Air Pollution Monitoring System using IoT

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Abstract—

Air pollution has become one of the most critical environmental issues of the 21st century, significantly affecting human health and the planet's ecosystem. Major pollutants such as carbon dioxide (CO_2), ammonia (NH_3), nitrogen oxides (NO_x), and benzene are continuously being released into the atmosphere due to the rapid growth of industrialization, vehicular traffic, and urbanization. To overcome the limitations of traditional air quality monitoring systems, this research presents a low-cost, IoT-based Air Pollution Monitoring System that provides real-time monitoring, analysis, and alert mechanisms. The proposed system employs a **NodeMCU microcontroller** integrated with an **MQ135 gas sensor** to detect air pollutants and transmit data to the **ThingSpeak cloud platform** using Wi-Fi. The system analyzes the collected data, categorizes air quality into safe or hazardous levels, and triggers a buzzer when pollution crosses threshold limits. This project aims to enhance environmental awareness, enable data-driven decisions, and promote sustainable living.

Keywords— Internet of Things (IoT), Air Quality Monitoring, NodeMCU, ThingSpeak, MQ135 Sensor, Cloud Computing, Environmental IoT.

I. INTRODUCTION

Air pollution has emerged as a major environmental concern worldwide, with urban and industrial regions facing severe air quality degradation. According to the World Health Organization (WHO), more than 90% of the global population breathes air that exceeds safe pollutant limits. The effects of air pollution include respiratory disorders, cardiovascular diseases, reduced life expectancy, and even premature death. Additionally, air pollution plays a significant role in climate change through the greenhouse effect and acid rain formation.**T**raditional air monitoring systems rely on large, expensive, and centralized equipment installed only at specific locations. These systems, although accurate, are limited by cost, maintenance complexity, and lack of mobility. Consequently, real-time air quality data remains inaccessible to the general public, especially in semi-urban and rural areas.

The advancement of the **Internet of Things (IoT)** provides a solution to these challenges. IoT allows physical devices to connect to the internet and exchange data autonomously. In this project, an IoT-enabled system is designed using the **NodeMCU ESP8266 microcontroller** and the **MQ135 gas sensor** to continuously measure gas concentrations. The sensor data is processed and uploaded to the **ThingSpeak cloud** where it is visualized through dynamic graphs and stored for analysis. If the air quality index (AQI) falls below a safe threshold, the system activates a buzzer alarm to notify users instantly.

II. OBJECTIVES AND SCOPE

A. Objectives

1. To design a low-cost, real-time IoT-based air pollution monitoring system.
2. To detect harmful gases such as CO_2, NH_3, and Benzene using the MQ135 sensor.
3. To transmit collected data to the ThingSpeak cloud for analysis and visualization.
4. To alert users instantly using a buzzer when pollution levels exceed safe limits.
5. To promote awareness and provide real-time air quality insights to communities.

B. Scope

The system can be implemented in both indoor and outdoor environments. It is highly scalable and can integrate multiple sensors such as PM2.5, PM10, humidity, and temperature sensors for comprehensive analysis. The project can further be enhanced with GPS integration for location-based data and mobile application development for personalized air quality notifications.

III. LITERATURE REVIEW

Several research studies and prototypes have demonstrated the importance and feasibility of IoT in air quality monitoring.

Parmar et al. (2020) developed a prototype using low-cost semiconductor sensors and Wi-Fi modules to detect gases such as CO, CO_2, SO_2, and NO_2. Their system displayed data through a web server and demonstrated the potential of IoT in low-budget pollution tracking.

Malleswari et al. (2022) focused on integrating IoT devices into smart cities to monitor environmental parameters such as temperature, humidity, and pollutant levels. Their study highlighted the effectiveness of real-time monitoring and cloud data storage in environmental protection.

Pal et al. (2023) presented an Arduino-based air monitoring system capable of detecting harmful gases and displaying PPM levels on an LCD and a web page. The system triggered an alarm when pollution exceeded thresholds, providing a direct local alert mechanism.

Dhingra et al. (2019) proposed a mobile-based IoT air pollution monitoring system, IoT-Mobair, that collected data from distributed sensors and transmitted it to the cloud. The users could access air quality data through an Android application.

Xiaojun et al. (2023) implemented an IoT-based system integrated with neural networks for pollution forecasting. By using historical data, their system could predict air quality trends, enhancing preparedness for pollution management.

These studies form the foundation for the proposed model, which aims to simplify real-time air quality tracking and make it accessible to the public through affordable and scalable IoT technology.

IV. SYSTEM DESIGN AND METHODOLOGY

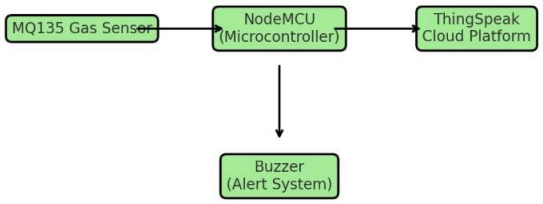
A. System Architecture

The system consists of three main components:

1. **Sensing Unit:** The MQ135 gas sensor detects harmful gases such as CO_2, NH_3, Benzene, and smoke.
2. **Processing Unit:** The NodeMCU microcontroller processes sensor readings and converts analog data into digital form.
3. **Communication and Cloud Unit:** The processed data is transmitted to the ThingSpeak cloud via Wi-Fi for visualization.

B. Block Diagram Description

Input: Air pollutants are sensed by the MQ135 sensor.
Process: NodeMCU reads and converts the analog data into PPM values and compares them with set thresholds.
Output: If pollution exceeds safe limits, a buzzer is activated, and data is displayed on ThingSpeak with real-time graphs.



C. Working Process

1. Power is supplied to NodeMCU and the sensor.
2. The MQ135 sensor senses the gas concentration.
3. The analog output is sent to NodeMCU for conversion.
4. Data is transmitted to the ThingSpeak IoT platform using Wi-Fi.
5. ThingSpeak plots real-time graphs of gas concentration.
6. If the air quality is poor, the NodeMCU triggers a buzzer alarm.

D. Hardware Components

- **NodeMCU ESP8266:** Acts as the main control unit with Wi-Fi connectivity.
- **MQ135 Gas Sensor:** Detects gases like CO_2, NH_3, and Benzene in parts per million.
- **Buzzer:** Provides audible alerts for poor air quality.
- **Power Supply:** 5V DC input for operation.

E. Software Requirements

- **Arduino IDE:** Used for programming NodeMCU.
- **ThingSpeak Cloud:** Used for real-time visualization of sensor data.
- **Proteus:** Used for simulation and testing of circuit design.

V. RESULTS AND DISCUSSION

The system was implemented and tested successfully. The MQ135 sensor was able to detect variations in air quality effectively. The NodeMCU uploaded the readings to the ThingSpeak cloud, where gas concentrations were plotted against time.

A. Observations

- The ThingSpeak dashboard displayed real-time values for CO_2, NH_3, and Benzene levels.
- When the gas concentration exceeded 1000 PPM, the system automatically triggered a buzzer.
- Data updates occurred at regular intervals (every 20 seconds), ensuring accurate monitoring.
- The system maintained reliable connectivity with minimal data loss.

B. Analysis

The real-time monitoring and alert mechanism demonstrated the potential for use in environments such as industries, hospitals, or schools. The system's low cost and easy deployment make it suitable for large-scale environmental monitoring projects. The use of ThingSpeak enables users to track pollution trends over time and make data-driven decisions.

VI. CONCLUSION AND FUTURE SCOPE

This paper presents a practical, low-cost, and efficient **IoT-based Air Pollution Monitoring System** using the NodeMCU ESP8266 and MQ135 sensor. The system successfully measures and reports real-time gas concentration data to the ThingSpeak cloud, categorizes air quality levels, and provides immediate local alerts through a buzzer.

The project contributes to environmental protection by empowering individuals and authorities to monitor and respond to air quality changes effectively. The use of IoT and cloud platforms ensures scalability, affordability, and ease of implementation.

Future Enhancements

1. Integration of additional sensors (PM2.5, PM10) for particulate matter measurement.
2. Incorporation of GPS modules for location-based tracking.
3. Development of a mobile application for user notifications.
4. Implementation of data analytics and machine learning algorithms for predictive air quality forecasting.
5. Integration with government databases for smart city deployment.

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