STM JOURNALS

Recent Trends in
Sensor Research & Technology

ISSN: 2393-8765
Volume 12, Issue 2, 2025
May–August
DOI (Journal): 10.37591/RTSRT

https://journals.stmjournals.com/rtsrt

Research RTSRT

Development of a Low-Cost Air Quality Monitoring System Using the MQ2 Sensor

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Abstract

Air pollution is becoming a major environmental problem, especially in cities, due to the quick expansion of industry and the rise in car emissions. The air is contaminated with dangerous chemicals such as carbon monoxide, nitrogen oxides, and fine particles, which have a major negative influence on human health by raising the risk of heart and respiratory diseases. Because of their dense populations and heavy traffic, urban areas are particularly affected by this problem. Air pollution also contributes significantly to acid rain, climate change acceleration, and ecological damage. Stricter pollution control regulations, the adoption of cleaner technologies, better public transportation, and more environmental awareness are all necessary to address this problem. Real-time monitoring of air quality is essential to assess pollution levels and take preventive measures. This study suggests an Internet of Things (IoT)-based air quality monitoring system that uses a MQ2 gas sensor and a NodeMCU microcontroller to identify dangerous gases. Through linked devices, the system gathers real-time data that allows users to effectively monitor environmental conditions, encouraging awareness and proactive pollution management. To facilitate remote access and analysis, the system tracks the quality of the air, displays data in real time on an LCD screen, and uploads it to an Internet of Things platform. This makes it possible to monitor the environment continuously and raise awareness of air pollution levels. The proposed system offers a cost-effective, real-time, and scalable solution for environmental monitoring applications by measuring the accurate presence of harmful gases including Carbon Monoxide (CO), Methane (CH_4), Liquified Petroleum gas and particulate matter.

Keywords: IoT, air quality monitoring, Node MCU, MQ2 sensor, pollution, LCD display, Blynk

INTRODUCTION

Air pollution is one of the most pressing environmental challenges in the modern world, significantly impacting public health, climate, and ecosystems. The rapid growth of industrialization, urbanization, and vehicular emissions has led to an alarming increase in pollutants in the atmosphere, particularly in densely populated regions. These pollutants include harmful gases such as carbon monoxide (CO), methane (CH_4), liquefied petroleum gas (LPG), and particulate matter, which pose serious risks to human health, especially for individuals with respiratory conditions.

Conventional air quality monitoring systems deployed by government agencies are typically expensive, stationary, and cover limited areas. They often involve complex infrastructure and are not accessible for local or personal use. Moreover, the lack of real-time data availability restricts timely decision-making and preventive measures [1, 2].

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Received Date: April 07, 2025
Accepted Date: April 15, 2025
Published Date: April 17, 2025

Citation: Deepanshi Saxena, Mahak Jain, Mansi Singh Parihar, Harshit Singh, Monika Kapoor. Development of a Low-Cost Air Quality Monitoring System Using the MQ2 Sensor. Recent Trends in Sensor Research & Technology. 2025; 12(2): 9–15p.

To address these limitations, advancements in the Internet of Things (IoT) have enabled the development of compact, cost-effective, and real-time environmental monitoring systems. IoT-based solutions integrate sensors, microcontrollers, and wireless communication modules to gather, analyze, and transmit environmental data to the cloud for remote monitoring and analysis.

This study presents the design and development of an IoT-based air quality monitoring system utilizing a Node MCU ESP8266 microcontroller and an MQ2 gas sensor. The MQ2 sensor can detect a variety of gases, including smoke, methane, butane, and LPG. The system captures air quality data, displays it on a 16×2 LCD screen, and transmits it to the Blynk IoT platform via Wi-Fi for real-time remote access using a smartphone. The overall system is portable, user-friendly, and affordable, making it ideal for educational, domestic, and small-scale industrial applications [3–5].

OBJECTIVES

The primary aim of this project is to develop a smart and cost-effective air quality monitoring system using IoT technology. The specific objectives are:

a. *To design and implement a real-time air quality monitoring system* that can detect the presence and concentration of harmful gases using the MQ2 sensor.
b. *To utilize the Node MCU ESP8266 microcontroller* for processing sensor data and enabling wireless data transmission over the internet.
c. *To display air quality data locally* using a 16×2 LCD screen, providing users with instant visual feedback.
d. *To integrate the system with the Blynk IoT platform* for remote access and monitoring of air quality data through a smartphone application.
e. *To ensure low power consumption and cost-effectiveness,* making the system suitable for widespread use in homes, schools, offices, and small industries.
f. *To provide a scalable and modular framework* that can be enhanced in the future with additional sensors (e.g., temperature, humidity, PM2.5) or extended to a network of monitoring nodes.

LITERATURE REVIEW

In recent years, the emergence of the Internet of Things (IoT) has led to the development of various smart air quality monitoring systems. Conventional air pollution monitoring stations, although accurate, are costly, stationary, and have limited spatial coverage. This has encouraged researchers to explore low-cost, scalable alternatives utilizing embedded systems and wireless connectivity.

- Pal *et al.* proposed an Arduino-based air quality monitoring system employing the MQ135 sensor and GSM module for data communication. While their system provided reliable results, the recurring cost of mobile network usage posed limitations for continuous monitoring [6].
- Arroyo *et al.* designed a wireless sensor network based on ZigBee modules to collect pollution data. Their system demonstrated energy efficiency but lacked sufficient data transfer speed and cloud integration capabilities [7].
- Karuppusamy developed an IoT-based environmental monitoring system using Node MCU along with multiple sensors for temperature, humidity, and CO_2 detection. They utilized the Blynk IoT platform to visualize real-time data on smartphones. Although their design achieved effective cloud-based monitoring, the use of multiple sensors increased the hardware complexity and cost [8].
- Marques *et al*. proposed that, the MQ_2 sensor, when integrated with microcontrollers like Arduino or Node MCU, serves as a practical tool for general indoor air quality detection [9]. The MQ2 gas sensor has gained popularity in similar applications due to its sensitivity to gases like methane, LPG, smoke, and hydrogen. It has been widely used in cost-sensitive applications where qualitative gas detection is sufficient.

Building upon these works, the proposed system in this study leverages the MQ_2 sensor and Node MCU ESP8266 module to design a simplified, low-cost, and Wi-Fi-enabled air pollution monitoring solution. Unlike previous multi-sensor systems, this implementation emphasizes cost-effectiveness and user-friendliness, offering both local display through an LCD and remote access via the Blynk IoT platform.

COMPONENTS REQUIRED

The proposed air quality monitoring system incorporates several electronic and IoT components to achieve accurate gas detection and real-time data communication.

The following are the primary components used:

- *Node MCU ESP8266:* The Node MCU is an open-source development board based on the ESP8266 Wi-Fi module. It features a 32-bit Tensilica L106 microcontroller with integrated Wi-Fi capabilities, making it ideal for IoT applications. It serves as the central controller, acquiring data from sensors and transmitting it to the cloud via Wi-Fi.
- *MQ2 Gas Sensor:* The MQ2 is a semiconductor-type gas sensor that can detect combustible gases such as methane (CH_4), butane (C_4H_{10}), LPG, smoke, and hydrogen (H_2). It provides both analog and digital output, where the analog pin is used to measure the gas concentration levels in the environment. It is selected for its low cost, high sensitivity, and reliability in indoor applications.
- *16×2 Alphanumeric LCD Display:* A 16×2 LCD module is used for local display of the sensor data. It displays real-time gas concentration levels, enabling the user to monitor air quality instantly without the need for external devices. The LCD operates at 5 V and communicates with the microcontroller through parallel or I^2C communication.
- *I^2C LCD Adapter Module:* To minimize the number of GPIO pins used, an I^2C module is interfaced with the LCD. This adapter allows communication over only two lines (SDA and SCL), conserving microcontroller resources and simplifying the circuit wiring.
- *Breadboard and Jumper Wires:* A standard solderless breadboard is used for circuit prototyping, allowing easy testing and modification of the design. Jumper wires are employed to make temporary connections between components during development and testing.
- *Micro-USB Cable:* The micro-USB cable is used to connect the Node MCU to a computer for programming and debugging. It also serves as a power source during the initial setup [10].
- *5 V Power Supply Module:* A regulated 5 V power supply or battery pack is used to provide power to the system during standalone operation. It ensures stable voltage and uninterrupted functioning of all connected modules.
- *Smartphone with Blynk Application:* A smartphone with the Blynk app installed is used for remote monitoring. The app communicates with the Node MCU through the Blynk IoT platform, enabling real-time visualization of air quality data on a graphical user interface.

METHODOLOGY

The proposed air quality monitoring system is designed using a modular approach, integrating sensing, processing, and communication functionalities to ensure efficient gas detection and real-time monitoring. The methodology adopted for the development and implementation of this system is outlined below (Figure 1).

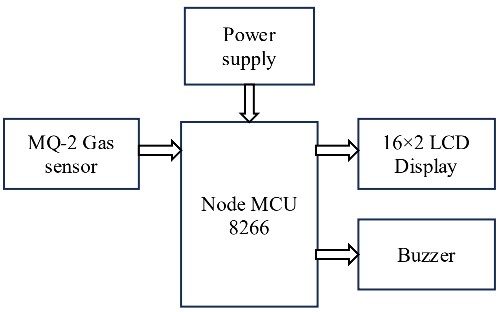

Figure 1. Block diagram of air quality monitoring system.

System Design

The core components of the system include the MQ2 gas sensor, Node MCU ESP8266 microcontroller, 16×2 LCD (with I²C interface), and the Blynk IoT platform. The system architecture is designed to be compact and cost-effective, suitable for both stationary and portable air quality monitoring applications.

Sensor Calibration and Integration

The MQ2 sensor is initially tested and calibrated to detect combustible gases such as methane, butane, LPG, and smoke. The analog output of the sensor provides a voltage proportional to the gas concentration. This signal is read by the Node MCU's ADC (Analog-to-Digital Converter) pin. Basic calibration is performed to define threshold levels for "safe", "moderate", and "hazardous" air quality conditions, based on sensor output values.

Microcontroller Programming

The Node MCU ESP8266 is programmed using the Arduino IDE. The firmware includes:

- Reading analog data from the MQ2 sensor.
- Processing and converting it into readable gas levels.
- Displaying the processed data on the 16×2 LCD screen via the I²C interface.
- Sending real-time data to the Blynk cloud server using the onboard Wi-Fi capabilities.

Data Display and Communication

The system displays gas concentration values locally on the LCD for immediate visibility. Simultaneously, it connects to a Wi-Fi network and communicates with the Blynk IoT platform using HTTP/MQTT protocols. The Blynk app is configured with virtual widgets (gauges, graphs) to visualize the data on a smartphone in real time.

Power Supply and Deployment

During testing, the system is powered via USB. For field use, a regulated 5 V power source or a battery pack is connected. The compact form factor of the system allows it to be placed indoors near kitchens, parking areas, or industrial equipment where gas leaks or pollution are likely.

Testing and Validation

The system is tested in various indoor environments with different gas concentrations (e.g., near an LPG stove, incense stick smoke) to validate the sensor response and overall functionality. The readings are compared for consistency across the LCD and the Blynk app, ensuring accurate data synchronization and transmission (Figure 2).

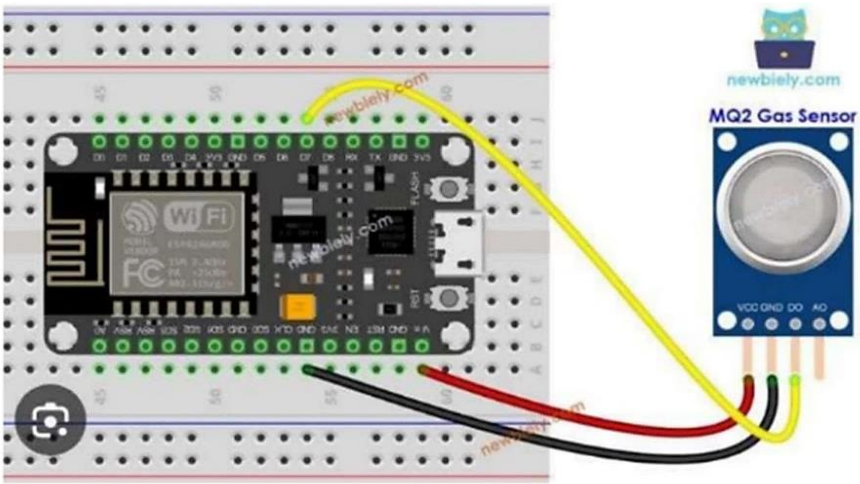

Figure 2. System implementation.

RESULTS AND DISCUSSION

The proposed air quality monitoring system was successfully developed and tested in various indoor environments. The results demonstrate the system's ability to detect harmful gases and provide real-time feedback both locally and remotely.

System Response

The MQ2 sensor responded effectively to the presence of smoke and combustible gases. When exposed to sources such as an LPG flame or incense stick, the analog values recorded by the sensor increased significantly, indicating a rise in pollution levels. The system successfully classified the air quality based on predefined threshold levels:

- *0–300:* Good (Safe environment).
- *301–600:* Moderate (Attention required).
- *>600:* Poor (Unsafe; possible gas leak).

These thresholds were reflected both on the *16×2 LCD display* and the *Blynk mobile application,* ensuring consistent and real-time data availability.

Real Time Monitoring

The integration of the Blynk platform enabled wireless data transmission to a smartphone. The app interface displayed the gas concentration using graphical widgets (e.g., gauges and charts), providing users with intuitive visual feedback. This functionality proved useful in scenarios where users were not in the immediate vicinity of the sensor.

Accuracy and Stability

While the MQ2 sensor does not differentiate between specific gases, it provided reliable qualitative information about the overall air quality. The sensor showed stable readings when not exposed to pollution sources and reacted rapidly to sudden changes in the environment.

Limitations

Although effective for basic air quality monitoring, the system has some limitations:

- The MQ2 sensor does not offer precise quantification of individual gas concentrations.
- Sensor readings can be influenced by temperature and humidity, which were not accounted for in the current design.
- Long-term stability may be affected without recalibration.

Practical Applications

The system is suitable for deployment in households, kitchens, parking areas, and small industrial spaces where gas leakage or smoke is a concern. Its low cost, simplicity, and mobile integration make it an accessible solution for early warning and indoor environmental monitoring.

ADVANTAGES

The proposed IoT-based air quality monitoring system offers several advantages over traditional and high-cost air monitoring stations. These benefits include:

- *Cost-Effective Design:* The use of affordable components such as the MQ2 sensor and NodeMCU makes the system economically viable for small-scale and personal applications.
- *Real-Time Monitoring:* Continuous monitoring and immediate reporting of gas concentration levels are achieved through the integration of Wi-Fi and the Blynk IoT platform.
- *Remote Accessibility:* Users can access air quality data from anywhere via the Blynk mobile application, enhancing convenience and safety.
- *Compact and Portable:* The system is lightweight and compact, allowing it to be deployed in various environments such as homes, kitchens, parking areas, and small industries.

- *User-Friendly Interface:* The 16×2 LCD display and smartphone dashboard provide clear and intuitive data visualization for both technical and non-technical users.
- *Quick Response to Gas Leaks:* The MQ2 sensor responds rapidly to changes in gas concentration, allowing for early detection of hazardous conditions.
- *Ease of Development and Customization:* Open-source hardware and software platforms (Arduino IDE and Blynk) make the system easy to modify or expand for future improvements.

APPLICATIONS

The developed air quality monitoring system has a wide range of applications in both residential and commercial environments. Its flexibility, portability, and real-time monitoring capabilities make it suitable for the following use cases:

- *Household Safety Monitoring:* Can be deployed in kitchens or living areas to detect smoke or gas leaks from stoves, heaters, or faulty appliances, thus enhancing domestic safety.
- *Parking Areas and Garages:* Monitors harmful gas emissions from vehicles, helping to alert users about poor air quality in enclosed parking spaces.
- *Small Industries and Workshops:* Useful in monitoring air pollution levels in environments where fuel combustion or chemical usage may release hazardous gases.
- *Schools and Educational Labs:* Serves as a practical tool for teaching environmental monitoring, IoT concepts, and embedded systems to students.
- *Healthcare and Hospitals:* Ensures clean air in sensitive environments such as patient wards or near oxygen supply storage where flammable gases could be dangerous.
- *IoT-Based Smart Homes:* Can be integrated into smart home ecosystems to automate ventilation systems or trigger alarms based on gas levels.
- *Restaurants and Commercial Kitchens:* Helps maintain safety standards by continuously tracking air quality in areas where open flames and gas usage are common.

SUSTAINABILITY

The proposed air quality monitoring system supports environmental sustainability by enabling early detection of harmful gases and promoting awareness of indoor pollution. Its low-power consumption, minimal hardware footprint, and wireless capabilities make it suitable for long-term deployment with minimal environmental impact. By encouraging individuals and organizations to take proactive safety measures, the system contributes to healthier living environments and reduced health risks from air pollution. Additionally, the use of open-source platforms (NodeMCU, Blynk, Arduino IDE) minimizes dependence on proprietary systems and supports a community-driven approach to technological development.

FUTURE SCOPE

The system can be enhanced and scaled for broader environmental and smart-city applications. Potential future developments include:

a. *Multi-Gas Detection:* Integrating additional sensors (e.g., MQ135, DHT11) to monitor CO_2, CO, NOx, temperature, and humidity.
b. *Data Logging and Analysis:* Implementing cloud storage and historical data visualization for long-term air quality tracking.
c. *Mobile Alerts and Automation:* Sending SMS/email alerts and triggering automated actions (e.g., turning on exhaust fans).
d. *Solar Power Integration:* Using solar panels for power to make the system energy-independent and more eco-friendly.
e. *Edge AI:* Incorporating basic machine learning at the edge to predict hazardous conditions or classify pollution sources.

CONCLUSION

In this study, an IoT-based air quality monitoring system was successfully designed and implemented using the Node MCU ESP8266 microcontroller and the MQ2 gas sensor. The system provides an efficient and low-cost solution for detecting harmful gases such as LPG, smoke, and methane in real-time. The integration of a local LCD display and the Blynk IoT platform enables both on-site and remote monitoring, ensuring user convenience and safety.

Experimental results confirmed that the system is capable of promptly detecting gas concentration changes and alerting users through visual and mobile-based feedback. Its compact design, wireless communication, and affordability make it highly suitable for deployment in homes, kitchens, parking areas, and small industries.

Future enhancements may include the integration of multiple sensors to detect a broader range of pollutants, incorporation of temperature and humidity compensation, and advanced data analytics for predictive monitoring. The developed system thus lays a foundation for scalable, smart environmental monitoring solutions in the context of smart cities and IoT ecosystems.

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