International Journal of Multidisciplinary Engineering in Current Research - IJMEC

Volume 11, Issue 7, July-2026, http://ijmec.com/, ISSN: 2456-4265

Air Quality Monitoring Robot

Dr N Pradeep Kumar[1], S Gayathri[2], V Haripriya[3], K Mayuri[4]

[1]Professor: Department of Electronics and Communication Engineering, Bhoj Reddy Engineering College for Women Hyderabad, India

[2,3,4]B. Tech Students: Department of Electronics and Communication Engineering, Bhoj Reddy Engineering College for Women Hyderabad, India

Mail Id: sapavatgaya3@gmail.com[2],vootukuriharipriya3@gmail.com[3], amakarate2821@gmail.com[4]

Accepted 5 July 2026

Abstract

Air pollution has become a critical environmental and public health concern due to rapid industrial growth, urbanization, and increasing vehicular emissions. Continuous monitoring of air quality is essential to control pollution levels and ensure a safe environment. This project presents the design and implementation of an ***Air Quality Monitoring Robot****, which is capable of detecting, analyzing, and reporting air pollution levels in real time.*

The system is equipped with multiple gas sensors to measure pollutants such as carbon monoxide (CO), carbon dioxide (CO_2), methane (CH_4), smoke, and particulate matter (PM2.5/PM10). These sensors are interfaced with a microcontroller such as Arduino or ESP32, which processes the data and displays it on an LCD screen. The robot is designed to be mobile, enabling it to travel across different locations and collect environmental data efficiently.

Furthermore, the system integrates IoT technology to transmit collected data to a cloud platform or mobile application for remote monitoring and analysis. This allows users to access real-time air quality information from anywhere. The system also includes an alert mechanism that activates when pollutant levels exceed predefined safety limits, ensuring timely warnings.

The proposed robot offers advantages such as low cost, portability, ease of use, and high efficiency. It minimizes human exposure to hazardous environments and can be widely used in industries, smart cities, traffic monitoring, and disaster management. Hence, this project provides a reliable and effective solution for continuous air quality monitoring and environmental protection.

Keywords— *Air Quality Monitoring Robot, Air Pollution, IoT, Gas Sensors, Arduino, ESP32, Environmental Monitoring, Real-Time Monitoring, Smart City, Pollution Detection.*

Introduction

Air pollution is one of the most serious environmental problems in today's world, mainly caused by rapid industrialization, urbanization, and increasing vehicle emissions. The presence of harmful pollutants such as carbon monoxide (CO), carbon dioxide (CO_2), nitrogen oxides (NOx), sulfur dioxide (SO_2), methane (CH_4), and particulate matter (PM2.5/PM10) has a significant impact on human health and the environment. Prolonged exposure to these pollutants can lead to respiratory diseases, cardiovascular issues, and other serious health complications. Therefore, continuous monitoring of air quality has become essential to ensure a safe and healthy living environment.

Traditional air quality monitoring systems are mostly stationary and limited to specific locations, which makes it difficult to obtain real-time data from different areas. To overcome these limitations, an **Air Quality Monitoring Robot** is introduced as a mobile and intelligent solution. This system is designed to move across different locations and monitor air pollution levels efficiently in real time.

The robot is equipped with various gas and environmental sensors that detect harmful gases and particulate matter present in the atmosphere. These sensors are interfaced with a microcontroller such as Arduino or ESP32, which processes the collected data and displays it on an LCD or OLED screen. In addition, the system integrates Internet of Things (IoT) technology to transmit data to cloud platforms or mobile applications, enabling remote monitoring and analysis.

The robot can operate either manually or autonomously, allowing it to cover multiple areas without human intervention. It also includes an alert mechanism that notifies users when pollution levels exceed predefined safety limits. This feature helps in taking timely preventive measures and reduces human exposure to hazardous environments.

Overall, the Air Quality Monitoring Robot provides a cost-effective, reliable, and efficient solution for continuous environmental monitoring. It has wide applications in industries, smart cities, traffic management, mining areas, and disaster-prone regions. By enabling real-time data collection and analysis, this system plays a crucial role in improving environmental awareness and protecting public health.

Apart from basic monitoring, the Air Quality Monitoring Robot also plays an important role in data-driven environmental management. The system not only collects real-time data but also helps in analyzing pollution patterns over time. This information can be used by government authorities and environmental agencies to take preventive measures and implement pollution control strategies.

The robot can be further enhanced with wireless communication technologies such as Wi-Fi, GSM, or Bluetooth, enabling seamless data transfer and real-time updates. With the advancement of smart technologies, these robots can be integrated into smart city infrastructure, where multiple monitoring units work together to provide a complete overview of air quality across large areas.

Another important aspect is the portability and flexibility of the system. Since the robot is mobile, it can be deployed in different environments such as urban areas, industrial zones, and rural regions without requiring permanent installation. This makes it more efficient compared to traditional stationary monitoring systems.

Literature Survey

Air quality monitoring has become a significant area of research due to the rapid increase in pollution levels and their serious impact on human health and the environment. Various researchers have developed systems using modern technologies such as the Internet of Things (IoT), embedded systems, and wireless communication to monitor air pollution effectively. These systems typically use gas sensors to detect pollutants such as carbon monoxide (CO), carbon dioxide (CO_2), nitrogen oxides (NOx), sulfur dioxide (SO_2), methane (CH_4), and particulate matter (PM2.5/PM10). The collected data is processed by a microcontroller and transmitted to cloud platforms for real-time monitoring and analysis.

Many existing air quality monitoring systems are based on IoT and provide continuous as well as accurate environmental data. These systems allow users to monitor pollution levels remotely through web or mobile applications. However, most of these systems are stationary and installed at fixed locations, which limits their ability to monitor large or dynamic environments effectively. Since pollution levels vary from one place to another, stationary monitoring systems cannot provide complete coverage of different areas.

To overcome these limitations, researchers have introduced Wireless Sensor Networks (WSNs), where multiple sensor nodes are deployed across different locations to monitor air quality. These sensor nodes communicate with each other and transmit environmental data to a central monitoring system. Although WSN-based systems improve monitoring coverage, they also increase the overall system cost, power consumption, communication complexity, and maintenance requirements.

Recent advancements in this field include the development of mobile air quality monitoring systems using robots and drones. These systems are capable of moving to different locations, collecting real-time environmental data, and providing wider coverage compared to conventional stationary monitoring systems. Some researchers have also integrated Artificial Intelligence (AI) and Machine Learning (ML) techniques to analyze pollution data, predict future pollution trends, and support better environmental decision-making. Despite these technological advancements, many of the existing systems are expensive, complex, and difficult to deploy on a large scale.

From the literature survey, it is observed that there is a growing need for a simple, low-cost, portable, and mobile solution for air quality monitoring. The proposed **Air Quality Monitoring Robot** addresses these limitations by combining gas sensor technology, embedded systems, robotics, and IoT communication to provide real-time, efficient, accurate, and flexible environmental monitoring. The system offers continuous air quality measurement, remote data access, and timely alerts, making it suitable for applications in industries, smart cities, traffic monitoring, and environmental protection.

Air Quality Monitoring Robot

Existing System

Traditional air quality monitoring systems are mostly stationary and installed at specific locations to measure pollution levels. These systems use advanced and highly accurate instruments, but they are expensive to install and maintain. Since they are fixed in one place, they provide limited area coverage and cannot monitor pollution in multiple locations effectively. In some cases, data collection and analysis may be time-consuming, leading to delays in obtaining results. Additionally, these systems require regular maintenance and calibration, increasing the overall cost and complexity.

Traditional air quality monitoring systems are mainly based on fixed monitoring stations that are installed in selected locations such as industrial zones, commercial areas, and urban regions. These systems provide accurate measurements of pollutants; however, they are capable of monitoring only the surrounding environment where they are installed. As a result, they cannot provide complete information about air quality across larger geographical areas.

Moreover, these systems often require a continuous power supply, regular calibration, and skilled personnel for operation, which further increases their installation, maintenance, and operational costs. In some cases, the collected data may not be available in real time, resulting in delays in monitoring, analysis, and decision-making. Although wireless sensor networks (WSNs) and IoT-based monitoring systems have been introduced to improve real-time data collection, they still face several challenges such as high deployment cost, energy consumption, network reliability issues, and communication complexity.

Another major drawback of the existing systems is the lack of mobility. Since they remain fixed at a particular location, they cannot monitor remote, hazardous, or difficult-to-access areas where pollution levels may change frequently. Expanding the monitoring coverage requires installing additional monitoring stations, which further increases infrastructure cost, maintenance effort, and system complexity.

Furthermore, many existing monitoring systems have limited scalability and flexibility. Covering larger areas requires deploying multiple sensing units, increasing both hardware and maintenance expenses. Although recent IoT-based approaches have improved remote monitoring capabilities, they are still not suitable for all applications, especially in hazardous environments where human presence is unsafe.

These limitations highlight the need for a more flexible, portable, and cost-effective solution that can provide continuous real-time monitoring over multiple locations. Therefore, a mobile **Air Quality Monitoring Robot** is proposed to overcome the limitations of conventional air quality monitoring systems by offering improved mobility, efficient environmental monitoring, reduced operational cost, and real-time data collection.

Proposed System

The proposed system is a **mobile Air Quality Monitoring Robot** designed to detect and monitor air pollutants in real time using multiple environmental sensors. The robot continuously measures the concentration of harmful gases and atmospheric parameters while moving across different locations. The collected sensor data is processed using a microcontroller such as Arduino or ESP32 and displayed on an LCD screen. The system also integrates IoT technology for remote monitoring, allowing users to access real-time environmental data through cloud platforms or mobile applications. In addition, the robot generates alerts whenever pollution levels exceed predefined safety limits. Compared to conventional monitoring systems, the proposed system provides a cost-effective, portable, reliable, and efficient solution for continuous air quality monitoring.

Real-Time Air Quality Monitoring

Unlike traditional methods that require manual sampling or periodic measurements, the proposed system continuously monitors air quality in real time using sensors such as **MQ135**, **MQ7**, and **DHT11**. These sensors detect harmful gases including carbon monoxide (CO), carbon dioxide (CO_2), smoke, and other environmental parameters. Continuous monitoring enables immediate detection of pollution levels and provides accurate, up-to-date information about environmental conditions.

Offline and Autonomous Operation

The system operates independently using a microcontroller such as **Arduino** or **ESP32**, without requiring continuous internet connectivity. Sensor data is processed locally, and alerts are generated immediately whenever pollutant levels exceed the predefined threshold values. This autonomous operation reduces communication delays, improves system reliability, and enables the robot to function effectively in remote or offline environments.

Smart Alert and Display System

The robot includes a smart alert and display mechanism that continuously shows air quality parameters on an LCD display. When pollutant concentrations exceed safe limits, the system automatically activates visual or audible alerts to notify users immediately. This eliminates the need for continuous manual monitoring and enables quick response to hazardous environmental conditions, thereby improving safety, efficiency, and user convenience.

Block Diagram

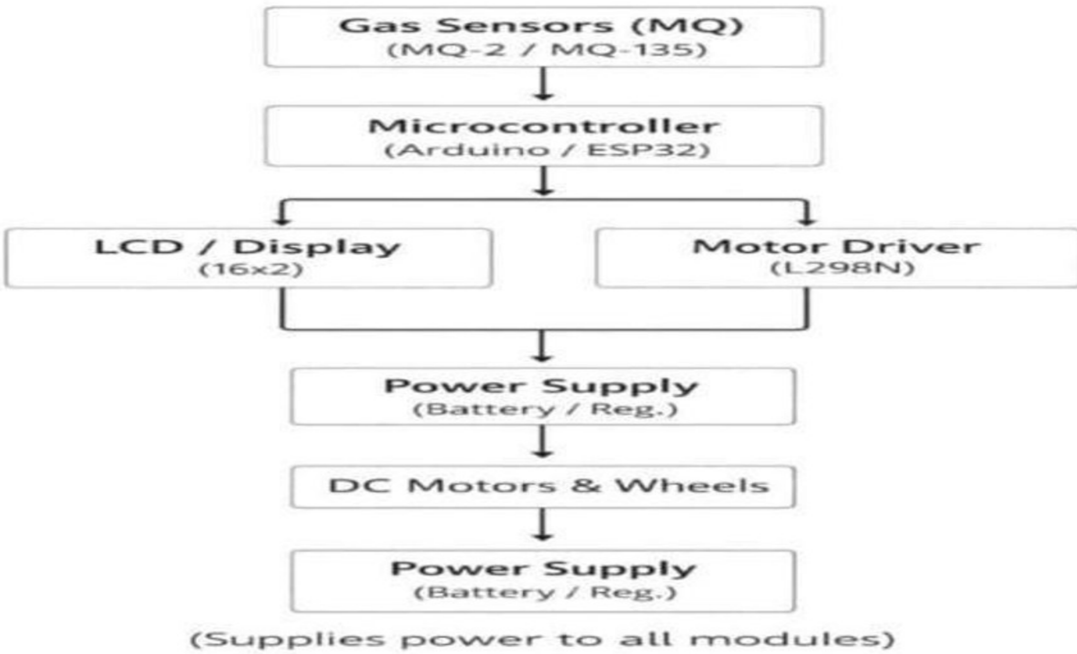

Figure 1: Block Diagram of an Air quality Monitoring Robot

Methodology

The Air Quality Monitoring Robot uses a **NodeMCU (ESP8266)** as the main controller to manage the entire system. When the system is powered ON, the **MQ-2** and **MQ-135** gas sensors continuously detect harmful gases present in the surrounding air and send the sensed values to the NodeMCU. The controller processes the received sensor data and compares it with predefined threshold values to determine the current air quality level. The measured values and air quality status are displayed on a **16×2 LCD**. If the detected pollution level exceeds the safe limit, the NodeMCU controls the **L298N motor driver** to move the robot to another location for further monitoring. The collected data can also be transmitted to cloud platforms through the built-in Wi-Fi module for real-time remote monitoring and analysis.

System Overview

The proposed Air Quality Monitoring Robot follows a closed-loop architecture consisting of the following components:

- **Gas Sensors (MQ-2 and MQ-135):** Detect harmful gases such as smoke, carbon dioxide (CO_2), LPG, and other air pollutants present in the environment.
- **NodeMCU (ESP8266):** Acts as the central controller that receives sensor data, processes the readings, compares them with predefined threshold values, and controls the overall operation of the robot.
- **Display Unit (16×2 LCD):** Displays the measured gas concentrations and the current air quality status in real time.
- **Motor Driver (L298N):** Controls the DC motors and enables the robot to move automatically to different locations whenever high pollution levels are detected.
- **Wi-Fi Communication:** Uses the built-in Wi-Fi capability of the NodeMCU to upload sensor data to cloud platforms for real-time remote monitoring and analysis.
- **System Operation:** The robot continuously performs the sequence **Detect → Process → Display → Move → Upload**, ensuring uninterrupted real-time air quality monitoring.

Live Video Capture and Frame Streaming

The robot is equipped with a camera module to capture live video of its surroundings. The camera continuously streams video frames to the NodeMCU or an external processing unit for real-time environmental monitoring. This enables users to visually inspect the monitored area while simultaneously observing air quality parameters measured by the gas sensors. The live video feed can be viewed on a computer interface, web application, or mobile device, providing both visual and sensor-based information. The system maintains synchronized video streaming and sensor monitoring, making it suitable for both remote surveillance and on-site environmental inspection.

Preprocessing and Sensor Data Extraction

Before analysis, the raw analog signals received from the **MQ-2** and **MQ-135** gas sensors are preprocessed to improve measurement accuracy. The NodeMCU continuously reads the sensor outputs through its analog input pins and converts the analog signals into digital values using its Analog-to-Digital Converter (ADC). Basic filtering and calibration techniques are applied to reduce noise and eliminate unwanted fluctuations in the sensor readings.

The processed sensor values are then compared with predefined air quality thresholds to determine the pollution level. These extracted values are displayed on the LCD and transmitted through Wi-Fi for cloud-based monitoring. Accurate preprocessing and sensor data extraction ensure reliable air quality measurement and improve the overall performance of the monitoring robot.

Working

The Air Quality Monitoring Robot works by continuously sensing the surrounding air using the MQ gas sensor. The sensor detects harmful gases, smoke, and pollution levels and sends the analog values to the NodeMCU (ESP8266) for processing.

The NodeMCU continuously compares the sensed gas values with predefined threshold values. If the gas concentration remains below the threshold, the system considers the environment safe and displays the message "AIR NORMAL" on the 16×2 LCD display.

When the gas concentration exceeds the predefined threshold, the system identifies the condition as "GAS DETECTED". In this situation, the buzzer is activated immediately, and the robot automatically stops its movement to indicate the presence of harmful gases and avoid entering highly polluted areas.

The robot movement is controlled through Wi-Fi communication. A mobile device connects to the NodeMCU access point, allowing the user to control the robot through a web interface containing buttons for Forward, Backward, Left, Right, and Stop movements.

Thus, the proposed system provides real-time air quality monitoring, gas detection, alert generation, automatic robot control, and wireless remote operation, making it suitable for environmental monitoring applications.

Results

The proposed **Air Quality Monitoring Robot** was successfully designed, implemented, and tested under different environmental conditions. The system continuously monitored the surrounding air using the MQ gas sensor and accurately detected harmful gases and smoke present in the environment.

During the testing process, the sensed gas values were displayed continuously on the 16×2 LCD display. Under normal atmospheric conditions, the detected gas concentration remained below the predefined threshold value, and the LCD displayed the message "AIR NORMAL", indicating that the surrounding environment was safe.

To evaluate the gas detection capability of the system, perfume spray was used as a source of gas near the MQ sensor. When the spray was introduced, the sensor readings increased rapidly and exceeded the predefined threshold value. The system successfully identified the polluted condition and displayed the message "GAS DETECTED" on the LCD display. At the same time, the buzzer was activated automatically, and the robot immediately stopped its movement to indicate the presence of harmful gases.

The Wi-Fi-based robot control was also tested successfully. The robot responded accurately to all movement commands, including Forward, Backward, Left, Right, and Stop, through the web-based control interface accessed from a mobile device. The communication between the mobile device and the NodeMCU remained stable during testing.

The sensor readings were simultaneously displayed in the Arduino IDE Serial Monitor, allowing real-time observation, monitoring, and debugging of the system.

The obtained results demonstrate that the proposed Air Quality Monitoring Robot provides accurate air quality monitoring, reliable gas detection, real-time alert generation, and efficient robotic movement control. Therefore, the system is suitable for applications such as smart environmental monitoring, industrial safety, pollution monitoring, and hazardous area inspection.

Output Showing Normal Air Condition and Robot Movement

The above figure shows the output of the **Air Quality** Monitoring Robot under normal environmental conditions. The MQ gas sensor detects that the gas concentration is below the predefined threshold value, indicating that the surrounding air quality is safe. Consequently, the 16×2 LCD displays the message "AIR NORMAL", and the robot continues its normal movement without interruption. The corresponding sensor values are also displayed in the Arduino IDE

Serial Monitor, enabling real-time monitoring, observation, and debugging of the system.

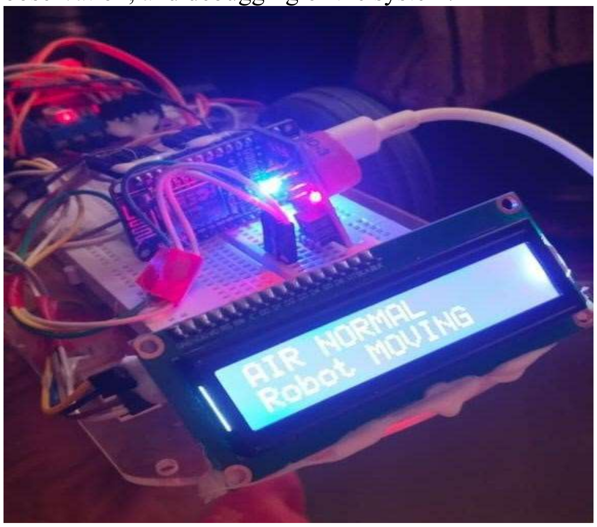

Fig 2: Output Showing Normal Air Condition and Robot Movement

Output Showing Gas Detection

The above figure shows the output of the Air Quality Monitoring Robot when perfume spray is introduced near the MQ gas sensor. The sensor detects a higher concentration of gas, causing the measured value to exceed the predefined threshold limit. As a result, the 16×2 LCD displays the messages "GAS DETECTED" and "Robot Stop", indicating the presence of harmful gases and the automatic stopping of the robot. Simultaneously, the buzzer is activated to provide an audible warning. The detected sensor values are also displayed in the Arduino IDE Serial Monitor for real-time observation, monitoring, and debugging, confirming the correct operation of the proposed system.

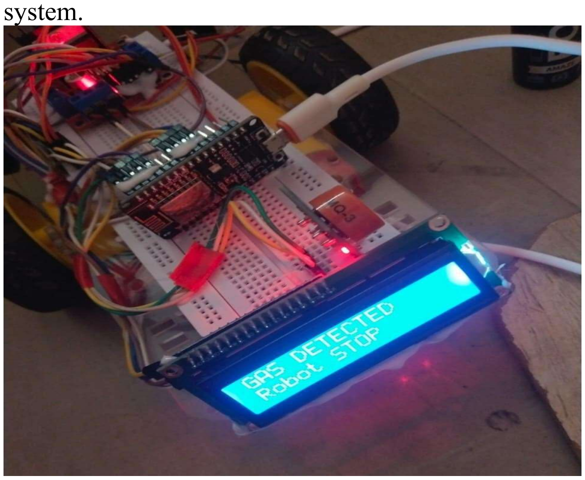

Fig 3: Output Showing Gas Detection

Conclusion

The **Air Quality Monitoring Robot** provides an efficient, reliable, and autonomous solution for real-time environmental monitoring. By integrating gas sensors, a NodeMCU (ESP8266), a 16×2 LCD display, a motor driver, and a mobile robotic platform, the system continuously monitors air quality, detects harmful gases, and provides immediate alerts whenever pollution levels exceed predefined safety limits. The robot is also capable of moving to different locations, enabling continuous monitoring over a wider area compared to conventional stationary monitoring systems.

The system operates effectively in both online and offline environments. Its offline operation ensures reliable performance even in areas with limited internet connectivity, while the built-in Wi-Fi capability allows optional cloud connectivity for remote monitoring, data visualization, and environmental analysis. The integration of real-time sensing, wireless communication, and autonomous robot movement makes the proposed system suitable for applications in industries, smart cities, educational institutions, traffic monitoring, mining areas, and hazardous environments.

Overall, the proposed Air Quality Monitoring Robot demonstrates a practical, cost-effective, portable, and scalable solution for continuous air quality monitoring. It contributes to environmental protection, improves public safety, and supports informed decision-making by providing accurate real-time information about air pollution levels.

Future Scope

The **Air Quality Monitoring Robot** offers considerable scope for future enhancements and advanced applications. In the future, the system can be integrated with IoT cloud platforms to enable real-time remote monitoring, automated notifications, and centralized storage of environmental data. Advanced gas sensors can be incorporated to detect a wider range of pollutants, including volatile organic compounds (VOCs), ozone (O_3), nitrogen dioxide (NO_2), and sulfur dioxide (SO_2), thereby improving monitoring accuracy.

Artificial Intelligence (AI) and Machine Learning (ML) algorithms can be integrated to analyze historical pollution data, predict future air quality trends, and recommend preventive measures. The robot can also be enhanced with GPS technology to generate pollution maps and identify pollution hotspots in different geographical regions.

Further improvements in robotic mobility, such as obstacle avoidance, autonomous navigation, and path-planning algorithms, will enable the robot to operate efficiently in complex indoor and outdoor environments without human intervention. The system can also be powered using solar energy to improve energy efficiency and support long-term outdoor deployment.

In addition, integration with smart city infrastructure, cloud-based analytics, mobile applications, and environmental management systems will make the robot more intelligent, sustainable, and suitable for large-scale environmental monitoring. These future enhancements will further increase the effectiveness of the Air Quality Monitoring Robot in protecting public health, supporting environmental research, promoting pollution awareness, and contributing to the development of cleaner and smarter cities.

References

[1] L. M. Easterline, A. A. Ravica Putri, P. S. Atmaja, and A. L. Dewi, "Smart Air Monitoring with IoT-Based MQ-2, MQ-7, MQ-8, and MQ-135 Sensors Using NodeMCU ESP32," *Procedia Computer Science*, vol. 245, pp. 815–824, 2024.

[2] M. Bermudez Arboleda and A. Shamim, "Self-Powered and Cost-Effective Wireless Sensor Node for Air Quality Monitoring with an Optically Transparent Smart Antenna System," *IEEE Sensors Journal*, vol. 24, no. 18, pp. 30015–30024, 2024.

[3] M. Janardhan, N. Rakshitha, E. Sravani, D. M. Afroz, and N. Supriya, "IoT and ML for Air Pollution Monitoring with Real-Time Data and Prediction of Health Advisory," in *Proceedings of the IEEE International Conference on Trends in Multimedia, Information, and Communication (ICTMIM)*, 2025.

[4] R. Sharma, K. Gupta, and A. Verma, "IoT-Based Air Pollution Monitoring System Using Cloud Storage," in *Proceedings of the IEEE International Conference on Electronics and Sustainable Communication Systems (ICESC)*, 2023.

[5] P. Kumar and L. Malhotra, "IoT-Enabled Air Quality Monitoring: Advancements, Applications, and Challenges," in *Proceedings of the IEEE International Conference on Internet of Things and Intelligence Systems*, 2024.

[6] "Advancing Air Quality Monitoring: A Low-Cost Sensor Network in Motion," *Environmental Research*, vol. 360, Art. no. 121179, 2024.