Development of Cost-Effective Water Quality Monitoring for Potable Drinking Water Using IoT

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Abstract. One of the main substances that significantly affects ecosystems is water. Unfortunately, with increased urbanization, sewage, abstraction of chemical fertilizers and pesticides in agriculture, which contaminate water, is now widely exploited. To monitor quality of the water across wide region, like rivers, lakes, or hydroponics, it is thus required to install a system. According to the state of world today, IoT and distant sensing methods are utilized in a variety of study fields to monitor, collect and analyze data from distant locations. The proposed system-DCWQM includes a wide variety of sensors interfaced to ESP-32 for measuring physical and chemical parameters of drinking water. This method allows analyzing of data that has been posted online through Blynk App and the real-time assessment of water body quality.

Keywords: IoT · water quality · ESP-32 · real time assessment · Blynk app

1 Introduction

All living things require water to survive, and it is not possible to live without it. Environmental pollution has grown to be a big issue as a result of technological development and industrialization. The most significant kind of pollution is water pollution. Our survival depends on the standard of the water we drink in a variety of forms, including juices made by the private sector. Any variation in quality of the water would have a negative impact on human health and disrupt ecological balance among all animals. In India among 1.3 billion population 6% of them does not have access to pure water and 54% of them are facing health issues due to lack of awareness about purifying and consuming the healthy drinking water [1]. Due to increased population most of the smart cities implement water reused system, reducing the dependency on fresh water. SiGeSn/GeSn based inter band multiple quantum well infrared photo detectors can provide better results in designing smart cities [2]. The characteristics of the water's chemical, radiological, and biological composition are referred to as its quality. Depending on how water is used, different important characteristics of the water quality apply. To protect the safety of the fish within an aquarium, for instance, it is required to keep the water's temperature, pH level,

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turbidity, and level within a specified typical range. Nevertheless, depending on how the water will be used for industrial and domestic purposes, some water characteristics must be checked more regularly. Rainwater may wash agricultural chemicals and fertilizers through the soil and into nearby bodies of water. Moreover, industrial effluents wash into bodies of water.as per statistical information about 2 million tons of water waste and other effluents are released in to water bodies [3]. These contaminants accumulate in the food chain until they reach poisonous levels, where they finally kill land and water animals. For irrigation and industry, the quality of the water can be variable, but it should be of excellent quality for drinking. River water is used by industries to cool down equipment and energies it. Increased water temperature reduces the amount of broken-down oxygen in the water, which affects biotic life. A system of instruments and procedures called a "water quality monitoring system" is used to continuously test and evaluate the water quality in a given area. IoT is a one of the trending technologies that brought drastic changes with respect to human needs such as agriculture, health care, supply chain management and water resources management. Low power IoT architecture has been developed addressing these challenges [4]. It is intended to give details on the biological, chemical, and physical characteristics of water as well as to point out any alterations or patterns in water quality. The system's main objective is to guarantee that the water is safe for consumption by humans and the environment. This is accomplished by routinely collecting samples of water and testing them for a variety of factors, like temperature, dissolved oxygen, turbidity, pH and different pollutants, contaminants including nitrates, phosphates, bacteria, and heavy metals.

The rest of the paper is organized as follows. Literature survey is discussed in Sect. 2. Proposed model and implementation are explained in Sect. 3. Results are highlighted in Sect 4. Paper is concluded in Sect. 5

2 Related Work

One of the main substances that significantly affect ecosystems is water. But, because to increased urbanization, human waste, and haphazard using pesticides and fertilizers in agriculture, it is now widely utilized, which contaminates the water. In order to monitor the water quality across a wide region, like rivers, lakes, and hydroponics, it is thus required to install a system. Many researchers have contributed in analyzing the quality of the water using different traditional and advanced techniques.

Authors [5] conducted a survey on water quality monitoring and discussed about various technologies used for measuring the water quality in real time. Yashwanth Gowda K.N et.al. Demonstrated a portable, automatic and real time water quality monitoring model [6]. Authors [7] proposed water quality monitoring system that measures 5 parameters of water and water temperature using distinct high-speed sensors. Authors [8] conducted a survey on environmental monitoring and water quality measurements using wireless technology. Srour, T et.al. Proposed an approach that monitors and controls the monitored parameters using interactive wireless sensor networks [9]. Authors [10] presented a review on smart water pollution monitoring system and proposed IoT based uninterrupted quality monitoring system.

Rao A.S. et.al, developed an inexpensive wireless water monitoring system that collects the data and assists water shed managers for maintains of water dependent living beings [11]. Authors [12] proposed a system that measures pH, conductivity, temperature of water in real time by a different sensor as part of water quality monitoring. The system's ZigBee module wirelessly transmits sensor data to the microcontroller, and a GSM module wirelessly transmits data from the microcontroller to the smart phone/PC. Kedia, N addressing the problem of contaminated water on a global scale and also focuses more on how the sensory to actuators systems reliable to maintain water quality [13]. Authors [14] presented a paper on water leak localization system using compression rates and graph theory Method. Mukta. M et.al, developed an application for testing the quality of water samples in comparison with WHO standards [15, 16].

The paper describes the development of a system monitoring water using LabVIEW software and microcontroller. The system was designed to monitor key parameters like pH, temperature, and turbidity. The data from these sensors is transmitted to a computer via a USB port, where it can be analyzed and visualized using LabVIEW software [17–19].

Monitoring the water quality has thus been one of the thrust areas of research in the past two-three decades. Though there has been lot of measuring procedures defined by the researchers still it is an open area which can be addressed with the new technologies like IoT and Machine learning. In this paper, the authors have contributed their work in monitoring the water quality so that it can be made convenient for drinking.

3 Implementation

Previously, water samples were collected by hand from water sources and sent to labs for analysis. This process typically takes a long duration, needs expensive equipment, and a more labor. In addition, the equipment needed to measure water quality is expensive, temperature- sensitive, and has a short lifespan. So, in this system, the temperature, TDS, turbidity, and pH readings of the water sample will be taken using respective sensors. The output obtained from these sensors will then be provided to the ESP32 micro controller to which they all are linked.

The ESP32 includes an inbuilt dual mode Bluetooth and wi-fi module, and the built-in wi-fi module has been used to link it to the Blynk app. We can check the water's parameters on the Blynk app and determine whether it is safe to drink or not.

The goal of this model is to give the harmless water to every individual and to understand the quality level of the water. The temperature can be measured with a high degree of accuracy using the LM35 temperature sensor IC (Integrated Circuit). The LM35's primary technical features include an output voltage of 10 mV per degree Celsius, the LM35 is intended to measure temperatures between –55 °C and 150 °C. The LM35 is a versatile instrument with a typical accuracy of 0.5 °C at room temperature signal output: The LM35 generates an analogue output signal with a linear scale of 10 mV per degree Celsius that is proportional to the temperature being measured. This makes integrating with other circuits.

To detect the amount of dissolved solids in water, a TDS (Total Dissolved Solids) sensor is employed. It functions by calculating a TDS value from a measurement of the water's electrical conductivity. To monitor the cleanliness of water used in production, TDS sensors are frequently used in applications including water quality monitoring, hydroponics, aquariums, and the food and beverage sector. TDS sensors come in a variety of forms, such as portable meters, inline sensors, and continuous monitoring systems. Their characteristics, measuring range, and accuracy differ. It's crucial to remember that TDS measurements cannot reveal the precise kinds of dissolved solids present in water. To determine the individual pollutants, further testing may be necessary.

Based on concentration of hydrogen ions in a liquid or solution, pH sensor is a device that decides whether a liquid is acidic or alkaline. The concentration of hydrogen ions in the solution affects how the pH sensor measures changes in the electrical potential of a solution. The electrical potential is translated into a pH reading by the pH sensor. A scale from 0 to 14 is used to describe the solution. The solution is neutral if the scale reads 7.0 it is alkaline if the scale reads between 8.0 and 14.0. When the PH scale value is 7.0, the temperature is 25 degrees Celsius. The PH scale has a range of –420 mV to + 420 mV on the mV scale. At 0 mV, the pH scale range is 7.0. The pH range for suitable drinking water is between 7.0 and 8.0.

An instrument called a turbidity sensor is used to detect how much water or other liquids scatter light. It operates by shining a light beam into the liquid, then observing how much light is reflected by the suspended particles. Turbidity sensors are used to show how clear or cloudy the liquid being measured is comparable to other liquids. To detect the concentration of suspended particles in water, turbidity sensors are frequently used in water treatment facilities, wastewater treatment facilities, and environmental monitoring. Although nephelometric sensors are often more precise, the color of the liquid being measured can have an impact. Turbidity sensors are often cleaned in order to preserve accuracy and dependability. They are routinely calibrated using a standard reference solution. Nephelometric Turbidity Units (NTUs) are the standard measuring units for turbidity sensors, with lower values denoting clearer liquids and larger values denoting cloudier liquids.

Express if Systems created the ESP32, a low-cost, low- power, and highly integrated microcontroller. The IoT, smart home mechanization, industrial mechanization, and wearable technology are just a few of the many uses for which it is built. With its in-built Bluetooth and wi-fi connection, ESP32 makes it simple to connect to the internet and other devices. It also has a dual-core CPU that enables it to do two tasks simultaneously.

A dual-core Tensilica LX6 CPU, able to operate at up to 240 MHz, powers the ESP32.The ESP32 contains up to 4 MB of flash memory and 520 KB of SRAM, both of which can be used to store data and programs. Wi-Fi, Bluetooth, and Bluetooth Low Energy (BLE) connectivity are all supported natively by the ESP32, making it simple to connect to other devices and networks.

With the help of the smartphone app Blynk, customers can remotely manage and keep an eye on their Internet of Things (IoT) devices. The software connects to a microcontroller running Blynk firmware, such as an Arduino or a Raspberry Pi, to function. The user may design unique user interfaces (UI) on the app that communicate with the microcontroller and its sensors and actuators once it is linked. For each project, Blynk offers a variety of pre-built widgets that may be altered, including buttons, sliders, graphs, and gauges. To build a more unique user interface, users may also submit their own graphics and icons. Both iOS and Android smartphones may use the software.

The client-server architecture used by the Blynk app places the microcontroller as the server and the mobile app as the client. Using the Blynk Cloud, which offers a secure and dependable internet connection, the app talks with the microcontroller. Data transmission is safe since it takes place via the Internet Protocol (IP) network and is encrypted using the SSL/TLS protocol. Users may build up to five projects with the free account on the Blynk app, which is available for download without cost. Users may purchase Blynk Plus, which offers a variety of extra features and larger project limits, for more sophisticated features and extra projects.

Monitoring water quality is an essential part of making sure that water supplies are safe and sustainable. Figure 1 Shows the block diagram of the proposed system. Water Body, Sensor Array, ESP32 Microcontroller, and Blynk Application are the system's four key components. The water body, which might be a lake, river, or any other body of water is the medium under observation and analysis. The Sensor Array is a collection of sensors that have been put in place in the water body to collect real-time data. Four separate sensors make up the Sensor Array: a temperature sensor, a pH sensor, a turbidity sensor, and a TDS sensor.

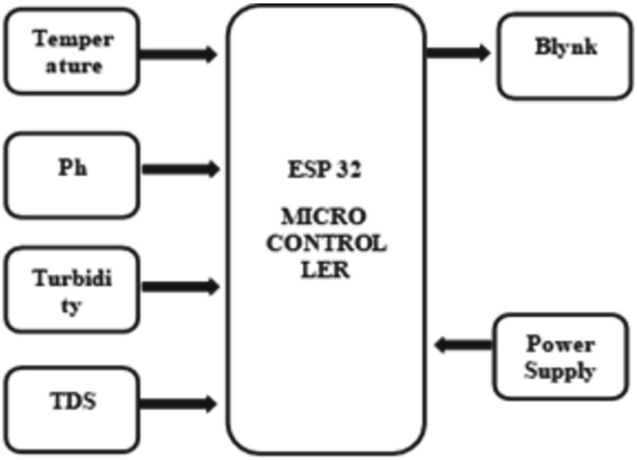

Fig. 1. Block diagram of DCWQM

The water body's temperature is gauged using the temperature sensor. And pH sensor is used to detect pH level, which is a crucial factor in figuring out whether a water body is acidic or alkaline. The TDS sensor measures the total quantity of dissolved solids in the water body, whereas the turbidity sensor measures the water body's clarity. The ESP32 Microcontroller, which serves as the system's primary control component, receives the data collected from the Sensor Array. The data gathered from the Sensor Array is processed and analysed by the ESP32 Microcontroller, which also generates alerts if the data deviates from the expected range. The information is also stored on the ESP32 Microcontroller and is accessible afterwards for analysis or decision-making.

The ESP32 Microcontroller is used by the Blynk Application, a mobile application, to show the data gathered by the Sensor Array. The user can view real-time data and keep track of the variables affecting the water quality using the application. The user can also set up alerts based on thresholds for different parameters, and receive notifications in case of any deviations. The flow chart of the proposed model is depicted in Fig. 2.

Fig. 2. Flow chart depicting the process of DCWQM

The process starts with measurement of various aspects of water quality, including temperature, pH, turbidity, and total dissolved solids (TDS). In order to send the data to a mobile application for remote monitoring, it also has a Blynk integration. The code defines variables and constants for the pins and sensors used and has a function to average analogue readings. The TDS sensor is read, the temperature compensation formula is applied, the value is converted to TDS, and it is then sent to the Blynk application in the loop () function. Next it reads the pH sensor, transforms the value to pH, and transmits it to Blynk. Temperature sensor is read, converted to Celsius, and sent to Blynk at the end. There is also commented out code that checks if the values of pH, turbidity, and TDS are within a certain range and turns on an LED if the water is drinkable.

4 Results

The proposed model for water quality monitoring has been physically designed and the prototype is as shown in Fig. 3.

Prototype of DCWQM includes temperature sensor, pH sensor, TDS sensor, and turbidity sensor and all are connected to ESP32 micro controller. Prototypes essentially have the components that got interfaced with each other, making them ready to use in the real-time scenario.

Figure 4 Depicts the immersion of the input parameters into the water to test its quality. The parameters were submerged into tap water, salt water, and mud water. The data that follows shows the water's appropriate quality.

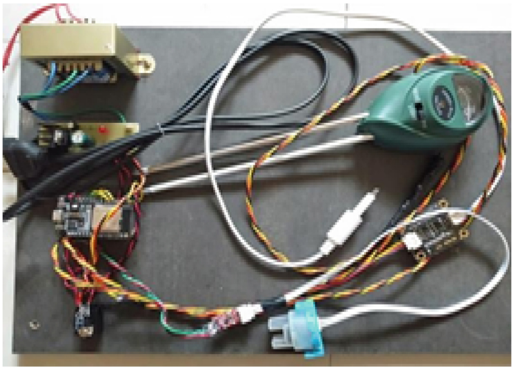

Fig. 3. Prototype of DCWQM

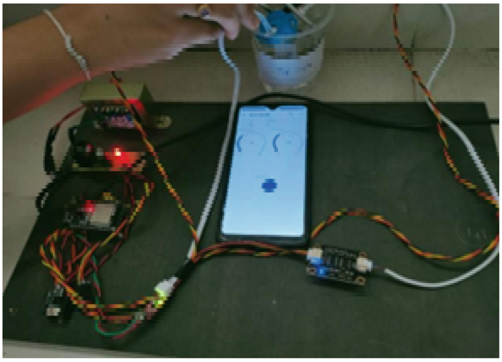

Fig. 4. Checking quality of water

The prototype has been subjected to provide the results for three different types of water as tap water, salt water and mud water. The observations with these three cases have been discussed below.

Fig. 5. Checking tap Water.

Figure 5 Shows the TDS and turbidity values obtained and stored in the Blynk app provided by the respective sensors connected to ESP32 controller.

The findings above indicate that the turbidity is 2.2 where it should be less than 1.5, the pH is 4.3 when it should be between 6.0 and 8.0, and the TDS is above 250 which shouldn't be used for drinking. The aforementioned graphic displays the turbidity and pH value of tap water, which may be used to determine if the water is pure and free of salt or dirt. Since the above image has shown the turbidity and pH values in the range of tap water it has proven that our prototype is working perfectly (Fig. 6 and Fig. 7).

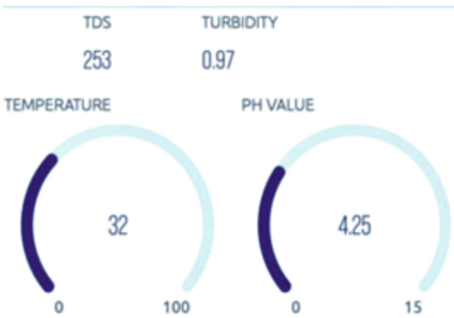

Fig. 6. Checking Salt Water

The aforementioned image was tested using salt water, in which we added NaCl levels to measure the quality of the water and to see if our model could identify its salinity in the water level because the quality difference is established.

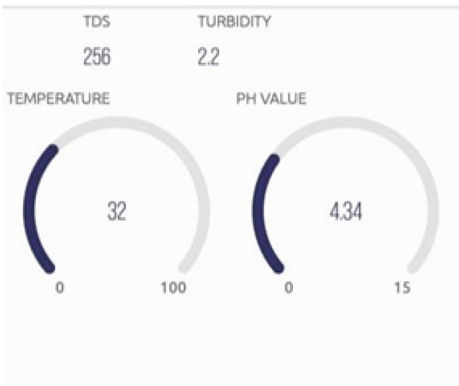

Fig. 7. Checking mud water

According to the aforementioned findings, the pH value is 4.3, which is acidic but should be between 6.0 and 8.0.and TDS is higher than 250 despite the fact that it should be between 50 and 150 and Turbidity is less than 1.5 making the water unfit for drinking (Table 1).

Table 1. Determines measuring principles and ranges of the sensors used for water quality monitoring.

Parameters	Measurement principle	unit	Range	Quality Range
Temperature	Optical/infrared scattering	Degree Celsius	0–100	—
turbidity	RTD Resistance	V	1.5–3.3	1.5–3.3
pH	Glass electrode	pH	0–14	6–8
TDS	Conductivity	Mg/l or ppm	50–1000	50–150

5 Conclusion

The system is used to monitor Temperature, pH, turbidity, and Total dissolved solids in the water. The System is reliable and used to remotely monitor the parameters. The system is adaptable and simple to understand and use. In this system various sensor array like temperature, pH, Turbidity, and TDS sensors were connected. And sensors are interfaced to the ESP32 micro controller and monitor the data in the Blynk application. The monitoring system is cost effective and can remotely monitor the data. The system finds its wide range of applications in various fields such as mining, ground water management and storm water management etc. The future of water quality monitoring system is promising, various other sensors like moisture sensors, conductivity sensors, and dissolved oxygen sensors, can also be added so that the water quality can be measured more accurately. Historical data, machine learning algorithms can be used to forecast water quality changes. This can assist spotting patterns and trends that conventional data analysis techniques might overlook.

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