

IoT based Smart STPs System for Efficient Sewage Water Treatment of Holy Rivers during Mahakumbh

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Abstract

The escalating demand for effective wastewater treatment for safeguard Holy River's water for maintaining its authenticity for the events like Mahakumbh is essential. For this, it is necessary to develop an efficient smart Sewage Treatment Plants (STPs) system to add pure water in rivers from various waste water sources. In this context, this paper presents a smart IoT technology based STPs model to improve its overall performance and improve water quality. The proposed model utilizes various sensors to monitor and acquire water quality parameters like pH level, temperature, and turbidity. A microcontroller based automated system continuously monitors and analysed real-time data of various sensors to take action to maintain the water quality and efficient operation of the plant. Based on predefined conditions, the proposed model can automatically control STPs equipment's like motor operation, valve adjustment, and aeration. In addition, collaborative action of IoT technology made it effective for remote monitoring and control, whenever any abnormal conditions occur. Thus, this automated model make it effective for remote operation and control, reduced human intervention, chances of mal-function, and reliable operation of the STPs. It also contributes to environmental protection and promotes sustainable water management.

Keywords Automation, Internet of Things (IoT), pH Level, Electrical Control System, Microcontroller, Sewage Treatment Plant (STPs), Water Quality Monitoring, Wastewater Management,

1. Introduction

The rapid urbanization, population growth, and industrial development causes the huge wastewater generation. It issue is rapidly growing year by year. As a result, proper sewage treatment has become an essential requirement to maintain water quality of rivers, safeguard the environment and public health [1]. The traditional Sewage Treatment Plants mainly depend on manual operation, monitoring and control, which often lead to error in operation, inefficiencies, slow response and lower water treatment quality [2]. To overcome these limitations, it is essential to develop an efficient and smart STPs system based on automation system and smart sensors [3]. By using electrical systems along with advanced sensors and microcontroller, it becomes possible to monitor the key parameters such as pH level, turbidity, oxygen level dissolved, and flow rate continuously and accurately [4] [5][6].

Sewage treatment is performed using different systems, ranging from small decentralized setups to large centralized networks with pipes and pumping stations. So, it consumes large power. The treatment process is usually done in two stages as primary and secondary stages. Which is used to remove harmful particles and gases

from sewage water. In third stage, further purification and nutrient removal was performed for better usability [7][8]. Secondary treatment mainly reduces organic matter using biological processes with aerobic or anaerobic.

The integration of Internet of Things (IoT) technology with STPs can further enhances the system monitoring by enabling remote accessing of real-time data and provide real time alert [9]. It can provide an instant alerts in case of system failures or abnormal conditions, which helps in quick decision-making and better maintenance planning [10]. In addition, this approach reduces operational costs and minimizes human intervention. The IoT-based system also improve energy efficiency and enhance performance in STPs by real time monitoring harmful gases like carbon monoxide, carbon dioxide, ammonia, methane, and hydrogen sulphide [11][12]. Few authors have explored smart system integrating UAV based data collection with wireless power transfer in WSNs. It has been observed that it significantly improves energy efficiency, network lifetime, and data reliability [13][14].

Many researchers have utilised Industrial Internet of Things (IIoT) technologies to enhance monitoring and control mechanism [15]. Many authors have utilised Programmable Logic Controllers (PLC) but it is limited to local operations and not reliable for remote accessibility [16]. In contrast, modern IoT-based systems support real-time monitoring and remote supervision [17] [18]. The microcontroller-based monitoring systems using GSM technology have been used by many researchers for quick communication [19]. The GSM based systems provide real-time alerts about any mal practice to enhance system reliability and usability during any abnormal conditions.

Another important issue is the reliability of sensors used in STPs. Any incorrect or faulty signals of sensor readings can mislead to improper system operation and reduced efficiency. To resolve these issues my authors have utilised advanced fault detection methods using machine learning techniques for automated fault diagnosis for its reliable operation.

Therefore, this manuscript aimed to design and develop an automated system for online monitoring and detecting various parameters in sewage treatment plants. It utilizes smart sensors and IOT enabled system. The proposed system focuses on improving reliability, efficiency, and environmental impacts using microcontroller based water treatment. It also enabled with smart display system and SMS based alert system to provide information to user in real time for any fluctuations.

2. Block Diagram of Proposed Smart Model

The operation of conventional Sewage Treatment Plant (STP) mainly depends on manual monitoring and control mechanism. In these systems, operators are regularly observe and measure important parameters of waste water such as pH level, turbidity, and flow rate. These measurements are either taken manually or with separate instruments in offline mode, which limits overall system efficiency and reliability. Few more advanced system uses automation using Programmable Logic Controllers (PLC) to control the mechanism, however their functionality is usually confined to local control. The remote monitoring is usually restricted, hence suffers for real-time data access. In addition to this, the data is also not recorded and stored in an organised way, making it difficult to study past performance of system or predict possible failures. In these systems, any abnormal conditions such as high pH value of water, temperature, contamination, or malfunction of equipment's may not be identified immediately. Thus it may be time consuming for any corrective action. Also, due to the lack of an efficient integration of communication system and smart control mechanism, these systems mainly depends on human operation. This increases the chances of misreading, large power drop, and reduces overall efficiency.

The proposed system is enabled with smart IoT technology, microcontroller based monitoring and control, and smart communication system and modern sensors to monitors and controls the treatment process in real time. It have various sensors to measure the parameters like pH level, turbidity, temperature, water level, and flow rate. Wastewater first enters the inlet tank, where water level and flow rate sensors monitor its movement into the primary filter system. As the water passes and processed using primary and secondary filter stages, the key parameters such as pH, turbidity, and temperature are continuously monitored using smart sensors. The data collected from sensor is processed by a microcontroller unit, which analyses water quality and decides whether this treated water is safe for discharge in river or requires further treatment process. The system is also connected to an IoT platform for remote monitoring, and a GSM module sends SMS alerts to concerned authorities if

pollution levels exceed safe limits, helping prevent the release of untreated water into sensitive river bodies. The complete flow chart of proposed methodology is shown by figure 1.

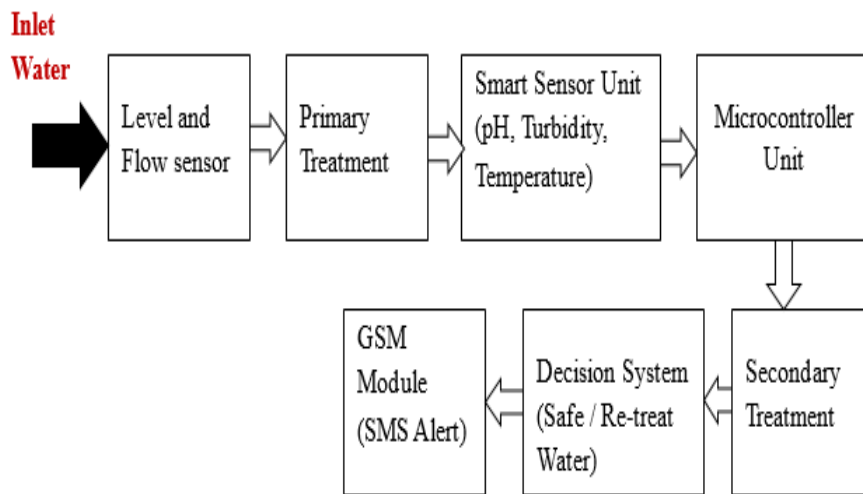


Figure 1. Block Diagram of proposed methodology for the treatment of the waste water

3. STP Detection and Monitoring System Architecture

The overall structure of an automated STP detection and monitoring system with real-time analysis and alert is shown by figure 2. The network data is first collected using a data acquisition system using interfaces like SNMP/API. This collected data is then sent to the STP frame analysis module, where anomalies and quality contents of water are identified. Then processed data is passed to the microcontroller-based analysis system, which acts as the core decision-making unit. It evaluates the incoming information and communicates with the GSM module to trigger alerts when required.

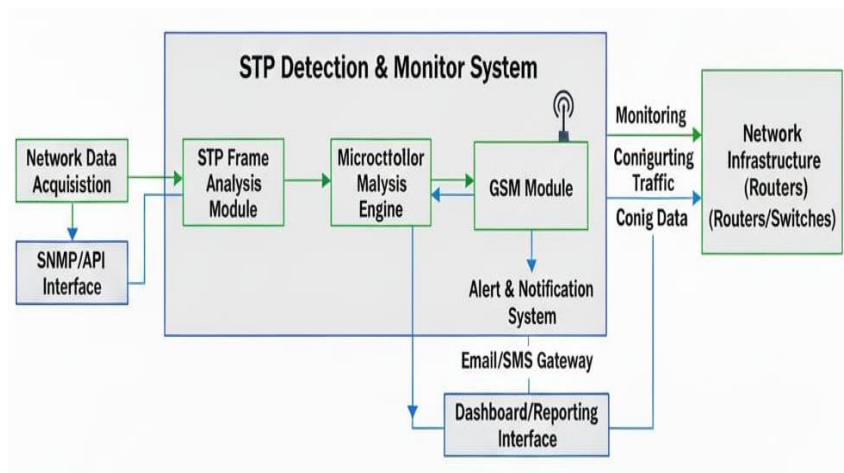


Figure 2. Communication System for Automated Sewage Treatment Plant Monitoring and Control System

4. Detailed Components Used

• Data Acquisition Module

This module collects real-time data from different devices and sensors. It gathers information of waste water contents like pH level, turbidity, and flow rate. This module is responsible for the accuracy and reliability of the entire module, as it ensures smooth and continuous data collection.

Various sensors used in this projects are

a) pH Sensor (pH-4502C)

Measures acidity/alkalinity of water (range: 0–14 pH). The safe limit of drinking water is between the limit of 6.5 to 8.5. The pH level of water should be in defined level to ensure the holiness of rivers. It is also helpful to the species living in the water.

b) Turbidity Sensor (SEN0189)

Detects water clarity by measuring suspended particles. High turbidity indicates poor treatment efficiency. It is measured in Nephelometric Turbidity Units (NTU). For drinking water it should be less than 1 and for river or natural resource water it is less than 20 NTU. Thus the turbidity of water should be as low as possible.

c) Temperature Sensor (DS18B20)

Monitors water temperature, which affects biological treatment efficiency and microbial activity. The high temperature of water is harmful for species.

d) Water Level Sensor (Ultrasonic – HC-SR04 or Float Sensor)

Tracks tank levels to control inflow/outflow and prevent overflow or dry running.

e) Flow Rate Sensor (YF-S201)

Measures the rate of water movement, ensuring proper process control and detecting blockages or leakage.

f) Microcontroller Specifications

The microcontroller collects sensor data, processes it, and sends it to the cloud or dashboard. The specification of microcontroller is given as

Controller Used: ESP32 / Arduino Uno

Clock Speed: Up to 240 MHz (ESP32)

Connectivity: Built-in Wi-Fi and Bluetooth (ESP32)

Analog Inputs: 12-bit ADC for accurate sensor data acquisition

GPIO Pins: ~30+ pins for multiple sensor interfacing

Power Consumption: Low-power modes for energy efficiency

Memory: ~520 KB SRAM (ESP32)

g) Communication & Alert System

GSM Module (SIM800/900): Sends SMS alerts when parameters exceed safe limits.

IoT Platform (ThingSpeak / Blynk / Firebase): Used for real-time monitoring, data logging, and remote access.

h) Actuators and Control Units

Relay Module: Controls pumps, valves, and aerators based on sensor data.

Water Pump & Solenoid Valves: Manage water flow, recirculation, and discharge.

By continuously monitoring these factors, it ensures stable system operation and prevents network-related issues such as congestion.

Table 1: Specifications of various components used in the model

Component	Model/Type	Specification	Function
pH Sensor	pH-4502C	Range: 0–14, Accuracy: ±0.1	Measures acidity/alkalinity
Turbidity Sensor	SEN0189	0–1000 NTU	Detects suspended particles
Temperature Sensor	DS18B20	-55°C to 125°C	Monitors temperature
Water Level Sensor	HC-SR04 / Float	2–400 cm	Measures tank level

Flow Sensor	YF-S201	1–30 L/min	Measures flow rate
Microcontroller	ESP32	240 MHz, Wi-Fi, 520KB SRAM	Processes data & IoT
GSM Module	SIM800/900	Quad-band GSM	Sends SMS alerts
Relay Module	5V Relay	10A switching	Controls pumps/valves
Pump	Submersible	12V/24V	Controls water flow
IoT Platform	ThingSpeak/Blynk	Cloud-based	Monitoring & storage
Display	LCD/OLED	16x2	Shows parameters

5. Circuit Diagram of Proposed Model

The circuit diagram of the model shows the electrical connections of various components in systematic way. The circuit diagram of proposed model is shown by figure 3. The main component of the model is ESP32 microcontroller that integrates multiple sensors and control components for real-time data monitoring and its automation. It is the central component and processing element of the complete model. The pH and turbidity sensors are connected to the analog input pins to measure water quality, while the temperature sensor (DS18B20) uses a digital pin for accurate thermal monitoring of the waste water. To measure the water level of the water an ultrasonic sensor HC-SR04 connected with the processing element, and a flow sensor YF-S201 tracks the rate of wastewater movement. All sensor data is continuously processed by the ESP32 microcontroller to assess treatment conditions of water.

Based on the analysed report, the microcontroller take action and controls a relay module that operates the water pump for treatment or recirculation of water. A GSM module is interfaced through serial communication to send SMS alerts if any parameter exceeds predefined limits. Additionally, an LCD display is used to provide a real-time value of water quality. The system is powered with a regulated supply of 12V, ensuring stable operation of the model. Thus, the proposed circuit model enables automated decision-making, efficient water treatment, and remote monitoring for improved sewage management.

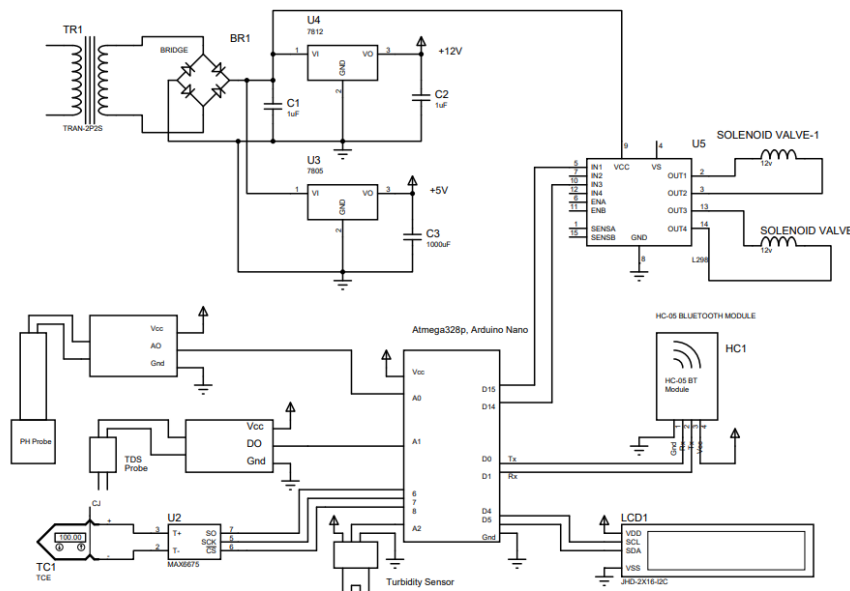


Figure 3. Circuit Diagram of the Proposed Automated Smart STPs System

6. Results and Discussion

The proposed automated sewage treatment plant for clean river's water was tested under a set of conditions to evaluate its performance and reliability. The prototype model of the proposed STPs system is shown by figure 4. The various parameters to show the quality of the water is clearly shown in figure. The testing results show that the model successfully monitored the water parameters as pH level, water level, and gas concentration in real time. The working of model is evaluated by expert team and suggested points were enabled in project for its more reliable operation. The result shows that all sensors performed accurately and provided real time data to the microcontroller. The pH value of water collected from different sources was monitored and communication system validated with high pH value of water and it work well. The live performance of different other sensors like ultrasonic sensor, gas sensors like MQ-4 and MQ-135 successfully verified. The result also show that Arduino microcontroller is effectively processing the sensor data efficiently and responding in real time for any abnormal conditions. The LCD display continuously displaying the sensor value in real time and IoT module also responded in normal setting times.

Thus, the proposed automated STPs improve the water quality at low cost, low power consumption, prevents system failures by early alarm, reducing environmental risks, and improve operational efficiency. However, some limitations were observed during testing of the model and was improved in early time.

The proposed model can further improved by integrating artificial intelligence technology for predictive analysis and fault detection

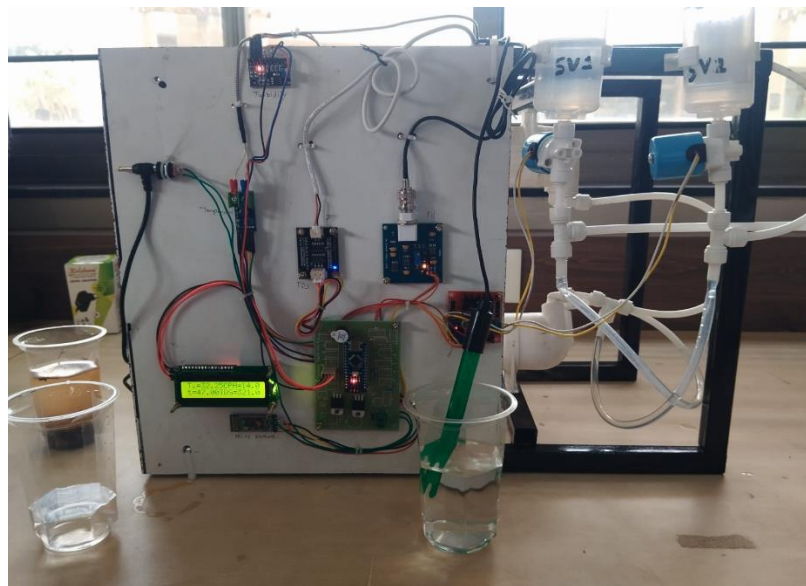


Figure 4. Operational Model of the IoT-Based Smart STP for Water Treatment

7. Conclusion

This paper presented an automated sewage treatment plant for real time monitoring and control of plant operation using smart sensors, and IoT-based technologies. The testing results have shown that proposed model demonstrated excellent result in terms of water quality alarm, its treatment, and efficiency of plant operation. Further, it automate the system by integrating IoT technology and smart sensors to reduces human intervention, improve accuracy, and ensures quick response to any abnormal conditions. Thus, the integration of IoT with smart sensor makes it feasible for automated output and more flexible to accurate response. Thus, the proposed model enhances the efficiency and reliability of sewage water treatment to clean the river especially during a broader events like a Mahakumbh.

Further, the efficiency and water management policy can be enhanced by incorporating machine learning algorithms, and energy optimization techniques.

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