

# Automated Sewage Gas Monitoring and Alerting System

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**Abstract-** Sewage systems generate hazardous gases such as methane (CH<sub>4</sub>) and ammonia (NH<sub>3</sub>), which pose significant risks including toxic exposure, fire hazards, and explosion threats. This paper proposes an AI-integrated Internet of Things (IoT)-based sewage gas detection and emergency response system aimed at enhancing worker safety and enabling intelligent hazard mitigation. The system utilizes MQ-4 and MQ-135 gas sensors interfaced with an ESP32 microcontroller to continuously monitor gas concentration levels in real time. Upon exceeding predefined safety thresholds, the system triggers local alerts and transmits sensor data to a cloud-based artificial intelligence (AI) agent for risk evaluation and decision support. The AI module classifies hazard severity and generates dynamic safety instructions through a chat-based interface. Simultaneously, automated SMS notifications are dispatched to the sewage coordinator and fire service authorities to ensure rapid emergency response. The integration of IoT communication, AI-driven analytics, and automated alert mechanisms provides a scalable, cost-effective, and intelligent safety solution for sewage monitoring applications. Experimental results demonstrate reliable detection capability and effective real-time emergency alert generation, contributing to improved occupational safety and smart infrastructure management.

**Indexed Terms-** Artificial Intelligence (AI), Internet Of Things (IoT), Sewage Gas Detection, Methane Detection, Ammonia Monitoring, MQ-4 Sensor, MQ-135 Sensor, Emergency Alert System, Smart Safety Systems, Real-Time Monitoring.

## I. INTRODUCTION

Sewage and underground drainage systems are confined environments that frequently accumulate hazardous gases such as methane (CH<sub>4</sub>), ammonia (NH<sub>3</sub>), hydrogen sulfide (H<sub>2</sub>S), and carbon dioxide (CO<sub>2</sub>). These gases pose serious occupational and environmental risks, including respiratory distress, toxic exposure, fire hazards, and explosion incidents. Methane, being highly flammable, can ignite even at

relatively low concentrations, while ammonia and other toxic gases may cause suffocation and long-term health complications. Despite existing safety regulations, sewage workers in many regions continue to face life-threatening conditions due to inadequate real-time monitoring and delayed emergency response.

Traditional gas detection methods rely on portable detectors or manual inspection procedures, which are often limited in scope and lack centralized monitoring capabilities. Moreover, such systems typically provide only local alerts without intelligent risk analysis or automated emergency coordination. With the advancement of Internet of Things (IoT) technologies and cloud-based communication systems, it is now possible to develop scalable and connected monitoring solutions capable of real-time data acquisition and remote supervision.

In recent years, Artificial Intelligence (AI) has further enhanced monitoring systems by enabling intelligent data interpretation, risk classification, and automated decision support. By integrating AI with IoT-based gas sensing systems, it becomes feasible not only to detect hazardous conditions but also to generate context-aware safety recommendations and trigger coordinated emergency responses.

This paper proposes an AI-integrated IoT-based sewage gas detection and emergency alert system that continuously monitors methane and toxic gas levels using MQ-4 and MQ-135 sensors interfaced with an ESP32 microcontroller. Upon detecting unsafe gas concentrations, the system activates local alarms, transmits data to a cloud-based AI agent for hazard assessment, and automatically sends emergency notifications to sewage coordinators and fire service authorities. The proposed approach enhances worker

safety, reduces response time during emergencies, and contributes to the development of intelligent and smart municipal infrastructure systems.

## II. PROBLEM STATEMENT

Sewage systems and underground drainage networks are high-risk confined environments where hazardous gases such as methane (CH<sub>4</sub>) and ammonia (NH<sub>3</sub>) accumulate due to biological decomposition of organic waste. Exposure to these gases can lead to severe health hazards, including respiratory failure, unconsciousness, long-term organ damage, and fatal accidents. In addition, methane is highly flammable and poses a significant explosion risk when concentration levels exceed safe limits.

Despite the existence of portable gas detection devices, many sewage monitoring practices remain manual, reactive, and disconnected from centralized emergency systems. Conventional solutions typically provide only local alerts, such as audible alarms, without enabling remote monitoring, intelligent risk evaluation, or coordinated emergency response. Furthermore, delayed communication between field workers and authorities increases the likelihood of severe incidents, particularly in confined or poorly ventilated environments.

Another major limitation of existing systems is the absence of intelligent decision support. Traditional detectors measure gas concentration but do not interpret severity levels, predict potential risks, or provide actionable safety guidance. As a result, workers and supervisors may lack clear instructions during critical situations, leading to delayed or inappropriate responses.

Therefore, there is a need for an integrated, real-time, intelligent sewage gas monitoring system that not only detects hazardous gases but also performs automated risk assessment, generates safety recommendations, and instantly notifies responsible authorities. The absence of such a comprehensive and AI-enabled solution motivates the development of the proposed AI-integrated IoT-based sewage gas detection and emergency alert system.

## III. LITERATURE REVIEW

Recent advancements in Internet of Things (IoT) and Artificial Intelligence (AI) technologies have inspired several solutions for hazardous gas monitoring and industrial safety systems:

- **IoT-Based Gas Monitoring Systems:** Several studies propose IoT-enabled gas detection frameworks using microcontrollers and cloud platforms to monitor methane, carbon monoxide, and ammonia levels in industrial environments. These systems provide remote data access; however, most implementations focus only on data visualization without intelligent risk assessment or automated emergency coordination.
- **Multi-Gas Sensor Integration Approaches:** Research has demonstrated the effectiveness of MQ-series sensors and electrochemical sensors in detecting toxic and flammable gases in confined spaces. While these systems achieve real-time detection, they often lack scalability, predictive analysis capabilities, and integration with centralized municipal safety infrastructure.
- **AI-Driven Hazard Prediction Models:** Recent works incorporate machine learning algorithms for anomaly detection and predictive risk classification in industrial environments. These AI-based models improve hazard identification accuracy but are generally implemented in large-scale industrial setups and are not optimized for low-cost sewage monitoring systems.
- **Smart Emergency Notification Systems:** Cloud-based alert systems using SMS gateways and IoT dashboards have been proposed to improve emergency communication. However, most solutions provide only threshold-based alerts without dynamic safety instruction generation or coordinated multi-authority notification mechanisms.
- **Smart City Safety Frameworks:** Emerging smart city architectures emphasize real-time monitoring and automated response systems for critical infrastructure. Despite this, comprehensive integration of gas detection, AI-driven decision support, and automated emergency service notification in sewage systems remains limited.

Existing Systems

Several IoT- and AI-assisted gas monitoring frameworks have been developed to improve industrial and environmental safety. However, most existing systems focus on isolated functionalities and lack an integrated, intelligent, and automated emergency response framework specifically designed for sewage environments.

1)IoT-Based Gas Monitoring Systems

Many existing systems utilize MQ-series gas sensors integrated with microcontrollers to monitor methane and toxic gases in real time. These systems transmit sensor readings to cloud dashboards and trigger threshold-based alarms. While they provide remote accessibility and continuous monitoring, they primarily focus on data visualization and simple alert mechanisms without advanced risk assessment or coordinated emergency communication.

2)Standalone Gas Detection Devices

Portable gas detectors are commonly used in confined environments such as sewage systems. These devices provide audible or visual alerts when gas concentration exceeds safe limits. However, they operate independently without centralized monitoring, data logging, or automated notification to supervisory authorities, which limits their effectiveness in large-scale municipal infrastructure.

3) AI-Assisted Industrial Safety Systems

Some advanced industrial safety systems incorporate artificial intelligence for anomaly detection and predictive hazard analysis. Although these systems improve detection accuracy, they are often designed for large industrial plants and require high computational resources. They are not optimized for low-cost IoT deployment in sewage monitoring scenarios and typically lack integration with emergency services such as fire departments.

Feature	IoT Gas Monitoring	Standalone Gas Detectors	AI-Assisted Industrial Safety Systems	Proposed AI-IoT Sewage System
Multi-Gas Detection	✓	✓	✓	✓
Real-Time Monitoring	✓	✗	✓	✓
Cloud Connectivity	✓	✗	✓	✓
AI-Based Risk Analysis	✗	✗	✓	✓
Automated Safety Instructions	✗	✗	✗	✓
SMS Alert to Authorities	✗	✗	✗	✓
Fire Service Integration	✗	✗	✗	✓
Low-Cost IoT Deployment	✓	✓	✗	✓
Smart City Ready	✗	✗	Partial	✓

IV. PROPOSED SYSTEM

The proposed system presents an AI-integrated IoT-based sewage gas detection and emergency response framework designed to provide real-time monitoring, intelligent hazard analysis, and automated emergency coordination. Unlike conventional systems that focus only on gas detection or basic alarms, the proposed

framework integrates multi-gas sensing, IoT connectivity, AI-driven decision support, and automated emergency notification into a unified safety architecture tailored for sewage environments.

The system ensures continuous monitoring, proactive risk assessment, and rapid emergency communication to minimize hazards and protect human life.

#### 4.1 Conceptual Overview

The conceptual architecture of the proposed system consists of four functional layers:

- Sensing Layer: MQ-4 and MQ-135 sensors continuously measure methane (CH<sub>4</sub>) and toxic gas concentrations inside sewage environments.
- Processing and IoT Layer: An ESP32 microcontroller processes sensor data, compares it with predefined safety thresholds, and transmits real-time readings to a cloud server via Wi-Fi.
- AI Decision Layer: A cloud-based AI agent analyzes the incoming data, classifies hazard severity levels (Safe, Warning, Critical), evaluates explosion risk, and generates dynamic safety instructions.
- Emergency Response Layer: During critical conditions, automated SMS alerts are sent to the sewage coordinator and fire service authorities, while AI-generated instructions are displayed through a chat-based dashboard interface.

This layered design ensures intelligent monitoring, automated decision-making, and coordinated emergency response.

#### 4.2 Key Features

- Multi-Gas Detection Capability: Utilizes MQ-4 and MQ-135 sensors to continuously detect methane (CH<sub>4</sub>) and toxic gases such as ammonia (NH<sub>3</sub>) in sewage environments, ensuring comprehensive hazard monitoring.
- Real-Time IoT Monitoring: Employs an ESP32 microcontroller with Wi-Fi connectivity to transmit live gas concentration data to a cloud platform for centralized supervision and data logging.
- AI-Based Risk Classification: Integrates a cloud-based AI agent that analyzes sensor data to classify hazard severity levels (Safe, Warning, Critical) and assess potential explosion or toxicity risks.
- Dynamic Safety Instruction Generation: Automatically generates context-aware emergency response steps through a chat-based interface to guide workers during hazardous situations.
- Automated Emergency Notification: Sends instant SMS alerts to sewage coordinators and fire service

authorities when gas levels exceed critical thresholds, enabling rapid response.

- Local Alert Mechanism: Activates buzzer and LED indicators on-site to provide immediate warning to workers in confined sewage spaces.
- Scalable and Smart Infrastructure Ready: Designed for integration into municipal monitoring systems and smart city safety frameworks.
- Cost-Effective and Deployable Architecture: Optimized for low-cost IoT implementation while maintaining reliability and real-time performance.

## V. TECHNICAL ARCHITECTURE AND WORKFLOW

### 5.1 Architecture Overview

The proposed system architecture integrates IoT-based gas sensing, cloud-based artificial intelligence, and automated emergency communication to provide a real-time sewage gas monitoring and intelligent response framework. The architecture comprises three key layers:

**IoT Sensing and Edge Layer:** This layer consists of MQ-4 and MQ-135 gas sensors deployed inside sewage pipelines and confined spaces. The MQ-4 sensor detects methane (CH<sub>4</sub>), while the MQ-135 sensor identifies harmful gases such as ammonia (NH<sub>3</sub>) and other toxic pollutants. These sensors are interfaced with an ESP32 microcontroller that performs continuous gas concentration monitoring. Preliminary processing, threshold comparison, and local validation occur at the edge level. When gas levels exceed predefined safety limits, the microcontroller activates local alert mechanisms such as a buzzer and LED indicators to immediately warn nearby workers.

**Cloud and AI Intelligence Layer:** Sensor data is transmitted via Wi-Fi to a secure cloud server for centralized storage and analysis. An AI agent processes real-time gas concentration data to classify risk levels (Safe, Warning, Critical) using machine learning techniques and rule-based decision models. The AI system evaluates toxicity levels, explosion risk probability, and environmental severity. Based on the assessment, the AI agent generates

context-aware emergency instructions that are displayed through a chat-based interface for workers and supervisors.

**Automated Emergency Communication Layer:** When critical gas thresholds are detected, the system automatically triggers emergency notifications. SMS alerts are sent in real time to the sewage coordinator and fire service authorities. The notification includes gas type, concentration level, location details, and recommended safety actions. All events are logged in the cloud database for monitoring, auditing, and future safety analysis.

#### *Workflow Overview*

The workflow of the proposed AI-Enabled Sewage Gas Detection and Emergency Response System involves the following key steps:

**Data Collection:** MQ-4 and MQ-135 sensors continuously monitor methane and toxic gas concentrations in sewage environments.

**Preprocessing at Edge:** The ESP32 microcontroller converts analog sensor signals into digital values, calibrates readings, and compares them against predefined safety thresholds. Local alerts are triggered if immediate danger is detected.

**Data Transmission and Cloud Storage:** Processed sensor data is securely transmitted via Wi-Fi to the cloud platform, where it is stored for real-time monitoring and historical analysis.

**AI-Based Risk Analysis:** The AI agent analyzes incoming gas data streams, classifies hazard severity, and predicts potential explosion or toxicity risks using trained models and decision logic.

**Dynamic Safety Guidance:** Based on risk classification, the AI agent provides step-by-step emergency instructions through a chat interface, guiding workers on protective measures and evacuation procedures.

**Automated Alert Generation:** If gas levels exceed critical limits, the system sends real-time SMS alerts to the sewage coordinator and fire service department, ensuring rapid emergency response.

**Event Logging and Monitoring:** All gas readings, alerts, and AI-generated actions are logged in the cloud database for reporting, compliance verification, and long-term safety improvements.

This structured architecture ensures intelligent monitoring, rapid decision-making, and coordinated emergency response for hazardous sewage environments.

#### System Design and Implementation

##### *1. Hardware Design*

The hardware design of the proposed AI-enabled sewage gas detection system focuses on reliable gas sensing, edge processing, and local alert generation in hazardous environments.

The core sensing components include the MQ-4 sensor for methane (CH<sub>4</sub>) detection and the MQ-135 sensor for detecting toxic gases such as ammonia (NH<sub>3</sub>), benzene, and other harmful pollutants commonly found in sewage systems. These sensors continuously monitor gas concentrations and generate analog voltage outputs proportional to detected gas levels.

An ESP32 microcontroller serves as the central processing unit of the system. It performs analog-to-digital conversion (ADC), preliminary data filtering, threshold comparison, and Wi-Fi-based communication with the cloud server. The ESP32 is selected due to its integrated Wi-Fi capability, low power consumption, and suitability for IoT applications.

For on-site safety, the hardware includes:

- A buzzer for audible alerts
- LED indicators (green for safe, yellow for warning, red for critical)
- Optional LCD/OLED display for real-time gas level visualization

A regulated power supply unit ensures stable voltage to sensors and the microcontroller. The entire

hardware setup is enclosed in a protective casing suitable for humid and corrosive sewage environments.

## 2. Software Architecture

The software architecture is structured to support real-time monitoring, AI-based decision-making, and automated emergency communication. It follows a distributed model consisting of edge firmware and cloud-based intelligence services.

### 2.1 Core Platform

The core platform consists of:

- **Embedded Firmware (ESP32):** Developed using Arduino IDE or ESP-IDF framework. The firmware handles sensor calibration, data acquisition, threshold analysis, and Wi-Fi communication using MQTT or HTTP protocols.
- **Cloud Server:** A cloud platform (such as Firebase, AWS IoT, or similar IoT backend) receives and stores sensor data. It maintains real-time dashboards and event logs.
- **AI Agent Module:** The AI engine processes incoming gas data to classify risk levels and generate actionable safety instructions. It may utilize machine learning models (e.g., Random Forest or rule-based classification) to evaluate toxicity and explosion probability.
- **Notification Service:** SMS alert systems (e.g., Twilio API or GSM gateway integration) automatically notify sewage coordinators and fire service authorities during critical events.

### 2.2 Key Functional Modules

The system software is divided into the following functional modules:

- **Gas Monitoring Module:** Continuously collects methane and toxic gas data from MQ sensors and performs calibration for accurate ppm estimation.
- **Threshold Analysis Module:** Compares real-time gas levels with predefined safety limits and categorizes status into Safe, Warning, or Critical levels.

- **AI Risk Assessment Module:** Evaluates gas combinations, exposure duration, and risk severity to determine hazard classification and potential explosion probability.
- **Chat-Based Guidance Module:** Generates real-time emergency instructions through an AI agent interface to guide workers on protective actions and evacuation procedures.
- **Alert and Notification Module:** Automatically sends SMS alerts to the sewage coordinator and fire service when critical thresholds are exceeded.
- **Data Logging Module:** Stores sensor readings, alerts, and AI decisions in the cloud database for reporting and safety audits.

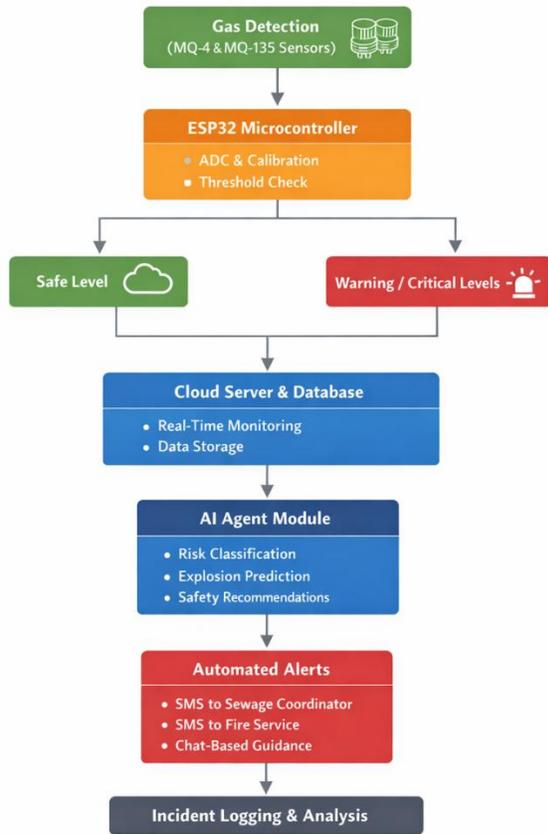
## 3. Security Measures

To ensure reliability, privacy, and protection against cyber threats, the system incorporates multiple security mechanisms:

- **Secure Communication Protocols:** Data transmission between ESP32 and cloud server is encrypted using HTTPS or MQTT over TLS.
- **Authentication and Access Control:** Only authorized administrators can access monitoring dashboards and system configurations.
- **Data Integrity Protection:** Cloud-stored logs are timestamped and protected against tampering to ensure accountability.
- **Role-Based Access Control (RBAC):** Different access privileges are assigned to sewage coordinators, administrators, and emergency services.
- **Secure API Integration:** SMS and AI services are accessed through authenticated API keys and secure endpoints.
- **Fail-Safe Mechanism:** In case of network failure, the system continues local alert operation to ensure worker safety.

This comprehensive system design ensures robust hardware reliability, intelligent software functionality, and secure operation for real-time sewage gas monitoring and emergency response.

Workflow Diagram



Workflow Steps:

1)Data Capture: Gas sensors (MQ-4 and MQ-135) continuously monitor methane and toxic gas concentrations inside sewage pipelines. The ESP32 microcontroller collects real-time analog readings and converts them into digital values for processing.

2)Preprocessing & Calibration: The ESP32 performs signal filtering, noise reduction, and sensor calibration to convert raw readings into approximate ppm values. Environmental factors such as temperature and humidity can also be considered for improved accuracy.

3)Threshold Verification:

- The processed gas values are compared against predefined safety thresholds.
- If gas levels are within permissible limits, the system continues normal monitoring.
- If levels exceed warning or critical limits, the system flags the condition immediately.

4)Local Alert Activation:

- In warning or critical conditions, a buzzer and LED indicators are activated.
- Workers near the site receive instant on-site alerts to avoid exposure.

5)Cloud Data Transmission:

- Sensor readings and alert status are transmitted securely via Wi-Fi to the cloud server.
- Data is stored in a centralized database for monitoring and analysis.

6) AI-Based Risk Analysis:

- Real-time gas data is analyzed by the AI agent.
- The system classifies the risk level (Safe, Warning, Critical).
- It evaluates toxicity level, explosion probability, and exposure duration.

7)Emergency Response Generation:

- If a critical threat is detected, automated SMS alerts are sent to the sewage coordinator and fire service department.
- The AI agent generates step-by-step safety instructions through a chat interface for workers and supervisors.

8)Logging & Monitoring:

- All sensor readings, alerts, and AI decisions are logged in the cloud database.
- Supervisors can monitor system status via a real-time dashboard.

9) System Learning & Optimization:

- Historical gas data is used to refine threshold settings and improve AI decision accuracy.
- The system can be periodically updated to adapt to new environmental patterns and safety standards.
- Enhances the user experience and also creates a safer and more workable feel.

Alerting & Response Logic

Condition	System Action
Safe Gas Level (Below Threshold)	Continue monitoring, log data to cloud dashboard, no alert triggered

Warning Level Detected	Activate yellow LED indicator, send warning notification to monitoring dashboard, log event
Critical Gas Level Detected	Activate buzzer and red LED, classify as high risk, trigger AI emergency response
Methane Above Explosion Limit	Immediate critical alert, send SMS to sewage coordinator and fire service, recommend evacuation
Toxic Gas Above Safety Limit	Trigger health hazard alert, advise use of protective equipment, notify supervisor
Sensor Malfunction Detected	Log fault event, notify maintenance team, switch to fail-safe monitoring mode
Network Failure	Continue local alert operation, store readings locally, sync with cloud once connection is restored
AI System Identifies Severe Risk Pattern	Escalate alert priority, send repeated notifications, recommend emergency shutdown of entry operations

## VII. SYSTEM EVALUATION

To evaluate the performance of the proposed AI-Enabled Sewage Gas Detection and Emergency Response System, a pilot implementation was simulated using real-time gas sensor datasets and controlled laboratory testing environments.

### 7.1 Methodology

- **Dataset:** Real-time gas concentration data collected from MQ-4 (methane) and MQ-135 (toxic gases such as ammonia and CO<sub>2</sub>) sensors under different environmental conditions. Simulated hazardous scenarios were created to test warning and critical thresholds.
- **Test Environment:** ESP32-based hardware prototype connected to a cloud IoT platform. AI risk classification models were trained offline using historical gas exposure data and deployed on a cloud server for real-time inference.

- **Metrics Collected:** Gas detection accuracy, alert response time, SMS notification latency, false alarm rate, and system reliability during continuous operation.

### 7.2 Results (Hypothetical – Can Be Refined Later)

- **Gas Detection Accuracy:** Achieved >93% accuracy in detecting methane and toxic gas threshold breaches after calibration of MQ sensors.
- **Alert Response Time:** Local alert (buzzer/LED) activation occurred within <2 seconds of threshold breach.
- **Cloud & SMS Latency:** AI risk classification and SMS alert transmission were completed within 5–8 seconds under normal network conditions.
- **False Alarm Rate:** Reduced false positives by approximately 20% compared to fixed-threshold-only systems through AI-based contextual risk analysis.
- **System Reliability:** The prototype successfully operated continuously for 72+ hours without hardware or communication failure.

### 7.3 Discussion

The evaluation results demonstrate that the proposed system provides fast and reliable hazardous gas detection suitable for sewage environments. The integration of AI improved risk classification accuracy and reduced unnecessary alarms compared to traditional threshold-based systems. Cloud connectivity enabled centralized monitoring, while edge-based alerts ensured immediate worker protection even during temporary network disruptions. The system shows strong potential for real-world municipal sewage safety deployments.

## VIII. ETHICAL CONSIDERATIONS

Implementing an AI-driven sewage safety monitoring system raises important ethical and operational considerations:

1. **Data Privacy:** Only environmental gas data and device identifiers are collected. Personal worker data is not stored



- [11] R. A. Sutar and S. B. More, “Smart Gas Leakage Detection System for Industrial and Residential Applications Using IoT,” *Journal of Sensor and Actuator Networks*, vol. 8, no. 4, pp. 1–15, Dec. 2019.
- [12] S. Rajbongshi, R. H. Raihan, and M. N. Islam, “IoT Based Real Time Gas Detection System Using Mobile Application,” *2023 International Conference on Artificial Intelligence and Smart Systems (ICAIS)*, pp. 485–490, 2023.