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An Approach to Implementation of an IoT-Based Remote Water Quality Monitoring for Smart Cities

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ABSTRACT

Water is an essential resource for life, but its quality is deteriorating due to industrialization and population growth. Consuming contaminated water leads to severe health issues, necessitating efficient monitoring systems. This project presents an IoT-Based Smart Water Purity Monitoring System designed to provide a low-cost, real-time solution for water quality assessment. The system utilizes a Total Dissolved Solids (TDS) sensor to measure impurities, an Arduino UNO for data processing, and a NodeMCU (ESP8266) for wireless transmission. Data is visualized on the Blynk IoT platform, allowing users to monitor water purity remotely via a smartphone application. This automated approach overcomes the limitations of manual laboratory testing, offering a scalable solution for households and industries.

Keywords: IoT, TDS Sensor, ESP8266, Water Purity, Remote Monitoring, Blynk Cloud

I. INTRODUCTION

Access to clean drinking water is a critical global challenge. In many regions, water sources are compromised by dissolved salts, minerals, and chemicals. Traditional water monitoring methods typically involve collecting water samples and analyzing them in laboratories. Although these techniques provide accurate results, they are time-consuming, labor-intensive, and not suitable for obtaining continuous real-time data. To overcome these limitations, modern technological innovations such as the Internet of Things (IoT) have enabled remote sensing, automatic data acquisition, and cloud-based analysis [1].

To address these issues, this project leverages the Internet of Things (IoT) and embedded systems. The primary objective is to develop a system that measures the Total Dissolved Solids (TDS)—a key indicator of water quality representing dissolved inorganic salts and impurities. By integrating a TDS sensor with microcontrollers and cloud connectivity, the system ensures immediate detection of purity variations and provides remote data accessibility [2]. This solution aims to be energy-efficient and scalable, suitable for smart homes, agriculture, and industrial water testing.

The water quality monitoring system offers several significant advantages. It provides real-time monitoring, allowing users to receive instantaneous readings without any delay. Through remote accessibility features, the system can be monitored from anywhere using a smartphone, making it highly convenient [3]. It is also cost-effective since it uses inexpensive and easily available components such as Arduino and TDS sensors. The automation capability removes the need for manual sampling and data recording, ensuring consistent and accurate measurements. Additionally, it enhances health safety by enabling early detection of water contamination, which helps prevent potential health risks.

This system can be applied across various fields due to its versatility and reliability. In drinking water monitoring, it is useful for homes, hostels, and water supply departments to ensure safe consumption. Industries such as pharmaceuticals, food processing, and chemical manufacturing can also benefit from continuous water quality assessment [4]. In the agricultural and aquaculture sectors, it helps maintain appropriate water conditions for irrigation and fish farming. Smart cities can incorporate such systems into their infrastructure for centralized monitoring of water purity. Furthermore, it contributes to environmental protection by enabling the tracking of pollution levels in rivers, lakes, and other natural water bodies [5].

II. MATERIALS (Software & Hardware)

2.1 Hardware Requirements

2.1.1 Meter Sensor: The TDS (Total Dissolved Solids) Meter Sensor is a key component used to measure the concentration of dissolved impurities such as salts, minerals, and organic matter in water. It determines the purity level by analysing the electrical conductivity of the water sample, as dissolved ions conduct electricity. The sensor converts this conductivity into a TDS value, usually expressed in parts per million (ppm), indicating the total amount of dissolved solids present [6].

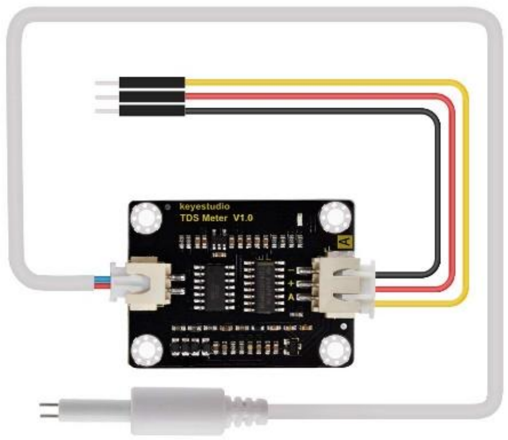

Fig. 1 TDS Sensor [7]

A higher TDS value suggests more impurities, while a lower value signifies purer water. The typical measurement range of a standard TDS sensor is 0–1000 ppm, though some advanced variants can measure up to 5000 ppm. Certain modules also include temperature compensation features to improve accuracy since conductivity varies with temperature. The sensor is compact, low-cost, and consumes very little power, making it ideal for continuous water monitoring applications. In this project, the TDS sensor plays the central role in detecting water quality. The analog signal it generates is processed by the Arduino UNO, which converts it into a readable TDS value using a predefined calibration formula. This data is then transmitted to the NodeMCU, which uploads the live readings to the Blynk IoT platform for real-time visualization. Through this process, users can remotely monitor the purity of water using their smartphones. The TDS sensor's simplicity, reliability, and easy interfacing make it an excellent choice for IoT-based smart water quality monitoring systems.

2.1.2 NodeMCU (Esp8266): The NodeMCU is an open-source microcontroller board based on the ESP8266 Wi-Fi module, widely used in IoT applications. It operates on 3.3V and features a Tensilica LX106 32-bit processor, which efficiently handles both data processing and wireless communication. The board has multiple digital I/O pins, supports UART, SPI, and I2C protocols, and can be easily programmed using the Arduino IDE. Its built-in Wi-Fi connectivity allows seamless data transmission to cloud platforms like Blynk IoT without the need for additional modules [8]. In this project, the NodeMCU serves as the IoT gateway, receiving real-time TDS readings from the Arduino UNO and sending them to the Blynk platform via Wi-Fi. This enables users to monitor water purity remotely on their smart phones. With its compact design, low power consumption, and reliable connectivity, NodeMCU is an ideal choice for smart water monitoring and other IoT-based automation projects [9].

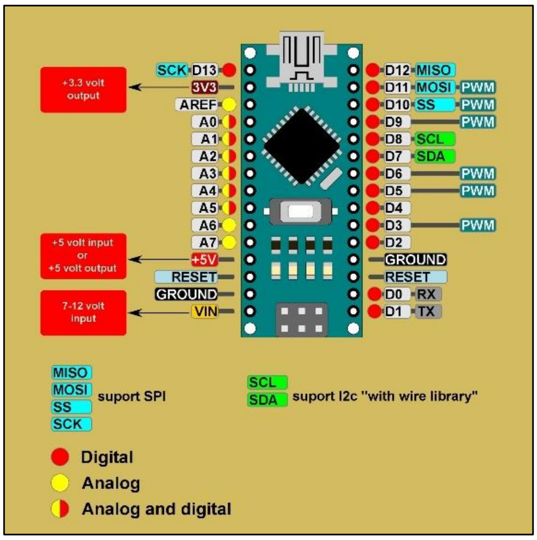

Fig. 2 Esp8266 board [10]

2.2 Software

2.2.1 Arduino IDE: The Arduino Integrated Development Environment (IDE) is an open-source software tool that provides a complete platform for developing, compiling, and uploading programs to Arduino boards and compatible microcontrollers such as Arduino UNO, NodeMCU, and others. Designed primarily for students, hobbyists, and researchers, the Arduino IDE offers a beginner-friendly programming environment while still providing flexibility for advanced embedded and IoT projects. In this Water Purity Monitoring System, the Arduino IDE plays a vital role in writing and managing the code that controls data flow between the TDS sensor, Arduino UNO, NodeMCU, and Blynk IoT platform [11]. The IDE allows precise calibration of the TDS sensor, enabling accurate conversion of analog voltage into TDS (ppm) values. The serial monitor helps in testing the sensor's output, while libraries such as ESP8266WiFi and BlynkSimpleEsp8266 areused to establish wireless communication between the NodeMCU and the Blynk server. This integration ensures smooth real-time monitoring of water quality.

Fig. 3 Arduino IDE interface [12]

2.2.2 Blynk IoT: Blynk IoT is an innovative cloud-based platform that enables users to build and manage Internet of Things (IoT) applications easily. It allows microcontrollers like NodeMCU or Arduino to connect with the internet and send or receive data in real time [13]. Blynk provides a user-friendly mobile and web dashboard where various widgets—such as gauges, graphs, and value displays—can visualize live sensor data. In this project, Blynk IoT is used to display the live TDS (Total Dissolved Solids) readings received from the NodeMCU [14]. The data collected from the TDS sensor via Arduino UNO is sent to the Blynk server, where it can be monitored through the Blynk mobile app in real time. This allows users to check water purity levels instantly from anywhere. Blynk also supports notifications and data logging, making the system smarter, more interactive, and efficient for continuous water quality monitoring [15].

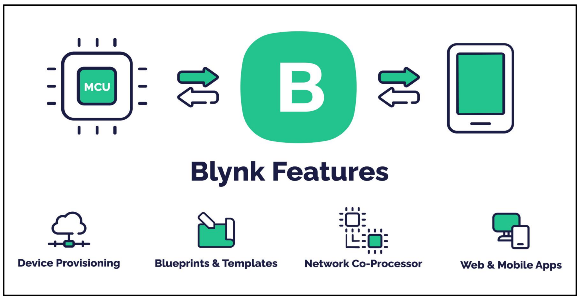

Fig. 4 Blynk IoT features [16]

III. METHODOLOGY

3.1 Objective

The primary objective of this IoT-Based Remote Water Quality Monitoring System is to design a real-time, lowcost, and remotely accessible solution for measuring water purity using a TDS sensor, NodeMCU ESP8266, andBlynk IoT Cloud. The system aims to:

- Accurately sense Total Dissolved Solids (TDS) in water using a TDS meter.
- Use NodeMCU ESP8266 as the main controller for data acquisition, processing, and cloud communication.
- Transmit purified water-quality data to the Blynk IoT cloud for remote access.
- Enable real-time monitoring, notifications, and historical tracking through a smartphone dashboard.
- Ensure a low-power, scalable, and reliable system suitable for households, industries, agriculture, and environmental monitoring.

3.2 System Design

The system design integrates sensing, processing, communication, and cloud visualization into a single IoT framework.

Key Components

- **TDS Sensor** – Measures water conductivity and determines dissolved impurities.
- **NodeMCU ESP8266** – Reads sensor values, processes TDS calculations, establishes Wi-Fi, and uploads data to cloud.
- **Blynk IoT Cloud** – Displays real-time readings through widgets, stores historical data, and sends notifications.

System Architecture Overview

1. The TDS sensor probe is placed in water to detect dissolved solids.
2. The sensor outputs an analog voltage proportional to TDS level.
3. NodeMCU reads this analog value using its ADC pin.
4. The microcontroller converts voltage into TDS (ppm) using calibration equations.
5. NodeMCU connects to Wi-Fi and uploads data to Blynk cloud.
6. The Blynk dashboard displays real-time purity level, graphs, and alerts.

The architecture avoids the use of Arduino UNO entirely and relies solely on NodeMCU for both sensing and IoT tasks, making the system more compact and efficient.

3.3 Working Principle

The system operates on two fundamental principles:

3.3.1 Electrical Conductivity to TDS Conversion

- Water with dissolved ions conducts electricity.
- The TDS sensor measures conductivity, converts it to a voltage signal, and sends it to NodeMCU.

- Higher conductivity → higher TDS → lower water purity.

3.3.2. IoT-Based Real-Time Communication

- NodeMCU connects to Wi-Fi using built-in ESP8266 communication modules.
- Processed TDS values are transmitted to Blynk Cloud using APIs.
- The Blynk dashboard updates values instantly through virtual pins.

Thus, the system continuously reads, processes, and uploads water purity data without manual sampling.

3.4 Implementation Steps

Step 1: Hardware Setup

- Connect TDS sensor's analog output to NodeMCU's ADC (A0).
- Power the TDS module using NodeMCU's 3.3V/5V output depending on sensor version.
- Ensure common GND for stable analog readings.
- Place the TDS probe in a clean water container.

Step 2: Firmware Programming (NodeMCU Only)

- Program NodeMCU using ArduinoIDE with ESP8266 board support.
- Initialise Wi-Fi credentials (SSID, password).
- Add Blynk Auth Token for cloud linkage.
- Read analog values from TDS probe.
- Convert analog sensor data → voltage → TDS ppm.
- Send the result to Blynk through Virtual Pin (e.g., V_0).

Step 3: IoT Integration using Blynk

- Create a new Blynk Template for TDS monitoring.
- Add Data Stream (Virtual Pin V0).
- Add widgets:
  - o Value Display (shows ppm)
  - o Gauge or Chart (trend analysis)
  - o Notification alerts when TDS exceeds safe levels

Step 4: Calibration & Testing

- Dip the probe in distilled/RO/tap water to compare readings.
- Adjust calibration constant for accuracy.
- Confirm stable Wi-Fi and smooth cloud updates.

Step 5: Real-Time Monitoring Deployment

- Place device near water tanks, taps, purifiers, aquaculture tanks, etc.
- Keep the probe submerged for continuous monitoring.
- Monitor data anytime from smartphone.

3.5 Block Diagram and Operation

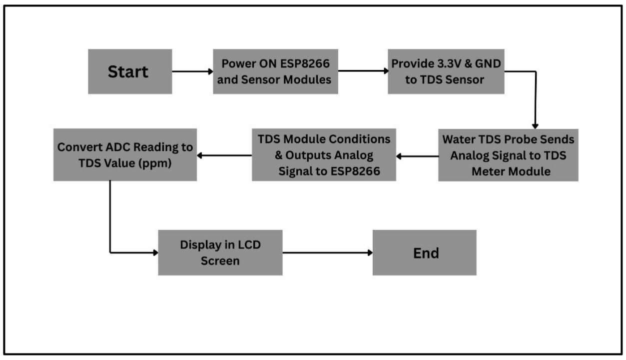

Figure 5: Block diagram

Operation Explanation

1. The TDS probe senses ion concentration in water.
2. The sensor converts this into an analog electrical signal.
3. NodeMCU reads the analog input and applies the calibration formula.
4. NodeMCU establishes Wi-Fi and sends the processed TDS data to Blynk.
5. The Blynk dashboard displays the data as numerical values and graphs.
6. Users receive push notifications if TDS exceeds safe drinking levels.

3.6 Result

After completing implementation and testing, the system successfully:

- Provided continuous real-time TDS readings without delay.
- Uploaded data to Blynk Cloud with stable communication.
- Displayed TDS values accurately in ppm on smartphone dashboards.
- Delivered instant alerts when TDS exceeded pre-set safety thresholds.
- Demonstrated consistency when tested with different water types:
  - o Distilled water: ~0–10 ppm
  - o RO water: ~20–50 ppm
  - o Tap water: ~150–350 ppm
  - o Groundwater: ~300–500+ ppm

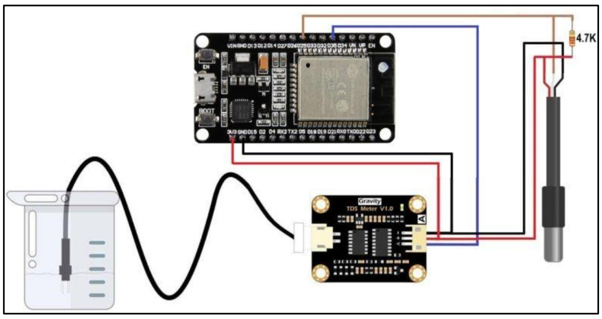

Fig. 6 Visual representation of the project

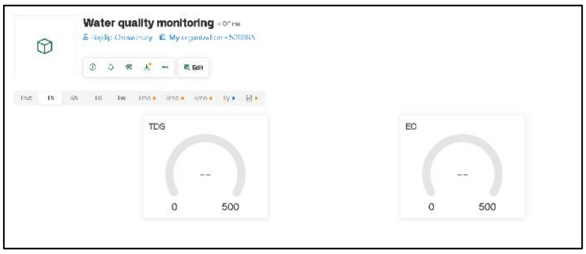

Fig. 7 Cloud interface of the project

IV. CONCLUSION

The IoT-Based Smart Water Purity Monitoring System successfully addresses the need for an affordable and accessible water quality testing solution. By automating the measurement of Total Dissolved Solids (TDS), the system eliminates the reliance on expensive laboratory equipment and manual sampling.

The integration of Arduino and NodeMCU ensures accurate data processing and reliable cloud transmission, while the Blynk platform provides a user-friendly interface for real-time monitoring. The system is highly versatile, with applications ranging from household water purifiers to industrial quality control and agricultural irrigation.

Future Scope: The system is designed to be scalable. Future enhancements could include integrating additional sensors for pH, turbidity, and dissolved oxygen to provide a comprehensive analysis of water quality. Furthermore, Artificial Intelligence (AI) could be implemented to predict contamination patterns based on historical data, and automated control mechanisms (like solenoid valves) could be added to stop water flow if impurities exceed safe limits.

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