International Journal of Scientific Research in Engineering and Management (IJSREM)
Volume: 10 Issue: 10 | Oct - 2026 SJIF Rating: 8.659 ISSN: 2582-3930

Air Pollution Monitoring System

Vaishnavi Telange
Student, E&TC Dept.
Bhivrabai Sawant Polytechnic, Wagholi, Pune

Shravani Shivale
Student, E&TC Dept.
Bhivrabai Sawant Polytechnic, Wagholi, Pune

Vaishnavi Bhor
Student, E&TC Dept.
Bhivrabai Sawant Polytechnic, Wagholi, Pune

Gauri Kamble
Student, E&TC Dept.
Bhivrabai Sawant Polytechnic, Wagholi, Pune

M.N. Waghmode
Guide, E&TC Dept.
Bhivrabai Sawant Polytechnic, Wagholi, Pune

Department of Electronics & Telecommunication, Bhivrabai Sawant Polytechnic, Wagholi, Pune, Maharashtra, India

Abstract-

Air pollution represents one of the most urgent threats to global health, environmental stability, and urban liveability. Traditional regulatory air quality monitoring networks (AQMNs) rely on stationary reference instruments that deliver high accuracy but suffer from extreme capital costs, large physical footprints, and sparse spatial density. This paper presents a systematic review of modern, decentralized Air Pollution Monitoring Systems (APMS). We analyze the end-to-end architecture: from solid-state and optical hardware sensors, low-power microcontrollers, and wireless communications. (LoRaWAN, NB-IoT, 5G), to cloud-native microservices, spatial interpolation, and deep learning AQI forecasting. Furthermore, three structural system diagrams are integrated to illustrate hardware sensor node assembly, cloud pipeline orchestration, and mobile application user workflows.

Key Words: Air Quality Monitoring System, Internet of Things (IoT), Low-Cost Sensors, Machine Learning, Data Calibration, Urban Analytics.

1. INTRODUCTION

Air pollution is one of the major environmental problems affecting human health and the natural environment across the world. It occurs when harmful gases, smoke, dust, and other particles enter the atmosphere and reduce the quality of the air. Rapid industrialization, increasing numbers of vehicles, construction activities, burning of fossil fuels, and improper waste disposal are some of the major sources of air pollution. Air pollution can affect human health, plants, animals, and the overall balance of the environment. Continuous monitoring of air quality is therefore important for understanding pollution levels and taking appropriate preventive measures.

An Air Pollution Monitoring System is a system designed to detect, measure, and monitor selected pollutants present in the surrounding air. It uses sensors and electronic devices to collect information about air quality. Depending on the components used, the system may monitor particulate matter such as PM2.5 and PM10, selected gases, temperature, and humidity. The collected data can be processed by a microcontroller and displayed on an LCD or OLED screen. In an advanced system, the readings can also be transmitted through Wi-Fi or another communication technology to a computer, mobile application, or cloud platform for remote monitoring.

Traditional air-quality monitoring stations use specialized instruments to measure pollutants. Although these stations can provide reliable information, their installation and maintenance can be expensive, and they may not be available in every location.

A low-cost, sensor-based Air Pollution Monitoring System can provide an educational and practical way to observe changes in air quality at selected locations. Such systems can be useful in schools, colleges, laboratories, homes, offices, and other places where environmental monitoring is required. However, low-cost sensors may have limitations in accuracy and selectivity, so their readings should be validated before being used for official or health-related decisions.

The main purpose of this project is to develop a simple, affordable, and user-friendly system for monitoring selected air-quality parameters. The system can include a microcontroller such as an Arduino Uno or ESP32, suitable air-quality sensors, a display unit, a power supply, and an alert system.

2. PROBLEM STATEMENT

Air pollution is one of the major environmental problems affecting human health and the natural environment. It is caused by increasing vehicle emissions, industrial activities, construction work, burning of fossil fuels, garbage burning, and other human activities. These activities release harmful gases and particulate matter into the atmosphere, reducing air quality.

3. OBJECTIVES

- **To monitor air quality:** Measure selected pollutants and environmental parameters using suitable sensors.
- **To detect particulate matter:** Monitor PM2.5 and PM10 concentrations when a compatible particulate matter sensor is used.

4. SYSTEM ARCHITECTURE

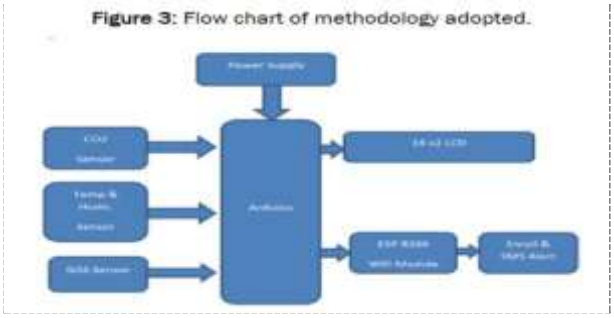


Fig. 1: Flow chart of methodology adopted

In the Air Pollution Monitoring System, the flowchart explains how the system starts, initializes the sensors, collects air quality data, processes the readings, checks pollution levels, displays information, generates alerts, and optionally sends data to an online platform.

The flowchart is useful for understanding the complete working logic before developing the hardware circuit and software program.

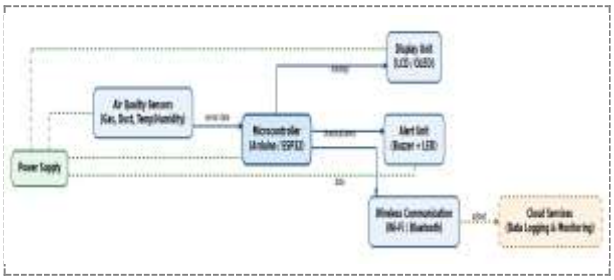


Fig. 2: Block diagram of the Air Pollution Monitoring System

The Air Pollution Monitoring System consists of air quality sensors, a microcontroller, a display unit, an alert unit, a power supply, and optional wireless communication and cloud services. Each component has a specific function, and the components work together to measure selected environmental parameters and present the results to the user.

5. HARDWARE COMPONENTS

1. **PM2.5 / PM10 Sensor:** This sensor measures the concentration of airborne particulate matter in the atmosphere.
2. **MQ-135 Gas Sensor:** This sensor responds to certain gases and vapours present in the surrounding air.
3. **DHT11 Temperature and Humidity Sensor:** This sensor measures the surrounding temperature and relative humidity.
4. **ESP32 / Arduino Uno:** The microcontroller acts as the brain of the system.
5. **LCD Display:** The LCD displays the readings received from the microcontroller.
6. **LED and Buzzer:** These components provide an alert when a configured pollution threshold is exceeded.
7. **Power Supply:** The power supply provides electrical energy to the circuit.
8. **Breadboard and Jumper Wires:** These components are used to connect the electronic devices during prototype development.
9. **Wi-Fi / Communication Module (Optional):** This module allows the system to send readings to an online platform.

6. COMPONENTS

6.1 HARDWARE COMPONENTS

1. PM2.5 / PM10 Sensor

This sensor measures the concentration of airborne particulate matter in the atmosphere.

Function: Detects fine and coarse airborne particles.
Output: Particle concentration, generally in µg/m³.
Example: PMS5003 or SDS011.



Fig. 3: PM2.5 / PM10 sensor

2. MQ-135 Gas Sensor

This sensor responds to certain gases and vapours present in the surrounding air.

Function: Detects changes in gas concentration.
Output: Electrical signal related to the sensor's response.
Use: General air-quality monitoring demonstrations.



Fig. 4: MQ-135 gas sensor

3. DHT11 Temperature and Humidity Sensor

This sensor measures the surrounding temperature and relative humidity.

Function: Monitors environmental conditions.
Output: Temperature in °C and relative humidity in %.
Use: Environmental data collection.



4. ESP32 / Arduino Uno

The microcontroller acts as the brain of the system.

Function: Receives and processes sensor data.

Controls: LCD display, LED and buzzer.

Additional feature: ESP32 supports built-in Wi-Fi for IoT monitoring.

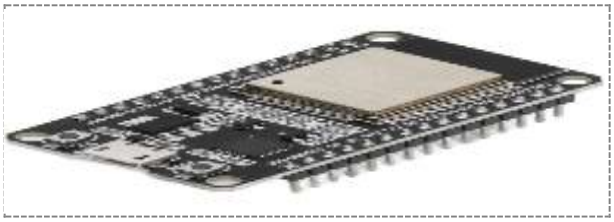


Fig. 6: ESP32 / Arduino Uno

5. LCD Display

The LCD displays the readings received from the microcontroller.

Function: Shows available sensor values and system status.

Example: PM2.5, temperature, humidity, and warning messages.

Type: 16×2 character LCD.



Fig. 7: 16×2 LCD display

6. LED and Buzzer

These components provide an alert when a configured pollution threshold is exceeded.

Function: Gives visual and audible warnings.

Operation: Controlled by the microcontroller.

Use: Indicates a high reading or warning condition.



Fig. 8: LED and buzzer

7. Power Supply

The power supply provides electrical energy to the circuit.

8. Breadboard and Jumper Wires

These components are used to connect the electronic devices during prototype development.

9. Wi-Fi / Communication Module (Optional)

This module allows the system to send readings to an online platform.

6.2 SOFTWARE COMPONENTS

1. ARDUINO IDE

Arduino IDE is a software development environment used to write, compile, and upload programmes to the ESP32 development board.

2. EMBEDDED C/C++

Embedded c/c++ is used to develop the programs that reads sensor values, processes data, and controls communication between the ESP32 microcontroller.

3. ESP32 BOARD SUPPORT PACKAGE

This software package enables the Arduino IDE to compile and upload programs for the ESP32.

- Configures the ESP32 board.
- Supports Wi-Fi and GPIO functions.
- Enables communication with compatible sensors and peripherals.

4. SENSOR AND LCD LIBRARIES

Libraries provide ready-made functions for communicating with compatible hardware.

- DHT sensor library for DHT11.
- LiquidCrystal or a compatible I²C LCD library.
- A compatible PMS5003 or SDS011 library, if required.
- An MQ-135 library or custom code, depending on the module.

The selected libraries must match the sensor model and interface.

7. WORKING PRINCIPLE

The Air Pollution Monitoring System is an electronic system designed to monitor air quality by detecting selected pollutants and environmental conditions. It uses different sensors, a microcontroller, a display unit, and an optional wireless communication module to collect, process, and present air quality information.

The system operates on the principle of sensing, signal conversion, data processing, threshold comparison, and output generation. The sensors detect changes in the surrounding air and provide electrical or digital signals to the microcontroller. The microcontroller processes these signals and displays the available readings on an LCD. If a measured parameter exceeds a predefined threshold, an LED or buzzer can provide a warning.

When Wi-Fi connectivity is available, the system can also transmit data to an online platform for remote monitoring, data storage, and graphical analysis.

This project is useful for educational purposes, environmental awareness, preliminary air quality monitoring, and IoT-based applications. The working principle of the system is based on the interaction between air quality sensors and a programmable microcontroller.

The sensors are installed in a location where air can reach their sensing elements. A particulate matter sensor estimates the concentration of airborne particles, while a gas sensor responds to certain gases or vapours. A temperature and humidity sensor records environmental conditions.

The sensor outputs are received by the microcontroller, such as an ESP32 or Arduino Uno. The controller processes the readings according to the program stored in its memory. It checks whether the received data is valid and compares relevant measurements with predefined thresholds.

The processed information is then sent to the output devices. The LCD displays the readings, while the alert unit provides a warning if a configured condition is met. An internet-enabled version can transmit the data to a cloud server or web dashboard.

The monitoring process repeats at regular intervals, allowing the system to observe changes in air quality over time.

8. IMPLEMENTATION METHODOLOGY

The implementation methodology describes the step-by-step process used to design, develop, assemble, program, and test the Air Pollution Monitoring System. The main purpose of this project is to monitor selected air quality parameters using electronic sensors and a microcontroller. The collected data is processed and displayed on an LCD, and an alert is generated when a measured parameter crosses a predefined threshold.

The system can be developed using an ESP32 or Arduino Uno, a particulate matter sensor, a gas sensor, a temperature and humidity sensor, an LCD display, and an LED or buzzer. An ESP32-based system can also use its built-in Wi-Fi capability to send measurements to an online platform.

The implementation is divided into several stages, starting from component selection and circuit design and ending with testing, evaluation, and final demonstration.

9. TESTING AND EVALUATION

Testing and evaluation is an important stage in the development of an Air Pollution Monitoring System. It is performed to verify that the hardware components, sensors, microcontroller, display unit, alert system, and optional IoT connectivity work correctly.

10. ADVANTAGES

- Real-Time Monitoring
- Automatic Data Collection
- Alert System
- Remote Monitoring
- Data Storage and Analysis
- Easy to Understand and Develop
- Cost-Effective Prototype

11. LIMITATIONS AND FUTURE SCOPE

The future scope describes how the Air Pollution Monitoring System can be improved and expanded to provide more reliable measurements, additional features, and better monitoring capabilities.

With advances in sensor technology, IoT, cloud computing, and artificial intelligence, the system can be developed into a more advanced environmental monitoring solution. Future improvements can focus on better sensors, wireless communication, automated alerts, data analysis, and energy-efficient operation.

- **Advanced Sensors:** Use more accurate sensors to measure different air pollutants.
- **IoT Integration:** Connect the system to the internet for real-time air quality monitoring.
- **Mobile Application:** Develop a mobile app to view air quality readings anytime.
- **Cloud Storage:** Store sensor data online for future analysis.
- **Solar Power:** Use solar energy to reduce dependence on conventional power supplies.
- **GPS Integration:** Add GPS to identify the location where pollution levels are measured.
- **Automatic Alerts:** Send SMS or mobile notifications when pollution levels become high.
- **AI-Based Analysis:** Use data analysis techniques to identify pollution patterns and estimate future trends.

12. APPLICATION

- **Urban Areas:** Monitors air pollution in cities and crowded areas.
- **Industrial Areas:** Helps observe air quality around factories and industries.
- **Schools and Colleges:** Creates awareness about air pollution among students.
- **Hospitals:** Helps monitor air quality in and around healthcare facilities.
- **Traffic Areas:** Measures selected pollutants near busy roads and traffic signals.
- **Smart Cities:** Supports IoT-based environmental monitoring systems.
- **Indoor Monitoring:** Observes indoor air quality in homes, offices, and classrooms.

13. CONCLUSION

1. The Air Pollution Monitoring System is designed to monitor air quality using sensors.

2. It measures selected air pollution parameters such as particulate matter and gas-related readings.

3. The microcontroller collects and processes data from the sensors.

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ACKNOWLEDGEMENT

I would like to express my sincere gratitude to our respected Principal and project guide for providing me with the opportunity to complete my micro-project on “Air Pollution Monitoring System.”

I am thankful to my project guide for their valuable guidance, support, and encouragement throughout the project. Their suggestions helped me understand the working principle, components, and implementation of the system.

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BIOGRAPHIES

	Ms. Vaishnavi Telange student of department of electronics and telecommunication engineering at Bhivrabai Sawant Polytechnic, Wagholi, Pune
	Ms. Shravani Shivale student of department of electronics and telecommunication engineering at Bhivrabai Sawant Polytechnic, Wagholi, Pune
	Ms. Vaishnavi Bhor student of department of electronics and telecommunication engineering at Bhivrabai Sawant Polytechnic, Wagholi, Pune
	Ms. Gauri Kamble student of department of electronics and telecommunication engineering at Bhivrabai Sawant Polytechnic, Wagholi, Pune
	Mr. Waghmode.M.N Lecturer of department of electronics and telecommunication engineering at Bhivrabai Sawant Polytechnic, Wagholi, Pune