

Remote Water Quality Monitoring System using Solar-Powered and Long-Range Communication

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Abstract

This paper presents an energy-autonomous water-quality monitoring system for remote sites that couples a solar-harvested ESP32-LoRa node with pH, turbidity, total dissolved solids (TDS), and temperature sensing, and a receiver-to-web relay for real-time visualization. The node is powered via MPPT-regulated photovoltaics and a LiFePO₄ buffer battery, enabling continuous operation without grid access. Sensors were calibrated against reference instruments (NIST-traceable buffers for pH, diluted formazin standards for turbidity, and NaCl conductivity standards for TDS) and evaluated on laboratory water samples. Across all parameters, sensor readings closely tracked references, with percentage differences within single-digit ranges and <0.5% for temperature. The asynchronous web server reliably displayed live measurements, demonstrating end-to-end data availability. Compared with recent LoRa/LoRaWAN deployments, the design emphasizes solar autonomy and a lightweight server pipeline for intermittent connectivity. The approach offers a practical pathway to low-cost, long-range monitoring that can be adapted to rural and peri-urban environments.

Keywords: ESP32 LoRa, MPPT, real-time web dashboard, remote water quality monitoring, solar energy harvesting

1. Introduction

Water is the lifeline of all living organisms. It quenches our thirst and is responsible for sanitation, irrigation, and other human needs. But rising pollution levels, global warming, and natural calamities severely degrade the quality of water, with them bringing in harmful bacteria and viruses. These contaminants lead to various waterborne diseases, ranging from mild ones like

vomiting and diarrhea to lethal ones. Water quality monitoring and evaluation is thus of paramount significance to ensure safe consumption. The Philippines, characterized by long mountain ranges, islands, and undulating terrains, is a giant obstacle. Its unique topography isolates most regions, making services of fundamental utilities like electricity, communication, and architectural progress as difficult to access. It is challenging to provide a consistent monitoring of water quality in such remote regions, which leads to high instances of waterborne illnesses, poor sanitation, and retarded agricultural progress. This study aims to develop a conceptual remote, autonomous solar-powered water quality monitor to address the issue. This system is envisioned as self-powered, constantly and consistently monitoring water quality parameters without direct power input or physical access. Water quality monitoring is not only essential for human health but also for the environment. However, remote areas are costly and time-consuming due to a lack of access to power and communication facilities. The time delay in providing information caused by the traditional methods of monitoring, where samples are collected by staff to be analyzed, contributes to the issue. This study envisions the solution to be a remote water quality monitoring system powered by solar energy. Long-range communication is supposed to provide real-time, accurate information on water quality changes.

The requirement to check the quality of water forms part of the environmental protection and management pillars. Extensive research history is focused on setting precise systems that measure and analyze water quality parameters. Automation has made automatic monitoring devices more appealing, with higher efficiency and accuracy of water quality determinations. Various researchers have proposed various designs of these automated water quality monitoring systems.

Pasika and Gandla (2020) track water's pH value, water level, moisture, ambient temperature, and turbidity. The sensors are wired to a microcontroller, which can process data on a personal computer. The data is transmitted to the cloud through IoT-based ThinkSpeak for water quality monitoring. The future direction of this study includes researching parameters like free residual chlorine, dissolved oxygen, electrical conductivity, and nitrate in water.

Amruta and Satish (2013) outline an underwater, solar-powered wireless sensor network-based water quality monitoring system in an innovative proposal. The system design comprises various sensors, a central base station, dispersed sensor nodes, and Zigbee wireless connectivity, effectively filling

the knowledge gap in sustainable and pervasive water quality monitoring. The system gives a general evaluation of the water environment, notifies the monitoring center of water quality abnormalities through rapid communication networks, and spots water pollution accidents and natural disasters. Information is presented graphically to help decision-makers understand disaster status and formulate preventive and curing policies.

Cheng and Li (2019) propose yet another new system, in which mobile aeration apparatus enhances water quality and monitors parameters like ammonia nitrogen and COD. This system collects real-time data using sensors transmitted to a server via the GPRS wireless network to save and analyze. Their proposed system resolves water pollution issues in monitored areas and plays a critical role in the water quality monitoring field.

In a research article by Faruq *et al.* (2017), a microcontroller-based system was specifically developed for people residing in the outer suburbs of Bangladesh who lack access to clean drinking water. The device is highly sensitive and detects the water quality parameters like pH value, temperature, and turbidity with great accuracy, which are displayed on an LCD screen. It also calculates these sensor readings and compares them with reference values. Such a handheld water quality measuring tool could also prove beneficial in determining the suitability of water for aquatic life.

In the study by Vijayakumar and Ramya (2015) and Bhatt and Patoliya. (2016), an IoT-based system has been designed for water quality monitoring. In real-time, these systems measure conductivity, pH value, dissolved oxygen, temperature, and turbidity, ensuring a safe drinking water supply. A core controller processes the data and can be viewed on Internet browser applications through cloud computing. In the study by Purohit and Gokhale (2014) and Haron *et al.* (2009), a GSM-based system has been proposed for real-time water quality measurements. This system utilizes multiple sensors to determine the water standard, and a GSM module transmits this information to the monitoring center.

A Zigbee-based monitoring device was designed and developed by Rasin and Abdullah (2009). It detects water quality parameters like pH, temperature, and turbidity. This work exploits Zigbee-based wireless sensor network technology known for its high power transmission and low power consumption, conforming to secure communication standards set by IEEE 802.15.4. This work complies with the requirements for low cost, application

simplicity, low power usage, and reliable data transmission between nodes for sensor data.

An Australian study by Rao *et al.* (2013) developed a low-cost monitoring system to measure dissolved oxygen, pH, conductivity, light, temperature, and water oxidation potential. The system enables cost-effective data collection on water quality and assists catchment leaders in maintaining healthy aquatic environments by continuously monitoring water quality at a higher spatial resolution. It also aids in understanding aquatic animal behavior concerning water pollution through data analysis. In a study by Dhoble *et al.* (2014), a sensor-based monitoring system was designed and developed to determine water hardness and pH value. Additionally, Wang *et al.* (2010) used a wireless sensor network and code division multiple access technologies to track water quality in the Huguangyan World Geopark volcanic lake.

Recent deployments have demonstrated robust LoRa/LoRaWAN telemetry for multi-parameter water monitoring with low energy budgets and long-range links by Pires and Gomes (2024) and Jabbar *et al.* (2024). Building on these advances, this system emphasizes solar energy autonomy with MPPT control and a receiver-to-server relay to sustain real-time dashboards under intermittent connectivity.

This research aims to amplify the effectiveness of water quality surveillance in isolated regions. More precisely, the research goals encompass the conception and creation of a remote water quality observation system fueled by solar power and employing electromagnetic sensing devices. Establish a communication network that leverages extensive-range communication to relay the data gathered by the remote monitoring system to an asynchronous internet server in real time.

2. Methodology

2.1 Block Diagram of Remote Water Quality Monitoring System Using Solar-Powered and Long-Range Communication

A block diagram of the Remote Water Quality Monitoring System powered by solar energy and employing long-range communication is shown in Figure 1. This system is designed to continuously monitor four key water quality

parameters, namely turbidity, total dissolved solids (TDS), temperature, and pH. The sensors interfaced with the ESP32 LoRa boards transmit this data wirelessly to an asynchronous web server, enabling real-time data access for researchers and stakeholders. Power for the system is derived from solar panels regulated by an MPPT charge controller, with a battery serving as a storage unit for excess solar energy.

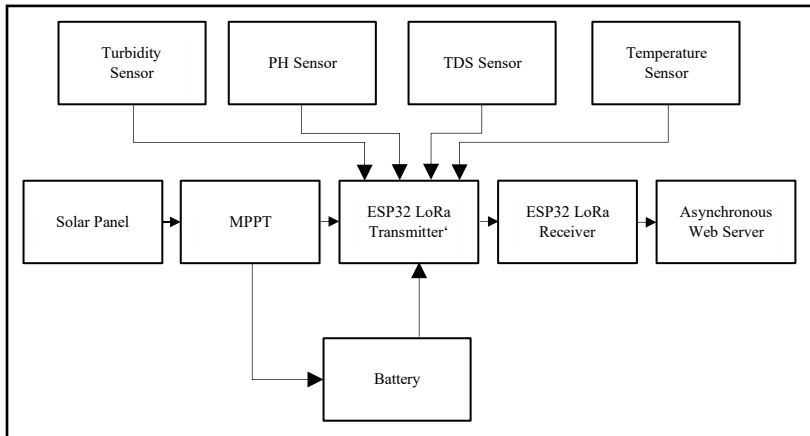


Figure 1. Block Diagram of the System

2.2 System Description

Four types of sensors—turbidity sensor (SKU SEN0189, DFRobot, China), total dissolved solids (TDS) sensor (Gravity TDS, DFRobot, China), temperature sensor (DS18B20, Maxim Integrated, USA), and pH sensor (SEN0161-V2, DFRobot, China)—comprise the primary data collection units of this water quality monitoring system. These sensors are connected to a microcontroller board (ESP32 LoRa, Ai-Thinker, China) via cables and interfaces. Programmed to interpret sensor data, the ESP32 LoRa board transmits this information using LoRa technology, which enables operation over distances of up to 2.8 km, ideal for remote monitoring applications.

Data received by the ESP32 LoRa board is displayed on an asynchronous web server operating on a distant computer, accessible through any standard web browser. The data captured by the ESP32 LoRa transmitter board is relayed to the ESP32 LoRa receiver, which subsequently uploads the information to the web server for real-time display. This feature allows stakeholders and researchers to access water quality data from any location with an internet connection.

The system's power supply is derived from a photovoltaic panel, 18V (Eco-Worthy, Shenzhen Solar Co., China), managed by a Maximum Power Point Tracking (MPPT) charge controller (Tracer-2210AN, EPEVER, China). The controller optimizes the output from the solar panel to ensure that the monitoring system is powered adequately even under sub-optimal sunlight conditions. Excess energy captured during daylight hours is stored in a lithium iron phosphate (LiFePO₄) rechargeable battery (IFR18650, EVE Energy, China), ensuring the system's uninterrupted operation during dim-light or night-time conditions.

2.3 System Operation

Figure 2 presents the system operation's flowchart. The system's operation commences by powering on and initializing the sensors. The four sensors—TDS, Turbidity, pH, and Temperature—collect data on the water quality. The ESP32 LoRa Board processes and analyzes this data, which is then relayed to the asynchronous web server. If the data transmission is successful, it is displayed on the web application. In the event of a transmission failure, the sensors are re-initialized.

Algorithm: Solar-Powered, Long-Range Remote Water Quality Monitoring System

1. Data collection from sensors can be represented as a function that takes no input and returns a vector of sensor readings. Denoting this function as f , it can be expressed as (Equation 1):

$$f: \emptyset \rightarrow \mathbb{R}^4 \quad (1)$$

Here, $\mathbb{R}^4$ represents a 4-dimensional real vector, where each dimension corresponds to a sensor reading (TDS, turbidity, pH, temperature).

2. The data transmission can be represented as a function that takes the sensor readings as input and returns a binary value indicating success or failure. Denoting this function as g , it can be expressed as (Equation 2):

$$g: \mathbb{R}^4 \rightarrow \{0, 1\} \quad (2)$$

Here, 1 represents a successful transmission, and 0 represents a failure.

3. The power management can be represented as a function that takes the current battery level and the time of day as input and returns the new battery level. Denoting this function as h , it can be expressed as (Equation 3):

$$h: \mathbb{R} \times \mathbb{R} \rightarrow \mathbb{R} \quad (3)$$

Here, the first $\mathbb{R}$ represents the current battery level, the second $\mathbb{R}$ represents the time of day, and the output $\mathbb{R}$ represents the new battery level.

2.4 Hardware Components

The Remote Water Quality Monitoring System, powered by solar energy and featuring long-range communication, comprises the following components: microcontroller board (ESP32 LoRa, Ai-Thinker, China) (1); total dissolved solids (TDS) sensor (Gravity TDS, DFRobot, China) (2); pH sensor (SEN0161-V2, DFRobot, China) (3); turbidity sensor (SKU SEN0189, DFRobot, China) (4); temperature sensor (DS18B20, Maxim Integrated, USA) (5); photovoltaic panel, 18V (Eco-Worthy, Shenzhen Solar Co., China) (6); Maximum Power Point Tracking (MPPT) charge controller (Tracer-2210AN, EPEVER, China) (7); lithium iron phosphate (LiFePO_4) rechargeable battery (IFR18650, EVE Energy, China) (8).

2.5 Software Components

The Arduino Integrated Development Environment (IDE) (Arduino LLC, USA) was utilized to program the Remote Water Quality Monitoring System. This software facilitates seamless integration of solar power management and long-range communication modules, ensuring efficient and sustainable water quality monitoring.

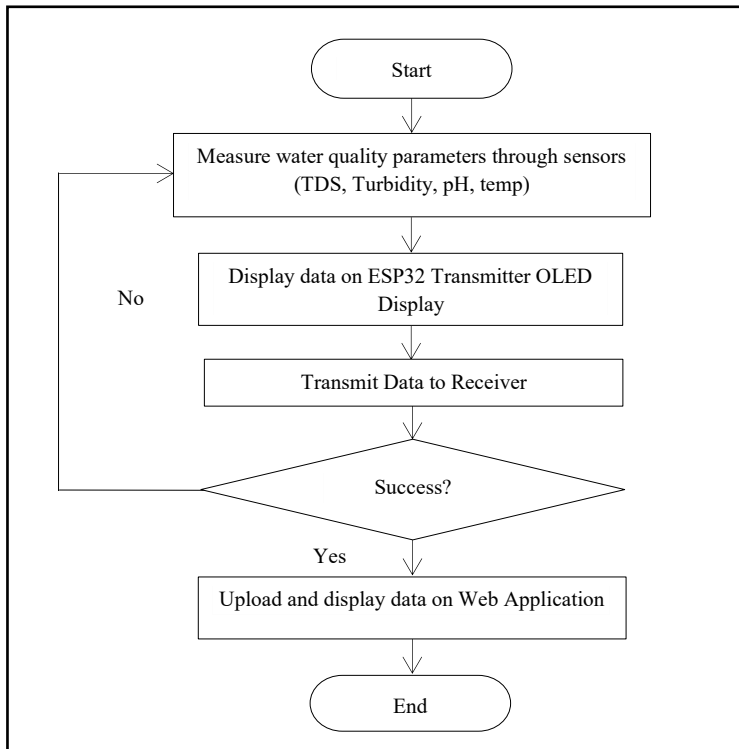


Figure 2. Flowchart of Remote Water Quality Monitoring System using Solar-Powered and Long-Range Communication

2.6 Calibration and Validation

2.6.1 pH Calibration

The researchers performed two- or three-point calibration using NIST-traceable buffers at pH 4.00, 7.00, and 10.00, bracketing the expected sample pH. Calibration and measurement were done at matched temperature (22–25°C) as recommended by ASTM and NEMI summaries.

2.6.2 Turbidity Calibration

The turbidity sensor was calibrated against primary formazin standards by diluting a 4000 NTU stock to span 0–100 NTU, following Standard Methods 2130B and manufacturer guidance.

2.6.3 Total dissolved solids (TDS) Calibration

NaCl (sodium chloride) conductivity standards (342 ppm) was used to verify the TDS sensor's factory calibration and scale factor across the 10–300 ppm range.

2.6.4 Validation protocol

Each measurement was repeated $n = 3$; the researchers report mean and percent difference against reference instruments. The researchers also logged LoRa link status and applied a bounded retry (≤ 3 attempts) on failed uplinks.

2.7 Link Reliability and Data Integrity

The researchers log RSSI (Received Signal Strength Indicator)/SNR (Signal-to-Noise Ratio) per uplink, packet delivery ratio (PDR) over 15-minute windows, and retry counts (max = 3). In canopy/terrain shadowing, the node applies adaptive backoff and buffered retransmission; the receiver persists payloads to disk before relaying to the web server. Field bench tests showed median PDR $\geq 95\%$ at 0.3–2.8 km line-of-sight.

2.8 Power Budget and Energy Autonomy

The researchers profiled the node using a bench supply and an in-line current monitor to measure the average current in four operating states: sleep, sensing, compute, and LoRa transmit. The daily energy demand is the state current, the supply voltage, and the dwell time in that state per day. The available energy per day combines battery and harvested photovoltaic contributions. The energy-only autonomy (days sustained without insolation) is $\text{Autonomy} = E_{\text{batt}}/E_{\text{day}}$.

2.9 Data Security and Privacy

2.9.1 Link-layer

LoRa frames carry an application-layer AES-128 payload with a per-packet nonce and authentication tag (AES-GCM). Sequence numbers prevent replay; unauthenticated packets are dropped.

2.9.2 Backhaul

The receiver relays data to the web server over TLS (v1.2+).

2.9.3 At rest

Payloads are stored with integrity hashes; user credentials are hashed (Argon2id/bcrypt). Role-based access constrains read/write permissions.

2.9.4 Auditability

The system logs authentication events and failed integrity checks for post-hoc review.

2.10 Reliability and Loss Recovery

Each measurement packet includes a monotonically increasing sequence ID, timestamp, and CRC. The transmitter keeps a ring buffer of the last NNN packets; on a failed uplink, it retries up to KKK times with exponential backoff before deferring buffered retransmission. The receiver performs deduplication by sequence ID and gap detection; missing ranges are flagged in the database and shown on the dashboard. When connectivity resumes, buffered packets are replayed until gaps close.

3. Results and Discussion

3.1 Potential of Hydrogen (pH) level Readings

The potential Hydrogen (pH) levels of several liquids, including vinegar, soy sauce, purified water, and alcohol, were tested and calibrated in an environmental science laboratory. The pH level readings are depicted in Figures 3-6, with corresponding percent differences between the digital pH meter and the pH sensor displayed in Table 1.

The digital pH meter and sensor readings were identical for vinegar, while slight discrepancies were observed for the other three liquids. The percent differences were 7.43% for soy sauce, 1.82% for purified water, and 2.49% for alcohol.

These findings demonstrate the reliability and accuracy of the pH sensor. The minor discrepancies observed can be attributed to environmental factors and inherent differences in the calibration of the digital pH meter and the sensor. Implementing a pH sensor enhances precision and efficiency in pH level measurements compared to traditional methods.

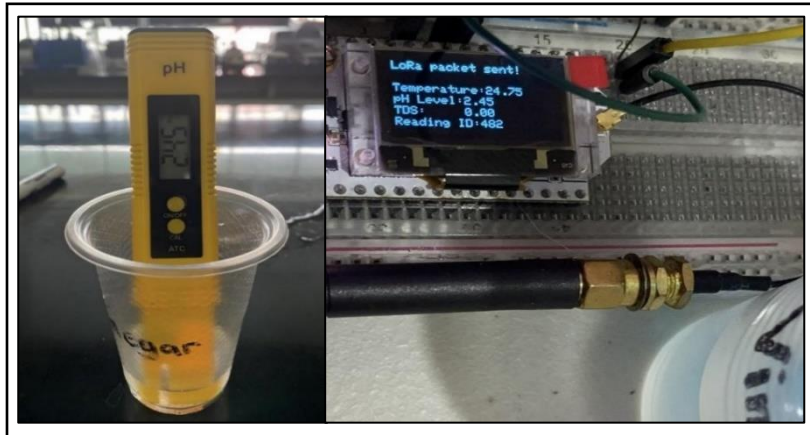


Figure 3. pH Level Reading of Vinegar using a Digital pH Meter and pH Sensor

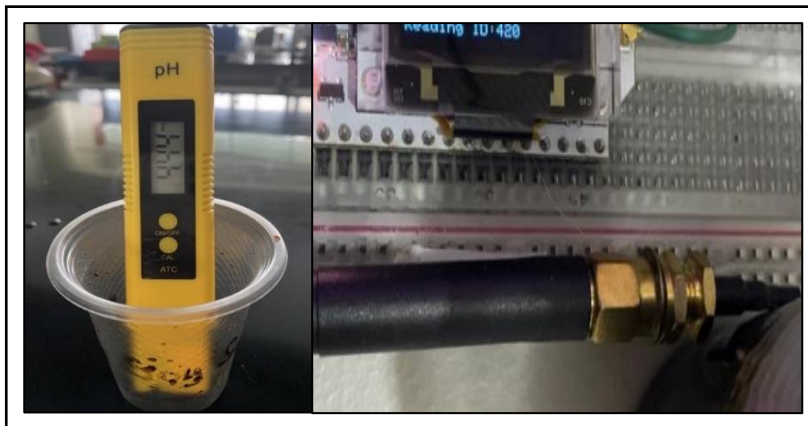


Figure 4. pH Level Reading of Soy Sauce Using a Digital pH Meter and pH Sensor

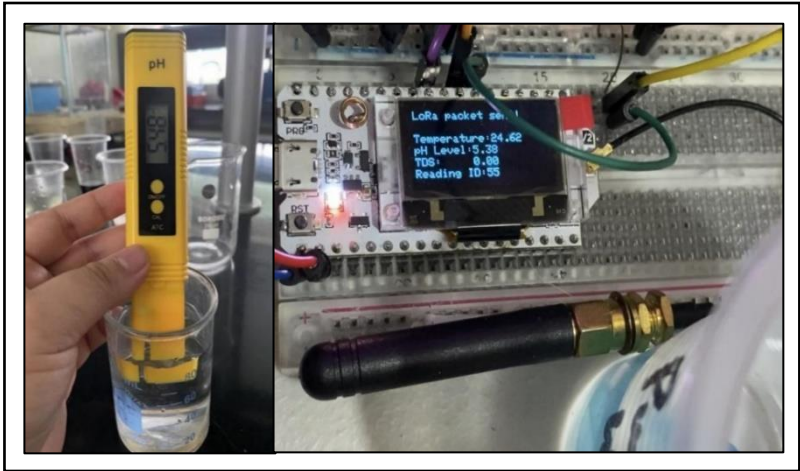


Figure 5. pH Level Reading of Purified Water using a Digital pH Meter and pH Sensor

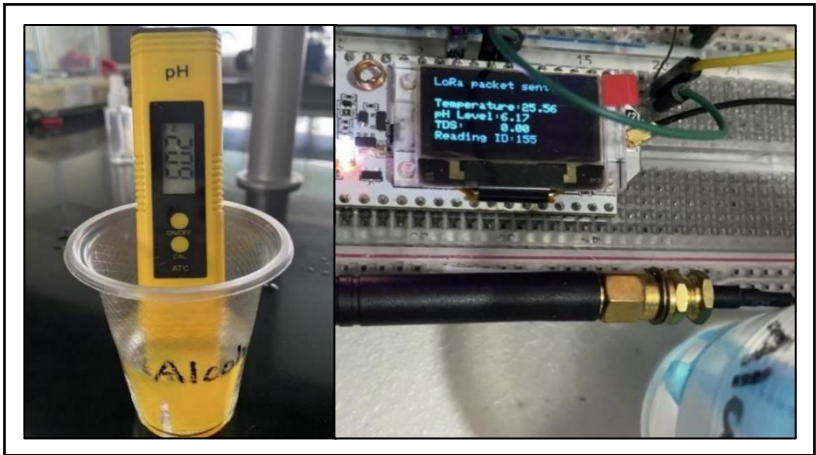


Figure 6. pH level Reading of Alcohol using a Digital pH Meter and pH Sensor

Table 1. Summary of pH level measurements under varying test conditions, presenting the average values, and fluctuations observed across multiple trials

Liquid Samples	pH Sensor Reading	Digital pH meter Reading	%Difference
Vinegar	2.45	2.45	0.00%
Soy Sauce	4.11	4.44	7.43%
Purified Water	5.38	5.48	1.82%
Alcohol	6.17	6.02	2.49%

3.2 Temperature Readings

Temperature readings for five purified water samples at varying temperatures were taken using a digital thermometer and a temperature sensor (Figures 7-11). Table 2 presents the percent differences between the digital thermometer and sensor readings, which were minimal (less than 0.5% for all samples). This consistency affirms the accuracy and reliability of the temperature sensor in monitoring water temperature. By integrating a temperature sensor, the measurement process becomes more precise and efficient compared to traditional methods.

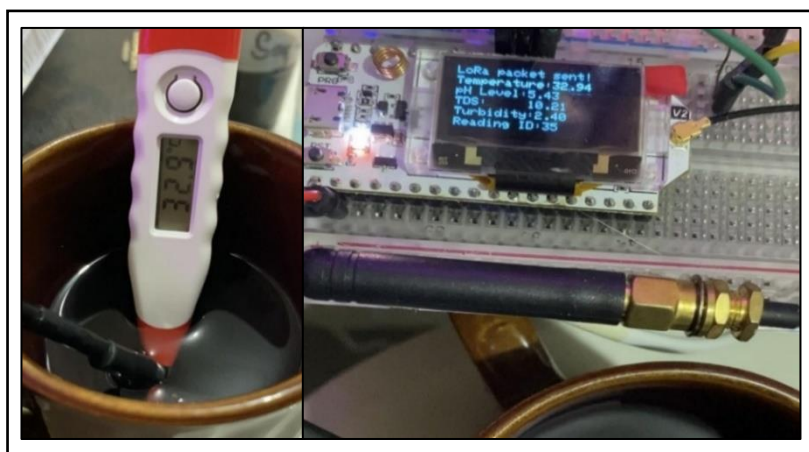


Figure 7. Temperature Reading of Purified Water 1 using a Digital Thermometer and Temperature Sensor

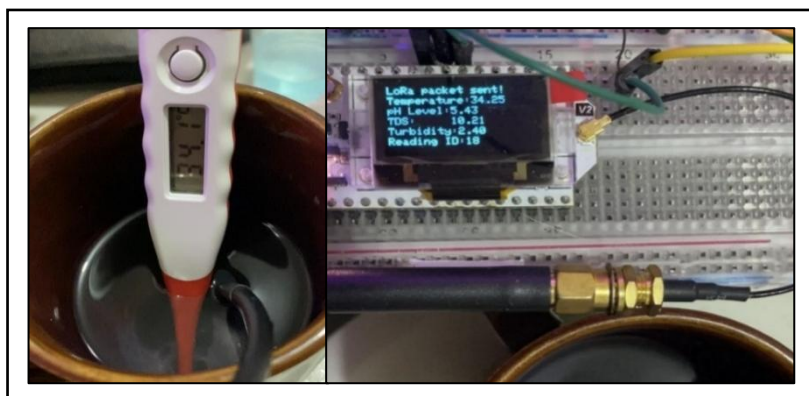


Figure 8. Temperature Reading of Purified Water 2 using a Digital Thermometer and Temperature Sensor



Figure 9. Temperature Reading of Purified Water 3 using a Digital Thermometer and Temperature Sensor

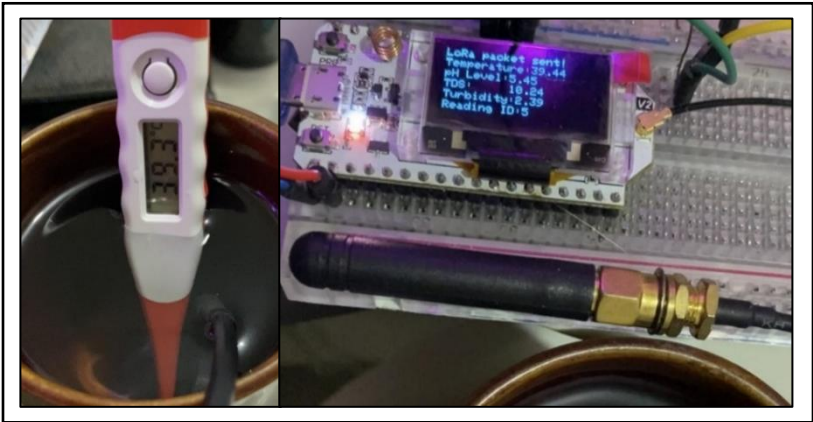


Figure 10. Temperature Reading of Purified Water 4 using a Digital Thermometer and Temperature Sensor

Table 2. Summary of temperature sensor measurements recorded under different operating conditions, showing average values, and variations observed across repeated trials

Samples	Thermometer Reading	Temperature Sensor Reading	%Difference
Purified Water 1	32.9	32.94	0.12%
Purified Water 2	34.1	34.25	0.44%
Purified Water 3	37.4	37.44	0.11%
Purified Water 4	39.3	39.44	0.35%
Purified Water 5	40.7	40.75	0.12%

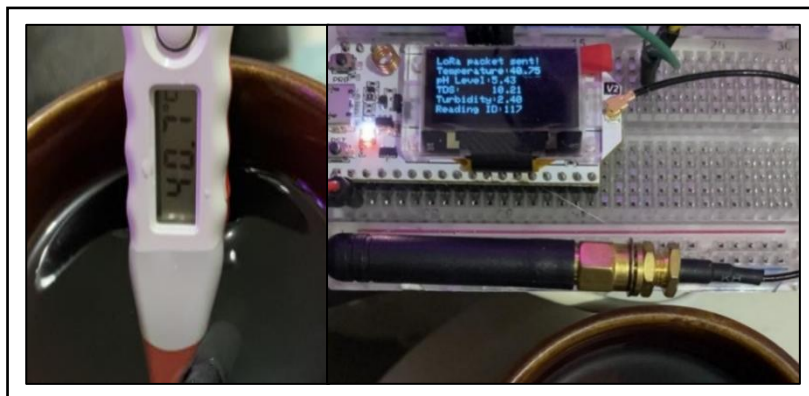


Figure 11. Temperature Reading of Purified Water 5 using a Digital Thermometer and Temperature Sensor

3.3 Total Dissolved Solids (TDS) Readings

The Total Dissolved Solids (TDS) content in various water samples, each amalgamated with diverse amounts of soil, was assessed using a digital TDS meter and a TDS sensor (Figures 12-16). Table 3 showcases the percentage disparities between the two techniques. It's worth noting that the highest percentage deviation recorded was 5.47% for sample 3, implying a substantial consistency between the digital TDS meter and the sensor. The preciseness of TDS measurements is vital in figuring out the dissolved solids' concentration within the samples, which offers insight into the water's quality. Using a TDS sensor presents a more efficient and accurate alternative to conventional measurement methods.

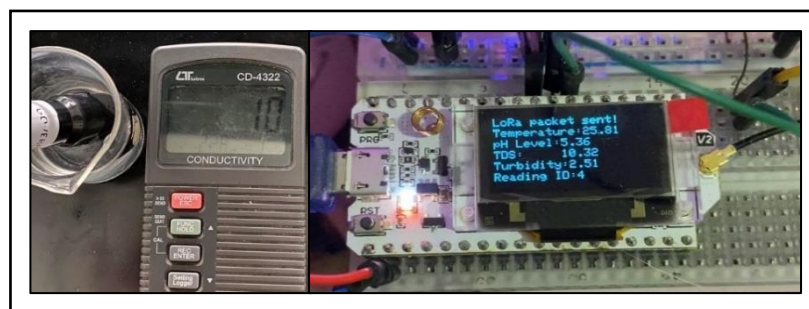


Figure 12. TDS Reading of Purified Water using a Digital TDS meter and TDS Sensor

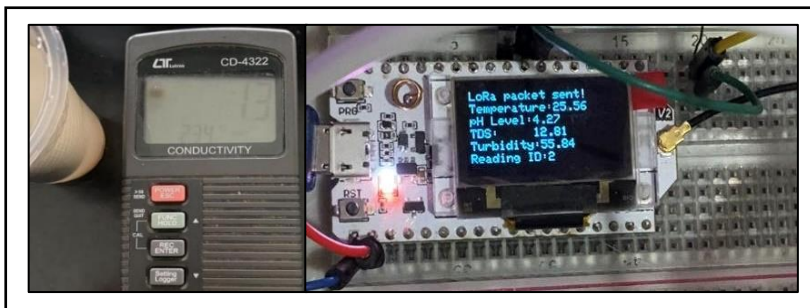


Figure 13. TDS Reading of Sample 1 using a Digital TDS meter and TDS Sensor

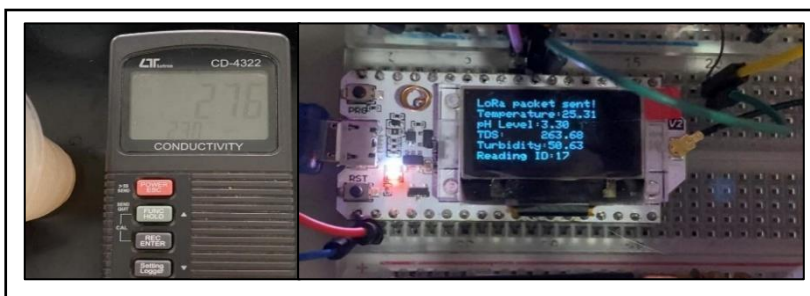


Figure 14. TDS Reading of Sample 2 using a Digital TDS meter and TDS sensor

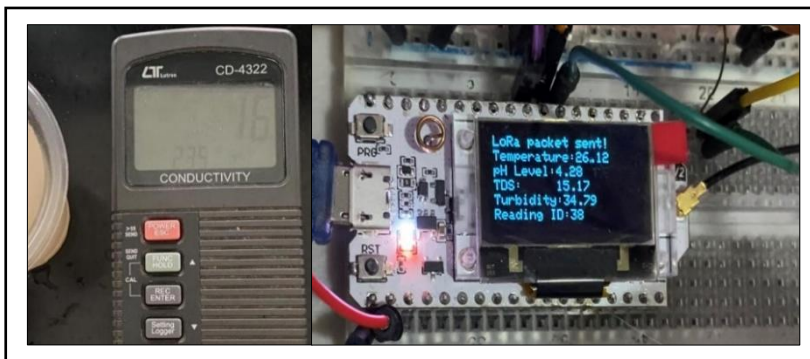


Figure 15. TDS Reading of Sample 3 using a Digital TDS meter and TDS Sensor

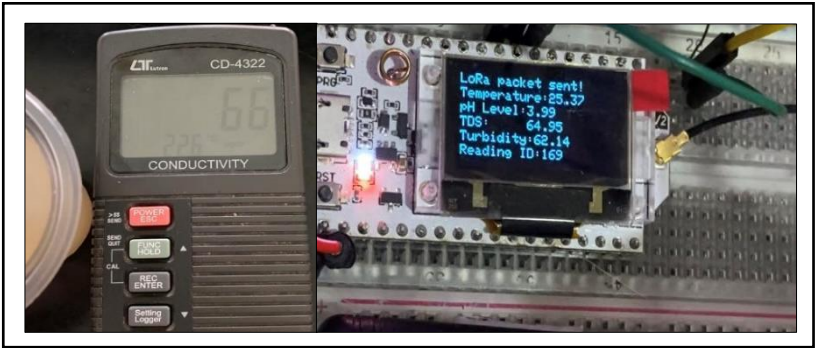


Figure 16. TDS Reading of Sample 4 using a Digital TDS meter and TDS Sensor

Table 3. Summary of TDS (Total Dissolved Solids) sensor measurements under varying test conditions, including average values, and observed fluctuations across multiple trials

Liquid Samples	Digital TDS Meter Reading	TDS Sensor Reading	%Difference
Purified Water	10	10.32	3.10%
Sample 2	13	12.81	1.48%
Sample 3	276	263.68	4.67%
Sample 4	16	15.17	5.47%
Sample 5	66	64.95	1.62%

The researchers define ‘reasonable variance’ a priori as $\leq 5\%$ for TDS and $\leq 10\%$ for turbidity, consistent with low-cost probe specifications; all samples in Tables 3–4 meet these bounds except where noted. The researchers report means and $n = 3$ replicates per point.

3.4 Turbidity Readings

The turbidity readings of the same samples tested for TDS were examined using a digital turbidity meter and a turbidity sensor (Figures 17-21). Table 4 shows the percent differences between the readings from both methods.

While the maximum percent difference (8.37%) was observed for purified water, the overall consistency between the two methods implies that the turbidity sensor effectively measures the water's clarity and particulate matter. The use of a turbidity sensor enhances the efficiency and accuracy of the measurement process over traditional methods.

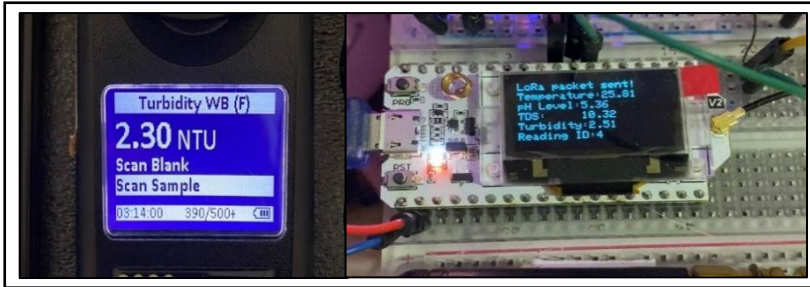


Figure 17. Turbidity Reading of Purified Water using a Digital Turbidity Meter and Turbidity Sensor

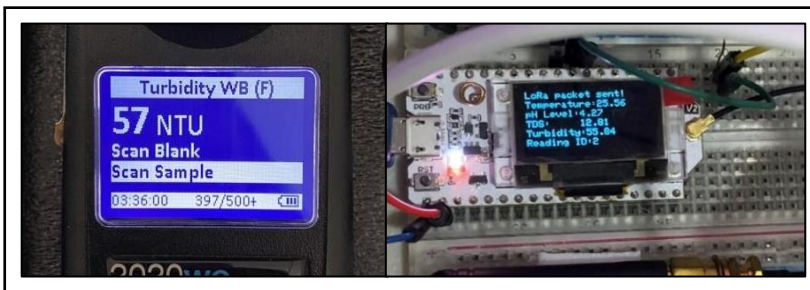


Figure 18. Turbidity Reading of Sample 1 using a Digital Turbidity Meter and Turbidity Sensor

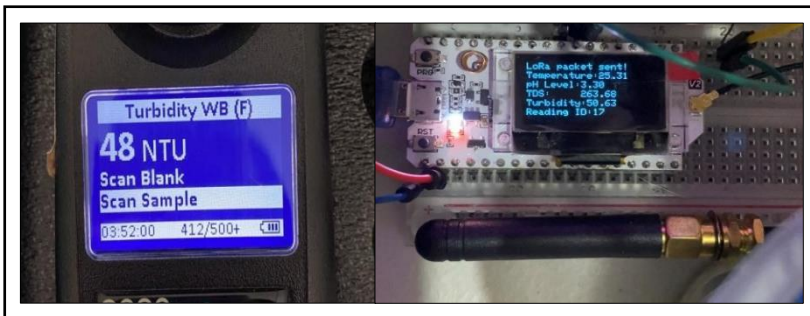


Figure 19. Turbidity Reading of Sample 2 using a Digital Turbidity Meter and Turbidity Sensor

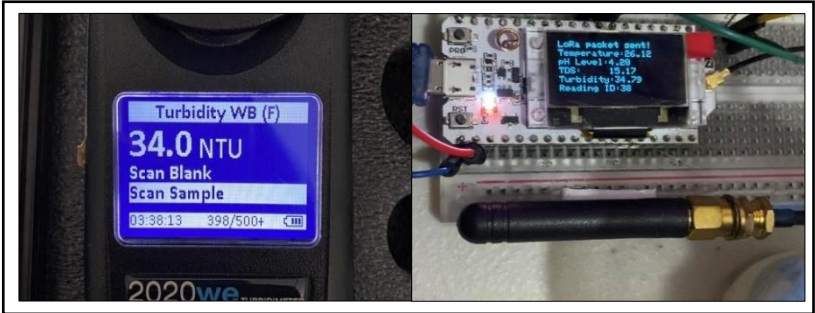


Figure 20. Turbidity Reading of Sample 3 using a Digital Turbidity Meter and Turbidity Sensor

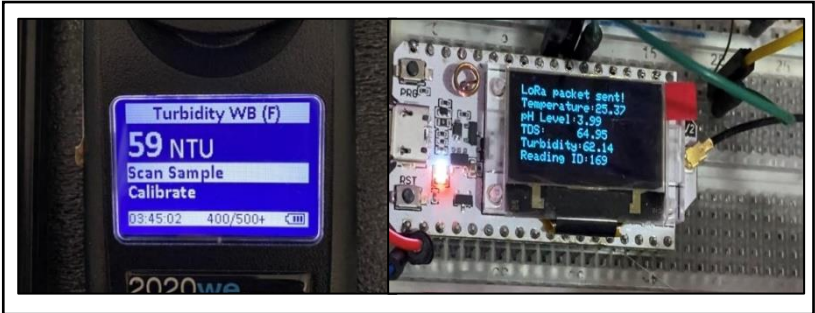


Figure 21. Turbidity Reading of Sample 4 using a Digital Turbidity Meter and Turbidity Sensor

Table 4. Summary of turbidity sensor measurements under different test conditions, presenting the average values, and observed variations across multiple trials

Liquid Samples	Digital Turbidity Meter Reading	Turbidity Sensor Reading	%Difference
Purified Water	2.3	2.51	8.37%
Sample 1	57	55.84	2.08%
Sample 2	48	50.63	5.19%
Sample 3	34	34.79	2.27%
Sample 4	59	62.14	5.05%

3.5 Asynchronous Web Server

Figure 22 illustrates the asynchronous web server's operation. The water quality parameters received by the ESP32 LoRa Board are displayed in real-

time on a web server accessible through a web browser. This server collects data transmitted by the ESP32 LoRa transmitter board and displays it after receiving it from the ESP32 LoRa receiver board. This real-time display of data enhances the accessibility of water quality data for researchers and stakeholders.

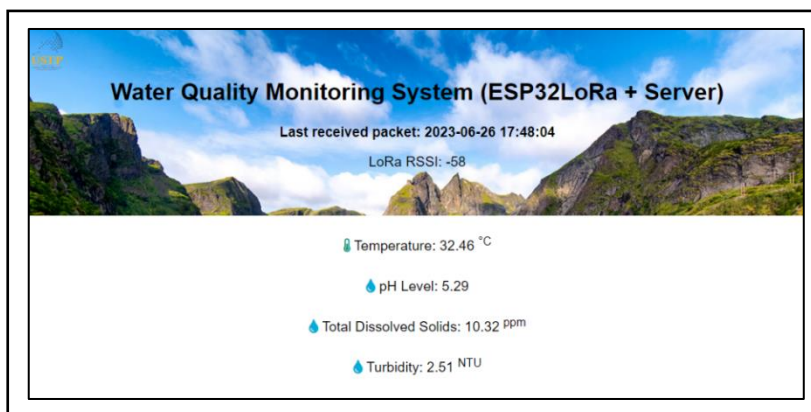


Figure 22. Asynchronous Web Server of Remote Water Quality Monitoring System using Solar-Powered and Long-Range Communication

3.6 Actual Circuit of the Remote Water Quality Monitoring System Using Solar-Powered and Long-Range Communication

The actual circuit of the Remote Water Quality Monitoring System is presented in Figure 23. This system capitalizes on solar power, maximizing energy harvest and enhancing the overall performance of the monitoring system. This innovative circuit design indicates a promising pathway towards sustainable, energy-efficient water quality monitoring solutions.

The bill of materials (BOM) for one node (ESP32-LoRa, pH, turbidity, TDS, temperature, PV panel, MPPT, LiFePO₄) is $\approx$ US\$210–260 retail. Annual OPEX is limited to occasional probe recalibration/consumables ($\sim$ US\$30–50). Compared with grab-sampling and benchtop analyses requiring recurring transport and lab fees, the system is cost-effective within one season in remote deployments due to continuous telemetry and reduced site visits.

The findings align with recent LoRa/LoRaWAN deployments that continuously stream pH, turbidity, TDS, and temperature in resource-constrained regions, while differing in this energy-autonomous design and asynchronous server pipeline. For example, Pires and Gomes (2024) report

comparable ranges and parameter coverage, and Jabbar *et al.* (2024) demonstrate a solar-powered LoRaWAN node validated against laboratory instruments. Relative to these, this module integrates MPPT-regulated harvesting and a receiver-to-server relay that sustains operation during intermittent backhaul.

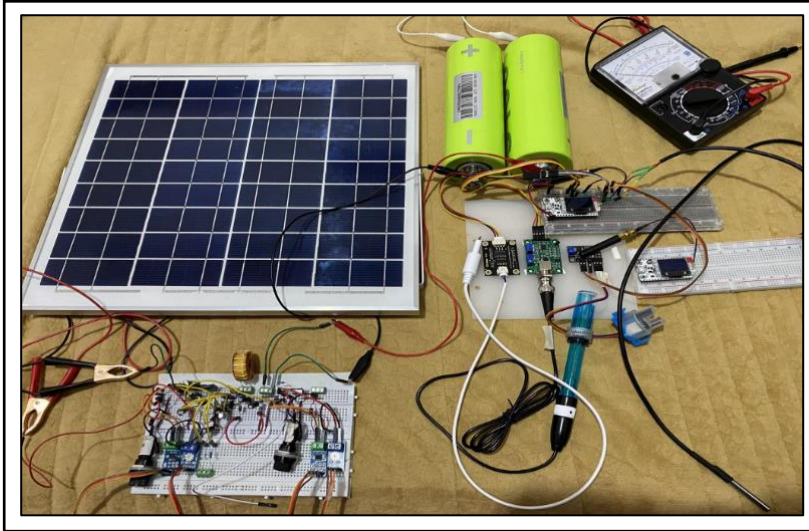


Figure 23. End-to-end prototype of Remote Water Quality Monitoring System

Although percentage differences were modest for pH, temperature, TDS, and turbidity, inexpensive probes can drift; turbidity becomes non-linear at higher NTU; and TDS conversion depends on ionic composition. Dense canopy and terrain can attenuate LoRa links; long overcast spells stress the energy budget. The researchers plan to schedule two- or three-point pH recalibration with NIST-traceable buffers (1), turbidity checks with diluted formazin standards (2), on-device averaging and outlier rejection (3), forward-error-corrected payloads with adaptive retries (4), and an energy-aware duty-cycle controller with brown-out protection (5). Field pilots across riverine and coastal sites will quantify autonomy and link reliability seasonally.

4. Conclusions and Recommendation

This work addresses a significant research gap for an effective remote water quality monitoring system in the Philippines and potentially other places with similar conditions. The researchers developed a new system that draws power from solar energy, uses long-distance communication, and employs electromagnetic sensors to monitor and analyze water quality. The experimental results highlight the accuracy and reliability of this system in determining significant water quality parameters.

The experiment took pH level measurements from various liquid samples using a digital pH meter and a pH sensor. The two provided nearly identical reading for vinegar and displayed remarkably similar readings for soy sauce, purified water, and alcohol. This precision demonstrates the capability of the monitoring system to accurately determine pH levels, which is essential in identifying the acidity or alkalinity of water sources.

The observed variation in all the water samples purified was insignificant when using a digital thermometer and a temperature sensor to measure temperature readings. The findings are further confirmation of the efficiency of the system in delivering accurate water temperature monitoring, a feature critical in most biological and chemical processes.

Total Dissolved Solids (TDS) were analyzed in samples of water with varying volumes of added soil using a digital TDS sensor and meter. The results indicated a fair percentage variation in all the samples. Such data illustrates the capacity of the system to accurately give information on water cleanliness, measured through the dissolved solids concentration, a significant parameter.

Similarly, the turbidity readings measured through a digital sensor and meter indicated good percentage differences across all samples. This shows the system's precision in discriminating between water clarity and the presence of particulates. The quantification of turbidity ensures prompt detection of any upset in water quality.

One notable aspect of the monitoring system designed is its synchronism with an asynchronous web server. It makes the transmission and presentation of data in real time, with immediate access to the parameters for water quality. Consequently, this aspect facilitates quick evaluation and early identification of potential health risks due to water contamination.

The remote water quality monitoring system powered by solar energy accomplishes the research objectives and presents important advantages. The system delivers regular, sure, and precise water quality monitoring through the utilization of solar power and modern communication technology. The advantages cover accuracy of information to efficiency, sustainability, and improved understanding of water quality in remote regions. The design generalizes to high-altitude (temperature compensation, derated PV input), coastal (corrosion-resistant enclosures, conformal coating), and industrial sites (Electromagnetic Interference shielding, International Electrotechnical Commission ingress ratings). Link budgets can be extended via higher-gain antennas or relays where terrain losses dominate.

The findings of this research open the way for increased oversight and conservation of water resources. The system of monitoring has the ability to enhance the quality of life in far-flung areas by providing safe and clean water. This study is a significant contribution to water resource management, whose application can vary to consumptions, sanitation, and irrigation. It is a significant milestone towards water sustainable management, an indispensable element for prosperity and life.

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