International Journal of Inventive Engineering and Sciences (IJIES)
ISSN: 2319-9598 (Online), Volume-13 Issue-6, June 2026

The IoT- Based Rural Water Supply Management System

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Abstract: ***The IoT-based Rural Water Supply Management System in this paper aims to automate water monitoring, water quality assessment, and water distribution to ensure safe supplies and minimise wastage. The system that monitors water levels and purity uses an ESP32 microcontroller, an ultrasonic sensor, and a water-quality sensor. The Flow Sensors regulate distribution via relay-controlled valves, and the Blynk app provides real-time monitoring with SMS alerts and user notifications. The solution promotes water conservation, saves labour, and maintains water management in rural areas.***

Keywords: IoT, Water Level Monitoring, Smart Water Distribution, ESP32, Ultrasonic Sensor, Water Quality Monitoring, Flow Sensor, Blynk App, Automated Water System.

Nomenclature:

TDS: Total Dissolved Solids

I. INTRODUCTION

Effective water management is crucial for sustaining rural communities, where access to clean water is essential for daily living, agriculture [7], and public health [4]. However, traditional rural water supply systems are often inefficient, relying on manual monitoring and distribution [8]. This can lead to problems such as water overflow, wastage, inconsistent supply, and poor water quality [5]. The absence of automation and real-time monitoring makes it difficult to ensure a reliable and safe water supply in these regions [6].

To address these challenges, this project introduces an "IoT-based Rural Water Supply Management System" that automates the entire process of water monitoring, quality assessment, and distribution. The primary objective is to ensure efficient water usage, reduce manual effort, and guarantee the delivery of safe water to rural households. The system is built around the ESP32 microcontroller, which serves as the central processing unit, collecting data from sensors and executing control actions. An ultrasonic sensor is used to measure the water level in the main tank and prevent overflow. TDS (Total Dissolved Solids) sensor measures the concentration of dissolved substances to determine portability; the turbidity sensor checks for suspended particles, indicating clarity and cleanliness; the pH sensor ensures the water's acidity or alkalinity is within a safe range; and the temperature sensor monitors water temperature, which can affect its usability and safety. At the same time, relay-controlled valves help direct water to the respective tanks. To make the system user-friendly and accessible, it integrates with the Blynk IoT mobile application, which provides real-time monitoring and control. Users can view tank levels, water quality readings, and control water flow remotely. Additionally, SMS alerts are sent to users when the water supply begins and when their respective tanks are filled, ensuring communication even without internet access.

This automated system enhances water conservation, ensures distribution of safe water and reduces dependence on manual supervision. It offers a scalable and sustainable solution tailored for rural environments, where reliable and smart water management is critically needed

II. LITERATURE SURVEY

Let us now discuss some significant contributions in the existing literature addressing this domain. Several researchers have explored various approaches to tackle similar challenges, as outlined below.

Sreekanth Narendran et al. [1] proposed an IoT-based system to enhance rural water supply management by automating tank-level measurement, leakage detection, and pump control to achieve efficient water distribution. The system employed ultrasonic sensors for water level measurement, flow sensors for leak detection, Raspberry Pi and Arduino microcontrollers for processing, and GSM modules for communication. Although efficient at controlling and monitoring the water supply, the system lacked water-quality evaluation capabilities and mobile app integration.

Abdulwahid et al. [2] introduced an IoT-based water supply system that supports remote valve operation via a mobile app, with a primary emphasis on control and automation rather than monitoring. The approach used solenoid valves for water flow control, GSM modules for communication, and Arduino microcontrollers for system control, with simple sensors to monitor water availability. While the system successfully provided remote

Manuscript received on 18 March 2026 | First Revised Manuscript received on 02 April 2026 | Second Revised Manuscript received on 24 May 2026 | Manuscript Accepted on 15 June 2026 | Manuscript published on 30 June 2026.

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access and manual override, it lacked real-time monitoring of water level or quality, which made it less useful for holistic rural water management.

Tangoi et al. [3] have presented an IoT system intended for rural and urban communities that utilises sensors to measure water levels, pressure, and flow through pipes. These data are processed and communicated via wireless communication modules, such as Wi-Fi or GSM, to a central server, enabling real-time monitoring and control via web and mobile apps. The system uses flow, pressure, and water-level sensors, along with microcontrollers, to process data and make decisions. Yet the system does not include water quality monitoring functions, such as pH or turbidity measurements, which limit its efficiency in rural settings.

Based on the earlier journals, a few important aspects are still missing:

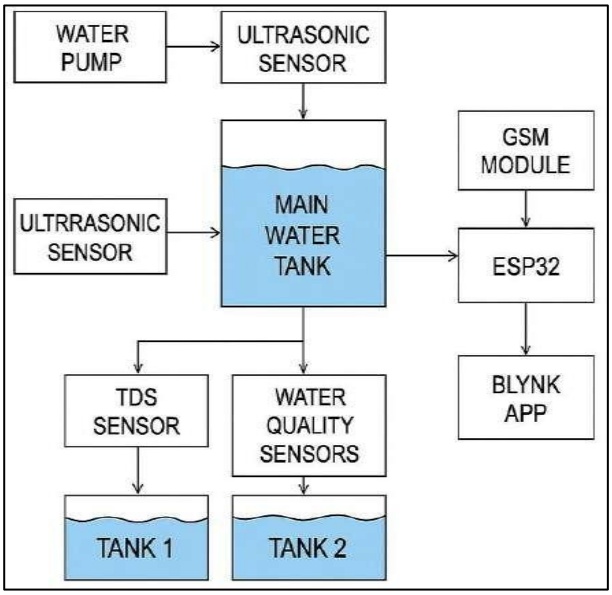
- They do not include water quality checks like pH or turbidity.
- Real-time updates and live monitoring features are missing.
- Mobile apps are not used.
- Most systems focus more on automation than full monitoring.
- They did not fully meet the unique needs of rural areas, like detecting contamination or supply issues.

To solve these problems, our project includes both water quality and quantity monitoring, real-time data access and a mobile app for easy control and tracking, making it more useful for rural water supply management.

III. PROPOSED METHOD

The proposed system is designed to manage water resources efficiently using an ESP32 microcontroller. It monitors the water level in the Main Water Tank, assesses water quality and automatically distributes water to Tank 1 and Tank 2. The system uses ultrasonic, TDS, turbidity, pH, and temperature sensors, as well as relay-controlled actuators. Real-time data monitoring and control are enabled via the Blynk mobile application.

A. Block Diagram



[Fig.1: Block Diagram for Water Management Supply System]

The Block diagram Fig. 1 illustrates the overall structure and data flow of the smart water management system. The system starts with a water pump that fills the main water tank, where an ultrasonic sensor measures the water level. Another monitors the water flow from the main tank. As water exits the main tank, it passes through sensors for TDS, turbidity, pH, and temperature to check parameters such as purity and contamination. Based on these results, the water is directed to Tank 1or Tank 2. All the sensor data is collected and processed by the ESP32 microcontroller. The GSM module then sends this data to the cloud, enabling remote access. Users can view the system's real-time status and control it through the Blynk mobile application.

B. Software Setup

The software component, which has been fully implemented, consists of firmware programmed on the ESP32 using the Arduino IDE software. It includes:

- Integration of sensor libraries.
- Sensor calibration logic.
- Relay control sequences for tank filling and distribution.
- Threshold logic for water level and quality decisions.
- Data transmission to Blynk for real-time visualization and alerts.

```
Start
↓
Read Sensors
↓
Is Water Level<Threshold?
├─Yes→ Start Pump
└─No→ Stop Pump
↓
Check Water Quality
↓
Is Water Quality Safe?
├─Yes→ Start Distribution
└─No→ Trigger Alert
↓
Update Blynk Dashboard
↓
Loop
```

[Fig.2: Flow Chart of the Smart Water Management System]

As shown in Fig. 2, the system starts by reading sensor data. If the water level in the main tank is below the threshold, the pump is started. When the threshold is reached, the pump stops, and water quality parameters are checked. If the water is deemed safe, it is distributed to Tank 1 and Tank 2. Otherwise, an alert is triggered. All data is updated in real-time on the Blynk dashboard.

C. Planned Hardware Setup

The hardware setup (to be implemented) will include wiring all sensors to the ESP32, configuring relays to control the water pumps and ensuring safe power distribution Fig. 3.

Retrieval Number: 100.1/ijies.E123915050426
DOI: 10.35940/ijies.E1239.13060626
Journal Website: www.ijies.org

Published By:
Blue Eyes Intelligence Engineering and Sciences Publication (BEIESP)

International Journal of Inventive Engineering and Sciences (IJIES)
ISSN: 2319-9598 (Online), Volume-13 Issue-6, June 2026

Start Hardware Setup
↓
Connect Power Supply (Regulated 5V/3.3V)
↓
Initialize ESP32 Microcontroller
↓
Connect Sensors to ESP32
├─HC-SR04→Water Level: Main Tank
├─YF-S201→Flow Rate Measurement (Tank 1&2)
├─TDS Sensor→ Water Quality (TDS)
├─Turbidity Sensor →Water Clarity
├─pH Sensor→ Acidity/Alkalinity
└─DS18B20→WaterTemperature
↓
Connect Relay Modules to ESP32
↓
Relays Control Water Pump(s)
↓
ESP32 Sends Data to Blynk Dashboard
↓
End Hardware Initialisation

[Fig.3: Planned Hardware Architecture]

D. System Operation Logic

The system functions in the following stages:

E. Tank Filling Logic

The ultrasonic sensor Fig. 4 in the main tank continuously monitors the water level. If the level drops below 70cm (e.g.), the relay activates a pump to start filling. The pump stops once the level reaches a certain level.

[Fig.4: Ultrasonic Sensor]

F. Water Quality Check

After filling, the system initiates a water quality test using a TDS sensor, a turbidity sensor Fig. 5, a temperature sensor, and a pH sensor. If any parameter exceeds its threshold, a buzzer alerts and water distribution is halted.

[Fig.5: Turbidity Sensor]

G. Water Distribution Logic

If the water is deemed safe, the system activates two relays to distribute water to Tank 1 and Tank 2, with each monitored by flow sensors to prevent overfilling.

H. Blynk Integration

i. All sensor values, pump/relay statuses and alerts are sent to the Blynk application for remote monitoring and control.

ii. A mock interface showing real-time tank levels, sensor values and system status.

Table I: Sensor Specification

Sensor Type	Model	Measurement Range	Accuracy	Purpose
Ultrasonic Sensor	HC-SR04	2 cm – 400 cm	±3 mm	Water level monitoring
Flow Sensor	YF-S201	1 –30L/min	±5%	Distribution flow monitoring
TDS Sensor	Gravity TDS003	0–1000 ppm	±1%	Total dissolved solids measurement
Turbidity sensor	SEN0189	0–1000NTU	±2 NTU	Water clarity measurement
Temperature Sensor	DS18B20	55°C–+125°C	±0.5°C	Water temperature monitoring
pH Sensor	Gravity PH2001	0–14 pH	±0.1pH	pH level measurement

Table 1 presents the technical specifications of the sensors used in the smart water management system. This includes the operating voltage, measurement range, and purpose of each sensor, such as water level, flow rate, TDS, turbidity, pH, and temperature.

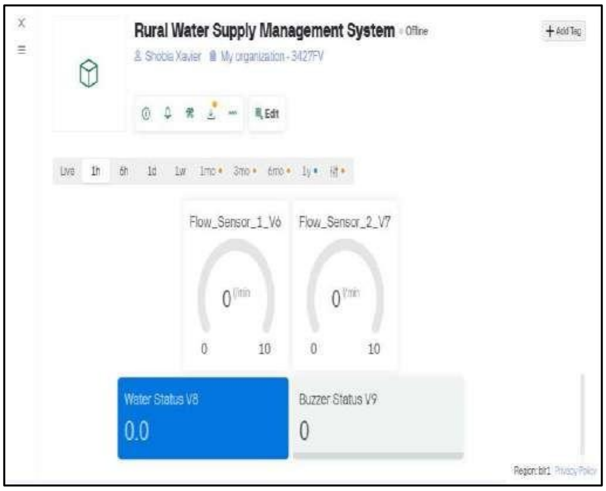
Table II: Summary of the Methodology

Stage	Action
Software Initialization	Load libraries, connect to Blynk, Initialize pins and thresholds.
Water Level Monitoring	UseHC-SR04to start/stop the pump.
Water Quality Evaluation	Read from TDS, pH, turbidity, and temp sensors.
Safety Decision	Block or continue based on sensor values.
Controlled Distribution	Use relays and flow sensorsforTank1and Tank 2
User Feedback	Send data to Blynk, activate the buzzer if unsafe.

Table 2 provides an overview of the hardware components integrated into the system. It includes microcontrollers, sensors, relays and power modules, detailing their role and functionality within the proposed architecture.

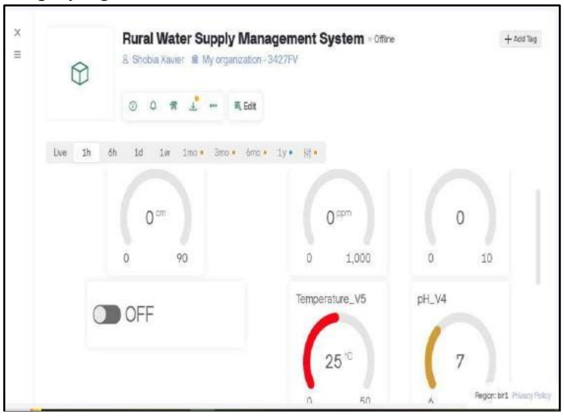
IV. RESULTS AND DISCUSSIONS

The IoT-based Rural Water Supply Management System has been successfully programmed using the Arduino IDE on a Windows 10 operating system with an Intel Core Processor. Simulations have shown that the system can collect data from various sensors, including ultrasonic, TDS, turbidity, pH, and temperature sensors. The system outputs these readings to the Blynk app, allowing real-time monitoring of water levels and quality. Although not yet fully implemented, these results demonstrate the system's potential to automate water management effectively.



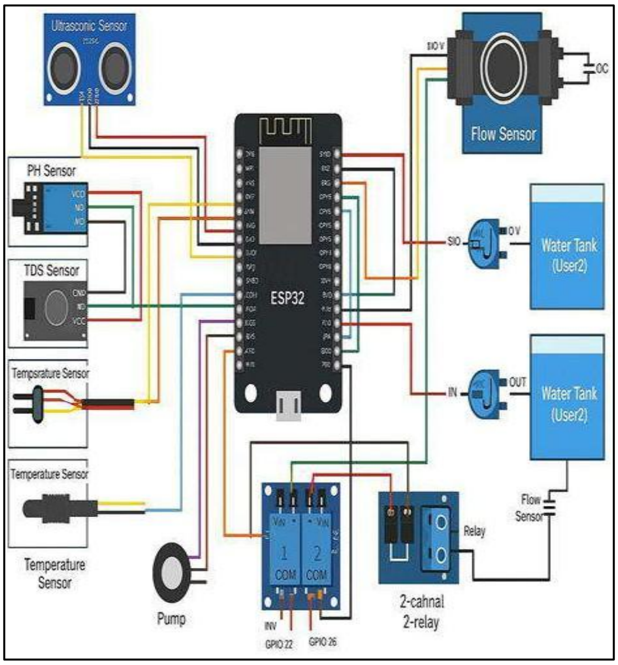
[Fig.6(a): Blynk app Dashboard]

In Fig. 6(a), the dashboard diagram shows gauges representing flow sensors 1 and 2, the water flow rate in litres/minute, and the LCD displaying the water level and buzzer status.



[Fig.6(b): Blynk app Dashboard]

In Fig. 6(b), the dashboard shows gauges for temperature, TDS, pH, and turbidity, as well as water-level sensors indicating the level in the main water tank. On/Off buzzer to shut off the motor in case of difficulty.



[Fig.7: Circuit Diagram for Planned Hardware Setup]

In this circuit, Fig. 7, various sensors and modules are connected to specific GPIO pins of the ESP32. The ultrasonic sensor is connected to digital pins to trigger and receive echo signals. The pH sensor, TDS sensor, and temperature sensors are connected to the analogue input pins to read their values. The flow sensor outputs pulses and is connected to a digital pin to count the flow rate. The relay module is connected to GPIO pins GPI026 and GPI027, which control the pump and water flow to different tanks. The ESP32 collects all sensor data and controls relays based on programmed logic, allowing automated operation.

V. CONCLUSION AND FUTURE SCOPE

The IoT-based Rural Water Supply Management System is designed to introduce smart automation to water monitoring and distribution, particularly in rural areas where manual management is still common. The system is developed using the Arduino IDE. It integrates multiple sensors, including ultrasonic, pH, TDS, temperature, and flow sensors, to monitor parameters such as water level, quality, and flow rate. These sensor readings are processed by the ESP32 microcontroller and transmitted in real time via the Blynk mobile application, allowing users to view and control system operations remotely from any location. This reduces the need for constant human supervision and minimises the risk of water waste, overflows, or unnoticed contamination. By automating both data collection and water distribution using relay-controlled pumps and valves, the system ensures a more reliable and efficient water supply. While full-scale deployment and field testing are not yet complete, the initial prototype results demonstrate the system's potential to transform rural water management through cost-effective, user-friendly IoT technology.

Future improvements include integrating a GSM module for better communication, solar panels for energy independence, a camera module for visual monitoring and a water pressure sensor for regulated flow, further enhancing the system's functionality and scalability in rural areas.

DECLARATION STATEMENT

After aggregating input from all authors, I must verify the accuracy of the following information as the article's author.

- **Conflicts of Interest/ Competing Interests:** Based on my understanding, this article has no conflicts of interest.
- **Funding Support:** This article has not been funded by any organizations or agencies. This independence ensures that the research is conducted objectively and without external influence.
- **Ethical Approval and Consent to Participate:** The content of this article does not necessitate ethical approval or consent to participate with supporting documentation.
- **Data Access Statement and Material Availability:** The adequate resources of this article are publicly accessible.
- **Author's Contributions:** The authorship of this article is contributed equally to all participating individuals.

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