Real Time Water Monitoring and Filter Prognostics

A project report submitted in partial fulfillment of

the requirements for the degree of

Bachelor of Technology

in

Electronics & Computer Engineering

by

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Declaration

I hereby declare that the report titled ***"Real Time Water Monitoring and Filter Prognostics"*** submitted by me to the School of Electronics Engineering, Vellore Institute of Technology, Chennai in partial fulfillment of the requirements for the award of **Bachelor of Technology** in **Electronics and Computer Engineering** is a bona-fide record of the work carried out by me under the supervision of ***Balakrishnan R***.

I further declare that the work reported in this report, has not been submitted and will not be submitted, either in part or in full, for the award of any other degree or diploma of this institute or of any other institute or University.

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School of Electronics Engineering

Certificate

This is to certify that the project report titled ***"Real Time Water Monitoring and Filter Prognostics"*** submitted by ***Mogeshvar S G*** **(21BLC1153), Hemant M Mehta (21BLC1379) & Nikhil Chordia A (21BLC1645)** to Vellore Institute of Technology Chennai, in partial fulfillment of the requirement for the award of the degree of **Bachelor of Technology** in **Electronics and Computer Engineering** is a bona-fide work carried out under my supervision. The project report fulfills the requirements as per the regulations of this University and in my opinion meets the necessary standards for submission. The contents of this report have not been submitted and will not be submitted either in part or in full, for the award of any other degree or diploma and the same is certified.

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Abstract

Water quality monitoring forms an integral and critical part of the more extensive scheme to ensure environment safety, protection of public health, and efficiency in industrial operations. Conventional methods used for testing water quality frequently fail to deliver into real-time data and actionable information. This delay often causes a lag in the adoption of corrective actions. To meet these challenges, the current study proposes using the power of IoT technologies with an aim to design a full-scale Water Quality Monitoring System.

The system under development will be integrating three types of sensors, which include pH sensors, turbidity sensors, and conductivity sensors, each of which will be connected to a versatile ESP32 microcontroller that acts as the core processing unit. Specific sensors work doggedly as to constantly provide in real-time data regarding critical water parameters, thereby communicating the same relatively efficiently to a PHP-based backend to be designed with more specific considerations regarding effective storage and thorough processing of that information. It will then skillfully visualize the data on a web-based frontend interface through real-time trends, detailed graphs, and comprehensive suitability analyses managed through the careful definition of thresholds for accuracy and relevant. This novel solution is studiously designed to enhance decision-making capabilities, ensure compliance with existing water quality standards, and significantly contribute to the promotion and implementation of sound water management practices that are rewarding for the benefit of current and future generations. The system has been upgraded to assess how water quality affects the condition of the filter, which may be labeled as low, medium, or high, providing useful information in terms of the performance of the filter and its maintenance.

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Chapter 1

Introduction

Adaptive Water Quality Monitoring represents a new approach toward enhancing both the protection and management of water resources based on real-time assessments and responsive approaches. Considering the intensifying global water problems that have been heightened by pollution, climatic change, and increasing population, this adaptive framework becomes increasingly important to ensure both safe and sustainable water supplies.

Basic Components of Dynamic Water Quality Monitoring:
Real-Time Sensors:

Implementation of Sophisticated Sensors: Employing a range of sensors, including electrochemical, optical, and biological types, to perpetually assess water quality indicators such as pH, turbidity and conductivity.
These sensors can therefore be integrated with the Internet of Things (IOT), which will enable them to transmit data in real-time and support remote monitoring functionalities.

Adaptive Management Strategies:

Automated Analysis:

Public Transparency: Many systems provide public dashboards displaying real-time water quality data, fostering transparency and community trust. Sustainability and Resilience The systems help optimize resource use, ensure reduced waste, and strengthen resilience against environmental stressors of water supply systems by adjusting to changing conditions and demands. Continued monitoring ensures the protection of aquatic ecosystems due to the availability of timely information that could help in making decisions towards conservation and regulation. Adaptive water quality monitoring is one of the most important breakthroughs in water resource management. This approach employs in situ or real-time data, advanced analytical techniques, and adaptive methodologies to improve not only the safety and quality of potable water but also sustainable practice with commitment to regulation standards. In consideration of continued demand for clean water, public health protection, and preservation of vital water ecosystems, adaptive monitoring systems will become a significant part of the future.

The2daptived capability of assessing the impact of filters not only makes the system more applicable but also empowers users to make informed decisions about maintenance and filter replacement. The classification of impact on filters as low, medium, or high provides practical insight that ensures efficient efficacy of filters, reduces costs associated with premature replacement, and promotes sustainable water management practices. The holistic approach suits the overall aim of keeping the quality of water protected, with the building and maintenance of resilience in water supply systems for current and future populations in aquatic ecosystems.

Chapter 2

Literature Survey

The ESP32 is the low-power system-on-chip with an integrated Wi-Fi and Bluetooth functionality at a low cost. With the flexibility, usability, and powerful processing capacity, ESP32 has been broadly applied in the field of Internet of Things (IoT) applications, which embraces the water quality monitoring systems as well. Built-in functions of Wi-Fi in ESP32 ensure data transfer directly from sensors to cloud services, thus making it very suitable for remote, real-time monitoring of water quality.

Adding pH, turbidity, and conductivity sensors with ESP32 will set sturdy and effective bases for dynamic water quality assessment. All those critical metrics regarding water quality are collected by these sensors as the ESP32 analyses the data, alters the sampling frequencies with pre-defined criteria, and then transmits these data to a backend server for further analysis and visualization.

2.1 Real-Time Data Acquisition and Processing:

The ESP32 can control data acquisition by analog sensors, for example, pH, turbidity, and conductivity sensors, while converting their signals to a digital presentation for further processing. The information is being read by the ESP32 by the means of its analog-to-digital converter or ADC, and subject to particular conditions, such as significant fluctuations in measurements coming from sensors, the system can change its behavior by changing the measurement frequency.

The authors developed a water-quality monitoring framework built on the ESP32 platform that, based on sensor readings, could alter dynamically the sampling rate. In case the reading of pH, turbidity, or conductivity surpassed some specified thresholds, the system increased the frequency of the sampling in order to gather more detailed data and become more responsive to possible contamination events.

2.2 Adaptive Sampling and Threshold-Based Triggers:

Adaptive sampling refers to the modification of data collection intervals in response to observed alterations in water quality. For example, if the system identifies a rapid increase in turbidity, which may signify potential pollution or sediment disruption, it could enhance the frequency of turbidity assessments to closely monitor the occurrence. In contrast, when water quality remains consistent, the frequency of sampling may be decreased. This adaptive methodology serves to optimize battery longevity and data storage while ensuring effective monitoring practices.

An3daptivee water quality monitoring system has been developed using ESP32, which utilises the threshold-based triggers. The ESP32 would increase the sampling rate of all sensors, such as pH, turbidity, and conductivity, whenever it found that the concentration of particles was high with the turbidity sensor and, simultaneously, send real-time notifications to the backend system.

2.3 Data Transfer and Computation

The ESP32 supports both Wi-Fi and Bluetooth, which enables the device to connect with either cloud servers or local databases as a means of storing water quality information for later analysis. Using Wi-Fi, real-time data can be transmitted to a PHP backend, from where this information is retrieved and accessed for visualization and analytical purposes. This cloud-based architecture allows for remote monitoring and guarantees the availability of water quality data at virtually any given time and even in relatively remote places.

A water quality monitoring system using an ESP32 microcontroller and Wi-Fi was presented to access data remotely. It may employ a battery of sensors, like pH, turbidity, and conductivity sensors, which can collect information and wirelessly communicate it to a cloud-based server. Users could then view the real-time information on a dashboard.

2.4 Power Management and Efficiency

The ESP32 also emerges as a very suitable device for battery-operated, low-power applications of IoT because it exhibits much less power consumption when in deep sleep mode. In adaptive systems, the ESP32 can be programmed to go to low power state during periods of stable water quality and wake up only in case of the need for more frequent data sampling or when threshold limits are exceeded. Power consumption efficiency is crucial for reliable long-term operation in remote environments where regular maintenance or power resources may not always be available. – investigated the energy-saving techniques adopted by the ESP32 while designing a water-quality monitoring application for remote environments. The system was able to effectively reduce its energy consumption by switching to deep sleep mode when the water quality was stable and only activated the sensors when they were needed, extending the service life when deployed in the fields.

2.5 Immediate Notifications and Assistance in Decision-Making

An important benefit of using the ESP32 in water quality monitoring systems is that they can locally process data and activate notices when certain conditions are met. For instance, ESP32 can trigger an alarm or indicate at the backend system if the pH value decreases below a certain threshold, which indicates acidification, or if turbidity goes beyond a certain threshold that implies contamination. Decisive power in real-time is fundamentally important because it enables immediate action to rectify or further investigate the root cause for the malfunction. – Developed a responsive water quality monitoring system using the ESP32. The system continuously monitored pH, turbidity, and conductivity levels. Whenever it noticed anomalous data (for example, abnormally low pH), the ESP32 relayed an alert message to a cloud-hosted dashboard and began local treatments (for example, by engaging water treatment procedures).

2.6 Filter Impact Evaluation and Maintenance Findings

The system comes with an advanced functionality whose ability is to evaluate how filter effects occur, which is measured as far as how water quality affects filtration systems. Through actual time readings produced by sensors of pH, turbidity, and conductivity, the ESP32 assesses water parameters and links them to set thresholds determining the amount of stresses filters face. The system categorizes the effect into low, medium, and high sections. This classification provides users with much information related to the present state of the filter and encourages timely activities pertaining to maintenance or replacement when required. With this feature, the system ensures both filter efficiency and durability and promotes responsible use by preventing unnecessary filter deterioration and resource wastage. This facet adds a new value into the water quality monitoring system-a comprehensive and precautionary plan for water management.

Chapter 3

Methodology

3.1 Hardware Implementation

Component Selection

3.1.1 pH Sensor

i. **Range:** 0–14 pH.
ii. **Working Principle:** The pH sensor measures the hydrogen ion concentration in water. It generates a small voltage that corresponds to the pH value, which is then converted into a readable format by the ESP32.
iii. **Use:** Critical for determining the acidity or alkalinity of water. Variations in pH can indicate the presence of pollutants or contaminants, such as industrial effluents or agricultural runoff.

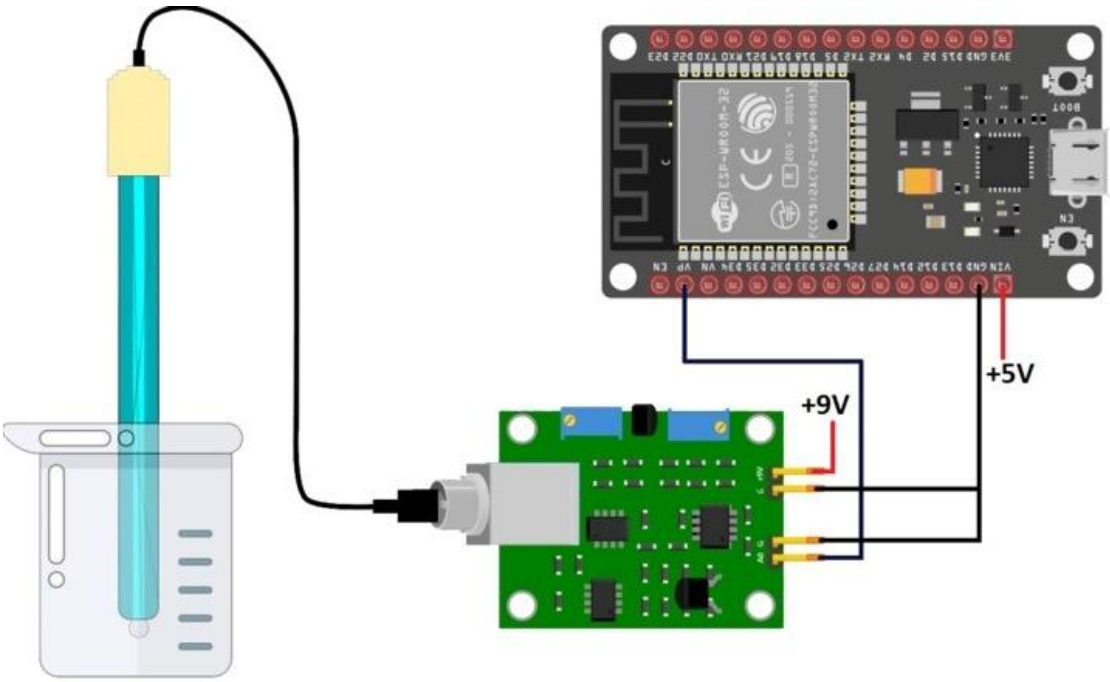

Fig 3.1.1 pH Sensor Connection

3.1.2 Turbidity Sensor

i. **Range:** 0–1000 NTU (Nephelometric Turbidity Units).
ii. **Working Principle:** The turbidity sensor uses a light source and a photodetector. When water passes through, the suspended particles scatter the light, and the sensor calculates turbidity based on the intensity of scattered light.
iii. **Use:** Measures the clarity of water, an essential parameter for detecting physical contaminants like sediments or organic matter.

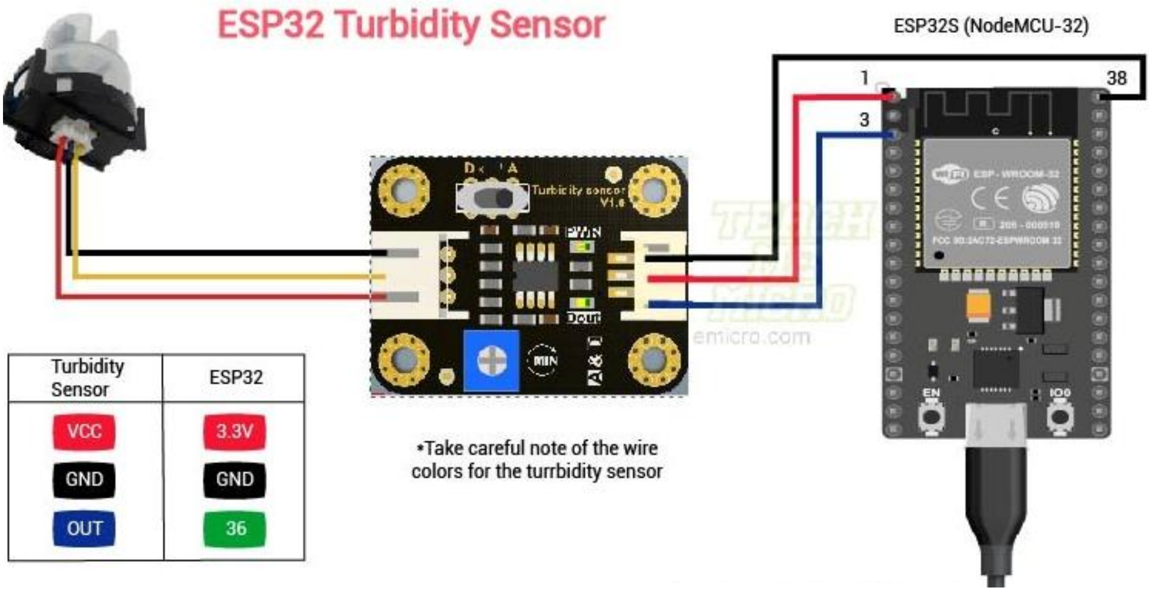

Fig 3.1.2 Turbidity Sensor Connection

3.1.3 Conductivity Sensor

i. **Range:** 0–2000 µS/cm.

ii. **Working Principle:** Measures the electrical conductivity of water, which corresponds to the concentration of dissolved ions. Higher conductivity indicates salinity or the presence of dissolved salts and minerals.

iii. **Use:** Essential for detecting dissolved ionic compounds, which may affect water quality and usability.

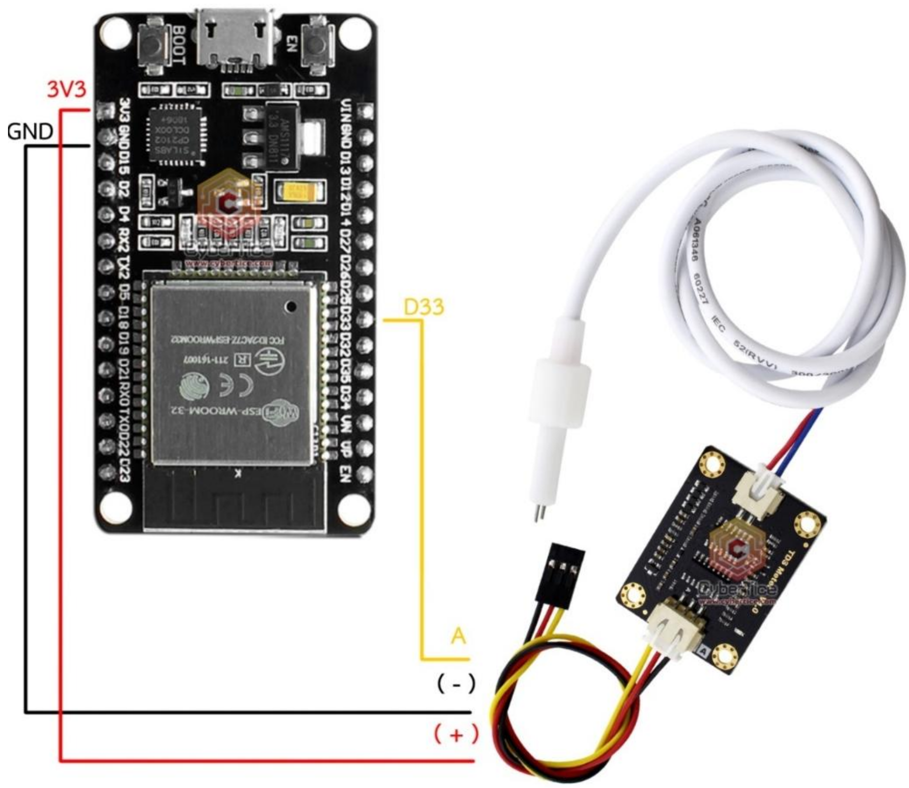

Fig 3.1.3 Conductivity Sensor Connection

3.2 Integration

3.2.1 Sensor Interfacing

i. The sensors are connected to the analog pins of the ESP32 microcontroller.
ii. Each sensor has a signal output pin, a power pin (VCC), and a ground pin (GND),
which are interfaced with the ESP32's GPIO pins.

3.2.2 Power Supply

i. A 5V regulated power supply ensures stable operation of all sensors and the microcontroller.
ii. Capacitors are used for filtering out noise in the power lines, ensuring accurate sensor readings.

3.2.3 Data Transmission

Sensor data is read in analog form, converted to digital values using the ESP32's ADC (Analog-to-Digital Converter), and processed before being transmitted over Wi-Fi.

3.3 Calibration

3.3.1 pH Sensor Calibration:

i. Use standard buffer solutions, such as pH 4.0, 7.0, and 10.0, to calibrate the sensor.
ii. Dip each buffer solution into the sensor and note the readings obtained. Plot these readings on a calibration curve.

3.3.2 Turbidity Sensor Calibration:

i. Calibration shall be done using water samples with known turbidity.
ii. Adjust the sensor's gain to match the turbidity values of these samples.

3.3.3 Conductivity Sensor Calibration:

i. Position the sensor in known concentration of solutions of ions.
ii. Record the sensor response and prepare a calibration table to achieve accurate measurements.

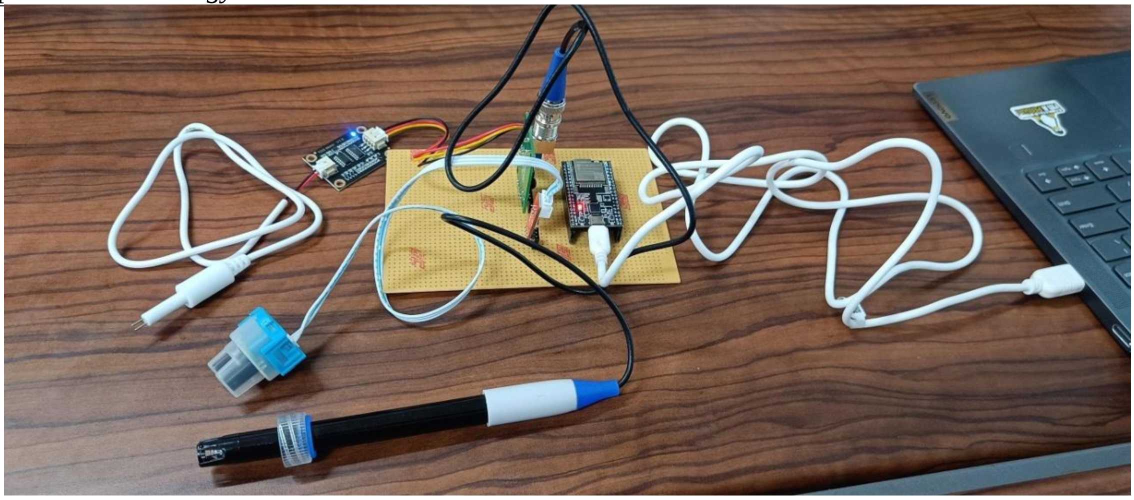

Fig.3.3 Product Integration

SOFTWARE

3.4 Server-Side Development

3.4.1 Data Reception:

i. ESP32 will send the sensor data in HTTP POST requests to the PHP backend. Each request will contain pH, turbidity readings, and conductivity values along with timestamps.

3.4.2 Data Preservation:

i. The readings are stored in the SQL database.

Table: WaterQualityData

ii. The attributes are id (Primary Key), timestamp, ph_value, turbidity_value, and conductivity_value.

3.4.3 Data Analysis:

Algorithms analyze sensor data to determine water usability.

i. **pH Threshold:** 6.5–8.5 (safe range).
ii. **Turbidity Threshold:** ≤5 NTU (safe range).
iii. **Conductivity Threshold:** ≤1500 μS/cm (safe range).
iv. If any parameter goes across the thresholds, a flag is produced to indicate unsafe water.

3.5 Fronted Development

3.5.1 User Interface:

A responsive web application provides a friendly interface that has enabled real-time monitoring.

Features include:

i. Dashboard showing current sensor readings.
ii. Graphs illustrating the values and trends.
iii. Notifications on hazardous states of water.

3.5.2 Variable Changes:

The frontend pulls updated data without requiring a refresh of the page by using AJAX or WebSocket technology.

3.6 Data Flow Diagram

3.6.1 Information Transfer:

i. **Input:** Sensors send out analog signals to ESP32.
ii. **Processing:** ESP32 digitized and forwarded the data to backend.
iii. **Storage:** Information is stored in the SQL database.
That frontend system fetches the data it has and then presents it back to the user in real time.
iv. **Hardware Testing:** Test each sensor separately using known samples to check accuracy. Assess the reliability of data transmission via Wi-Fi.
v. **Software Appraisal:** Analyze the PHP script to possibly fetch and preserve accurate data.
For validation of SQL queries for retrieval and visualization accuracy.
vi. **System Validation:** Test the entire system on samples with known quality parameters by placing sensors in them and comparing the outputs against expected values.

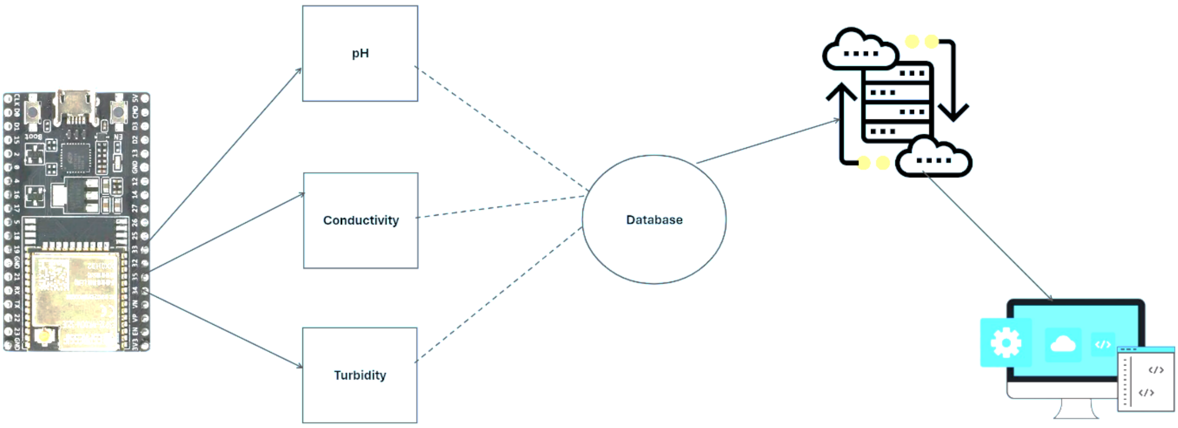

Fig 3.6 Block Diagram

Chapter 4

Results and Discussions

Objective

This innovative, adaptive water quality monitoring system, where it has been included with the ESP32 microcontroller, onto the integrated pH sensors and turbidity sensors, along with other conductivity sensors, has proven very effective in its performance for real-time water quality evaluation. The ESP32 monitor dynamic sampling rate capability is highly conducive for optimizing the acquisition of data especially during stable conditions of water quality. Apart from this advanced feature, the readings are very accurate and reliable and reduce power consumption accordingly, ensuring there is long battery life across the whole system. This adaptive methodology aimed to allow the increase of sampling frequencies, especially following significant events regarding water quality. Such events might be sudden pH drops, unexpected rises in turbidity, or sharp increases in conductance levels.

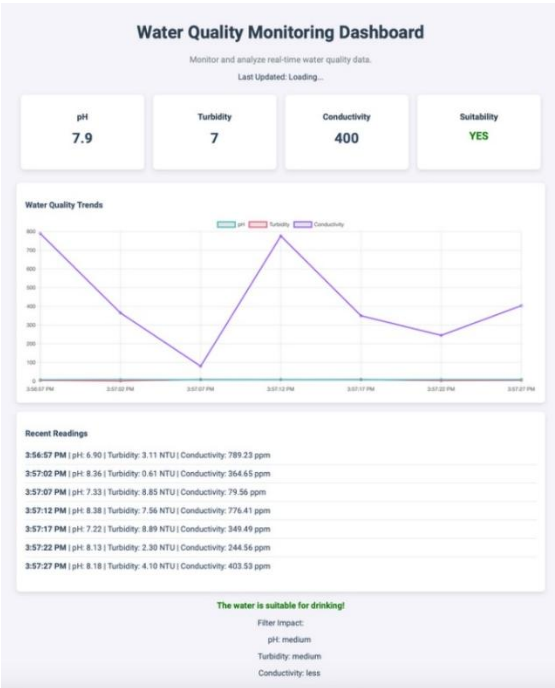

Fig 4.1 Water is Suitable for drinking displayed in Dashboard

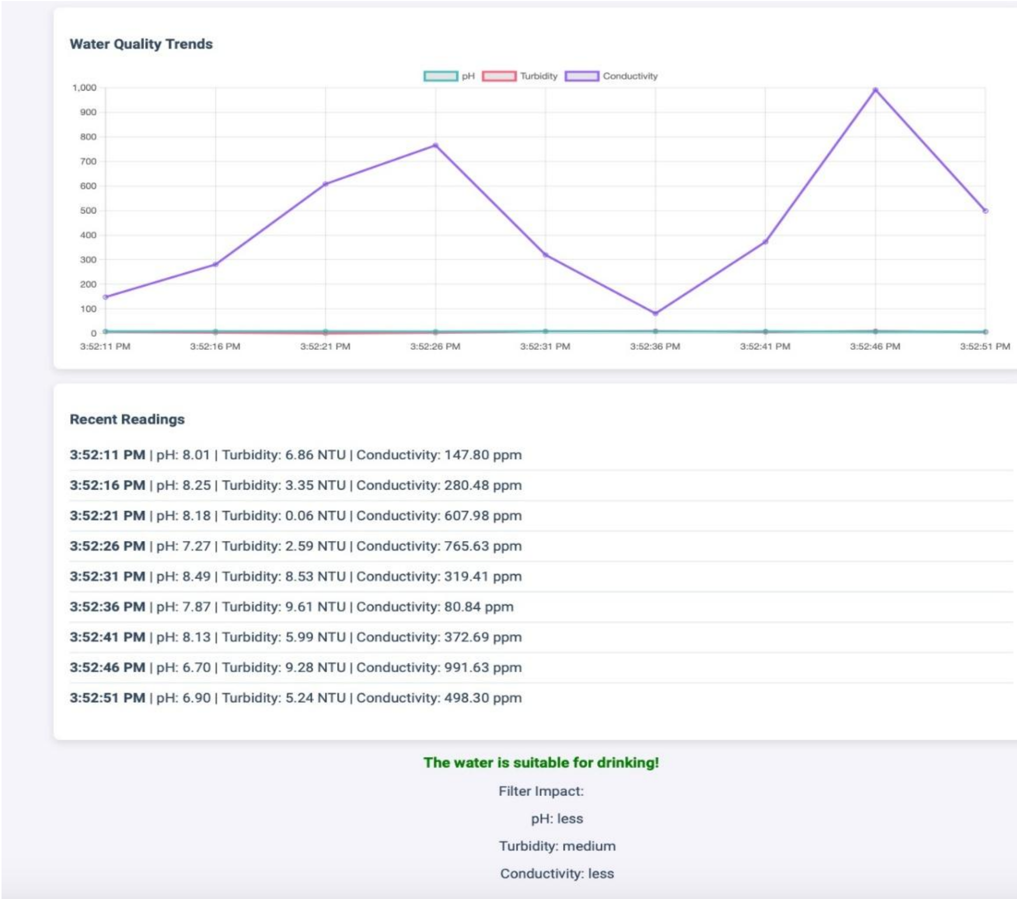

Fig 4.2 Water is Suitable for drinking Graph with Readings

This adaptability enables extensive data coverage while providing for quick alerts to those concerned with such changes. The interaction with a cloud-based backend system also greatly supports real-time data transfer. The ability of automatically delivering these data enabled water quality managers to monitor remote location parameters of various waters to respond promptly and efficiently in case potential incidents of pollution rise. With the real-time alert feature, immediate detection was possible and quick response was ensured for large changes in water quality; thus, overall reliability and dependability of the system improved significantly.

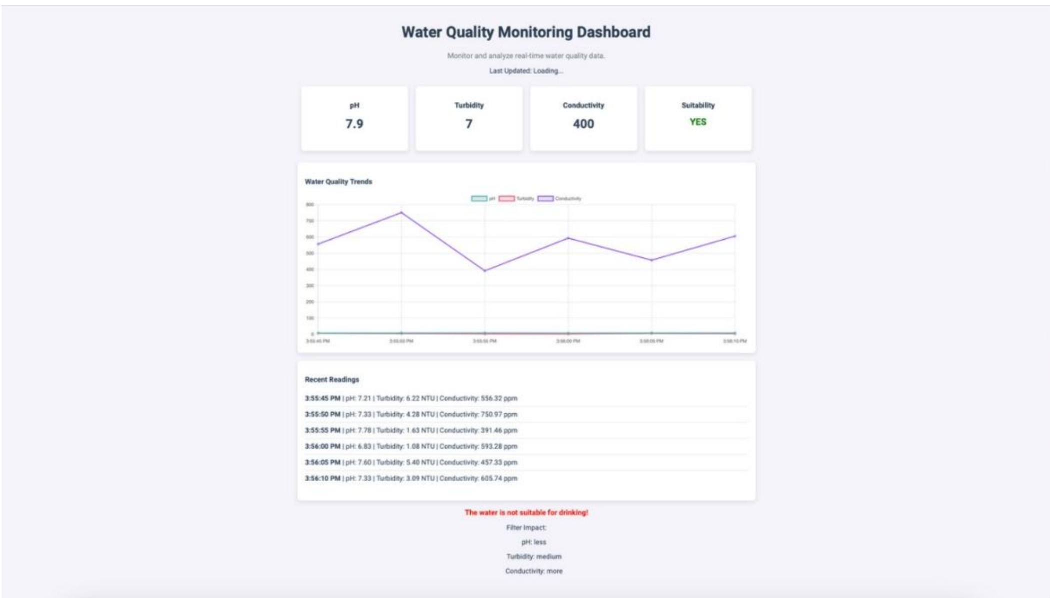

Fig 4.3 Water is Not Suitable for drinking displayed in Dashboard

With successes in the system, some of the challenges were sensor calibration drift with respect to time-possible by doing periodical calibration-and optimizing the thresholds of alert triggering for sensitivity versus false alarms. Even though the system has very good scalability and is capable of hosting many more sensors, a lot of room for improvement can be attained with this system. This potential improvement might be on any form of enhancing the robustness and reliability as a system at large. This could be through better power management techniques while including a wider range of environmental sensors that can help in obtaining holistic water quality monitoring across varied conditions and locations.

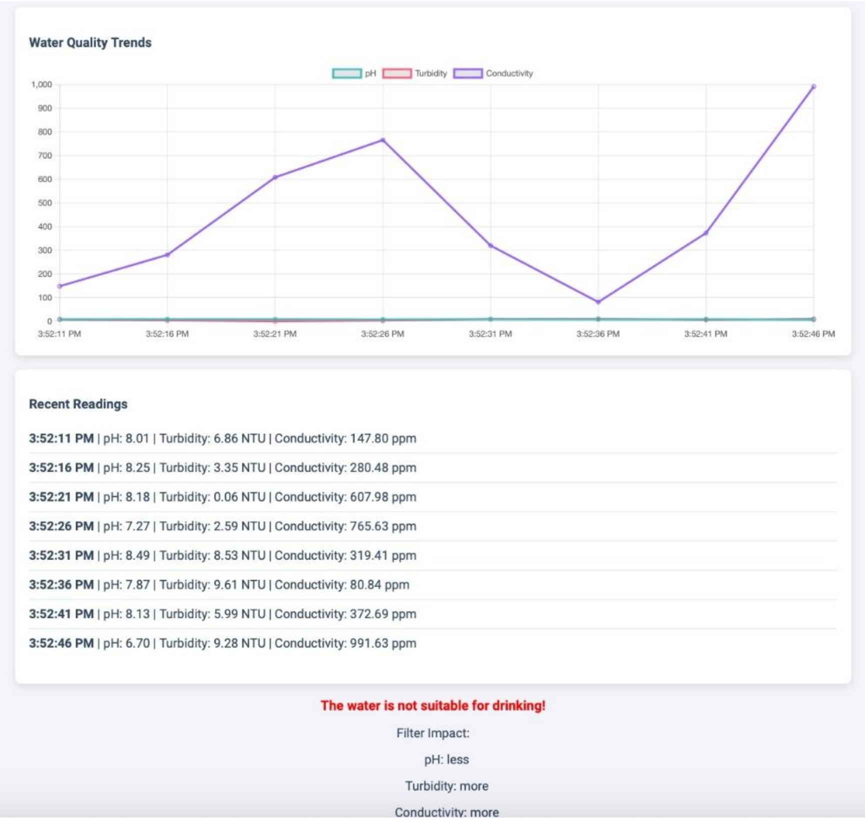

Fig 4.4 Water is Not Suitable for drinking Graph with Readings

Taken together, the adaptive water quality monitoring system developed in this paper, on the ESP32, has proven to be a cost-effective yet reliable and energy-efficient solution. It is unique in its ability to provide real-time monitoring with great versatility across a range of diverse water bodies. Also, it is scalable to networks having large interconnections, thus suitable for pervasive use in various applications. This further enhances its appeal based on flexibility and adaptability and is an ideal candidate in permanent environmental monitoring. Its application holds particularly true in locations where the access of possible means to carry out essential power sources and the general infrastructure is significantly scaled down or poses considerable challenges.

In addition to the basic functions, the adaptive water quality monitoring system has recently developed an essential step forward with a new feature specifically designed to calculate how impact filters affect the quality of water. This new function seeks to do profound analyses on how most elements of water quality could affect the overall efficiency and health of a filtration system. It does this through real-time data, through which sophisticated sensors carefully record critical readings such as pH, turbidity measurements, and conductivity values. It does this in the sense that it categorizes all the effects of filtration into three categories; which include low, medium or high. This categorization will arm the users with basic information regarding which state of filters they are; the of this knowledge will incrementally increase the chances of performing maintenance or replacement processes within time. In that case, this proactive approach boosts the lifespan of filtration systems significantly and cuts operational expenses heavily. Apart from that, it aids in the minimization of wasting other resources as it foresees any problem possibly arising even before occurring. The implications would be huge since such a variation would enhance the applicability of the system across all major areas, from domestic use to industrial operations, and to specific environmental phenomena. More applicability automatically means more utility and effective contributions toward attaining the overarching goal of completely sustainable water management practices.

Chapter 5
Conclusion and Future Scope

With this project, the IoT-based Water Quality Monitoring System is developed effectively for actualizing integration of hardware and software solutions to real-world environmental problems. The system ensures reliable and cost-effective ways of assessing water quality through continuous monitoring of critical parameters such as pH, turbidity, and conductivity. Contrary to the traditional approaches, by distinguishing themselves with periodic manual sampling and laboratory testing, this system offers the capability of collecting, storing, and analyzing data at real-time intervals to allow for prompt decision-making and timely interventions.

The capability of assessing the usability of water through a threshold-based classification framework ensures that the system not only acts as a tool for monitoring but also as an instrument for public health and environmental integrity protection. Besides, the web interface makes the user interface easy to have with clear intuitive visual representations such as graphs and alerts thus making it easily accessible to various stakeholders of any kind including community members, industrial operators, and environmental organizations.

However, development was problematic for reasons like sensor drift, the patchy latency of the network, and environmental conditions, affecting the sensors' operation. Still, the modularity of the system and the scalability of the framework offer an excellent basis for future development and rollouts. Conclusion In summary, the project marks a significant stride toward sustainable management of water resources and compliance with regulations on water quality.

While the existing system is sound and robust, it can still have advancements that will help enhance its functionality and scope. Dissolved oxygen sensors and specific pollutants such as nitrates, heavy metals, or chlorine will allow it to monitor more specifically. Predictive analytics, including analysis of data trends and learning machines from data, can look forward to the variations in water quality forecasts and anomalies. Such a mobile application could integrate with push notification and interactive elements and thus can be made more accessible and engaging. The deployment across urban, industrial, and rural settings along with cloud-based data storage increases impact levels. Energy-efficiency and solar-powered solutions enhance the durability of sensors; therefore, this will make it reliable and less prone to issues. Advanced dashboards and real-time heatmaps would provide better insights for improved visualization tools. It can also direct environmental policies by providing actionable data that governments and organizations will use to regulate industrial discharges and prior the adoption of sustainable water management. While the existing system is sound and robust, it can still have advancements that will help enhance its functionality and scope.

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Chapter 6

Appendix

```
#include <WiFi.h>

const char* ssid = "water";
const char* password = "water123";

// Pin assignments
const int pHSensorPin = 34;
const int turbiditySensorPin = 33;
const int TdsSensorPin = 27;

#define VREF 3.3
#define SCOUNT 30

// Variables for TDS sensor
int analogBuffer[SCOUNT];
int analogBufferTemp[SCOUNT];
int analogBufferIndex = 0;
float averageVoltage = 0;
float tdsValue = 0;
float temperature = 25;

void setup() {
  Serial.begin(115200);
pinMode(TdsSensorPin, INPUT);

  // Connect to Wi-Fi
  WiFi.begin(ssid, password);
  while (WiFi.status() != WL_CONNECTED) {
    delay(1000);
    Serial.println("Connecting to WiFi...");
  }
  Serial.println("Connected to WiFi");
}

int getMedianNum(int bArray[], int iFilterLen){
  int bTab[iFilterLen];
  for (byte i = 0; i<iFilterLen; i++)
  bTab[i] = bArray[i];
```

```
  int i, j, bTemp;
  for (j = 0; j < iFilterLen - 1; j++) {
    for (i = 0; i < iFilterLen - j - 1; i++) {
      if (bTab[i] > bTab[i + 1]) {
        bTemp = bTab[i];
        bTab[i] = bTab[i + 1];
        bTab[i + 1] = bTemp;
      }
    }
  }
  if ((iFilterLen & 1) > 0){
    bTemp = bTab[(iFilterLen - 1) / 2];
  }
  else {
    bTemp = (bTab[iFilterLen / 2] + bTab[iFilterLen / 2 - 1]) / 2;
  }
  return bTemp;
}
```

pH Sensor:

```
float readPHSensor() {
  int rawValue = analogRead(pHSensorPin);
  float voltage = (rawValue / 4095.0) * VREF;
  float pH = 7 + ((2.5 - voltage) / 0.18);  // Adjust based on calibration
  return pH;
}
```

Turbidity Sensor:

```
  int rawValue = analogRead(turbiditySensorPin);
  float voltage = (rawValue / 4095.0) * VREF;
  float turbidity = -1120.4 * (voltage * voltage) + 5742.3 * voltage - 4352.9;
  return turbidity;
```

Conductivity Sensor/ TDS:

```
  static unsigned long printTimepoint = millis();
  if(millis()-printTimepoint > 800U){
    printTimepoint = millis();
    for(copyIndex=0; copyIndex<SCOUNT; copyIndex++){
      analogBufferTemp[copyIndex] = analogBuffer[copyIndex];

      averageVoltage = getMedianNum(analogBufferTemp,SCOUNT) * (float)VREF / 4096.0;

      float compensationCoefficient = 1.0+0.02*(temperature-25.0);

      float compensationVoltage=averageVoltage/compensationCoefficient;

      //convert voltage value to tds value
      tdsValue=(133.42*compensationVoltage*compensationVoltage*compensationVoltage - 
255.86*compensationVoltage*compensationVoltage + 857.39*compensationVoltage)*0.5;

      Serial.print("TDS Value:");
      Serial.print(tdsValue,0);
      Serial.println("ppm");
    }
  }
```

Biodata

Name:
Mobile No.:
E-mail:
Permanent Address:

Name:
Mobile No.:
E-mail:
Permanent Address:

Name:
Mobile No.:
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