# Solar Powered GPRS Smart Water Quality Monitoring system using RPI

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**Abstract**

Water quality is an important and a valuable issue. The Raspberry Pi-based Solar Powered GPRS Water Quality Monitoring System has effective, real-time, and eco-friendly to water quality monitoring in all location. Water quality indicators pH, temperature, turbidity, Total Dissolved Solids TDS are sensed in the processing subsystem by their conventional method interfaced to the Rpi microcontroller. The complete system is powered by a solar panel, ensuring that it continues to operate and is sustainable in problematic and less desirable places where reliable access to the power is only irregular.

The data collected is sent wirelessly (and in real-time) to remote monitoring location or cloud (server) as the GPRS (General Packet Radio Service) connectivity allows for real-time analysis of water conditions from any location. It is also possible to aid is the early detection of water contamination, thus enabling safe running water for usages like domestic, agricultural or industrial.

This project involves the successful integration of IoT (Internet of Things) technology, and renewable energy technology to develop low cost, scalable and energy-efficient environmental monitoring solution, while also addressing the touches on the principles of science environmental sustainability toward continuous solutions to development challenges such as water management and pollution control.

**Keywords**
Raspberry Pi, turbidity TDS, pH, temperature and humidity, cloud integration.

## I. Introduction

Water is one of the most essential resources, sustaining all forms of life on earth. Clean and safe water is main role for human consumption, agriculture, industry, and eco-friendly. Due to rapid industrialization, urbanization, and growth of population, our water bodies is becoming more polluted and contaminated. Declining water quality is a global challenge causing water-borne diseases and disrupting ecosystems. Continuous and pure water quality monitoring is an important step towards environment and protection of society.

Water quality monitoring employs manual sampling and laboratory testing, this are accurate but impractical for monitoring in real-time, expensive, and slow. Modern technologies including IoT solutions, renewable energy systems, and wireless communication provide beneficial solutions for automating environmental monitoring systems in real-time. The project proposed a Solar Powered GPRS Water Quality Monitoring System using Raspberry Pi. This project unique and sustainable solution for observing the water quality. It is a solar powered system, providing a continuous operation even in off grid and remote areas. It warns the use of electrical sensors to capture and monitor water quality variables such as, pH level, temperature, turbidity, and total dissolved solids (TDS). These different sensors are connected to a single Raspberry Pi and serve as a central control and processing unit.

In general, the Raspberry Pi collects and processes the sensor, and then using GPRS (General Packet Radio Service) technology, transmit the data to a cloud-based environment or web server. The user is then able to remotely monitor water quality data in real-time usages

Through the web. The project utilizes and utilizes GPRS communication rather than traditional wired infrastructure, therefore, lowering costs while also allowing for scalability and improving ease of deployment in many different environments, e.g., lakes, rivers, reservoirs, and industrial wastewater outlets.

In IoT technology and renewable solar energy enables the system to be both advanced and environmentally friendly. The system provides continuous and real-time monitoring that will help in monitoring pollution early, aiding both governments and environmental agencies in making decisions, and preventing water diseases. The system helps achieve the goals of sustainability by promoting sustainable water use and conservation.

The Solar Powered GPRS Water Quality Monitoring System implemented on Raspberry Pi provides an intelligent, eco- friendly solution for water quality issues. This solution offers the benefits of IoT-based monitoring, solar power functionality, and wireless communication in a valid, automated and sustainable way, thereby achieving improved access to clean water for generations to come.

## II. LITERATURE REVIEW

Water quality monitoring systems have made significant result of the necessity to aquatic ecosystems and public health. Researchers are exploring community-based designs to introduce affordable and highly innovative approaches using advanced methodologies such as wireless sensor networks and cloud-based data, and provide assessments of water quality indicators. In this study, we aimed to explore the significant advancements in aquaculture water quality monitoring systems, their use across ecosystems, and implications for sustainable water resources management. Through the analysis outlined, we hope to point to deficiencies in existing systems for monitoring water quality and how promising technology could be leveraged to better facilitate monitoring that is transformative and enhances efficiencies, accuracy and reliability.

The authors of interest are Hairol et al. they designed an aquaculture automation system using an Arduino Mega to automate fishponds. This system specifically highlights near real-time monitoring of critical water parameters such temperature, pH levels and dissolved oxygen levels. The implementation of this system reduced the need for human interference and was successful with improved fish welfare and production, aquaculture settings [1].

Cheng et al. introduced a functional integration system that integrates information technologies with the practice of eco-aquafarming. Another publication describes how sensor networks, accompanied by centralized processing, are used in aquaculture for the purpose of addressing issues of sustainable ecological practices while providing efficiencies in operation with new technologies [2].

Khan et al. presented a comprehensive overview of the building blocks of the Internet of Things (IoT) and applicable deployments in practice. The IoT was presented to facilitate monitoring the quality of water through improved data gathering, real-time reporting, and the capability to integrate the IoT; however challenges in its applicability, cyber security, and standardization presented themselves [3].

The researches Adu-Manu et al. studied evaluating water purity using wireless sensor network technology with an emphasis on their ability to offer real-time monitoring with convenient access and accuracy for monitoring information. The studies identified strategies for sensor placement issues, the planning of the infrastructure, and longevity of effectively monitoring live water purity. [4].

The authors Uddin et al. researched models across the world to assess the quality of global surface waters. Their interest was in identifying how Water Quality Indices effectively summarize complex water quality information and provide useful information for managing ecosystems and developing policies [5].

Kumār et al. wrote about an Internet of Things-based advanced water quality monitoring platform for pond management. The proposed device was integrated with multiple detectors, moisture permits to a remote server supports data storages of information, and calculation methods targeting ecological conservation activities. Lao's research documented improved water cleaning methods coupled with improved conservation practices using Internet of Things technology [6].

In an investigation by Manoj et al., low-cost technologies were studied that engaged Internet-of-Things practices combined with sensors engaged for monitoring aquatic conditions of the ecosystems of pond watersheds. Advanced methods, innovations in sensors and Internet of Things protocols for automation of observation measures without compromising accuracy and efficiency cost, were considerations [7].

In the study with Lambrou et al., a cost-efficient sensing framework was developed for real-time observation and detection of contaminants in publicly accessible water sources. The obtaining factors of cost-efficient, reliable, and scale-able were highlighted as factors to facilitate application across a larger scale in observing water quality [8].

In the study engaged by Bandes et al., an economical sensing system was highlighted for ongoing monitoring of water purity. The planned observations included real-time monitoring of parameters such as pH level, temperature, and turbidity value that would alert changes in the conditions of the water within the basin [9].

Lucio and others wrote upon IoT-based floating sensors to carry out crowd-sourced data on coastal marine ecosystem systems. A study was performed that investigated the utilization of sensors installed on drift items coupling to data analysis tools to improve the accuracy of water quality readings of purity as well as timing of environmental monitoring in aquatic systems [10].

The researchers in this article were Mo et al. developed an automated monitoring system to assess water quality with the incorporation of cellular networks. There was a way for remote monitoring of water status offered, giving real-time alerts of any differences in water quality that occurs in real time [11].

The authors Jan and others examined smart wastewater quality monitoring devices that incorporated IoT for use in residential settings. They provided an overview of the state of existing methods, developments, and challenges in terms of sensors, network protocols, and reasonable engineering tools for deployment in residential water quality management systems [12].

Researchers Al-Khashab et al. ran a smart city initiative, which installed a water quality monitoring network powered by the Internet of Things in Mosul to provide continuous measurements for healthful supplies. The study highlighted issues regarding handling "municipal wastewater," and larger public health consequences [13].

Authors Chowdhury et al. developed an Internet of Things-based continuous monitoring to enable real time assessment of river water quality. The system provided constant monitor of a selection of environmental indicators, critical water quality attributes like pH, temperature and turbidity and useful for conservation-related research [14].

A framework presented an Internet of Things-enabled water quality monitoring platform integrated to an Android application to provide real time, user friendly evaluation of water parameters through mobile phones. The application provided a simple dashboard to user interface and simple access through mobile networks [15].

Passa and Ganda have developed an IoT-enabled smart water quality monitoring device that is economically viable. Their focus was on keeping it low-cost to enable prompt installation and to provide continuous current information about monitoring water resources for households and businesses [16].

The work was done by Wang et al. who developed an environmental monitoring device that was self-contained, mobile sensing nodes to measure aquatic health in real time. This system has a baseline infrastructure for continuous and dispersed monitoring of aquatic health, and is flexible and adaptable to existing telecommunication [17].

They examined seven Water Quality Indices (WQIs) in a Mediterranean stream. Their study demonstrated the capability of Water Quality Indices to effectively assess aquatic health and subsequently ascertain informed decision making processes [18].

Silva et al. studied technological advancements related to both remote and automatic systems for monitoring water quality. They researched sensor methodologies; the Internet of Things; and real-time data capture to provide one option for sustainable water management systems [19].

Amruta and Satish designed a sustainable water health tracker from solar energy through wireless sensor networks technology. This research highlighted a combination of renewable energy technologies to ensure independent monitoring of water bodies and indicated ecological benefits [20].

## III. METHODOLOGY

### A. Existing Methodology

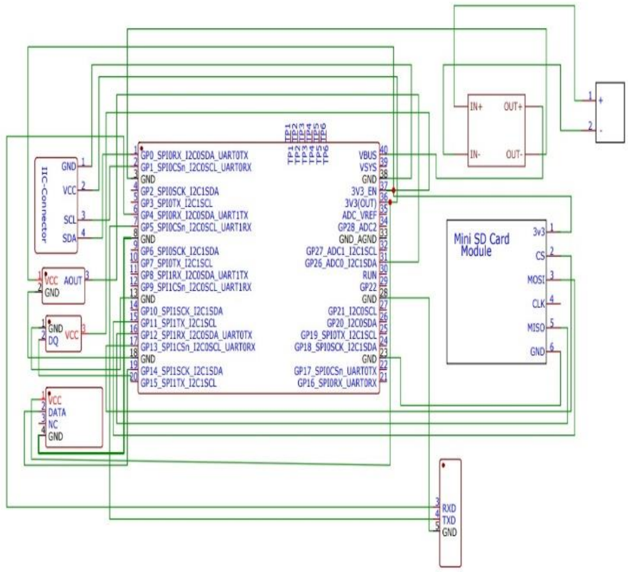
The existing methodologies for monitoring water quality rely on a manual and laboratory-based process for analysing water samples. An operator takes samples from water bodies, such as rivers, lakes, ponds and industrial waste and transports to a laboratory for physical and chemical change of pH, turbidity, humidity, temperature and total dissolved solids (TDS). This approach provides accurate data, it is time-consuming, labour intensive and not suitable for real-time monitoring. Most existing systems are also reliant on wired electricity and an operator. Continuous monitoring will be problematic at remote or rural locations where there is electricity and infrastructure to support conventional systems. By the time of analysis is completed, the water can changed and may lead to delays in detecting pollution or response to contamination events. As a result, systems are inadequate for facilitating timely decision making or correct action.

Semi-automated systems developed with microcontrollers and sensors are available currently but do not have real-time monitoring and data features. The sensor data is either presented locally on an lcd screen or stored on a memory card so that the drive to the location is still required to capture the data. There is no process in place to automatically transmit the readings to a remote monitoring station or cloud system. Additionally, these systems rely on standard electricity for power rather than renewable energy power sources. Consequently, they lack efficiency and cannot maintain continuous operation in either an outdoor area or an off-grid scenario. The lack of wireless transmission features along with renewable energy support is, in essence, a barrier to utilizing existing systems for long-term, large-scale environmental monitoring projects. Therefore, it can be stated that existing systems lack fully automated, real-time, energy-efficient, and remote access capabilities for continuous monitoring of water quality in an outdoor setting. The limitations indicate the need to develop a better, sustainable, and intelligent system that uses iot technology, solar energy, and GPRS communication to alleviate the limitations of current system.

### B. Proposed Methodology

The Solar-Powered GPRS-Enabled Smart Water Quality Monitoring System using Raspberry Pi. To provide an effective, cost-effective and labour intensive method to monitor water quality in real time for effective water management. The system provides continuous monitoring of water quality parameters, such as turbidity, Total Dissolved Solids, pH, temperature, and humidity, which are critical to the health of aquatic systems and the absolute safety of water. This system provides a modern solution using technology such as wireless transmission of data and solar power, minimizing a human-centred approach while establishing operational efficiency and sustainability. The first phase of the methodology consists of the installation of several sensors to obtain real-time water quality data. The main sensor devices of turbidity, TDS (Total Dissolved Solids), and pH will measure water clarity, chemical constituents, and acidity, while temperature and humidity sensors will measure the external effects on water quality.

The sensors will run simultaneously in order to establish comprehensive conditions of the water at different locations in the pond. The data gathered will be sent to the Raspberry Pi 2040 microcontroller, which will provide a computer unit that uses sensor data, conducts real-time processing, and communicates the information using GPRS (General Packet Radio Service), which in allows for the seamless transfer of data from the pond to the cloud for analysis and remote monitoring.




Circuit Diagram

The system has been calibrated extensively to ensure precision, while also minimizing the sensor errors that can be problematic in conventional methods of water monitoring. Sophisticated filtering processes are used to improve the quality of the data, minimizing the variance, and delivering precise measures. This automated system provides a more consistent, more scalable option than time-consuming manual sampling methods, which are prone to errors. The system has been deployed in a network of ponds in southern Tamil Nadu to test the effectiveness of the system in a real-world scenario. The system measures and produces real-time monitoring information for anticipate and proactive management of water. The system represents an innovative solution state of the sensor technologies powered by solar and cloud storage infrastructure to deliver sustainable and solutions for water quality maintenance and aquatic ecosystem with real time preservation.

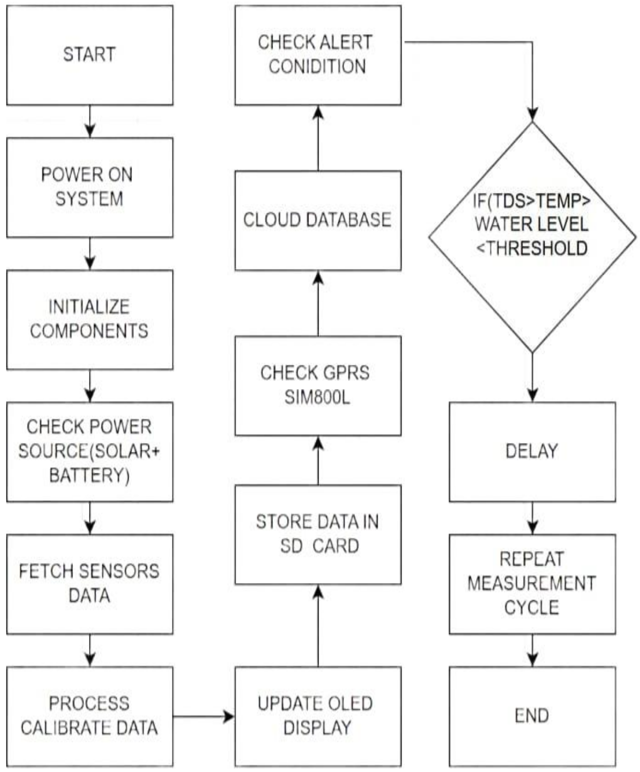



Fig 1: Flow diagram

Figure 1

Raspberry Pi is real-time and remote monitoring of water quality analysis. The system operates the energy collected by a solar panel is power the system; the battery maintains the system operation. After powered on, the Raspberry Pi turns on all components and check the system has a sufficient power supply. The Raspberry Pi receives a sensor readings from all sensors; most devices include a Total dissolved solids sensor, temperature sensor, humidity and water level detector. After receiving readings, all sensor readings are processed to ensure accuracy, and a real time process takes place to give the system the correct readings. The processed readings are displayed on an OLED screen for local, real-time display. Data is recorded on an SD card for storage and data in offline. Next, the system checks for GPRS connected to the SIM800L module, which allows for data transfer to a cloud address. The data sent to the cloud server can be accessed remote monitoring. As a result, the user can monitor the water conditions in anytime. The system checks if any of the values it is monitoring exceeds that are already determined. For example, if excessive TDS, excessive temperature, or low water level conditions arise in the water, the system gives an alert. The alerts can send a signal to the user informing them, thus preventing possible health hazards or environmental situations. The system goes into a short delay/wait period if health or environmental hazards do not arise to monitor the water conditions again.

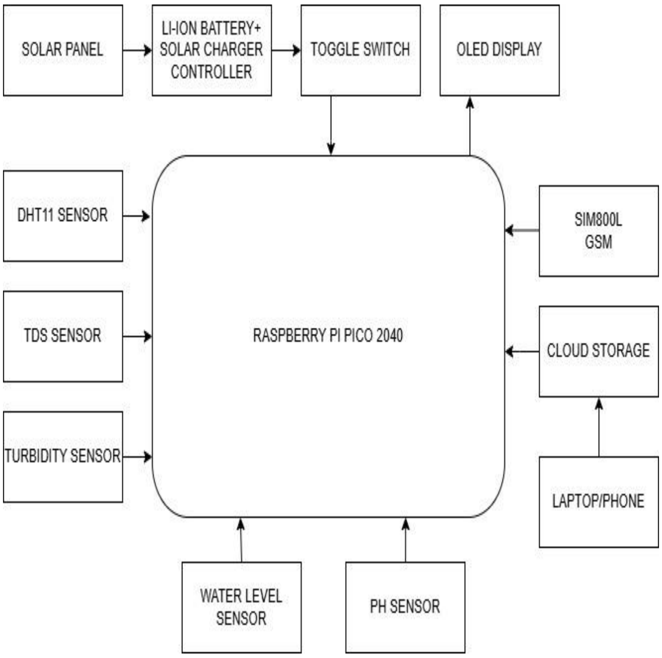



Fig 2. Structural diagram

Figure 2

Shows the structural diagram for the Solar Powered GPRS-Enabled Smart Water Quality Monitoring System, which uses a 6V/3W solar panel for sustainable energy to supply power for the system operation in remote areas. The TP4056 charger module is included to charge and control the charging of a 3.7V Li-ion battery that powers the entire system. The toggle switch is provided to control the power of the system manually and to turn the system on and off as needed. The data collected from the sensors are sent using GPRS technology and can be accessed by a web page or mobile app to remotely access the data from anywhere in the world, assuming internet connection is available. Results and Discussion. The Solar Powered GPRS Water Quality Monitoring System using Raspberry Pi was designed, implemented, and ultimately tested to provide performance of real-time water quality monitoring using IoT technology. The prototype was designed to employ multiple sensors, including pH, TDS, Turbidity, and Temperature sensors, with the use of a Raspberry Pi microcontroller integrated all of sensors and data into Raspberry pi Pico 2040. Powering the system is a solar panel that is connected with a rechargeable battery that allows for continuous operation for any outdoor use where an outlet may not be available. It can be powered by solar charger controller combo, making it viable for off-grid or remote applications solar charger controller combo Data collected from the sensors can be displayed on an OLED display, while a SIM800L GSM module can transmit this data to a cloud storage application in order to monitor from a phone or laptop remotely. This type of setup could be very useful for monitoring water quality in lakes or rivers or at water treatment plants because of the remote or off-grid abilities and real-time monitoring system can provide.

## IV.COMPARISON TABLE

| PARAMETER | ARDUINO UNO, ESP32 | RESPBERRY PI PICO (2040) |
|---|---|---|
| DEPLOYMENT MODEL | Manual spot sampling at fixed intervals. | Remote-autonomous stations; plug-and-play field nodes. |
| POWER SOURCE | Grid power or battery is replaced periodically. | Solar panel, Li-ion battery with charge controller. |
| SENSORS | Usually 2-3parameters per sample (pH or TDS). | Integrated sensors: pH, humidity,turbidity, temperature. |
| SAMPLING RESPONSE | Intermittent(daily/weekly) | Continuous/programmable. |
| DATA ANALYSIS | Manual data entry or periodic uploads. | Automatic push to cloud over GPRS (sim800l) with local SD backup. |
| LOCAL DISPLAY& ALERTS | No local immediate alerts. | OLED/local display + configurable SMS/email/phone alerts. |
| COST | Lower per–sample cost but higher operational cost. | Higher initial hardware cost per node, lower recurring manpower costs. |
| RESPONSE TIME FOR INCIDENT | Slow depends on the samples schedule and lab turnaround | Fast-immediate alerts enable timely mitigation |

## V.RESULT AND DISCUSSION

### 1. Sensor Output Observation

During testing, the sensors produced more stable and accurate readings across different water samples such as tap water, pond water and bore well water. The system effectively captured real-time variation, validating the accuracy of the sensor used in experimental setup.

Typical results are shown below:

| Parameter | Tap Water | Pond Water | Borewell Water | Acceptable Range |
|---|---|---|---|---|
| pH Value | 7.0 | 6.2 | 7.4 | 6.5 – 8.5 |
| Turbidity (NTU) | 1.5 | 2.6 | 4.2 | 0 – 10 |
| TDS (ppm) | 220 | 720 | 350 | < 500 |
| Temperature (°C) | 28 | 30 | 27 | 20 – 35 |

Show that tap water is within acceptable levels for all parameters, whereas pond water had high turbidity and TDS levels which indicate contamination. The bore well water exhibited moderate TDS, which is deemed acceptable for household use. These values were corroborated with manual measurements with standard laboratory instruments demonstrating that the sensor system is valid.

### 2. Real-Time Data Analysis

The system sent a data to the cloud every 30 seconds to the GPRS module. The data were displayed on a web dashboard with appropriate time stamps, providing a graph for each parameter. GPRS communication allowed remote display of data and enabled users to check the water quality remotely, from any device with internet access. The data visualization included plotted line graphs to show the pH, TDS, and turbidity changes over time, which was helpful in quickly seeing abnormal changes in water characteristics. The fluctuation of the parameters was easily seen in the graphs when different water samples were tested and confirmed sensitivity in the system.

### 3. Solar Power Performance

The solar energy system performed well during the real time monitoring, charging the battery to power the sensors and the Raspberry Pi continuously. Even in low conditions, the energy stored in the battery operate the system for over 7 hours without sunlight. This demonstrates that the system is self-sufficient and can be used in rural or urban areas there is no access to connect electricity.

### 4. System Reliability and Response Time

The average sensor response time was less than 4seconds, provide real-time monitoring. The GPRS module required approximately 3–4 seconds for data transmission and cloud storage, which is update for continuous environmental monitoring applications. The Raspberry Pi efficiently handled data processing, storage, and communication without system reliability.

### 5. Discussion

The experimental results developed a system effectively measures the essential real time water quality parameters and transmits. The integration of solar energy eliminates dependency on conventional power supply, promoting water monitoring.

The readings obtained closely with laboratory standard, indicating correct sensor calibration and measurement error. The minor variations observed may result from sensor drift or environmental sustainability, which can be minimized through periodic results and use of high-precision sensors.

Compared to existing manual and semi-connected systems, the proposed design provides more advantages:

- **Continuous real-time monitoring** instead of periodic analysis.
- **Wireless data transmission** through GPRS for remote accessibility.
- **Low maintenance cost** and easy scalability for large-scale deployment.

VI.ANALYSIS

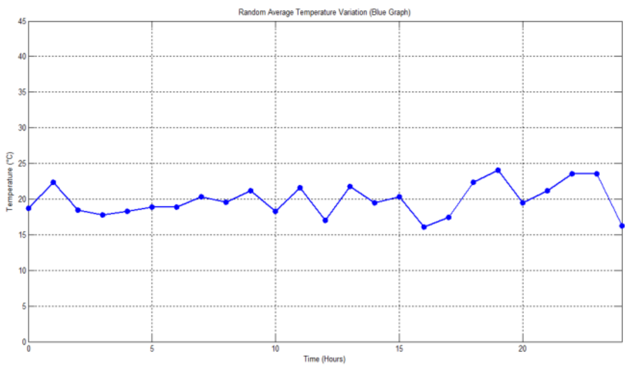



Fig 1.Average temperature

The figure 1 displays changes in average temperature during 24 hours, recorded with a sensor connected to the Raspberry Pi. Data was collected and sent data through the GPRS module. The temperature varies from 17°C to 23°C, day to night real time analysis. Monitoring temperature indicates environmental conditions which can impact water quality. The system is powered through solar energy for use in remote locations.

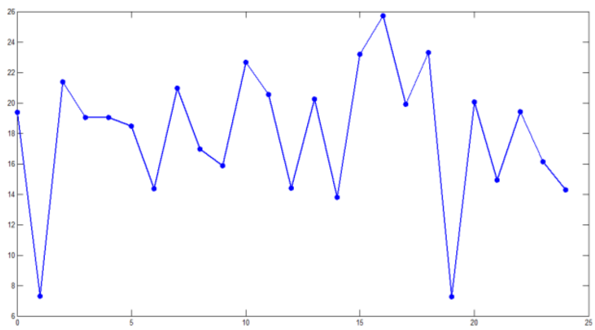


Fig 2.Average turbidity

The figure 2 shows the average turbidity levels observed by a Raspberry Pi-based solar-powered GPRS water quality monitoring system. Turbidity is a measure of how cloudy or clear the water is, demonstrated by a considerable variability in the observed data, ranging approximately from 7 NTU to 26 NTU. This flux indicates changing water quality in real-time, possibly due to environmental factors such as rainfall, surface runoff, or stream of pollutants.

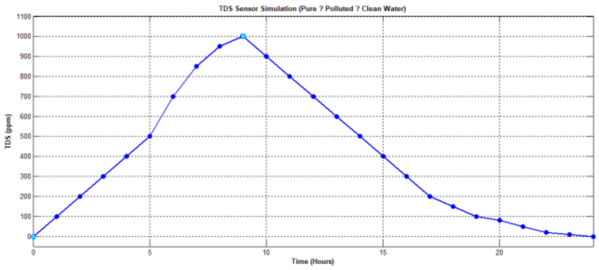



Fig .3 Maximum and Minimum of TDS

The figure 3 displays the continual increase in Total Dissolved Solids (TDS) over a 24-hour period collected via a solar powered GPRS water quality monitoring system based on a Raspberry Pi. The TDS started at a little less than 10 ppm at hour 0, peaked at 1000 ppm at hour 9, and then returned back down to about 10 ppm by hour 24 and gave the impression of a continual eventual decrease back to clean water. The patterns of TDS accumulation could simulate a typical cycle of water pollution i.e., the continuous accumulation of sedimentation into water and the subsequent natural or man-made purification processes.

## VII. Conclusion

Water is a necessary resource for all living organisms, and water quality affects health, environment, and economy for every nation. With industrialization and urbanization happening to a continuously increasing extent around the world, water pollution has become a serious issue. Therefore, it has become globally important to develop a water quality monitoring system that is efficient, reliable, and capable of real time results. The developed Solar Powered GPRS Water Quality Monitoring System (using Raspberry Pi), fulfils this need by fusing the best of IoT technology, renewable solar energy, and wireless communication into one sustainable product.

This project explain a novel approach to environmental monitoring through the automation of water quality measurement and reporting. The system successfully measures parameters including pH, Turbidity, Total Dissolved Solids, and Temperature, all of which are important sensors of water quality. The stored cloud data is processed through the Raspberry Pi microcontroller, which acts as the primary controller and communication gateway. The use of a GPRS module, the system will send real-time data to an online cloud storage, so users can monitoring water quality measurement through an online application or smart phone.

By utilizing solar energy, the system can run regularly and independently, which makes the system suitable for use in urban off-grid rural locations that do not have power supply. This develops sustainability and decreases maintenance costs and environmental harm and represents an adequate solution for rural water management, agriculture, wastewater monitoring in factories, and conservation efforts. Analysis of experimental results indicates reliable sensor readings with minor error rates compared to laboratory measurements of standard. Data transmission through GPRS was stable, and the solar energy means was efficient in sustaining a continuous operation. These findings indicate that it is feasible and efficient to combine renewable energy with an IoT based monitoring framework.

In a wider perspective, this project supports the development of smart environmental monitoring systems while advancing sustainable development objectives, promotes the adoption of green technology, and supports data-oriented approaches to the management of natural resources. The project is scalable, and extensions can be done to monitor multiple water bodies or expand with sophisticated analytics using predictive capacities for pollution detection and alerting. However, like any technology, there is always room for enhancement. Future developments of this project may consider integrating additional sensors like PH, temperature,TDS and humidity, forecasting water quality using machine learning algorithms, and a hybrid technology approach for communication.AI-based data analysis will also enable good maintenance and early warning systems for  detection. In summary, the Solar Powered GPRS Water Quality Monitoring System using Raspberry Pi is an labour intensive, low-cost, and sustainable technology that connects the gap between advanced technology and environmental sustainability. By allowing the real-time, data, and energy-efficient monitoring of water quality parameters, it contributes to a safe and clean environment with safe drinking water and quality management.

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