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Real-Time Water Quality Tracking in Aquaculture

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Abstract: Preserving water quality is vital for sustaining aquatic life and maintaining ecosystem balance. This project extends the existing IoT-based water quality monitoring system by introducing an advanced alert mechanism based on real-time data from pH, turbidity, and Total Dissolved Solids (TDS) sensors. The system employs an Arduino (ESP32) microcontroller integrated with NEO GPS to accurately identify the location of water quality issues. Collected data is transmitted to the cloud and analyzed via the Arduino IoT Cloud Remote App. The system generates visual alerts as a red zone alert for poor water quality and a green zone alert for acceptable water quality, based on thresholds optimized for aquatic species. The system's capability to provide real-time, location-based alerts enhances monitoring efficiency and supports proactive measures to protect aquatic ecosystems.

Index Terms **– ESP32 microcontroller, GPS, Arduino IoT Cloud, Arduino IoT Cloud Remote App**

1.INTRODUCTION

Water quality plays a crucial role in sustaining life, maintaining ecosystems, and ensuring public health. Natural water bodies like ponds and lakes often serve as sources for drinking water, irrigation, and aquaculture. However, these are increasingly threatened by pollution from industrial waste, agricultural runoff, and human activities. Traditional water quality monitoring methods are time-consuming and not suitable for real-time analysis. This project proposes an automated, real-time water quality monitoring system using IoT and cloud technology. The system is solar-powered and sends alerts when water quality deviates from WHO standards. It offers a scalable, eco-friendly approach to continuous monitoring and environmental protection.

2.IMPLEMENTATION METHODOLOGY

This system is implemented in two phases. In the first phase, this system enables real-time water quality monitoring in aquaculture using IoT technology. It reads pH, TDS, and turbidity levels, compares them with WHO standards, and uploads data to the cloud. If Wi-Fi is unavailable, readings are stored on an SD card and uploaded once connectivity is restored. A GPS module logs the measurement location, and alerts are sent if contamination is detected. The system ensures accurate tracking, remote access, and timely notifications for water safety management.

In the second phase, the ESP32 is programmed via Arduino IDE to read sensor data and transmit it to the Arduino IoT Cloud for real-time monitoring. Each sensor value is mapped to variables on the cloud and visualized using custom dashboards with gauges and line charts. The system enables remote access through the Arduino IoT Cloud Remote App. If Wi-Fi is unavailable, data is stored locally on an SD card. Upon reconnection, the ESP32 syncs the stored data to the cloud, ensuring continuous and reliable monitoring.

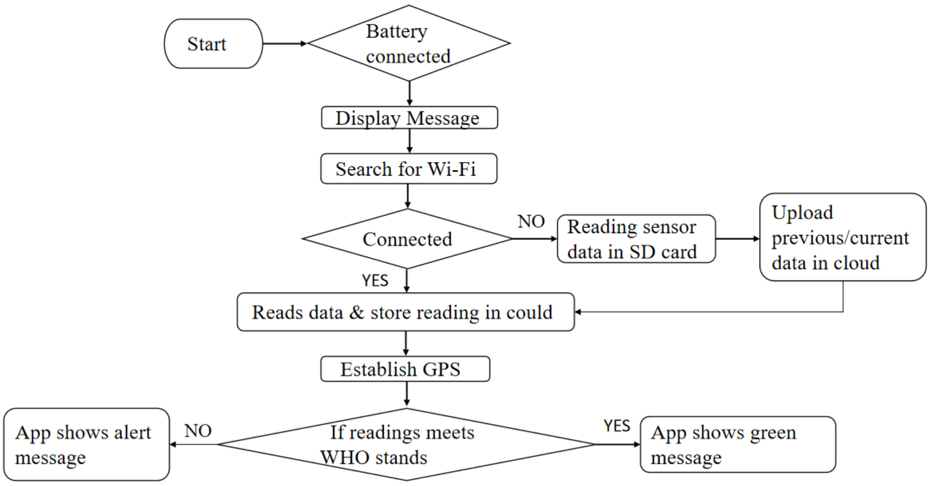


Fig. 2.1 Flow Chart of Implementation Methodology using Hardware

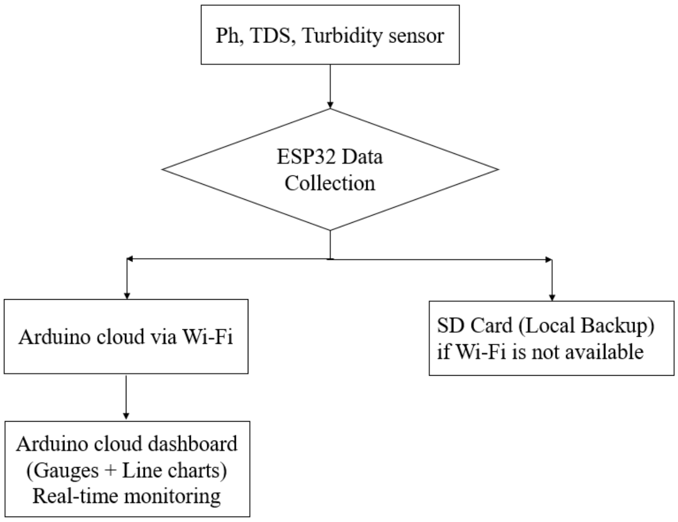


Fig. 2.2 Flow Chart of Implementation Methodology using Software

2.1 System Initialization

The process begins when the system is powered on. The first check is to confirm if the battery is connected. Once the battery is confirmed to be in place, the system proceeds to display a startup message, signaling that the device is active and beginning its routine operations.

2.2 Sensor Data Acquisition

The system begins with the collection of water quality parameters using various sensors. These include a pH sensor to measure the acidity or alkalinity of water, a TDS (Total Dissolved Solids) sensor to assess the concentration of dissolved substances, and a turbidity sensor to evaluate the clarity of the water. These sensors provide the raw data necessary for monitoring water quality

2.3 Data Collection Using ESP32

The ESP32 microcontroller acts as the central unit for data collection. It reads the inputs from all three sensors and processes the data. This microcontroller is chosen for its built-in Wi-Fi capabilities and ability to handle real-time data processing efficiently.

2.4 Wi-Fi Availability Check

Once the sensor data is collected, the ESP32 checks whether Wi-Fi connectivity is available. This step is crucial to decide whether the data can be uploaded to the cloud or needs to be stored locally.

2.5 Data Upload to Arduino Cloud (If Wi-Fi is Available)

If Wi-Fi is available, the ESP32 uploads the collected data to the Arduino IoT Cloud. This allows the user to remotely access the data in real time. The Arduino Cloud dashboard provides a visual interface where sensor readings are displayed using gauges and line charts. This enables users to monitor water quality trends and changes instantly from any location.

2.6 Data Storage on SD Card (If Wi-Fi is Not Available)

In cases where Wi-Fi is not available, the ESP32 stores the sensor data on a local SD card. This serves as a backup solution, ensuring that no data is lost during periods of network unavailability. The locally stored data can later be retrieved and analyzed manually or uploaded once connectivity is restored.

2.7 GPS Activation

Once the data is processed and either uploaded or stored, the system establishes a GPS connection. This step is crucial for location tagging of the sensor readings, providing spatial context for monitoring purposes.

2.8 Data Evaluation Against WHO Standards

After obtaining the readings and GPS location, the system evaluates the data based on the World Health Organization (WHO) standards. If the readings comply with the prescribed safety limits, the associated app displays a green message to indicate safe conditions. Conversely, if the readings exceed safe thresholds, the app issues an alert message to warn users of potential health hazards.

3.IMPLEMENTATION USING HARDWARE AND SOFTWARE

3.1 Implementation using Hardware

This project involves integrating multiple sensors and modules with the ESP32 microcontroller to monitor water quality parameters efficiently. The system consists of pH, TDS, and turbidity sensors to measure water quality, an OLED display to show real-time readings, and an SD card module for offline data storage. A GPS module is used to track the location of measurements, while a Wi-Fi module enables cloud connectivity for remote monitoring. The system is powered by a rechargeable Li-ion battery with a charging module, ensuring uninterrupted operation. All components are carefully interfaced with the ESP32 to ensure accurate data collection and transmission, making the system reliable for real-time water quality assessment.

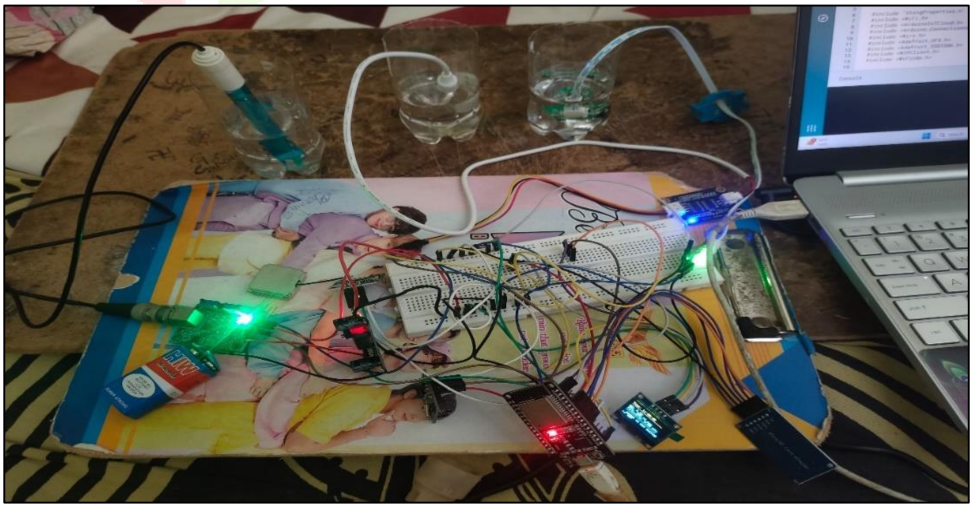


Fig 3.1 Hardware Connections of real time water quality tracking in Aquaculture

Fig 3.2 Testing water quality in different ponds

3.2 Implementation using Software

For software implementation, Arduino IoT Cloud is used. This platform displays the output values on a dashboard, which can be accessed via both a webpage and a mobile phone. Microcontroller – ESP32 Acts as the central processing unit. Continuously reads analog signals from the connected pH, TDS, and Turbidity sensors. Raw voltage values from sensors are converted into meaningful units pH scale (0–14), Total Dissolved Solids in ppm, Turbidity in NTU (Nephelometric Turbidity Units).

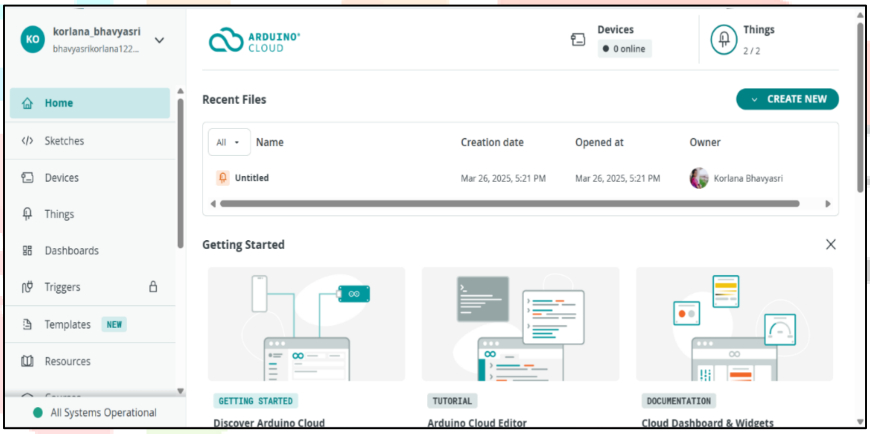


Fig 3.2 Arduino IoT Cloud

To connect the hardware to the cloud, we need to write the code in the sketch. The output can be viewed in the Serial Monitor, and the values update in real time.

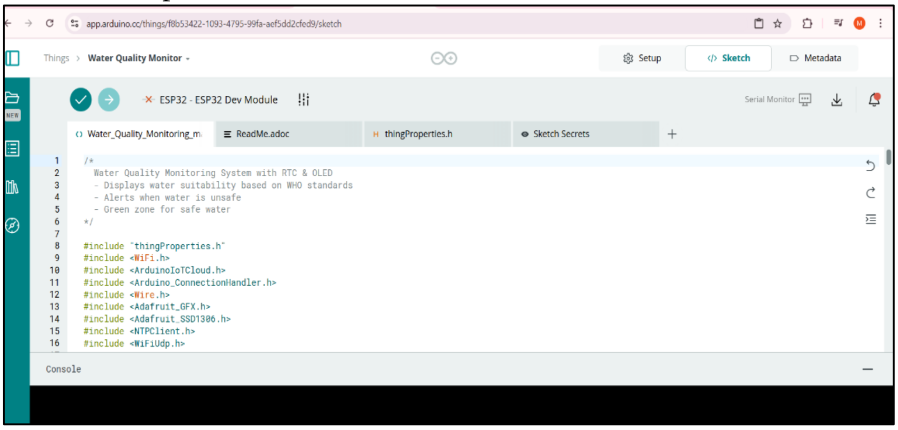


Fig 3.3 Writing code for software implementation in sketch

4.RESULTS

We tested water quality from ponds near Salur, Kottakki, Kandilavalsa and Srikakulam. Results were shown on an OLED display and the Arduino Cloud dashboard. We compared the data with WHO standards for aquatic life. The ideal pH range is 6.5–9.0; extreme values harm aquatic organisms. Turbidity should be below 50 NTU, as high turbidity blocks sunlight and affects gills. TDS should be under 500 mg/L to prevent osmoregulation issues and toxicity. If any value exceeds these limits, the water is marked unsafe for aquatic life.

4.1 HARDWARE IMPLEMENTATION RESULTS

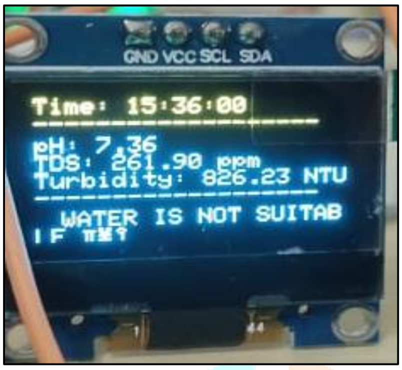


Fig 4.1.1 Simulation result for Salur region pond

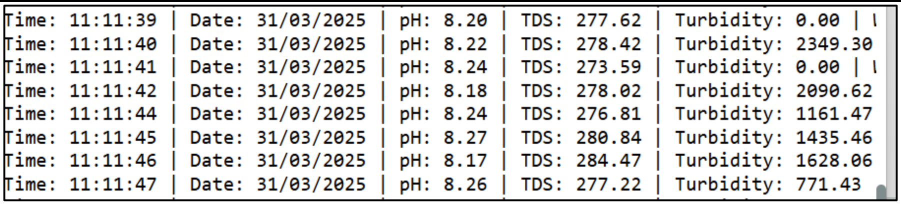
Fig 4.1.2 Simulation result for Kottakki region pond

Fig 4.1.3. Simulation result for Kandilavalasa region pond

Fig 4.1.4. Simulation result for Srikakulam region pond

4.2 ARDUINO IoT CLOUD SERIAL MONITOR AND DASHBOARD RESULTS

Here, we can view the results on the Arduino IoT Cloud dashboard. Live graphs for pH, turbidity, and TDS are displayed, and the values of these parameters are shown on a gauge meter, with fixed minimum and maximum ranges. Additionally, the values can be viewed in the Serial Monitor. Alert is triggered when the monitored water quality parameters do not meet the standards specified by the World Health Organization (WHO), indicating that the water is potentially unsafe for aquatic life or human use.



```
Time: 11:11:39 | Date: 31/03/2025 | pH: 8.20 | TDS: 277.62 | Turbidity: 0.00 | l
Time: 11:11:40 | Date: 31/03/2025 | pH: 8.22 | TDS: 278.42 | Turbidity: 2349.30
Time: 11:11:41 | Date: 31/03/2025 | pH: 8.24 | TDS: 273.59 | Turbidity: 0.00 | l
Time: 11:11:42 | Date: 31/03/2025 | pH: 8.18 | TDS: 278.02 | Turbidity: 2090.62
Time: 11:11:44 | Date: 31/03/2025 | pH: 8.24 | TDS: 276.81 | Turbidity: 1161.47
Time: 11:11:45 | Date: 31/03/2025 | pH: 8.27 | TDS: 280.84 | Turbidity: 1435.46
Time: 11:11:46 | Date: 31/03/2025 | pH: 8.17 | TDS: 284.47 | Turbidity: 1628.06
Time: 11:11:47 | Date: 31/03/2025 | pH: 8.26 | TDS: 277.22 | Turbidity: 771.43
```

Fig 4.2.1. Serial Monitor Output of Salur region pond

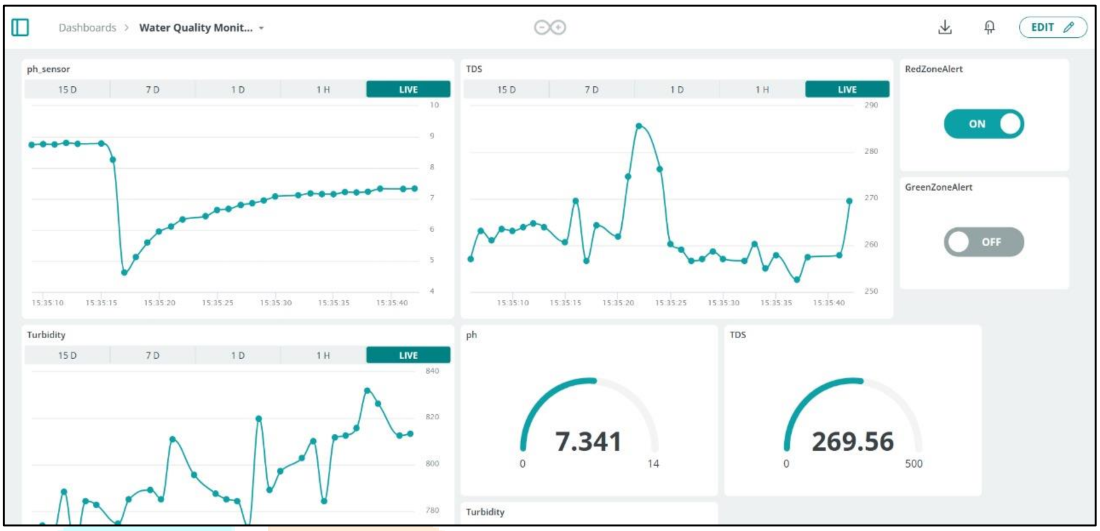
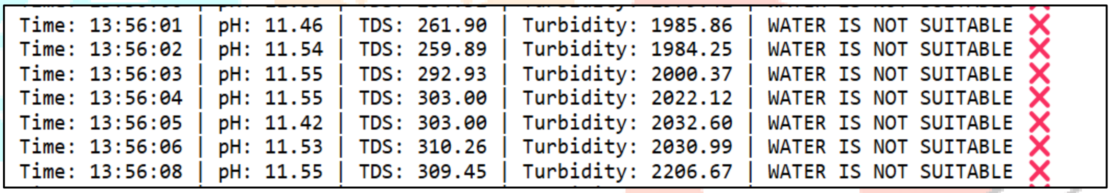


Fig 4.2.2. Arduino cloud Dashboard of Salur region pond



```
Time: 13:56:02 | pH: 11.54 | TDS: 259.89 | Turbidity: 1984.25 | WATER IS NOT SUITABLE ❌
Time: 13:56:01 | pH: 11.46 | TDS: 261.90 | Turbidity: 1985.86 | WATER IS NOT SUITABLE ❌
Time: 13:56:03 | pH: 11.55 | TDS: 292.93 | Turbidity: 2000.37 | WATER IS NOT SUITABLE ❌
Time: 13:56:04 | pH: 11.55 | TDS: 303.00 | Turbidity: 2022.12 | WATER IS NOT SUITABLE ❌
Time: 13:56:05 | pH: 11.42 | TDS: 303.00 | Turbidity: 2032.60 | WATER IS NOT SUITABLE ❌
Time: 13:56:06 | pH: 11.53 | TDS: 310.26 | Turbidity: 2030.99 | WATER IS NOT SUITABLE ❌
Time: 13:56:08 | pH: 11.55 | TDS: 309.45 | Turbidity: 2206.67 | WATER IS NOT SUITABLE ❌
```

Fig 4.2.3. Serial Monitor Output of Kottakki region pond

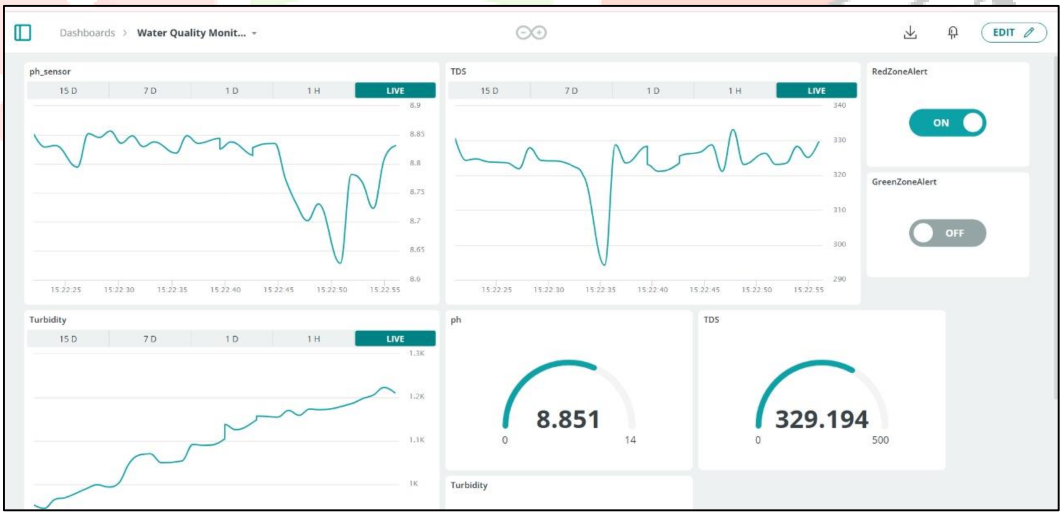


Fig 4.2.4. Arduino cloud Dashboard of Kottakki region pond

```
Connected to Arduino IoT Cloud
Thing ID: f8b53422-1093-4795-99fa-aef5dd2cfed9
Time: 11:30:19 | Date: 31/03/2025 | pH: 8.24 | TDS: 391.25 | Turbidity: 2300.95 | WATER IS NOT SUITABLE ❌
Time: 11:30:20 | Date: 31/03/2025 | pH: 8.27 | TDS: 388.83 | Turbidity: 2101.10 | WATER IS NOT SUITABLE ❌
Time: 11:30:21 | Date: 31/03/2025 | pH: 8.30 | TDS: 394.07 | Turbidity: 2113.99 | WATER IS NOT SUITABLE ❌
Time: 11:30:23 | Date: 31/03/2025 | pH: 8.26 | TDS: 393.26 | Turbidity: 2112.38 | WATER IS NOT SUITABLE ❌
Time: 11:30:24 | Date: 31/03/2025 | pH: 8.26 | TDS: 391.25 | Turbidity: 2105.93 | WATER IS NOT SUITABLE ❌
Time: 11:30:25 | Date: 31/03/2025 | pH: 8.23 | TDS: 389.63 | Turbidity: 2289.67 | WATER IS NOT SUITABLE ❌
Time: 11:30:26 | Date: 31/03/2025 | pH: 8.32 | TDS: 386.81 | Turbidity: 2280.81 | WATER IS NOT SUITABLE ❌
Time: 11:30:27 | Date: 31/03/2025 | pH: 8.24 | TDS: 391.25 | Turbidity: 2114.80 | WATER IS NOT SUITABLE ❌
Time: 11:30:28 | Date: 31/03/2025 | pH: 8.27 | TDS: 387.22 | Turbidity: 2286.45 | WATER IS NOT SUITABLE ❌
Time: 11:30:29 | Date: 31/03/2025 | pH: 8.24 | TDS: 391.25 | Turbidity: 2288.86 | WATER IS NOT SUITABLE ❌
Time: 11:30:31 | Date: 31/03/2025 | pH: 8.29 | TDS: 390.84 | Turbidity: 2292.89 | WATER IS NOT SUITABLE ❌
```

Fig 4.2.5. Serial Monitor Output of Kandilavalsa region pond

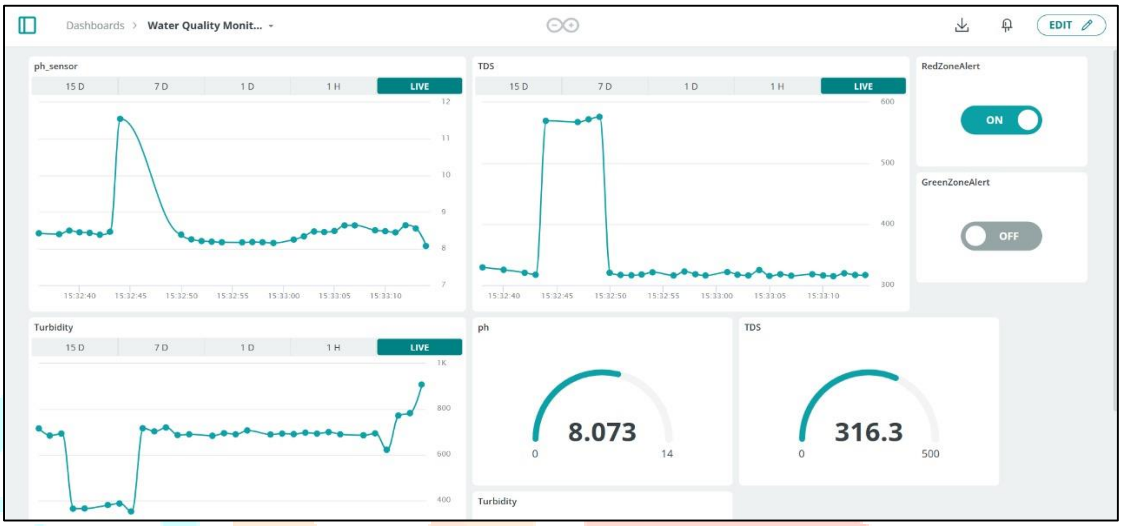


Fig 4.2.6. Arduino cloud Dashboard of Kandilavalsa region pond

```
Time: 15:11:22 | pH: 9.03 | TDS: 43.92 | Turbidity: 526.45 | WATER IS NOT SUITABLE ❌
Time: 15:11:23 | pH: 9.08 | TDS: 47.95 | Turbidity: 487.77 | WATER IS NOT SUITABLE ❌
Time: 15:11:24 | pH: 9.01 | TDS: 44.73 | Turbidity: 473.26 | WATER IS NOT SUITABLE ❌
Time: 15:11:25 | pH: 9.02 | TDS: 51.58 | Turbidity: 465.20 | WATER IS NOT SUITABLE ❌
Time: 15:11:27 | pH: 9.03 | TDS: 50.77 | Turbidity: 458.75 | WATER IS NOT SUITABLE ❌
Time: 15:11:28 | pH: 9.06 | TDS: 39.49 | Turbidity: 440.22 | WATER IS NOT SUITABLE ❌
Time: 15:11:29 | pH: 9.04 | TDS: 41.10 | Turbidity: 474.07 | WATER IS NOT SUITABLE ❌
Time: 15:11:30 | pH: 9.03 | TDS: 44.73 | Turbidity: 445.86 | WATER IS NOT SUITABLE ❌
Time: 15:11:31 | pH: 9.01 | TDS: 39.49 | Turbidity: 464.40 | WATER IS NOT SUITABLE ❌
Time: 15:11:32 | pH: 9.06 | TDS: 47.55 | Turbidity: 437.80 | WATER IS NOT SUITABLE ❌
Time: 15:11:33 | pH: 9.03 | TDS: 47.14 | Turbidity: 437.80 | WATER IS NOT SUITABLE ❌
Time: 15:11:35 | pH: 8.99 | TDS: 50.37 | Turbidity: 407.99 | WATER IS NOT SUITABLE ❌
```

Fig 4.2.7. Serial Monitor Output of Srikakulam region pond

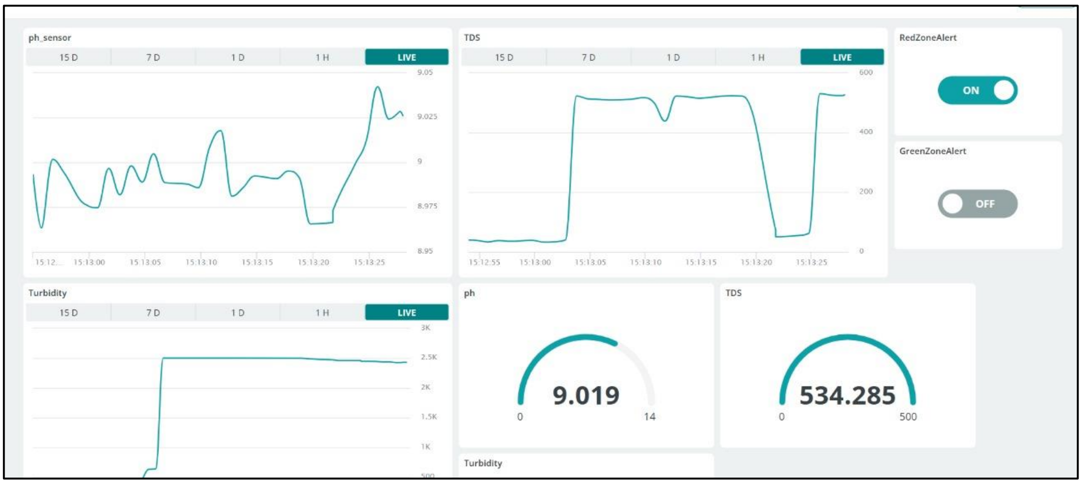


Fig 4.2.8. Arduino cloud Dashboard of Srikakulam region pond

4.3 RESULT ANALYSIS

4.3.1 Test case-1:

- If pH > 9, TDS < 500 ppm and Turbidity > 50 NTU,
- pH: Low risk (30%) (Slightly it slightly exceeds the limit)
- TDS Low risk (50%) (Since it is extremely high)
- Turbidity Extreme risk (10%) (Within limit but approaching higher levels)
- Total Harm percentage: 30%+50%+10%=90%

4.3.2 Test case-2:

- If pH < 9, TDS < 500 ppm and Turbidity > 50 NTU,
- pH: Low risk (10%) (Slightly alkaline but safe),
- TDS Low risk (10%) (Safe, but monitored)
- Turbidity Extreme risk (80%) (Highly unsafe, severely impacts aquatic life)
- Total Harm percentage: 10%+10%+80%=100%

5.CONCLUSION

This paper presented a real time water quality tracking for aquatic life. The analysis of the two test cases shows that turbidity has the most significant impact on water quality. In Test Case-1, although pH is moderately high and TDS is within limits, high turbidity results in 80% harm to aquatic life. This shows that turbidity alone can drive a high-risk level. In Test Case-2, even with safe pH and TDS levels, extreme turbidity leads to 100% harm. Thus, turbidity is a critical parameter that can overshadow the effect of other factors. Slight increases in pH or TDS pose low to moderate risks when turbidity is low. However, when turbidity rises, the overall harm percentage increases sharply. Maintaining turbidity below 50 NTU is essential for water safety. Excessive turbidity affects light and oxygen levels, harming aquatic ecosystems. Continuous turbidity monitoring is necessary to ensure a healthy aquatic environment.

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