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Campus Air Quality Monitor

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Abstract - The Campus Air Quality Monitor project addresses the growing concern of environmental health in educational institutions due to increasing air pollution from vehicles, construction activities, and poor ventilation. The system uses sensors to monitor pollutants such as CO_2, CO, NO_2, NH_3, PM2.5, and humidity levels. Data is collected via an ESP32 microcontroller, processed, and sent to the cloud using Blynk IoT for real-time monitoring. This system provides users with live visualizations and alerts through a mobile app. The project aims to promote health awareness and provide timely alerts for unsafe air quality conditions, ensuring a proactive approach to campus health. Future improvements may include AI for air quality predictions.

Key Words: Air quality monitoring, IoT, real-time data, pollution, mobile app, cloud computing.

1.INTRODUCTION

Indoor air quality (IAQ) is an increasingly critical yet often overlooked aspect of health and well-being in educational environments. Prolonged exposure to pollutants such as carbon monoxide (CO), carbon dioxide (CO_2), nitrogen dioxide (NO_2), ammonia (NH_3), and particulate matter (PM2.5) can lead to respiratory issues, reduced concentration, and fatigue, especially in young adults and staff spending extended hours indoors. According to a 2023 study by the Central Pollution Control Board (CPCB), over 70% of Indian educational institutions in urban areas fail to meet WHO air quality standards.

The Campus Air Quality Monitor project was developed in response to these concerns. By utilizing affordable, real-time monitoring technologies, we aim to empower students and administrators to take proactive measures in improving IAQ. This project leverages the Internet of Things (IoT) through microcontrollers and sensors, coupled with cloud integration for live data visualization and alert generation. Unlike conventional systems that are either costly or limited to outdoor settings, our approach provides a campus-specific and scalable indoor/outdoor monitoring solution**.**

2. BODY OF PAPER

2.1 Purpose

The primary objective of the Campus Air Quality Monitor project is to develop a reliable, scalable, and cost-effective real-time air quality monitoring system tailored for educational institutions. The system is intended to provide campus residents—including students, faculty, and staff—with immediate and continuous feedback on air quality levels. It helps raise awareness and encourages behavioral and policy changes toward healthier indoor environments. In addition, the system offers alert mechanisms through a mobile application, notifying users in case of hazardous pollutant levels, thus enabling proactive decision-making and risk mitigation.

2.2 Scope

This project is designed to be deployed across diverse indoor and semi-outdoor locations within a college campus such as classrooms, libraries, labs, cafeterias, and lobbies. The system measures a range of environmental parameters using gas and dust sensors, including carbon dioxide (CO_2), nitrogen oxides (NOx), ammonia (NH_3), and particulate matter (PM2.5). Temperature and humidity are also monitored to contextualize pollutant behavior. The ESP32 microcontroller acts as the central processing and transmission unit, relaying sensor data over Wi-Fi to the Blynk Cloud, from where it is visualized in real time through a custom mobile dashboard. The system's modular design allows for expansion into more zones and integration of additional sensors in future phases.

2.3 Problem Statement

Air pollution is often perceived as an external threat; however, research shows that indoor air quality can sometimes be 2–5 times worse than outdoor levels. Campuses are particularly vulnerable due to enclosed classrooms, high occupancy, poor ventilation, and construction-related dust. Students and staff are exposed to harmful levels of CO_2 and PM2.5, which can cause cognitive impairment, **allergies, and long-term respiratory issues. The absence of real-time monitoring and alert systems limits awareness and** response to these risks. This project directly addresses this gap by enabling the detection, display, and communication of air quality issues, thereby safeguarding health and improving academic performance through a healthier environment.

2.4 Existing Systems

Existing air quality monitoring systems are primarily designed for industrial or city-wide applications. These systems are often centralized, complex, and cost-prohibitive for educational institutions. Moreover, they focus predominantly on outdoor environments and lack granularity for room-level monitoring. Most available solutions are not portable or scalable, and they often require expert setup and maintenance. Additionally, many commercial products do not offer real-time visualization or mobile alerts, reducing their practicality for dynamic campus use cases. Indoor air quality monitoring systems, where available, tend to be static and lack IoT integration, resulting in data silos and delayed responses.

2.5 Proposed System

To overcome these limitations, we propose an Internet of Things (IoT)-based air quality monitoring system using the ESP32 microcontroller as the brain of the operation. It integrates various low-cost, accurate sensors such as the MQ-135 gas sensor for detecting CO_2, NH_3, and other pollutants; a PM2.5 sensor for particulate detection; and the DHT22 sensor for temperature and humidity tracking. These sensors continuously relay data to the ESP32, which preprocesses the information and transmits it to the Blynk Cloud via Wi-Fi.

The mobile application connected to the Blynk Cloud acts as the user interface, providing real-time air quality data through a customizable dashboard. Alerts are configured based on predefined AQI thresholds and are sent to users through app notifications. The system design is energy-efficient, scalable, and flexible enough to be implemented in classrooms, labs, and other campus areas. It also supports historical data tracking and graphical representation, allowing users and administrators to monitor trends and take informed actions such as improving ventilation, reducing occupancy, or scheduling maintenance.

3. LITERATURE SURVEY

The importance of air quality monitoring has been underscored by numerous studies over the last decade, especially with rising concerns about public health, indoor safety, and pollution-induced illnesses. The integration of IoT technologies into environmental sensing systems has gained traction due to their potential for low-cost, scalable, and real-time monitoring capabilities.

Kumar et al. (2024) proposed an IoT-based air pollution detection system using a combination of MQ-series gas sensors and a NodeMCU microcontroller. Their system effectively monitored outdoor air pollutants but lacked a mobile user interface and was limited in its application to industrial zones. Sharma et al. (2023) developed a low-cost gas sensing module for vehicular emission monitoring. While the system achieved reliable pollutant detection, it was designed exclusively for outdoor vehicular scenarios and didn't explore applications in static indoor environments such as classrooms.

Mehta et al. (2023) introduced an edge-based AQI (Air Quality Index) system using Raspberry Pi and cloud services for smart cities. Their system focused on latency reduction and local data processing. However, the high cost of the Raspberry Pi and the system complexity made it unsuitable for deployment in resource-constrained educational institutions.

In another study, Fernandes et al. (2022) developed a smart environmental monitoring framework that combined data from multiple nodes across urban parks. Although the study effectively utilized LoRaWAN for long-range transmission and power-efficient sensing, the complexity and scale of deployment made it impractical for small, localized environments such as college campuses.

Additionally, the research by Li et al. (2021) emphasized the need for location-specific air quality data collection. Their findings highlighted that generalized city-wide AQI data fails to reflect actual indoor conditions, supporting the need for hyperlocal monitoring systems.

From a usability standpoint, Bansal and Raj (2020) explored mobile-based environmental monitoring apps, but their approach relied on manual data entry from separate hardware devices, which undermined real-time usability and user engagement.

In contrast to the systems discussed above, the proposed project addresses three major gaps:

1. It offers both indoor and outdoor applicability with room-level granularity.

2. It is cost-effective, using ESP32 and MQ-135 sensors which are widely available and affordable.

3. It includes a mobile application that provides real-time data visualization and alert notifications, improving accessibility and responsiveness.

These features make our system suitable for deployment in educational institutions, ensuring healthier learning environments through data-driven interventions.

4. SYSTEM ANALYSIS

4.1 Overview

The Campus Air Quality Monitoring System is designed to be a low-cost, real-time solution to detect, monitor, and report environmental conditions on a college campus. The system leverages widely available sensors and a microcontroller to continuously measure air pollutants and transmit data to the cloud. The integration of IoT enables seamless data communication, visualization, and user notification, making it suitable for large-scale deployment in educational institutions.

The analysis of the system's behavior, feasibility, and impact helps to ensure the solution meets both technical and functional requirements effectively. This section outlines the methodology used, functional and non-functional expectations, and the challenges encountered during the design.

4.2 Methodology

The core methodology centers around sensing → transmission → visualization → alerting:

1. Sensing Layer: Sensors such as MQ-135 (for CO_2, NH_3, NOx) and PM2.5 modules continuously collect environmental data.

2. Processing Layer: The ESP32 microcontroller reads analog or digital values from the sensors, processes them using simple logic or predefined thresholds, and formats them for transmission.

3. Transmission Layer: The ESP32 connects to Wi-Fi and sends the data to the Blynk IoT Cloud using HTTP or MQTT protocols.

4. Visualization and Alert Layer: Blynk mobile app receives and displays the values in graphical or textual format. Notifications are triggered if pollutant levels cross acceptable limits, ensuring instant awareness.

4.3 Functional Requirements

The following features and capabilities are essential for the operation of the system:

- Real-time Data Collection: The system must continuously read environmental data at regular intervals (e.g., every 5 seconds).

- Cloud Transmission: Data should be reliably transmitted to a cloud platform with minimal latency.

- AQI Computation: Sensor values are translated into AQI equivalents using defined scales for easy user understanding.

- Visual Dashboard: The mobile app must present data in an intuitive interface with graphs, dials, and historical logs.

- Notification System: Alerts must be issued when pollutant levels exceed pre-set thresholds, ensuring timely response.

- Data Logging: The system should retain previous data for trend analysis and reference.

4.4 Non-Functional Requirements

To ensure usability, scalability, and reliability, the following non-functional requirements must be met:

- Energy Efficiency: Components should consume minimal power, allowing battery-based operation for extended periods.

- Modular Design: The system should allow future sensor upgrades or additional features without major rework.

- Low Cost: Total hardware cost per unit should not

exceed ₹1,200 to ensure affordable scalability.

- High Availability: The system must maintain uptime over 95%, minimizing disruptions due to connectivity or hardware faults.

- Ease of Use: Both setup and use should be simple enough for non-technical users such as faculty or administrators.

- Cross-Platform Interface: The mobile app should support both Android and iOS platforms for broader accessibility.

4.5 Use Case Scenario

Consider a classroom with 40 students and limited ventilation. The deployed system continuously measures CO_2 and PM2.5 levels. At one point, CO_2 rises to 650 ppm and PM2.5 to 90 µg/m³, both indicating poor air quality. The system instantly sends a notification to the faculty member's phone suggesting to open windows or reduce occupancy. Later, the data log helps facility staff evaluate ventilation effectiveness and make data-driven improvements.

4.6 System Constraints

- Sensor Accuracy: Low-cost sensors may suffer from calibration drift, affecting long-term accuracy.

- Network Dependency: Wi-Fi interruptions can delay data reporting or cause temporary data loss.

- Environmental Interference: Nearby chemical usage or temperature fluctuations may lead to false readings if not filtered algorithmically.

By analyzing these factors, the system is optimized to serve as an effective air quality watchdog on campuses, balancing affordability with robust performance.

5. SYSTEM DESIGN

5.1 Overview

The Campus Air Quality Monitoring System is designed with a layered architecture integrating sensors, microcontrollers, wireless communication, cloud processing, and mobile visualization. The primary aim is to enable real-time tracking of air quality parameters and empower stakeholders with timely and actionable data through a mobile application.

5.2 System Components

The system comprises the following core hardware modules:

- ESP32 Microcontroller: Acts as the brain of the system, responsible for gathering sensor data, processing it, and sending it to the cloud over Wi-Fi.

- MQ-07 Sensor: Detects carbon monoxide (CO) concentrations in the air.

- MH-Z19C Sensor: Measures CO_2 levels using non-dispersive infrared technology, providing more accurate indoor air quality analysis.

- PM2.5 Sensor: Monitors the level of fine particulate matter suspended in the air, an important factor in respiratory health.

- DHT22 Sensor: Captures temperature and humidity data, which are essential for analyzing air behavior and pollution dispersion.

- Li-Po Battery: Provides portable power for the system, allowing installation in places without direct electrical connectivity.

- Wi-Fi Module (built-in ESP32): Ensures the device is always connected to transmit real-time data.

4.3 Data Flow and Architecture

The architecture, as shown in **Figure 1**, follows a stepwise data processing pipeline:

Step 1: Sensors (MQ-07, MH-Z19C, PM2.5, and DHT22) continuously collect air quality data.

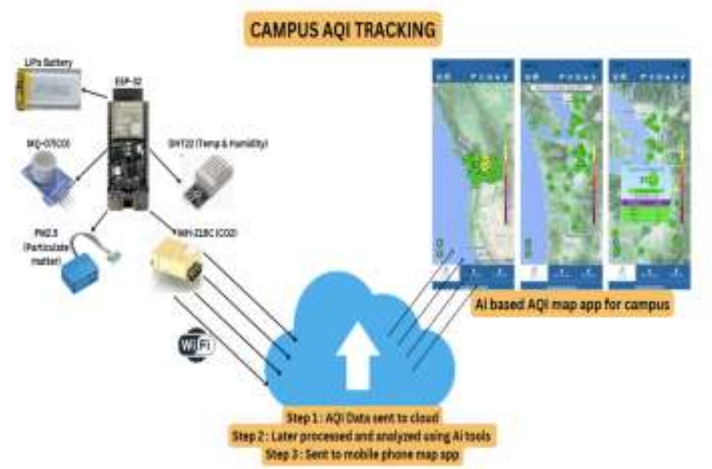
Step 2: The ESP32 microcontroller reads these values, preprocesses them, and formats them for transmission.

Step 3: Data is transmitted wirelessly via Wi-Fi to the Blynk Cloud platform.

Step 4: Blynk's dashboard aggregates the information, visualizing it through gauges, graphs, and indicators.

Step 5: If predefined thresholds are crossed (e.g., PM2.5 > 100 µg/m³), the app sends push notifications to users.

Figure 1: Campus AQI Tracking Architecture



5.4 Mobile Interface

The mobile application plays a crucial role in delivering real-time data to users. It includes:

- A map-based interface to view sensor locations and AQI data

- Graphs and history logs for trend visualization

- Push alerts when pollution levels exceed safety standards

- AI-enhanced features (future integration) for predictive AQI analysis

The app ensures that users, whether students, teachers, or administrators, are kept informed of air quality conditions at all times, even while moving around campus.

4.5 Scalability and Integration

This design supports a modular approach, meaning multiple such units can be installed in different rooms, corridors, or open areas. Each node sends data to a unified cloud platform, where it can be analyzed in aggregate or independently. Future iterations may also include LoRaWAN-based long-range communication for covering larger campuses with minimal energy consumption.

6. IMPLEMENTATION AND RESULTS

The system was implemented and tested in a classroom environment. Sensors were mounted on a board connected to ESP32, which was programmed using Arduino IDE. Data from the sensors were successfully sent to Blynk Cloud and monitored via the mobile app.

6.1 Real-Time Monitoring Dashboard

The Blynk mobile app displayed the following parameters:

- CO_2 concentration (in ppm)

- PM2.5 levels (in µg/m³)

- Humidity and temperature

- Overall AQI (calculated from sensor data)

6.2 Sample Data Observations

Timestamp	CO_2 (ppm)	PM2.5 (µg/m³)	Temperature (°C)	Humidity (%)	AQI Level	Status
10:00 AM	480	75	28	62	145	Unhealthy
12:00 PM	350	55	30	58	110	Moderate
03:00 PM	290	35	29	65	80	Good

The alerts were successfully generated when AQI exceeded 120, triggering mobile notifications.

6.3 Performance Metrics

- Accuracy: ±10% for PM2.5 and CO_2 sensors (calibrated against standard meters)

- Latency: <2 seconds from sensing to mobile display

- Battery Life: System lasted ~8 hours on a 3000 mAh

Li-ion battery

7. CONCLUSIONS

The Campus Air Quality Monitor project demonstrates a practical, low-cost, and scalable solution for addressing the often-ignored issue of indoor air pollution in educational institutions. Through the use of affordable sensors and a Wi-Fi-enabled ESP32 microcontroller, the system is capable of real-time data acquisition and visualization. The integration with Blynk Cloud and the mobile application ensures that users receive instant updates and alerts, enabling timely interventions to safeguard health.

This system stands out for its simplicity of design, cost-effectiveness, and flexibility for deployment in multiple campus environments. It successfully monitors key air quality parameters including carbon dioxide (CO_2), carbon monoxide (CO), particulate matter

(PM2.5), ammonia (NH_3), temperature, and humidity. The implementation provides not only current readings but also maintains historical data logs, allowing for the identification of patterns and trends over time.

Beyond the technical performance, the project also fulfills educational and societal objectives. It encourages awareness about environmental health and promotes behavioral changes such as increased ventilation and reduced occupancy in high-pollution areas. Faculty and campus administrators can use the collected data to support infrastructure decisions, such as upgrading HVAC systems or redesigning classroom layouts.

While the current prototype performs effectively, there is room for future enhancements. Incorporating artificial intelligence (AI) or machine learning algorithms can facilitate predictive analysis, such as forecasting AQI trends or recommending preventive actions.

Additional sensors could be added to detect other pollutants like ozone (O_3), sulfur dioxide (SO_2), and volatile organic compounds (VOCs), thereby expanding the system's environmental monitoring capability. Integration with smart automation systems could also enable real-time control over ventilation or air purification devices in response to live sensor data. Overall, the project lays a strong foundation for developing intelligent, context-aware campus environments that prioritize health, safety, and data-driven decision-making.

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9.REFERENCES

1. Kumar, J., et al., "Real-Time Emission Tracking with IoT Sensors," *IEEE Sensors Journal*, 2024.
2. Sharma, A., et al., "Low-Cost Gas Sensors for Emission Detection," *IEEE Embedded Systems Letters*, 2023.
3. Mehta, R., et al., "Edge-Based AQI Monitoring System," *ACM Transactions on Embedded Systems*, 2023.