A COMPREHENSIVE REVIEW OF GAS LEAKAGE DETECTING METHANE QUALITY SERIES DEVICES FOR ENHANCED SAFETY OPERATION

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ABSTRACT

Gas leakage detection system is very important in preventing accident in both domestic and industrial environment to ensure the safety of personnel and equipment. The effectiveness of this system depends on the performance and type of Gas sensors used which is responsible for detecting gas concentration and leakages. This comprehensive review evaluates the various methane quality (MQ) sensors employed in Gas leakage detection system focusing on their capabilities, limitations and applications. In the course of the review, it was discovered that MQ2 and MQ5 are versatile for domestic environment while MQ4 and MQ6 are more specialized for Methane and LPG detection. It should also be noted that MQ9 are deployed for high resolution detection of Methane and carbon monoxide. Also, the review identifies MQ135 with the largest border for air quality monitoring. Analyzing these MQ series sensors helps to offer insights into their suitability in the various gas leakage detection.

Keywords: Gas leakage sensors, Methane quality (MQ), Arduino, Liquified natural gas, Sensing element, Part per million (PPM)

1.0 INTRODUCTION

Gas leakage detection is a critical aspect of safety management in domestic or industrial environment where hazardous gas is produced or used (Suraj *et al.,* 2026). Effective leakage detection system is used to prevent accident, protect the health and reduce environmental impact on people around the area (Onah *et al.,* 2025). Gas sensors which play a central role in this system are designed to detect specific gases and provide real time measurement of their concentration (Onah *et al.,* 2025). The choice of sensor technology can greatly impact on their reliability, accuracy and their overall performance of the detection system. Various gas leakage monitoring system using MQ sensors have been carried out. MQ sensors considered are: MQ2, MQ4, MQ5, MQ6, MQ9 and MQ135 sensors. The following authors have researched on the possibilities of using MQ sensors (Adamu & Suleman, 2021; Anusuya *et al.,*2019; Anusuya *et al.,* 2020). Gas Sensors are the cornerstone of any gas leakage detection system, it works by detecting changes in resistance due to gas concentration in the air, which are then converted into voltage signals that can be processed by a microcontroller. (Ahmed, *et al.,* 2023).

MQ2 gas sensors is an electronic sensor used for sensing the concentration of gases in the air such as LPG, propane, methane, hydrogen, alcohol, smoke and carbon monoxide. (Adamu & Suleman, 2021). MQ2 gas sensor is also known as Chemi resistor. It contains a sensing material whose resistance changes when it comes in contact with the gas. This change in the value of resistance is used for the detection of gas. (Alshammari, & Chughtai, 2020). This sensor contains a sensing element, mainly aluminium oxide-based ceramic, coated

with Tin dioxide; sensing element has six connecting legs attached to it, two leads are responsible for heating the sensing element, the other four are used for output signals. Oxygen gets adsorbed on the surface of the sensing material when it is heated in air at high temperature. Then donor electrons present in the oxide are attracted towards this oxygen, thus preventing the current flow. When reducing gases are present, these oxygen atoms react with the reducing gases thereby decreasing the surface density of the adsorbed oxygen. Now current can flow through the sensor which generated voltage values. These voltage values are measured to know the concentration of gas. Voltage values are higher when the concentration of gas is high.

Many Research work has been carried out on MQ2 gas sensor by: (Adamu & Suleman, 2021; Anusuya, *et al.,* 2019; Priya & Kowsalya, 2021; Ranjithkumar, *et al.,* 2021; Nguyen & Nguyen, 2020; Anandhakrishnan, *et al.,*2019; Soh *et al*.,2019; Marin, 2013; Sai *et al*. 2023). These sensors are used to detect the presence of gases in the air such as methane, LPG and smoke but they are unable to distinguish between gases. This sensor is also used for Air quality monitoring, Gas leak alarm and for maintaining environmental standards in hospitals. In industries, these are used to detect the leakage of harmful gases. The merits of MQ2 gas sensor includes but not limited to; Low cost, relatively inexpensive compared to other types of gas sensors, high sensitivity, they are sensitive to a range of gases, including smoke, methane and Butane, simple integration. In order words, the limitations of MQ2 include but not limited to: MQ2 sensors are not known for their high accuracy and should not be used for precise measurements, they can be affected by temperature fluctuations, especially in outdoor environments, MQ2 sensors require a warm-up period before they can accurately detect gases, they draw power and get hot, which may be a concern in certain applications, they are susceptible to environmental conditions and may not be suitable for all environments. Some of the alternatives of MQ2 gas sensors are MQ4, MQ6, sensors.

The MQ4 methane gas sensor is extremely used for detecting gas leakage at home or in industries like Methane (CH4) & CNG gas. This gas sensor is highly responsive in very little time, so based on sensitivity requirements, it can be adjusted through a potentiometer. This is an analog output sensor, used like a CNG (compressed natural gas) sensors within the series of MQ sensors. MQ4 sensors are designed to be highly sensitive to methane and other natural gas components, enabling them to detect even small concentrations. They respond quickly to changes in gas concentration and recover quickly after the gas is removed, making them suitable for applications requiring real-time monitoring. MQ4 sensors are known for their durability and long lifespan, reducing the need for frequent replacement. They are designed with analog output signals and are easy to interface with microcontrollers and other electronic devices, simplifying integration into various systems. They consume relatively low power, making them suitable for Battery-powered applications. Many research work has also been carried out on MQ4 sensors by: (Naik *et al.,* 2019; Srivastavas & Varshini, 2021; Sudar *et al.,* 2021; Medilla *et al.,* 2018). The draw-backs of the sensor include but not limited to; sensitivity to humidity, temperature, and other environmental conditions, potentially leading to inaccurate readings. They can respond to other gases besides methane, which may lead to false alarms or misinterpretations. Regular calibration is necessary to maintain accuracy over time as their sensitivity can degrade over time. The sensors may not be suitable for detecting very high concentrations of methane.

The MQ5 methane and natural gas sensor module is a gas sensor designed for detecting methane, natural gas and LPG concentration in the air. It is widely used in gas leakage detection equipment, home safety devices, and various industrial applications. The module provides a quick and accurate response to gas presence, making it ideal for safety and environmental monitoring. Research work has been carried out on MQ5 sensors by (Ashammaru & Churgtai, 2020; Inamdar *et al.,* 2021; Amuthan & Zin., 2021; Palandurkar *et al.,* 2020). The MQ5 sensors is specially designed to detect LPG (Liquified Petroleum Gas) natural gas, and methane with good sensitivity. It can quickly respond to changes in gas concentration, making it suitable for real-time

monitoring. The MQ5 sensor is generally affordable, making it accessible for various applications. The sensor designed for long-term operation and stability. Gas leakage detectors; used in homes and industrial gas leakage detection systems. Environmental monitoring; monitors air quality and gas concentration in various environments. Safety systems; Integrated into safety systems for gas detection and alarm triggers. Industrial Equipment; used in industrial applications for gas concentration monitoring. DIY Projects; suitable for hobbyist and educational electronics projects. The MQ5 sensor can be influenced by other gases in the environment, potentially leading to false readings. Ambient temperature can affect the sensors readings, requiring calibration or temperature compensation. The sensors measurement range may be limited, particularly in the lower concentration range.

Research work carried out on MQ6 sensors are as follows: (Malipatil *et al.,* 2019; Chandak *et al* 2020; Madhivathana *et al.,* 2020; Shah *et al.,* 2021; Ramalisa *et al.,* 2021; Tamizarasan *et al.,* 2019; Khan, 2020; Evalina *et al.,* 2020; Johare *et al.,* 2022; Kapadnis *et al.,* 2022; Ahmed *et al.,* 2023; Naveen *et al.,* 2023). The MQ6 gas sensors is designed to detect the presence of butane (C4H10) and propane (C3H8) gases in the air. It utilizes a semiconductor sensing element that changes its resistance based on the concentration of gases. The module provides an analog output voltage proportional to the gas concentration, making it suitable for application such as gas leak detection, air quality monitoring and safety systems. MQ6 sensors are generally inexpensive, making them accessible for various applications. They are sensitive to a range of gases, including butane, propane, and methane, with sensitivity range of 200 ppm to 10000 ppm for the gases they detect. MQ6 sensors react quickly to changes in gas concentration. The sensors design is relatively straightforward, making it easy to implement and integrate into systems. They can be used in gas leak detection systems, air quality monitoring, and safety systems. They can be easily connected to microcontrollers and other electronic systems, allowing for data collection and control.

Performance can be affected by humidity, temperature, and other environmental conditions. The sensor may respond to multiple gases, potentially leading to false readings The range of gas concentrations the sensor can accurately measure may be limited. Regular calibration is required to maintain accuracy over time. The sensor needs a heating element to function properly, adding to overall complexity. Sensor technology can generate large amount of data, which can be challenging to manage and analyze. Implementing sensor technology can be complex, especially for those without technical expertise.

Research work carried out on MQ9 sensors was done by Shiyana & Deepa (2017)**.** MQ-9 gas sensor has high sensitivity to carbon Monoxide, Methane and LPG. The sensor could be used to detect different gases that contains CO. Sensitive materials of MQ-9 gas sensor is Sno2 which with lower conductivity in clean air. It makes detection by method of cycle high and low temperature, and detect CO when low temperature (heated by 1.5V). The sensors conductivity is higher along with the gas concentration rising. When high temperature (heated by 5.0V), it detects Methane, Propane etc. Combustible gas and cleans the other gases absorbed under low temperature. MQ9 gas sensor has high sensitivity to carbon Monoxide, Methane and LPG. The sensor could be used to detect different gases that contains CO and combustible gases, it is with low cost and suitable for different application. It is used for domestic gas leakage detector and industrial gas leakage detector**.** MQ9 sensors are relatively inexpensive compared to other gas detection technologies**.** They exhibit good sensitivity to target gases like carbon monoxide, LPG, and methane. MQ9 sensors can detect gas changes quickly, making them suitable for real-time monitoring. They can be used in various application, including gas leakage detection in homes and industries and air quality monitoring. MQ9 sensors offer both digital and analog outputs, providing flexibility in data acquisition and processing. The sensitivity of MQ9 sensors can be affected by the presence of other gases in the air, potentially leading to false positives. Ambient temperature can influence the sensors performance, requiring calibration or temperature compensation. The measurement

range of MQ9 sensors may be limited, particularly at higher gas concentration. MQ9 sensors may experience drift over time, requiring periodic recalibration. External electromagnetic fields can interfere with the sensor's operation, potentially leading to inaccuracies.

Research work was also carried out on MQ135 by Sidika & Hossain (2020), Rohan *et al*. (2021), Subarayudu *et al*. (2019) and Hassan *et al*., (2022). The MQ135 Sensors can detect gases like Ammonia (NH3), sulfur (S) Benzene (C6H6), CO2, And other harmful gases and smoke. Similar to other MQ series gas sensor, this sensor also has a digital and analog output pin. When the level of these gases goes beyond a threshold limit in the air the digital pin goes high. This threshold value can be set by using the on-board potentiometer. The analog output pin, outputs an analog voltage which can be used to approximate the level of these gases in the atmosphere. The MQ135 air quality sensor module operates at 5V and consumes around 150mA. It requires some pre heating before it could actually give accurate results. The gas has a wide range of gas detection that includes but not limited to ammonia (NH3), nitrogen oxides (Nox), alcohol, benzene, smoke, and carbon dioxide (CO2). MQ135 sensors are generally cost effective, making them accessible for various applications. The sensors analog and digital outputs make it easy to integrate with microcontrollers and other electronic systems for air quality monitoring. The sensor is designed for continuous operation and long-lasting performance in diverse environments. It small size allows for versatile use in various applications and setups.

Table 1: Overview of Gas leakage detection by MQ Series devices

S/N	Author (s)	Insights	Limitation(s)
1	(Jadhav *et al*., 2024)	The paper looked at MQ2, MQ7, and MQ135 sensors for industrial gas leakage detection, stressing their capabilities in monitoring flammable hydrocarbons and toxic gases, while ensuring real-time data transmission and integration with existing safety systems for enhanced safety measures.	The authors primarily focused on the description and merits of the IoT-enabled gas leakage detection system. The work highlights the system's capabilities, features, and merits without explicitly stating any limitations or areas for future improvement.
2	(Rahul *et al*., 2024)	The authors shows that various modern sensors which are not limited to MQ2 and MQ5 can be used for domestic use, while MQ4 and MQ6 specialize in Methane and LPG detection. The work emphasizes that MQ9 offers high-resolution detection for Methane and carbon II oxide	The work did not look at MQ135 that has a broader range of gas detection systems.
3	(Majumder, 2024)	The work emphasizes that MQ5 gas sensor is used for gas leakage detection, stressing its role in alerting users and activating safety measures. It highlights the importance of timely detection to	The system is specified to detect gas leakage using an MQ5 gas sensor, which is generally suitable for LPG and natural gas detection. However, the paper does not address its applicability or limitations in

		prevent accidents in domestic and industrial environments.	detecting other types of hazardous gases that might be present in industrial or domestic settings.
4	(Sakthi, 2023)	The paper focuses on the MQ-2 sensor, which is effective for detecting gas leaks in enclosed spaces, specifically for gases like butane and propene. It shows the system's integration with mobile technology for enhanced safety and real-time monitoring system	The research paper indicates that the gas leakage detection system prototype was "successfully developed and tested with gases such as BUTANE and PROPENE". This suggests that the system's effectiveness has only been validated for these specific gases, and its performance with other hazardous gases common in residential or industrial settings (e.g., natural gas, carbon monoxide, hydrogen sulfide) is not detailed or confirmed
5	(Gaikwad & Ghodke, 2024)	The authors developed an LPG gas detection system using ESP32 and email notifications, employing an MQ-series sensor to detect leaks and trigger alerts when gas levels exceed a pre-defined threshold, promoting remote monitoring and safety in homes and industries.	The work is tailored towards detection of LPG gas only.

2.0 METHODOLOGY

2.1 Algorithm for Gas Leakage Detection using MQ sensors

To obtain an MQ sensor that detects all gas leaks, follow these steps:

i. Determine the type of gases to detect: Identify the specific gases you want to detect (e.g., LPG, propane, methane, carbon dioxide, CO, etc.).
ii. Choose the right MQ sensor model: Select an MQ sensor suitable for your application, such as MQ-2, MQ-4, MQ-5, or MQ-9, MQ-135, etc, each detecting different gases.
iii. Purchase from authorized suppliers: Buy from reputable sources like SparkFun, Adafruit, or Amazon to ensure authenticity and quality.
iv. Read the datasheet: Understand the sensor's specifications, sensitivity, and operating conditions.
v. Integrate with a microcontroller: Connect the MQ sensor to a microcontroller (e.g., Arduino) and write code to read sensor data.
vi. Calibrate the sensor: Perform calibration according to the manufacturer's instructions to ensure accurate readings.
vii. Implement safety features: Add alarms, SMS alert, notifications, or automatic shut-offs to respond to gas leaks.
viii. Test and validate: Verify the sensor's performance in detecting gas leaks.

More importantly, an exploit of the flowchart in Figure 1 can be helpful in getting the Q sensor that is of general purpose.

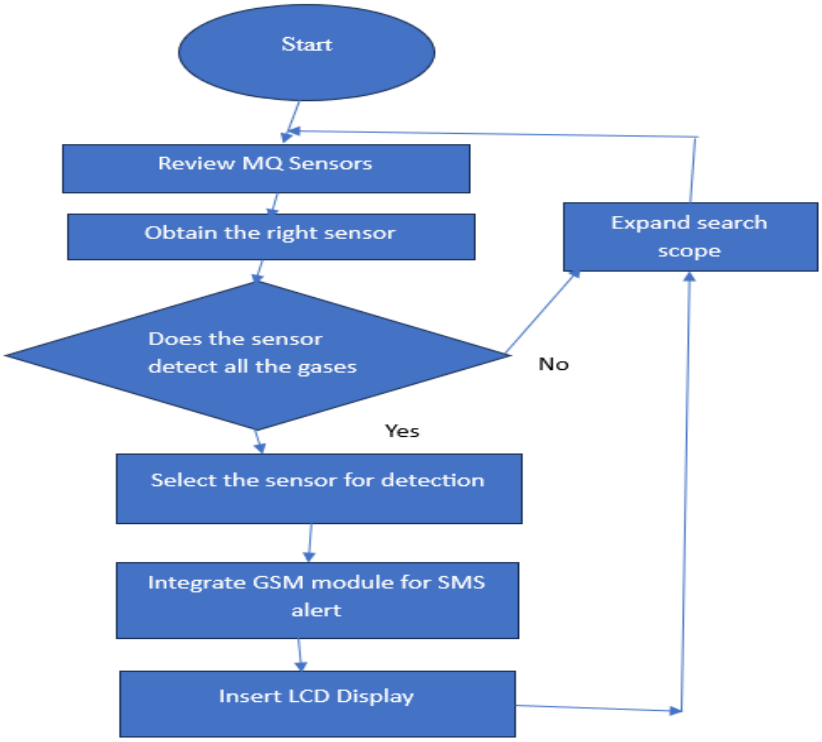

Figure 1: Flowchart for gas detection

The various MQ series devices, detectable gases of each of the devices, their weaknesses and their strengths are identified in Table 2.

Table 2: MQ Series Devices for enhanced safety

MQ Series	Detectable gases	Insights	Limitations
MQ2	LPG(Liquefied Petroleum Gas) Propane Hydrogen Smoke	This sensor is also used for air quality monitoring; Gas leak alarm and for maintaining environmental standards in hospitals. In industries, these are used to detect the leakage of harmful gases.	MQ2 sensors require a warm-up period before they can accurately detect gases; they draw power and get hot; which may be a concern in certain applications; they are susceptible to environmental conditions and may not be suitable for all environments.
MQ4	Methane (CH4) Natural Gas LPG (Liquefied Petroleum Gas)	MQ4 sensors are designed to be highly sensitive to methane and other natural gas components, enabling them to detect even small concentrations. They respond quickly to changes in	sensitivity to humidity, temperature, and other environmental conditions potentially lead to inaccurate readings. They can respond to other gases besides methane,

		gas concentration and recover quickly after the gas is removed, making them suitable for applications requiring real-time monitoring. MQ4 sensors are known for their durability and long lifespan, reducing the need for frequent replacement.	which may lead to false alarms or misinterpretations. Regular calibration is necessary to maintain accuracy over time as their sensitivity can degrade over time. The sensors may not be suitable for detecting very high concentrations of methane.
MQ5	LPG (Liquefied Petroleum Gas) Natural Gas Coal Gas	The MQ5 sensors is specially designed to detect LPG (Liquified Petroleum Gas) natural gas, and methane with good sensitivity. It can quickly respond to changes in gas concentration, making it suitable for real-time monitoring. The MQ5 sensor is generally affordable, making it accessible for various applications. The sensor designed for long-term operation and stability. Gas leakage detectors; used in homes and industrial gas leakage detection systems.	The MQ5 sensor can be influenced by other gases in the environment, potentially leading to false readings. Ambient temperature can affect the sensors readings, requiring calibration or temperature compensation. The sensors measurement range may be limited, particularly in the lower concentration range.
MQ6	LPG(Liquefied Petroleum Gas) Butane Propane	The sensors design is relatively straightforward, making it easy to implement and integrate into systems. They can be used in gas leak detection systems, air quality monitoring, and safety systems. They can be easily connected to microcontrollers and other electronic systems, allowing for data collection and control.	Performance can be affected by humidity, temperature, and other environmental conditions. The sensor may respond to multiple gases, potentially leading to false readings The range of gas concentrations the sensor can accurately measure may be limited. Regular calibration is required to maintain accuracy over time. The sensor needs a heating element to function properly, adding to overall complexity. Sensor technology can generate large amount of data, which can be challenging to manage and analyze. Implementing sensor technology

			can be complex, especially for those without technical expertise.
MQ9	Methane, Propane etc. Combustible gas and cleans the other gases absorbed under low temperature. MQ9 gas sensor has high sensitivity to carbon Monoxide, Methane and LPG. The sensor could be used to detect different gases that contains CO	It is used for domestic gas leakage detector and industrial gas leakage detector. MQ9 sensors are relatively inexpensive compared to other gas detection technologies.	The sensitivity of MQ9 sensors can be affected by the presence of other gases in the air, potentially leading to false positives. Ambient temperature can influence the sensors performance, requiring calibration or temperature compensation. The measurement range of MQ9 sensors may be limited, particularly at higher gas concentration. MQ9 sensors may experience drift over time, requiring periodic recalibration. External electromagnetic fields can interfere with the sensor's operation, potentially leading to inaccuracies.
MQ135	The MQ135 Sensors can detect gases like Ammonia (NH3), sulfur (S) Benzene (C6H6), CO2, methane, smoke, Nitrogen oxides and other harmful gases.	The sensors analog and digital outputs make it easy to integrate with microcontrollers and other electronic systems for air quality monitoring. The sensor is designed for continuous operation and long-lasting performance in diverse environments. Its small size allows for versatile use in various applications and setups.	

3.0 RESULTS AND DISCUSSION

Early detection and alert systems of these gases could prevent accidents and minimize risks. Implementing MQ Series devices can reduce costs associated with gas leaks and accidents. These devices help meet safety standards and regulations, avoiding potential fines. The devices have real world implementations in the sense that integrating MQ series devices with IoT technology will enable real-time monitoring and remote alerts. For automated safety systems, these devices can trigger automatic shutdowns or ventilation systems to prevent accidents. Advancements in sensor technology are focused on improving accuracy, reducing cross-sensitivity, and enhancing durability. Emerging technologies such as nanomaterials and advanced signal

processing are expected to address some of the current limitations and offer more reliable gas detection solutions.

4.0 CONCLUSION

Gas sensors are vital components of gas leakage detection systems, providing crucial data for preventing hazardous situations. The choice of sensor depends on the specific gases to be detected, the required sensitivity, and the environmental conditions. While traditional sensors like the MQ series offer versatile solutions, newer technologies and improvements continue to enhance detection capabilities and reliability. Understanding the strengths and limitations of various MQ gas sensors is essential for designing effective gas leakage monitoring systems and ensuring safety in both domestic and industrial environments. Unlike other related devices, the MQ135 Sensors can detect gases like Ammonia (NH3), sulfur (S) Benzene (C6H6), CO2, methane, smoke, Nitrogen oxides and other harmful gases. Therefore, on the account of versatility and better features, the study proposes MQ135 for multi-purpose functionality in oil and gas industry

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