Beyond the Burn: Delhi’s winter smog intensifies even after stubble fires fade

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A new analysis by the Centre for Science and Environment (CSE) sheds light on the shifting air quality trends in Delhi and the National Capital Region (NCR). The study compares the "early winter" months of October and November—a period heavily influenced by farm fires—with the "post-farm fire" period of December, when the impact of stubble burning becomes negligible and finds that the post-stubble burning phase has experienced intense, widespread smog across the NCR – more severe than the stubble burning period.

These findings reveal a concerning reality: Delhi’s winter pollution does not dissipate once stubble burning ends; instead, it intensifies. Despite the farm-fire contribution to PM2.5 levels dropping sharply in December the average PM2.5 levels have actually increased. The stark contrast between declining fire influence and rising pollution levels across Delhi and NCR indicates dominance of local and regional sources—vehicles, industry, waste burning, solid fuels for domestic cooking and heating. While managing farm fires is important, air quality goals cannot be met without aggressive, year-round action against urban and regional emission sources for zero emissions transition. The smog is a combination of local emissions, regional inflows, and secondary aerosol formation, requiring coordinated airshed-level action alongside aggressive control of local sources.

The build-up of pollution was felt across various urban centers in the NCR. While some towns saw marginal declines, most cities recorded a sharp rise in PM2.5 levels: Noida: 38 per cent increase; Ballabhgarh: 32 per cent increase; Baghpat: 31 per cent increase and Delhi: 29 per cent increase. This regional spike is driven by local emission sources and exacerbated by stagnant winter meteorology, which prevents the dispersion of pollutants. Furthermore, secondary particles formed through atmospheric chemical reactions involving precursor gases make up nearly two-thirds of PM2.5, with a substantial share comprising aged secondary aerosols transported into the city.

Moreover, data from the Decision Support System (DSS) for December 1–15 highlights the complexity of the problem. During this period, local sources within Delhi accounted for only about 35 per cent of total PM2.5. The remaining 65 per cent originated from neighboring NCR districts and regions further away. Within Delhi’s local contribution, vehicles are the dominant primary source, accounting for nearly half of all local emissions.

This analysis is based on the real time data available from the current working air quality monitoring stations in Delhi-NCR. Estimate of contribution of farm stubble fire smoke to Delhi’s air quality is sourced from Ministry of Earth Science’s System of Air Quality and Weather Forecasting and Research (SAFAR). Real-time source contribution and chemical composition data are taken from the Decision Support System (DSS) developed by IITM.

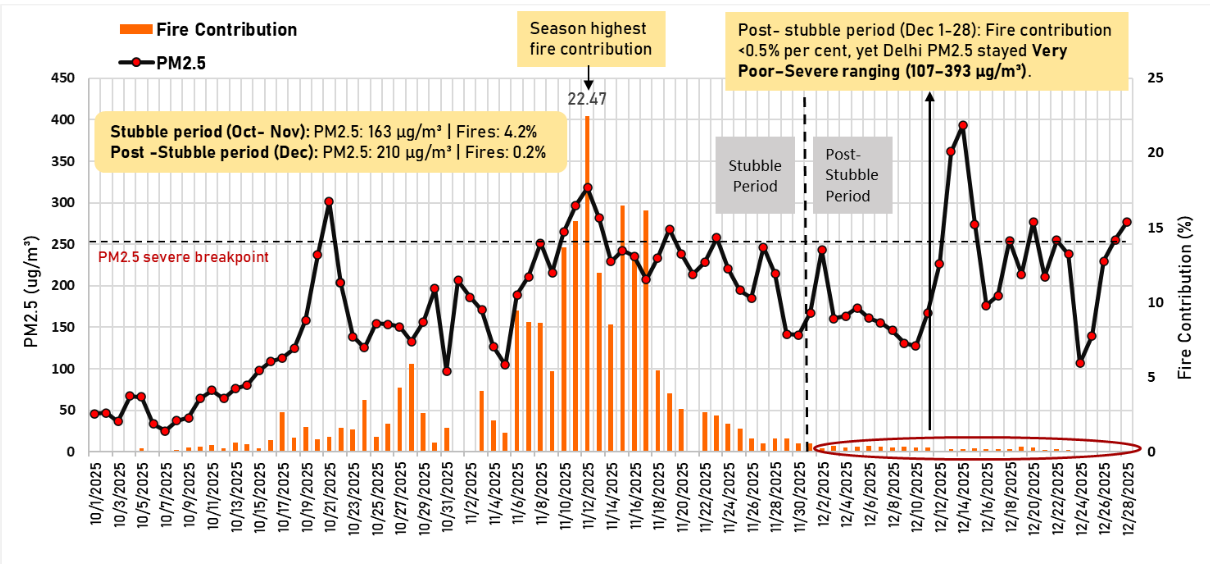
The Key Highlights

Varying trends between stubble burning period and post burning: An analysis of daily PM2.5 trends demonstrates that winter pollution in Delhi cannot be attributed solely to stubble burning. The data reveals a significant shift in air quality dynamics across two distinct phases:

The Stubble-Burning Period (October 1 – November 30): During this phase, average PM2.5 levels stood at 163 µg/m³. Farm fires contributed approximately 4.2 per cent to the total on average, though this peaked briefly at over 22 per cent in mid-November. While these fires caused temporary, episodic spikes in pollution, air quality did not improve once the season concluded.

The Post-Stubble Period (December 1 – 28): Contrary to expectations, air quality worsened after the farm fires ended. The average PM2.5 concentration rose sharply to 210 µg/m³, representing a 29 per cent increase over the previous period. This surge occurred even as the contribution from farm fires plummeted to just 0.2 per cent. During this time, Delhi continued to suffer from "Very Poor" to "Severe" air quality, with daily PM2.5 concentrations fluctuating between 107 µg/m³ and 393 µg/m³. *(see Graph 1: Daily PM2.5 trend during Stubble and Post-Stubble Period).*

Graph 1: Daily PM2.5 trend during Stubble and Post-Stubble Period



Note: Average PM2.5 concentration is based on mean of daily values recorded at 37 CAAQM stations in the city that have adequate data, average includes all the Delhi stations except Lodhi Road IITM, Chandni Chowk IITM and East Arjun Nagar.
Source: CSE analysis of CPCB real-time data

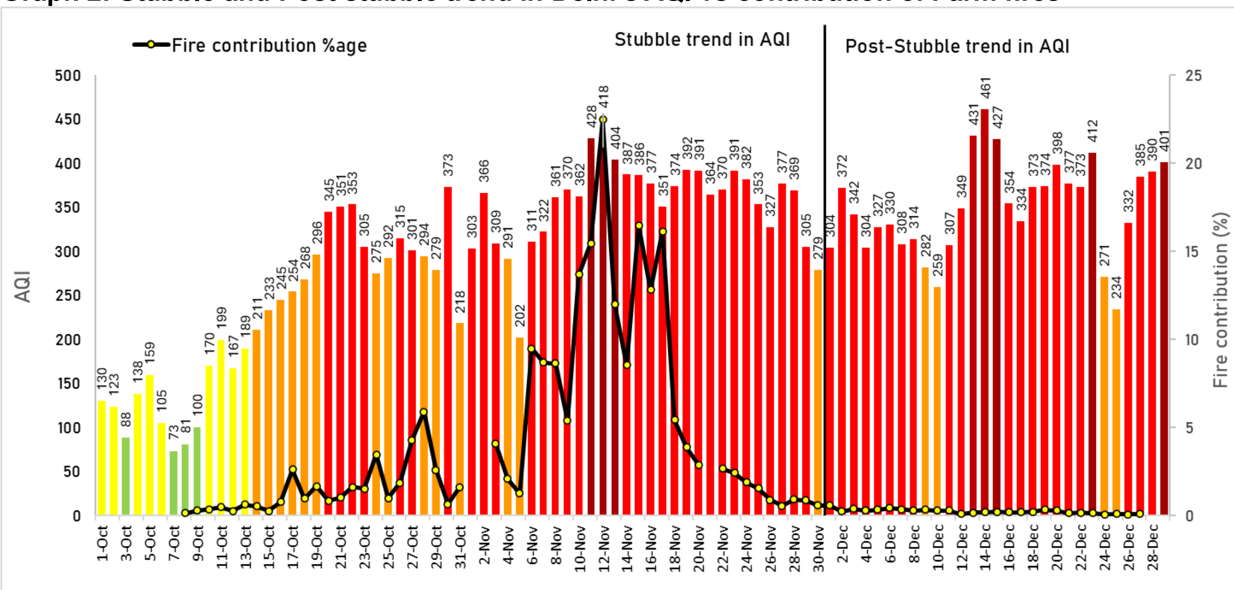
Persistent Very Poor–Severe AQI levels in Delhi, often exceeding 450: Stubble burning is largely confined to October and November, and its influence sharply declines by December. Yet the post-stubble trend in air quality shows no corresponding relief. Throughout December, even as farm-fire contribution fell to negligible levels, Delhi's AQI remained firmly in the Very Poor to Severe range of Air Quality Index on most days, frequently crossing 300 and even 450 *(see Graph 2: Stubble and Post stubble trend in Delhi's AQI vs contribution of Farm fires).*

A comparison of pollution severity across the two periods further highlights this shift.

During the stubble-burning phase (October 1–November 30), Delhi recorded 3 Severe AQI days, with the highest AQI reaching 428 on November 11, 2025.
In contrast, **the post-stubble period (December 1–29)** saw 5 Severe AQI days, with the season's worst air quality recorded on December 14, when AQI surged to 461, about 1.1 times higher than the peak observed during the stubble period. The season's worst air quality occurred on December 14, when the

AQI surged to **461**, which is approximately **1.1 times higher** than the peak seen during the stubble phase.
PM2.5 concentrations ranged between **107 and 393**, keeping Delhi firmly in the **"Very Poor" to "Severe"** range on most days. *(see Graph 2: Stubble and Post stubble trend in Delhi's AQI vs contribution of Farm fires).*

Graph 2: Stubble and Post stubble trend in Delhi's AQI vs contribution of Farm fires



Source: CSE analysis of CPCB'S AQI data and Farm fire contribution is based on data from SAFAR.

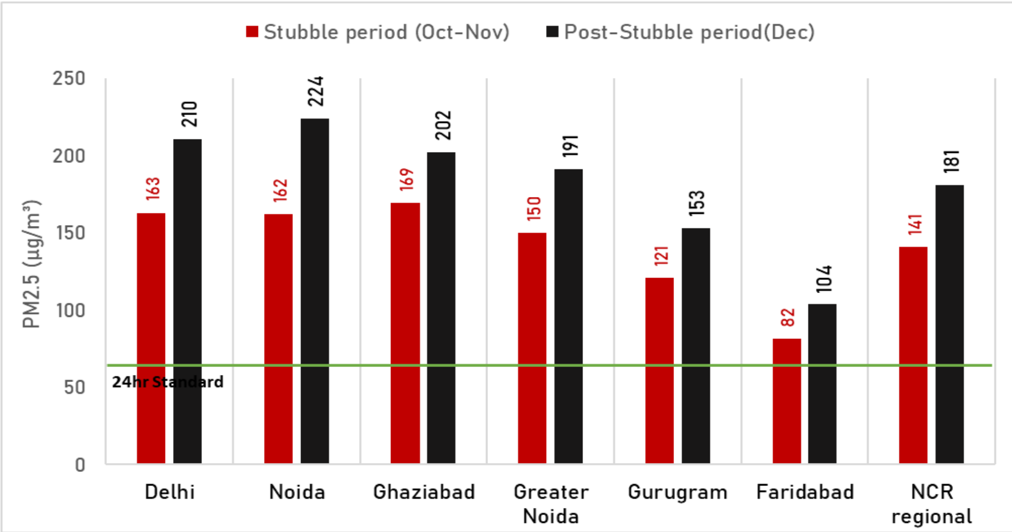
The Post-Stubble Intensification in NCR as well: The air pollution crisis in the National Capital Region (NCR) extends far beyond Delhi, with PM2.5 levels rising sharply across the entire region even after stubble burning has concluded. Data indicates a region-wide escalation of winter pollution, proving that the hazard is persistent and widespread.

At the regional level, average PM2.5 concentrations increased by 28 per cent in the post-stubble phase compared to the active burning period. This upward trend was observed across major urban centers:

Noida recorded the steepest surge, with PM2.5levels jumping by 38 per cent. Delhi experienced a 29 per cent increase. Greater Noida registered a 28 per cent rise. Gurugram & Faridabad saw a pronounced increase of 27 per cent each.

The absolute concentration of pollutants remained dangerously high across the region, far exceeding the 24-hour air quality standards. *(see Graph 3: Post-Stubble PM2.5 Levels exceed Stubble-Period averages across NCR cities).*

Graph 3: Post-Stubble PM2.5 Levels exceed Stubble-Period averages across NCR cities

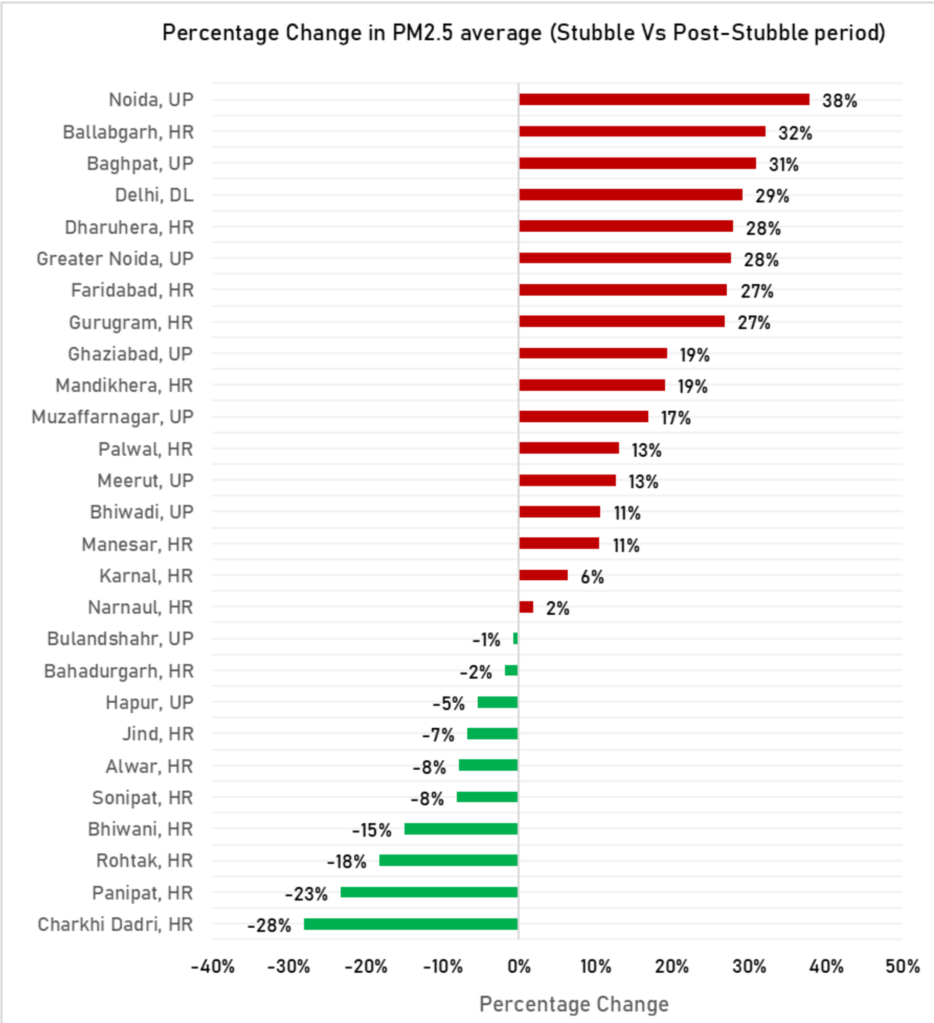


Note: Average PM2.5 concentration is based on mean of daily values recorded at CAAQM stations. Regional NCR includes: Delhi, Gurugram, Faridabad, Greater Noida, Noida and Ghaziabad. Data is from 1 Oct – 28 Dec 2025.
Source: CSE analysis of CPCB real-time data

The shift in absolute pollution concentrations further illustrates the severity of the regional crisis. While most core cities and their peripheries saw intensified pollution, the trend was not uniform across the entire region. Peripheral towns like Karnal saw a marginal increase of only 6%, and Narnaul remained nearly stable with just a 2 per cent rise.

Conversely, a few towns actually experienced a decline in PM2.5 levels during the post-stubble phase, including Charkhi Dadri (28 per cent), Panipat (23 per cent), Rohtak (18 per cent), and Bhiwani (15 per cent), with smaller declines noted in Sonipat and Alwar (8 per cent each). These divergent trends highlight how the distribution of winter pollution is uneven and heavily shaped by variations in local emission sources, urban activity levels, and specific dispersion conditions. Pollution levels across the NCR generally peak in December, long after farm fire contributions have diminished, driven instead by local and regional sources. *(see Graph 4: Change in average PM2.5 levels from Stubble to Post-Stubble Period).*

Graph 4: Change in average PM2.5 levels from Stubble to Post-Stubble Period



Note: Average PM2.5 concentration is based on mean of daily values recorded at CAAQM stations.
Source: CSE analysis of CPCB real-time data

Smong episode during post-stubble - between December 12 and 15. During this phase, air quality across the NCR deteriorated sharply, with Noida recording the highest concentration of PM2.5 at 352 µg/m³, making it the most polluted location in the region. Delhi followed closely, experiencing a three-day smog episode from December 13 to 15 with an average concentration of 343 µg/m³.

Other major NCR cities, including Ghaziabad and Greater Noida, also remained engulfed in dense smog during this period, recording levels above 300 µg/m³. Notably, Baghpat, a smaller town in Uttar Pradesh, also experienced a sustained smog episode from December 12 to 14, with PM2.5 levels averaging 312 µg/m³. The spread of intense smog beyond core urban centres highlights the growing regionalisation of winter pollution in the NCR, even in the absence of stubble-burning influence.

Table 1: NCR cities showing smog period in December

Stations	Dates	Smog Intensity (µg/m³)
Noida, UP	12-15 Dec	352.2
Delhi, DL	13-15 Dec	343.1
Baghpat, UP	12-14 Dec	312.2
Greater Noida, UP	12-15 Dec	310.6

Ghaziabad, UP	12-15 Dec	305.5

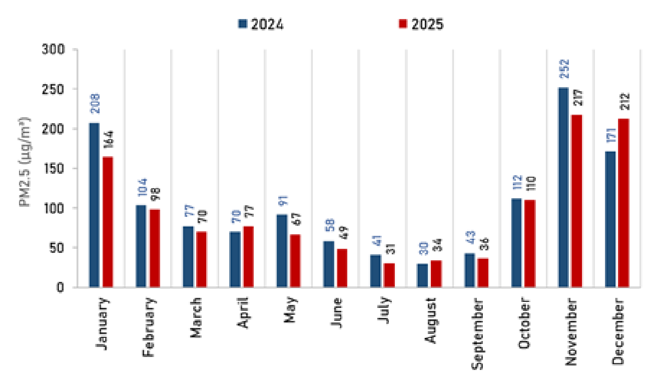
Note: stations exceeding 250 µg/m³ for three consecutive days considered as smog period.

Annual PM2.5 trends in Delhi show an improvement compared to last year: On an annual average basis, PM2.5 concentrations declined by about 7 per cent, falling from 105 µg/m³ in 2024 to 97 µg/m³ in 2025. A closer month-wise analysis reveals that PM2.5 levels declined in most months of the year, with reductions ranging from 2 to 27 per cent. However, three months- April, August, and December recorded increases in PM2.5 concentrations by 10 per cent, 13 per cent, and 24 per cent, respectively *(see Graph: Comparison of monthly average PM2.5 levels in Delhi (2024–2025)).* These increases are likely linked to transitional seasonal conditions, local emission build-up, and episodic pollution events.

The most significant declines were observed during May, June, July, and September, when PM2.5 levels dropped sharply. This improvement can be largely attributed to excessive and prolonged rainfall during the monsoon and pre-monsoon periods, which effectively cleaned the atmosphere through wet deposition, while also limiting dust resuspension and combustion-related emissions.

Overall, while the annual reduction signals progress, the recurrence of elevated pollution levels in certain months highlights the strong role of seasonal and meteorological factors in shaping air quality.

Graph: Comparison of monthly average PM2.5 levels in Delhi (2024–2025)



Source: CSE analysis of CPCB real-time data.

Local vs regional pollution: The study utilizes two critical datasets from the **Indian Institute of Tropical Meteorology (IITM)** to provide dynamic insights into the sources and nature of Delhi's air quality.

The core of this analysis is the Decision Support System (DSS) for Air Quality Management. Unlike traditional, one-time source apportionment studies that provide a static snapshot, the DSS offers real-time estimates of dynamic, daily relative contributions of 29 different pollution sources to PM2.5levels in Delhi. This is a granular categorization that distinguishes between eight local source categories within Delhi, contributions from neighboring NCR districts, stubble burning, and cross-boundary pollution from "other districts".

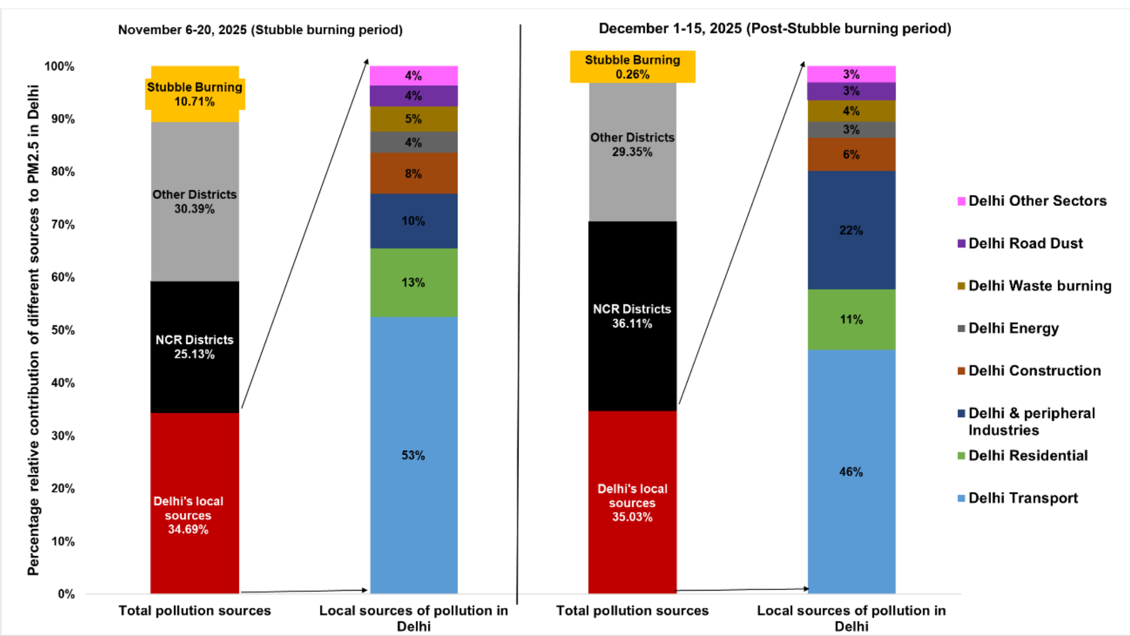
An analysis of DSS data for the post-stubble period (December 1–15, 2025) reveals a critical shift in how pollution is distributed: Only about 35 per cent of Delhi's total PM2.5 originated from local sources within the city. The remaining 65 per cent share of pollution is attributed to NCR districts and other regions outside the city limits. This also shows that stubble burning contributed only a negligible fraction during this period, confirming its limited role in December's hazardous air quality.

Breakdown of Delhi's Local Emission Sources - Vehicles, not just farm fires: the hidden drivers of Delhi's persistent smog: Analysis of DSS data for the stubble (November 6–20, 2025) and post stubble period (December 1–15, 2025) period highlights a critical shift in Delhi's pollution profile.When examining only the emissions generated within Delhi's borders during the post-stubble period, specific sectors emerge as the primary drivers.

Transport or vehicles remains the single largest contributor, accounting for nearly half—**46 per cent**—of Delhi's local 2.5 load during this period. The industrial sector contributed 22 per cent to the local pollution profile. Household-level emissions accounted for 11 per cent. Other sectors, including construction, energy use, waste burning, and road dust, contributed smaller but persistent shares. *(see Graph 5: Average fractional contribution of sources of pollution to PM2.5 in Delhi during stubble and post stubble period).*

The study highlights that while the relative contribution of vehicles declined by approximately **13 per cent** from the stubble to the post-stubble phase, transport emissions continued to dominate Delhi's local pollution profile. The persistence of these high levels is exacerbated by winter meteorological conditions, such as shallow mixing heights and weak dispersion. These conditions cause emissions from routine urban activities to accumulate rapidly, driving hazardous pollution levels even in the absence of external factors like stubble burning.

Graph 5: Average fractional contribution of sources of pollution to PM2.5 in Delhi during stubble and post stubble period.



Source: Based on the CSE's analysis of DSS data by IITM

Transboundary pollution dominated by the secondary particulates formed from gases from combustion sources: The analysis further highlights a critical second dataset from the Indian Institute of Tropical Meteorology (IITM) that focuses on the chemical composition of air pollutants to uncover the "hidden drivers" of Delhi's winter smog.

The second assessment examines non-refractory PM2.5 (NR-PM2.5), which identifies secondary particles formed through atmospheric chemical reactions rather than those emitted directly from a source. This chemical "fingerprinting" allows researchers to distinguish between local emissions and those transported from the wider region.

The study reveals that Delhi's pollution is as much a matter of atmospheric chemistry as it is of direct emissions due to secondary pollutants and transboundary pollution

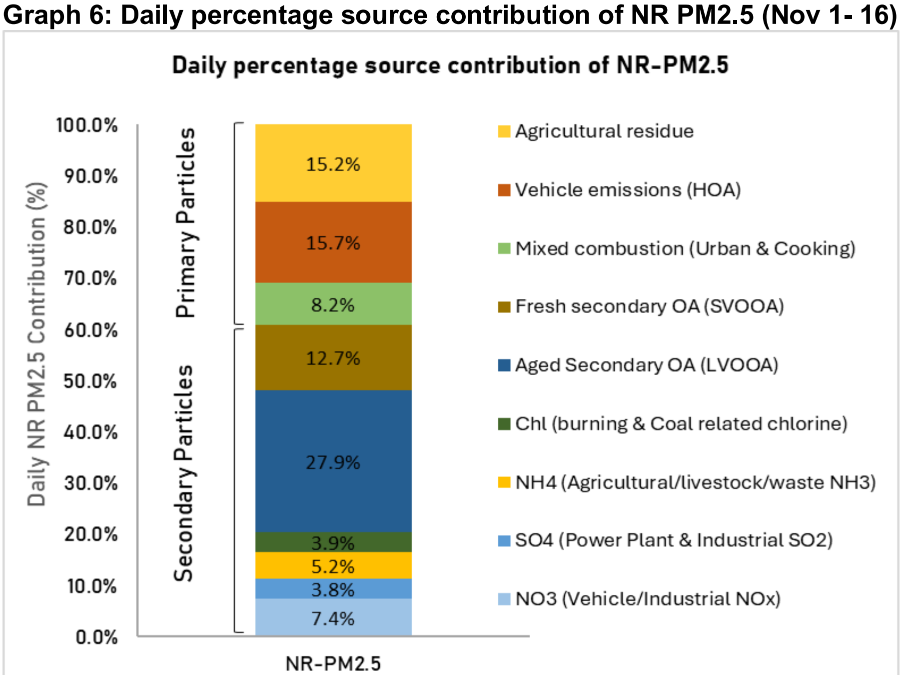
This brings out the dominance of Secondary Particles. Data from November 1–16, 2025, shows that directly emitted primary particles (from vehicles, industries, and fires) account for only 39% of the pollution. The remaining 61 per cent consists of secondary particles formed in the atmosphere. These particles form when precursor gases like SO2, NOx, NH3, and VOCs react in the air. Stagnant winter conditions—characterized by low temperatures, weak winds, and shallow mixing heights—accelerate these reactions, allowing gases to convert into particles up to 1.6 times faster than primary particles are emitted. This has transboundary impact. A major share of these are Aged Secondary Organic Aerosols (OOA), which are highly oxidized particles associated with long-range transport into Delhi from the wider region.

Despite the significant role of secondary chemistry, vehicles remain the undisputed leader in primary emissions. Within the primary particle fraction, vehicles contribute nearly 40 per cent, aligning closely with separate DSS estimates that attribute 46 per cent of Delhi's local PM2.5 emissions to the transport sector. Vehicles are also a major source of the precursor gases (like NOx) that eventually react to form the secondary nitrates and organic aerosols that dominate the city's transboundary pollution.

This assessment indicates that air quality cannot be improved simply by managing visible smoke; it requires a coordinated strategy to reduce the invisible precursor gases emitted by vehicles and industries across the entire regional airshed *(see Graph 6: Daily percentage source contribution of NR PM2.5 (Nov 1- 16)).*

Because secondary particles are typically finer, more persistent, and more toxic—penetrating deeper into the lungs—understanding their chemical makeup allows for more accurate assessments of the public health risk.

Graph 6: Daily percentage source contribution of NR PM2.5 (Nov 1- 16)



Note: HOA stands for Hydrocarbon like Organic Aerosol, SVOOA stands for Semi-Volatile Oxygenated Organic Aerosol and LVOOA stands for Low-Volatile Oxygenated Organic Aerosol.
Source: CSE analysis of IITM data.

This data analysis reveals that Delhi's winter pollution is a complex, structural crisis that persists independently of seasonal agricultural activities. By examining both local and transboundary sources, the study identifies a "dual challenge" that requires more than just episodic management.

This requires shifts in the policy focus. This data analysis proves that winter pollution cannot be solved by focusing only on visible emitters like farm fires. Effective control must target invisible precursor gases emitted by vehicles, power plants, industries, and household fuel use. Vehicles, in particular, are a key upstream driver of nitrate pollution through NOx emissions, making traffic control critical not just for reducing primary PM2.5. At the same time, power plants, industries, diesel generators, waste and biomass burning, and household fuel use also emit substantial amounts of these precursor gases.

Implement clean air action strategy across the Airshed. This requires coordinated regional strategies rather than isolated city-level actions. Only a comprehensive approach that reduces both direct primary emissions and the regional gases driving secondary particle formation can deliver sustained improvements in Delhi's air quality.

CSE has proposed the following key action points:

- **Meet ambitious electrification targets** for all segments of vehicles in a time-bound manner for zero tailpipe emissions; **scrap and replace older vehicles**
- **Upscale integrated public transport** with last-mile connectivity and walking and cycling infrastructure to increase ridership and active commuting
- **Restrain the use of personal vehicles** with parking caps and pricing and congestion tax
- **Encourage industry to switch** over to affordable cleaner fuels and stringent emissions control; lower the taxes on natural gas; electrify industrial processes
- **Close the waste loop** to stop burning: segregate waste, remediate legacy waste and promote recycling
- **Force power plants to meet emission standards**
- **Recycle construction waste, enforce dust-control**; put into place smart monitoring systems for enforcement throughout the year
- **Ensure access to clean fuels for households** for cooking and heating
- **Eliminate farm fires --** decompose or plough straw back into the soil to increase soil carbon. Encourage bio-methanation of straw for fuel and natural gas to increase the income of farmers