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# Real-Time Water Quality Monitoring using IOT

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Corresponding Author: Btvenky2003@gmail.com**Abstract**- The monitoring of water quality in real-time has become essential following the heightened cases of water pollution, and the escalating needs of safe water resources. Manual and periodic sampling methods are usually laborious, slow and unable to detect sudden changes in the environment. The paper suggests the IoT-driven water quality monitoring system that is continuous and automated and requires low-priced sensors, wireless communication technologies, and cloud analytics. Parameters included in the system, including pH, turbidity, temperature, and dissolved oxygen, are monitored and communicated in real time to a cloud system to be inspected, warned, and analyzed. Experimental findings prove to be accurate, scale-able, and can be deployed in large scale, thus providing a trusted solution to smart water management and environmental protection.

**Keywords**- Cloud Analytics, Environmental Monitoring, Internet of Things, Real-Time Sensing, Water Quality Monitoring

## I Introduction

Water is among the basic resources required by human beings to survive, agricultural activities, industries, and the sustainability of the ecosystem. Nonetheless, the high rate of industrialization, urbanization and agricultural practices have largely impaired the quality of water in most regions of the world. Pollution of water causes severe health effects, losses to the environment and financial loss. Traditional methods of monitoring water quality rely on laboratory analysis and manual sampling, which is costly, time-consuming, and unable to provide real-time data. These restrictions complicate the process of identifying the occurrence of sudden contamination and reacting in time.

The Internet of Things (IoT) development has brought new applications in the environmental monitoring. IoT technology enables networked devices and sensors to continually gather, send, and analyze data via the internet. pH, turbidity, temperature, and dissolved oxygen are a few examples of sensors used in water quality monitoring that are integrated into IoT-based systems that also contain microcontrollers and wireless communication modules. These systems will gather real-time facts on water bodies and send it to cloud-based platforms to be stored, visualized, and analyzed.

Monitoring in real time has a number of benefits, such as the ability to collect data constantly, its remoteness, automatic notifications, and lower cost of operation. Cloud-based dashboards enable authorities to monitor the water conditions in real-time, whereas threshold-based notifications make it easier to identify the abnormal parameter change. Moreover, the combination of data analytics and the machine learning approach can boost the analysis of predictions and assist in applying proactive approaches to water management.

The IoT-based monitoring systems offer a cost-effective and scalable water quality management despite the presence of sensor calibration, power management, and network reliability problems. This paper concentrates on developing and installing an IoT-based water quality monitoring system in real time to make sure that contamination is detected in time and to facilitate sustainable management of water resources.

## II Literature Survey

Water quality surveillance helps in safeguarding water resources and safe drinking water to human usage. Manual sampling and laboratory analysis techniques are the foundation of traditional water quality monitoring techniques, which are labor-intensive and unable to provide real-time monitoring. Because of how quickly the Internet of Things (IoT) is developing, researchers are beginning to think about automated monitoring that may provide real-time data regarding the condition of the water. Kumar and Patel created an Internet of Things-based water quality monitoring system that uses sensors to assess important characteristics including temperature, turbidity, and pH. The system consists of sensors and an Arduino microcontroller that collects sensor data and uses Wi-Fi to transmit it to a cloud platform. The dashboard can be used to monitor the water quality levels even remotely and provide analysis of historical trends in water quality data with the use of a web-based dashboard. In spite of these shortcomings, the suggested system shows that the IoT technology can be applied to facilitate automated and efficient water quality monitoring systems in environmental management and to facilitate public safety uses [1].

The applications of wireless sensor networks (WSNs) in environmental monitoring have equally found numerous applications because it can be used to gather data in more than one location at a given time. Sharma and Patel came up with a water quality monitoring system employing distributed sensor nodes located at various locations of a river. All sensor nodes have sensors that detect parameters like pH, turbidity and temperature and are attached to a microcontroller that acquires data. As data are collected, they are sent into a central monitoring station through the use of the GSM communication technology, which enables the authorities to access the water conditions at a distance. There is also the integrated system of the automatic alarming system that will notify in the event that any parameter goes above the preset safe limits. The system was tested experimentally and experimental evidence indicated that the system is faster and more accurate in detecting pollution than the conventional manual monitoring methods. Nevertheless, the researchers noted that there are a number of challenges that are related to

wireless sensor network deployment such high power consumption, maintenance of the sensor and environmental factors that can influence the performance of the sensor. The importance of energy efficient communication technologies and strong sensor designs to guarantee consistent long-term monitoring of water quality parameters had been highlighted in the study [2].

Cloud computing technologies have also increased the functions of the IoT-based monitoring systems allowing storing data on a large scale and conducting sophisticated analytics. A cloud-based water quality monitoring system (IoT sensors) that continually measures the pH, temperature, and dissolved oxygen of the water was proposed by Lee et al. The system uses an ESP32 microcontroller that is linked to sensors and data gathered are sent to a cloud server over the MQTT communications protocol. A web-based dashboard enables users to visualize data of water quality in real-time and analyze the trends over the long term. The researchers also used anomaly detecting algorithms to reveal sudden variations in the quality of water which might reflect contamination incidents. The experimental assessment revealed that the system can offer reliable real-time monitoring and give quality data reports. The authors did, however, point at the possible security risks involved in sending the environmental data via cloud platforms. They suggested the use of encryption and authentication systems to keep sensitive data safe and exclude unauthorized access. The paper has shown the significance of combining IoT and cloud computing to establish scalable and effective systems to monitor water quality [3].

The issue of energy efficiency plays a vital role in the implementation of remote-based monitoring systems that are based on the IoT in areas that might not have constant power supply. The solar-powered water quality monitoring system suggested by Reddy and Prakash was meant to be used in the rural and remote setting. The researchers have used field experiments that have demonstrated consistent system performance with greater monitoring times. Communication was however disrupted by weather conditions like heavy rains and signal interference at times. The authors have come to the conclusion that the combination of the renewable energy sources and the IoT technologies can make the environmental monitoring systems more sustainable and reliable. In their study, the authors point to the opportunities of the solar-powered IoT systems in facilitating the use of the systems in large-scale water quality monitoring applications [4].

Recent developments in machine learning and artificial intelligence have encouraged academics to include predictive analytics into IoT-based monitoring systems. In order to assess and forecast the data, Ahmed et al. created an automated water quality monitoring system that integrates IoT sensor networks with machine learning algorithms. Using sensors that detect pH, turbidity, and dissolved oxygen, the system can collect data on water quality in real time. Such data are sent to a cloud platform where machine learning patterns analyze trends and identify abnormalities in water conditions. Predictive nature of the system will also help in identifying the occurrences of contamination early enough and authorities can therefore take preventive measures before the water quality can degrade considerably. Through experimental findings, it was observed that machine learning algorithms led to higher levels of accuracy in anomaly detection in comparison with the conventional threshold-based monitoring systems. However, the researchers found that training machine learning models takes a lot of time and computer power. The research proposes that the implementation of IoT monitoring with artificial intelligence will allow improving the process of environmental management and optimizing the operation of water quality monitoring tools [5].

It has come up with mobile and web-based monitoring platforms to facilitate its accessibility and provide the user with the ability to access environmental data remotely. Using GSM connection modules and a Raspberry Pi microprocessor, Gupta and Singh presented an Internet of Things water quality monitoring system. It is equipped to detect the water parameters (pH, turbidity, and total dissolved solids) and send data to a mobile app. The application is accessible to users who are interested in seeing the real-time water quality and receive notification when the parameters have surpassed a safe limit. The suggested system will enhance the quality of communication between the monitoring authorities and the users, which will give an opportunity to respond more quickly to the contamination incidents. The experimental testing proved that the system was able to transfer sensor data to the mobile platform in a minimum delay. The authors, however, noted that network connectivity problem can also impact system reliability when using remote locations. They proposed the combination of various technologies of communication including Wi-Fi, GSM and LoRa to enhance the reliability of data transmission. The article identifies the significance of mobile-based monitoring systems in the optimization of the usability and functionality of IoT-based environmental monitoring systems [6].

Edge computing has been a recent phenomenon that has shown itself to be a practical solution to assist in enhancing the efficiency and responsiveness of the IoT monitoring systems. A similar concept was suggested by Wang et al. in which an edge-based water quality monitoring architecture is proposed, where primary data processing is carried out on the sensor node rather than sending raw data to the cloud. Parameters measured by the sensors include pH, temperature and turbidity and the edge device processes the data on the spot with an embedded processor. Such a method will greatly minimize the bandwidth consumption in the network, and the response time to detect the abnormal conditions is enhanced. They are able to produce alerts as soon as an abnormal pattern has been identified in water quality parameters. The experimental analysis proved that the edge computing architecture decreases the communication delays and improves the system performance. But to introduce edge computing, more advanced hardware is needed, which can make the system more expensive and consume more power. The authors came to a conclusion that the integration of the edge computing technology with cloud-based analytics may offer a fair solution to real-time monitoring of the environment applications. They emphasize that edge-enabled IoT systems can be useful in efficient and scalable water quality monitoring [7].

Mass IoT surveillance systems have been created to track numerous water sources at the same time and to facilitate massive environmental surveillance initiatives. Fernandes et al. suggested a cloud-based IoT monitoring architecture that combines the distributed sensor nodes that are deployed in various water bodies. All nodes read the parameters of water quality and send the data to a centralized cloud server where data is stored and processed. The system delivers a web based dashboard enabling several users to view real-time monitoring data and past trends. This platform enables environmental agencies to observe the water conditions of multiple locations at the same time, and trace the source of pollution in a more efficient way. The experimental testing revealed that the system offers sound data transfer and scalability in monitoring. Nevertheless, the authors pointed out that to ensure a long-term deployment, the sensors need frequent maintenance and calibration to ensure the accuracy of measurements. The research found that IoT-based monitoring systems could make a very important contribution to the better management of water resources and contribute to the further implementation of sustainable environmental protection measures [8].

## III System Architecture and Design

### 3.1 System Overview

The proposed system is an Internet of Things (IoT)-based real-time water quality monitoring system designed to analyze important water parameters including pH, turbidity, and Total Dissolved Solids (TDS). The architecture will have three primary layers that include the sensing layer, the processing layer and the cloud communication layer. The system constantly gathers the information about water quality, processes it with the help of a microcontroller, and sends it to a cloud-based system to visualize it and store information and provide alerts.

### 3.2 Hardware Architecture

The following are the major components of the hardware architecture:
Sensing Layer: It is a layer comprising of pH, turbidity and TDS sensors. These detectors lead to measuring acidity/alkalinity, water clearness, and concentration of dissolved solids respectively. The sensors produce analogous signals that are proportional to the parameters that they measure.

Processing Layer: An Arduino Nano microcontroller is taken as the central processing unit. It measures the analog signals of the sensors and transforms them into digital values by a built-in ADC module and preprocesses and calibrates some data.

Communication Layer: There is a (ESP32) Wi-Fi module that provides the possibility of wireless data transfer. The data processed is transferred to a cloud server via an internet connection.

Power Supply Unit: A 12V power supply that has a voltage regulator provides a constant power supply to the microcontroller and sensors.

### 3.3 Software Architecture

The software architecture is sub-divided into three major modules:
Data Acquisition Module: This module is in charge of constantly taking sensor measurements at a specified time interval.

Data Processing Module:Calibration Adjustments and transforms raw sensor values into meaningful units (pH scale, NTU, ppm) and compares the measurements to preset threshold values against the standards of safety.

Cloud Integration Module: Sends processed information to an IoT cloud service e.g. ThingSpeak or Blynk. The platform keeps historical information, provides graphical representation, and allows remote monitoring.
Data Flow Design

- Sensors react with water sample.
- Analog electrical signals are generated by sensors.
- Arduino reads and processes sensor inputs.
- ESP8266 sends data to cloud server.
- Data is visualized and stored on a cloud platform.
- In case parameter is above threshold, alert notification will be made.

### 3.4 Alert and Monitoring Mechanism

The system has an alert mechanism that is controlled by threshold. Safe limits are predetermined by international standards of water quality. Notifications are created with the use of the IoT platform when any parameter passes beyond allowable levels. This would make provision of corrective action in time and avoid the possible health risks.

### 3.5 Design Considerations

The following are the objectives of the system:

- Low implementation cost
- Very high scalability of multiple applications.
- Low power consumption
- Simple maintenance and installation.
- Live online accessibility.

## IV Algorithm used

### 4.1 Monitoring and Alert Algorithm

Step 1: Reset microcontroller, Wi-Fi module (ESP32), and sensors modules (pH, Turbidity, TDS).

Step 2: Connect to Wi-Fi and set cloud platform API.

Step 3: Display readings of the analog pH, Turbidity, and TDS sensors.

Step 4: Convert analog values into digital values with the help of ADC.

Step 5: Transform raw values to standard units using calibration formulae:

- pH
- Turbidity (NTU)
- TDS (ppm)

Step 6: Compare each parameter with predefined threshold limits:

- pH: 6.5–8.5
- Turbidity: < Below the permissible NTU limit
- TDS: < permissible ppm limit Step 7:
- When values fall into range of safety - Upload data to cloud.
- In case any of the values goes above threshold - Send out an alert and log data.

Step 8: Save data on cloud database to view and analyse the historical data.

Step 9: Wait until sampling interval. Step 10: Continue the process.

### 4.2 Nature of Algorithm in the system.

The system primarily uses:

- Threshold-Based Decision Algorithm
- Continuous Real-Time Monitoring Algorithm
- Event-Driven Alert Mechanism

This will guarantee low calculation efficiency, short response time as well as appropriateness to embedded IoT applications.

## V Methodology

The real-time water quality monitoring system is proposed based on the structured and modular approach that implies the stages of sensing, data processing, communication, and cloud- based monitoring.

The sensing stage involves the use of three main sensors, namely, pH, turbidity, and Total Dissolved Solids (TDS), that assess central water quality parameters. Such sensors produce analog voltage signals in accordance with the values being measured. The inputs of the Arduino Nano microcontroller are joined to the analog outputs.

During the processing phase, the analog signals are read on the microcontroller, and they are converted into digital numbers through its in-built Analog-to-Digital Converter (ADC). Raw sensor data are converted to standard units by using calibration equations to convert the data into pH scale, Nephelometric Turbidity Units (NTU), and parts per million (ppm). The resulting processed values are then contrasted with pre-set safety limits using the global standards of water quality.

During the communication phase, an ESP32 Wi-Fi board is used to send the data that has been processed to a cloud platform. The data is stored in the cloud server, is graphical and can be remotely monitored via the web or mobile interface.
There is an alert system set to raise an alert when the values of the parameters are beyond safe values. The system is a continuous operation system with fixed sampling time interpreting real time monitoring, power saving, scalability, and reliability in various water management applications.

The proposed real-time water quality monitoring system is developed to follow the modular framework of an IoT so that the monitoring can be continuously provided, it could be accessed remotely, and automatic alerts are generated. This methodology explains as follows:

1. Sensor Selection and Integration
2. Data Acquisition
3. Signal Processing
4. Threshold Comparison
5. Wireless Data Transmission
6. Cloud Storage and Visualization
7. Alert Generation
8. Continuous Monitoring

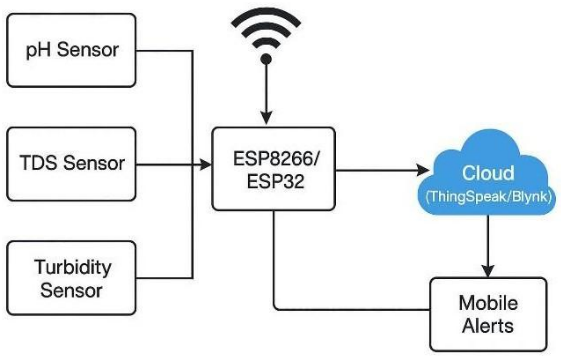


Fig 5.1 System Architecture For Real-Time Water Quality Using IOT

**VI Proposed System**

The suggested system is an Internet of Things (IoT)-based real- time water quality monitoring system that is intended to assess the water's vital characteristics, such as pH, turbidity, and total dissolved solids (TDS). Sensors, a microcontroller, a Wi-Fi module, and a cloud platform are all part of the system that will be continuously monitored and remotely accessed.

The water quality is measured with the pH, turbidity and TDS sensors, which produce analog signals. These signals are read by an Arduino Nano microcontroller which transforms them into digital values in an ADC and uses the calibration to obtain correct values. The data is then processed and sent to a cloud platform with the ESP32 Wi-Fi module.

The information is stored in the cloud server and presented in the form of graphic trends and can be monitored remotely using mobile or web-based applications. An alert handling mechanism applies a threshold against measured values

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comparing them to a set of safety limits. In case any of the parameters falls outside the acceptable limit, alerts are issued to allow the initiation of corrective measures in time.

The system guarantees low-cost integration, real-time control, scalability and dependable functioning of different water quality management applications.

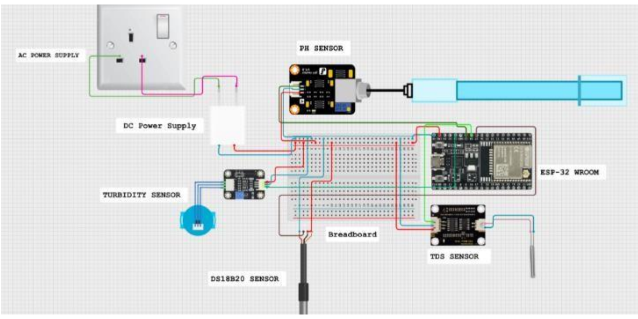


Fig 5.2 Block Diagram For Real-Time Water Quality Using IOT

## VII Materials And Methods

### 7.1 Hardware Requirements

➢ ESP32 Arduino Nano

- 32-bit dual-core microcontroller
- Integrated Wi-Fi & Bluetooth
- 12-bit ADC for analog sensor acquisition
- Operates at 3.3V logic
- Low power consumption
- Multiple GPIO, UART, SPI, I2C interfaces

Fig 7.1.1 PH Sensor Module of Real-Time Water Quality with IOT.

- Measurement range: 0–14 pH
- Analog voltage output
- Requires calibration using buffer solutions (pH 4, 7, 10)

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- Signal conditioning board included

**Purpose: Measures acidity/alkalinity of water**

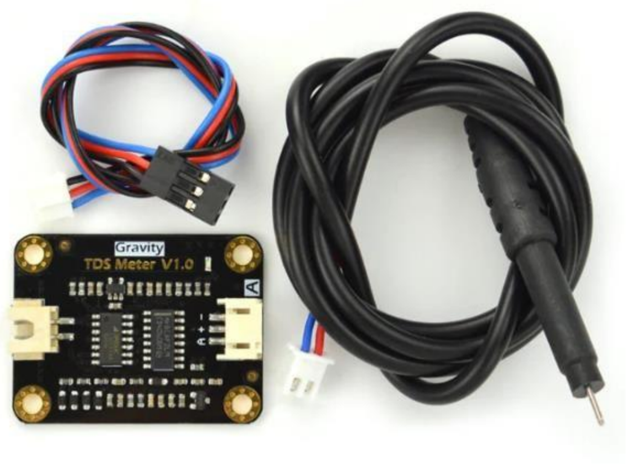


Fig 7.1.2 TDS Sensor For Real-Time Water Quality Using IOT

- Range: 0–1000 ppm (typical)
- Analog output
- Operates at 3.3–5V
- Temperature compensation optional

**Purpose: Determines Total Dissolved Solids in water.**

Fig 7.1.3 Turbidity Sensor For Real-Time Water Quality Using IOT
- Range: 1000– NTU
- Optical IR-based detection
- Analog voltage output

**Purpose: Measures suspended particles/water clarity.**

**7.2 Software Requirements**

1. Arduino IDE

- Embedded C/C++ programming
- ESP32 board configuration
- Serial debugging

 

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2. ThingSpeak

- Cloud data visualization
- Real-time graph plotting
- CSV export for analysis
- API key-based communication

3. Data Analysis Tools

- Microsoft Excel (CSV processing)
- MATLAB (optional simulation & validation)

**7.3 Supporting Components**

- PCB Board
- Jumper wires / Ribbon cable
- Breadboard (for prototyping)
- Calibration solutions Power Supply:

12V voltage controlled Adapter. OR
Regulated 5V lithium battery.

**7.4 Functional Requirements**

Table 7.4.1 For Real-Time Water Quality Using IOT

| **Requirement** | **Description** |
|---|---|
| Real-time Monitoring | Continuous acquisition of sensor data |
| WQI formula | Weighted arithmetic method |
| Cloud Upload | HTTP-based API transmission |
| Alert System | Threshold-based notification |
| Data Logging | Historical CSV storage |
| Low Cost | Affordable for rural implementation |

**7.5 Non-Functional Requirements**

- System accuracy ≥ 90% after calibration
- Response time < 5 seconds
- Low power consumption
- Scalable architecture
- Reliable Wi-Fi connectivity

**7.6 Minimum System Specifications**

- OS: Windows 10/11
- RAM: 4GB minimum
- Internet connection for IoT upload
- USB-to-Serial driver for ESP32

## VIII Results and Discussions

### 8.1Experimental Results

Sensors measuring important factors including pH, turbidity, and temperature were used to test the proposed IoT-based water quality monitoring system. The system's sensors were continuously collecting data and transmitting it to a cloud platform for real-time monitoring. To assess the system performance, sensor values were taken after intervals and compared to the reference values of standard results which were achieved under laboratory conditions.

The findings indicate that the system is capable of tracking water quality parameters with a low delay real-time data transmission. The IoT platform was able to store and visualise the data using a live dashboard. The system also put up alert in the case where the parameters values went outside the set safe levels.

The table demonstrates the constant checking of the water parameters with slight changes because of the environmental conditions.

Table 8.1.1 For Real-Time Water Quality Using IOT

| Time (min) | pH Value | Turbidity (NTU) | TDS (ppm) |
|---|---|---|---|
| 0 | 7.1 | 4.5 | 320 |
| 10 | 7.3 | 4.7 | 325 |
| 20 | 7.2 | 5.0 | 330 |
| 30 | 7.4 | 5.3 | 335 |
| 40 | 7.5 | 5.1 | 325 |
| 50 | 7.3 | 4.9 | 328 |

Table 8.1.1 For Real-Time Water Quality Using IOT

### 8.2Graph Explanation

**pH Trend Analysis:**

The chart of pH is the level of acidity or alkalinity of water at different time periods. The pH values in the experimental results were ranging between 7.1 and 7.5, a factor that depicts neutral to slightly alkaline water. These concentrations are regarded as being safe in terms of drinking and aquatic life. The minor changes that are witnessed in the chart are primarily caused by natural changes in the environment. Constant check pH is used to identify contamination of water or discharge of industries.

**Turbidity Trend Analysis:**

Turbidity is used to measure the clarity of water and it is used to reveal the presence of the suspended particles like sediments or organic matter. The experiment had a turbidity of between
4.5 NTU and 5.3NTU. The monitoring period showed a slight rise of turbidity which can be attributed to the stirring of the sediments or foreign pollutants in the water source. The graph can be used to show sudden spikes that can be linked to contamination incidences or environmental disruptions.

**TDS Trend Analysis:**

Total Dissolved Solids (TSS) represent the concentration of minerals, salts, and impurities in water that are in solution. In the experimental findings, the values of TDS were between 320 ppm and 335 ppm throughout the determination of the time. There was a slight rise in the TDS with time that could be attributed to dissolution of natural minerals or environmental factors. Nevertheless, the values were not too high to consume drinking water. TDS should be monitored continuously to be able to identify sudden jumps in dissolved particles that can reflect contamination. The findings indicate that the IoT-based system can solve the problem of real-time monitoring of the TDS changes efficiently and offer water quality management.

## IX Conclusion

This paper has developed and deployed a real-time IoT-based water quality monitoring system to overcome the constraints associated with the traditional manual testing process. The suggested system is capable of monitoring the main parameters of water quality including pH, turbidity, and Total Dissolved Solids (TDS) via specific sensors connected to an Arduino Nano microcontroller. Connection of the ESP32 Wi- Fi module provides the possibility to transmit the processed data to a cloud platform remotely and visualize it on the remote side.

The system also has a threshold-based alert mechanism, which informs the user whenever the measured parameters go beyond the allowable safety limits. This makes the difference in time and minimizing the risks of water contamination. The system is scalable, cost-effective and simple to install in a wide range of systems, such as household water tanks, aquaculture systems, agricultural irrigation, and water treatment plants due to the modular nature of the system.

In general, the suggested solution increases reliability, accessibility and efficiency of water quality monitoring. The sensor technology used in conjunction with IoT and cloud computing makes the system a contribution to sustainable water management and enhanced safety of the population health. Further improvements can be added of more sensors, integration of GPS and predictive analytics in making intelligent decisions.

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