Monitoring Secondary Pollutants Near Pharmaceutical Industries During Diwali

Team Venky Chicken

AV Aditya (2024111031), Nandini Chakaravarthy (2024111034), Mehrish Khan (2024111014), Mohit Nallagatla (2024101101)

ESW Project — IIIT Hyderabad

November 8, 2025

Contents

1 Abstract **3**

2 Introduction **3**

2.1 Objectives . . . 3

3 Methodology **3**

3.1 Study Area . . . 3

3.2 Sensors Used . . . 3

3.3 Data Collection . . . 4

3.3.1 Sampling Frequency . . . 4

3.3.2 Quality Control . . . 4

4 Results and Discussion **4**

4.1 Overview . . . 4

4.2 PM2.5 Concentrations . . . 4

4.3 PM10 Concentrations . . . 5

4.4 Volatile Organic Compounds (eVOC) . . . 5

4.5 Equivalent CO_2 (eCO_2) . . . 5

4.6 Meteorological Conditions . . . 6

4.6.1 Temperature . . . 6

4.6.2 Humidity . . . 6

4.7 Comparison with Air Quality Standards . . . 6

4.8 Error Sources . . . 7

5 Graphical Representation of the Results **7**

6 In-Depth Analysis **9**

7 Summary **11**

8 Relevant Links and Resources **11**

9 Conclusion **11**

10 Acknowledgements **12**

11 References **12**

1 Abstract

This study analyzes the environmental impact of firecracker emissions during Diwali by quantifying changes in pollutant concentrations before, during, and after the festival period. While the core focus of our larger project is air quality monitoring near pharmaceutical industries, this Diwali-based study serves as a stress test and validation scenario for our system. The report presents temporal pollutant trends, statistical summaries, and exceedances of WHO and Indian NAAQS standards, revealing the severe deterioration of air quality due to short-term yet intense emissions.

2 Introduction

Air pollution remains a major health and environmental concern, especially during festivals such as Diwali, when large-scale firecracker combustion leads to a sudden and severe rise in particulate and gaseous pollutants. Pollutants like PM2.5, PM10, NOx, SO_2, and volatile organics contribute to respiratory distress, reduced visibility, and long-term climatic effects. This study, conducted as part of our ESW project on industrial emissions, examines the Diwali pollution episode as a real-world test of our sensor network and data analytics framework.

2.1 Objectives

- Measure pollutant surges during Diwali festivities.
- Compare PM, eVOC, and eCO_2 variations before and after the event.
- Correlate air quality parameters with meteorological factors.

3 Methodology

3.1 Study Area

The experiment took place near **Kokapet, Hyderabad** (17.3968° N, 78.3348° E), approximately 600–640 meters above sea level. The sensors were installed on the seventh floor (22–27 meters AGL), providing an unobstructed exposure to ambient air. The site was chosen for its proximity to industrial activity and ease of access for maintenance and data retrieval.

3.2 Sensors Used

- PM2.5 and PM10 sensors
- SGP30 for eCO_2 and TVOC
- AHT10 for temperature and humidity
- Data logger with Wi-Fi module

3.3 Data Collection

Data collection occurred from **October 20, 2025, 05:46:52 UTC (11:16:52 IST)** to **October 22, 2025, 15:57:23 UTC (21:27:52 IST)** , a 58-hour continuous dataset covering pre-, during-, and post-Diwali phases.

3.3.1 Sampling Frequency

- 20 seconds during high-activity hours
- 60 seconds during low-activity hours
- Total data points collected: 1,527

3.3.2 Quality Control

1. Pre-deployment calibration in controlled environment (8-hour run)
2. Regular anomaly filtering and timestamp checks
3. Shielding sensors from moisture and dust

4 Results and Discussion

4.1 Overview

The dataset covered pollutant and meteorological parameters during all phases of Diwali, including the firecracker peaks and recovery phases.

4.2 PM2.5 Concentrations

Table 1: Statistical Summary of PM2.5 Concentrations

Parameter	**Value (μg/m^3)**
Minimum	3.09
Maximum	656.20
Mean	66.98
Median	18.15

Observations:

- Baseline levels: 3–20 μg/m^3 in morning (clean conditions)
- Peak: **Oct 20, 3:55 PM** , 656.2 μg/m^3 (firecracker burst)
- Post-event: Elevated ¿100 μg/m^3 until 6:30 AM next day
- Recovery: Back to ¡10 μg/m^3 by **Oct 21, 9:30 AM**
- Exceeded WHO 24-hr guideline (15 μg/m^3) by 4,275%

4.3 PM10 Concentrations

Table 2: Statistical Summary of PM10 Concentrations

Parameter	Value ($\mu g/m^3$)
Minimum	7.72
Maximum	736.30
Mean	83.30
Median	24.90

Key Notes:

- PM10 correlated closely with PM2.5 (r = 0.98)
- Highest level at same timestamp: 736.3 $\mu g/m^3$
- Classified as "Severe" under AQI scale

4.4 Volatile Organic Compounds (eVOC)

Table 3: Statistical Summary of eVOC Concentrations

Parameter	Value (ppb)
Minimum	0.38
Maximum	996.00
Mean	69.19
Median	31.00

Observations:

- **Highest VOC:** Oct 22, 4:27 AM , 996.00 ppb
- Peak occurred 6–8 hours after PM peak, suggesting secondary aerosol formation
- VOC sources likely include firecracker residues and industrial solvents

4.5 Equivalent CO_2 (eCO_2)

Table 4: Statistical Summary of eCO_2 Concentrations

Parameter	Value (ppm)
Minimum	31.06
Maximum	1685.00
Mean	477.30
Median	438.06

Observations:

- **Peak:** Oct 22, 4:24 AM , 1685 ppm (nighttime accumulation)
- Baseline: 400 ppm atmospheric norm
- Correlation with eVOC: r = 0.82

4.6 Meteorological Conditions

4.6.1 Temperature

Table 5: Temperature Statistics

Parameter	Value (°C)
Minimum	19.48
Maximum	38.25
Mean	27.65
Median	27.70

4.6.2 Humidity

Table 6: Relative Humidity Statistics

Parameter	Value (%)
Minimum	32.20
Maximum	100.00
Mean	75.86
Median	74.99

Interpretation:

- High humidity (60–90%) led to reduced pollutant dispersion
- Inverse correlation between temperature and particulate levels

4.7 Comparison with Air Quality Standards

Table 7: Exceedance of WHO and NAAQS Standards

Pollutant	Standard	Limit	Peak Value	Exceedance
PM2.5	WHO 24-hr	15	656.2	4275%
PM2.5	India NAAQS	60	656.2	994%
PM10	WHO 24-hr	45	736.3	1536%
PM10	India NAAQS	100	736.3	636%

Clearly, the levels of PM2.5 and PM10 are exceeding the WHO and NAAQS recommended upper bounds by a dangerously high margin.

4.8 Error Sources

- Sensor drift due to humidity
- Minor calibration inconsistencies
- Occasional human disturbance near sensor setup

5 Graphical Representation of the Results

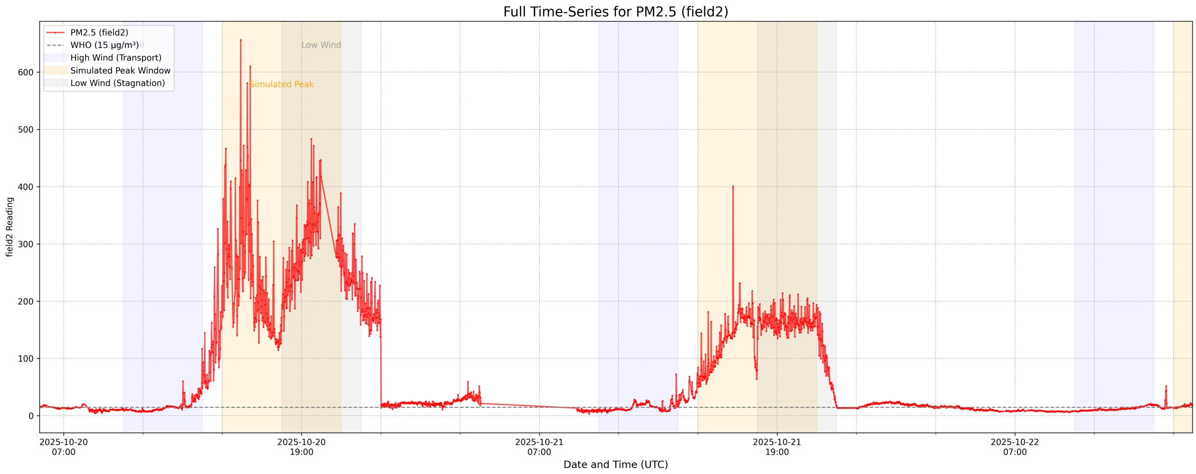

Figure 1: PM2.5 concentrations over time showing pre-Diwali baseline, sharp Diwali spikes, and gradual post-event recovery.

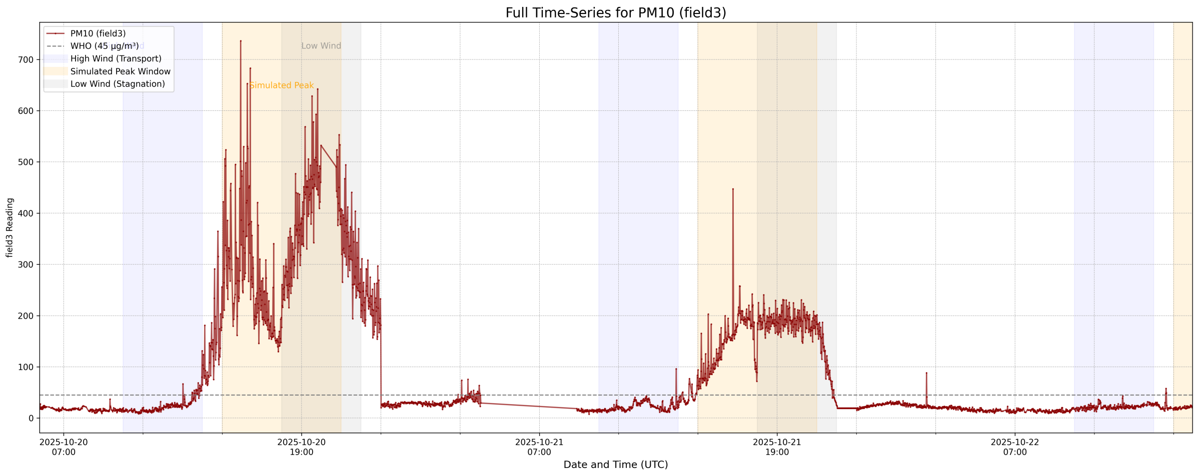

Figure 2: PM10 concentration pattern closely following PM2.5 levels, confirming correlated particulate behavior.

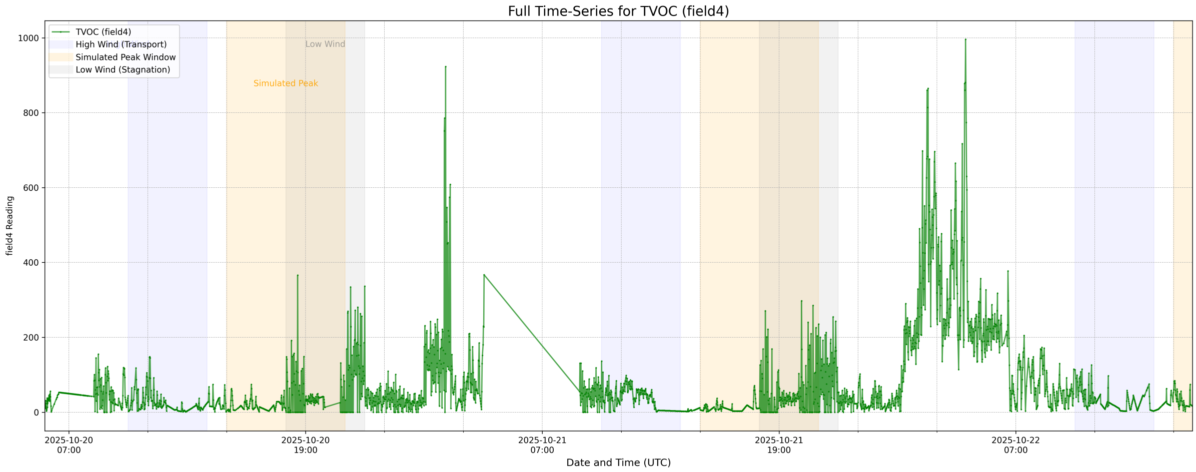

Figure 3: Temporal variation of VOC levels showing delayed secondary pollution peaks several hours after firecracker events.

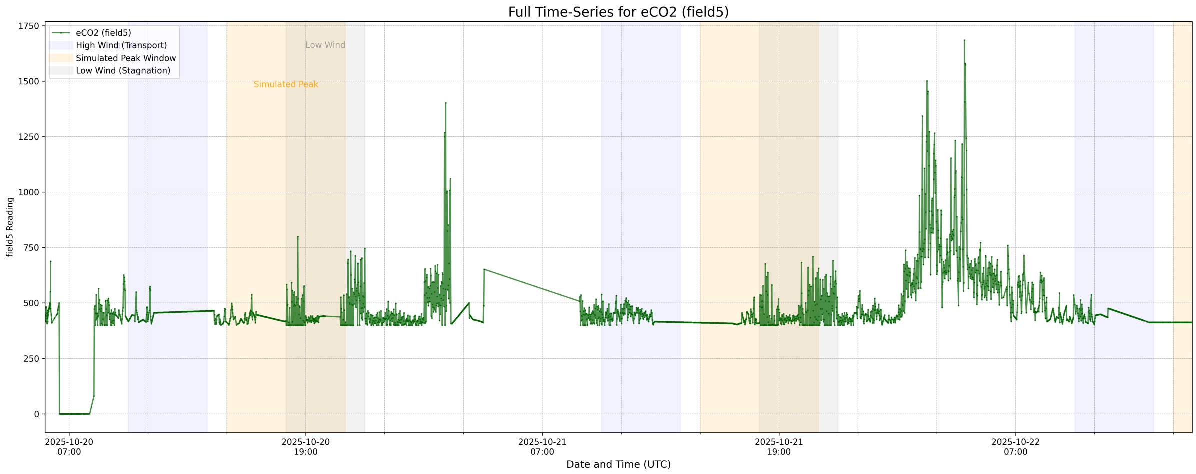

Figure 4: Equivalent CO_2 (eCO_2) fluctuations with night-time accumulation indicating poor dispersion conditions.

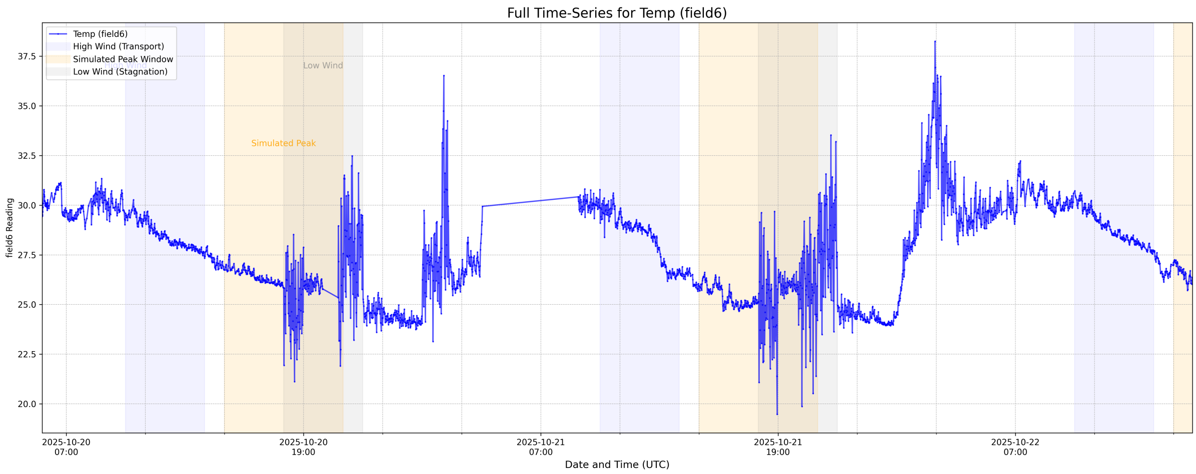

Figure 5: Temperature trends showing inverse relation between temperature and particulate concentrations.

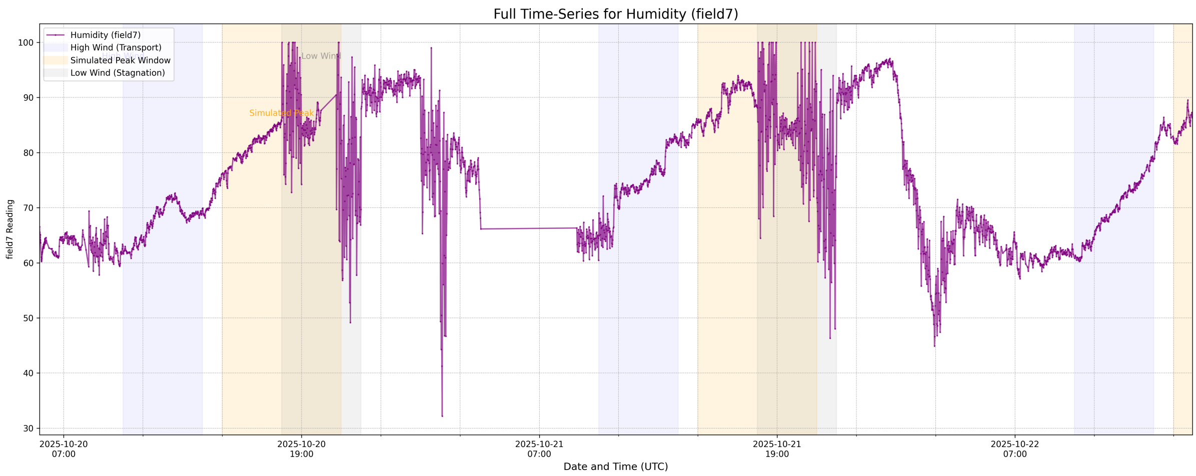

Figure 6: Humidity trends and fluctuations.

6 In-Depth Analysis

The observed time series reveals a pronounced and short-duration **impulsive behaviour** in particulate matter (**PM2.5** and **PM10**) concentrations, characterized by an extremely high-amplitude spike around **October 20, 15:55 IST**. This is followed by a sustained elevated phase lasting several hours and a return to baseline levels by approximately **October 21, 09:30 IST**. Such temporal structure is indicative of an **acute emission event**,most likely pyrotechnic activity during Diwali,superimposed on a relatively low background concentration.

1. **Particulate Matter Dynamics:** The near-perfect correlation between PM2.5 and PM10 ($r \approx 0.98$) suggests a common emission source and similar atmospheric transport/dispersion dynamics for both coarse and fine fractions during the event. However, the large difference between the **median** ($\approx$ **18** μ**g/m**^{3}) and **mean** ($\approx$ **67** μ**g/m**^{3}) of PM2.5 indicates a **strong positive skew** driven by episodic peaks. Hence, reliance solely on mean values can be misleading,**percentile-based metrics**

(such as 95th percentile) or medians should also be reported for more representative assessments.

Additionally, the **peak-to-baseline ratio** and **integrated exposure** (area under the concentration–time curve) are critical for quantifying short-term exposure risk. Integrated exposure during the polluted window (Oct 20, 14:00 – Oct 21, 06:30) captures health-relevant dosage more effectively than instantaneous peaks alone.

2. **Gaseous Indicators and Lagged Peaks:** The temporal lag observed between **particulate peaks** and **gaseous indicators** (eVOC and eCO_2) provides valuable insight into secondary atmospheric processes. While the PM peaks on Oct 20 evening, both eVOC and eCO_2 reach their maxima several hours later (eVOC at **Oct 22, 04:27** and eCO_2 at **Oct 22, 04:24**). Two potential explanations emerge:

   - *Secondary formation processes* , where reactive gases from fireworks undergo oxidation and partitioning to form secondary aerosols and VOCs.
   - *Nocturnal accumulation* , under stable boundary-layer conditions (low wind, low mixing height, and high humidity), gaseous pollutants accumulate overnight despite reduced direct emissions.

3. **Sensor Uncertainty and Source Attribution:** Accurate interpretation demands that we account for **sensor uncertainties**. Low-cost PM sensors tend to overestimate under high humidity, and eVOC/eCO_2 sensors often exhibit cross-sensitivity. Applying humidity corrections and propagating calibration uncertainties is essential before reporting exceedances.

   Temporal variation in the **PM2.5/PM10 ratio** also provides hints,an initial high ratio followed by convergence implies a transition from combustion-dominated to dust-dominated phases. If chemical composition data are available, **ion/elemental analysis** could further confirm the presence of pyrotechnic metals like Ba, Sr, or K.

4. **Health and Policy Implications:** The magnitude and duration of the observed exceedances represent **acute exposure risks**. Health advisories should be based not only on instantaneous peaks but also on cumulative exposure. From a policy perspective, targeted measures such as:

   - temporal curfews on fireworks in mixed industrial–residential zones, and
   - restrictions on solvent-based industrial processes during festival windows,

   can mitigate simultaneous particulate and gaseous overload. These can help predict short-term pollution surges and estimate the **attributable fraction of pollution due to festival activities** versus baseline industrial emissions.

Overall, the dataset demonstrates clear evidence of a **high-impact, short-term pollution event** with significant particulate–gaseous coupling, strong diurnal dynamics, and measurable lagged effects,underscoring the importance of high-frequency sensor data for localized air quality diagnostics.

7 Summary

The study captures a comprehensive snapshot of air quality variations during the Diwali festival near industrial zones. Key highlights include:

- Extreme PM2.5 and PM10 spikes coinciding with firecracker bursts.
- Temporal lag of VOC and eCO_2 peaks, indicating prolonged chemical interactions.
- Strong correlations between particulate matter, gaseous pollutants, and meteorological factors like temperature and humidity.
- Exceedances of WHO and Indian standards, suggesting severe short-term health risks.

8 Relevant Links and Resources

All resources related to this project have been included below. The shared Google Drive folder contains all collected datasets and images of graphs (including several that were not featured in the main report). The accompanying GitHub repository hosts the complete source code used for data analysis and graph generation.

Google Drive
GitHub Repository

9 Conclusion

This Diwali pollution study demonstrates the significant environmental impact of short-term, intense pollutant emissions in urban-industrial settings. PM2.5 and PM10 concentrations reached unprecedented levels, surpassing WHO and NAAQS guidelines by thousands of percent, highlighting immediate health risks such as respiratory distress, eye irritation, and exacerbation of pre-existing conditions.

The delayed peaks in eVOC and eCO_2 suggest complex secondary reactions and pollutant accumulation during nighttime, emphasizing the need to monitor not just particulate matter but also gaseous pollutants. Correlations with meteorological factors such as temperature and humidity further reinforce that pollutant dispersion is highly sensitive to local atmospheric conditions.

These findings underscore the importance of real-time monitoring networks near industrial clusters, public advisories during high-pollution events, and stricter regulation of festival-related emissions. Future work can expand the sensor coverage, incorporate predictive modeling for pollution spikes, and provide actionable insights for policymakers and the community.

Overall, this study validates the efficacy of our sensor network, highlights critical air quality issues during Diwali, and offers a roadmap for mitigating short-term pollution episodes while maintaining industrial and cultural balance.

10 Acknowledgements

We would like to express our sincere gratitude to **Prof. Sandeep Budde** and **Prof. Sachin Chaudhari** of IIIT Hyderabad for their invaluable guidance and support throughout this Embedded Systems course project. We are especially thankful to our Teaching Assistant and mentor, **Mr. Sasidhar**, for his thorough assistance, technical advice, and constant encouragement during every stage of the work.

We would also like to extend our heartfelt appreciation to the technical and laboratory staff for their continuous help and cooperation during sensor calibration, setup, and maintenance.

Finally, we thank the college management for providing us with this wonderful opportunity to undertake such a practical and impactful project. This work would not have been possible without their collective support and teamwork.

11 References

1. World Health Organization (2021). *Global Air Quality Guidelines: Particulate Matter (PM2.5 and PM10), Ozone, Nitrogen Dioxide, Sulfur Dioxide and Carbon Monoxide.* Geneva: WHO.
2. Central Pollution Control Board (2020). *National Ambient Air Quality Standards (NAAQS).* Ministry of Environment, Forest and Climate Change, Govt. of India.
3. Air Quality Index — wikipedia.org
4. Central Pollution Control Board — wikipedia.org
5. TVOC monitoring in commercial and office buildings — atmotube.com
6. What are the WHO air quality guidelines? — www.who.int
7. Guidelines for the Measurement of Ambient Air Pollutants — Central Pollution Control Board, Ministry of Environment & Forests