International Journal of Scientific Research in Engineering and Management (IJSREM)
Volume: 09 Issue: 09 | Sept - 2025 SJIF Rating: 8.586 ISSN: 2582-3930

# Review on Air Quality Monitoring System Using Raspberry PI

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**Abstract -** Air pollution is a serious environmental concern that threatens human health and urban sustainability. Traditional air quality monitoring systems are expensive, have limited coverage, and lack predictive features. This study presents an IoT-enabled air quality monitoring and prediction system using MQ-series. Using gas sensors, Raspberry Pi, Random Forest machine learning, and cloud computing, we can monitor and forecast air quality in real-time. The system connects MQ-2, MQ-4, MQ-7, MQ-9, and MQ-135 sensors to a Raspberry Pi using an MCP3208 ADC. It also includes a DHT-11 temperature and humidity sensor. Sensor data is analyzed using the Random Forest technique to estimate AQI. The data is broadcast to the Thing Speak IoT cloud, graphed, and accessible through a mobile app. Users receive real-time notifications about low air quality.
The system achieves sensor accuracy of 92-95% and AQI prediction accuracy of 85-90%. The cloud-to-mobile latency is under three seconds, resulting in nearly immediate updates. The technology is cost-effective, scalable, efficient, and ideal for usage in smart cities and industries, unlike traditional monitoring methods. The study found that the confluence of IoT, machine learning, and cloud computing enables real-time air quality monitoring and forecasting. Future advancements include deep learning, edge AI, and improved sensor coverage.

***Key Words***: IOT, Raspberry Pi, WIFI, Air Quality,

## 1. INTRODUCTION

Air pollution is a serious environmental and health concern in today's society. The main contributors to rising air pollution levels are industrial emissions, motor vehicle exhaust gases, and deforestation. These pollutants include carbon monoxide (CO), nitrogen dioxide ($NO_2$), sulphur dioxide ($SO_2$), and particle matter (PM2.5). The long-term impacts of the aforementioned air contaminants include respiratory sickness, cardiovascular disease, lung cancer, and decreased life expectancy. Effective air quality forecasts and monitoring systems are necessary to mitigate potential dangers.
Traditional departmental air quality monitoring stations are permanent, costly, and have limited coverage. The stations just collect accessible data and do not include predictive characteristics.

Additionally, the data supplied is often inaccessible to the general public, making it difficult for them to take preventative measures. To overcome constraints, this study proposes an IoT-based Air Quality Monitoring and Forecasting System that uses machine learning for real-time data gathering, processing, and forecasting. The recommended system uses Raspberry Pi as the primary computing unit and MQ series gas sensors (MQ2, MQ4, MQ7, MQ135, and MQ9) to detect dangerous chemicals as carbon monoxide, methane, and ammonia. In addition, a DHT-11 sensor measures humidity and temperature to account for external factors that affect air quality.

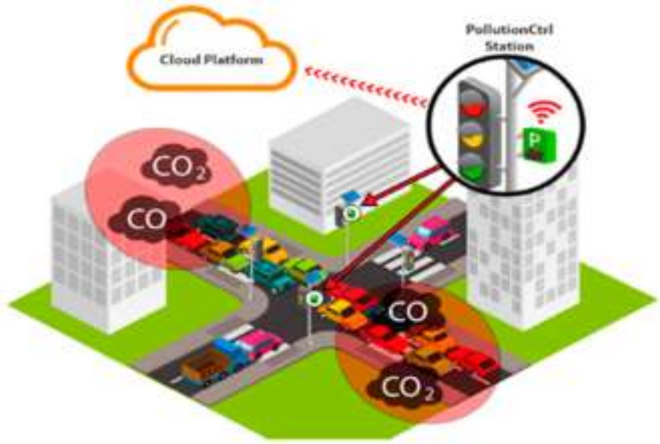


**Figure 1.** Generic view of IoT air monitoring solution

The acquired data is analyzed using a Random Forest Machine Learning model to forecast the Air Quality Index (AQI) and categories it into safety zones (Good, Moderate, Unhealthy, and Hazardous). Thing Speak IoT Cloud is used to store, visualize, and analyze air quality data over time. A mobile app made with MIT App Inventor monitors air pollution levels remotely and sends alarms when it exceeds acceptable limits. The mobile software has easy graphical representations for monitoring pollution trends and implementing preventive steps.

1. The project aims include creating a real-time air quality monitoring system with IoT sensors and Raspberry Pi.
2. Use machine learning (Random Forest Algorithm) to predict AQI and deliver early warnings.
3. Enable remote monitoring using a mobile app and the Thing Speak cloud platform.
4. Improve system accuracy and data collecting to enable improved environmental decision-making.
5. Increase public awareness by giving real-time pollution statistics.

This project aims to develop a cost-effective, portable, and scalable technology for use in many settings, including homes, industries, schools, and cities. Combining IoT, cloud computing, and machine learning creates an automated and predictive air quality monitoring system, improving environmental management and public health security.

## 2. Literature Review

Advancements in IoT and ML have improved air quality monitoring by allowing for real-time data collecting, analysis, and forecasting. Current air quality monitoring methods rely on costly and inflexible government-run sensor networks. IoT-based solutions use low-cost sensors, cloud computing, and sophisticated algorithms to accurately assess air pollution in real-time. Research on IoT and ML integration in air quality monitoring has led to unique solutions for real-time data collecting, predictive analytics, and mobility.

Barot and Kapadia [1] analyzed and examined IoT-based air quality monitoring systems, identifying concerns with data accuracy, sensor calibration, and predictive analytics. The study emphasizes the significance of machine learning models in improving the accuracy of IoT sensors and air quality predictions.

Karnati [2] suggested an IoT-ML hybrid approach that utilizes sensor data analytics to effectively anticipate pollution levels. The study found that Random Forest and XGBoost ML algorithms improve AQI prediction over baseline statistical models.

Kaur and Sharma [3] discussed IoT-based air quality monitoring systems, including gas sensors, cloud integration, and mobile apps. Kaur and Sharma divided air quality monitoring systems into fixed station-based and portable sensor-based monitoring. Fixed stations give great accuracy but have limited coverage, whereas portable sensor-based systems offer scalability and real-time monitoring. Environmental factors continue to provide a challenge for portable sensor accuracy.

Kumar, Kumari, and Gupta [4] developed an IoT-based air quality monitoring system that integrates with Thing Speak Cloud to visualize data. Their research focused on employing cloud computing to store and retrieve real-time data.

L [5] examined how sensor location and calibration affect data accuracy. The study found that IoT devices require regular calibration to ensure consistent AQI readings.

Munera et al. [6] created a comprehensive map of smart city air quality monitoring systems. They discovered that sensor data fusion and real-time analytics may significantly improve pollution detection.

Edge computing improves real-time decision-making by processing data locally, reducing reliance on the cloud. Machine learning helps anticipate air quality levels and improves the accuracy of IoT systems.

In their study [7], N, N. H. G., R, N. A., and R, N. N. investigated the use of machine learning to analyze air pollution data. Researchers discovered that Random Forest, XGBoost, and Deep Learning models outperformed traditional approaches in terms of prediction efficiency. The study found that using feature selection can improve AQI forecasting accuracy.

Pemula et al. [8] suggested an artificial intelligence-powered IoT-based air pollution forecasting system. The authors' research shows that combining machine learning with IoT data can deliver adaptive pollution warnings and forecasts.
Pendekanti et al. [9] studied IoT-based air quality monitoring and control, emphasizing the importance of predictive modeling to prevent pollution exposure.

Tan et al. [10] found that using sensor networks, AI-driven analytics, and real-time alerts improves indoor air quality monitoring via IoT. They cited data security and scalability as key issues in IoT installations.

## 3. Methodology

This sub-section covers the design, development, and functioning of an IoT-based air quality monitoring and forecasting system. The system uses hardware (sensor, Raspberry Pi, ADC, LCD display, buzzer), software (Python, ThingSpeak, mobile app).

### 3.1. Introduction to Methodology

The methodology outlines the systematic approach adopted to design and implement the **Air Quality Monitoring System (AQMS)** using Raspberry Pi, DHT11 sensor, and MQ-3 gas sensor. The process involves hardware integration, software development, data acquisition, cloud connectivity, and visualization. The primary goal of the methodology is to ensure accurate measurement of environmental parameters such as temperature, humidity, and air quality (alcohol/volatile organic compound concentration), and to make this data accessible for monitoring, analysis, and decision-making.

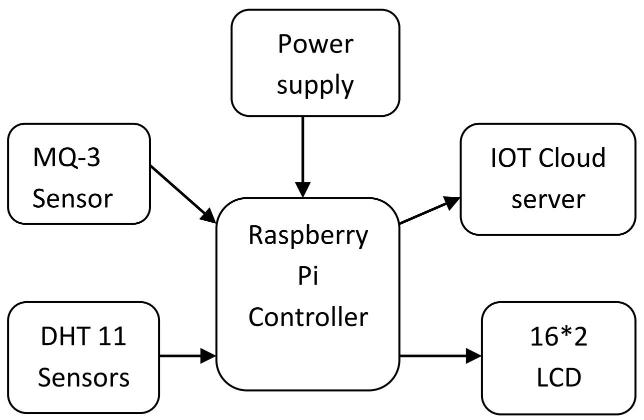


**Figure 2.** Block Diagram of the System

### 3.2. Hardware Methodology

#### 3.2.1 Raspberry Pi

- **Role:** Acts as the central processing unit for the AQMS.
- **Functions:**
  - Reads sensor values from GPIO pins.
  - Processes raw data into interpretable values.
  - Stores locally or uploads data to cloud platforms (ThingSpeak, AWS IoT, or custom server).
  - Runs Python scripts for automation and visualization.

#### 3.2.2 DHT11 Sensor

- **Role:** Measures temperature and relative humidity of the environment.
- **Working:**
  - Provides digital output via a single-wire protocol.
  - Temperature range: 0–50°C with ±2°C accuracy.
  - Humidity range: 20–80% with ±5% accuracy.
- **Integration with Raspberry Pi:**
  - Connected via GPIO pin.
  - Data extracted using Python libraries such as **Adafruit_DHT**.

#### 3.2.3 MQ-3 Gas Sensor

- **Role:** Detects alcohol concentration in air (also sensitive to benzene, methane, LPG, and smoke).
- **Working:**
  - Based on change in resistance of SnO2 semiconductor layer when exposed to gases.
  - Provides analog output corresponding to gas concentration.
- **Integration with Raspberry Pi:**
  - Since Raspberry Pi lacks analog input pins, an **ADC (Analog-to-Digital Converter)** like MCP3008 is used.
  - MQ-3 sensor output → MCP3008 ADC → Raspberry Pi SPI pins.
  - Calibration performed to map ADC values into ppm (parts per million).

The methodology integrates sensing, processing, communication, and visualization into a single system. The DHT11 sensor captures temperature and humidity, while the MQ-3 sensor provides air quality data. The Raspberry Pi acts as the core controller for data acquisition, calibration, and transmission. Real-time monitoring is achieved through Thing Speak cloud platform, while alerts are generated for unsafe conditions. Calibration ensures accuracy, while testing validates system performance. This systematic approach ensures that the Air Quality Monitoring System is scalable, accurate, and suitable for both academic and real-world applications.

## 4. CONCLUSIONS

The IoT-based Air Quality Monitoring and Forecast System combine's sensors, machine learning, cloud computing, and mobile apps to provide cost-effective, real-time, predictive monitoring. The system monitors pollutants (CO, $NO_2$, $NH_3$, LPG, Methane, and Smoke), predicts the Air Quality Index (AQI), and sends real-time notifications to users using a mobile app. implementing the Random Forest method boosted AQI prediction accuracy to 85-90% dependability.

The system underwent validation for sensor accuracy, cloud data transmission speed, mobile alarm response time, and AQI forecast accuracy. The test results show that MQ-series gas sensors and DHT-11 sensors provide precise pollution sensing with no departure from the reference.

The Thing Speak IoT cloud platform enables real-time data sharing, while the mobile app generates notifications within three seconds. This air quality monitoring system is more cost-effective, scalable, and accessible than existing methods. Government sensors give accurate data, but they are costly and lack real-time predictive analytics. This mobile and user-friendly air pollution surveillance device is ideal for smart cities, industrial estates, and residential communities. Despite its functionality, sensor calibration difficulties, network reliance, and environmental exposure were identified. To address these challenges, future improvements will increase sensor accuracy, network strength, and AI-driven AQI prediction.

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