Another toxic winter: Air pollution crisis in Delhi-NCR

Anumita Roychowdhury and Avikal Somvanshi
Reseach contribution: Sharanjeet Kaur

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As the winter season comes to a close, an analysis of the overall winter trend in Delhi and NCR indicate continuing drop in seasonal average but elevated levels prevailed. If not acted upon immediately this trend can worsen in the coming years negating the downward dip of the pandemic years. This has been the second winter since 2020 when the hard and partial lockdowns had started. This has emerged from the new analysis of the air quality tracker initiative of the Centre for Science and Environment (CSE).

This analysis of the real-time data from monitoring stations in Delhi-NCR for the entire winter period (October 1-February 28), shows that despite heavy and prolonged rains in different phases this winter, long smog episodes and elevated levels have prevailed. Region recorded a few days of satisfactory air quality in January which has not happened in previous three seasons. This was due to unprecedented heavy rainfall and lockdown imposed on the city due to omicron-wave of pandemic in January.

Elevated pollution levels and smog episodes are an evidence of the systemic pollution that has continued in the region due to inadequate infrastructure and systems for pollution control in all sectors. This can be tamed only if round-the-year action becomes more stringent and uniform across sectors and the region. Action has to be performance based to meet the clean air standards

Even though there is considerable variation in seasonal averages across the region, winter pollution episodes are alarmingly high and synchronized in the region despite large distances. This is the challenge of this landlocked region. Despite being the wettest winter, the overall winter average of PM2.5 has stayed elevated and the overall contribution of the local and regional sources are higher than the stubble-smoke

Data used in the analysis: The analysis is based on publicly available data from various government agencies. Most granular data (15-minute averages) has been sourced from the Central Pollution Control Board's (CPCB) official online portal Central Control Room for Air Quality Management - All India (https://app.cpcbccr.com/). This has analysed data recorded by 81 air quality monitoring stations under the Continuous Ambient Air Quality Monitoring System (CAAQMS) of CPCB. Farm stubble fire data has been sourced from System of Air Quality and Weather Forecasting and Research (SAFAR). Weather data has been sourced from the Safdarjang weather station of Indian Meteorological Department (IMD). Delhi (40), Ghaziabad (4), Noida (4), Gurugram (4), Faridabad (4), Meerut (3) and Greater Noida (2) have more than one real-time station, therefore citywide average is used for comparative analysis and it is defined as average of all city stations that meet minimum 75 per cent data availability criteria.

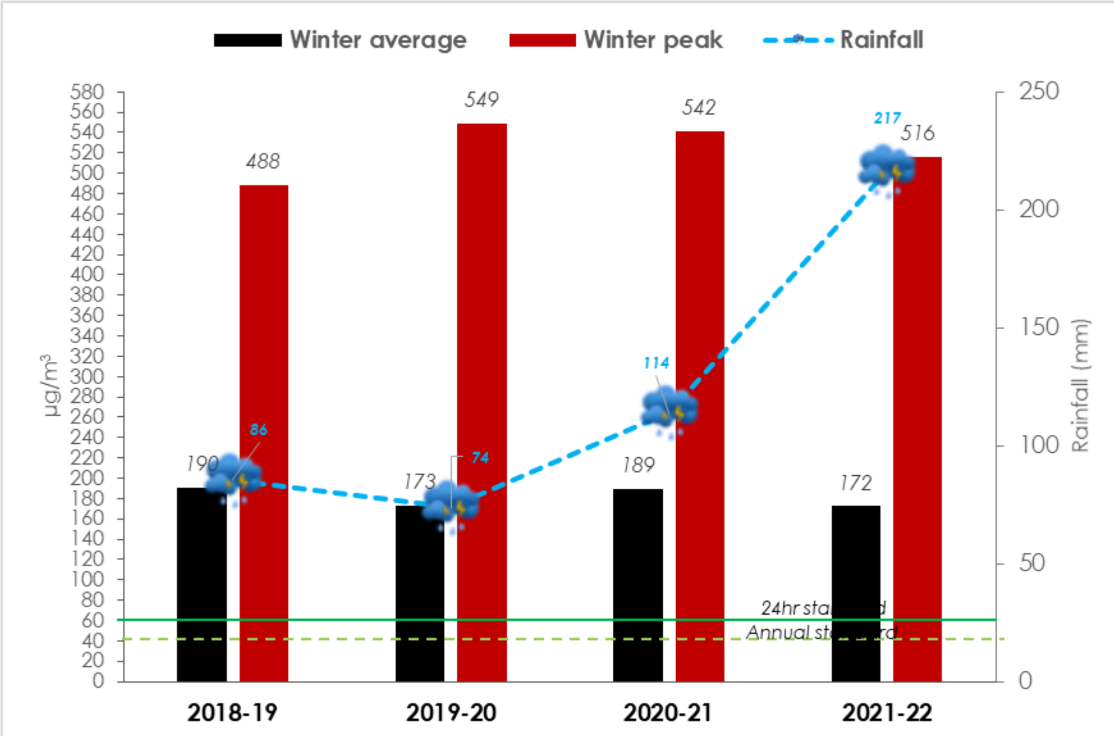
Key highlights

Delhi

Only marginal improvement in Delhi's air quality despite the wettest winter in over a century: The citywide winter average for Delhi stood at 172 $\mu g/m^3$ which is identical to the seasonal average of 2019-20 winter but 9 per cent lower than seasonal average of 2020-21 winter. The seasonal peak was about 5 per cent lower than both preceding winters (See *Graph 1: Trend on winter pollution in Delhi*).

Meteorologically, this winter was the wettest in recent years with almost 2-3 fold more rainfall compared to previous winters, bulk of which happened in January making it least polluted January since real time air quality monitoring started in the city. But this meteorological advantage did not give much reprieve to the city as rapid built-up in-between rain-spells and formation of smog episodes during rainless periods kept overall seasonal average toxically high.

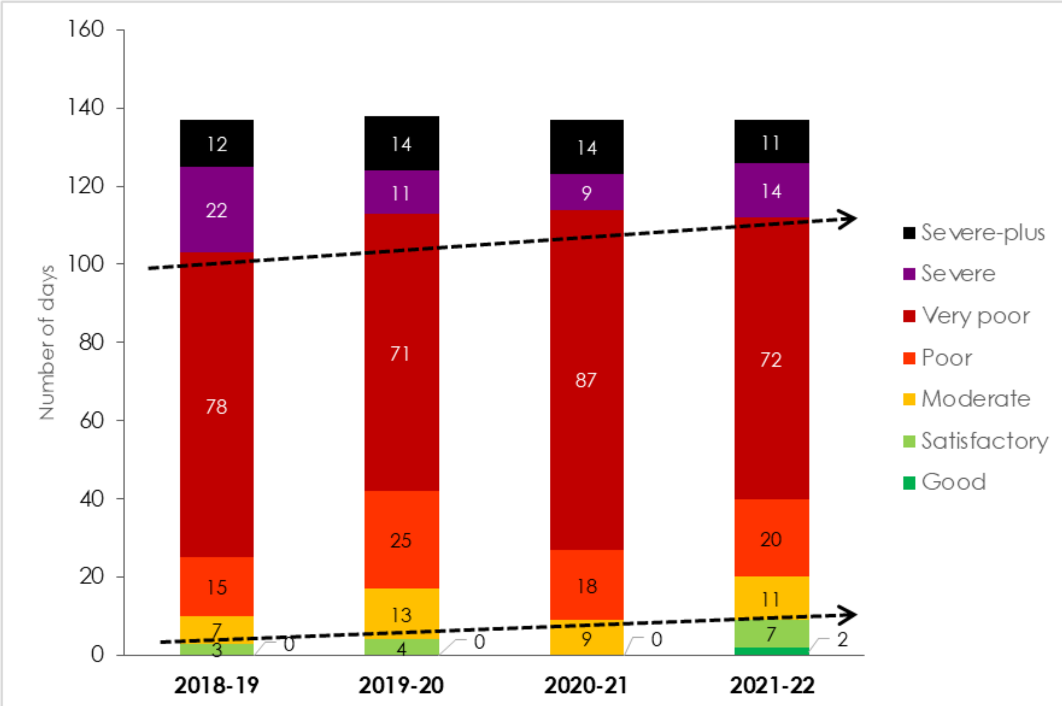
Graph 1: Trend on winter pollution in Delhi



Note: Average $PM_{2.5}$ concentration is based on mean of daily values recorded at 38 CAAQM stations in the city that have adequate data for all four winters.
Source: CSE analysis of CPCB's real time air quality data and IMD's weather data.

Number of days with severe or worse air quality bounced back to pre-covid level: This winter 25 days had citywide average in "severe' or worse AQI category, this is up from 23 such days in pervious winter and at par with 25 days in 2019-20 winter (See *Graph 2: Decline in number of "severe" and worse air days in Delhi*). City also saw 2 days of good air and 7 days of satisfactory air this winter which is an improvement from last winter when no such low pollution days were recorded. This high variability in air quality this winter can be attributed to increased number of heavy rainfall days and colder than weather.

Graph 2: Decline in number of "severe" and worse air days in Delhi

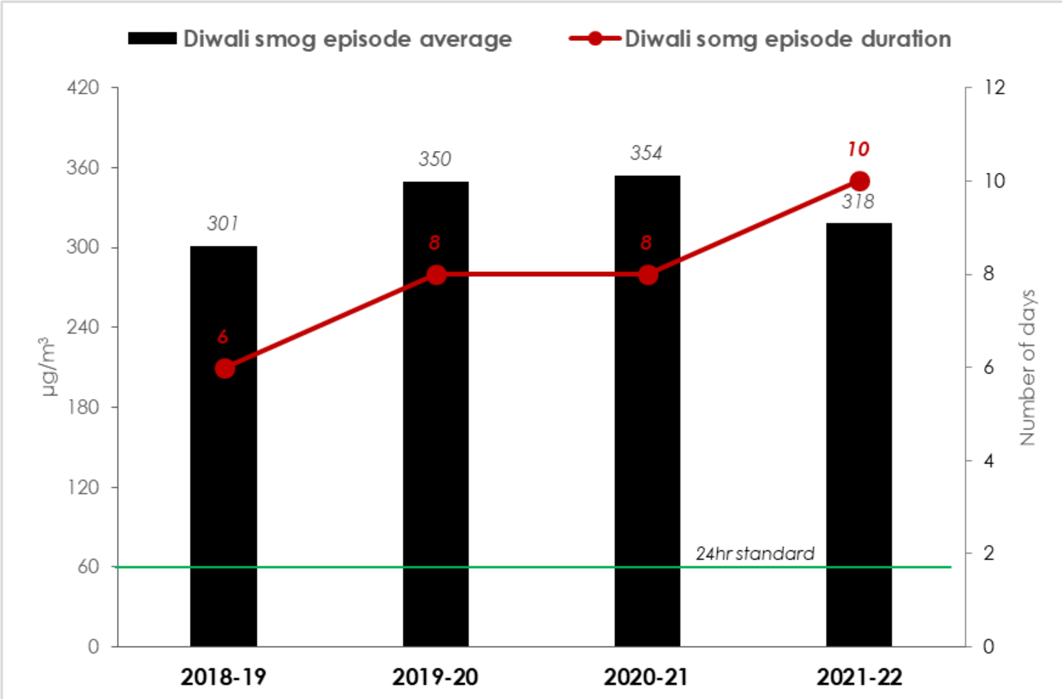


Note: Average $PM_{2.5}$ concentration is based on mean of daily values recorded at 38 CAAQM stations in the city that have adequate data for all four winters.
Source: CSE analysis of CPCB's real time air quality data

Intensity of winter smog dips but duration lengthens this winter: This year's early winter smog episode that built up around Diwali (starting on Nov 04) lasted 10 days which is longer than the longest Diwali smog episodes recorded in previous three winters (See *Graph 3: Intensive and duration of Diwali smog episodes 2018-2022*). Smog episodes in 2018-19, 2019-20, and 2020-21 lasted 6 days (starting on 8 Nov 2018), 8 days (starting on 28 Oct 2019), and 7 days (starting on 4 Nov 2020) respectively. Intensity of this year's main smog episode was 318 ug/m3 per day, which is about 10 per cent lower than the intensity of main smog episodes of previous two winters. It can be argued that this marginal decline in the intensity is negated by the longer duration of the episode. Technically, a smog episode is defined for the purpose of emergency action under the Graded Response Action Plan when the levels of $PM_{2.5}$ remain in "severe" category for three consecutive days. In this study, if two consecutive smog episodes are separated by only one day and the PM2.5 level of that day doesn't drop below 200 ug/m3 then the whole period is considered a single extended smog episode.

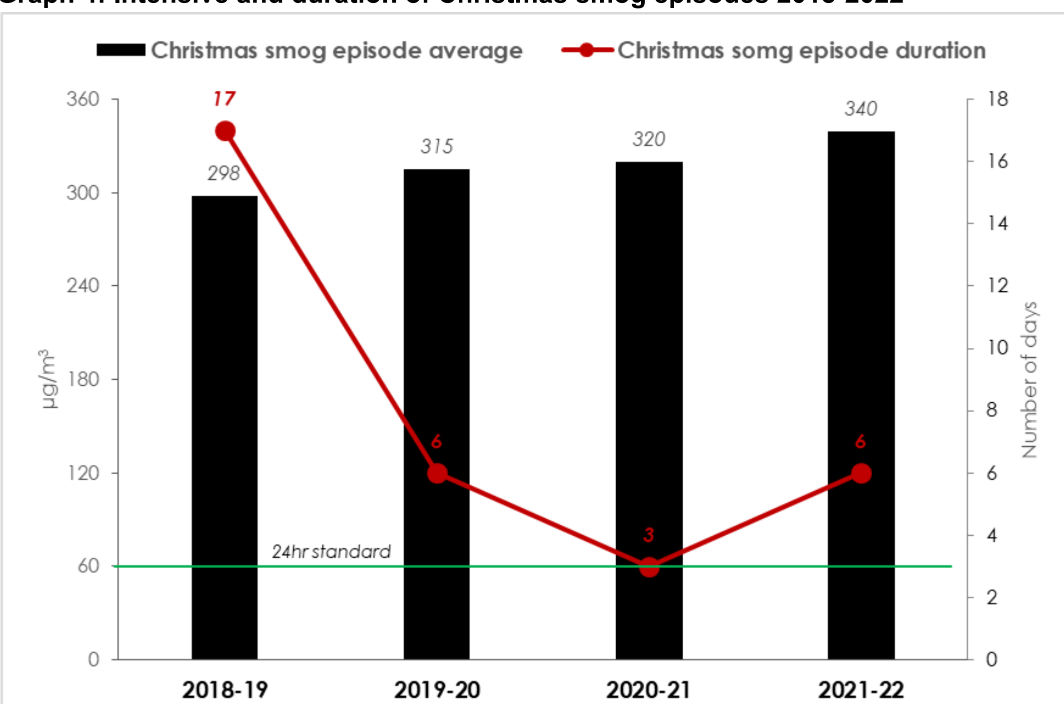
Similarly, the late winter smog this year started on 21st Dec and lasted 9 days with intensity of 340 ug/m3 per day (See *Graph 4: Intensive and duration of Christmas smog episodes 2018-2022*). This was both longer and more intense compared to previous Christmas smog which started 22nd Dec and last only 3 days with intensity of 320 ug/m3. Duration wise 2018 Christmas smog was the longest in recent years lasting 17 days. Interestingly, this is the first year when the smog intensity during Christmas smog episode is found to be higher than the intensity of its Diwali smog episode.

Graph 3: Intensive and duration of Diwali smog episodes 2018-2022



Note: Average $PM_{2.5}$ concentration is based on mean of daily values recorded at 38 CAAQM stations in the city that have adequate data for all four winters. Diwali smog episodes for 2018-19, 2019-20, 2020-21, and 2021-22 started on 8 Nov 2018, 28 Oct 2019, 4 Nov 2020 and 4 Nov 2021 respectively.
Source: CSE analysis of CPCB's real time air quality data

Graph 4: Intensive and duration of Christmas smog episodes 2018-2022



Note: Average $PM_{2.5}$ concentration is based on mean of daily values recorded at 38 CAAQM stations in the city that have adequate data for all four winters. Christmas smog episodes for 2018-19, 2019-20, 2020-21, and 2021-22 started on 20 Dec 2018, 28 Dec 2019, 22 Dec 2020 and 21 Dec 2021 respectively.
Source: CSE analysis of CPCB's real time air quality data

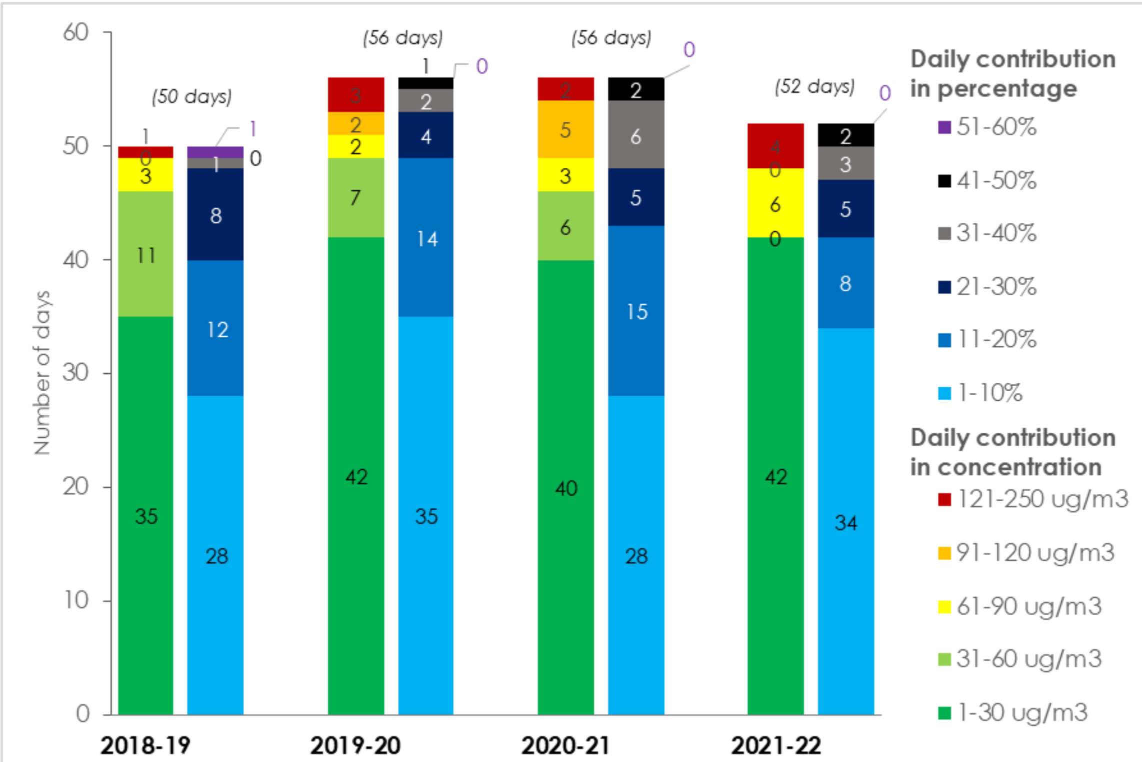
The days with severe air quality occurred in cluster of days making extended smog episode. This is different from previous winter when they were spread across the season leading to lesser number and duration of smog episodes. Smog pattern is similar to the one observed in 2019-20 winter. This year there were three smog episodes first started on 4rd Nov and lasted 10 days, second started on 25th Nov and last 4 days, and third started on 21st Dec and lasted 6 days (See *Graph 5: Map of smog episode in Delhi*). These are more and longer compared to previous winters which had only two smog episodes lasting 7 days and 3 days. 2019-20 winter had three smog episodes of 8 days, 5 days and 6 days durations. 2018-19 winter had four smog episodes of 6 days, 17 days, 3 days and 5 days durations last two occurring in January. Relatively slow dissipation of smog episodes this year compared to previous year points towards increase in the overall pollution load in the larger air shed (all the gains of lockdowns lost) and ineffectiveness of ad-hoc pollution control efforts. Higher intensity of Christmas time smog episode also points towards increased load from local pollution.

Graph 5: Map of smog episode in Delhi

Note: Average $PM_{2.5}$ concentration is based on mean of daily values recorded at 38 CAAQM stations in the city that have adequate data for last four winters.
Source: CSE analysis of CPCB's real time air quality data

Stubble burning more concentrated in time: According to SAFAR smoke from the stubble fire in northern states started contributing to Delhi's PM2.5 level from 10th October and ended on 30th November. During this 52 days percentage contribution varied between 1 per cent and 48 per cent with later being reported on 7th November. This winter's stubble fire season was 4 days shorter than ones in previous two winters. Number of days when percentage contribution was over 40 per cent was same this winter as last year, i.e. 2 days. But if looked from absolute concentration terms this year had twice the number of days when PM2.5 load from stubble fire was high enough to plunge Delhi's air quality into "very poor" on its own (See *Graph 6: Daily distribution of stubble fire smoke contribution to Delhi's air*). Further, these high contribution load days happened in cluster. Which indicates that mega bulk burning instances took place in span of a few days this year than previous years. This might be due to extended monsoon which reduced the rain-free period before sowing of wheat crop.

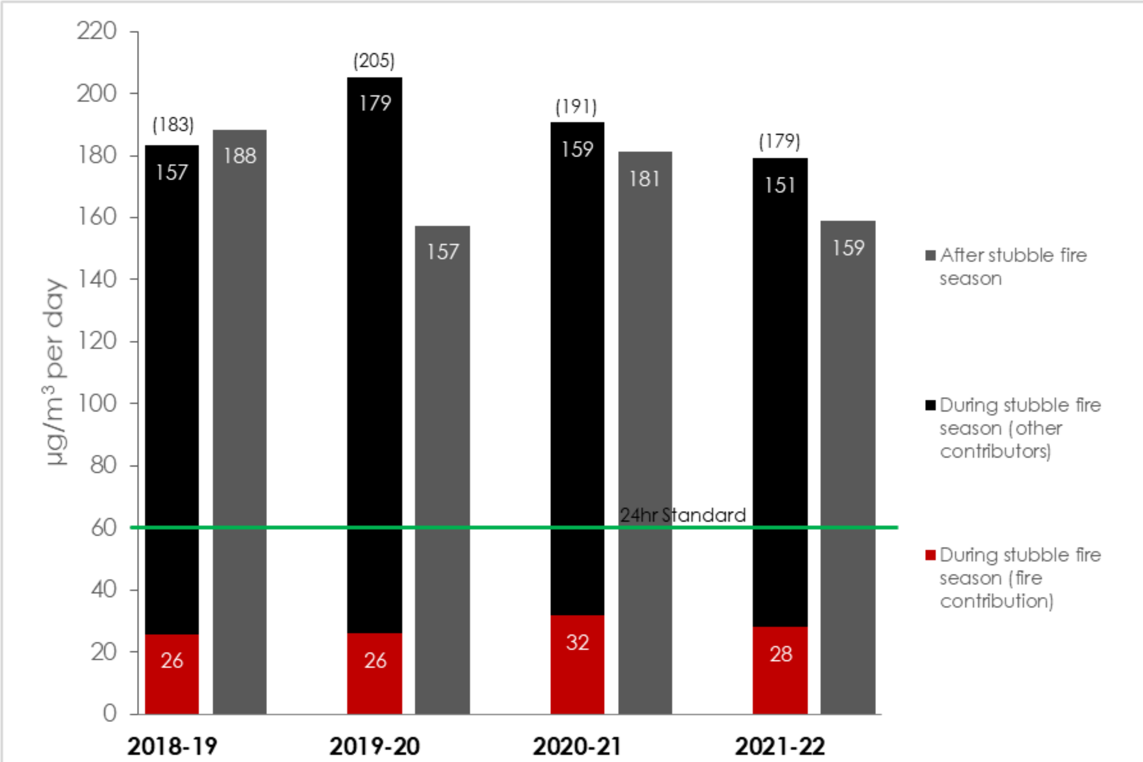
Graph 6: Daily distribution of stubble fire smoke contribution to Delhi's air



Note: Average $PM_{2.5}$ concentration is based on mean of daily values recorded at 38 CAAQM stations in the city that have adequate data for all four winters. Stubble fire smoke started entering Delhi air for 2018-19, 2019-20, 2020-21, and 2021-22 on 10 Oct 2018, 16 Oct 2019, 10 Oct 2020 and 10 Oct 2021 respectively.
Source: CSE analysis of CPCB's real time air quality data and SAFAR's stubble fire contribution data

Winter gets smoggy even without the stubble smoke:. Average concentration of stubble fire smoke in Delhi's air during the 52 days in Oct-Dec this year was 28 ug/m3 per day (See *Graph 7: Seasonal distribution of stubble fire smoke contribution to Delhi's air*). The rest of the PM2.5 in Delhi during those days was of non-stubble fire origin. This is consistent with the trend noted during previous winter. Smoke from stubble fires only tips over the local-regional pollution load, which is already elevated due to inversion, to severe category. In fact, smog episodes during late December occur even without the influence of stubble smoke. The average daily load of PM2.5 post-stubble fire season (mid-December to end-February) when there is no influence of stubble smoke the average PM2.5 was only 5 per cent higher than the average note during the stubble fire season this year. As noted in during previous winters as well, over 80 per cent of daily PM2.5 level on average is of non-stubble origin.

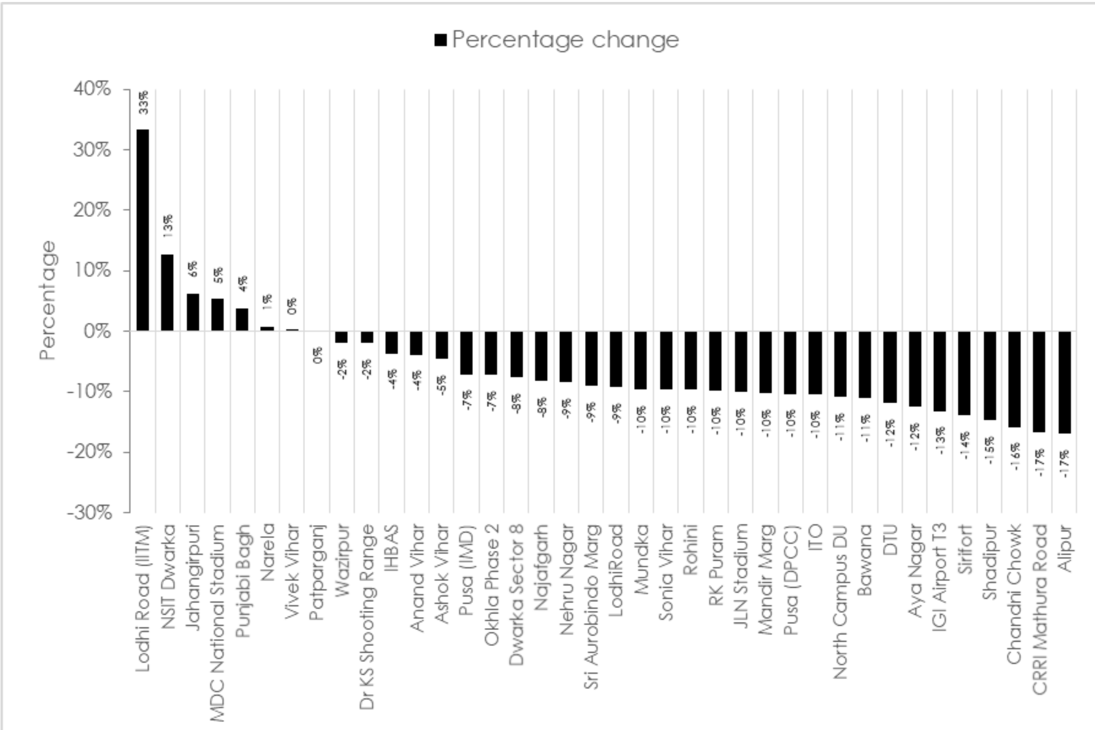
Graph 7: Seasonal distribution of stubble fire smoke contribution to Delhi's air



Note: Average $PM_{2.5}$ concentration is based on mean of daily values recorded at 38 CAAQM stations in the city that have adequate data for all four winters. Stubble fire smoke started entering Delhi air for 2018-19, 2019-20, 2020-21, and 2021-22 on 10 Oct 2018, 16 Oct 2019, 10 Oct 2020 and 10 Oct 2021 respectively.
Source: CSE analysis of CPCB's real time air quality data and SAFAR's stubble fire contribution data

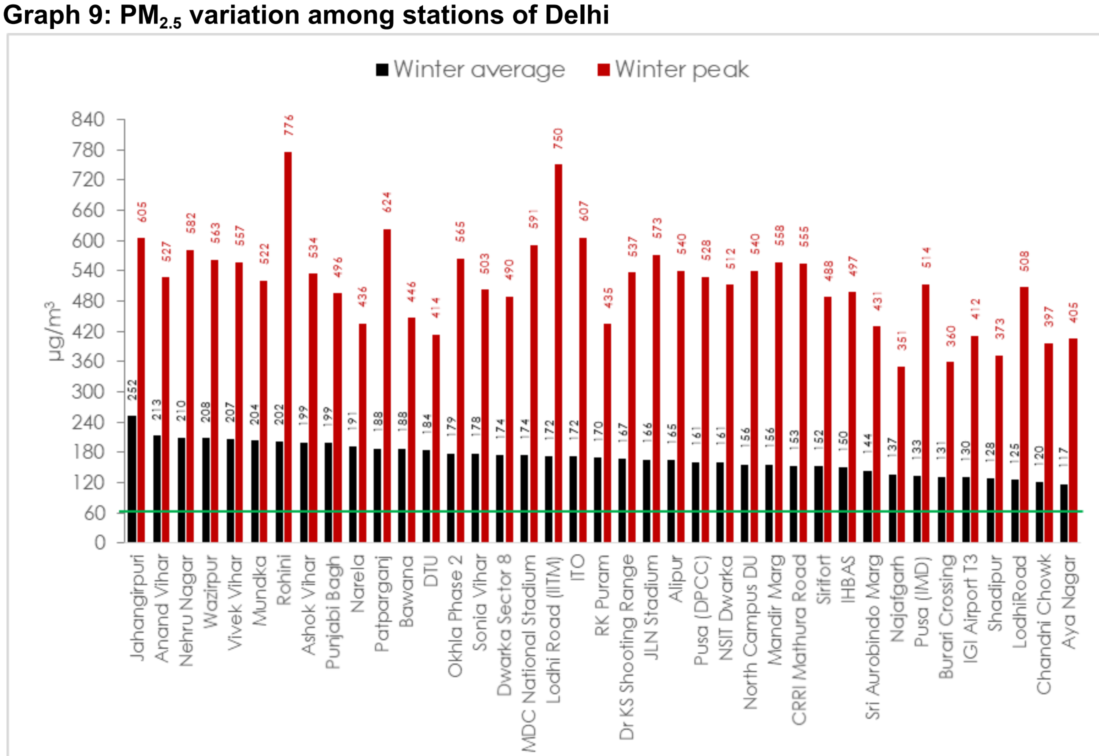
Variation among city's stations remain significant, indicating dominance of local pollution sources, influence of micro climate and level of action: 30 out of 38 stations saw improvement in their seasonal average over last year. Most improvement was noted at Alipur and CRRI Mathura Road which registered 17 per cent lower seasonal average this winter compared to mean of pervious three winters. Most increase was noted at Load Road (IITM) station (See *Graph 8: Change in seasonal $PM_{2.5}$ level among stations of Delhi compare to mean of previous three winters*). Even though most station saw improvement this winter pollution level remained very high. The seasonal average ranged between 252 ug/m3 at Jahangiripuri and 117 ug/m3 at Aya Nagar. This 145 ug/m3 variation within the city indicates dominance of local pollution sources and level of action in different hotspots. Other than Jahangirpuri, stations at Anand Vihar, - Wazirpur, Mundka, Rohini and Ashok Vihar also recorded seasonal average in excess of 200 ug/m3. Lodhi Road and Rohini registered highest peak pollution day with 24hr average crossing 700 ug/m3. Najafgarh's peak of 351 ug/m3 was the lowest in the city despite being almost 6-times the 24-hr standard (See *Graph 9: $PM_{2.5}$ variation among stations of Delhi*).. Peak pollution days occur approximately around same time across all the city stations. But there seems to be no correlation between magnitude of seasonal peak and seasonal average.

Graph 8: Change in seasonal $PM_{2.5}$ level among stations of Delhi compare to mean of previous three winters



Note: Average $PM_{2.5}$ concentration is based on mean of daily values recorded at CAAQM stations in the city that have adequate data for all three winters.
Source: CSE analysis of CPCB's real time air quality data

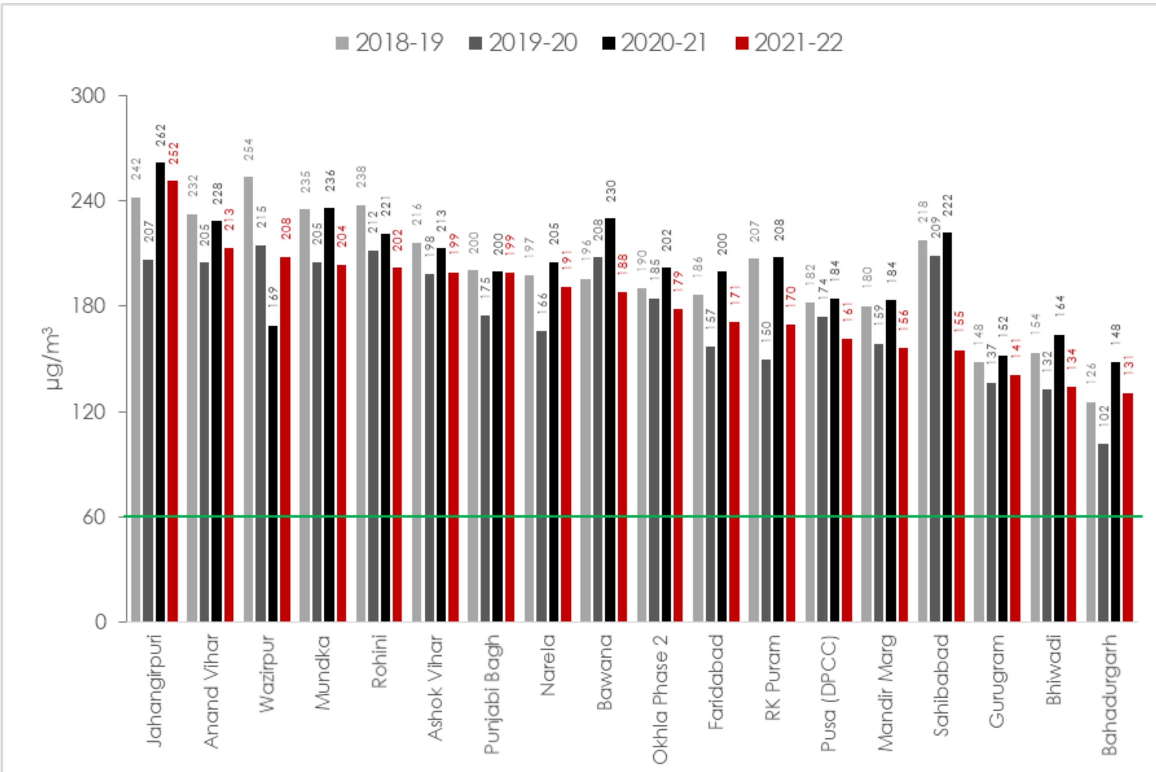
Graph 9: $PM_{2.5}$ variation among stations of Delhi



Source: CSE analysis of CPCB's real time air quality data

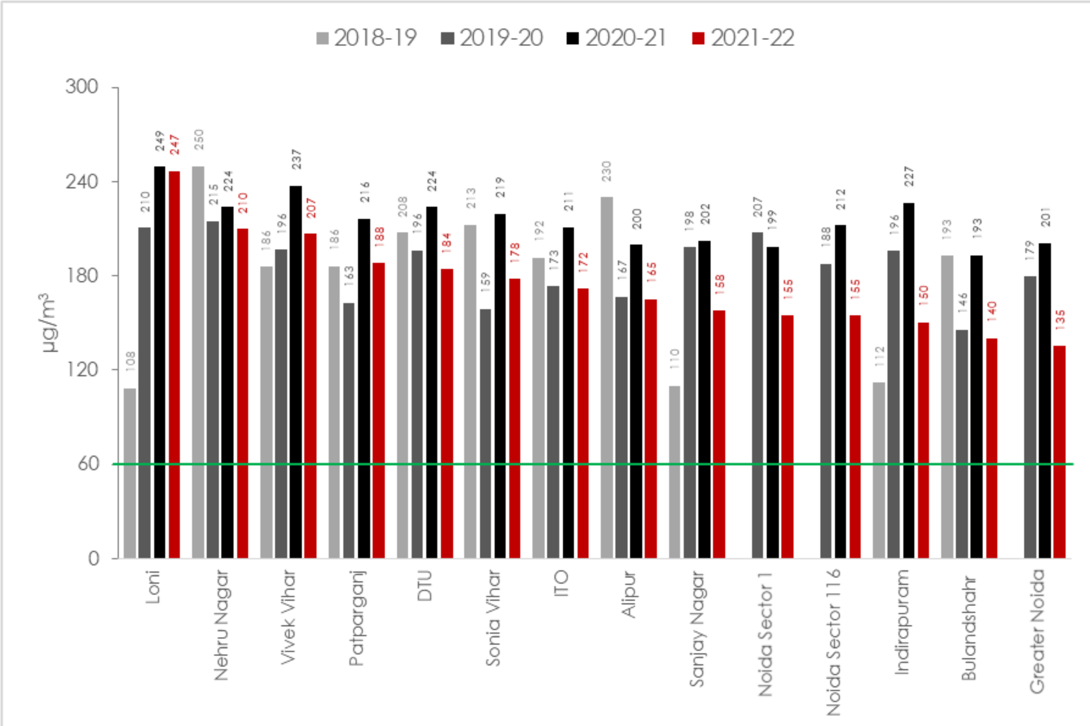
Wizirpur was the only recognized hotspot that registered worsening of air: Except Wazirpur, all the locations on Delhi-NCR pollution hotspot list saw decline in the seasonal PM2.5 level compared to last winter. Bahadurgarh with seasonal average of 131 ug/m3 continues to be the least polluted of the hotspots (See *Graph 10: Winter pollution at hotspots*). Jahangirpuri with a seasonal average of 252 µg/m^3 was the dirtiest among the recognized hotspots. Very high levels were noted among emerging hotspots identified by CSE in the previous winter (See *Graph 11: Winter pollution at emerging hotspots*). Loni in Ghaziabad was the most polluted among the emerging hotspots with seasonal average of 247 ug/m3. Greater Noida with seasonal average of 135 ug/m3 was the least polluted from this group.

Graph 10: Winter pollution at hotspots



Note: Average $PM_{2.5}$ concentration is based on mean of daily values recorded at the CAAQM stations given it has adequate data for the winter. . Mayapuri and Sahibabad don't have a CAAQM station, therefore nearest station to them (Pusa DPCC and Vasundhara respectively) is used to represent their air quality. Gurugram and Faridabad are represented by their oldest station- Vikas Sadan and Sector 16A respectively.
Source: CSE analysis of CPCB's real time air quality data

Graph 11: Winter pollution at emerging hotspots

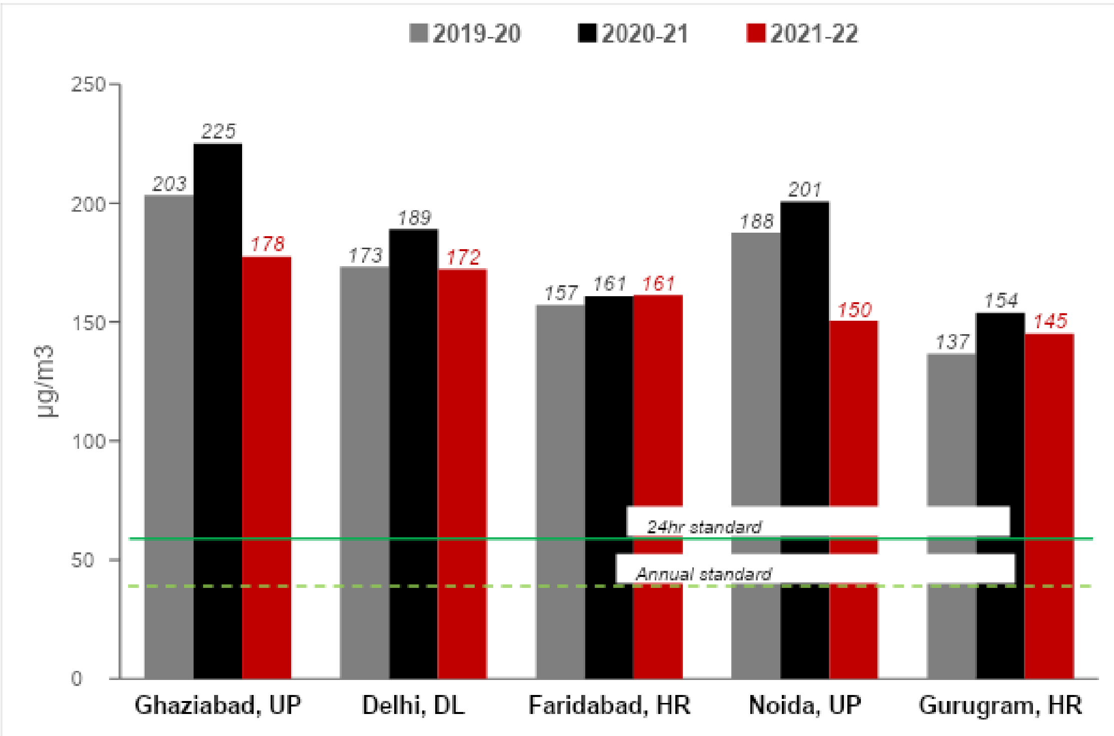


Source: CSE analysis of CPCB's real time air quality data

National Capital region

Ghaziabad was the most polluted among the four major satillite towns in NCR. Only Faidabad registered increase in seasonal average compared to last winter. Among the four big NCR cities, Gaziabad and NOIDA have registered relatively higher improvement in their seasonal winter average compared to Gurugram and Faridabad (See *Graph 12: Winter pollution in main NCR cities*).

Graph 12: Winter pollution in main NCR cities

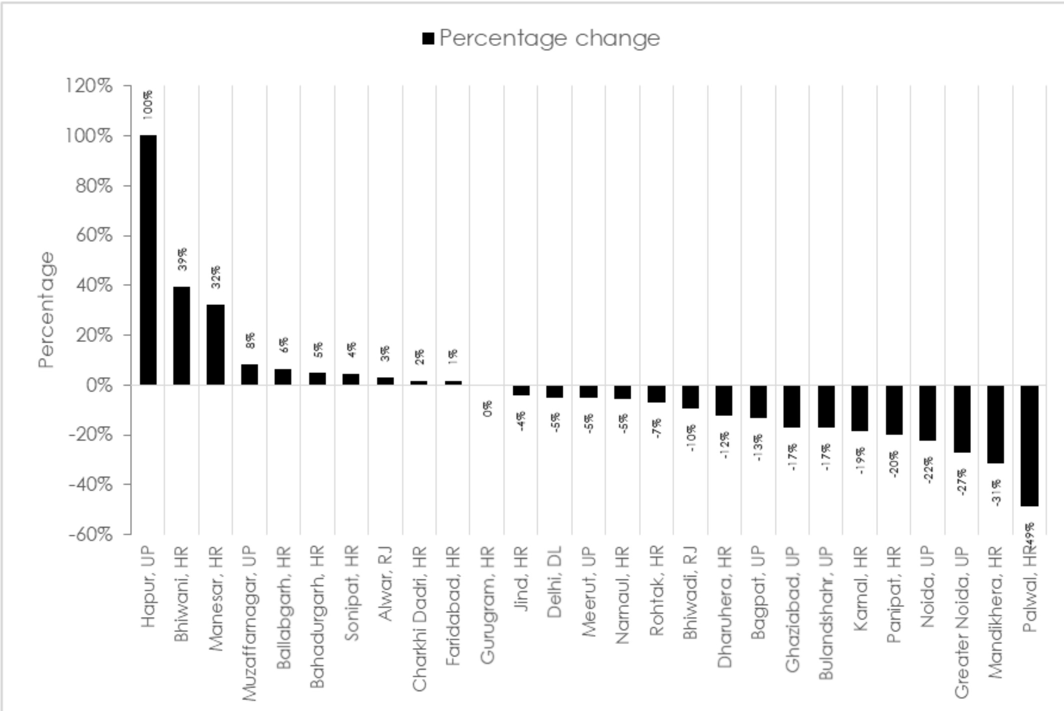


Note: Average $PM_{2.5}$ concentration is based on mean of daily values recorded at CAAQM stations in the city that have adequate data for all three winters.
Source: CSE analysis of CPCB's real time air quality data

Pollution is rising in smaller towns of NCR though there is a mixed trend: Ten out of 27 NCR towns show detoriation in sesonal average from the mean of previous three winters, even though Delhi registered improvement. All these are smaller towns. Air quality detoriated most in Hapur in UP which saw doubling of its seasonal average to 142 ug/m3 this winter. It was followed by Bhiwani and Manesar in Haryana that registered over 30 per cent decline in seasonal air quality. Palwal and Mandikhera in Haryana registered most improvement (exceeding 30 per cent). Half of the cities show less than 10 per cent change in their seasonal average (See *Graph 13: Change in seasonal PM2.5 level among NCR cities compare to mean of previous three winters*).

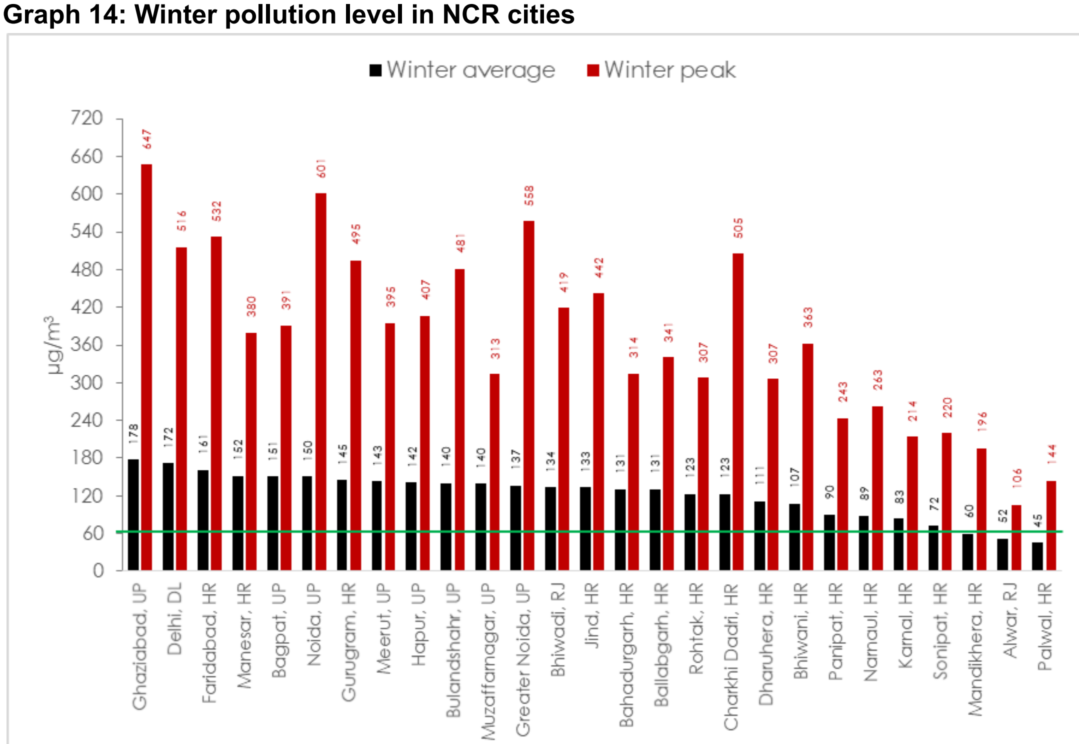
Big cities of NCR continue to be the most polluted with highest seasonal average and peak pollution levels but smaller towns are not far behind. Predictably, Ghaziabad, Delhi and Faridabad were the most polluted cities in the NCR this winter. But Manesar and Bagpat with seasonal average over 150 ug/m3 overtook Nodia and Gurugram (See *Graph 14: Winter pollution level in NCR cities*). Similarly, Hapur and Bulandshahr recorded higher seasonal averages than industrial town of Bhiwadi. Palwal, Alwar and Mandikhera at the southern edge of NCR recorded the lowest seasonal average.

Graph 13: Change in seasonal $PM_{2.5}$ level among NCR cities compared to mean of previous three winters



Note: Average $PM_{2.5}$ concentration is based on mean of daily values recorded at CAAQM stations in the city that have adequate data for the winter.
Source: CSE analysis of CPCB's real time air quality data

Graph 14: Winter pollution level in NCR cities

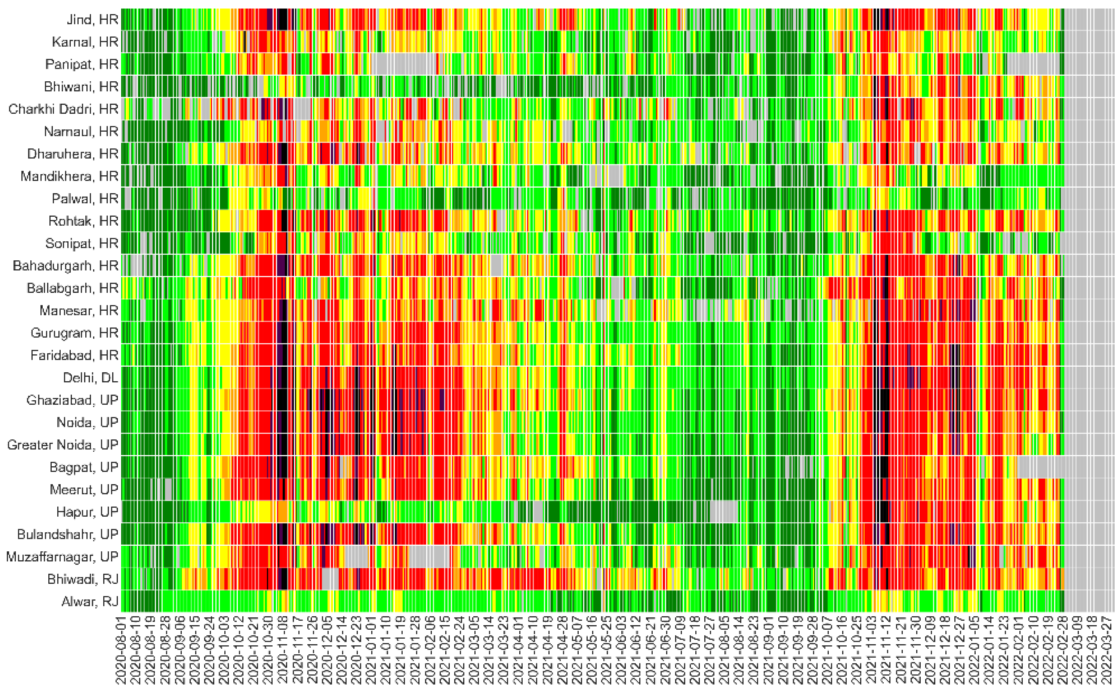


Note: Average $PM_{2.5}$ concentration is based on mean of daily values recorded at CAAQM stations in the city that have adequate data

for the winter.
Source: CSE analysis of CPCB’s real time air quality data

Early winter smog synchronise across the region but is more severe in Delhi and big four: Normally the smog episodes of November synchronise across the northern region. But it is more intense and lingers longer in Delhi and its immediate neighboring cities. Atmospheric changes during winter that include inversion, calm conditions, change in wind direction and seasonal drop in ambient temperature across North India entraps pollution. This is further tripped into severe category by smoke from farm fires and Diwali firecrackers during November. But air quality improves from severe to poor and moderate category in cities farther from Delhi but it remains in very poor category in Delhi and big four till February (See *Graph 15: PM2.5 calendar for NCR cities*).

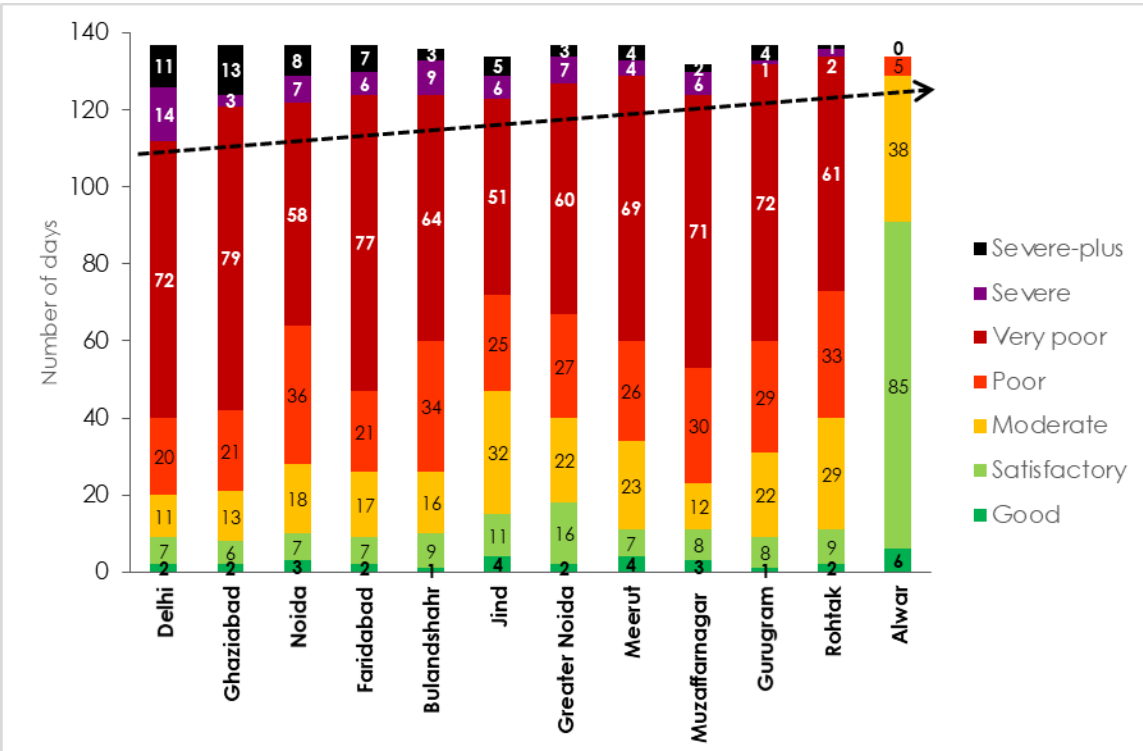
Graph 15: PM2.5 calendar for NCR cities



Note: Average $PM_{2.5}$ concentration is based on mean of daily values recorded at all CAAQM stations in the city that have adequate data for the winter.
Source: CSE analysis of CPCB’s real time air quality data

Though on a declining trend, Delhi still had the highest number of days in severe or worse air quality categories among the major NCR cities: Though the overall number of days in severe or very poor quality reduced and stabilsued during this winter, the city has still recorded higher number of most severe days compared to other big cities in NCR during 2021-22 winter. Delhi recorded 25 days with severe or worse air quality this winter. It was followed by Ghaziabad recording 16 days of severe or worse air quality (See *Graph 16: AQI days distribution for NCR cities*).. Noida, Faridabad and Gurugram recorded with 15 days, 13 days and 5 days of severe or worse days respectively. Despite significant variation in number of highly polluted days among the cities, number of good air days are identical across the region. These 2-4 good air days coincide with heavy rainfall and are not result of on ground pollution control.

Graph 16: AQI days distribution for NCR cities



Note: Average $PM_{2.5}$ concentration is based on mean of daily values recorded at all CAAQM stations in the city that have adequate data for the winter.
Source: CSE analysis of CPCB's real time air quality data

Need upscaled action

This final analysis of winter pollution in Delhi and NCR has shown that there is a risk of pollution bouncing back with the reopening of the economy and increased traffic intensity post hard locked down phases. High winter pollution only indicates the magnitude of local and regional pollution that gets easily trapped when winter conditions turn cool and calm with deepening of inversion. This requires strong action to introduce clean energy across all sectors, transformation of urban commuting with upscaled public transport, walking and cycling infrastructure and vehicle restraint measures and long distance freight management, and complete recycling of all waste streams through a strong infrastructure for material recovery. This region now requires performance based action to ensure clean air standards are met in a time bound manner.