Winter smog thinning over Delhi-NCR: End of winter air pollution analysis

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As the winter season comes to a close, an analysis of PM2.5 trends for the period October-January in the Delhi and the National Capital Region (NCR) region conducted by the Urban Lab at the Centre for Science and Environment (CSE) has revealed a continuing drop in seasonal average levels of air pollution, although elevated levels prevailed at city stations. This analysis was conducted to understand the behavior of winter pollution in the region, and to compare it with the longer term context of seasonal variation and annual trends in particulate pollution.

This analysis of the real-time data from monitoring stations in Delhi-NCR for the winter period (October 1-January 31), reveals that this winter was the cleanest since large scale air quality monitoring started in 2018, largely due to heavy and extended rainfall in the early phases of the season. However, there were still 10 days of severe or worse air quality and one four days long smog episode during this winter. In the larger NCR, seasonal averages vary considerably among the cities and towns but high pollution episodes are synchronized despite large distances. Delhi and neighboring cities of Faridabad, Ghaziabad, Gurugram, and Noida are relatively more polluted than other NCR towns but not by significantly. This is the challenge of this landlocked region.

A comprehensive analysis of the PM2.5 trend during the entire winter season (October-January) in Delhi and National Capital Region (NCR) show bending of the winter pollution curve and lowering of peak levels.

This analysis was conducted to understand the behavior of winter pollution in the region, and assess the long seasonal trends. The shows that there were still 10 days of severe and severe plus air quality and one four day long smog episode during this winter. In the larger NCR, seasonal averages varied considerably among the cities and towns but high pollution episodes are synchronized despite large distances. Delhi and neighboring cities of Faridabad, Ghaziabad, Gurugram, and Noida are relatively more polluted than other NCR towns but not by significantly.

This improvement is a combined effect of meteorology and emergency action based on pollution forecasting. There was heavy and extended rainfall in the early phases of the season that prevented smog episodes from building up and also lowered the seasonal average. Despite the decline, Delhi continues to remain the most polluted among the cities and towns of NCR. This downward trend will have to be sustained with much stronger action on vehicles, industry, waste burning, construction, solid fuel and bio mass burning to meet the clean air standard.

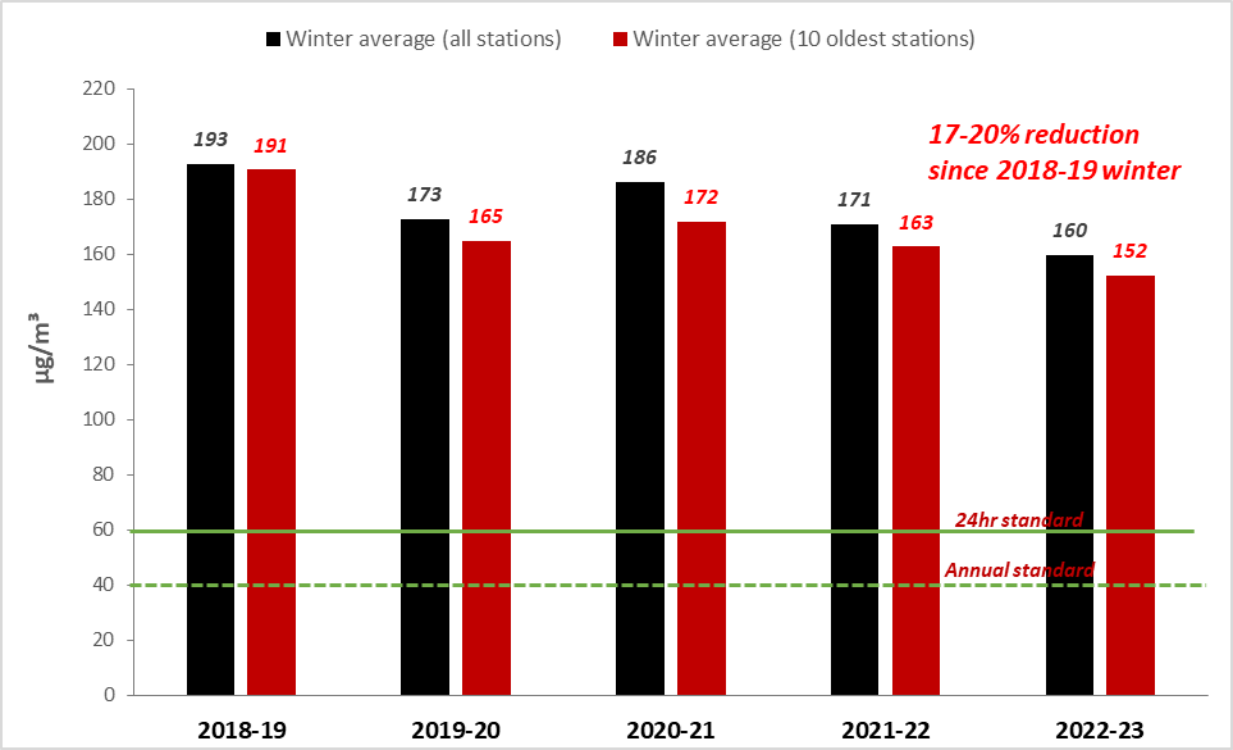
Data used in the analysis: This is an assessment of annual and seasonal trends in PM2.5 concentration for the period 1 October to 31 January for 2018, 2019, 2020, 2021 and 2022. This analysis is based on the real time data available from the current working air quality monitoring stations in Delhi-NCR. A huge volume of data points have been cleaned and data gaps have been addressed based on USEPA method for this analysis. This analysis covers 81 continuous ambient air quality monitoring stations (CAAQMS) spread across cities of Delhi-NCR. 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. Meteorological data for the analysis is sourced from the Palam weather station of Indian Meteorological Department (IMD). Fire count data is sourced from NASA's Fire Information for Resource Management System, specifically Moderate Resolution Imaging Spectroradiometer (MODIS) and Visible Infrared Imaging Radiometer Suite (VIIRS) product is used. 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).

Key highlights

Delhi

This winter was the least polluted in last five years: The citywide winter average for Delhi stood at 160 µg/m³ for the October – January period which is the lowest level recorded since wide scale monitoring started in 2018-19 *(See Graph 1: Trend in average winter pollution in Delhi).* PM2.5 level, computed by averaging monitoring data from 36 CAAQMS stations located in the city, this October-January has been 17 per cent lower compared to seasonal average of 2018-19 winter. Based on the subset of the ten oldest stations, improvement is of almost 20 per cent.

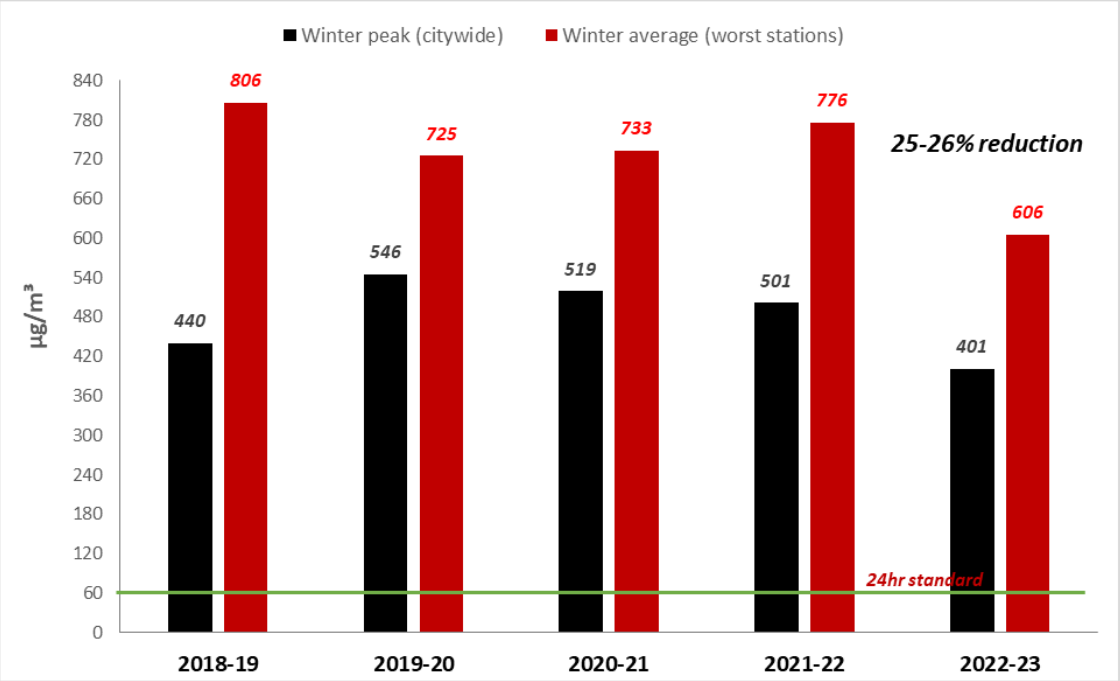
Graph 1: Trend in average winter pollution in Delhi



Note: Average $PM_{2.5}$ concentration is based on mean of daily values recorded at 36 CAAQMS stations in the city that have adequate data for all winters.
Source: CSE analysis of CPCB's real time air quality data.

Peak pollution level down but still toxic: Like the citywide winter average for Delhi, the winter peak pollution level was found to be the lowest recorded since wide scale monitoring started in 2018-19 stood. The citywide peak this year stood at 401 µg/m³ which was recorded on 3 November 2022 *(See Graph 2: Trend in peak winter pollution in Delhi).* Peak PM2.5 24-hour value, computed by averaging monitoring data from 36 CAAQMS stations located in the city, this winter has been 26 per cent lower compared to the highest recorded winter peak (546 µg/m³ in 2019-20 winter). Worst station level peak was 25 per cent lower compared to the highest recorded station level winter peak (806 µg/m³ in 2018-19 winter).

Graph 2: Trend in peak winter pollution in Delhi



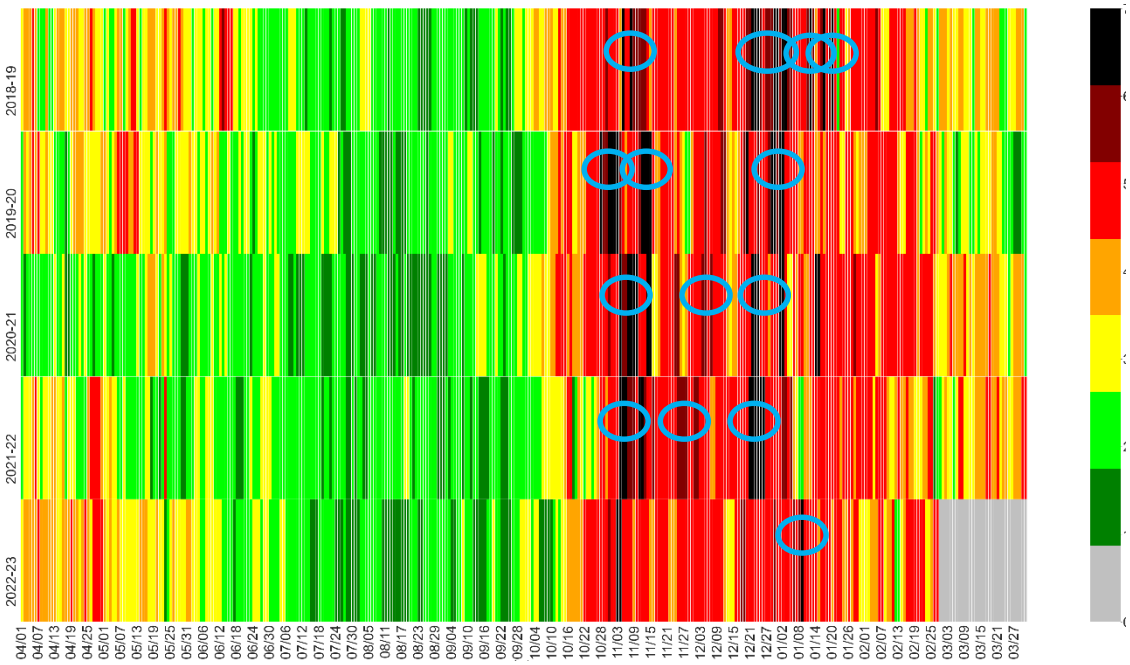
Note: Average $PM_{2.5}$ concentration is based on mean of daily values recorded at 36 CAAQMS stations in the city that have adequate data for all winters.
Source: CSE analysis of CPCB's real time air quality data.

Only one smog episode this winter: As is the global practice at least three continuous days of severe AQI is considered a smog episode. In previous winters such episodes have been recorded lasting 6-10 days. This winter only one smog episode was recorded from 6-9 January (See *Graph 3: Air quality calendar of Delhi*). Average daily intensity of this smog stood at 287 µg/m³. This winter was first in last five years when both Diwali and late December around Christmas did not experience a smog episode.

Number of days with severe or sever plus air quality was lowest in last five years: This winter 10 days had citywide average in "severe' or worse AQI category, which is much lower compared to 24 such days in previous winter and with 33 days in 2018-19 winter. *(See Graph 4: Distribution of October-November days as per AQI category for Delhi).*

City also recorded five days of good air this year which is an improvement over pervious winter which recorded one "good" AQI day. Among earlier winters when no good air quality days were recorded. All these "good" AQI days this winter coincided with heavy rainfall days in October.

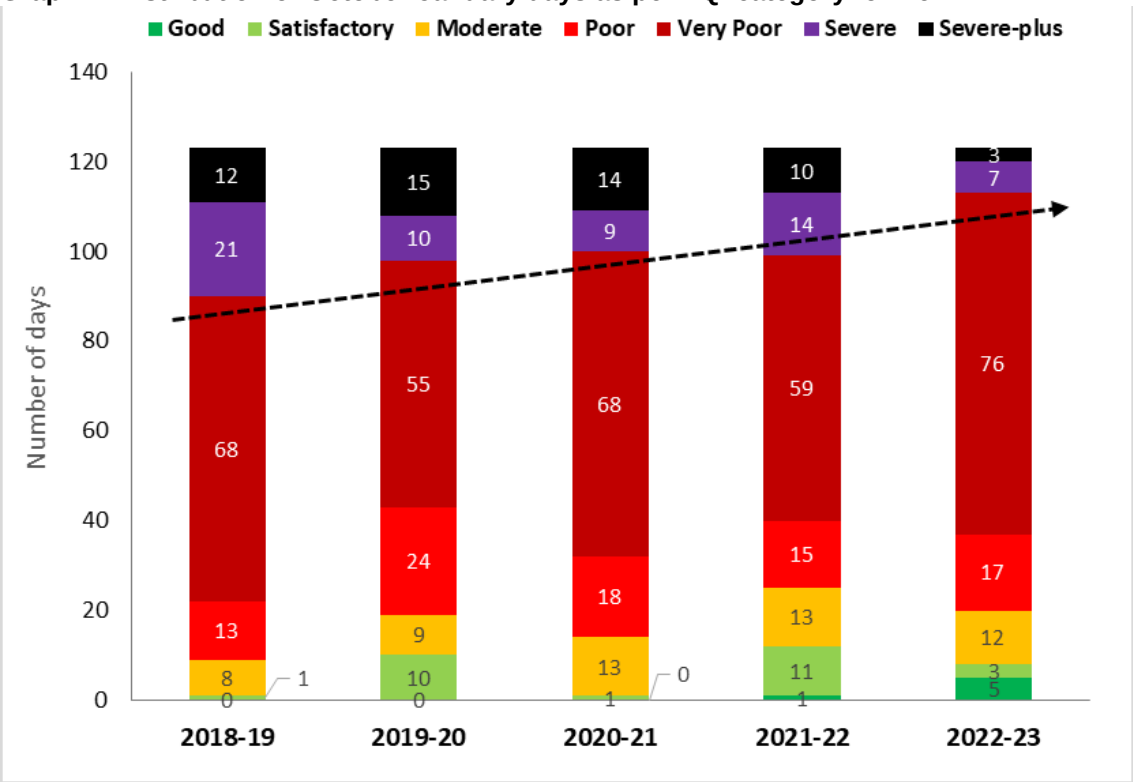
Graph 3: Air quality calendar of Delhi



Note: PM2.5 level is based on average of 37 stations which includes all the Delhi stations except Lodhi Road IITM, Chandni Chowk IITM and East Arjun Nagar. Cell colour is based on the official colour-scheme of AQI sub-categories. Blue loops mark smog episodes.

Source: CSE analysis

Graph 4: Distribution of October-January days as per AQI category for Delhi

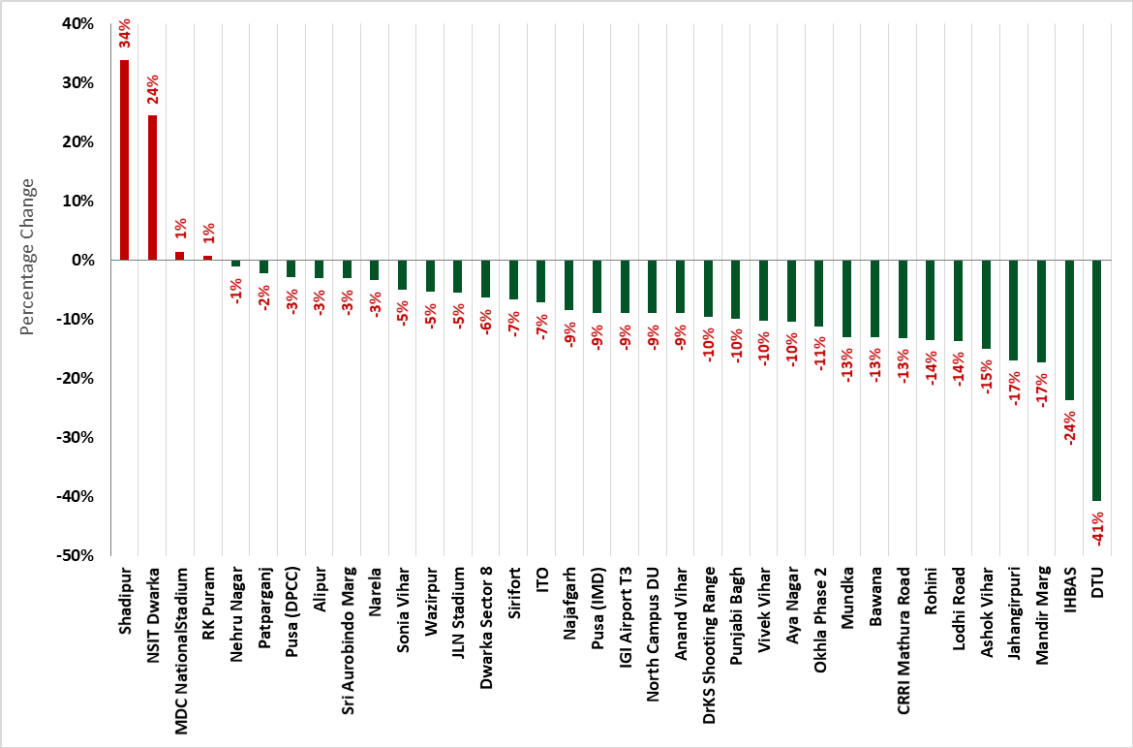


Note: Average $PM_{2.5}$ concentration is based on mean of daily values recorded at 36 CAAQMS stations in the city that have adequate data for all four winters.
Source: CSE analysis of CPCB's real time air quality data

Variation in pollution level among city's stations remain significant: This winter, 32 out of 36 CAAQMS stations saw improvement in their seasonal average over last three year average. Most improvement was noted at DTU and IHBAS which registered 41 per cent and 24 per cent lower seasonal average this winter compared to mean of pervious three winters respectively. Shadipur (34 per cent), NSIT Dwarka (24 per cent), National Stadium (1 per cent) and RK Puram (1 pre cent) were the three stations that registered increase in seasonal PM2.5 level compared to previous winters (See *Graph 5: Change in seasonal $PM_{2.5}$ level among stations of Delhi compare to mean of previous three winters*).

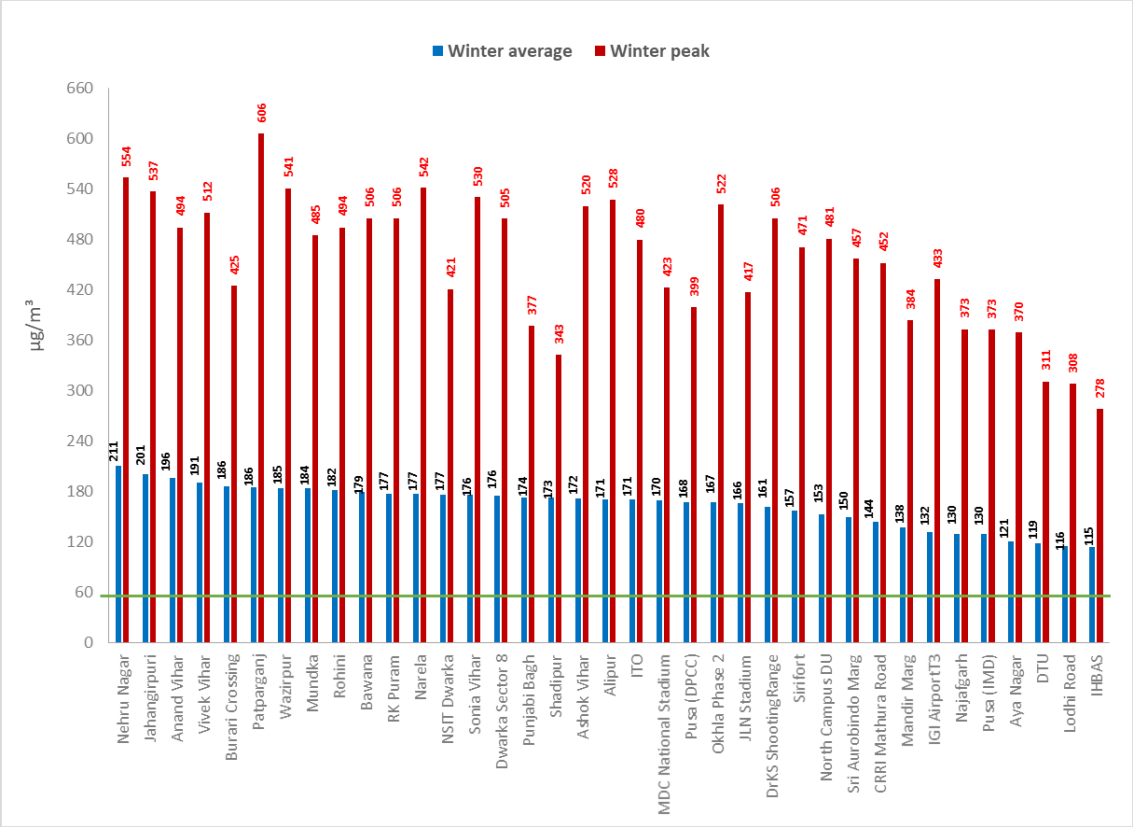
Despite improvement this winter, pollution level still remained very high across all stations. The seasonal average ranged between 115 µg/m³ at IHBAS and 211 µg/m³ at Nehru Nagar. Jahangirpuri was the second most polluted location in the city with the seasonal average of 201 µg/m³ (See *Graph 6: $PM_{2.5}$ variation among stations of Delhi*). Peak pollution ranged from 278 µg/m³ at IHBAS to 606 µg/m³ at Patparganj.

Graph 5: 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 36 CAAQMS stations in the city that have adequate data for all three winters.
Source: CSE analysis of CPCB's real time air quality data

Graph 6: $PM_{2.5}$ variation among stations of Delhi

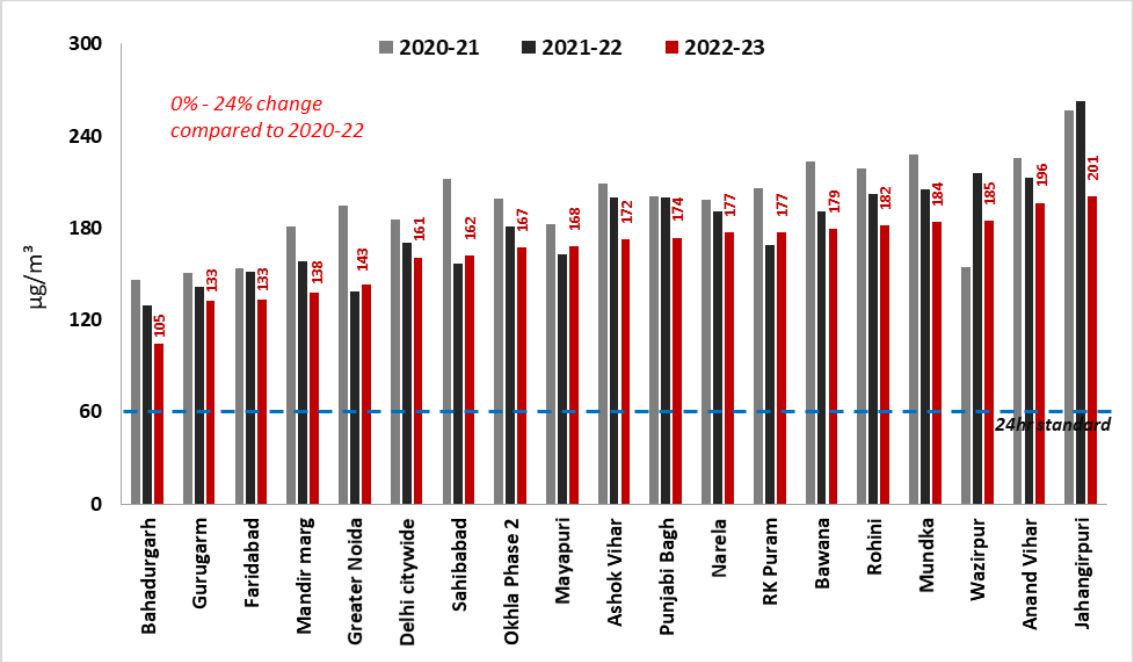


Note: Average $PM_{2.5}$ concentration is based on mean of daily values recorded at 36 CAAQMS stations in the city that have adequate data.
Source: CSE analysis of CPCB's real time air quality data

Pollution hotspots continue to remain problematic: Hotspots located in North and East Delhi were the most polluted in the city. Jahangirpuri was the most polluted neighborhood with October-January average PM2.5 level of 201 µg/m³ *(See Graph 7: Trend in October-January $PM_{2.5}$ level among the official hotspots).* Other most polluted hotspots were Anand Vihar (196 µg/m³), Wazirpur (185 µg/m³), Mundka (185µg/m³), Rohini (182 µg/m³) and Bawana (179 µg/m³). Bahadurgarh with 105 µg/m³, Gurugram and Faridabad each with 133 µg/m³ were the least polluted among the official hotspots.

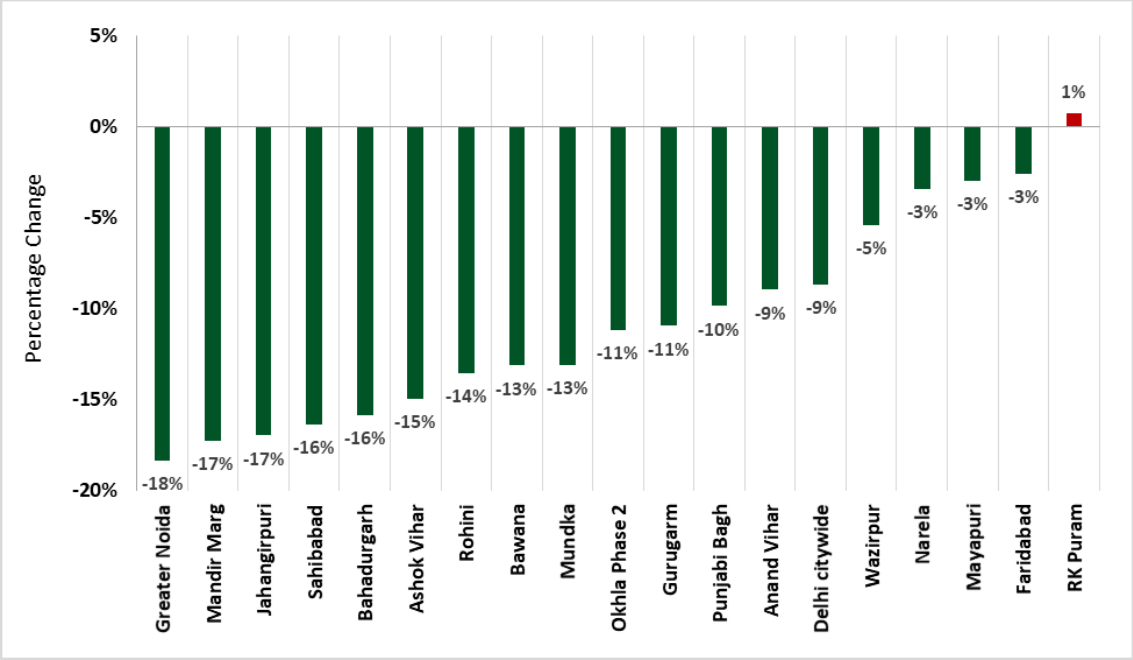
All hotspots have shown improvement compared to average pollution level recorded over previous three winters except RK Puram. Greater Noida has registered most improvement with its October-January levels this year being 18 per cent lower than average of previous three winters (See *Graph 8: Improvement in October-January $PM_{2.5}$ level among the official hotspots compared to previous three winters*). RK Puram registered 1 per cent increase for the same duration. Wazirpur (5 per cent), Narela (3 per cent), Mayapuri (3 per cent) and Faridabad (3 per cent) registered improvement but it is less than the improvement noted in Delhi's citywide average.

Graph 7: Trend in October-January $PM_{2.5}$ level among the official hotspots



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

Graph 8: Improvement in October-January $PM_{2.5}$ level among the official hotspots compared to previous three winters

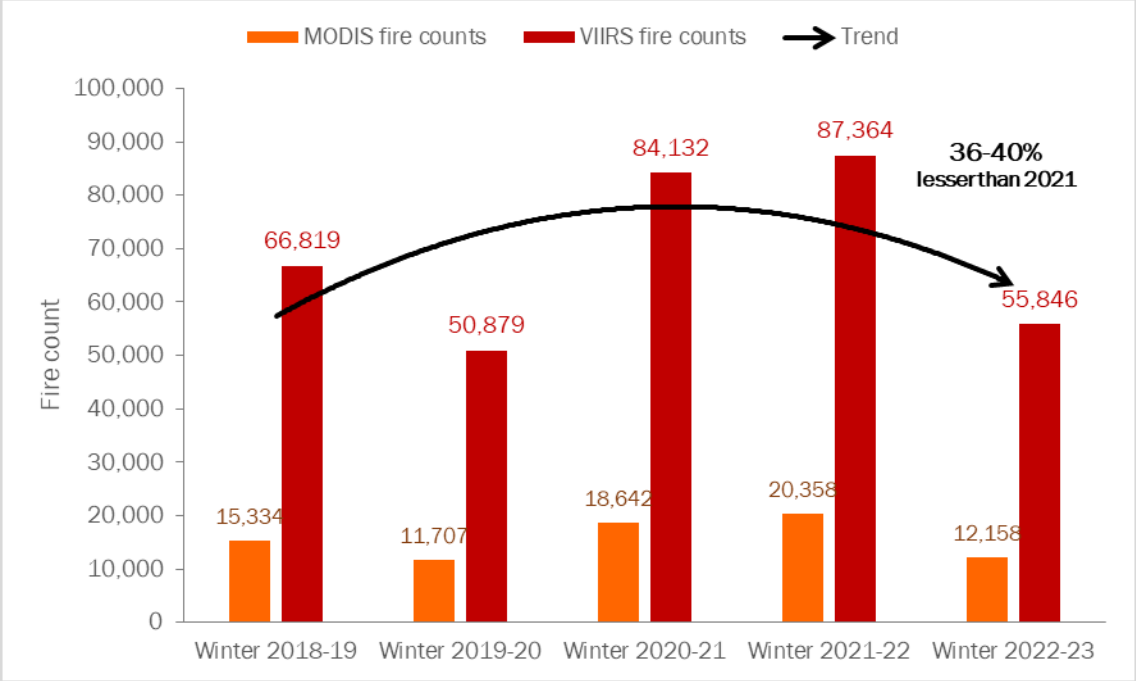


Note: Average $PM_{2.5}$ concentration is based on mean of daily values recorded at 36 CAAQMS stations in the city that have adequate data for all three winters.
Source: CSE analysis of CPCB's real time air quality data

Farm stubble fires this winter about half of last winter: The total count of farm stubble fires reported this year from Punjab, Haryana and Delhi in months of October and November stood at 55,846 according to NASA's VIIRS satellite and 12,158 according to NASA's MODIS satellite (See *Graph 9: Trend in farm stubble fire counts in Punjab, Haryana and Delhi during October-January*). These are respectively 36 per cent and 40 per cent lower than the figures for October-January of 2021-22. If the FRP (fire radiative power is measure of intensity of fire) is taken into account in addition to the number of fire, it becomes clear that not only the fires were lesser in count but also lesser in intensity compared to previous two years. The total FRP this October-January has been 373 kW and 199 kW according to VIIRS and MODIS respectively (See *Graph 10: Trend in farm stubble fire power in Punjab, Haryana and Delhi during October-January*). This is 43 per cent and 49 per cent lower than last year's values of VIIRS and MODIS respectively.

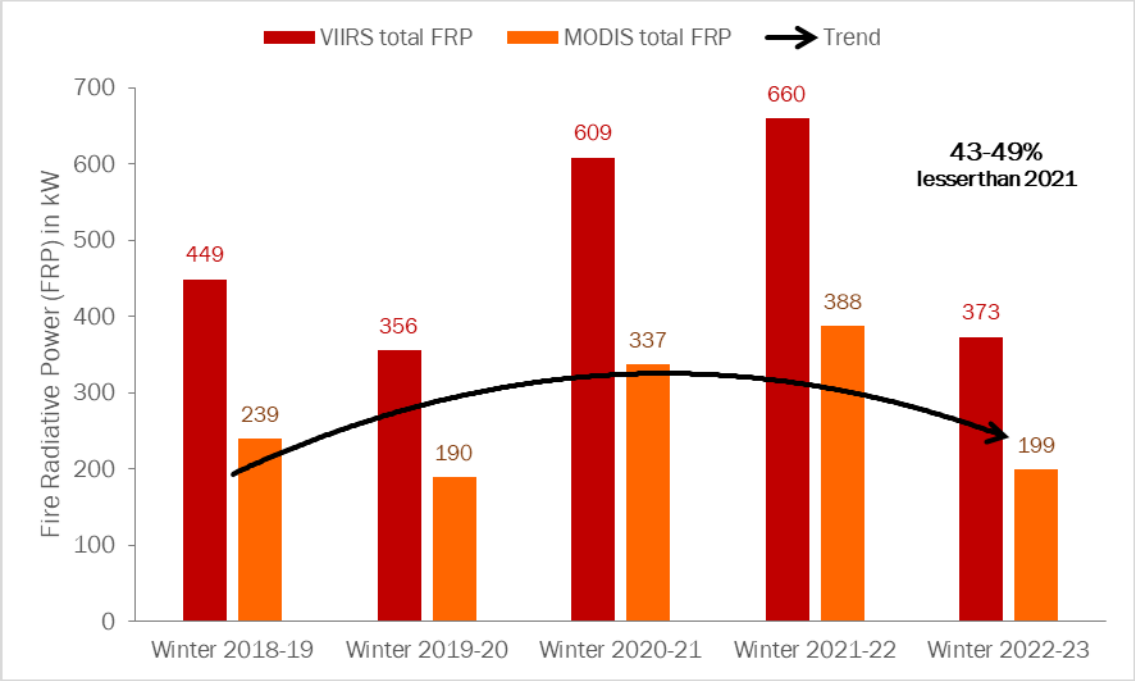
Fires have been lower this October-January both in count and intensity compared to previous two seasons, but are marginally higher compared to 2019-20 season. Therefore, it can be argued that spike seen in the fires since pandemic started has ended and situation has reverted to pre-pandemic scenario. This is relatively better scenario but still far from clean air objective.

Graph 9: Trend in farm stubble fire counts in Punjab, Haryana and Delhi during October-January



Note: Fire data is based on NASA's Moderate Resolution Imaging Spectroradiometer (MODIS) and Visible Infrared Imaging Radiometer Suite (VIIRS) products. It covers Punjab, Haryana and Delhi. Data up till 31 January 2023.
Source: CSE analysis

Graph 10: Trend in farm stubble fire power in Punjab, Haryana and Delhi during October-January

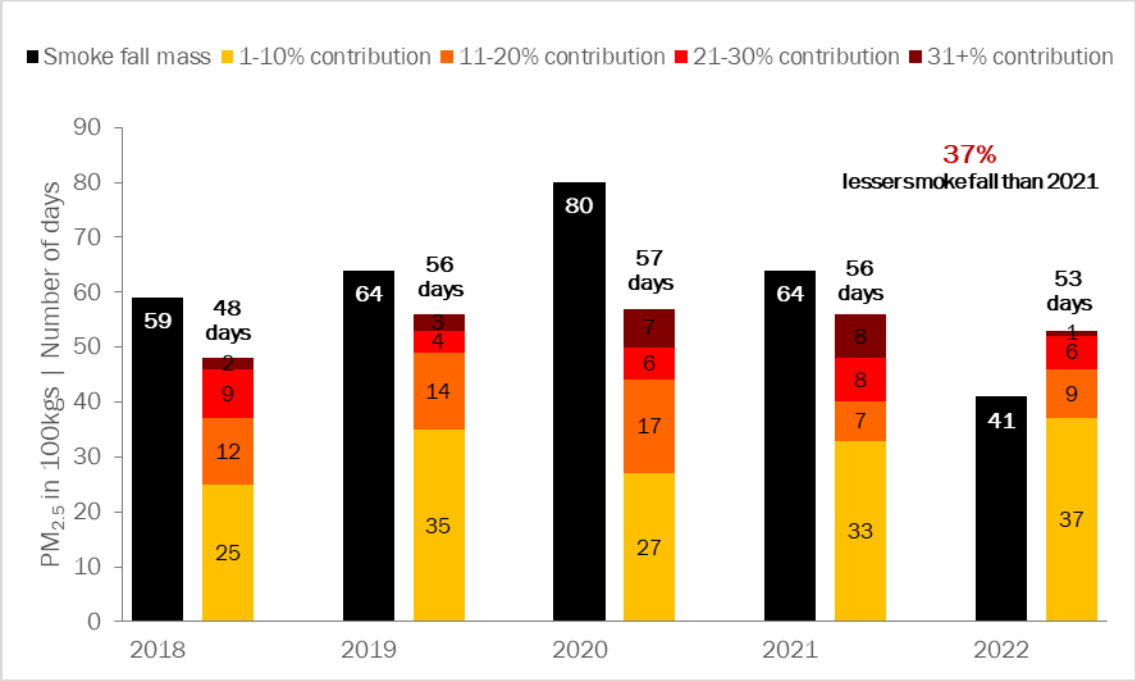


Note: Fire data is based on NASA's Moderate Resolution Imaging Spectroradiometer (MODIS) and Visible Infrared Imaging Radiometer Suite (VIIRS) products. Total FRP is calculated as product of average FRP for a day and fire count for that day, done state wise. It covers Punjab, Haryana and Delhi. Data up till 31 January 2023.
Source: CSE analysis

Over four tonne of smoke fell on Delhi, lowest in last five years: This year smoke from the farm stubble fires contributed to PM2.5 levels in Delhi on 53 days, starting October 12 and ending on December 3, 2022. This is lesser than previous three years when smoke intrusion was reported on 56 days, but it is higher than 2018-19 winter figure of 48 days. Highest contribution this year was 34 per cent and it was reported on November 3, 2022. But given the overall low PM2.5 levels this year, 34 per cent contribution accounts for much lesser in terms of actual PM2.5 concentration in the Delhi's air. Therefore, it is critical to look also at the absolute mass of PM2.5 that got transported to the city from the fires.

The quantity of smoke from farm stubble fires that falls over Delhi is dependent upon two major factors: quantity and intensity of farm stubble fires, and meteorological conditions conducive for transportation of the smoke to Delhi. This winter not only the quantity and intensity of farm stubble fires have been low but also the meteorological conditions have been less conducive for the transport of the smoke. As a result total smoke that fell upon Delhi in from of PM2.5 has been considerably lesser. CSE estimated that about 4.1 tonne of PM2.5 fell over Delhi this winter in from of smoke fall, this is 37 per cent lesser than 6.4 tonne that fell last year and almost half of 2020-21 winter figure (See *Graph 11: Trend in quantity of smoke fall in Delhi during winter*).

Graph 11: Trend in quantity of smoke fall in Delhi during winter



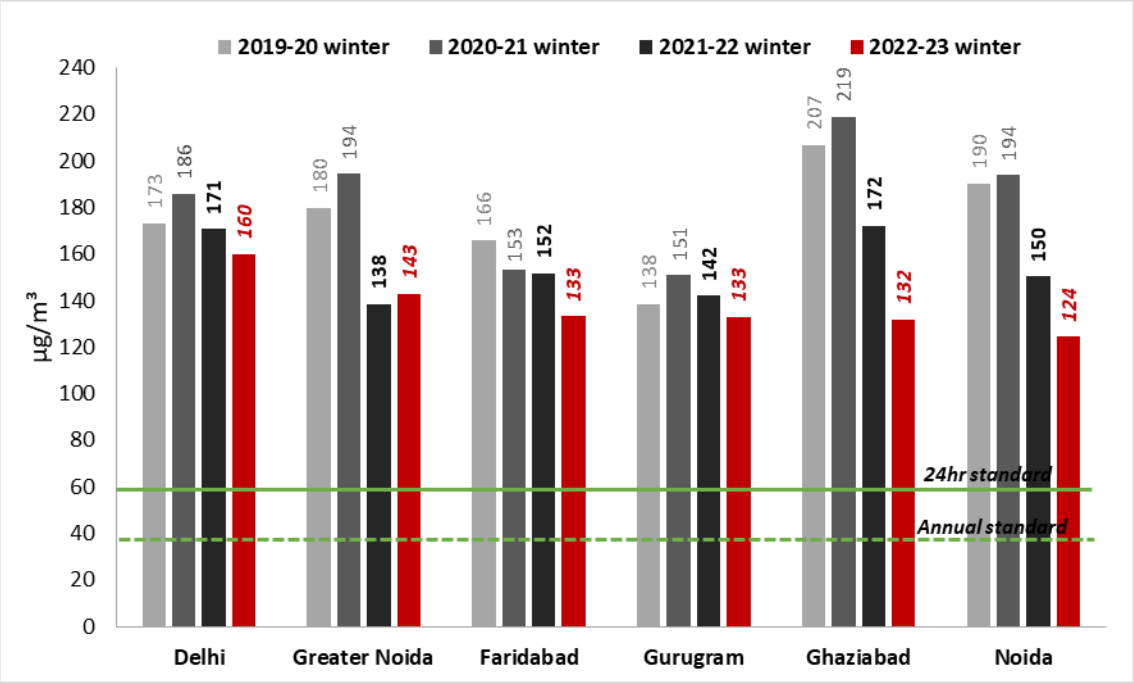
Note: Total smoke fall PM2.5 quantity is calculated using SAFAR India's data on farm stubble fire smoke contribution to Delhi's PM2.5 level and daily PM2.5 concentration data based on average of 37 stations of Delhi. The calculation assumes Delhi's geographical area to be 1,483 km² and air slab of 3m from the ground (standard height for placement of the monitoring equipment). Mass of smoke fall is computed for everyday based on SAFAR India and CPCB data, and then added up to arrive at seasonal number. Data up till 31 January 2023.
Source: CSE analysis

National Capital Region (NCR)

Delhi was the most polluted among the five major towns in NCR: In absolute concentration, Delhi was the most polluted major city in NCR with winter average of 160 µg/m^3. Greater Noida with 143 µg/m^3 was the next most polluted major city in NCR (See *Graph 12: Winter pollution in main NCR cities*). Faridabad and Gurugram both registered 133 µg/m^3 while Ghaziabad did marginally better with winter average of 132 µg/m^3. Noida was the least polluted major city with winter average of 124 µg/m^3.

Among the five big NCR cities, Ghaziabad registered the highest improvement in its winter $PM_{2.5}$ level with a reduction of 23 per cent compared to pervious winter average. Noida (17 per cent), Faridabad (12 per cent) and Gurugram (6 per cent) also registered improvement in air quality but it worsened for Greater Noida (-3 per cent).

Graph 12: Winter pollution trend among major NCR cities

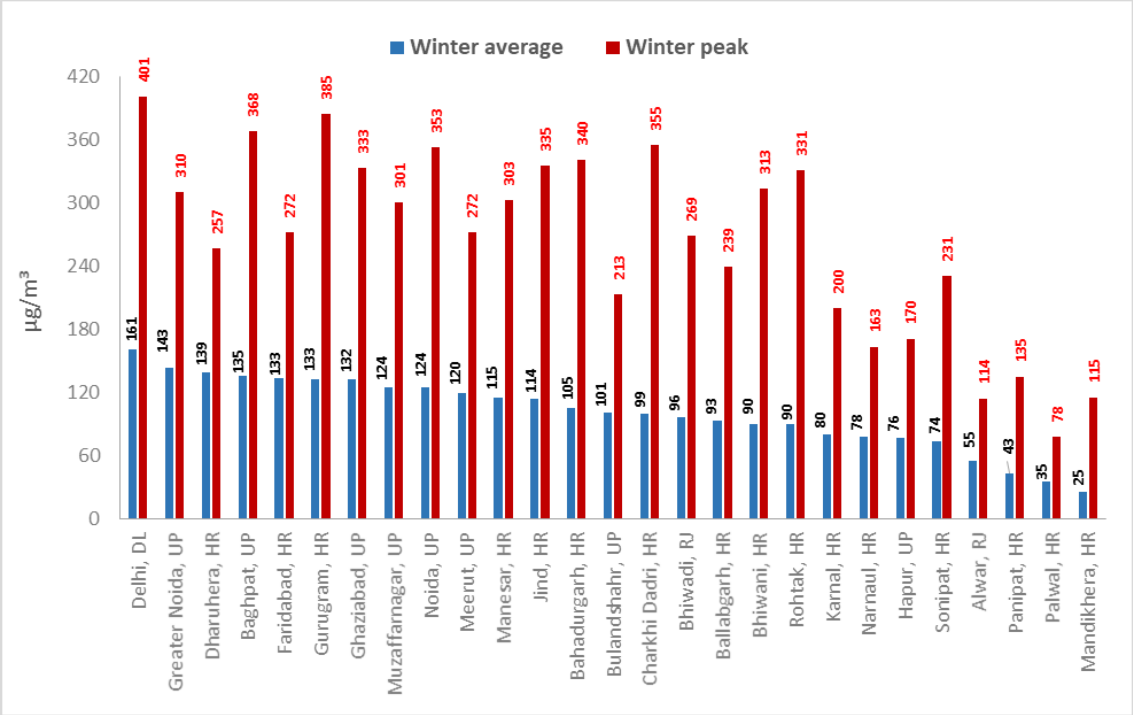


Note: Average $PM_{2.5}$ concentration is based on mean of daily values recorded at CAAQM stations in the city that have adequate data for all four winters.
Source: CSE analysis of CPCB's real time air quality data

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: Delhi was the most polluted city in the NCR followed by Greater Noida, this winter. But Dharuhera and Baghpat, much smaller towns, were next on this worst polluted list, placed above much larger cities of Faridabad, Gurugram and Ghaziabad (See *Graph 13: Winter pollution level in NCR cities and towns*). Mandikhera and Palwal were the least polluted towns in the NCR with their winter average settling below 40 µg/m³. Likewise, Delhi citywide registered the highest peak pollution with 24hr average at 401 µg/m³ followed by Gurugram at 385 µg/m³ and Baghpat at 368 µg/m³. Palwal peak of 78 µg/m³ was the lowest in the NCR.

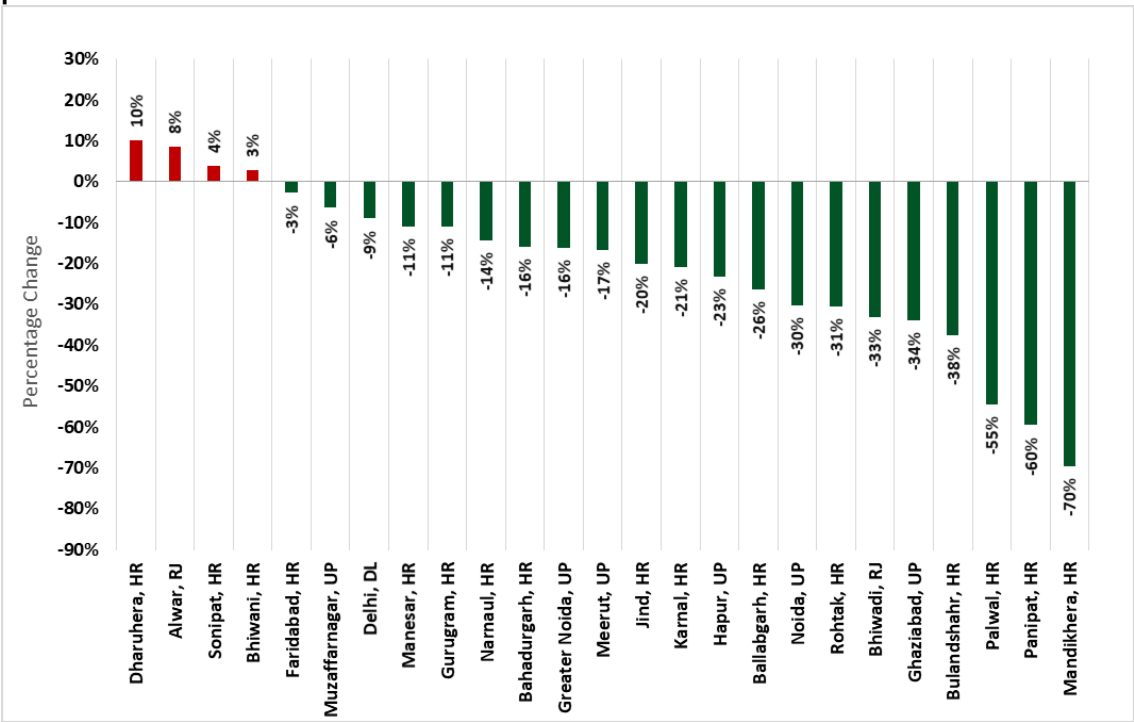
Only four out of 25 NCR towns show detoriation in their winter average from the mean of previous three winters. Air quality detoriated most in Dharuhera in Haryana by 10 per cent with winter average of 139 µg/m³. It was followed by Alwar in Rajasthan and Sonipat in Haryana that registered 8 per cent and 4 per cent decline in winter air quality respectively compared to the average of previous three winters. Mandikhera (-70 per cent), Panipat (-60 per cent) and Palwal (-55 per cent) in Haryana registered most improvement (See *Graph 14: Change in seasonal $PM_{2.5}$ level among NCR cities and towns compare to mean of previous three winters*).

Graph 13: Winter pollution level in NCR cities and towns



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

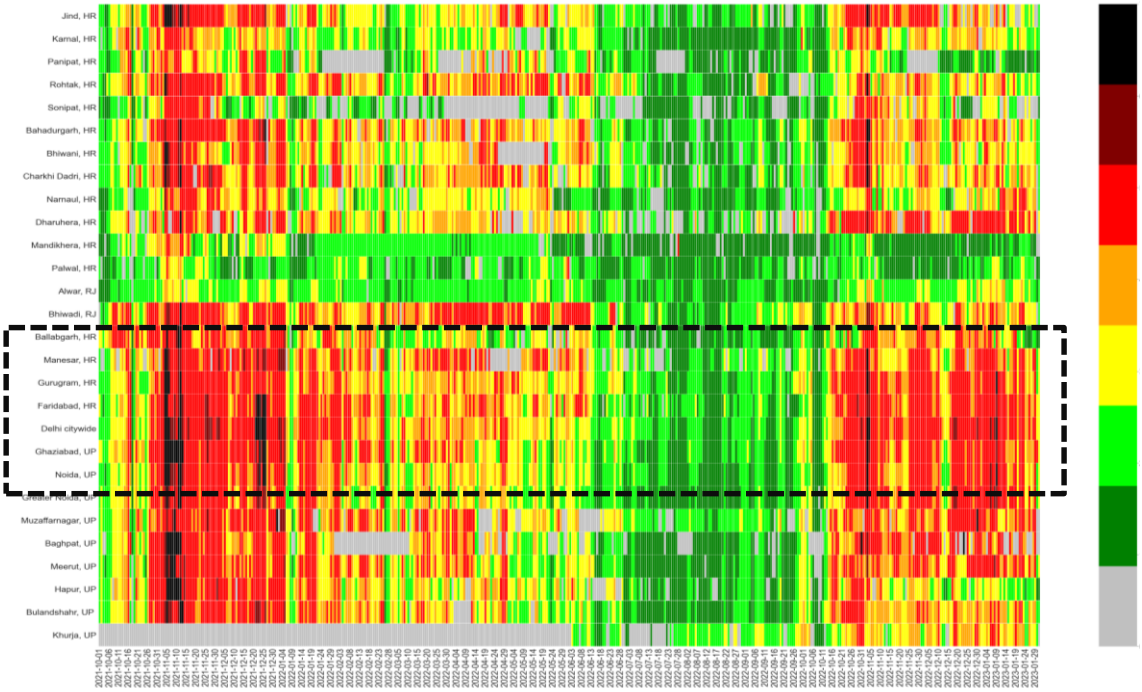
Graph 14: Change in seasonal $PM_{2.5}$ level among NCR cities and towns compared to mean of previous three winters



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.

Early winter smog synchronise across the region and is more severe in Delhi and big four: Normally the smog episodes of November are synchronised across the northern region. But it is more intense and lingers longer in Delhi and its immediate neighboring cities. During winter, the atmospheric changes such as inversion, change in wind direction, and seasonal drop in ambient temperature across North India entraps pollution. Additionally, smoke from farm fires and Diwali firecrackers in November makes the situation even worse. However, the air quality in cities further away from Delhi improves from severe to poor and moderate categories, although Delhi and the big four cities continue to have very poor air quality through the end of January (See *Graph 15: PM2.5 calendar for NCR cities and towns*).

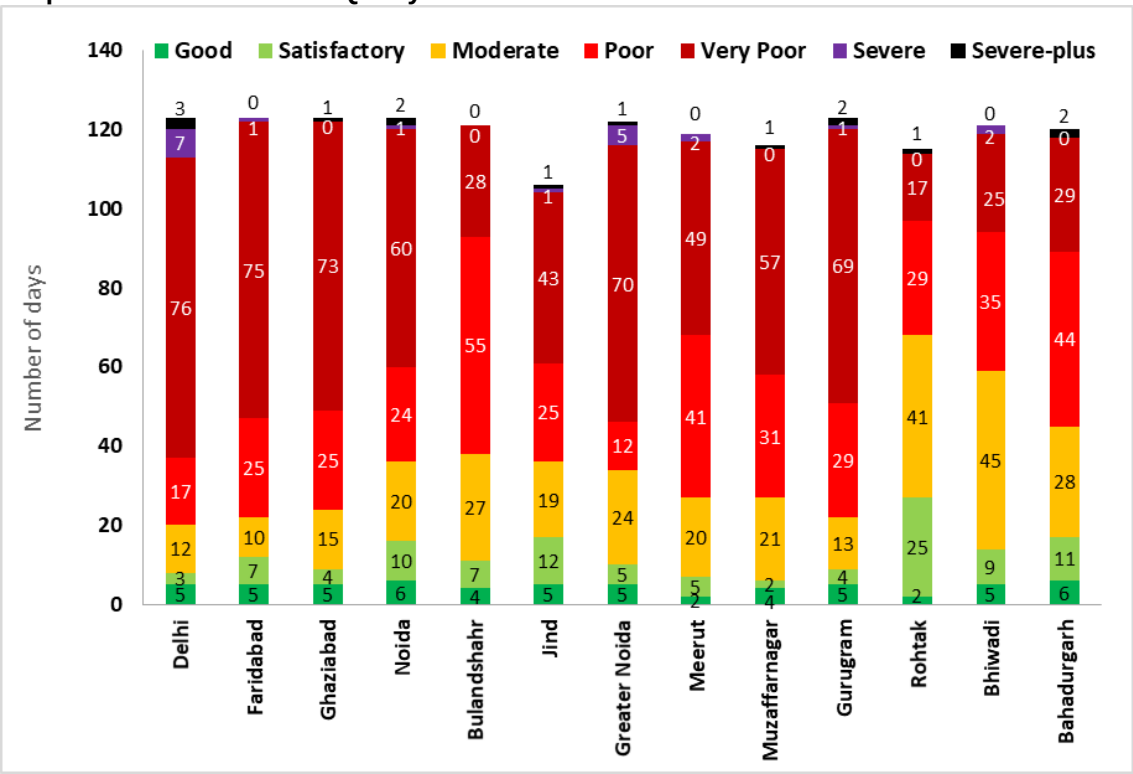
Graph 15: $PM_{2.5}$ calendar for NCR cities and towns



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. Cell colour is based on the official colour-scheme of AQI sub-categories.
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: Although the overall number of days with severe or very poor air quality decreased and stabilized this winter, Delhi still recorded more days with the most severe air quality compared to other major cities in the NCR during the 2022-23 winter. Delhi had 10 days with severe or worse air quality, followed by Greater Noida with 6 days (see *Graph 16: Distribution of AQI days for NCR cities and towns*). Noida and Gurugram each had 3 days, and Faridabad and Ghaziabad each had 1 day of severe or worse air quality. Despite the large differences in the number of highly polluted days between the cities, the number of days with good air quality was almost the same across the region. These 2-6 days with good air quality coincided with heavy rainfall and were not the result of on-ground pollution control measures.

Graph 16: Distribution of AQI days for NCR cities and towns



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

Way forward

Winter pollution is the litmus test of clean air action in the region. The only way to prevent the high peaks and smog episodes during winter is to ensure sustained improvement in air quality to meet the national ambient air quality standard. This requires region-wide implemenation of:

- Clean fuels and emissions control systems in industry,
- Massive electrification of vehicle fleet,
- Scaling up of integrated public transport options with vehicle restraint measures like parking restraints
- Waste mangement based on 100% segregation, material recovery and zero landfill policy
- Clean construction and recycling of C&D waste
- Replacement of solid fuels in households
- Urban greening and dust control

Annexure 1: October-January $PM_{2.5}$ level at station levels

Stations	2018-19	2019-20	2020-21	2021-22	2022-23
Nehru Nagar, DL	252	212	220	209	211
Jahangirpuri, DL	250	206	257	263	201
Anand Vihar, DL	243	209	226	213	196
Vivek Vihar, DL	192	199	234	207	191
Burari Crossing, DL	218	169		141	186
Patparganj, DL	191	164	213	191	186
Wazirpur, DL	256	215	154	216	185
Mundka, DL	243	203	228	205	184
Rohini, DL	248	209	219	202	182
Bawana, DL	195	205	224	190	179
RK Puram, DL	205	154	206	169	177
Narela, DL	206	162	198	191	177
NSIT Dwarka, DL	162	171	94	161	177
Sonia Vihar, DL	217	159	216	183	176
Dwarka Sector 8, DL	182	188	198	176	176
Sector 16A Faridabad, HR	197	166	198	172	174
Punjabi Bagh, DL	203	178	201	200	174
Shadipur, DL	190	147	112	130	173
Ashok Vihar, DL	216	199	209	200	172
Alipur, DL	230	167	197	167	171
ITO, DL	196	172	209	172	171
MDC National Stadium, DL	168	155	173	174	170
Pusa DPCC, DL	187	174	183	163	168
Okhla Phase 2, DL	196	185	199	181	167
JLN Stadium, DL	195	180	179	168	166
Sector 62 Noida, UP	183	184	195	150	165
Vasundhara Ghaziabad, UP	227	213	212	157	162
DrKS Shooting Range, DL	160	175	192	168	161
KPIII Greater Noida, UP	198	179	191	143	160
Sirifort, DL	172	180	174	152	157
Sector 11 Faridabad, HR			159	189	153
North Campus DU, DL	183	165	179	159	153
Sector 51 Gurugram, HR			172	163	152
Loni Ghaziabad, UP		213	246	244	152
Sri Aurobindo Marg, DL	158	153	165	146	150
Sector 116 Noida, UP		191	202	166	149
CRRI Mathura Road, DL	223	166	178	154	144
Dharuhera, HR	120	109	156	112	139
Mandir Marg, DL	181	161	181	158	138
Gwal Pahari Gurugram, HR	161	166	148	138	136
SPIC Baghpat, UP					135
Teri Gram Gurugram, HR			125	134	135
Jaibhimnagar Meerut, UP		133	178	147	135
IGI Airport T3, DL	152	149	155	133	132
KPV Greater Noida, UP		182	198	140	131
Najafgarh, DL	153	142	152	133	130
Pusa IMD, DL	150	131	159	138	130
Ganganagar Meerut, UP		133	149	137	129
Vikas Sadan Gurugram, HR	154	122	158	155	127
Muzaffarnagar, UP	180	128	136	135	124
New Industrial Town Faridabad, HR			132	139	123
Sector 1 Noida, UP		208	197	158	123
Aya Nagar, DL	130	139	145	121	121
DTU, DL	210	193	220	189	119
Sanjay Nagar Ghaziabad, UP		205	198	159	117
Indirapuram Ghaziabad, UP		199	221	153	116
Lodhi Road, DL	148	140	133	130	116
Manesar, HR	124	106	125	156	115
IHBAS, DL	165	146	154	152	115
Jind, HR	70	132	156	139	114
Sector 30 Faridabad, HR			153	151	112
Pallavpuram Meerut, UP		160	160	148	111

Bahadurgarh, HR	176	98	146	130	105
Bulandshahr, UP	198	148	196	143	101
Charkhi Dadri, HR			129	122	99
Bhiwadi, RJ	160	128	167	137	96
Ballabgarh, HR	134	131	109	138	93
Bhiwani, HR	63	112	44	107	90
Rohtak, HR	73	116	149	123	90
Karnal, HR	62	117	97	88	80
Narnaul, HR	84	89	95	89	78
Hapur, UP	205	86	63	148	76
Sonipat, HR	150	52	88	73	74
Sector 125 Noida, UP	211	180	193	144	63
Alwar, RJ	49	43	55	53	55
Panipat, HR	103	136	97	87	43
Palwal, HR	116	133	53	43	35
Mandikhera, HR	91	100	83	61	25
New Collectorate Baghpat, UP	186	162	176	142	
Lodhi Road IITM, DL*			133	160	285
Chandni Chowk IITM, DL*			153	120	124
East Arjun Nagar, DL*					

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