



IMPLEMENTATION OF TOXIC GAS DETECTION AND ALERTING SYSTEM

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Abstract : *In the bustling urban landscape of India, where sprawling underground drainage systems silently snake beneath the city streets, the responsibility of upkeep falls squarely on the shoulders of Municipal Corporations. Yet, it is the unsung heroes, the manual scavengers, who brave the depths of manholes daily, confronting a perilous adversary: insidious and odourless deadly gases such as carbon monoxide, hydrogen sulphide, and methane.*

To combat this invisible threat, we have engineered a sophisticated and life-saving monitoring system. Harnessing the power of specialized gas sensors meticulously placed within these labyrinthine passages, our innovative solution stands as a vigilant guardian against danger. When these sensors detect the slightest rise in hazardous gas levels, the system springs into action, illuminating the dark confines of the manhole with a vivid warning light. Simultaneously, it dispatches urgent notifications through the Internet of Things (IoT) to authorized personnel, ensuring swift response and safeguarding the lives of those who navigate these treacherous depths. This technology-infused marvel not only enhances operational efficiency but also stands as a beacon of safety in the hazardous world beneath our bustling cities, offering peace of mind to those who undertake this vital yet perilous task.

1. INTRODUCTION

Hidden beneath the bustling streets of our cities lies an intricate web of manholes and sewers, silently performing the crucial task of maintaining sanitation and infrastructure. Yet, amidst this labyrinth of underground passages, it is the often-overlooked heroes who shoulder the burden of essential duties. These brave individuals delve into the enigmatic depths of manholes, confronting a formidable and unseen adversary: hazardous gases that lurk within.

Traditionally, outdated methods such as candle tests and chemical analyses in laboratories were relied upon to gauge the safety of these subterranean chambers. However, these methods fell short, leaving the risks posed by methane, carbon dioxide, ammonia, carbon monoxide, and hydrogen sulphide largely uncharted. It became increasingly evident that a more sophisticated, efficient, and timely solution was imperative to safeguard the lives of these courageous workers against these invisible threats.

Enter the revolutionary Manhole Hazardous Gas Detection and Alerting System, a beacon of hope in the realm of underground safety. This technological marvel seamlessly blends the prowess of advanced gas sensors, real-time data analysis, and cutting-edge machine learning. Not merely content with gas detection, this system elevates collected data into actionable insights. The culmination is a comprehensive solution that stands as a vigilant guardian, shielding those who venture into the depths of manholes from harm.

The journey towards this innovative system was paved with challenges and a deep understanding of the dangers faced by sewer maintenance personnel. Conventional methods, with their limitations and gaps in safety, spurred the need for a more proactive and responsive approach. The Manhole Hazardous Gas Detection and Alerting System was born from this necessity, born to redefine safety standards in underground environments.

At its core, the system is a symphony of technological brilliance. Specialized gas sensors, meticulously placed within the network of manholes, tirelessly monitor the air for any signs of hazardous gases. When these sensors detect elevated levels beyond safety

thresholds, the system springs into action with precision. A vibrant, unmistakable light illuminates the darkness of the manhole, signaling a warning to those within its confines. Simultaneously, through the wonders of the Internet of Things (IoT), notifications are swiftly dispatched to authorized personnel. These real-time alerts empower quick decision-making and prompt responses, ensuring the safety and well-being of every worker underground.

But the system's capabilities do not end there. The collected data, flowing seamlessly through the system's intricate network, undergoes rigorous analysis. Advanced machine learning algorithms, such as the Neuro Swarm approach, work tirelessly to transform raw data into meaningful insights. Patterns, anomalies, and trends in gas concentrations are identified, providing a deeper understanding of the underground environment. This wealth of information equips authorities with the tools to not only react but also proactively address potential hazards before they escalate.

The impact of the Manhole Hazardous Gas Detection and Alerting System reverberates far beyond the confines of the manholes themselves. It heralds a new era of safety, one where technology serves as a steadfast ally to those who work in hazardous conditions.

2. Problem Statement and Objectives

Problem: Traditionally, the safety assessment protocols for manual scavengers relied on rudimentary methods such as candle tests or laborious laboratory chemical analyses. These outdated techniques, however, proved to be insufficient and highly risky. They failed to detect the presence of lethal gases such as methane, carbon dioxide, carbon monoxide, ammonia, and hydrogen sulphide, leaving workers vulnerable to severe health hazards. The absence of comprehensive gas detection measures posed an imminent threat to the lives of those entering manholes. A dire need arose for a more sophisticated, efficient, and comprehensive solution to ensure the safety and well-being of sewer maintenance personnel in the face of these invisible yet deadly dangers.

Objective: The primary objective of this project is to engineer an advanced gas detection system tailored specifically for the hazardous environment of manholes. The system aims to swiftly and accurately identify the presence of lethal gases such as methane, carbon dioxide, carbon monoxide, ammonia, and hydrogen sulphide within these confined spaces. By leveraging cutting-edge gas sensors and real-time communication technologies, our goal is to provide timely and actionable alerts to prevent accidents and ensure the safety of sewer maintenance personnel.

This innovative system will revolutionize the way manholes are monitored and maintained. It will enable remote monitoring of manholes, eliminating the need for direct exposure of workers to the dangers lurking within. Through device indicators and displays, real-time data on gas levels will be readily available, offering a comprehensive overview of the environment's safety status. This remote monitoring capability will not only enhance worker safety but also streamline maintenance operations, minimizing downtime and maximizing efficiency.

By overcoming the limitations of traditional methods such as slow chemical testing and limited gas detection capabilities, this system promises to be a game-changer in the field of underground infrastructure maintenance. Its advanced sensors and rapid alerting mechanisms will provide a robust safety net, ensuring that those who venture into the depths of manholes do so with confidence and security.

3. Methodology

3.1 Integration of MQ4 Methane Sensor and MQ7 CO Sensor with Arduino Uno:

The first step in the development of the Manhole Hazardous Gas Detection and Alerting System involves the integration of two crucial components: the MQ4 Methane Sensor and the MQ7 CO Sensor with the Arduino Uno microcontroller. These sensors are carefully selected for their sensitivity and accuracy in detecting methane and carbon monoxide, respectively.

The MQ4 Methane Sensor is connected to the Arduino Uno's analog pin, enabling it to measure the concentration of methane gas in the surrounding environment. Similarly, the MQ7 CO Sensor is also connected to an analog pin, allowing it to detect the presence of carbon monoxide gas.

These sensors act as the frontline detectors within the manhole, continuously monitoring the air for any signs of elevated methane or carbon monoxide levels. The data obtained from these sensors forms the foundation of the system's real-time monitoring capabilities.

3.2 Integration of LCD Display and Gas Sensor Indicators:

To provide a visual representation of the sensed data, an LCD display is integrated with the Arduino Uno using I2C Module. This display serves as a user-friendly interface, showcasing the current levels of methane and carbon monoxide in the manhole environment.

Additionally, two indicators are connected to the Arduino Uno, each corresponding to one of the gas sensors. If the CO level surpasses the predefined threshold, the indicator linked to the MQ7 CO Sensor will illuminate, alerting personnel to the presence of elevated carbon monoxide levels. Similarly, if the methane level exceeds the safe limit, the indicator connected to the MQ4 Methane Sensor will glow, indicating the potential danger posed by methane gas.

This integrated display and indicator system provides immediate and intuitive feedback to users, allowing for quick responses to any hazardous conditions detected within the manhole.

3.3 Integration of NodeMCU ESP8266 for Data Transmission:

To enable remote monitoring and data transmission, the NodeMCU ESP8266 Wi-Fi module is integrated with the Arduino Uno. This module facilitates the wireless transmission of the sensed gas data to the ThingSpeak server, a cloud-based IoT platform.

The NodeMCU establishes a secure connection to the local Wi-Fi network, allowing seamless communication with the ThingSpeak server. The Arduino Uno processes the data from the gas sensors and transmits it to the NodeMCU for transmission.

3.4 Real-Time Data Analysis and Email Alerts on ThingSpeak Server:

On the ThingSpeak server, the sensed gas data is displayed in real-time on separate graphs for methane and carbon monoxide levels. This visual representation allows for a quick and comprehensive overview of the manhole environment.

Additionally, the server continuously analyzes the incoming data over a specified period. If the average gas concentration levels exceed the predefined threshold values during this analysis period, an email alert is generated and sent to the designated authorities.

This proactive alert system ensures that any potentially hazardous conditions are promptly identified and communicated to the relevant personnel, enabling swift and decisive action to be taken.

3.5 Integration of Solenoidal Valve and Air Pump for Gas Sampling:

To facilitate the sampling of gases from the manhole, a solenoidal valve and air pump are integrated with the Arduino Uno. The solenoidal valve controls the flow of gases into the sampling tube, while the air pump creates suction to draw the gases from the manhole into the sensors.

These components are connected to the Arduino Uno via relays, allowing for precise control and synchronization of the gas sampling process. When triggered, the solenoidal valve opens, and the air pump activates, sucking the gases from the manhole into the sensors for analysis.

This integrated sampling system ensures that the gas sensors receive a continuous and accurate supply of air from the manhole, enabling reliable detection of methane and carbon monoxide levels.

In summary, the methodology of the Manhole Hazardous Gas Detection and Alerting System encompasses the integration of advanced gas sensors, visual indicators, wireless data transmission, real-time data analysis, and automated gas sampling. This comprehensive approach ensures the safety of sewer maintenance personnel by providing timely alerts and actionable insights in the face of potentially dangerous gas levels within manholes.



Fig 1: Hardware Setup for device

4. Hardware and Software components

4.1 Hardware Components:

4.1.1 MQ4 Methane Sensor and MQ7 CO Sensor:

These sensors are the core components of the system, responsible for detecting methane and carbon monoxide gases within the manhole environment.

4.1.2 Arduino Uno Microcontroller:

The Arduino Uno serves as the brain of the system, managing the sensors, data processing, and control of other hardware components.

4.1.3 LCD Display with I2C Interface:

Arduino Uno communicates with the LCD display using the LiquidCrystal_I2C library, allowing it to display precise methane and carbon monoxide readings in a clear and easily readable format.

4.1.4 Gas Sensor Indicators:

Two indicators are connected to the Arduino Uno, one for each gas sensor. These indicators visually alert personnel when methane or CO levels exceed safe thresholds.

4.1.5 NodeMCU ESP8266 Wi-Fi Module:

The NodeMCU ESP8266 module enables wireless data transmission to the ThingSpeak server, allowing remote monitoring and analysis.

4.1.6 Solenoidal Valve and Air Pump:

These components are used for gas sampling from the manhole. The solenoidal valve controls gas flow, while the air pump creates suction to draw gases into the sensors.

4.1.7 Relays:

Relays are utilized to control the solenoidal valve and air pump, enabling precise and synchronized gas sampling.

All of these hardware components are detailed and illustrated in the accompanying block diagram, providing a comprehensive overview of the Manhole Toxic Gas Detection and Alerting System.

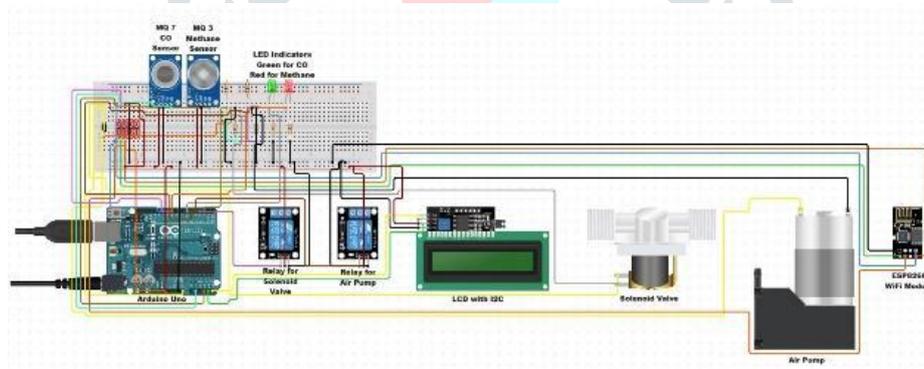


Fig 2: Block Diagram of the Manhole Toxic Gas Detection and Alerting System

4.2 Software Components:

4.2.1 Arduino IDE:

The Arduino Integrated Development Environment (IDE) is used to program the Arduino Uno microcontroller. This includes coding for sensor data acquisition, processing, and control of hardware components.

4.2.2 ThingSpeak Platform:

The ThingSpeak platform is a cloud-based IoT platform where the sensed gas data is transmitted for storage, visualization, and analysis. It allows for real-time monitoring and generates email alerts when gas levels exceed predefined thresholds.

4.2.3 WiFi Library:

The WiFi library in the Arduino IDE is utilized to establish a secure connection between the NodeMCU ESP8266 module and the local Wi-Fi network. This enables data transmission to the ThingSpeak server.

4.2.4 LiquidCrystal Library:

The LiquidCrystal library is used to interface with the LCD display, allowing for the display of real-time gas concentration levels in a user-friendly format.

5. Working Procedure

5.1 Sample Collection from Manhole:

The system is equipped with a sampling tube fitted with a solenoidal valve that extends into the manhole. When gas sampling is required, the solenoidal valve opens under control from the Arduino Uno. A vacuum pump is then activated, creating suction to draw air from the manhole into the sampling tube for analysis.

5.2 Gas Accumulation in Airtight Chamber:

The sampled air is directed into an airtight chamber within the main device, ensuring that the gas sample remains isolated from the external environment. Within this chamber, gas sensors for methane, and carbon monoxide are strategically placed to detect the presence and concentration of these hazardous gases.

5.3 Gas Sensing and Data Collection:

The gas sensors, including the MQ4 Methane Sensor and MQ7 CO Sensor, continuously monitor the concentration of ammonia, methane, and carbon monoxide within the airtight chamber. These sensors provide real-time data on the levels of these gases, sending analog signals to the Arduino Uno for processing.

5.4 Data Processing and Transmission:

The Arduino Uno, acting as the system's central processor, receives the analog signals from the gas sensors. It then processes this data, converting the analog readings into digital values for accuracy and reliability. The processed gas concentration data is then transmitted to the ThingSpeak server via the NodeMCU ESP8266 module.

5.5 Alerting and Reporting:

If the gas levels detected by the sensors exceed predefined thresholds, the system triggers alerts to indicate potential hazards. These alerts can take the form of visual indicators on the LCD display, LED indicators present on device and remote notifications sent to authorized personnel via email or SMS.

Simultaneously, the ThingSpeak server displays real-time gas concentration graphs and generates email alerts to alert authorities of any dangerous gas levels.

6. Results and Analysis

Methane (CH_4) has a Lower Explosive Limit (LEL) of 5% vol and an Upper Explosive Limit (UEL) of 15% vol, making it potentially explosive at concentrations between these limits. The Threshold Limit Value (TLV) for methane is 1000 ppm (0.1%) for an 8-hour period, with concentrations of 5% to 15% posing explosive risks and extremely high concentrations causing oxygen starvation.

Carbon Monoxide (CO) has an LEL of 12.5% vol and a Permissible Exposure Limit (PEL) of 50 ppm for an 8-hour time-weighted average. Exposure to CO can lead to hypoxia, respiratory distress, and adverse health effects, with concentrations above 250 ppm causing severe symptoms.

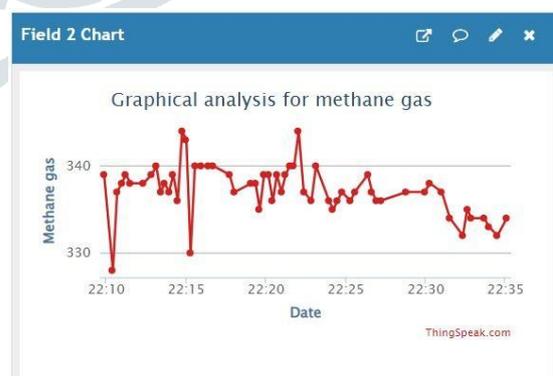
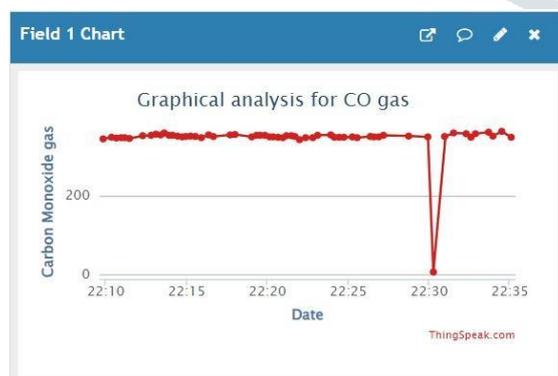


Fig 3: Graphical representation of CO gas data in real time

Fig 4: Graphical representation of Methane Gas data in real time

Two graphs shown above display real-time data of toxic gases inside the manhole and data sensed by gas sensors uploaded to the ThingSpeak server via NodeMCU. Initially, the solenoidal valve opens upon triggering by Arduino Uno, and simultaneously, the air pump begins suctioning gases from the manhole. During this time, gases accumulate in the airtight section of the device where gas sensors are located. Sensor readings commence only after the pump ceases operation. The analytical process involves retrieving real-time data from the server and analyzing the data from the last hour. Mean values are calculated, and if these values exceed the

threshold for toxic levels, an email alert is promptly dispatched to the relevant authority as a warning.

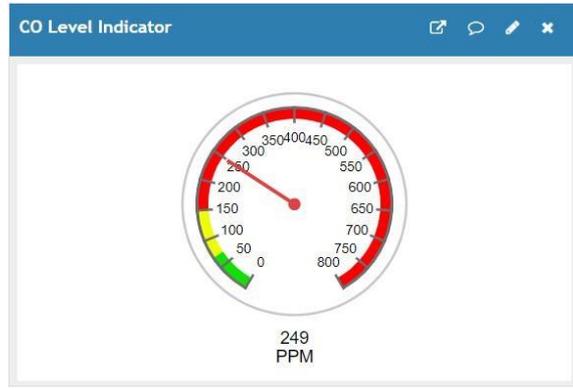


Fig 5: Indicator for CO gas level

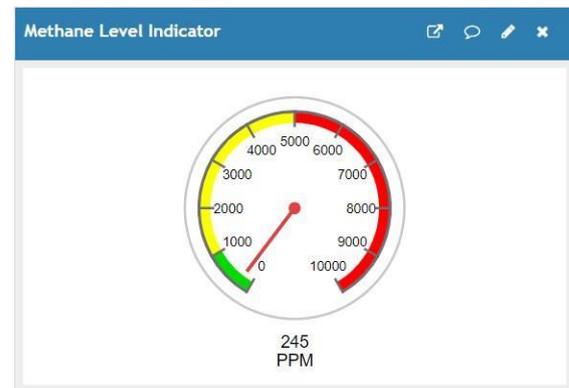


Fig 6: Indicator for Methane gas level

The server interface features two indicators displaying real-time gas data. Each indicator is set with predefined ranges for gas levels. As gas concentrations change, the indicators update dynamically, providing instant feedback on manhole conditions to enhance safety during maintenance.

Now the question arises, what makes this device different and suitable from other devices? There are several factors that make this device stand out.

- Firstly, it can be pole-mounted near the manhole, with a pipe connecting it to the keeps the device safe from any potential damage.
- The solenoid valve and air pump ensure that gases are only sampled when necessary and protect the device during waterlogging or floods.
- The device protects workers from direct exposure to toxic gases by using indicators for both gases. These indicators alert workers when gas concentrations exceed threshold levels, such as 70 ppm for CO and 1000 ppm for methane.
- The device features server-based analysis and alert systems, uploading real-time gas data for remote monitoring. An email alert is triggered if the mean gas concentration over the last hour exceeds threshold levels. Continuous high levels of toxic gases indicate potential choking hazards, signaling the need for immediate manhole maintenance.

The sample of data analysis results from the ThingSpeak server is depicted below.

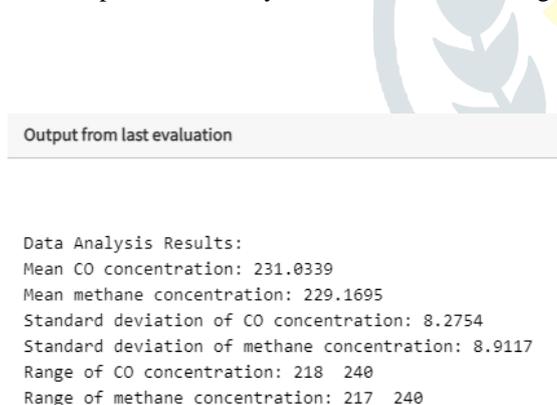


Fig 7: Sample of data analysis result from last evolution.

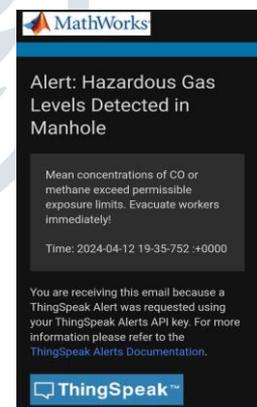


Fig 8: Email Alert Generated to authorities.

7. Conclusion

In conclusion, the Manhole Hazardous Gas Detection and Alerting System offers a robust solution for monitoring toxic gas levels in manholes, prioritizing worker safety and operational efficiency. Through advanced sensors and server-based analysis, real-time methane and carbon monoxide data are continuously collected and analyzed. Pole-mounted installation and threshold alerts mitigate worker exposure to hazardous gases, enhancing safety protocols. This innovative system enables proactive measures in response to elevated gas levels, minimizing potential hazards. In conclusion, this project represents a significant advancement in sewer maintenance safety, with the potential to improve worker well-being and operational efficiency in urban infrastructure management, while contributing to a reduction in human health risks associated with hazardous environments.

8. References

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