

# IOT System for Smart Air Quality Measurement

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**Abstract**—Air pollution has become a major concern due to the rapid growth and development of cities. In order to assess the level of air pollution, it is necessary to continuously monitor the air quality, so that preventive measures can be taken. This paper proposes the design of a smart air quality monitoring system using the Internet of Things (IoT) technology, where low-cost sensors are utilized for continuous monitoring. The system measures, processes, and analyzes air quality information by combining gas sensors with a microcontroller and cloud server. To allow remote monitoring the key parameters such as carbon dioxide (CO<sub>2</sub>), carbon monoxide (CO), and dangerous gases are to be identified and transmitted wirelessly. The system is useful for industrial, smart city, and public health applications because it provides accurate and update the information on air quality. The proposed approach is highly effective for continuous assessment of air quality.

**Index Terms**—Internet of Things (IoT), Smart Air Quality Measurement, Real-Time Data Monitoring, Wireless Sensor Network, ESP32, Alert System.

## I. INTRODUCTION

One of the most significant environmental issues affecting the health of humans as well as the environment is air pollution. Exposure to air pollution results in respiratory diseases, cardiovascular diseases, and many other severe health issues. The rising levels of air pollutants in cities have become a significant concern for sustainable development [5]. Traditional air quality monitoring systems rely on expensive monitoring stations that are limited in number and coverage. As a result, they cannot provide continuous and widespread monitoring of environmental conditions. Recent advancements in Internet of Things (IoT) technology have enabled the development of low-cost air quality monitoring systems capable of collecting real-time environmental data using sensor networks [2], [6]. Several studies have explored the use of IoT for environmental monitoring and air quality prediction. Advanced machine learning models such as Long Short-Term Memory (LSTM) networks have been proposed to predict air pollution levels in smart cities [1]. Additionally, IoT-based sensor networks combined with cloud platforms allow remote monitoring and visualization of environmental data [8]. Therefore, this paper

proposes an IoT-based smart air quality monitoring system that continuously monitors pollutant concentrations using multiple gas sensors and transmits the data to a cloud platform for remote analysis.

## II. LITERATURE SURVEY

### A. Toward Cleaner Industries: Smart Cities' Impact on Predictive Air Quality Management

The research also considers integrating the Weather Smart Grid (WSG) in the model of a smart city, where the Bidirectional Stacked Long Short-Term Memory (BSLSTM) is used for the prediction of the concentration of pollutants in the air up to 12 hours in advance. The large-scale IoT-based data sets, in conjunction with the spatiotemporal correlation analysis, increase the accuracy of the prediction using a reduced level of complexity. The experiments have confirmed the superiority of the proposed model of SPAM in comparison to other conventional models such as SVM, MLP, LSTM, and BLSTM. Such a system can be useful for sustainable planning, industrial pollution management, etc [1].

### B. Design of a Low-Cost System for the Measurement of Variables Associated With Air Quality

The sensors, which include CO, SO<sub>2</sub>, ozone, temperature, and relative humidity sensors, use low-cost technology with the Arduino MEGA 2560. The technology also includes the use of wireless IoT technology, GPS technology, and data storage technology. Calibration was also carried out for the sensors so that the technology could provide reliable information. The technology was deployed in Cienfuegos, Cuba, where it was successful in detecting pollutants using stable and efficient technology. The study also highlights the need for using low-cost technology so that it can provide reliable technology for the development of the country [2].

### *C. Influences of Human Presence on the Indoor Air Quality of Educational Institutions: Concurrent Multipollutant Sensing Approach*

The aim of this paper is to introduce a cost-effective solution for an edge-based air quality monitoring system to investigate the impact of occupancy on air quality in a classroom. Data has been collected for seven days on different air quality parameters such as CO<sub>2</sub>, VOCs, PM<sub>2.5</sub>, PM<sub>10</sub>, CO, NH<sub>3</sub>, temperature, and humidity. The results showed a high positive correlation between occupancy and CO/VOC levels, and air ventilation reduced pollutant accumulation effectively. An occupancy-based Indoor Air Quality Index has been proposed using an exponential moving average method [3].

### *D. Changing Idling Behavior Through Dynamic Idle Detection and Air Quality Messaging*

The Smart Air system contains IoT technology for air quality sensors, microphones, cameras, and a machine learning algorithm to detect idling vehicles in real-time. The Smart Air system will also monitor pollutants like CO and display messages on screens to encourage drivers to turn off their vehicle engines. The Smart Air system was tested in a hospital drop-off location to test its effectiveness. The experimental results indicate that dynamic feedback messages on digital screens have a significant impact on drivers, reducing the average duration of idling by 28 percent. The SmartAir system was able to reduce approximately 29.5 percent of CO emissions [4].

### *E. Real-Time Air Quality Monitoring: A Smart IoT System Using Low-Cost Sensors and 3-D Printing*

The system is based on the Raspberry Pi platform, which uses different sensors to monitor different parameters such as CO<sub>2</sub>, CO, NO<sub>2</sub>, ozone, particulate matter, VOCs, temperature, and humidity. The system is also designed in such a manner that it can be carried anywhere in a small 3D printed case, thus providing ease of usage. The tests were performed in different environments such as classrooms, cities, forests, and automobiles to test the parameters of the system. The results show that the system can provide accurate results with a level of accuracy of 95 percent, thus providing cost-effectiveness to the system [5].

### *F. IoT-Based Indoor Air Quality Management System for Intelligent Education Environments*

The system will utilize a wireless sensor network to collect important air quality parameters, including CO, PM<sub>2.5</sub>, temperature, humidity, and volatile organic compounds, from various classrooms. The sensors will send real-time data to the processing layer, where Complex Event Processing, machine learning, and deep learning will be utilized. The system will utilize an LSTM network to predict air quality in the near future, and a decision tree will be utilized to analyze relationships between various environmental factors. The system will also utilize blockchain technology to store important events. The system has been tested in various classrooms and

laboratories in a university, and it has been able to monitor variations in air quality caused by occupancy and ventilation. The system has been able to predict air pollution levels and provide healthy indoor air quality [6].

### *G. Energy-Constrained Indoor Air Quality Optimization for HVAC System in Smart Building*

The paper “Energy-Constrained Indoor Air Quality Optimization for HVAC System in Smart Building” aims at enhancing air quality in smart buildings while reducing energy consumption by using an HVAC system. The authors in the paper propose an air quality optimization method that uses the air supply rate of an HVAC system to ensure that the temperature in the smart building is within the comfortable range. They create a system model that accounts for the behavior of the temperature in the smart building, as well as the energy consumption by the HVAC system. They take into account different parameters in their system model, such as temperature outdoors, thermal disturbances, and air supply rates. The authors use the Lyapunov Optimization Theory to develop an algorithm called Utility-Optimal Air Quality Optimization (UAQO) that is capable of calculating the air supply rates even without prior information from the environment. They use simulation to show that the proposed method is effective in balancing the supply of air and energy consumption in smart buildings while maintaining the temperature within the comfortable range. They show that the UAQO algorithm is effective in achieving optimal system performance [7].

### *H. Graph-Deep-Learning-Based Inference of Fine-Grained Air Quality From Mobile IoT Sensors*

The solution utilizes both fixed monitoring stations and mobile IoT devices fixed on vehicles to gather environmental information such as NO, PM<sub>2.5</sub>, PM<sub>10</sub>, temperature, and humidity from the urban area. Since the information collected from the sensors is usually incomplete and scattered, the researchers have introduced a deep learning method using Variational Graph Autoencoders (VGAE) to estimate the air pollution values for the locations where the information is not collected. The model also utilizes the spatial and temporal relationships between different monitoring points using the road network as a graph. Another feature of the solution is the data processing pipeline that enables the visualization of the air quality information on a city map using a web interface. The results show that the proposed solution is more accurate in estimating the air quality compared to the existing methods such as interpolation and matrix completion [8].

## III. METHODOLOGY

### *A. System Overview*

The system is developed by making use of the Internet of Things (IoT) technology for real-time monitoring of the quality of air. The system is able to continuously monitor the concentration of harmful gases present in the air by making use of multiple sensors. The data is then transmitted to the cloud for remote monitoring. IoT-based environmental monitoring

systems have been widely used to measure air pollutants and provide real-time environmental information [5], [8].

### B. Hardware Architecture

The core processing unit of this system is the ESP32 microcontroller. The ESP32 is selected because it provides integrated Wi-Fi connectivity, a dual-core processor, low power consumption, and multiple analog input channels, making it suitable for IoT-based monitoring systems. Similar microcontroller-based air quality monitoring architectures using low-cost sensors have been proposed in previous studies [2], [5]. Multiple MQ series of gas sensors are used in the system to detect different types of pollutants that are present in the environment. The MQ-135 sensor detects general air pollutants such as ammonia (NH<sub>3</sub>), nitrogen oxides (NO<sub>x</sub>), benzene, and carbon dioxide (CO<sub>2</sub>). The MQ2 sensor detects combustible gases and smoke, while the MQ3 sensor detects alcohol vapors. The MQ7 sensor detects carbon monoxide (CO), while the MQ131 sensor detects ozone (O<sub>3</sub>). The use of multiple sensors allows the system to monitor several pollutants simultaneously and improve the reliability of air quality assessment [5]

### C. Data Acquisition and Processing

The analog output of the MQ sensors is connected to the Analog to Digital Converter (ADC) pins on the ESP32 microcontroller. The ESP32 makes use of its ADC to convert the analog voltage signals into digital signals. After the conversion into digital signal, the equations are used to convert the output received from the sensor into ppm units. Once the data is converted to ppm, it is then compared to threshold limits to determine the quality of the air, such as Good, Moderate, Bad, and so forth. This data processing method is employed in other IoT-based systems for monitoring air quality for environmental analysis [5], [6].

### D. Display and Communication Module

An I2C-based LCD module is interfaced with the ESP32 microcontroller to display real-time gas concentration values and air quality status. The I2C communication protocol is used because it reduces wiring complexity and allows multiple devices to communicate using only two lines (SDA and SCL). For remote monitoring, the ESP32 transmits processed sensor data to a cloud platform through its built-in Wi-Fi module. The cloud server stores and visualizes the collected data, allowing users to monitor environmental conditions through a web dashboard or mobile application. Cloud-based IoT platforms are widely used in environmental monitoring systems to provide real-time data access and analysis [6], [8].

### E. System Operation

The fig.1 shows overall operation of the system begins with environmental gas detection by the sensors. The sensed analog signals are converted into digital data by the ESP32, processed to obtain ppm values, categorized into air quality levels, displayed locally on the LCD, and finally uploaded to

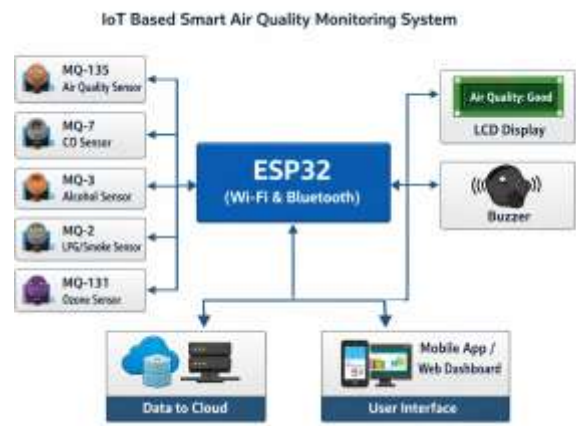


Fig. 1. Block Diagram of Proposed System

the cloud platform. This continuous monitoring cycle ensures real-time environmental awareness and early detection of hazardous conditions [5].

### F. Gas Sensing Unit

The sensing unit as shown in fig.1 consists of multiple MQ-series gas sensors, each dedicated to detecting specific gases present in the atmosphere.

- 1) **MQ135 – Air Quality Sensor** The MQ135 sensor is used to detect overall air pollutants like ammonia (NH<sub>3</sub>), nitrogen oxides (NO<sub>x</sub>), benzene, and carbon dioxide (CO). The sensor gives an analog output voltage in relation to the concentration of these gases. Therefore, it can be used to measure overall air quality.
- 2) **MQ7 – Carbon Monoxide Sensor** The MQ7 sensor is specifically designed to detect carbon monoxide (CO), a highly toxic gas. It operates using a heating cycle method and produces an analog output corresponding to CO concentration in ppm.
- 3) **MQ3 – Alcohol Sensor** The MQ3 sensor detects alcohol vapors in the environment. It is highly sensitive to ethanol and is commonly used in breath analyzer applications. In this system, it helps monitor volatile organic compounds related to alcohol emissions.
- 4) **MQ2 – LPG/Smoke Sensor** The MQ2 sensor detects combustible gases such as LPG, methane, propane, and smoke. It enhances safety by identifying leakage or fire-related hazards.
- 5) **MQ131 – Ozone Sensor** The MQ131 sensor is used to detect ozone (O<sub>3</sub>) concentration in the air. Since ozone at ground level can cause respiratory issues, monitoring its level is important for environmental safety. Each sensor outputs an analog signal that varies according to the detected gas concentration.

### G. Processing and Control Unit – ESP32

[!htbp] The ESP32 microcontroller serves as the central processing unit of the system. It performs the following

functions:

- Reads analog signals from all connected gas sensors through its ADC pins.
- Converts an analog voltage signal into a digital form.
- Applies a series of formulas for calibration purposes, which calculate the gas concentration in parts per million (ppm).
- Compares the data with a series of threshold limits.
- Manages output devices like the LCD display and buzzer.
- Transfers data to the cloud through its Wi-Fi facility. Wi-Fi and Bluetooth functionality make the ESP32 highly suitable for IoT projects.

#### H. Display Unit – LCD Module

The LCD display block, as shown in Fig. 1 above, enables the real-time visualization of the parameters of air quality. The parameters that can be visualized using the LCD display block are:

- Individual gas concentration values (in ppm)
- Overall air quality status (Good, Moderate, Bad)

The LCD interface is usually carried out using the I2C communication protocol, which minimizes wiring complexity and uses only two communication wires (SDA and SCL).

#### I. Alert System – Buzzer

The buzzer depicted in fig.1 is utilized as an emergency alert system. In case the concentration of the gas surpasses the predefined safety thresholds, the ESP32 will activate the buzzer to alert users of the hazardous environment.

#### J. Cloud Communication Module

The processed sensor data is transmitted to a cloud server via the ESP32's Wi-Fi module. This block enables:

- Remote monitoring
- Data storage
- Historical data analysis
- Real-time updates through internet connectivity

The cloud platform ensures accessibility from anywhere using an internet-enabled device.

#### K. User Interface (Mobile App / Web Dashboard)

The user interface block represents the mobile application or web dashboard used in data visualization. The user can scan:

- Monitor real-time levels of pollutants
- View graphical trends and historical data
- Receive alerts and notifications
- Analyze air quality status remotely

The user interface block improves usability and provides continuous environmental monitoring.

#### L. Circuit Implementation

The circuit diagram for the proposed IoT-based Smart Air Quality Monitoring System is shown in fig.2. Various sensors are connected to this circuit, i.e., MQ135, MQ7, MQ3, MQ2, and MQ131. These sensors are connected to a 5V regulated

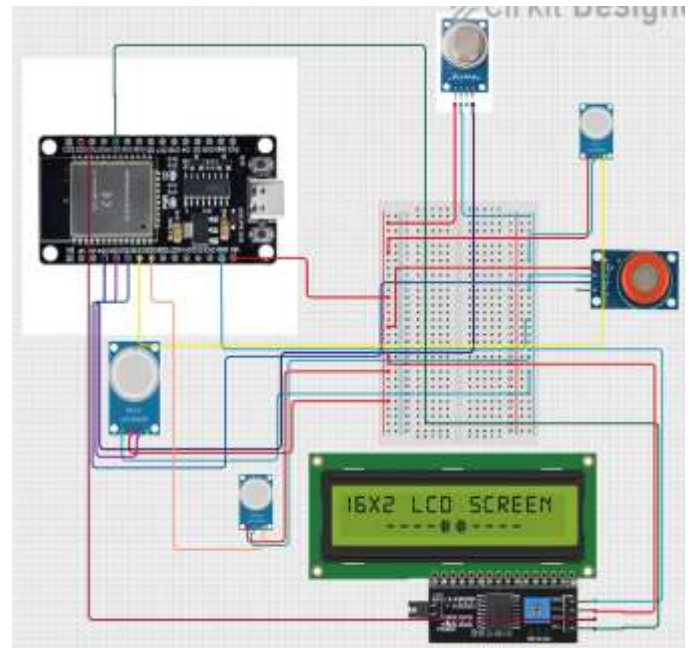


Fig. 2. Circuit Diagram

voltage source. This voltage source is connected to the respective rails on the breadboard. A grounding connection is maintained among all components. Each sensor has an analog output proportional to the concentration of gases detected. These analog outputs are connected to ADC-enabled GPIO pins on ESP32. These analog outputs are then sent to be calibrated to parts per million. A 16x2 LCD interface is connected to this circuit. This interface uses an I2C interface module. This interface has only four connections: VCC, GND, SDA, and SCL. These are connected to respective I2C interface pins on ESP32. This interface has low pin count, which makes communication efficient. This interface will be used to show real-time values of concentration along with air quality. The ESP32 reads these signals, processes them using calibration algorithms, displays the results on the LCD, activates the buzzer if required, and simultaneously transmits the data to a cloud platform via its built-in Wi-Fi module. This integrated hardware configuration ensures accurate sensing, reliable processing, and real-time environmental monitoring suitable for IoT-based applications.

## IV. RESULTS AND DISCUSSION

### Clean Indoor Environment (Good Category)

Under normal room conditions with good ventilation, the concentration is within the safe zone as shown in fig.3.

- MQ135: 90–140 ppm
- MQ7 (CO): 1–4 ppm
- MQ2: 120–180 ppm
- MQ3: 0–1 ppm
- MQ131 (O): 0.01–0.03 ppm

The calculated Air Quality Index is below 50. The LCD display shows “Air Quality: Good.” The buzzer is in an inactive

position. The system is showing stable readings with minor changes due to air movements.



Fig. 3. Clean Environment

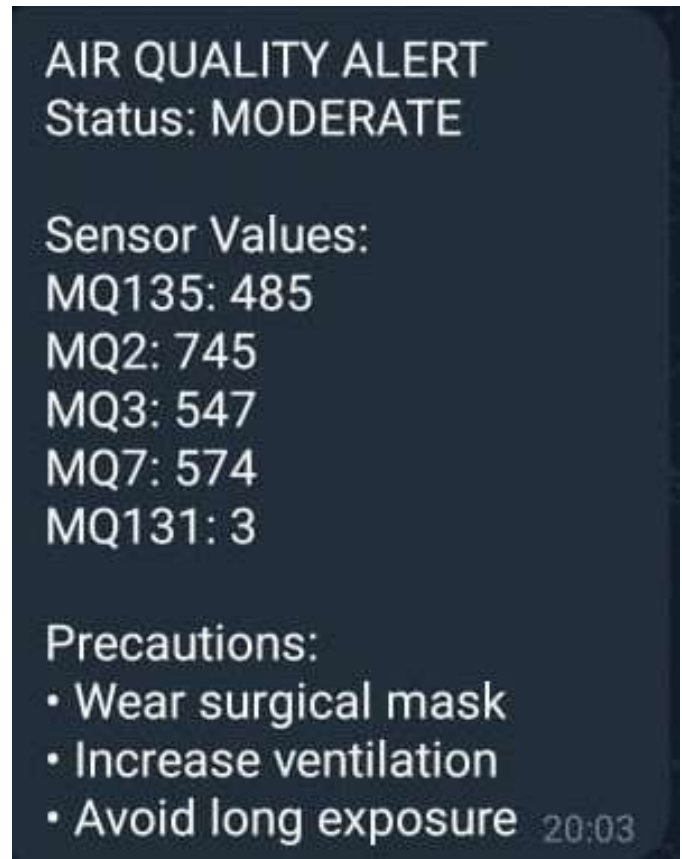


Fig. 4. Moderate condition

**Moderate Pollution Condition (Moderate Category)**

When exposed to mild smoke or alcohol vapors, a significant increase in output was noticed as shown in fig.4.

- MQ135: 180–260 ppm
- MQ7 (CO): 6–12 ppm
- MQ2: 220–350 ppm
- MQ3: 1–3 ppm

The AQI ranged between 60 and 120 depending on pollutant concentration. The LCD displayed “Air Quality: Moderate.” In some cases, when concentration crossed the moderate threshold, the buzzer activated intermittently. The response time of the sensors was observed to be approximately 5–15 seconds.

**High Pollution Condition (Bad Category)** When the sensors were directly exposed to smoke or a concentrated gas source, a rapid increase in analog output was observed as shown in fig.5.

- MQ135 :> 300ppm
- MQ7(CO) :> 15ppm
- MQ2 :> 400ppm
- MQ3 :> 3ppm
- MQ131(O) :> 0.08ppm

The AQI was computed to be above 150, indicating the quality of air to be “Bad.” The buzzer was continuously activated to serve as a warning alert. The system demonstrated good detection speed, with noticeable changes occurring in

a few seconds. The results obtained from the experiments demonstrated the capability of the system to detect changes in the concentration of pollutants. The ESP32 module was able to process analog signals from multiple sensors simultaneously without any significant delay. The results obtained from the experiments are as follows:

- **Response Time:** The average response time was observed to vary between 5-15 seconds based on the type and concentration of gas.
- **Stability:** The readings were observed to stabilize after an initial warm-up period for the MQ sensors, taking around 1-2 minutes.
- **Accuracy:** Although the MQ sensors are not accurate, the results obtained showed good accuracy in terms of consistency. The use of multiple MQ sensors improves the reliability of the overall air quality assessment compared to using a single sensor. The AQI calculation based on the maximum concentration improves the detection capability of the overall environmental safety level based on the critical pollutant present.

Some minor changes were observed due to the changes in the temperature and the cross-sensitivity of the sensor. This is because it is the inherent property of the MQ series of sensors. But the changes did not affect the overall classification of the AQI value. The results validate the fact that the proposed system is a cost-effective solution for real-time environment

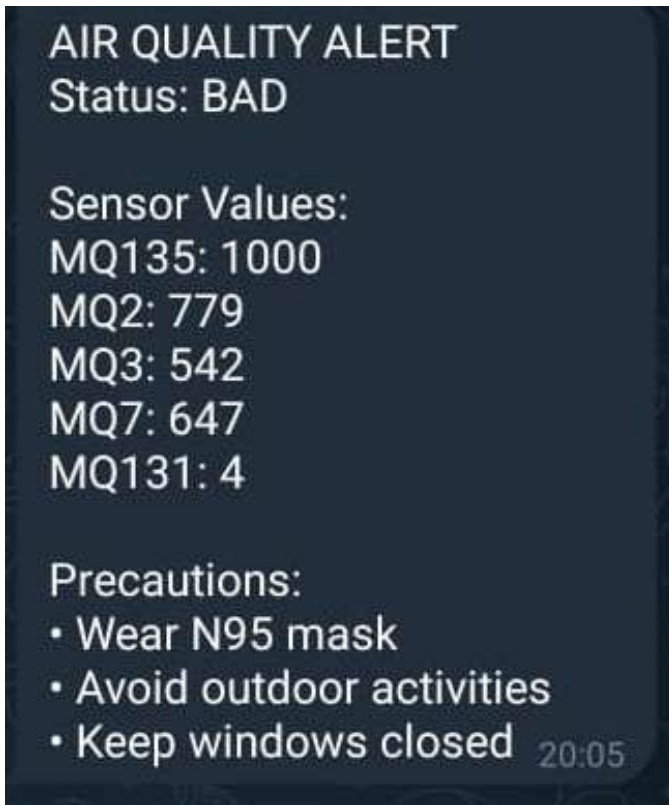


Fig. 5. Bad Condition



Fig. 6. IoT Dashboard

monitoring. It can be implemented for indoor air quality measurement, labs, parking areas, and semi-urban areas where the monitoring of the environment is of prime importance and where the early detection of hazards is necessary. relative variation corresponding to pollution levels.

- Alert Mechanism: The buzzer activation is accurate and corresponds to the conditions of exceeding the threshold value.
- Cloud Monitoring: The data transmission using Wi-Fi is smooth and real-time without any loss of packets.

#### V. CONCLUSION

The IoT System for Smart Air Quality Measurement is able to deliver an efficient and cost-effective solution to measure

the air quality in the environment. In this context, the proposed system is able to make use of a ESP32 Microcontroller and various types of Gas Sensors such as a MQ135 Gas Sensor, a MQ2 Gas Sensor, a MQ3 Gas Sensor, a MQ7 Gas Sensor, and a MQ131 Gas Sensor to measure various types of harmful gases that are available in the environment. The output that is generated by the sensors is converted to a digital format using an ADC that is connected to the ESP32 Microcontroller. This output is further used to estimate the output to find the concentration of various types of gases that are available in the environment in Parts per Million. This output is used to find the Air Quality by comparing it with various ranges to categorize it under various types such as Good, Moderate, Bad, etc. This information can be used to deliver awareness about various environmental conditions and can also be used to take preventive measures to avoid exposure to various types of harmful gases that are available in the environment. This project can be further enhanced by incorporating more precise sensors and different applications for efficient monitoring of air pollution levels.

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