for Mineral water is Goodsince the value of TDS and pH lies in the range of 6.5-8.5 and 0-500 respectively. The remarks forSoap water is bad since the TDS value is above 500. The remarks for Tap water is Average sincethe TDS value is above 500 but the pH value is in acceptable range of 6.5-8. The output of the developed WQM system on the mobile application is as as shown in Fig4.2.4(a),(b),(c). The app displays the three values of senors i.e., the values of temperature, TDSand pH sensor and the status of the sample along with the colour. The threee samples are labelledas "Good", "Average" and "Bad" according to the Table 2.



Water Quality Monitoring
Temperature :32.1
pH : 7.4
TDS : 50
The sample is
🟩 Good

Water Quality Monitoring
Temperature :32.1
pH : 7.6
TDS :630
The sample is
🟧 Average

Water Quality Monitoring
Temperature :32.1
pH : 9.5
TDS :1120
The sample is
🟥 Bad

(a) (b) (c)

Fig. 4. Screenshot of Mobile Application

IV. CONCLUSION

Water-quality monitoring in rural areas makes a significant impact on reducing the number of people with water-borne diseases. With the proposed water quality monitoring system, water quality can be monitored in less time, at a low cost and without personnel on duty. Sensors are used to monitor pH, TDS, and temperature, and these sensors are controlled by a microcontroller. This device was used to monitor the water quality of various samples of water. The correlation between the results and the standards was acceptable. In order to facilitate water quality monitoring, the system can send alerts through its mobile application if the water falls below standards. To put it another way, water quality monitoring will most likely be more convenient, faster, and most crucially, less expensive.

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