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An Intelligent Manhole Gas Safety and Human Risk Advisory System

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***Abstract*— Manhole workers are often exposed to toxic gases such as methane and carbon monoxide, which pose serious safety risks. This paper proposes an Intelligent Manhole Gas Safety and Human Risk Advisory System for real-time gas detection. The system uses ESP32 with MQ-series gas sensors to monitor gas levels inside sewer environments. When unsafe conditions are detected, alerts are triggered and notifications are sent through a GSM module. A monitoring dashboard enables authorities to track gas levels and improve worker safety.**

Keywords— Manhole safety, Gas detection, ESP32, IoT monitoring, Worker safety.

I. INTRODUCTION

Manhole maintenance workers are frequently exposed to hazardous gases such as methane, carbon monoxide, and other toxic pollutants present in sewer systems. These gases can cause serious health issues and sometimes lead to fatal accidents due to lack of proper monitoring systems. Traditional inspection methods often rely on manual checking, which increases the risk for workers entering confined spaces. To address this problem, an **Intelligent Manhole Gas Safety and Human Risk Advisory System** is proposed for real-time monitoring of sewer environments. The system uses gas sensors connected to an **ESP32 microcontroller** to detect harmful gas concentrations inside the manhole. When the gas level exceeds safe limits, the system activates **audio-visual alerts and sends notifications through a GSM module**. In addition, a remote monitoring dashboard allows municipal authorities to observe gas conditions continuously. This approach improves worker safety by providing early warnings and reducing the chances of exposure to dangerous gases during maintenance operations.

II. PROPOSED SYSTEM

The proposed system is designed as a portable gas monitoring device capable of detecting hazardous gases present inside manholes before workers begin maintenance operations. The device integrates gas sensors, communication modules, and alert systems to provide real-time monitoring and early warning.

The system architecture consists of three main functional layers:

1. **Gas Detection Layer**
2. **Processing and Communication Layer**
3. **Alert and Monitoring Layer**

The **gas detection layer** includes MQ-series gas sensors that continuously monitor the presence of methane, carbon monoxide, and other toxic gases. These sensors send analog signals to the ESP32 microcontroller.

The **processing layer** consists of the ESP32 controller, which analyzes sensor data and determines whether gas concentrations exceed predefined safety thresholds.

The **alert layer** provides immediate warnings through a buzzer and RGB LED indicators. In addition, the system sends alert messages using a GSM communication module and updates a remote monitoring dashboard for municipal authorities.

The integration of these layers enables **early hazard detection and rapid safety response**, minimizing risks to sanitation workers.

III. SYSTEM DESIGN AND DEVICE STRUCTURE

The device is designed as a **compact cylindrical unit** that can be easily lowered into a manhole using a cable or support rod. This structure ensures direct exposure of sensors to the underground gas environment.

The design consists of three structural sections:

Bottom Section

The bottom section contains the **gas sensors (MQ-4, MQ-7, MQ-135)**. Vent openings are provided around the sensor area to allow surrounding gases to enter and interact directly with the sensors for accurate detection.

Middle Section

The middle section houses the **ESP32 microcontroller**, **SIM800L GSM module**, internal wiring, and power supply components. This section acts as the control unit responsible for processing sensor data and managing communication.

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Top Section

The top section contains the **20×4 LCD display**, **RGB LED indicators**, **buzzer**, and **GSM antenna**. These components provide real-time status information and visual alerts for workers operating the device.

The system also includes a **mini DC blower fan** to assist with ventilation

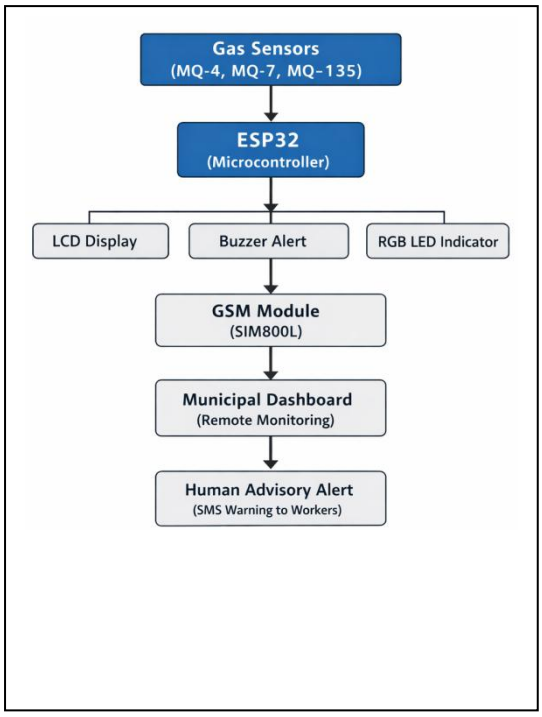

Fig. 1. Block diagram of proposed system

V. LITERATURE REVIEW

Based on the findings obtained in the ious research papers like Intelligent Manhole Gas Safety and Human Risk Advisory System by L.K. Hema et al. and IoT-Based Safety Monitoring System by A. Vellingiri et al., the existing systems are mainly concerned with the detection of toxic gases and the alert notification system with the assistance of a gas sensor and the application of the Internet of Things (IoT) technology.

IV. SYSTEM IMPLEMENTATION

The proposed system operates by continuously monitoring gas concentrations inside the manhole environment using the installed sensors. Each sensor detects specific types of gases and transmits analog signals to the ESP32 microcontroller.

The ESP32 processes the sensor data and compares the values against predefined safety thresholds. If gas levels remain within safe limits, the system displays the readings on the LCD screen and updates the monitoring dashboard.

However, when gas concentrations exceed the safe threshold:

- The **buzzer activates immediately**
- The **RGB LED changes color to indicate danger**
- The **GSM module sends alert messages**
- The **dashboard updates the warning status**

The **dashboard interface**, monitored by the municipal corporation, provides real-time visualization of gas readings. Authorities can observe methane, carbon monoxide, and air quality levels through a graphical interface, enabling them to make quick safety decisions before sending workers into the manhole.

This integration of **hardware monitoring and remote dashboard visualization** improves situational awareness and ensures timely response to hazardous conditions

These system ms contribute to human safety by means of real-time monitoring and communication, but they lack such sophisticated functions as automatic gas reduction systems and precise analysis of human health risks and preventive measures additionally, the vast majority of existing models are not able to detect multiple gases and make intelligent decisions and take preventive measures.Consequently, the proposed system is entitled An Intelligent Manhole Gas Safety and Human Risk Advisory System that will address these shortcomings. It is a multi-gas sensing system, real-time monitoring system and human risk advisory. It also offers GSM based alert communication and other safety provisions like automatic sprinkler and ventilation devices to improve safety of the workers and avoid accident.

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TABLE 1: Summary of Key Research Efforts on Manhole Gas safety and Human Risk Advisory System

Ref	Systematic Review	Dataset/ Experiment	Tecchnological Approach	Results & Analysis	Challenges & Future Scope	Contribution
Hema [1]	✓	✓	MQ gas sensors with alert system	Detects methane and toxic gases; basic alert provided	No automatic gas control; lacks risk analysis	Provides basic gas detection system for manholes
Chandraprabh [2]	✓	✓	IoT-based real-time monitoring system	Continuous monitoring and remote data access	No automatic response mechanism	Improves real-time monitoring using IoT
Vellingiri [3]	✓	✓	IoT with GSM communication	Enables two-way communication and alerts	No multi-gas detection; no automation	Enhances communicatio n for worker safety
Pushpakumar [4]	✓	✓	Drainage monitoring with alert system	Provides alert for hazardous conditions	No human risk advisory; limited analysis	Basic safety monitoring system
Ambeth Kuma [5]	✓	✓	Wireless gas sensing system	Detects gases and sends alerts wirelessly	No intelligent decision-making; no control system	Introduces wireless sensing for sewer safety
Proposed work	✓	✓	MQ sensors + ESP32 + GSM + Sprinkler & Fan	Real-time multi-gas detection, risk analysis, automatic response	Future: AI integration and cloud monitoring	Complete system with detection, analysis, alert, and automatic safety action

The findings obtained in the works of different researchers including: "Smart Manhole Toxic Gas Identification and Alerting System" by L.K. Hema et al., "Real-Time Manhole Monitoring System" by Chandraprabha R et al., and IoT-Based Safety Monitoring System for Sewage Workers by A. Vellingi et al. show significance of toxic gas detection in sewage areas with the help of gas sensors and IoT technologies. These systems are aimed at detecting toxic fumes like methane and carbon monoxide and delivering a notification of the presence of such fumes by real-time tracking and communication. Others also have wireless communication and remote monitoring in order to enhance safety awareness and coordination among workers as well as with the authorities.

Altogether, the mentioned methods help to minimize risks in closed spaces where it is possible to conduct early observations and timely signals.

Most of the available systems can however only perform the gas detection and gas alert systems but do not have the high-level features such as multi-gas, intelligent decisions and automatic response to the concentration of gas among others. Furthermore, there are very few studies, which can give in-depth analysis of human health risks in relation to exposure of the gas. Thus, the proposed Intelligent Manhole Gas Safety and Human Risk Advisory System attempts to overcome the limitations through the incorporation of multi-gas sensing, real-time monitoring,

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human risk advisory, GSM-based alert communication and automatic safety devices of sprinkler and ventilation. It is a holistic strategy that improves the safety of the workers, avoids accidents, and helps to construct safer and smarter city infrastructure.

RESEARCH METHODOLOGY

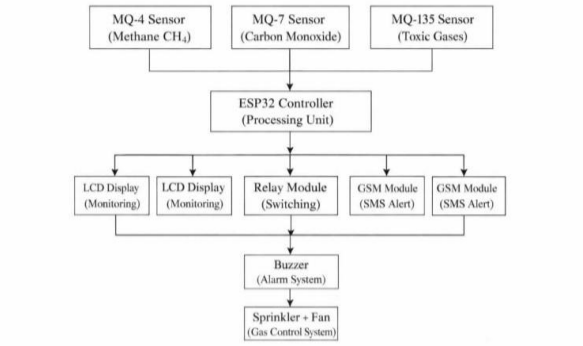

Figure 1 System Design of Gas Detection and Alert system

TABLE II: Components specifications

Module	Voltage	Current
ESP32 Microcontroller	5V	80 - 240 mA
MQ-4 Gas Sensor (CH4)	5V	150 mA
MQ-7 Gas Sensor (CO)	5V	150 mA
MQ-135 Gas Sensor (Air Quality)	5V	150 mA
SIM800L GSM Module	3.7V - 4.2V	350 - 500 mA
LCD Display (20x4 I2C)	5V	20 - 60 mA
Buzzer	5V	20 - 30 mA
RGB LED	2V - 3V	10 - 20 mA
Relay Module	5V	10 - 20 mA
Water Pump (Sprinkler)	5V / 12V	200 - 500 mA
DC Fan Blowe	5V / 12V	100 - 300 mA
Rechargeable Battery	7.4V / 12V	Depends on Load

The gas detection system suggested can be implemented in such a way that it combines various hardware specifications to achieve time-efficient monitoring and control. The ESP32 microcontroller will serve as the hub in processing sensor data recorded by MQ-4, MQ-7 and MQ-135 gas sensors sensing methane, carbon monoxide and toxic gases respectively. Real-time transmission of alerts is through a GSM module with a local monitoring through an LCD display. Safety operations of external devices like a buzzer, sprinkler and the exhaust fan are controlled through the relay module. Every element will be used at specified current and voltage ranges as shown on Table II and as such all elements will have reliable and efficient performance of the system.

The system is made to react fast to the dangerous conditions enhancing safety in the domestic and industrial setup. This is due to the low-power components that maximize energy efficiency. The system is also easy to expand and maintain as it has a modular design. This method is cost effective and applicable in real time operations. Multiple sensors are incorporated to enhance the detection accuracy and the dependability. On-site monitoring helps preventive measures to be taken instantly in case of leakage of gas. Automation reduces the human input in the system. In sum, it is an efficient and flexible design to monitor environmental safety.

TABLE III: Comparative Analysis of Existing Gas Detection System And Proposed System

Feature / Parameter	Existing Systems (Conventional / GSM / Wired)	Proposed ESP32-Based Gas Detection System
Power Consumption	High (continuous power required for GSM/Wi-Fi modules)	Low, energy-efficient operation
Gas Detection	Limited to single gas or low sensitivity	Multi-gas detection (MQ-4, MQ-7, MQ-135)
Response Time	Slower due to manual monitoring or delay	Fast, real-time automatic response
Alert System	Basic alert or manual notification	Instant SMS alert using GSM module
Automation	Mostly manual or semi-automatic	Fully automatic detection and control
Safety Action	No automatic control mechanism	Activates buzzer, sprinkler, and fan

Installation	Complex wiring required	Simple and compact design
Cost	High due to infrastructure and maintenance	Low-cost and affordable components
Real-Time Monitoring	Limited or not continuous	Continuous real-time monitoring
Scalability	Difficult to expand	Easily scalable and modular design

VI. RESULTS AND DISCUSSION

The proposed system is currently under development and focuses on providing an efficient solution for early detection of hazardous gases in sewer environments. The integration of multiple gas sensors enables detection of various harmful gases that are commonly found in underground sanitation systems.

The system architecture provides several advantages:

- Real-time gas monitoring
- Immediate safety alerts
- Remote supervision through dashboard monitoring
- Portable device design for easy deployment
- Additional ventilation and mist mechanisms for safety support

Once implemented, the system is expected to significantly reduce the risk faced by sanitation workers by ensuring that hazardous gas levels are detected before human entry into confined spaces.

VII. CONCLUSION

This paper presents an Intelligent Manhole Gas Safety and Human Risk Advisory System designed to improve safety during sewer maintenance operations. The system combines multiple gas sensors, an ESP32 microcontroller, GSM communication, and a remote monitoring dashboard to detect hazardous gases and provide timely alerts.
The proposed cylindrical device structure allows easy deployment inside manholes, ensuring direct gas exposure for accurate detection. With the addition of visual alarms, remote notifications, and municipal monitoring support, the system provides an effective approach to preventing accidents and improving worker safety in urban sanitation infrastructure.

VIII. FUTURE SCOPE

The system can also be improved by incorporating internet of things in remote monitoring and analysis of data. In order to achieve better results in detection and prediction of dangerous conditions advanced algorithm can be applied. The system is scalable to a large industrial setup that has several sensor nodes. Moreover, the use of safe communication measures will enhance transparency and information security. Hybrid communication technologies may also be a part of the further upgrades to enable a higher connectivity and coverage.

Future Scope
Future improvements may include:

- Integration with IoT cloud platforms
- AI-based gas risk prediction
- Mobile application monitoring
- Automatic ventilation control systems
- GPS-based manhole location tracking

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