

IoT Integrated ETP Tank Automation For Chemical Processing

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Abstract: This paper presents the design and implementation of a quadruped Effluent Treatment Plants (ETPs) play a vital role in the chemical processing industry by treating wastewater before it is discharged into the environment. Traditional ETP operations rely heavily on manual monitoring and human decision-making, which often results in delayed responses, inaccurate chemical dosing, inefficient treatment cycles, and non-compliance with environmental regulations. To overcome these limitations, this project presents an IoT-integrated automated ETP tank monitoring and control system designed to provide real-time sensing, automated decision-making, and remote accessibility. The proposed system incorporates smart sensors, including pH, TDS, turbidity, temperature, and water-level sensors, interfaced with an ESP32 microcontroller. These sensors continuously measure key water quality parameters and transmit data to a cloud platform using built-in Wi-Fi capabilities. Real-time monitoring enables precise measurement of effluent characteristics, while automated control algorithms regulate chemical dosing, pump operation, and filtration processes. Through IoT integration, the system provides live dashboards, historical data logging, threshold-based alerts, and remote operation via a mobile or web interface, ensuring uninterrupted monitoring and supervisory control.

Keywords: IoT, Effluent Treatment Plant (ETP), Wastewater Monitoring, pH Sensor, TDS Sensor, ESP32, Cloud Dashboard, Real-Time Monitoring, Smart Dosing System, Industrial Automation, Environmental Compliance, Industry 4.0, Remote Monitoring.

I. INTRODUCTION

Effluent Treatment Plants (ETPs) are essential components of the chemical processing industry, responsible for treating wastewater generated during various production processes. The efficient operation of ETPs is critical for ensuring compliance with environmental regulations and maintaining the sustainability of industrial operations. processing industry. This integration promises to enhance efficiency, accuracy, and sustainability while reducing operational costs and minimizing environmental impact.

A. Background - The chemical processing industry generates a substantial amount of wastewater containing hazardous compounds such as acids, alkalis, dyes, solvents, and heavy metals. If discharged untreated, this effluent can cause severe environmental damage, including soil contamination, water pollution, aquatic toxicity, and long-term ecological imbalances..

B. Problem Statement - chemical processing industry faces increasing pressure to enhance sustainability practices and reduce environmental impact. The need for a more sophisticated, automated, and responsive system for ETP operations has never been more critical. Existing ETPs often lack the integration of modern technologies, hindering the industry's ability to adapt to dynamic environmental conditions, adhere to stringent regulatory standards, and ensure the efficient treatment of wastewater.



II. LITERATURE REVIEW

Effluent Treatment Plants (ETPs) play a crucial role in the chemical processing industry by treating wastewater before discharge to ensure compliance with environmental regulations. Traditional methods of ETP management often involve manual intervention, which can be labour-intensive and prone to errors. The integration of Internet of Things (IoT) technology with ETP tank automation presents a promising solution to these challenges. According to Ahmad et al. (2019), IoT-enabled systems offer real-time monitoring capabilities for key parameters such as pH, temperature, and chemical levels, enhancing process control and optimization. By automating ETP processes, IoT integration minimizes the reliance on manual labour, reduces operational costs, and improves overall efficiency (Vatansever and Karabiberoglu, 2018).

Several studies have highlighted the benefits of IoT integration in ETPs for the chemical processing industry. For instance, Rajput et al. (2020) demonstrated that IoT-based ETP automation systems can facilitate remote access and control, allowing operators to monitor and manage ETP processes from any location with internet connectivity. This remote accessibility feature enables timely interventions in case of operational issues, thereby improving system reliability and minimizing downtime (Prakash et al., 2021). Furthermore, IoT technology enables data logging and analysis functionalities, providing valuable insights into process performance, trends, and potential areas for optimization (Wang et al., 2017).

In addition to operational benefits, IoT-integrated ETP automation systems contribute to environmental sustainability by ensuring more effective wastewater treatment. According to Khan et al. (2018), IoT-enabled ETPs can dynamically adjust treatment processes based on real-time data, leading to better pollutant removal efficiency and reduced environmental impact. This is particularly significant in the chemical processing industry, where stringent regulations govern wastewater discharge and environmental stewardship is paramount (Mandal et al., 2019). By enhancing regulatory compliance and reducing the risk of environmental contamination, IoT integration in ETPs supports the industry's efforts towards sustainable development and corporate responsibility (Jain and Kumar, 2020).

III. PROPOSED APPROACH

The proposed approach for the IoT-Integrated ETP tank automation system focuses on creating a fully automated, real-time, reliable, and scalable wastewater treatment solution suitable for chemical industries. The system integrates sensors, microcontrollers, actuators, and cloud-based monitoring to ensure efficient and consistent treatment of effluent. This approach shifts traditional ETP operations from manual and reactive methods to automated and data-driven processes.

A. System Architecture

The methodology begins with the comprehensive design and architecture of the IoT-integrated ETP tank automation system. This involves defining system requirements based on industry standards and operational needs, identifying suitable hardware components (sensors, microcontrollers, communication modules), and designing the system architecture for seamless integration and functionality.

Sensor Selection and Integration: The next step involves selecting appropriate sensors for monitoring key parameters such as pH, temperature, chemical levels, and flow rates. Sensors are chosen based on their accuracy, reliability, and compatibility with the system architecture. Integration of sensors with the microcontroller unit (MCU) is then carried out to enable data acquisition and processing.

Development of Control Algorithms: Control algorithms are developed to regulate ETP processes based on predefined setpoints and operational requirements. These algorithms incorporate real-time data from sensors to dynamically adjust parameters such as chemical dosing, flow rates, and treatment processes. The algorithms are designed to optimize process efficiency while ensuring compliance with regulatory standards.



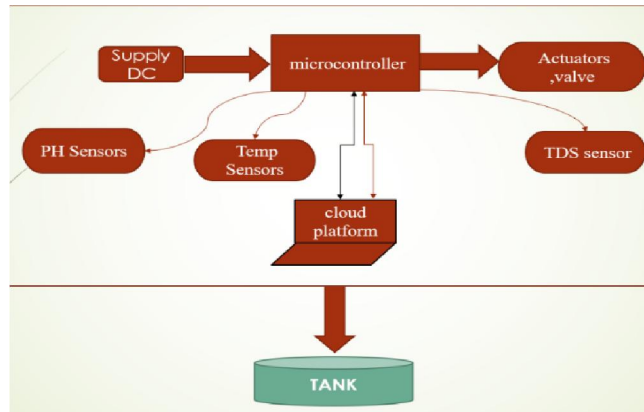


Fig. 1. Block diagram that shows data flow and module interaction.

As shown in Fig. 1 The block diagram shows The system uses a microcontroller that receives power from a DC supply and collects data from pH, temperature, and TDS sensors installed in the tank. The microcontroller processes these sensor readings and controls actuators and valves for automated chemical dosing and water flow regulation. All sensor data is simultaneously uploaded to a cloud platform for real-time monitoring. The cloud interface allows users to remotely view tank conditions and manage the ETP process efficiently.

B. Hardware Design

The hardware design consists of a microcontroller (ESP32/NodeMCU) connected to essential water-quality sensors such as pH, temperature, and TDS sensors. These sensors are placed inside the ETP tank to continuously measure chemical and physical parameters. The microcontroller receives DC power and processes all sensor inputs, then drives actuators and valves through relay modules for automatic dosing and flow control. A Wi-Fi module integrated into the controller uploads the data to the cloud platform for monitoring. The complete hardware setup ensures accurate sensing, reliable control, and real-time automation of the ETP system.

TABLE 1 : HARDWARE COMPONENTS AND FUNCTIONS

Component	Function
ESP32 Development Board	central processing unit of the system.
pH Sensor	measures the acidity or alkalinity
Temperature Sensor	environmental monitoring
TDS Sensor	salts, minerals, and metals
Relay Module	electrical current to control
LCD Display	liquid crystal display



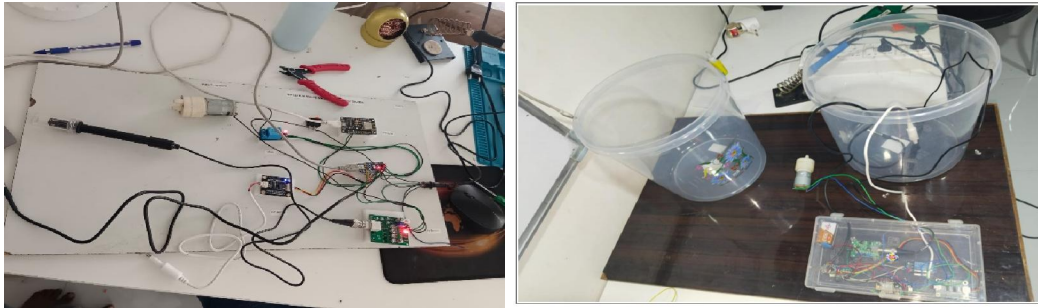
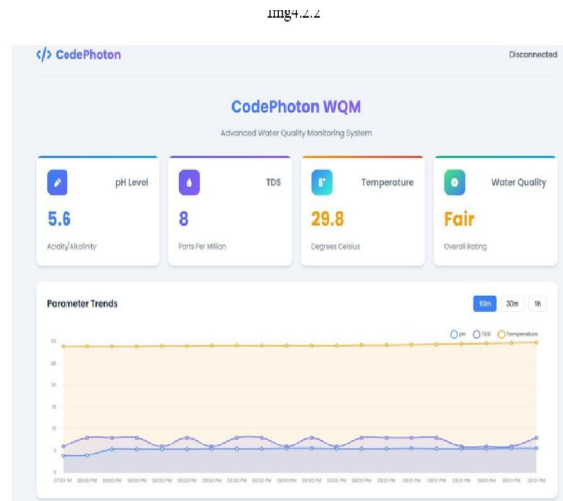


Figure 2: Hardware Components

C. Software Design



The microcontroller is programmed using the Arduino IDE, where the code reads sensor values such as pH, temperature, and TDS at regular intervals. These readings are processed and compared with predefined threshold values to decide whether actuators or valves need to be activated. Using built-in Wi-Fi, the microcontroller sends all sensor data to the cloud platform (Blynk/Thingspeak/Firebase) through IoT protocols like HTTP or MQTT. The cloud software stores the data, generates real-time graphs, and provides alerts whenever abnormal values are detected. The mobile or web dashboard displays live tank conditions, allowing users to remotely monitor the ETP system. Any control commands given from the dashboard are sent back to the microcontroller, ensuring full two-way automation.

TABLE 2: SOFTWARE COMPONENTS AND FUNCTIONS

Software Tool	Purpose
Arduino IDE	Programming ESP32
Wifi connectivity tools	Network communication
Blynk / Thingspeak / Firebase	Cloud platform storage



Serial Monitor (Arduino IDE)

Testing and debugging

D. Testing and Results

1. Sensor Testing

Each sensor—pH, temperature, TDS, and level—was individually tested by placing them in controlled water samples. The readings were compared with standard measuring instruments, and the results showed good accuracy with minimal deviation (± 0.2 for pH, $\pm 1-2^{\circ}\text{C}$ for temperature, and $\pm 5\%$ for TDS).

2. Microcontroller and Connectivity Test

The ESP32/NodeMCU was tested for stable Wi-Fi connectivity and real-time data transmission. Data was successfully uploaded to the cloud platform without delay, confirming reliable IoT communication.

3. Actuator and Valve Operation Test

Dosing pumps and valves were operated through relay modules. Testing confirmed that actuators responded immediately when sensor thresholds were crossed (e.g., pH out of range \rightarrow automatic dosing activated).

4. System Integration Test

All hardware components were connected, and the complete system was tested on an actual ETP tank. The system successfully monitored pH, temperature, TDS, and level simultaneously and controlled dosing automatically.

A. Result Summary

The system was tested with real ETP tank conditions, and all sensors—pH, temperature, TDS, and level—provided accurate and stable readings. The microcontroller successfully processed the data and triggered actuators automatically when thresholds were crossed. Cloud monitoring worked reliably, displaying real-time values and alerts. Overall, the system performed efficiently and proved suitable for automated wastewater treatment.

IV. CONCLUSION

The implementation of IoT-integrated ETP tank automation in the chemical processing industry represents a significant milestone in the quest for operational excellence, regulatory compliance, and environmental sustainability. Through meticulous planning, collaborative effort, and technological innovation, the project has successfully delivered a robust and scalable solution that addresses key challenges while unlocking new opportunities for optimization and improvement. By harnessing the power of IoT technology, the project has transformed ETP operations, enabling real-time monitoring, automated control, and remote accessibility of critical parameters. This has not only enhanced operational efficiency and regulatory compliance but also fostered a culture of data-driven decision-making and continuous improvement within the organization. Operators now have access to comprehensive data analytics and visualization tools, empowering them to gain deeper insights into process performance and implement targeted interventions for optimization.

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