International Journal of Engineering Technology and Management Science
Website: ijetms.in Issue: 2 Volume No.9 March - April – 2025
DOI:10.46647/ijetms.2025.v09i02.102 ISSN: 2581-4621

IOT BASED WATER QUALITY MONITORING SYSTEM USING SOLAR POWER AND WIFI

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Abstract
This project focuses on the development of an IoT-based water quality monitoring system that utilizes solar power and WIFI communication to transmit real-time data to a cloud server. The system integrates sensors to measure parameters such as pH, turbidity, temperature, electrical conductivity. These sensors are connected to a microcontroller, which processes the data and transmits it via the WIFI network. The solar panel powers the system, ensuring a sustainable and uninterrupted operation, making it suitable for remote locations where conventional power sources are unavailable. Data transmitted through the WIFI network is received by a cloud server, where it is processed and displayed in real-time, enabling remote monitoring through a web interface. This allows users to access and analyze water quality data remotely, facilitating timely interventions for applications in agriculture, industrial processes, and environmental management. The
system's long-range, low-power capabilities make it ideal for deployment in locations with limited infrastructure, providing a cost-effective solution for continuous monitoring.
The system was designed for long operational durations with low maintenance requirements. The integration of a solar panel ensures that the system remains powered, with the battery being charged for up to 36 hours, even in remote areas. The water quality measurements are highly accurate, with an error rate below 5%, ensuring reliable data collection for various environmental monitoring tasks. The combination of IoT, solar power, and WIFI offers a robust platform for data-driven decision-making in real-time monitoring scenarios.
This solution serves as a foundation for future advancements in water quality monitoring. Further development can include additional sensors for enhanced data collection, improved system efficiency, and scalability for broader applications such as wastewater treatment, environmental monitoring, and aquaculture management.
Keywords: iot, water, quality, wastewater, aquaculture

Introduction
The IoT-Based Water Quality Monitoring System is designed to provide real-time analysis of water parameters such as pH, turbidity, conductivity, and temperature using low-cost sensors powered by solar energy. The system is built around the ESP8266 microcontroller, which collects data from the sensors and transmits it via Wi-Fi to the ThingSpeak cloud platform for continuous monitoring. An LCD displays live readings, and a GSM module sends SMS alerts when water quality falls below predefined thresholds. Compared to conventional systems using LoRaWAN and CAT Starter Kits, this solution is more cost-effective, easier to implement, and ideal for both urban and remote applications due to its reliance on readily available Wi-Fi networks and sustainable power sources.
Access to clean and safe water is an ongoing challenge, particularly in rural and underserved areas. Contamination from industrial waste, agricultural runoff, and other pollutants has made water quality monitoring an essential task for governments and environmental agencies. The existing methods of water quality analysis are often reactive rather than proactive, meaning that problems are detected only after they have caused harm to the environment or human health. Moreover, the deployment of water quality monitoring systems in remote or difficult-to-access areas is often hindered by the lack of infrastructure, reliable power sources, and high operational costs.
IoT technology offers a promising solution to this problem by enabling continuous, real-time

monitoring of water quality. By integrating sensors with IoT devices, water quality data can be transmitted remotely to cloud-based platforms, providing timely insights for decision-making. WIFI, a low-power, long-range communication protocol, ensures that data can be transmitted over long distances, even in areas with poor connectivity. Solar power further reduces the system's operational cost and increases its sustainability by providing an independent energy source, making it ideal for deployment in off-grid locations.

The primary objective of this project is to design and implement an IoT-based water quality monitoring system that uses solar power for sustainability and WIFI for communication. The system is intended to continuously monitor key water quality parameters, including pH, turbidity, temperature, electrical conductivity, and GPS location, and transmit the data to a cloud server for real-time analysis. The system aims to provide a low-cost, scalable, and energy-efficient solution for water quality monitoring in remote areas. Specifically, the key objectives of the project are:

1. **Design and develop a sensor-based system** for measuring water quality parameters.
2. **Integrate a solar power source** to ensure uninterrupted operation in off-grid locations.
3. **Utilize WIFI communication technology** for long-range transmission of data to a cloud-based platform.
4. **Enable real-time data monitoring and analysis** through a web-based interface, accessible from any location.

Literature Survey

The literature survey reviews existing water quality monitoring methods, highlighting the limitations of traditional systems, such as high costs, limited coverage, and lack of real-time data. It also explores the potential of solar-powered, sensor-based solutions for efficient and sustainable monitoring, especially in remote areas. This survey identifies key gaps that the proposed system aims to address.

Water quality monitoring is a crucial aspect of ensuring public health and environmental sustainability. Over the years, various technologies have been adopted to automate and improve the efficiency of water testing systems

This survey highlights that while prior systems laid the groundwork for remote water monitoring, they often suffer from high cost, communication complexity, or power constraints. Our system addresses these limitations by combining low-cost hardware, Wi-Fi communication, solar energy, and intuitive alert mechanisms in a scalable and eco-friendly design

Below is a survey of literature based on the concept of **Water Quality Monitoring System** , incorporating relevant technologies and related research topics.

Title: IoT-based Real-Time Water Quality Monitoring and Control System

Authors: M.Patel, R.K.Jain, S.S.Mehta

Introduction:

This paper presents an IoT-based system for real-time water quality monitoring and control. The system employs sensors to measure parameters such as pH, turbidity, and dissolved oxygen. The data is transmitted to the cloud for remote monitoring, enabling stakeholders to make timely interventions. The paper emphasizes automation and continuous monitoring, which are essential for effective water quality management, especially in critical water bodies where manual intervention is inefficient.

✅ **Merits:**

1. **Real-time Monitoring**: Enables continuous tracking of water quality, which is crucial for timely corrective actions.
2. **Automation**: Reduces the need for manual sampling and analysis, thereby saving labor and time.
3. **Remote Accessibility**: Cloud integration allows stakeholders to access data from anywhere, aiding decision-making.
4. **Multi-parameter Analysis**: Simultaneous measurement of pH, turbidity, and dissolved oxygen provides comprehensive insight into water quality.

5. **Scalability**: The system can be expanded across multiple water bodies or industrial units with minimal modifications.

❌ **Demerits:**

1. **High Initial Setup Cost**: Deployment of multiple sensors and IoT modules can be expensive.
2. **Sensor Drift**: Over time, sensors may become inaccurate and require recalibration or replacement.
3. **Power Dependence**: Constant power supply is required, which may be a challenge in remote areas.
4. **Data Overload**: Continuous data collection may result in large volumes of data that require significant storage and processing.
5. **Network Reliance**: The system is heavily dependent on uninterrupted internet connectivity for real-time data transmission.

⚠ **Challenges:**

1. **Environmental Robustness**: Sensors must withstand harsh environmental conditions like algae, sediment buildup, and temperature changes.
2. **Data Security**: Transmitted data needs to be protected from unauthorized access or tampering.
3. **Maintenance**: Regular cleaning and calibration of sensors are essential for accuracy but can be labor-intensive.
4. **Integration with Existing Infrastructure**: Adapting the system to fit into existing water management systems can be technically complex.
5. **Alert Accuracy**: Ensuring that the system provides accurate alerts without false positives/negatives is critical for trustworthiness.

Title: Design and Implementation of a Solar-Powered Water Quality Monitoring System

Authors: A.R.Kumar, P.Singh, V.N.P Rao

Introduction:

This study focuses on the design of a solar-powered water quality monitoring system. The system uses low-cost sensors to monitor parameters such as turbidity, pH, and temperature, and operates independently using solar energy. This is particularly beneficial for off-grid and rural areas where electricity infrastructure is limited or unavailable. The paper emphasizes the importance of renewable energy in ensuring sustainability and reducing operational costs in remote water quality monitoring.

✅ **Merits:**

1. **Energy Independence**: Operates on solar power, eliminating reliance on grid electricity—ideal for rural and remote areas.
2. **Cost-Effective Operation**: Solar energy significantly reduces long-term operational costs.
3. **Sustainability**: Promotes the use of renewable energy, contributing to eco-friendly technology adoption.
4. **Basic Parameter Monitoring**: Effectively tracks key water quality indicators (turbidity, pH, temperature).
5. **Deployment Flexibility**: Can be easily installed in inaccessible locations without infrastructure dependency.

❌ **Demerits:**

1. **Limited Sensor Accuracy**: Use of low-cost sensors may affect the precision and reliability of readings.
2. **Weather Dependency**: Solar efficiency decreases in overcast or rainy conditions, affecting performance.
3. **Low Processing Power**: Energy constraints may limit real-time data analytics or local processing.
4. **Basic Monitoring Scope**: May not include critical parameters like dissolved oxygen, conductivity, or heavy metals.

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5. **Battery Degradation**: Energy storage systems (batteries) wear out over time and require replacement.

⚠ **Challenges:**

1. **Solar Panel Maintenance**: Dust and debris accumulation on panels can reduce efficiency and require regular cleaning.
2. **Data Transmission**: Ensuring reliable wireless data transfer from remote areas can be difficult due to poor network coverage.
3. **Component Durability**: Ensuring the entire system withstands environmental stress in remote outdoor settings.
4. **Energy Management**: Efficient energy usage and storage are crucial to ensure 24/7 monitoring.
5. **Scalability Issues**: Expanding the system while maintaining cost-effectiveness and performance in multiple sites can be complex.

Title: Wireless Water Quality Monitoring System Using WIFI Technology

Authors: R.K.Tiwari, S.G.Kulkarni, V.P.Pandey

Introduction:

This paper investigates the use of WI-FI technology in wireless water quality monitoring systems. The study highlights the use of WI-FI to transmit data from remote water bodies to central servers. Parameters such as turbidity, temperature, and pH are measured using sensors and sent wirelessly over long distances. The paper discusses how WI-FI technology's limited range, low-power capabilities make it suitable for large-scale deployments, particularly in rural or remote areas where connectivity and infrastructure are limited.

✅ **Merits:**

1. **Wireless Data Transmission**: Enables remote monitoring by transmitting data from isolated water bodies to centralized servers.
2. **Ease of Integration**: Wi-Fi modules are commonly available and easy to integrate with microcontrollers and sensors.
3. **Cost Efficiency**: Utilizes low-power Wi-Fi modules which are generally affordable and suitable for small-scale systems.
4. **Moderate Data Bandwidth**: Wi-Fi offers sufficient bandwidth for transmitting typical sensor data like turbidity and pH.
5. **Real-Time Alerts**: Facilitates instant alerts and updates to stakeholders via cloud or local networks.

❌ **Demerits:**

1. **Limited Coverage**: Wi-Fi has a relatively short range (~100 meters in open areas), which can restrict deployment in larger water bodies.
2. **Interference Sensitivity**: Wi-Fi is prone to interference from other wireless devices and environmental obstacles.
3. **Power Consumption**: Though classified as low-power, continuous transmission may drain power in battery-powered systems.
4. **Security Vulnerabilities**: Without encryption, data transmitted over Wi-Fi can be intercepted or altered.
5. **Infrastructure Dependency**: Requires existing Wi-Fi networks or routers, which may not always be available in remote locations.

⚠ **Challenges:**

1. **Network Stability**: Ensuring consistent Wi-Fi connectivity in rural or harsh environments can be problematic.
2. **Scalability with Wi-Fi Mesh**: Setting up a large-scale Wi-Fi mesh network to extend coverage requires careful planning and extra cost.
3. **Sensor Calibration**: Like other systems, maintaining sensor accuracy over time in outdoor conditions is challenging.

4. **Energy Management**: Balancing data transmission frequency with available power to avoid frequent battery replacements.
5. **Cloud Integration Complexity**: Building a reliable backend to receive, process, and visualize Wi-Fi-transmitted data can be technically demanding.

Title: LoRa-Based Smart Water Quality Monitoring System for Remote Areas
Authors: N. Sharma, T. Das, R. Bhatnagar

Introduction : This paper presents a smart water quality monitoring system using **LoRa (Long Range)** communication technology for data transmission. Designed specifically for remote or rural areas, the system measures key parameters such as **pH, turbidity, temperature, and electrical conductivity**. Unlike Wi-Fi or GSM, LoRa enables **long-distance, low-power communication**, making it ideal for geographically isolated locations. The system sends real-time data to a centralized cloud platform for analysis and alerting. The paper emphasizes LoRa's high coverage range, low energy consumption, and suitability for **decentralized environmental monitoring**.

✅ Merits**:**
1. **Long-Range Communication**: LoRa supports data transmission over 5–15 km, perfect for covering large or rural areas.
2. **Low Power Consumption**: Ideal for battery or solar-powered setups, enabling months of operation without recharge.
3. **Network Independence**: Operates on unlicensed spectrum—no need for cellular or Wi-Fi infrastructure.
4. **Multi-node Support**: Can support multiple sensor nodes with a single LoRa gateway, reducing deployment cost.
5. **Scalability**: Easily expandable to monitor multiple water sources over wide regions.

❌ Demerits**:**
1. **Low Data Rate**: Not suitable for transmitting large data volumes (like images or complex analytics).
2. **Latency**: LoRa networks typically operate with higher latency compared to Wi-Fi or cellular.
3. **Gateway Cost**: LoRaWAN gateways can be more expensive than simple Wi-Fi routers.
4. **Technical Complexity**: Requires specialized setup and knowledge of LPWAN protocols.
5. **Limited Urban Use**: More suited for open or rural spaces; performance drops in high-interference urban areas.

⚠ Challenges**:**
1. **Environmental Factors**: Signal degradation in dense forests, hills, or extreme weather conditions.
2. **Data Aggregation**: Managing and processing large volumes of distributed data across multiple nodes.
3. **Security Implementation**: Ensuring secure data transfer over LoRa requires advanced encryption techniques.
4. **Sensor Maintenance**: Similar to other systems, long-term accuracy depends on regular sensor upkeep.

Working Process

🔹 Power Supply System
- A 12V solar panel charges a rechargeable battery that powers the water quality sensors.
- The ESP8266 microcontroller requires a stable 5V input, provided through an external adapter or 5V battery bank.
- This dual-power setup ensures reliable operation of both sensors and the controller independently.

🔹 Sensor Data Collection
- The system uses four sensors: pH, Turbidity, Temperature, and Electrical Conductivity.
- These sensors continuously collect analog signals corresponding to the water quality.

- The ESP8266 reads sensor values through its ADC (Analog-to-Digital Converter) pins.

❖ Data Processing and Transmission

- The ESP8266 is programmed using the Arduino IDE to read, process, and evaluate sensor data.
- Data is transmitted wirelessly over Wi-Fi to the ThingSpeak cloud server at regular intervals.
- ThingSpeak displays the data in real-time charts for remote monitoring.

❖ Local Display and Alerts

- A 16x2 LCD is connected to show current sensor readings and water quality status on-site.
- A GSM module is used to send SMS alerts to a mobile phone if any parameter crosses the safe threshold.
- This ensures alerts are delivered even when internet connectivity is unstable.

❖ Quality Evaluation Logic

- Predefined threshold values are used to categorize the water quality.
- If all sensor values are within safe limits, the water is displayed as “Good Quality.”
- If any value exceeds its threshold, the system marks the water as “Bad Quality” and sends an alert.

❖ Key Features and Advantages

- Continuous real-time monitoring using low-cost sensors and ESP8266.
- Renewable energy usage makes the system eco-friendly and suitable for remote areas.
- Dual communication methods (Wi-Fi + GSM) ensure reliable data delivery.
- Compact, cost-efficient, and scalable design ideal for practical deployment in rural and semi-urban areas.

Results

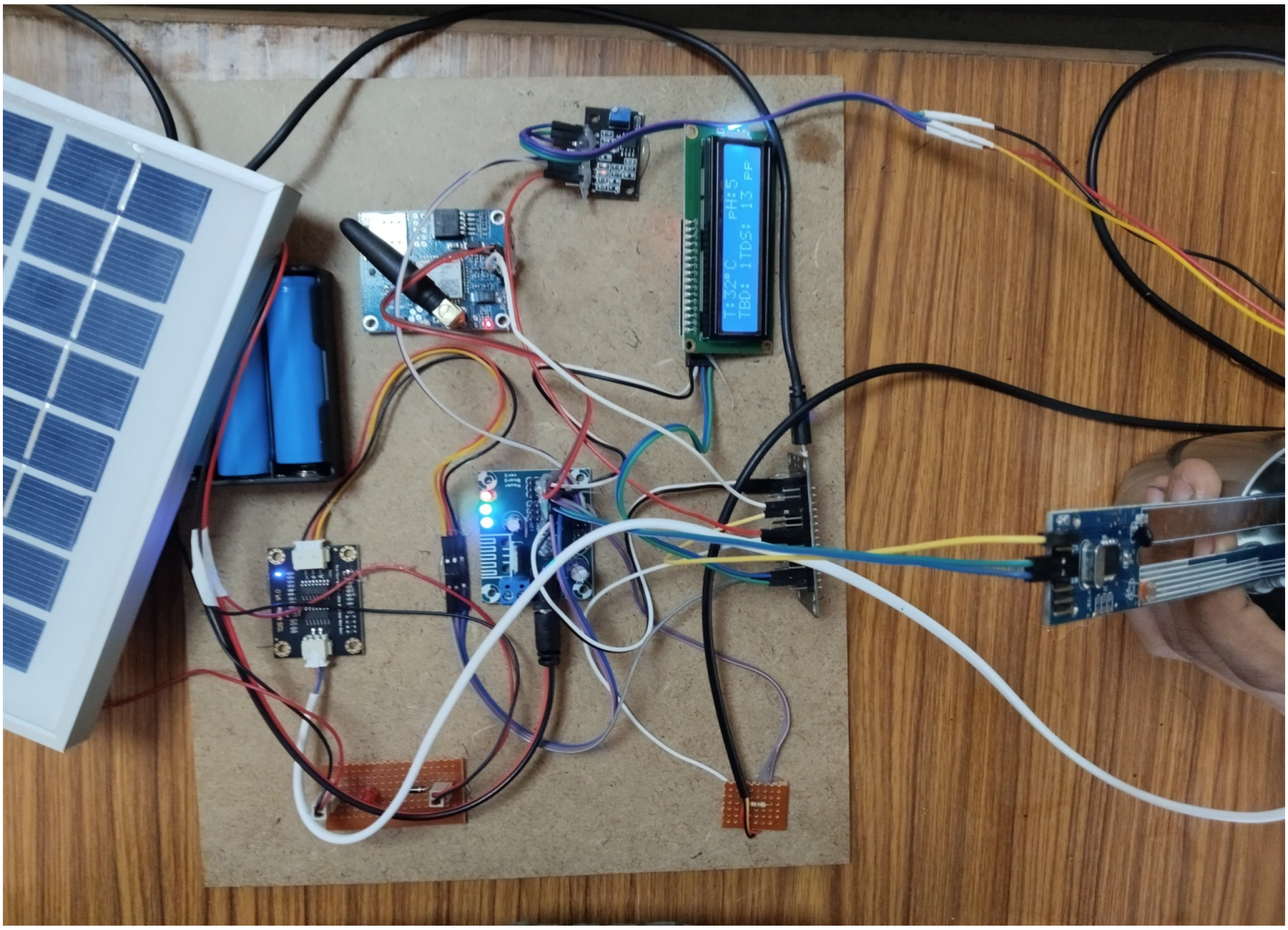

Fig : Design Connections

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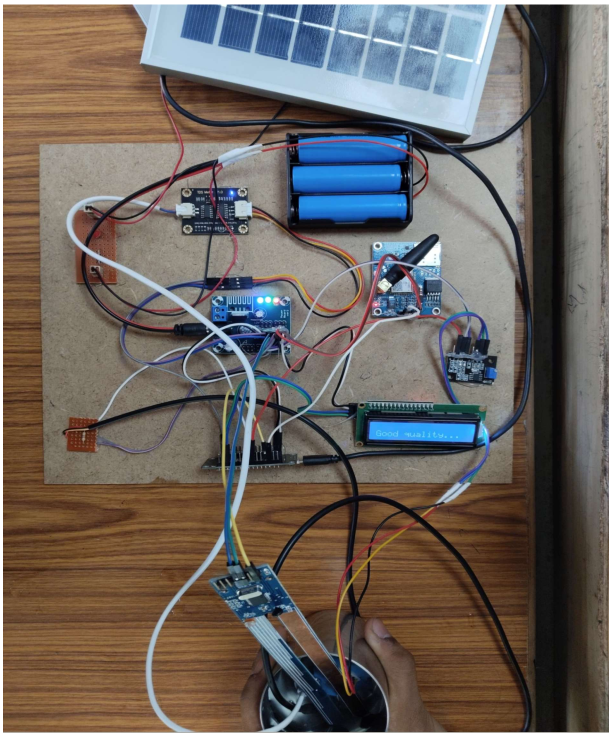

Fig : Output 1 showing good quality of water

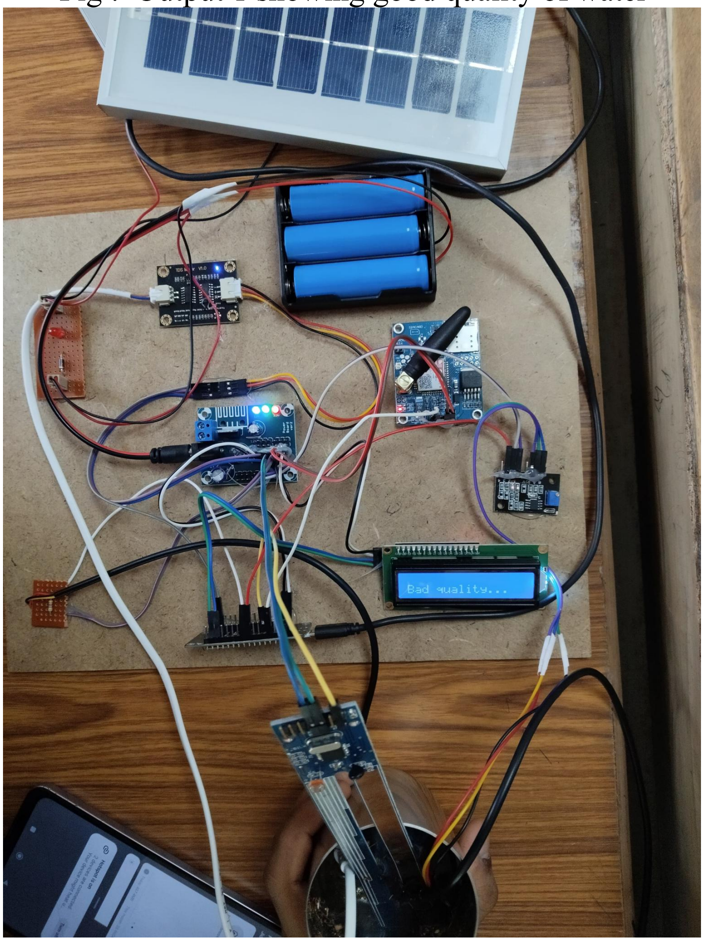

Fig : Output 2 showing Bad Quality of water

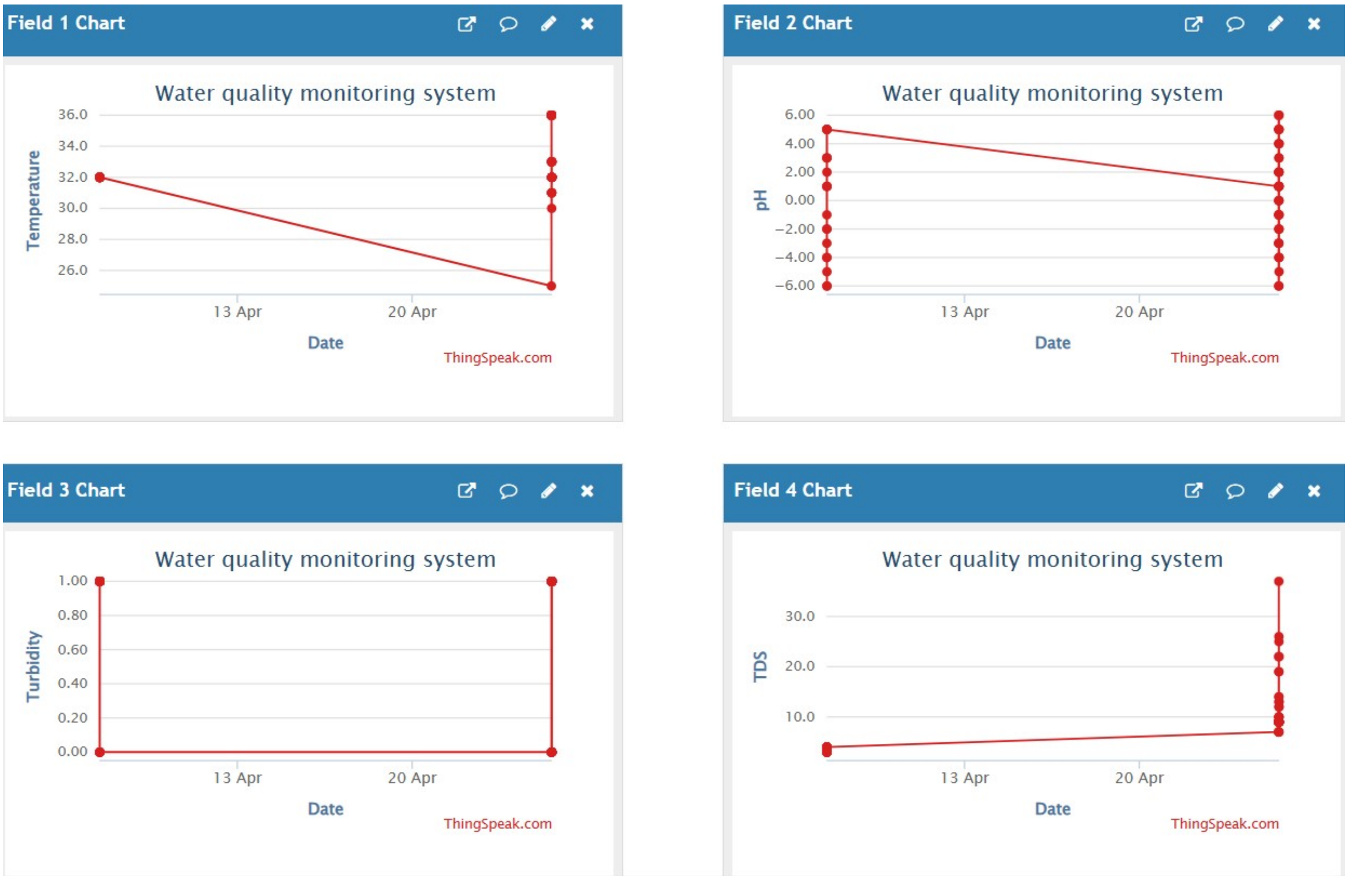

Fig : Output in ThingSpeak Server

Conclusion

This project successfully designed, implemented, and tested a solar-powered, IoT-based water quality monitoring system using WIFI communication. The system effectively addresses the need for real-time, remote monitoring of crucial water quality parameters, offering a significant improvement over traditional, often manual, methods.

The IoT-based water quality monitoring system developed in this project offers a practical, cost-effective, and sustainable solution for real-time environmental monitoring. By harnessing the power of solar energy and Wi-Fi connectivity, the system ensures uninterrupted operation and seamless data transmission from even the most remote or off-grid areas. It successfully measures essential water quality parameters such as pH, turbidity, temperature, conductivity enabling timely detection of pollution or contamination. The data is uploaded to a cloud platform for continuous analysis and easy accessibility, allowing authorities and stakeholders to take prompt and informed action. The integration of GSM for SMS alerts further enhances the responsiveness of the system. Overall, this project not only addresses the limitations of traditional water monitoring methods—such as manual sampling, high costs, and lack of real-time insights—but also lays a strong foundation for scalable deployment and future technological enhancements. It contributes meaningfully to the fields of environmental protection, public health, and sustainable resource management.

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