



Cloud-Based IoT System for Real-Time Monitoring and Filtration of Industrial Wastewater for Multi-Purpose Reuse

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Abstract: Industrial wastewater containing harmful chemicals, heavy metals, and suspended solids poses severe environmental risks if discharged without treatment. Traditional laboratory-based testing is time-consuming and lacks real-time capability. This paper presents a cloud-based IoT system for real-time monitoring and automated filtration of industrial wastewater using an Arduino UNO integrated with pH, turbidity, temperature (DS18B20), and TDS sensors. Sensor data is transmitted to the ThingSpeak platform via the ESP8266 Wi-Fi module for remote visualization. An L298N motor driver controls a water pump for automated filtration, and a buzzer activates when parameters exceed safe thresholds. Experimental results confirm effective detection before and after filtration with real-time cloud updates. The proposed system is cost-effective, scalable, and suitable for industrial wastewater management and environmental compliance.

Keywords: IoT, Arduino UNO, water quality monitoring, pH sensor, TDS sensor, ThingSpeak, ESP8266, industrial wastewater.

I. INTRODUCTION

Water is an essential natural resource for all living beings, and maintaining its quality is critical for human health and environmental sustainability. Due to rapid industrialization and population growth, water pollution has become a major global concern. Industrial processes frequently generate wastewater containing harmful chemicals, heavy metals, and suspended solids that can severely damage ecosystems if discharged without adequate treatment.

Traditional water quality assessment relies on manual sampling and laboratory analysis, which is time-consuming and incapable of providing continuous real-time information. Existing SCADA-based monitoring systems require manual shift inspections and are reactive rather than proactive. To address these limitations, Internet of Things (IoT) sensor-based monitoring systems have emerged as a practical solution enabling continuous, automated, and remotely accessible water quality management.

The proposed system uses an Arduino UNO microcontroller connected to pH, turbidity, temperature (DS18B20), and TDS sensors. Processed data is transmitted to the ThingSpeak cloud platform through an ESP8266 Wi-Fi module. When water quality parameters exceed safe limits, a buzzer alert activates and an L298N motor driver engages a water pump for automated filtration. This paper describes the system design, hardware and software components, experimental results, and future scope.

A. Motivation of the Research

Water is one of the most important natural resources required for the survival of all living organisms. Increasing industrial activities, urbanization, and population growth have led to severe water pollution. Contaminated water causes serious health problems and environmental damage. Traditional monitoring methods rely on manual sampling, which is time-consuming and cannot provide real-time information. These limitations necessitate a smart and automated monitoring system capable of continuously checking water quality parameters.

With the advancement of sensor technology and microcontrollers, real-time water quality monitoring has become feasible. The motivation of this work is to develop a cost-effective and reliable system that monitors water quality continuously, detects contamination at an early stage, and takes corrective action through automated filtration.



B. Objectives of the Work

The main objective of this project is to design and develop a water quality monitoring system using sensors and a microcontroller. The system measures pH, turbidity, temperature, and TDS in real time; compares values against standard water quality ranges; activates alerts and automated filtration when thresholds are violated; and transmits data to a cloud platform for remote monitoring. The overall goal is to provide a simple, efficient, and cost-effective solution for continuous industrial water quality management.

II. LITERATURE SURVEY

Several research efforts have explored IoT-based approaches to water quality monitoring. Khurana et al. [1] developed an IoT-based water health monitoring system measuring pH, turbidity, temperature, and conductivity, transmitting data to a cloud server for remote access. Deqing et al. [2] proposed an automatic water quality measurement and reporting system using GSM communication, enabling remote notifications when parameters deviate from safe ranges.

Vijayakumar and Ramya [3] presented a real-time IoT water quality monitoring framework using multiple sensors and cloud connectivity. Rao et al. [4] designed a low-cost autonomous water quality monitoring system using wireless sensor networks. Pradeepkumar et al. [5] implemented an IoT environment for real-time water quality tracking in both domestic and industrial contexts.

Khatri et al. [6] proposed an IoT-based real-time pH monitoring system for municipal wastewater. Saravanan et al. [7] integrated IoT with SCADA for real-time water quality monitoring. Spandana and Rao [8] presented an IoT-based smart water quality monitoring system. Karmakar et al. [9] reviewed Industrial IoT frameworks, highlighting the importance of sensor integration and cloud connectivity.

These works collectively highlight the importance of sensor integration and cloud connectivity. However, most existing systems lack integrated automated control mechanisms. The proposed system addresses this gap by combining continuous real-time monitoring with automated pump actuation, buzzer alerts, and cloud-based visualization on ThingSpeak.

III. METHODOLOGY

A. System Overview

The system architecture consists of four layers: (i) sensing layer — pH, turbidity, DS18B20 temperature, and TDS sensors; (ii) processing layer — Arduino UNO microcontroller; (iii) communication layer — ESP8266 Wi-Fi module; and (iv) cloud layer — ThingSpeak IoT platform. An L298N motor driver interfaces the Arduino with a submersible water pump for automated filtration control.

B. Block Diagram

The block diagram of the proposed system is shown in Fig. 1. Sensors transmit analog/digital signals to the Arduino UNO, which processes data, updates the 16×2 LCD, and forwards readings to the ESP8266 module. The module uploads data to ThingSpeak via HTTP GET requests. When any parameter exceeds the predefined threshold, the buzzer activates and the motor driver triggers the pump.

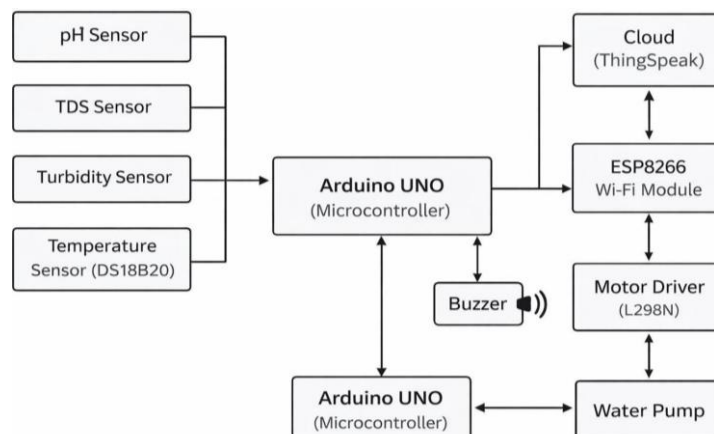


Fig. 1. Block Diagram of Industrial Wastewater Monitoring System.



C. Circuit Diagram

The complete hardware interconnection is shown in Fig. 2. The pH sensor connects to analog pin A2, turbidity sensor to A1, TDS sensor to A0, and DS18B20 to digital pin 7 via the 1-Wire protocol. The 16×2 LCD uses digital pins 8–13. The buzzer connects to pin 4 and the motor driver control signal to pin 6.

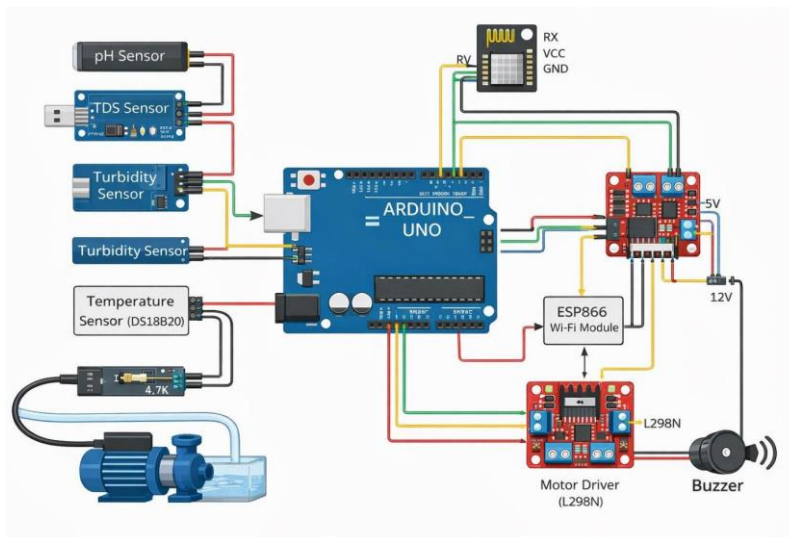


Fig. 2. Circuit Diagram of the Proposed System.

D. Existing vs. Proposed System

The existing industrial monitoring setup uses an analog pH electrode connected to a SCADA display, requiring workers to manually check readings during shifts. This approach is reactive, labor-intensive, and prone to delayed responses. The proposed IoT-based system provides continuous automated monitoring, real-time cloud data logging, remote access, and automatic pump actuation, significantly reducing human intervention.

IV. HARDWARE COMPONENTS

A. Arduino UNO Microcontroller

The Arduino UNO (ATmega328P, 16 MHz, 32 KB flash, 14 digital I/O pins, 6 analog input pins, 5 V operating voltage) serves as the central processing unit. It collects sensor readings, evaluates threshold conditions, controls the LCD, triggers the buzzer and motor driver, and manages UART communication with the ESP8266 module.

B. pH Sensor

The pH sensor (Signal Conversion Board V2 + BNC probe) operates at 3.3–5.5 V, output range 0–3.0 V, accuracy ± 0.1 at 25°C, detection range 0–14 pH. The safe discharge range for industrial wastewater is 6.5–8.5 pH. The system triggers an alert for $\text{pH} < 5$ or > 8.5 .

C. DS18B20 Temperature Sensor

The DS18B20 is a digital temperature sensor using the 1-Wire protocol (Arduino digital pin 7). It supports 9–12-bit programmable resolution, range -55°C to $+125^{\circ}\text{C}$. The system activates an alert when temperature exceeds 41°C and uses readings for TDS compensation.

D. Turbidity Sensor

The turbidity sensor measures suspended particle concentration across 0–1000 NTU, analog output 0–4.5 V, response time < 500 ms, 5 V DC supply connected to Arduino pin A1. An alert is flagged when the raw analog reading exceeds 700.

E. TDS Sensor

The TDS meter measures total dissolved solids in the range 0–1000 ppm, $\pm 2\%$ full-scale accuracy, 1 ppm resolution. The analog output connects to Arduino pin A0. Temperature compensation is applied using the DS18B20 reading. An alert activates when TDS exceeds 700 ppm.



F. ESP8266 Wi-Fi Module

The ESP8266 features a 32-bit Tensilica Xtensa processor with 802.11 b/g/n Wi-Fi. It communicates with the Arduino via UART and uploads sensor data to ThingSpeak using HTTP GET requests. The module operates at 3.3 V, drawing approximately 70–80 mA during transmission.

G. Supporting Components

A 6 V DC active buzzer (~2300 Hz) gives audio alerts on threshold violations. The L298N motor driver bridges the Arduino and a 12 V DC submersible water pump for automated filtration

V. WATER QUALITY THRESHOLDS

TABLE I. WATER QUALITY SAFE RANGES AND ALERT CONDITIONS

Parameter	Safe Range	Alert Condition
pH	6.5 – 8.5	< 5 or > 8.5
Temperature	20°C – 35°C	> 41°C
Turbidity	< 5 NTU	> 700 (analog)
TDS	< 500 ppm	> 700 ppm

VI. SOFTWARE IMPLEMENTATION

A. Arduino IDE Firmware

The system firmware is developed in the Arduino IDE using the OneWire and DallasTemperature libraries for the DS18B20 sensor, and LiquidCrystal for the LCD. The main loop reads all sensors, applies temperature compensation to the TDS calculation, updates the LCD, evaluates threshold conditions, controls the buzzer and motor, and transmits data to the ESP8266 every ~15 seconds to respect ThingSpeak rate limits.

B. ThingSpeak IoT Platform

ThingSpeak is a MathWorks-hosted IoT platform for data collection, storage, and visualization. A channel is configured with four fields: Field 1 (pH), Field 2 (Temperature), Field 3 (Turbidity), and Field 4 (TDS). The ESP8266 sends HTTP GET requests containing the channel Write API key and sensor values. ThingSpeak renders real-time graphs for each field, enabling monitoring from any internet-connected device.

VII. RESULTS AND DISCUSSION

A. System Operational Flow

The operational flow of the proposed system is shown in Fig. 3. The system collects water quality parameters using pH, turbidity, temperature (DS18B20), and TDS sensors. The Arduino UNO processes the data, displays values on the 16×2 LCD, and transmits data to ThingSpeak via the ESP8266 module. If any parameter exceeds the threshold, a buzzer alert activates and the L298N motor driver triggers the water pump to initiate automated filtration.

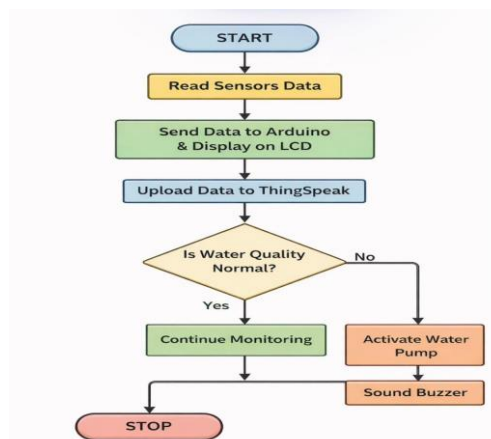


Fig. 3. System Operational Flowchart.



B. Experimental Results

The proposed system was tested using wastewater samples. Parameters — pH, turbidity, temperature, and TDS — were measured before and after a multi-stage filtration process comprising sand, activated carbon, and membrane filtration layers.

Before filtration, the water exhibited high turbidity, elevated TDS, and irregular pH values indicating contamination. After filtration, turbidity decreased significantly, TDS values were reduced, and pH approached the safe range, confirming effective detection and automated remediation.

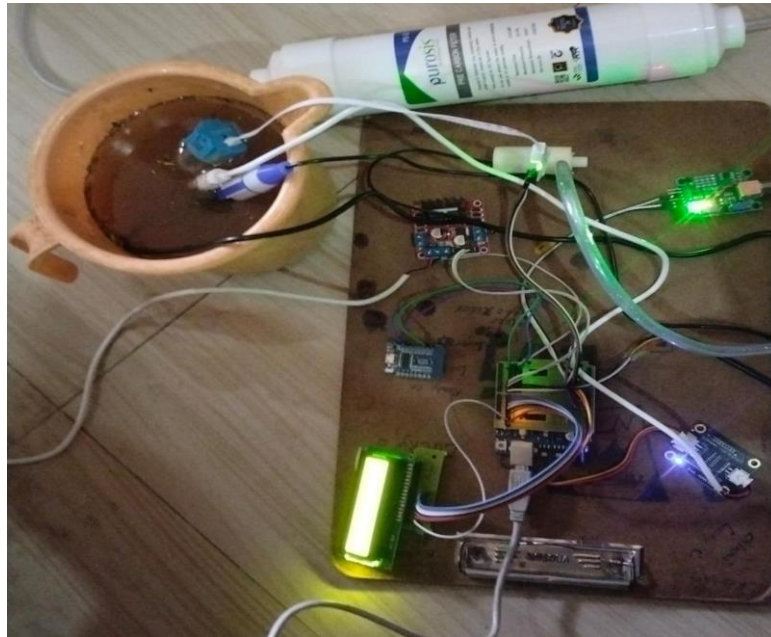


Fig. 4. Wastewater Sample Before Filtration Process.

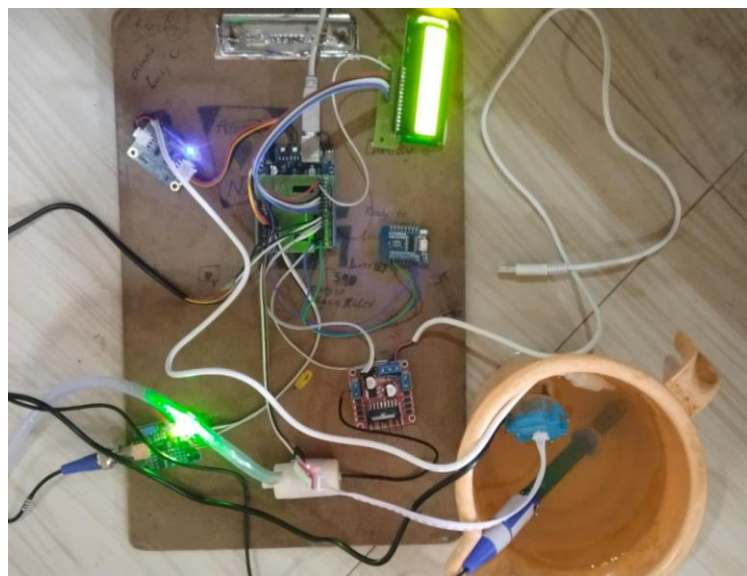


Fig. 5. Wastewater Sample After Filtration Process.

C. Cloud Monitoring Results

Sensor data is successfully transmitted to ThingSpeak. The platform provides real-time graphical visualization of pH, temperature, turbidity, and TDS as shown in Fig. 6. Continuously updated graphs confirm reliable end-to-end communication, enabling remote monitoring from any location.

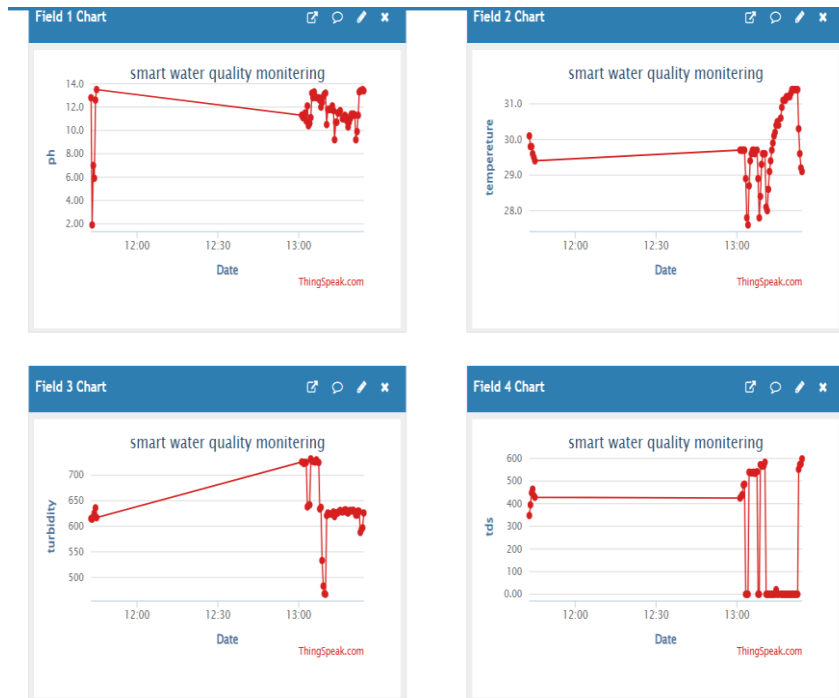


Fig. 6. Real-Time Water Quality Monitoring on ThingSpeak.

D. LCD Display Output

Fig. 7 shows the 16×2 LCD displaying live sensor values before filtration. The top row shows pH and temperature; the bottom row shows TDS and turbidity, providing immediate on-site feedback without internet connectivity. Fig. 8 shows the LCD output after filtration, reflecting the improved parameter values.



Fig. 7. LCD Display Parameter Values Before Filtration.



Fig. 8. LCD Display Parameter Values After Filtration.

E. Assembled Prototype

The fully assembled prototype is shown in Fig. 9. All sensors, the Arduino UNO, ESP8266 module, L298N motor driver, 16×2 LCD, buzzer, and filtration unit are integrated into a single testable system suitable for laboratory and field deployment.



Fig. 9. Assembled Prototype Pictorial Representation.

F. System Advantages

The proposed system provides: (i) real-time continuous multi-parameter monitoring; (ii) remote cloud-based access from any location; (iii) automated purification without human intervention; (iv) early contamination detection with buzzer alerts; (v) significant reduction in operational cost; and (vi) scalability for multi-station industrial deployments.

VIII. CONCLUSION

This paper has presented an industrial cloud-based IoT system for real-time monitoring and automated filtration of industrial wastewater quality. The system integrates pH, turbidity, temperature, and TDS sensors with an Arduino UNO microcontroller and ESP8266 Wi-Fi module to deliver continuous automated monitoring with remote access via ThingSpeak. Experimental results confirm reliable parameter detection, effective alert triggering, and successful automated pump actuation during threshold violations.

The system is cost-effective, easily replicable, and suitable for industrial wastewater treatment plants, environmental monitoring agencies, and smart city water management infrastructure. It provides a practical and scalable solution for ensuring water quality compliance while minimizing human intervention.

IX. FUTURE WORK

Although the proposed system achieves strong performance, several enhancements are planned. Integration of heavy-metal sensors (lead, arsenic, mercury) would extend detection capability. AI-based predictive analytics would enable trend forecasting and preventive action before threshold violations occur. A dedicated mobile application with push notifications would improve user accessibility. Solar power integration would enable remote and off-grid deployment. Finally, blockchain-based immutable data logging could ensure regulatory compliance and tamper-proof environmental reporting.

ACKNOWLEDGMENT

The authors express sincere gratitude to G. Vijay Kumar, Assistant Professor, and Dr. T. Lakshmi Narayana, Head of the Department of Electronics and Communication Engineering, Andhra Loyola Institute of Engineering and Technology, Vijayawada, for their invaluable guidance and support throughout this work. The authors also thank the Management of ALIET for providing the laboratory facilities required for this project.

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