EPJ Web of Conferences **367**, 03008 (2026) https://doi.org/10.1051/epjconf/202636703008
RIACT 2026

IoT based Portable Manhole Gas Sensing System

Rahul Harikrishnan[1], *Yuvan* Shankar[1], *Lokesh* Babu[1], *Venkatachalam* Rajarajan Balaji[2,1*], and *Jesuwanth* Sugesh Ramesh Gabriel[3]

[1]School of Electronics Engineering, Vellore Institute of Technology, Chennai, Tamil Nadu, India

[2]Centre for Healthcare Advancement, Innovation and Research, Vellore Institute of Technology, Chennai, Tamil Nadu, India

[3]Department of Electronics and Communication Engineering, School of Engineering and Technology, CHRIST University, Bengaluru, Karnataka, India

Abstract. Maintenance of sewage systems requires workers to enter confined manholes, where hazardous gases can build up. These toxic, flammable gases create a serious safety risk. To address this problem, a portable gas monitoring system based on IoT technology was designed for real time sensing and observation. The proposed system comprises of MQ-4, MQ-6, and MQ-7 gas sensors, along with a DS18B20 temperature sensor, all interfaced to an ESP32 microcontroller. The data is then transmitted to a cloud platform built with Node.js and MongoDB, enabling real-time monitoring. Whenever the gas concentrations exceed the safety limits, alerts are triggered to enable early action. The experimental results show an accuracy of approximately ±2% compared to standard measurement instruments, with the latency less than 500 ms. Early warning of dangerous gas levels can significantly reduce risks during sewage maintenance.

1 Introduction

Manhole maintenance during flood conditions and other emergencies can expose workers to toxic gases, gas explosions, and inhalation hazards, which have caused fatalities in India. Methane (CH_4), Carbon monoxide (CO) and liquefied petroleum gas (LPG) are a few of the toxic gases that are present in the manhole sewage system that can cause severe respiratory issues and may lead to be fatal. Because manholes are poorly ventilated, gas accumulation can occur without any visible warning. Conventional gas detection instruments are often unsuitable for such environments due to their size, cost, or inability to provide continuous remote monitoring. In addition, the absence of real-time communication limits timely response during emergency situations. Suitable gas detecting device with IoT technology can be a better solution for the above. Existing gas detectors are bulky, expensive, or lack real-time connectivity, which fails to meet the requirements. This work proposes an IoT-

* Corresponding author: balaji.vr@vit.ac.in

enabled manhole gas sensing system which continuously senses the level of the various gases and temperature. If the measured level exceeds the threshold level, alerts are produced and sent to the concerned responsible personnel to prevent accidents. This can be achieved by installing the device under the manhole cover.

Several studies have explored IoT-based monitoring of manholes and sewer Infrastructure. An IoT-based system for manhole monitoring, using sensor nodes and a central monitoring interface to measure gas levels and the abnormal atmosphere in manholes to prevent accidents, was presented in [1]. A method using AI-based auto encoders, sensors and a suitable learning algorithm to detect in manholes was proposed in [2]. The presence of methane and hydrogen sulfide in a manhole can be detected using the model proposed by [3]. Deep learning techniques were used in [4] to detect physical faults, and an NB-IoT-based manhole cover monitoring system was proposed in [5]. A reliable system for monitoring and sending alerts was proposed in [6]. IoT-based frameworks were proposed in [7] and [8] for improving municipal infrastructure maintenance through real-time data sharing and alert notifications. A LoRa-based portable manhole monitoring system to identify abnormal cover movements with the help of accelerometers was developed in [9]. A multi-sensor portable gas detection system for confined spaces was designed in [10], a gas detection system integrated with cloud-based logging was discussed in [11] and [12]. A system specifically for identifying uncapped manholes in waterlogged areas during monsoon using image processing technology and sensors was designed in [13].

In [14], an IoT-based system for monitoring water level, leakage, and motor control in smart water was presented, with a primary focus on water management and automation. In their study [15], the authors discussed the concept of smart everything, highlighting the integration of intelligent technologies into urban systems. A smart manhole cover safety monitoring system integrated with urban infrastructure was proposed in [16], enabling real-time detection of abnormal conditions to enhance safety. A secured manhole management system using IoT and machine learning was introduced in [17].An IoT-based manhole monitoring system utilizing sensors to detect hazardous conditions and transmit real-time alerts was developed in [18]. Similarly, an IoT-enabled smart manhole system integrating multiple sensors and environmental and structural parameters is reported in [19].

Many earlier works focused on single parameter sensing, and some are not portable. In this work, it is proposed to detect various gases and also the temperature. Gas and temperature sensors are selected based on the environmental conditions and integrated with the ESP32 microcontroller in this sensing system.

2 Methodology

The main objective of this work is to achieve real time monitoring of the manholes with accurate sensing and instant response by adequate data transmission. The same is obtained by using the gas sensors viz. MQ 4, MQ6, MQ7 and temperature sensor DS18B20 accomplished with ESP32 microcontroller. The ESP32 continuously acquires sensor data and transmits the readings over Wi-Fi to a backend server developed using Node.js. The received data are stored in a MongoDB database and visualized through a Next.js–based dashboard. Alert notifications are generated whenever measured values exceed predefined safety limits. The operational flow of the system is illustrated in Figure 1.

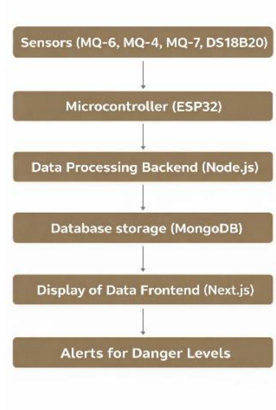
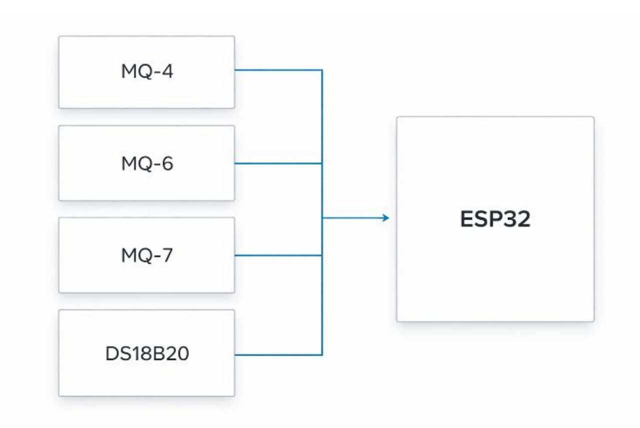


Fig. 1. Flow Chart of Portable Manhole Gas Detector

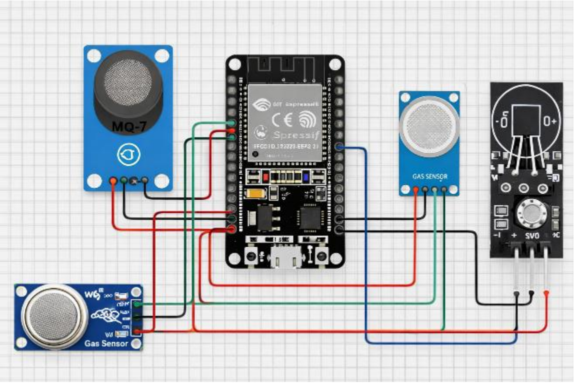
2.1 Hardware Configurations

The proposed system is centred around the ESP32 microcontroller that is selected due to its integrated Wi-Fi support, low power usage and high processing rate, which makes it appropriate for IoT-based portable devices. The ESP32 gathers information from a number of gas sensors and sends it wirelessly to the dashboard for monitoring.

Figure 2 (a) shows the architecture of the hardware components used in the proposed device. It comprises of MQ - 4, MQ - 6 and MQ - 7 sensors for gas monitoring, and DS18B20 sensor for monitoring the temperature. The MQ-7 sensor is used to sense CO concentration, which is an important gas to be sensed in manhole conditions because it is toxic and poses a danger to human life. The MQ-4 sensor is used for CH_4 concentration detection, since methane is very combustible and can condense in limited spaces such as manholes and create serious explosion risks. The MQ-6 sensor is also used for the detection of LPG and butane, which offers extended coverage in detecting flammable gases. All the sensors are connected to the ESP32 microcontroller which facilitates multiple sensor concurrent data acquisition from sewer pipes. Figure 2 (b) shows the overall circuit diagram of the proposed system, combining several gas sensors with the ESP32 microcontroller unit.



(a)



(b)

Fig. 2. (a) Architecture of the hardware components used. (b) Circuit Diagram of Portable Manhole Gas Detector.

2.2 System Configurations

The important components, such as the ESP32 Microcontroller and the power supply module, and the signal conditioning electronic components are assembled on the Printed Circuit Board with due care. Figure 3 illustrates the internal structure of the portable manhole gas detector. Proper rigid casing is provided to prevent the components from dust, moisture and other environmental conditions. The salient features of this portable and user friendly device are its robustness, compatibility to deploy in any complicated places, reliability and operational life span. Future upgrades can also be done effectively in this device.

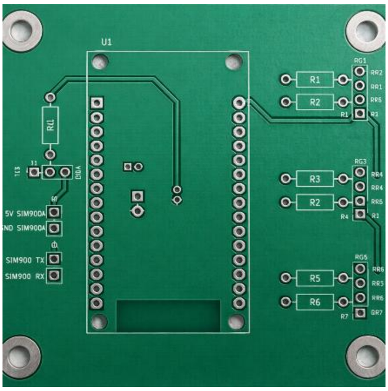


Fig. 3. PCB for Portable Manhole Gas Detector.

2.3 Training

The software setup of this device ensures smooth data collection, storage, and display for real-time monitoring. The readings are collected through gas sensors (MQ-6, MQ-4 and MQ-7) and a DS18B20 temperature sensor. The ESP32 continuously reads the sensor values and sends them over Wi-Fi to a Node.js backend. The received data are stored in

MongoDB and displayed on a Next.js-based dashboard. Whenever the measurement exceeds the predefined safety threshold, the system notifies via an alert. Recorded data are also used to improve detection of abnormal conditions. Data normalization and augmentation techniques are applied to reduce variation and improve robustness across dynamic environmental conditions.

3 Results and discussion

Practical testing was performed to analysis the performance of the developed portable manhole gas detection system. Figure 4 shows the prototype of the developed Portable Manhole Gas Detector.

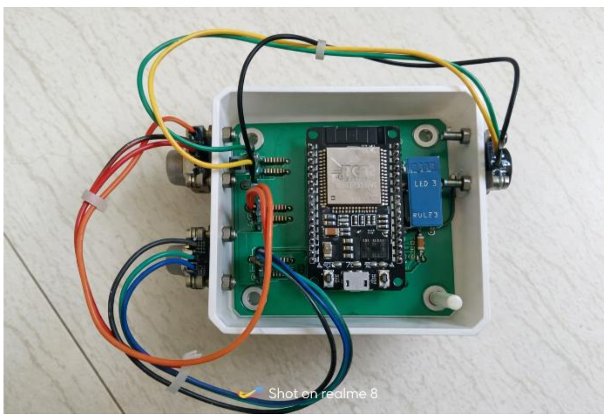


Fig. 4. Prototype of Portable Manhole Gas Detector

3.1 Real-time analysis

During testing, the system responded quickly to changes in gas concentration. The data transmission delay remained below 500 ms, which is suitable for near real-time monitoring. The backend handled continuous sensor updates efficiently with minimal latency. The measured values also matched standard reference instruments closely, with an average deviation of about ±2%.

3.2 Discussion of results

Figure 5 presents the monitoring dashboard for gas concentration and ambient temperature. The interface gives a clear visualization of the sensor readings in real time. In one test, the ambient temperature inside the manhole setup was approximately 34.63°C, which is reasonable in a poorly ventilated confined space. The MQ-4 sensor measured methane at about 109 PPM, indicating possible gas accumulation. The MQ-6 sensor reported LPG at 4 PPM, which suggests a low but detectable flammable-gas level. The MQ-7 sensor measured carbon monoxide at 202 PPM, which is above recommended safety limits and indicates a hazardous condition. These results highlight the need for continuous monitoring in such environments. The use of multiple sensors improves reliability by covering different gas types, and the alert system allows maintenance personnel to act before entering unsafe areas.

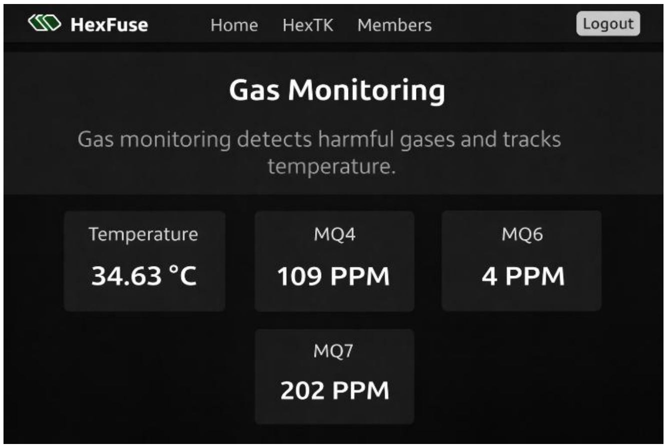


Fig. 5. Results from the sensors of the Portable Manhole Gas Detector

Table 1. Comparison of Previous Works with Proposed System

Ref	Technology Used	Sensors / Parameters	Communication	Limitations	Proposed Work Advantage
[1]	IoT-based manhole monitoring	Gas level monitoring with sensor nodes	Wi-Fi	Limited to single-location monitoring; no portability	Portable device with multi-gas detection and cloud dashboard
[2]	AI (Autoencoders) + IoT	Sensor data anomaly detection	Wireless (unspecified)	Complex ML setup, less focus on portability	Simple, low-cost real-time alerts, can later integrate ML
[3]	IoT + Smart Sensors	Methane, H_2S detection	Wi-Fi	Focused on fixed installations	Portable, covers multiple gases (CH_4, CO, LPG)
[5]	NB-IoT	Manhole cover displacement	NB-IoT	No gas detection	Adds gas + temperature monitoring with real-time alerts
[9]	LoRa + Accelerometer	Manhole cover movement	LoRa	Mechanical monitoring only	Gas and temperature monitoring in confined spaces
[11]	Web-based Smart Monitoring	Gas data logging	Cloud / Wireless	Limited to data logging; not fully portable	Compact, wearable-ready, instant threshold alerts
[12]	IoT + Cloud	Multiple manhole parameters	Cloud	Scalable but not portable	Portable real-time detection,

	Analytics				deployable anywhere
Proposed Work	IoT + ESP32 + Cloud	MQ-4 (CH_4), MQ-6 (LPG), MQ-7 (CO), DS18B20 (Temp)	Wi-Fi + Cloud (Node.js, MongoDB)	Minor sensor calibration needed	Multi-gas detection, temperature detection, low-cost, portable, real-time dashboard + instant alerts

Table 1 presents a comparison between the proposed system and existing works. This portable proposed device combines IoT with multi-gas sensing to provide real-time notifications. These features of the system ensure that it is a priceless asset for protecting the safety and health of maintenance personnel.

4 Future work

Several improvements can be considered to further enhance the proposed system. Figure 6 highlights the proposal for future work. A compact wearable design, such as an armband-based system (as shown in Figure 7), can be explored to enable continuous monitoring without manual handling. Incorporating edge processing within the ESP32 can allow preliminary decision making at the device level, especially in scenarios where network availability is limited. Future work may also include testing the system under a wider range of real world conditions, such as different humidity levels, gas mixtures, and long-duration deployments. These experiments would provide better insight into the long-term reliability and robustness of the system.

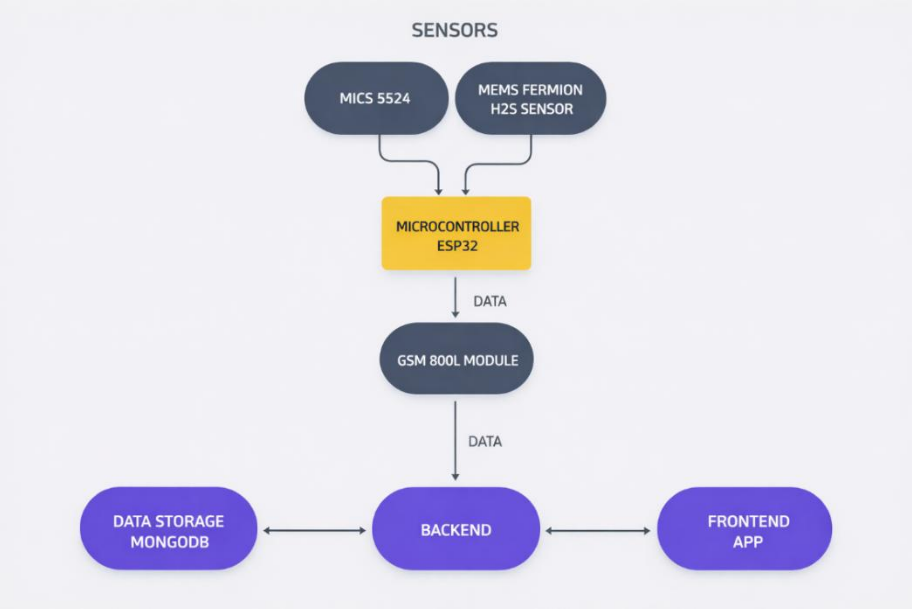


Fig. 6. Block diagram of the proposed wearable armband-based gas detection system for continuous real-time

Fig. 7. Three-dimensional design of the wearable arm band device illustrating compact form factor and portability.

5 Conclusion

This work presents a portable gas monitoring system for manhole environments using IoT technology. The system combines MQ-series gas sensors and a temperature sensor with an ESP32 microcontroller to monitor methane, carbon monoxide, and LPG continuously. Experimental testing showed an accuracy of about ±2% compared with standard instruments. The response time was within 500 ms, which is adequate for near real-time monitoring in confined spaces. Overall, the proposed device offers a compact and practical way to improve safety by providing early warning of dangerous conditions.

References

1. S.Himanshu, J.Bharani Kumar, K. Shashank, T.Rama Swamy, IOT based manhole detection and monitoring system. Int J Res Appl Sci Eng Technol, 10(6), 1608-1613 (2022).
2. Y.Safyari, M.Mahdianpari, H. Shiri, A review of vision-based pothole detection methods using computer vision and machine learning.Sens. 24(17), 5652 (2024).
3. N.S.Kumar, G.Chandrasekaran, K.P. Rajamanickam, An integrated system for smart industrial monitoring system in the context of hazards based on the internet of things. Int. J. Saf. Secur. Eng.11(1), 123-127(2021).
4. D.Pang, Z.Guan, T.Luo, W.Su, R.Dou, Real-time detection of road manhole covers with a deep learning model. Sci. Rep. *13*(1), 16479 (2023).
5. P.Roosipuu, I. Annus, A.Kuusik, N.Kändler, M.M. Alam, Monitoring and control of smart urban drainage systems using NB-IoT cellular sensor networks. Water Sci. Technol., 88(2), 339-354 (2023) .
6. W.M.Rasheed, R.Abdulla, L.Y. San, Manhole cover monitoring system over IOT.J. Innov. Appl. Technol. 5(3)(2021).
7. S.Himanshu, J.Bharani Kumar, K.Shashank, T.Rama Swamy, IOT based manhole detection and monitoring system. Int J Res Appl Sci Eng Technol. 10(6), 1608-1613(2022).

8. K.Gunasegeran, M.H.b.Zohari,IOT Based Outdoor Manhole Detection and Monitoring System. PEAT. 6(2), 225-234 (2025).
9. H. Zhang, L. Li, X. Liu, Development and test of manhole cover monitoring device using LoRa and accelerometer. IEEE Transactions on Instrumentation and Measurement, **69**, 2570-2580 (2020). https://doi.org/10.1109/TIM.2020.2967854
10. W. M. Rasheed, R. Abdulla, L. Y. San, Manhole cover monitoring system over IoT. J. Appl. Technol. Innov., 5(3) (2021).
11. R.Ajay, G.S.Manu, V.Poornima, S.Vaibhav, L.K.Sudha, Low Cost Sewage Monitoring System Using IoT in Smart Cities. J. Xidian Univ. 18(4), 1352-60(2024).
12. F.Solano, S.Krause, C.Wöllgens. An internet-of-things enabled smart system for wastewater monitoring. *IEEE Access*, *10*, 4666-4685(2022).
13. Y. Utepov, A. Neftissov, T. Mkilima, Z. Shakhmov, S. Akhazhanov, A. Kazkeyev, A. K. Kozhas, Advancing sanitary surveillance: Innovating a live-feed sewer monitoring framework for effective water level and chamber cover detections. *Heliyon*, 10(6) (2024).
14. F. Jan, N. Min-Allah, S. Saeed, S. Z. Iqbal, R. Ahmed, IoT-based solutions to monitor water level, leakage, and motor control for smart water tanks. *Water*, 14(3), 309 (2022).
15. N. Streitz, Beyond ‘smart-only’ cities: redefining the ‘smart-everything’ paradigm. *J. Ambient Intell. Humaniz. Comput.*, 10(2), 791–812 (2019).
16. F. Mo, L. Yu, Z. Zhang, Y. Zhao, Design and implementation of manhole cover safety monitoring system based on smart light pole. *Math. Probl. Eng.*, 2022(1), 3081649 (2022).
17. R. S. Krishnan, A. Sangeetha, D. A. Kumari, N. Nandhini, G. Karpagarajesh, K. L. Narayanan, Y. H. Robinson, A secured manhole management system using IoT and machine learning. In *Recent Advances in Internet of Things and Machine Learning: Real-World Applications*, pp. 19–30 (2022).
18. S. Islur, A. Hadal, A. D. Mane, IoT based manhole monitoring system. *SSGM J. Sci. Eng.*, 1, 189–193 (2023).
19. B. A. Praveena, B. P. Shetty, M. S. S. Kalasi, S. S. Yadav, M. Prasad, M. N. Sujith, L. Mallikarjun, Design and development of smart manhole. In *IOP Conf. Ser.: Mater. Sci. Eng.*, 1013(1), 012006 (2021).