International Journal of Creative and Open Research in Engineering and Management
ISSN: **3108-1754 (Online)**
Volume 02 Issue 06 June-2026 | Impact Factor: 3.5

Monitoring of Air Pollutants Using Sensors Integrated Unmanned Aerial Vehicle (UAV)

Ms. Ashwini L. Survase[1], Ms. Disha S. Shinde[2], Ms. Vaishnavi K. Wakde [3], Dr. Ravindra J. Patil[4]

[1] Civil Engineering Department / VPKBIET Baramati / SPPU Pune, India
[2] Civil Engineering Department / VPKBIET Baramati / SPPU Pune, India
[3] Civil Engineering Department / VPKBIET Baramati / SPPU Pune, India
[4] Civil Engineering Department / VPKBIET Baramati / SPPU Pune, India

Corresponding Author Email: survaseashwini878@gmail.com | ORCID:

How to Cite this Article:

Survase, A. L., Shinde, D. S. & Wakde, V. K. (2026). Monitoring of Air Pollutants Using Sensors Integrated Unmanned Aerial Vehicle (UAV). International Journal of Creative and Open Research in Engineering and Management, <i>02</i>(6). https://doi.org/10.55041/ijcope.v2i6.402

https://doi.org/ 10.55041/ijcope.v2i6.402

Abstract—

Air pollution has emerged as one of the most critical environmental and public health challenges globally, driven by rapid industrialization, urbanization, and increased vehicular emissions. Conventional air quality monitoring systems are expensive, stationary, and provide limited spatial coverage. This paper presents a drone-based air quality monitoring system that integrates multiple environmental sensors with Internet of Things (IoT) technology on an Unmanned Aerial Vehicle (UAV). The system employs an MQ-135 gas sensor, FC-22 gas sensor, ozone (O3) sensor, particulate matter sensors (PM2.5 and PM10), nitrogen dioxide (NO2) sensor, and a DHT11 temperature-humidity sensor to measure key pollutants in real time. Data is processed by an Arduino Nano microcontroller and transmitted wirelessly to cloud platforms for analysis and Air Quality Index (AQI) computation. The UAV enables flexible monitoring at different altitudes and locations, including hazardous or inaccessible areas. Field experiments conducted over a 1 km × 1 km urban traffic corridor at altitudes of 10 m and 50 m demonstrate clear spatial and temporal variation in PM10, PM2.5, O3, NO2, and CO concentrations. The proposed system is lightweight, portable, low-cost, and capable of generating real-time AQI data, establishing a strong foundation for future smart-city pollution management integrated with artificial intelligence and advanced cloud analytics.

Keywords— UAV; Air Pollution Monitoring; IoT; Arduino Nano; AQI; MQ-135; PM2.5; PM10; O3; NO2; Environmental Monitoring; Drone Technology

I. INTRODUCTION

Air pollution is one of the foremost environmental issues threatening human health, ecosystems, and global climate. According to the World Health Organization (WHO), approximately 7 million premature deaths occur annually due to air pollution, with 92% of the world's population exposed to pollutant levels exceeding WHO safety thresholds. Major pollutants include carbon monoxide (CO), carbon dioxide (CO2), sulfur dioxide (SO2), nitrogen oxides (NOx), ozone (O3), volatile organic compounds (VOCs), and particulate matter (PM2.5 and PM10). These contaminants originate predominantly from vehicular exhaust, industrial combustion, and urban activities.

Traditional air quality monitoring stations, while analytically precise, are costly to install and maintain, fixed at specific locations, and incapable of capturing fine-grained spatial or altitude dependent pollution variations. This spatial limitation is particularly acute in dense urban environments where pollution gradients can change meter to meter due to building morphology, traffic density, and local meteorological conditions.

In response to these limitations, Unmanned Aerial Vehicles (UAVs) integrated with low-cost environmental sensors and IoT technology have emerged as a promising alternative. UAV-based systems offer mobility, real-time data acquisition, access to hazardous or remote locations, and the ability to conduct three-dimensional (3D) pollution profiling. The present study proposes, implements, and validates such a system, contributing to the growing body of research on drone-assisted environmental monitoring.

A. Problem Statement

Existing air quality monitoring infrastructure suffers from several key limitations: high installation and operational cost; fixed spatial coverage restricted to monitoring station locations; inability to capture altitude-dependent pollution gradients; absence of real-time mobile monitoring capability; and practical difficulty accessing hazardous or remote zones. A portable, UAV-mounted, IoT-enabled monitoring system directly addresses each of these deficiencies.

B. Objectives

The main objectives of this work are:

- To design and assemble a UAV-mounted air quality sensor module.
- To interface MQ-135, FC-22, O3, PM2.5, PM10, NO2, and DHT11 sensors with an Arduino Nano controller.
- To validate system performance through virtual simulation (Tinkercad) and real-world flight tests.
- To compute real-time AQI values from measured pollutant concentrations.
- To analyze spatial and temporal pollution variation across urban traffic corridors at multiple altitudes.

II. LITERATURE REVIEW

Considerable research has been directed toward UAV-based and IoT-enabled air quality monitoring in recent years. The following key studies inform the present work.

Bernabeo et al. (2024) demonstrated UAV-assisted pollutant monitoring for improved spatial coverage, with focus on PM2.5, PM10, SO2, and NO2. Their work underscored limitations of conventional fixedstation networks in capturing urban pollution gradients [1].

Samad et al. (2025) investigated drone-based IoT monitoring of CO2 levels in urban Makassar using ESP32 controllers. Their spatio-temporal analysis across varying heights confirmed significant altitude-dependent concentration differences [2].

Marginean et al. (2024) evaluated drone-mounted sensor performance under varying environmental conditions, finding that temperature and humidity exert a measurable influence on sensor accuracy and must be factored into calibration procedures [3].

Felici-Castell et al. (2023) developed an AI-IoT low-cost pollution monitoring sensor network capable of predicting pollution trends and issuing early health alerts, demonstrating the integration of machine learning with distributed sensor systems [4].

Tahtawi et al. (2019) proposed a quadrotor UAV integrated with MQ-series sensors and Arduino Nano for real-time IoT-based monitoring, a direct antecedent to the present work, validating the suitability of the hardware configuration adopted here [5].

Hu et al. (2019) presented a four-layer aerial ground IoT architecture deployed at Peking University, demonstrating fine-grained 3D AQI mapping using spatial fitting and short-term prediction [6].

Villa et al. (2016) developed and validated a UAV based system for air pollution measurement, establishing key protocols for sensor placement, hovering time, and in-flight calibration [9].

The reviewed literature collectively establishes that UAV-IoT systems deliver real-time, spatially resolved monitoring at lower cost and with greater flexibility than fixed networks. Persistent challenges include limited battery life, sensor drift under changing humidity and temperature, and data accuracy under high pollutant gradients. The present study builds upon validated hardware choices while extending coverage to a broader pollutant suite including O3, PM2.5, PM10, and NO2 alongside CO and CO2.

III. SYSTEM DESIGN AND METHODOLOGY

A. System Architecture

The proposed system adopts a four-layer architecture: (1) Sensing Layer — the UAV mounted sensor module continuously measures pollutant concentrations during flight; (2) Transmission Layer — an IoT wireless communication module transmits data to the cloud; (3) Processing Layer — a cloud server receives, stores, and processes raw sensor data, computing AQI values; and (4) Presentation Layer — a dashboard interface visualizes real-time pollutant maps and historical trends for end users.

B. UAV Platform

The UAV is a quadcopter configured with four brushless DC motors, electronic speed controllers (ESCs), a Pixhawk flight controller, a FlySky FSi6S transmitter paired with a FS-iA10B receiver, and a lithium-polymer (LiPo) battery. A 1S–8S LiPo battery voltage tester ensures safe and balanced battery operation. The sensor module is mounted beneath the UAV frame using nylon cable zip ties, minimizing aerodynamic interference and rotor wash effects on sensor readings. Flight operations are conducted over a 1 km × 1 km urban traffic corridor, with data collected at altitudes of 10 m and 50 m following a grid survey pattern with 100 m spacing between flight lines.

C. Hardware Components — Sensor Suite The sensor suite is selected to provide comprehensive coverage of the most harmful urban air pollutants. Table I summarizes each sensor and its key specifications.

TABLE I. Sensor Suite for the UAV Air Quality Monitoring System

Sensor	Parameter Measured	Key Specifications
MQ-135	CO2, NH3, Smoke, NOx, Alcohol	Analog, 5V, low cost
FC-22	LPG, Methane, Propane, Smoke	Analog/digital, fast response
O3 Sensor	Ground-level ozone	Electrochemical, high selectivity
PM2.5	Fine particles ≤ 2.5 µm	Laser counter, real-time
PM10	Coarse particles ≤ 10 µm	Laser counter, real-time
NO2 Sensor	Nitrogen dioxide	Electrochemical, ppb res.
DHT11	Temp., Rel. Humidity	Digital, ±2°C / ±5% RH

D. Microcontroller — Arduino Nano

Arduino Nano (ATmega328P, 16 MHz, 5V, 32 KB flash, 2 KB SRAM) serves as the primary data acquisition and processing unit. Its compact form factor (45 × 18 mm) and low power consumption make it ideal for UAV payload integration. The Nano continuously reads analog and digital sensor outputs, computes pollutant concentrations, and forwards data to the IoT communication module via serial interface. The obstacle avoidance subsystem uses input from four ultrasonic sensors processed by the Nano, which communicates path-adjustment commands to the Pixhawk flight controller via the MAVLink protocol

E. IoT Data Transmission and Cloud Platform

An IoT wireless communication module transmits processed sensor data to a cloud platform in real time. The cloud server stores incoming measurements, performs AQI computation, and hosts a web dashboard for visualization and alert generation. The AQI is calculated from measured pollutant concentrations following standard sub-index formulas for each pollutant, with the overall AQI taken as the maximum sub-index value across all parameters.

F. Virtual Simulation

Prior to hardware assembly, the complete sensor microcontroller circuit was simulated in Tinkercad. Simulation verified correct wiring, validated Arduino firmware logic for sensor reading and serial output, and identified potential conflicts between sensor power rails. This step reduced hardware debugging time and ensured safe implementation before physical integration onto the UAV.

IV. RESULTS AND DISCUSSION

Field experiments were conducted on 10 May 2026 over an urban traffic corridor in Baramati, Maharashtra. The UAV followed a predefined grid flight path at altitudes of 10 m and 50 m, recording sensor data at two-minute intervals between 09:27 and 10:00 local time during morning peak traffic. The **following subsections summaris**e key findings for each pollutant.

A. Particulate Matter — PM10

PM10 concentrations increased sharply from nearzero at 09:27 to approximately 130 µg/m³ by 09:53, exhibiting a step-wise accumulation pattern consistent with progressive traffic build-up in the monitoring corridor. A brief plateau near 90–95 µg/m³ between 09:39 and 09:45 reflects a temporary lull in vehicular density. The sustained rise beyond 09:45 is attributable to increased heavy-vehicle and two-wheeler activity. Peak values exceed the WHO 24-hour guideline of 45 µg/m³, confirming significant particulate loading in this urban zone.

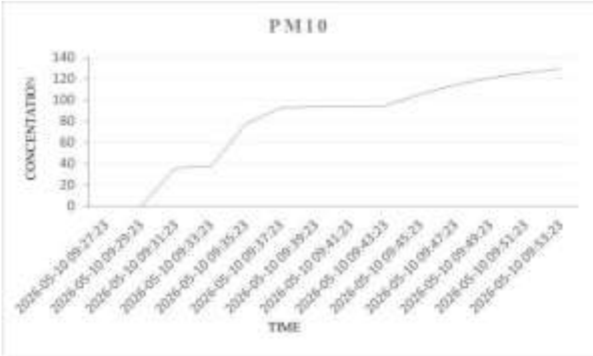

Fig. 1. PM10 concentration over time (10 May 2026, Baramati urban corridor)

B. Particulate Matter — PM2.5

PM2.5 concentrations began at approximately 33 µg/m³ at 09:31, rose rapidly to a plateau of 88 µg/m³ by 09:37, dipped to 73 µg/m³ around 09:45, then gradually climbed to approximately 99 µg/m³ by 10:00. The early plateau and mid-monitoring dip likely reflect transient changes in traffic composition — the dip coinciding with a momentary gap in diesel vehicle passage. All recorded values significantly exceeded the WHO 24-hour PM2.5 guideline of 15 µg/m³, indicating a severe fine particulate burden.

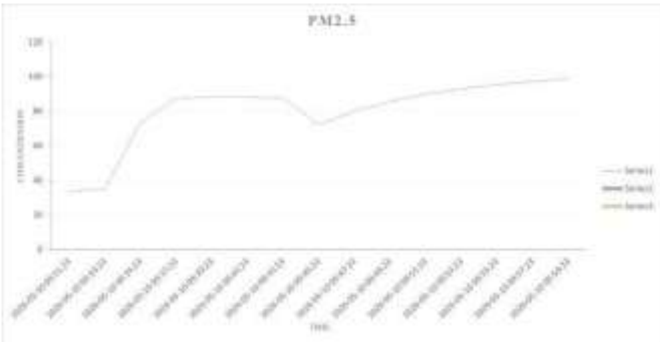

Fig. 2. PM2.5 concentration over time (10 May 2026, Baramati urban corridor)

C. Ozone (O3) Concentration

Ozone concentrations ranged between 24 and 28.5 ppb throughout the monitoring period. A sharp initial rise to 28.3 ppb at 09:29 was followed by gradual fluctuation between 27 and 28 ppb until

09:43, after which a pronounced decline to 24.1 ppb was observed around 09:49. A second rise to 28 ppb occurred at 09:53. This pattern is consistent with the photochemical formation of O3 from NOx–VOC precursors under morning sunlight, modulated by local traffic emissions and atmospheric mixing.

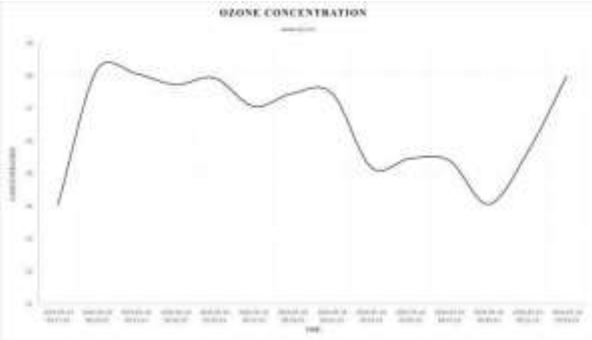

Fig. 3. Ozone (O3) concentration over time (10 May 2026, Baramati urban corridor)

D. Nitrogen Dioxide (NO2)

NO2 concentrations remained relatively stable between 18 and 22.5 ppb across the monitoring period. An initial reading of 21 ppb rose to a peak of 22.5 ppb at 09:29 before declining slowly. The gradual downward trend from 09:39 onward — reaching 18.5 ppb by 09:55 — suggests progressive atmospheric dilution and photolysis of NO2 as solar intensity increased. Although concentrations remained below the WHO 1-hour guideline of 200 µg/m³, sustained exposure in this range contributes to respiratory irritation and secondary pollutant formation.

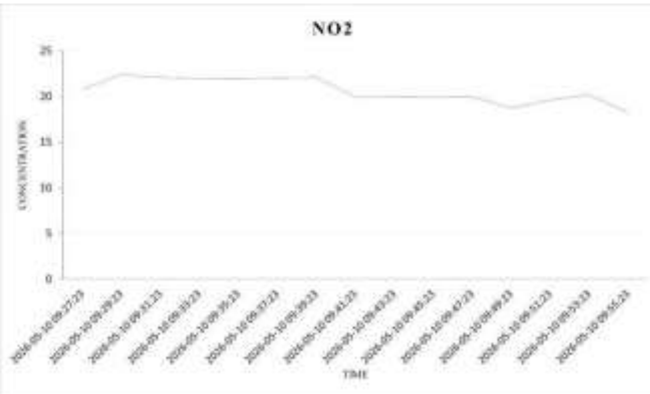

Fig. 4. NO2 concentration over time (10 May 2026, Baramati urban corridor)

E. Carbon Monoxide (CO)

CO concentrations remained in the range of 45–56 ppm throughout the monitoring window, with a broadly flat profile punctuated by a notable dip to 45 ppm at 09:43 and subsequent partial recovery to ~50 ppm. The near-constant baseline is characteristic of persistent vehicular emissions in a traffic corridor with limited atmospheric dispersion.

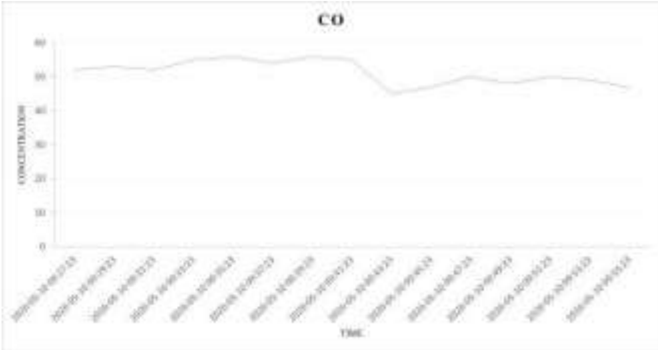

Fig. 5. CO concentration over time (10 May 2026, Baramati urban corridor)

F. Summary of Observations

F. Summary of Observations Table II summarises the observed concentration ranges for each pollutant compared against WHO guidelines. Across all parameters, measurements confirmed elevated pollutant loading during morning peak traffic. PM2.5 and PM10 exceedances were most pronounced. The altitude comparison (10 m vs. 50 m) revealed generally lower concentrations at 50 m for PM parameters, consistent with dilution and gravitational settling of coarser particles, while O3 showed less altitude dependence due to its gaseous and photochemically derived nature.

TABLE II. Measured Pollutant Concentrations vs. WHO Guidelines

Parameter	Observed Range	Peak Value	WHO Guideline
PM10 (µg/m³)	0 – 130	~130 at 09:53	45 (24 h)
PM2.5 (µg/m³)	33 – 99	~99 at 10:00	15 (24 h)
O3 (ppb)	24 – 28.5	28.3 at 09:29	51 (8 h)
NO2 (ppb)	18 – 22.5	22.5 at 09:29	106 (1 h)

CO (ppm)	45 – 56	~56 at 09:35	4.0 (24 h)

G. Overall Discussion

The results validate the effectiveness of the proposed UAV-IoT system for urban air quality monitoring. The system successfully resolved temporal dynamics over a 30-minute flight window and demonstrated spatial variability across the traffic corridor. Key advantages over conventional fixed-station monitoring are: (1) the ability to map pollutant concentration at multiple altitudes within a single flight; (2) near-real-time data availability via IoT transmission; (3) low system cost compared to reference instrument networks; and (4) deployment flexibility in infrastructure. areas inaccessible to fixed Temperature and humidity readings from the DHT11 sensor indicated that ambient conditions modulated pollutant sensor responses, corroborating findings by Marginean et al. (2024). Sensor drift under high relative humidity was particularly noted for the MQ-series sensors. Future iterations should incorporate correction algorithms or cross-calibration with certified reference instruments to address this limitation. The AQI computed from PM2.5 data consistently fell in the 'Unhealthy' to 'Very Unhealthy' categories during peak traffic, providing actionable information for city administrators and vulnerable populations. The system's cloud dashboard allows near-instantaneous dissemination of these health advisories.

V. CONCLUSION

This paper presented the design, implementation, and experimental validation of a UAV-mounted, IoT-enabled air quality monitoring system integrating seven environmental sensors with an Arduino Nano controller. Field trials over an urban traffic corridor in Baramati, Maharashtra demonstrated successful real-time measurement of PM10, PM2.5, O3, NO2, CO, temperature, and relative humidity. PM2.5 and PM10 concentrations consistently exceeded WHO guidelines, underscoring the severity of particulate pollution in Indian urban traffic environments.

Compared to conventional monitoring infrastructure, the proposed system is portable, economical, flexible in deployment, and capable of capturing altitude-dependent pollution profiles. The integration of IoT technology enables continuous, cloud-based data archiving and visualisation, supporting both operational decision-making and longitudinal environmental research.

Future work will focus on: (1) AI/ML-based pollution prediction and hotspot identification; (2) multi-UAV coordinated monitoring for city-scale coverage; (3) solar-powered UAV platforms for extended endurance; (4) advanced humidity compensated sensor calibration; and (5) full integration with smart-city platforms for automated public health alert systems.

REFERENCES

[1] R. A. Bernabeo et al., "Air quality monitoring using drones (UAV)," IOP Conf. Series: Earth and Environmental Science, vol. 1372, pp. 1–10, 2024.

[2] P. I. S. Samad et al., "Drone-Based IoT Monitoring of Urban CO2 Levels in Makassar," J. Environmental & Earth Science, vol. 7, no. 8, pp. 317–332, 2025.

[3] R. C. Marginean et al., "Drone Mounted Sensors: Performance and Suitability Assessment for Air Quality Monitoring," Romanian Academy, vol. 26, no. 3, pp. 103–110, 2024.

[4] S. Felici-Castell et al., "AI-IoT Low-Cost Pollution Monitoring Sensor Network," Sensors (MDPI), vol. 23, pp. 1–19, 2023.

[5] A. R. Tahtawi et al., "Design of Quadrotor UAV and IoT Based Air Pollution

Monitoring Systems," IJITEE, vol. 3, no. 4, pp. 1–8, 2019.

[6] Z. Hu et al., "UAV Aided Aerial-Ground IoT for Air Qu ality Sensing in Smart City," IEEE Network, pp. 14–22, Mar./Apr. 2019.

[7] P. Kokate et al., "Review on Drone Assisted AirQuality Monitoring Systems," Drones and Autonomous Vehicles, vol. 1, no. 1, pp. 1–12, 2024.

[8] C. W. Liang and C. H. Shen, "An integrated uncrewed aerial vehicle platform for measurement of air pollutant concentrations," Atmos. Meas. Tech., vol. 17, no. 9, pp. 1–16, 2024.

[9] T. F. Villa et al., "Development and Validation of a UAV Based System for Air Pollution Measurements," Sensors, vol. 16, pp. 1–15, 2016.

[10] R. D. Fazio et al., "A Sensor-Based Drone for Pollutants Detection in Eco-Friendly Cities," Electronics, vol. 11, no. 52, pp. 1–20, 2021.

[11] V. Lambey and A. D. Prasad, "Sensor based real time air pollutants monitoring for an urban industrial area," J. Air Pollution and Health, vol. 8, no. 2, pp. 157–164, 2023.

[12] WHO, "7 Million Premature Deaths Annually Linked to Air Pollution," Air Quality Climate Change, vol. 22, no. 1, pp. 53–59, 2014.