

Smog Detection Research Project

Supervised by Dr. Walther Schwarzacher, Dean
of SBASSE

Project Report (2025-2026)

Project Overview

SPADES, under the supervision of Dr. Walther Schwarzacher, Dean of the Syed Babar Ali School of Science and Engineering (SBASSE) at LUMS, launched Lahore's first student-led air quality research project, hereby connecting schools across the city to collect and analyze PM 2.5 data.

At its core, the project was about more than just measuring smog. It was designed to give high school students a genuine introduction to scientific research: understanding measurement uncertainties, working with the limitations of real instruments, and learning how to collect data reliably. All of this, in service of one of Lahore's most pressing environmental issues.

Selected teams were provided with smog detection equipment, power banks, and wiring by Dr. Walther, and over the course of two months, recorded air quality data from their own neighborhoods across the city. The result was a city-wide, student-generated dataset, along with a cohort of young researchers who gained first-hand experience in the process.

Details

Timeline

- 1 Orientation & Workshops : 3 Guest Speaker Sessions (Theoretical & Technical Training)
- 2 Data Collection Phase: 2-Month Long Environmental Monitoring
- 3 Conclusion: Paper Submission & Review

Selection & Participation

The project received an overwhelming response from Lahore's high school community (O/A Level students), with a record 213 teams submitting applications. Outreach was driven through SPADES's social media platforms, alongside a targeted word-of-mouth campaign through teachers who work across multiple schools in the city. This allowed the project to reach students organically and ensured that those who applied were genuinely motivated to participate.

Following a competitive review process, 20 teams were selected to join the project, chosen on the basis of their enthusiasm, research potential, and commitment to seeing the project through over the two-month data collection period. This was a total of 90 students from various schools across Lahore, including LGS, Aithcison, ISL, Crescent, and more

Workshop 1 - Introduction & Device Usage

The first workshop was conducted on 8 November 2025, running for approximately two hours. It set the foundation for the entire project and was designed from the start to be hands-on and interactive. Led by Muhammad Wasay Rafaqat, the session introduced students to smog as an environmental challenge, with a particular focus on why Lahore is one of the most polluted cities in the world during winter months, where PM 2.5 levels routinely exceed $150 \mu\text{g}/\text{m}^3$ against the WHO's recommended limit of $5 \mu\text{g}/\text{m}^3$.

Going beyond the conventional narrative, the workshop also shed light on summer smog - a phenomenon that rarely gets attention - helping students develop a more complete picture of air quality as a year-round issue. Teams then brainstormed their own research questions, exploring angles like morning vs evening pollution, green zones vs traffic zones, or the effect of rainfall on air quality.

The session also included a live demonstration of the PM Tracker devices, covering everything from powering the unit and navigating its menus, to starting data collection and safely storing readings to the SD card. Each team then got hands-on time with their own device, practicing startup and verifying real-time PM 2.5 readings both indoors and outdoors before taking the equipment home.



Workshop 2 - Understanding Uncertainties & Data Collection

Led by Ahmad Jalil, the second workshop was conducted on 9 November. It tackled one of the most important (and often overlooked) aspects of scientific research: measurement uncertainty. Students learned to distinguish between systematic errors (such as sensor calibration offsets or poor device placement) and random errors (like fluctuations caused by wind gusts or passing vehicles). The session also covered how environmental factors such as humidity and temperature can influence sensor readings, and why documenting these contextual details is vital in interpreting data accurately. Teams then took part in a hands-on calibration activity, placing their PM Trackers side by side to compare readings and identify baseline offsets between devices.

Following the workshop, teams were handed their PM Tracker devices to take home and begin independent data collection. Over the course of December and January, spanning Lahore's most heavily polluted winter months, the selected teams recorded air quality readings from their own neighborhoods and schools all across the city.

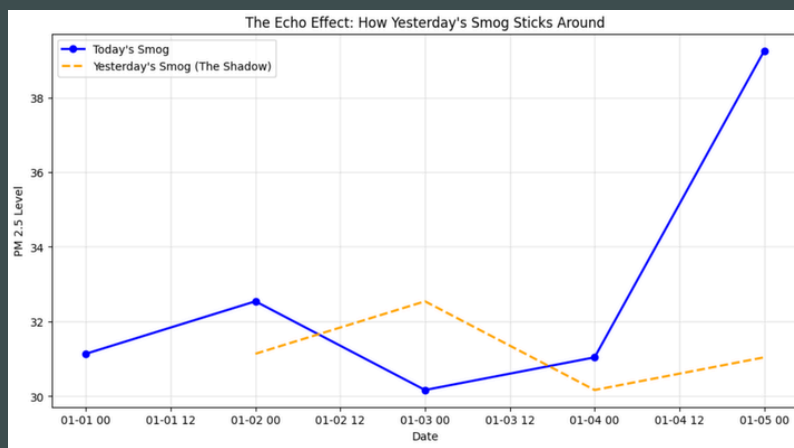


Workshop 3 - Data Visualization, Analysis & Predictive Modeling

Led by Muaaz Warraich, the final workshop, conducted on 24 January, 2026 was the most interactive and longest of the three — and fittingly so, as it brought together everything the teams had spent the past two months working towards. Held after the data collection period had concluded, the session was designed to give students the tools to make sense of the raw numbers sitting on their SD cards and transform them into something visually meaningful and scientifically communicable.

The workshop opened with a conceptual introduction to linear regression and building an intuitive understanding of how relationships between variables can be modeled mathematically. Students learned how factors like time of day, temperature, and humidity could serve as predictors of PM 2.5 levels, and how plotting these relationships could reveal patterns that raw data alone couldn't. This theoretical grounding was kept accessible and example-driven, ensuring that even students without a strong math background could follow along and appreciate the logic behind the models.





From there, the session moved into hands-on implementation using Visual Studio, where Muaaz walked teams through writing code to extract their collected data directly from the PM Tracker's SD card. Students learned how to read and process the data programmatically, feeding it into models and predictive algorithms that would then render it as graphs on screen. Seeing their own months of field work materialize into visual trends in real time made for one of the most engaging moments of the entire project.

The session closed with a broader discussion of data visualization as a research skill; how a well-constructed graph can communicate findings more powerfully than paragraphs of text, and how the techniques learned that day would be directly applicable to writing and presenting their final research papers.



Results

Across the twenty participating teams, each group brought a distinct analytical lens to the same dataset, and all impressively met the project's requirements, submitting complete papers with documented data, proper methodology, and thoughtful analysis. Some teams examined how pollution levels shifted between weekdays and weekends, while others compared daytime and nighttime readings.

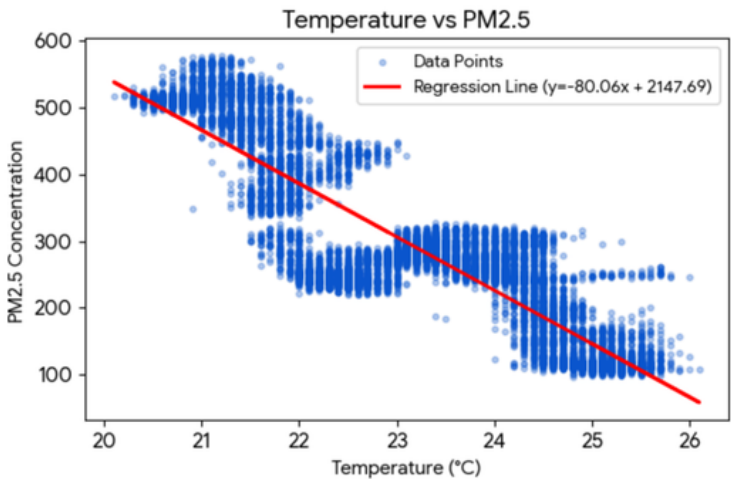
Two papers stood out for the sophistication of their methodology and the clarity of their conclusions. The first, produced by team CETC, was titled, *‘Analysing the Correlation Between Temperature and PM2.5 Levels in Lahore Using Linear Regression’*

Data Collection Summary

Sr#	Location	Time/Duration
1)	LUMS Campus (outside PDC)	9th November (Sunday) from 11 am to 11:15 am (15 minutes)
2)	LUMS Campus (at main parking)	9th November (Sunday) from 11:39 am to 11:54 am (15 minutes)
3)	Awan Town	From 10th November (Monday) 9 am to 11th November (Tuesday) 9 am (24 hours)
4)	Crescent Model Higher Secondary School, Shadman	14th November (Friday) from 11 am to 12 pm (1 hour)
5)	Pace Woodlands, Bedian Road	23rd November (Sunday) from 10 pm to 3 am (5 hours)

Table 2.1

As can be seen from Table 2.1, multiple readings were taken through a PM2.5 Tracker in order to conduct this research.



Their R^2 value of 0.79 was one of the stronger results across the cohort, meaning that temperature alone explained nearly 79% of the variation in PM2.5 levels in their dataset.

6. Results and Interpretation

The results support the original hypothesis that PM2.5 concentration decreases with increasing temperature. Overall, higher PM2.5 levels were observed during cooler periods, particularly in the evening and early morning, while lower concentrations occurred during warmer midday hours.

A major trend observed was the sharp increase in PM2.5 during late afternoon hours, even before temperatures had fallen significantly. This suggests that human activities, especially traffic emissions, play a crucial role alongside meteorological factors. No completely unexpected patterns were observed, but the magnitude of the evening PM2.5 surge highlights the strong influence of localised emission sources.

7.1 Generalizability

This study is based on data collected during a single 24-hour period from one densely populated suburban location in Lahore. Because emission sources and activity patterns vary across different parts of the city, the observed relationship between temperature and PM2.5 may not apply equally. In addition, the short duration of data collection does not account for daily or seasonal changes in weather and pollution levels.

7.2 Accuracy

The accuracy of the results may be affected by limitations in measurement and data coverage. PM2.5 and temperature were recorded using a single sensor, which may introduce minor instrumental uncertainty and sensitivity to local environmental conditions. Furthermore, wind speed and nearby emission sources were not directly measured or included in the regression analysis. These influences likely contributed to short-term fluctuations in the data.

Results

The second paper, produced by JT Defenders from LGS, was titled, *‘Meteorological and Anthropogenic Drivers of PM2.5: A Comparative Spatiotemporal Analysis of Fine Particulate Matter Using Linear Regression.’*

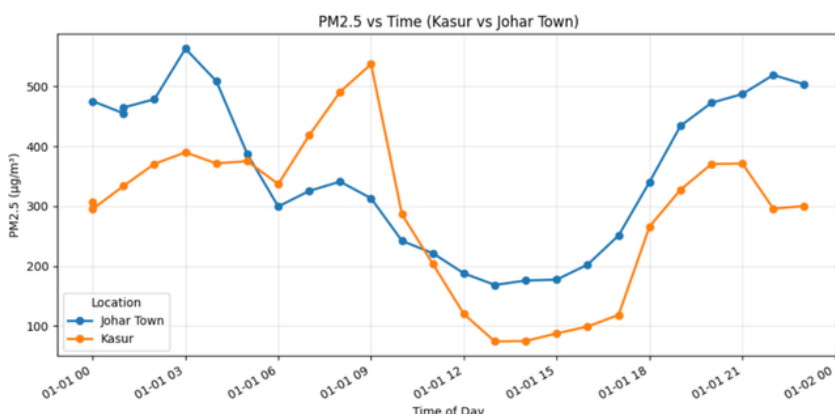
The team collected data from sixteen locations across Lahore and Kasur, mapping how PM2.5 levels responded to seasons, temperature, humidity, traffic density, and time of day.

Among their most important findings was the data on the anthropogenic load (the additional pollution directly attributable to human activity) which went over 460 $\mu\text{g}/\text{m}^3$ above baseline in Johar Town during peak traffic hours, levels classified as hazardous and more than ten times the WHO safe limit.

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Peak Traffic Time

Location	02:00–04:00 AM ug/m3	08:00–10:00 AM ug/m3	09:00–11:00 PM ug/m3	Average Anthropogenic Load ug/m3
Johar Town D2 Block	200	110	80	+130
Kasur	80	200	120	+130
Punjab Society	100	60	110	+90
Kahna	130	50	80	+85
Johar Town P Block	90	100	60	+83



The most unexpected discovery, however, was what the data revealed about Kasur. Despite having far fewer vehicles and industries than Lahore, the city recorded dangerously high PM2.5 levels. The team attributed these to pollution travelling across Punjab on the wind, compounded by cross-border haze from India. It was a finding that reframes smog not as a city-level problem, but as a regional crisis with no geographical boundary.

Closing Reflections

When SPADES first conceived of this project, the goal was straightforward: give high school students real research experience, rooting from one of Lahore's most visible and urgent environmental problems. What emerged over the course of three workshops, two months of data collection, and 13 submitted papers was something that exceeded those initial ambitions considerably.

What stood out most was not any single finding, but the consistency of the work across the board. 13 teams, spread across the city, operating independently with instruments they had learned to use only weeks earlier, produced papers that were methodologically sound, analytically honest, and in several cases genuinely surprising in their conclusions.

The project also quietly demonstrated something about Lahore's young people that often goes unacknowledged: that given the right mentorship, and a problem worth solving, they are more than capable of contributing meaningfully to scientific discourse. For them, the smog is not an abstract concept. It is the air outside their schools, their homes, everywhere really.

SPADES extends its deepest gratitude to Dr. Walther Schwarzacher, whose supervision and generosity made the project possible, and to every teacher, and school that supported their students through the process. Most of all, to the students themselves for showing up, staying curious, and doing the work.

