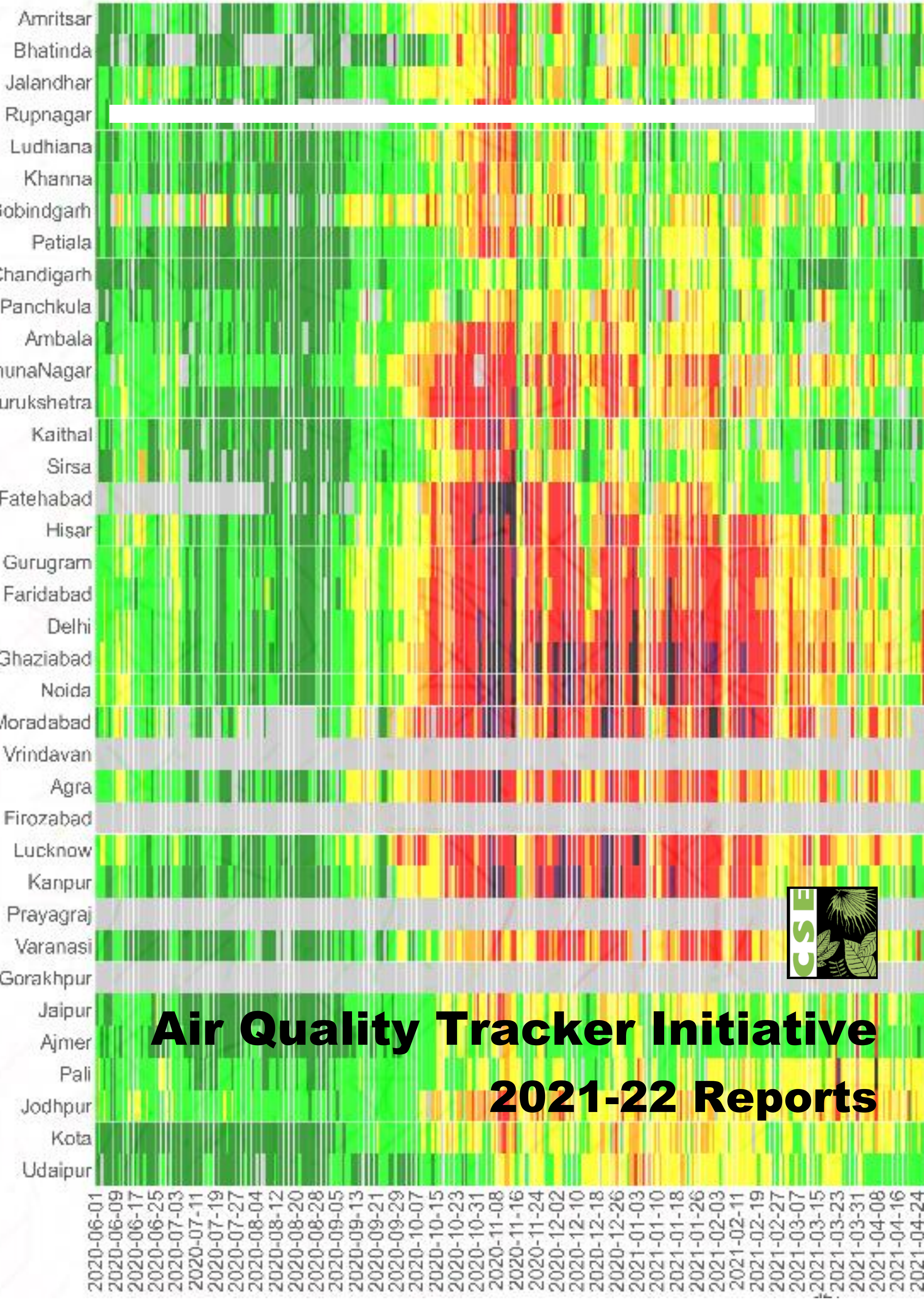

Air Quality Tracker Initiative

2021-22 Reports

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CONTENT

Spread and scale of winter air pollution in India - 2021-22

Anumita Roychowdhury and Avikal Somvanshi
Research contribution: Sharanjeet Kaur

Centre for Science and Environment, March 16, 2022

The particulate pollution spiked and stayed elevated with varying intensity across all regions during the winter of 2021-22 (15 October to 28 February). Even though the overall regional averages of PM2.5 levels were lower than the previous winter in most regions, the winter smog episodes recorded severe spikes in several regions. Peak pollution is alarmingly high and synchronized despite large distances within the regions –especially in northern and eastern plains.

This has emerged from the concluding analysis for 2021-22 winter air quality tracker initiative of the Urban Data Analytics Lab of Centre for Science and Environment (CSE).

Clearly, the winter pollution challenge is not limited to mega cities or to one specific region; it is now a widespread national problem that requires urgent and deliberate action at a national scale. This requires quicker reforms and action in key sectors of pollution – vehicles, industry, power plants and waste management to bend the annual air pollution curve and daily spikes.

As availability of real time air quality data has improved in several regions with expansion of the air quality monitoring systems, it has become possible to assess the regional differences and understand the unique regional trends. This needs to inform the regional clean air action.

This air quality tracker initiative has helped to benchmark the winter air quality for peer-to-peer comparison within each region and inter-regional differences.

Data analysis: This analysis is based on publicly available granular real time data (15-minute averages) from the Central Pollution Control Board's (CPCB) official online portal Central Control Room for Air Quality Management. The data is captured from 326 official stations under the Continuous Ambient Air Quality Monitoring System (CAAQMS) spread across 161 cities in 26 states and union territories. Apart from Delhi, Puducherry and Chandigarh, there are 8 cities in Punjab, 24 cities in Haryana, 16 cities in Uttar Pradesh, 23 cities in Bihar, 6 cities in West Bengal, 8 cities in Rajasthan, 15 cities in Madhya Pradesh, 6 cities in Gujarat, 5 cities in Andhra Pradesh, 22 cities in Karnataka, two in Odisha, 6 cities in Kerala, 7 cities in Maharashtra, 3 cities in Tamil Nadu, 12 cities in Chhattisgarh, city each in Anurachal Pradesh, Jammu & Kashmir, Telangana, Assam, Meghalaya, Mizoram, Nagaland, and Tripura.

Delhi (40), Mumbai (21), Bengaluru (10), Chennai (8), Pune (8), Ahmedabad (8), Kolkata (7), Lucknow (7), Hyderabad (6), Patna (6), Agra (6), Moradabad (5), Ghaziabad (4), Noida (4), Gurugram (4), Faridabad (4), Navi Mumbai (4), Kanpur (4), Varanasi (4), Prayagraj (3), Meerut (3), Jaipur (3), Howrah (3), Kochi (3), Chandigarh (3), Gandhinagar (3), Gaya (3), Muzzafarpur (3), Thiruvananthapuram (2), Guwahati (2), Greater Noida (2), Chandrapur (2), Firozabad (2) and Gwalior (2) have more than one real-time station, therefore citywide average is used for analysis and it is defined as average of all city stations that meet minimum 75 per cent data completeness criteria.

Key highlights

Regional profile of winter pollution shows eastern region is as polluted as Delhi-NCR: The winter average of PM2.5 in eastern plains that also include the newly monitored 19 cities and towns of Bihar, was same as that of Delhi-NCR. Most polluted cities this winter are from Bihar and Delhi-NCR. Six Bihar towns feature in the top 10 most polluted cities this winter with Siwan and Munger at the top. In northern plains, Ghaziabad, Delhi, Faridabad, and Manesar are third, fifth, seventh and tenth in the list of ten most polluted cities. Even though the seasonal average in smaller cities of Bihar rivals the mega-cities of NCR, their peak pollution during smog episodes are comparatively milder.

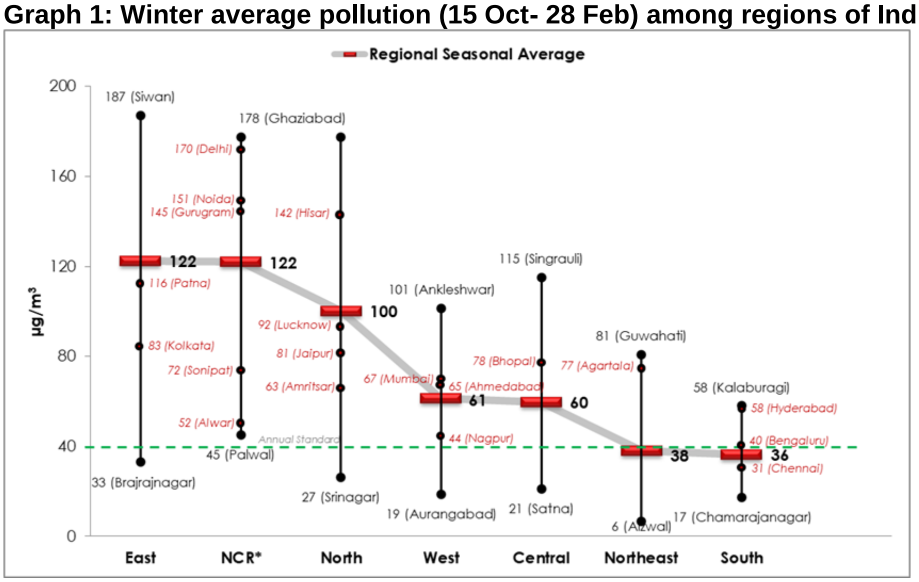
The NCR cities have experienced the most severe daily (24-hr average) $PM_{2.5}$ levels with Ghaziabad being the worst hit. Delhi, Noida, Faridabad, Greater Noida, and Gurugram have experienced he worst peak pollution (24-hr average) this winter.

The PM2.5 average of the eastern region is over three times the average of the cities in southern India and 22 per cent more polluted than North Indian cities (See *Graph 1: Trend in winter average pollution among regions of India*). Within the East, the Bihar sub-region is the most polluted.

From the peak 24-hr PM2.5 level perspective North Indian cities have recorded the highest daily pollution levels on an average. Within North, Delhi-NCR remains the most polluted sub-region with their worst days being almost five times the average. Its peak pollution is also almost five times higher the average peak of northeastern India cities (region with lowest peak pollution) and about 60 per cent higher than the average peak of eastern cities (region with the worst regional average).

It is important to note that mega cities are not the most polluted in any of the regions, it is the smaller and upcoming cities that are pollution hotspots. This is even more evident in the winter peak daily pollution data (See *Graph 2: Trend in winter peak pollution among regions of India*).

Graph 1: Winter average pollution (15 Oct- 28 Feb) among regions of India

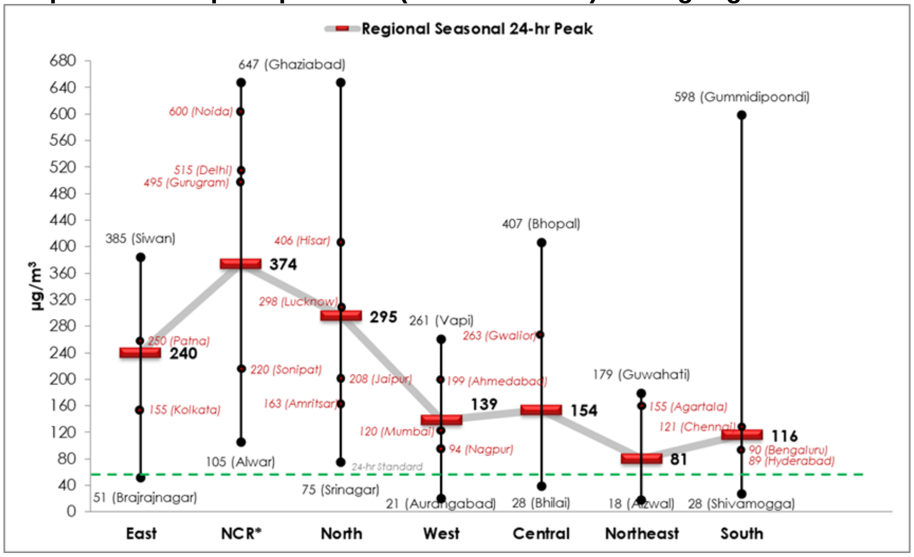


Note: Regional average $PM_{2.5}$ concentration is based on mean of winter value determined for each cities in the region. Winter value of a city is based on mean of daily $PM_{2.5}$ values recorded at CAAQM stations in a city with minimum 75 per cent data for this winter.
Source: CSE analysis of CPCB's real time air quality data

The average winter pollution of 2021-22 is lower than the previous winter: The regional $PM_{2.5}$ levels this winter is lower compared to previous winter across all regions with some variation. Air quality on an average was 12 per cent cleaner this winter compared to previous winter based on an average of 136 cities that have valid daily $PM_{2.5}$ concentration data for over 75 per cent of days of both winters (15 October to 28 February). Most improvement on average was noted in Northeast region (33 per cent) while Western region cities showed the least improvement (8 per cent).

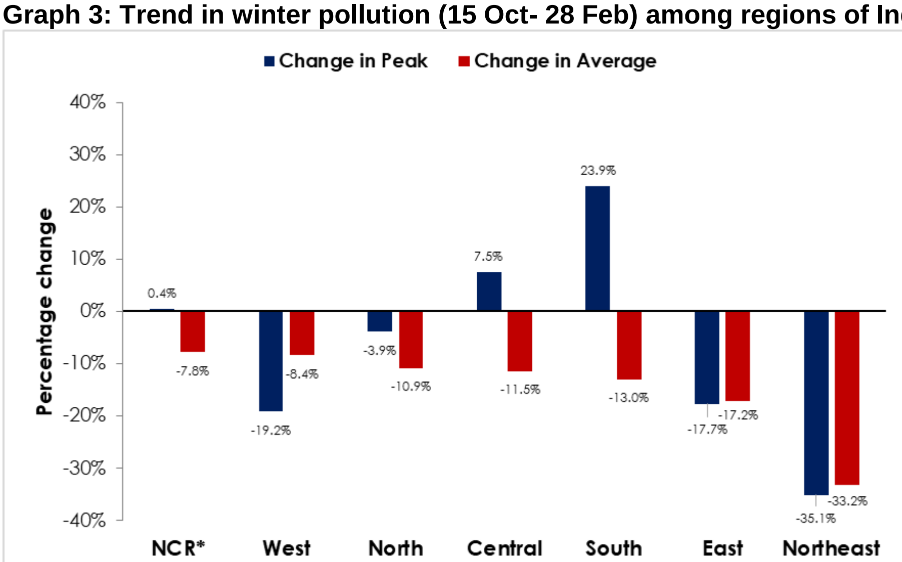
North Indian cities on an average have recorded 11 per cent lower PM2.5 level this winter, but the improvement in sub-region of Delhi NCR is smaller - just about 8 per cent (See *Graph 3: Trend in winter pollution (15 Oct- 28 Feb) among regions of India*). Delhi-NCR also saw marginal increase in their average peak 24-hr pollution. The peak pollution rose significantly from the baseline among the cities in the South (24 per cent) and Central Indian cities (7 per cent) despite the overall fall in the winter average.

Graph 2: Winter peak pollution (15 Oct- 28 Feb) among regions of India



Note: Regional $PM_{2.5}$ peak is based on mean of winter peak value determined for each cities in the region.
Source: CSE analysis of CPCB's real time air quality data

Graph 3: Trend in winter pollution (15 Oct- 28 Feb) among regions of India



Note: Based on cities that have data for both winter seasons (2020-21 and 2021-22).
Source: CSE analysis of CPCB's real time air quality data

Smaller cities of Bihar recorded higher pollution during winter than big cities of Delhi-NCR: Siwan in Bihar was the most polluted city in India this winter with seasonal average of 187 µg/m3. In fact, 13 cities of Bihar feature in top 25 cities with highest levels in winter (See *Annexure 1: All India peer comparison of winter pollution*). Delhi NCR has 11 cities in the list of 25 most polluted cities. Hisar in Northern Haryana is the only city in top 25 outside the sub-regions of Bihar and NCR.

From peak winter pollution perspective NCR cities completely dominate the list of most polluted with significantly worse 24-hr averages compared to rest of the country. Ghaziabad has witnessed the worst peak (24-hr average) among all the cities this winter with levels 647 µg/m3 (almost 11-times the Indian standard).

Aizwal in Mizoram and Shillong in Meghalaya were the least polluted cities in the country.

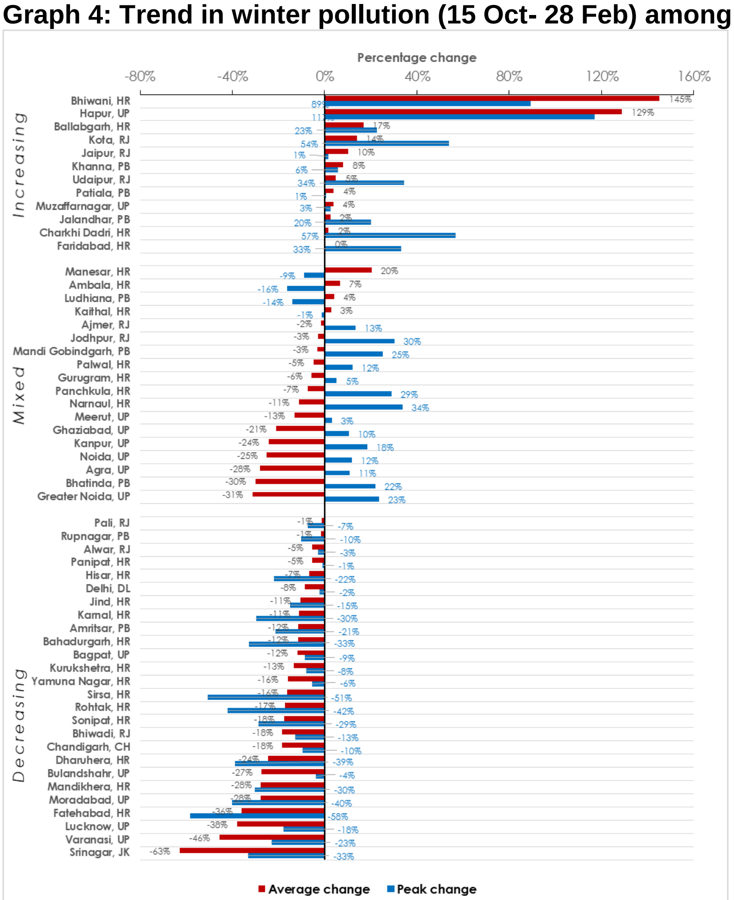
Winter air quality in northern region

The northern region includes 60 cities with real time monitoring facilities and are spread across the states of Punjab, Haryana, Chandigarh, Delhi-NCR, Rajasthan and UP. 56 of these cities had functional monitoring in 2020 winter as well. Geographically, this region represents the North Central Plains.

Cities with increasing trend: 12 cities in the region show increasing trend, i.e. both winter average and peak increased compared to their previous winter. Bhiwani in Haryana saw a staggering jump of 145 per cent in the winter average and 89 per cent increase in peak. It was followed by Hapur in UP that registered 129 per cent increase in winter average and 117 per cent increase in peak. Other cities that show increase include Ballabgarh, Kota, Jaipur, Khanna, Udaipur, Patiala, Muzaffarnagar, Jalandhar, Charkhi Dadri, and Faridabad (See *Graph 4: Trend in winter pollution among cities of North India*).

Cities with mixed trend: 18 cities in the region show mixed trend, i.e. their winter average has declined but the peak pollution increased compared to their previous winter or visa-versa. Manesar, Ambala, Ludhiana and Kaithal show increase in their winter average but registered lower peak pollution. Ajmer, Jodhpur, Mandi Gobindgarh, Palwal, Gurugram, Panchkula, Narnaul, Meerut, Ghaziabad, Kanpur, Noida, Agra, Bhatinda, and Greater Noida saw decline in their winter average but registered higher peaks compared to last winter. Greater Noida has the most divergent trend as its winter average declined by 31 per cent but its peak is 23 per cent higher.

Graph 4: Trend in winter pollution (15 Oct- 28 Feb) among cities of North India



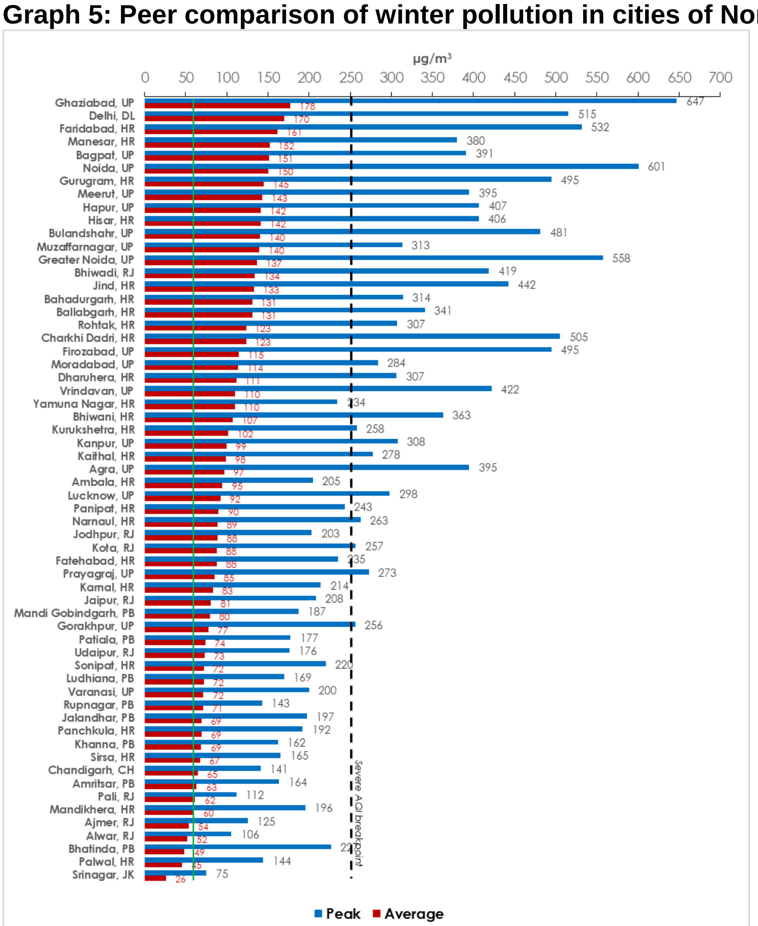
Note: Change in winter average and peak of a city is based on mean of daily $PM_{2.5}$ values recorded at CAAQM stations in the city that have minimum 75 per cent data for this winter and previous winter.
Source: CSE analysis of CPCB's real time air quality data

Cities recording declining trend in winter pollution: 26 cities show declining trend, i.e. both winter average and peak decreased compared to their previous winter. Srinagar in Jammu & Kashmir saw the highest decline with a drop of 63 per cent in their winter average and 33 per lower peak. Delhi also registered decline but marginal. Its winter average declined by 8 per cent and peak by 2 per cent. Other cities with declining trend include Pali, Rupnagar, Alwar, Panipat, Hisar, Jind, Karnal, Amritsar, Bahadurgarh, Bagpat, Kurukshetra, Yamuna Nagar, Sirsa, Rohtak, Sonipat, Bhiwadi, Chandigarh, Dharuhera, Bulandshahr, Mandikhera, Moradabad, Fatehabad, Lucknow, and Varanasi.

Most polluted cities: Most polluted city in the region during winter was Ghaziabad with winter average of 178 µg/m³ followed by Delhi that had a winter average of 170 µg/m3. Next eight spots are all occupied by neighboring NCR cities, namely Faridabad, Manesar, Bagpat, Noida, Gurugram, Meerut, and Hapur. Cities of NCR completely dominated the list of the most polluted. Hisar is the most polluted city in North outside NCR with winter average of 142 µg/m3 followed by Firozabad, Moradabad and Vrindavan. All in immediate vicinity of NCR. (See *Graph 5: Peer comparison of winter pollution in cities of North India*).

Least polluted cities: Srinagar is the cleanest city in North. Palwal in Haryana, Bhatinda in Punjab and Alwar in Rajasthan are the other cities with relatively lower winter average. Interestingly, the peak pollution exceeded the standard of 60 µg/m³ in all the cities.

Graph 5: Peer comparison of winter pollution in cities of North India



Note: Winter average and peak of a city is based on mean of daily $PM_{2.5}$ values recorded at CAAQM stations in the city that have minimum 75 per cent data for this winter.
Source: CSE analysis of CPCB's real time air quality data

Air quality in eastern region

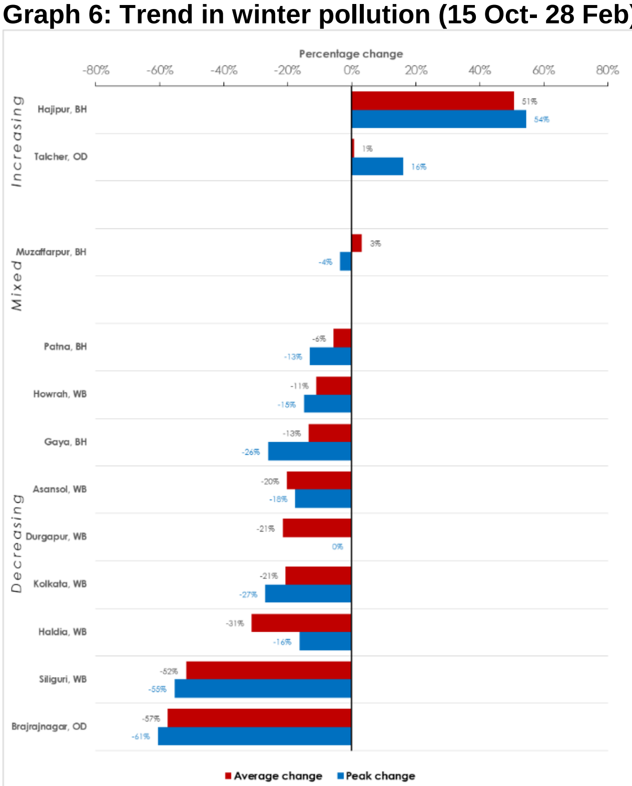
The eastern region includes 28 cities spread across Bihar, West Bengal, Jharkhand and Odisha. Geographically, this region represents the Eastern Plains and Eastern Highlands.

Cities with increasing trend: Two cities in the region show increasing trend, i.e. both winter average and peak increased compared to their previous winter. Hajipur in Bihar saw a jump of 51 per cent in the winter average and 54 per cent increase in peak. Talcher in Odisha registered 1 per cent increase in winter average and 16 per cent increase in peak. (See *Graph 6: Trend in winter pollution among cities of North India*).

Cities with mixed trend: Muzaffarpur is the only city in the region that show mixed trend, i.e. their winter average declined but peak pollution increased compared to their pevious winter or visa-versa. Its winter average increased by 3 per cent but its peak was 4 per cent lower.

Cities with declining trend: Nine cities in the region show declining trend, i.e. both winter average and peak decreased compared to their last winter. Brajrajnagar in Odisha saw the most decline with a drop of 57 per cent in their winter average and 61 per lower peak. Kolkata also registered decline -- winter average declining by 21 per cent and peak by 27 per cent. Other cities with declining trend are Patna, Howrah, Gaya, Asansol, Durgapur, Haldia, and Siliguri.

Graph 6: Trend in winter pollution (15 Oct- 28 Feb) among cities of eastern region

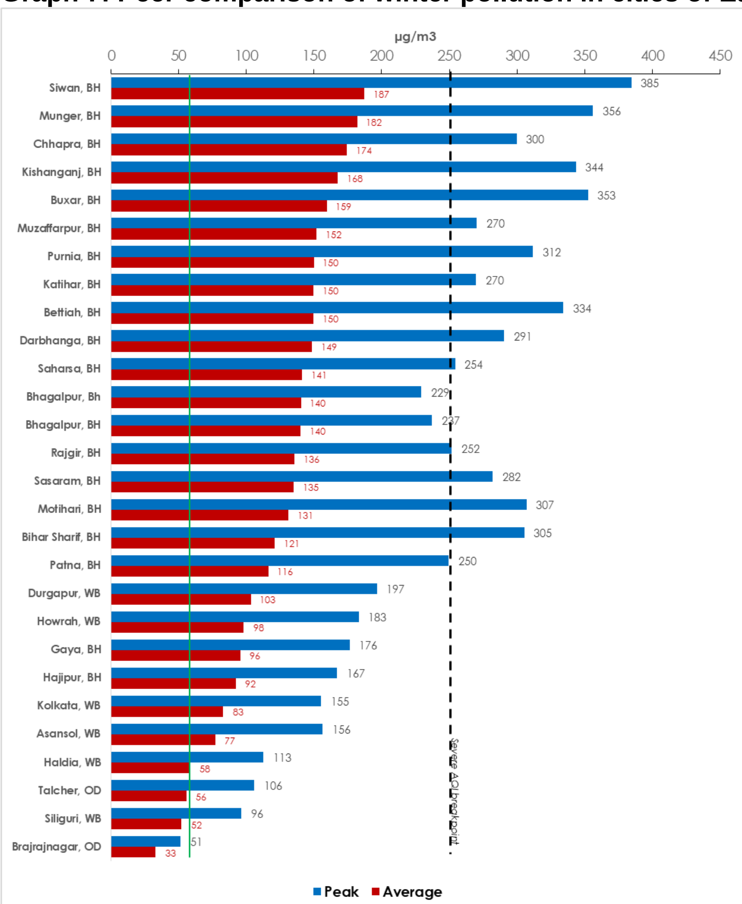


Note: Change in winter average and peak of a city is based on mean of daily $PM_{2.5}$ values recorded at CAAQM stations in the city that have minimum 75 per cent data for this winter and previous winter.
Source: CSE analysis of CPCB's real time air quality data

Most polluted cities: Most polluted city in the region was Siwan in Bihar with winter average of 187 µg/m³. In fact, small cities of Bihar completely dominate the list of most polluted and occupy the top 17 spots. Durgapur with winter average of 103 µg/m3 was the most polluted city in West Bengal. Patna and Kolkata occupied 18th and 23rd position on the chart (See *Graph 7: Peer comparison of winter pollution in cities of East India*).

Least polluted cities: Brajrajnagar in Odisha and Siliguri in West Bengal recorded the lowest winter average in the region. Brajrajnagar is the only city in the region with peak pollution under that 24-hr standard.

Graph 7: Peer comparison of winter pollution in cities of East India



Note: Winter average and peak of a city is based on mean of daily $PM_{2.5}$ values recorded at CAAQM stations in the city that have minimum 75 per cent data for this winter.
Source: CSE analysis of CPCB's real time air quality data

Air quality in western region

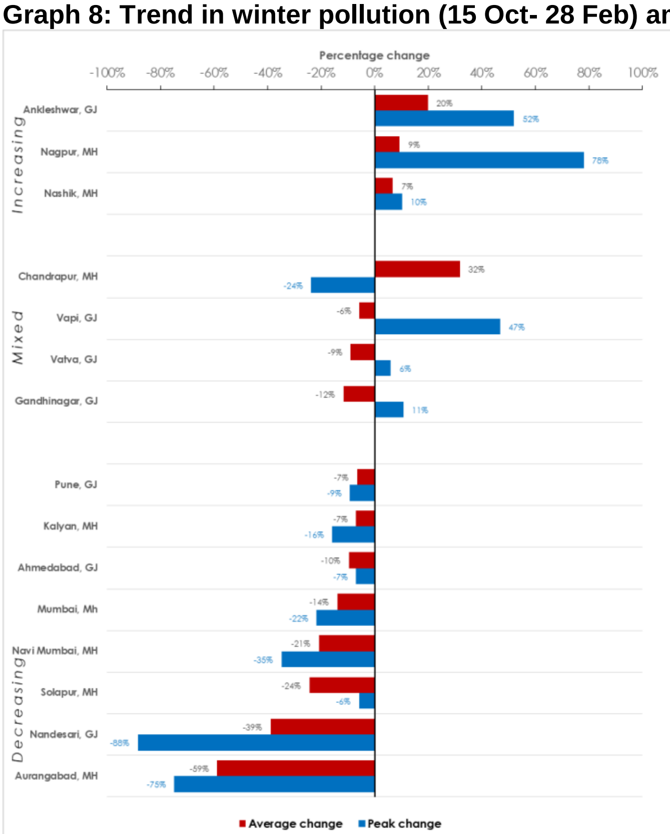
The region includes 15 cities spread across Gujarat and Maharashtra. All cities have data for both winter seasons. Geographically, this region represents the arid west, Northern Deccan plateau and Konkan Coast.

Cities with increasing trend: Three cities in the region show increasing trend, i.e. both winter average and peak increased compared to their previous winter. Ankleshwar in Gujarat saw a jump of 20 per cent in the winter average and 52 per cent increase in peak. Nagpur in Maharashtra registered 9 per cent increase in winter average and 78 per cent increase in peak. Nashik in Maharashtra registered 7 per cent increase in winter average and 10 per cent increase in peak. (See *Graph 8: Trend in winter pollution among cities of West India*).

Cities with mixed trend: Four cities in the region show mixed trend, i.e. their winter average declined but peak pollution increased compared to their previous winter or visa-versa. Chandrapur had the most divergent trend with winter average increasing by 32 per cent but its peak was 24 per cent lower.

Cities with declining trend: Eight cities in the region show declining trend, i.e. both winter average and peak decreased compared to their last winter. Aurangabad saw the most decline with a drop of 59 per cent in their winter average and 75 per lower peak. Mumbai also registered decline -- winter average declined by 14 per cent and peak by 22 per cent. Other cities that show declining trend include Pune, Kalyan, Ahmedabad, Navi Mumbai, Solapur and Nandesari.

Graph 8: Trend in winter pollution (15 Oct- 28 Feb) among cities of West India

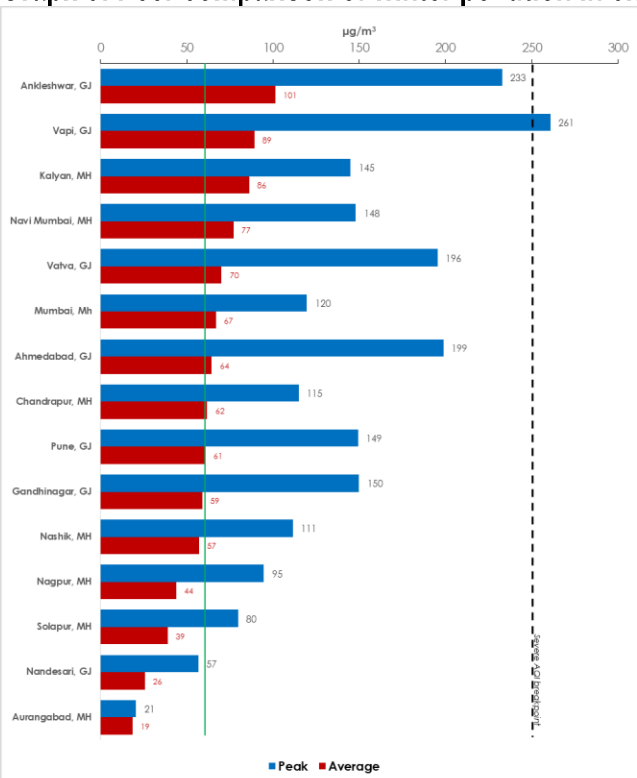


Note: Change in winter average and peak of a city is based on mean of daily $PM_{2.5}$ values recorded at CAAQM stations in the city that have minimum 75 per cent data for this winter and previous winter.
Source: CSE analysis of CPCB's real time air quality data

Most polluted cities: Most polluted city in the region was Ankleshwar with seasonal average of 101 µg/m³. Next two spot were occupied by Vapi and Kalyan. (See *Graph 9: Peer comparison of winter pollution in cities of West India*).

Least polluted cities: Aurangabad and Nandesari recorded the lowest winter average in the region. Chandrapur, Solapur round up the list of three least polluted.

Graph 9: Peer comparison of winter pollution in cities of West India



Note: Winter average and peak of a city is based on mean of daily $PM_{2.5}$ values recorded at CAAQM stations in the city that have minimum 75 per cent data for this winter.
Source: CSE analysis of CPCB's real time air quality data

Air quality in Central region

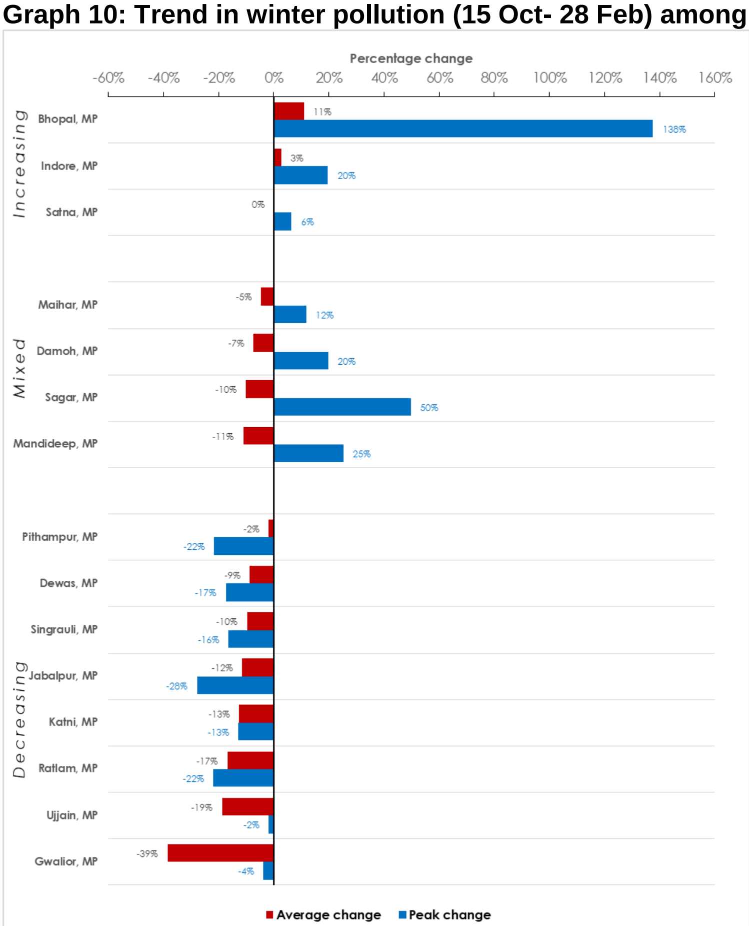
The region includes 17 cities spread across Madhya Pradesh and Chhattisgarh. 15 of these cities have data for both winters. Geographically this region represents the Central Highlands.

Cities with increasing trend: Three cities in the region show increasing trend, i.e. both winter average and peak increased compared to their last winter. Bhopal saw a jump of 11 per cent in the winter average and 138 per cent increase in peak. Indore registered 3 per cent increase in winter average and 20 per cent increase in peak. Satna registered no change in winter average but 6 per cent increase in peak. (See *Graph 10: Trend in winter pollution among cities of Central India*).

Cities with mixed trend: 4 cities in the region show mixed trend, i.e. their winter averaged declined but peak pollution increase compared to their last winter or visa-versa. Sagar had most divergent trend with winter average increased by 10 per cent but its peak was 50 per cent lower. Other cities with mixed trend in the region are Maihar, Damoh, and Mandideep.

Cities with declining trend: Eight cities in the region show declining trend, i.e. both winter average and peak decreased compared to their last winter. Gwalior saw the most decline with a drop of 39 per cent in their winter average and 4 per lower peak. Other cities with declining trend are Pithampur, Dewas, Singrauli, Jabalpur, Katni, Ratlam, and Ujjain.

Graph 10: Trend in winter pollution (15 Oct- 28 Feb) among cities of Central India

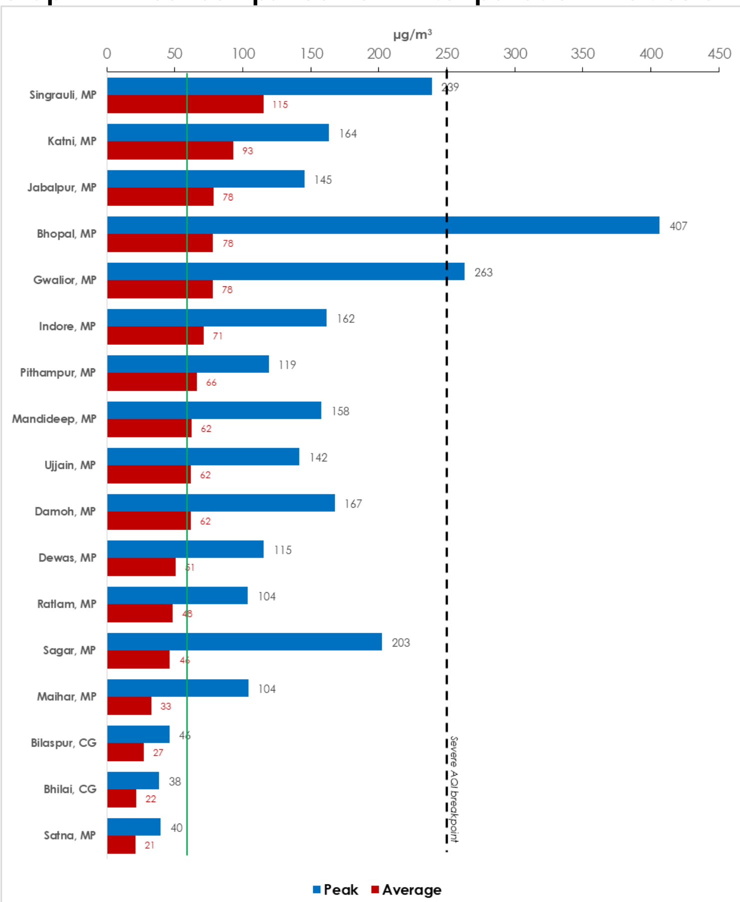


Note: Change in winter average and peak of a city is based on mean of daily $PM_{2.5}$ values recorded at CAAQM stations in the city that have minimum 75 per cent data for this winter and previous winter.
Source: CSE analysis of CPCB's real time air quality data

Most polluted cities: Most polluted city in the region was Srigrauli with winter average of 115 µg/m³. Next two spot were occupied by Katni and Jabalpur. Bhopal with peak 24-hr level of 407 µg/m3 had highest peak pollution in the region. (See *Graph 11: Peer comparison of winter pollution in cities of Central India*).

Least polluted cities: Satna and Bhilai recorded the lowest winter average in the region. But the data from these two cities is of suspicious nature as the monitoring stations are owned and operated by industry and not the state pollution control board.

Graph 11: Peer comparison of winter pollution in cities of Central India



Note: Winter average and peak of a city is based on mean of daily $PM_{2.5}$ values recorded at CAAQM stations in the city that have minimum 75 per cent data for this winter.
Source: CSE analysis of CPCB's real time air quality data

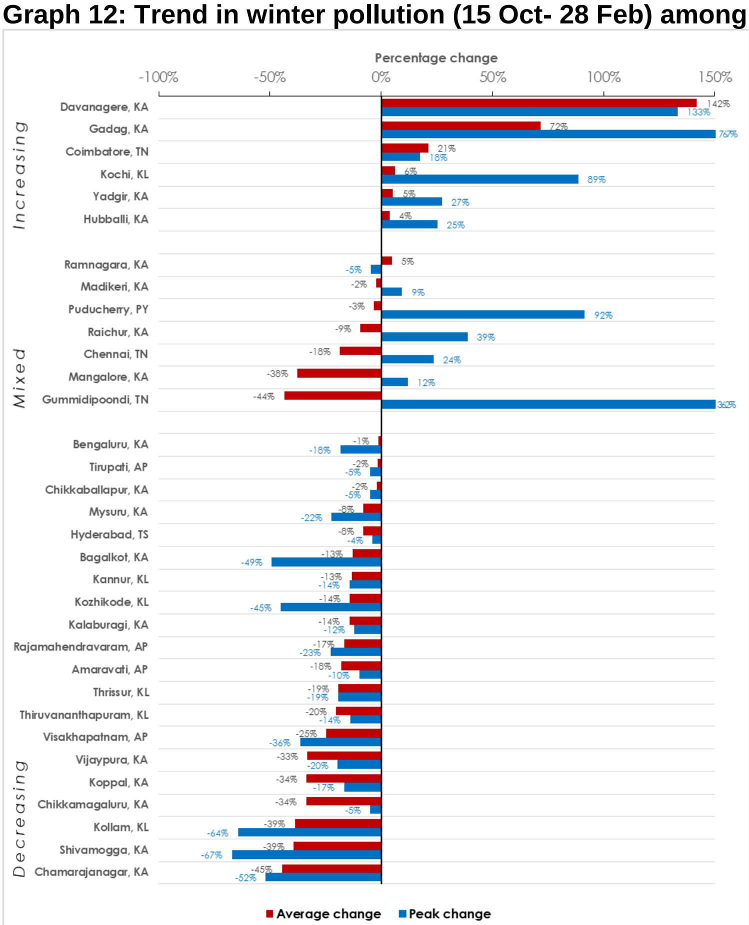
Air quality in southern region

The region includes 35 cities spread across Andhra Pradesh, Karnataka, Kerala, Puducherry, Tamil Nadu and Telangana. Geographically, this region represents the southern Deccan plateau, Western Ghats, Malabar and Coramandal coasts. Southern region recorded the lowest regional $PM_{2.5}$ average this winter but it also registered almost 24 per cent increase in regional average peak pollution compared to previous winter. Industrial towns of south namely Gummidipoondi in Tamil Nadu and Gadag in Karnataka, also appear in the worst 10 cities for peak pollution (24-hr value).

Cities with increasing trend: Six cities in the region show increasing trend, i.e. both winter average and peak increased compared to their previous winter. Davanagere saw a jump of 142 per cent in the winter average and 133 per cent increase in peak. Comibatore and Kochi are the major cities with increasing trend. Other cities with increasing trend in the region are Gadag, Yadgir, and Hubballi. (See *Graph 12: Trend in winter pollution among cities of South India*)

Cities with mixed trend: Seven cities in the region show mixed trend, i.e. their winter averaged declined but peak pollution increase compared to their last winter or visa-versa. Gummidipoondi in Tamil Nadu had the most divergent trend with winter average decreasing by 44 per cent but its peak was 362 per cent higher from its low base. Chennai also recorded mixed trend with winter average decreasing by 18 per cent but its peak was 24 per cent higher. Other cities with mixed trend in the region are Ramnagara, Madikeri, Puducherry, Raichur and Mangalore.

Graph 12: Trend in winter pollution (15 Oct- 28 Feb) among cities of southern region



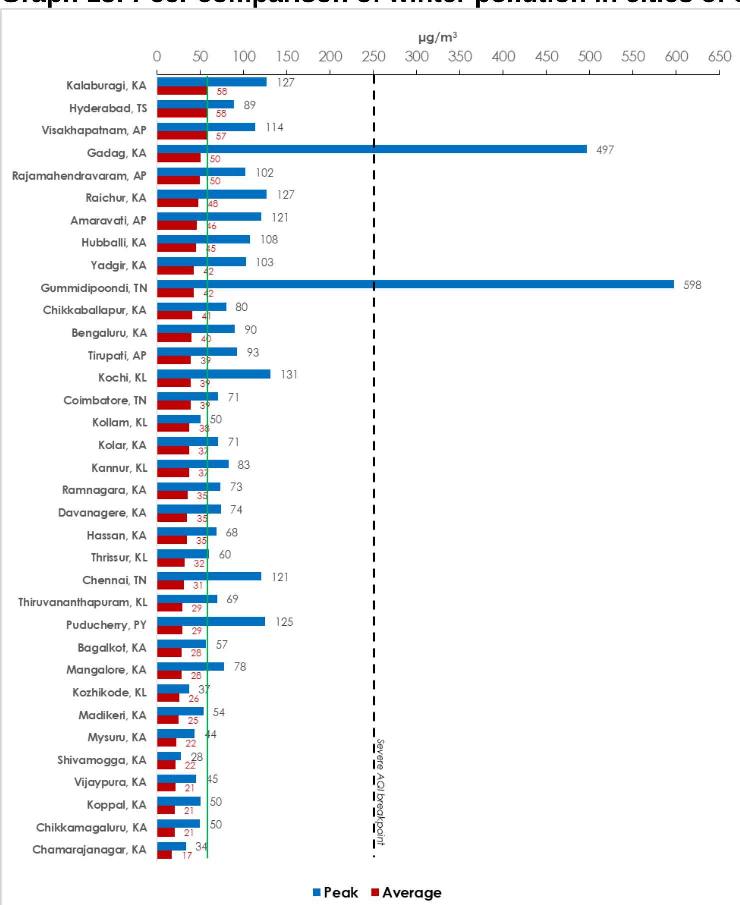
Note: Change in winter average and peak of a city is based on mean of daily $PM_{2.5}$ values recorded at CAAQM stations in the city that have minimum 75 per cent data for this winter and previous winter.
Source: CSE analysis of CPCB's real time air quality data

Cities with declining trend: 20 cities in the region show declining trend, -- both winter average and peak decreased compared to their previous winter. Chamarajanagar in Karnataka saw the highest decline with a drop of 45 per cent in their winter average and 52 per lower peak. Bengaluru and Hyderabad show marginal decline in their winter average and peak values. Other cities with declining trend are Tirupati, Chikkaballapur, Mysuru, Bagalkot, Kannur, Kozhikode, Kalaburagi, Rajamahendravaram, Amaravati, Thrissur, Thiruvananthapuram, Visakhapatnam, Vijaypura, Koppal, Chikkamagaluru, Kollam, and Shivamogga.

Most polluted cities: Most polluted cities in the region was Kalaburgi and Hyderabad, both had winter average of 58 µg/m³. They are followed by Visakhapatnam (See *Graph 13: Peer comparison of winter pollution in cities of South India*).

Least polluted cities: Chamarajanagar and Chikkamagaluru in Karnataka recorded the lowest winter average in the region. Karnataka has the least polluted cities of the region followed by Kerala.

Graph 13: Peer comparison of winter pollution in cities of South India



Note: Winter average and peak of a city is based on mean of daily $PM_{2.5}$ values recorded at CAAQM stations in the city that have minimum 75 per cent data for this winter.
Source: CSE analysis of CPCB's real time air quality data

Air quality in Northeastern region

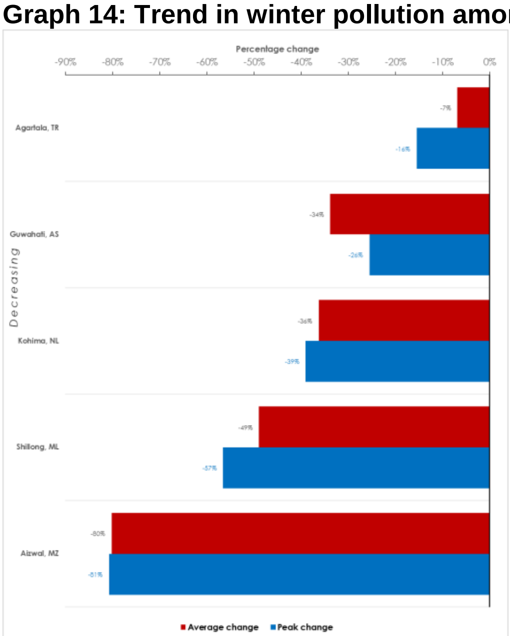
The region includes six cities. Geographically this region represents the Eastern Himalayas and Brahmaputra plains.

Cities with declining trend: All cities in the region show declining trend, i.e. both winter average and peak decreased compared to their previous winter. Aizwal in Mizoram saw the most decline with a drop of 50 per cent in their respective winter averages and 51 per cent lower peak. Agartala registered least change with its winter average declining by 7 per cent and peak level declining by 16 per cent. (See *Graph 14: Trend in winter pollution among cities of Northeast India*).

Most polluted cities: Most polluted city in the region include Guwahati with winter average of 81 µg/m³. This is followed by Agartala that registered winter average of 77 µg/m³ (See *Graph 15: Peer comparison of winter pollution in cities of Northeast India*).

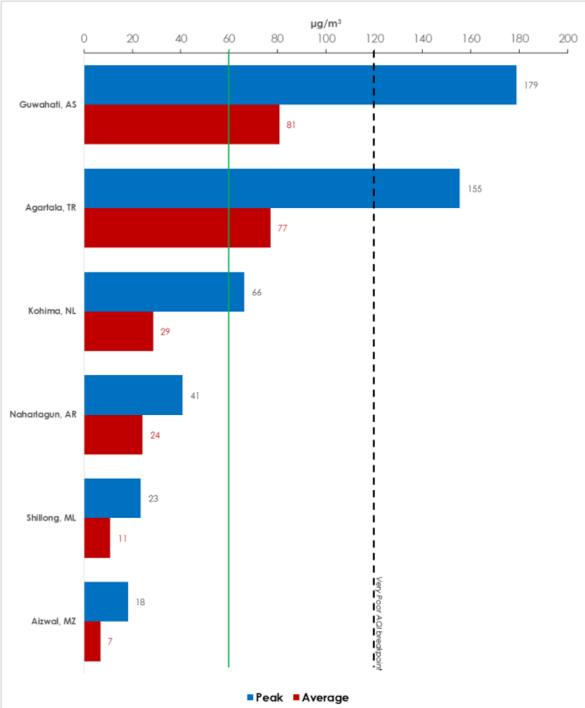
Least polluted cities: Aizwal and Shillong recorded the lowest winter average in the region. Hill stations are relatively less polluted than cities in river valleys and foothills. Aizwal and Shillong in Northeast had the lowest levels compared to the all other cities of all regions this winter. But cities and towns even with low seasonal average have suffered high spikes in daily levels.

Graph 14: Trend in winter pollution among cities of Northeast India



Note: Change in winter average and peak of a city is based on mean of daily $PM_{2.5}$ values recorded at CAAQM stations in the city that have minimum 75 per cent data for this winter and previous winter.
Source: CSE analysis of CPCB's real time air quality data

Graph 15: Peer comparison of winter pollution in cities of Northeast India



Note: Winter average and peak of a city is based on mean of daily $PM_{2.5}$ values recorded at CAAQM stations in the city that have minimum 75 per cent data for this winter.
Source: CSE analysis of CPCB's real time air quality data

Take away

The widely divergent trend in pollution levels across regions is strongly influenced by local geoclimatic conditions, meteorology and the intensity of pollution. But the emerging trend points towards a national air quality crisis. While the regions are battling to meet the national ambient air quality standards, winter conditions are aggravating the problem further. Even though the pandemic conditions have arrested the trend overall trend in most regions, there is still a mixed trend. Despite having a relatively lower annual average pollution levels the peak pollution during winter can spike. This indicates the influence of cool and calm winter conditions and also the regional influence.

While cities require their respective clean air action plans for controlling local pollution, the effort will have to be scaled up for the region to control pollution from widely dispersed sources across the urban and rural landscape. The multi-sector plan has to address vehicles, industry, power plants, household pollution, waste burning and more. This granular tracking of regional and local pollution needs to inform policy making and the compliance framework for air quality management to meet the clean air targets.

Annexure 1: All India peer comparison of winter pollution

Rank	City	Winter PM2.5 average (µg/m^3)	Peak 24hr value (µg/m^3)
1	Siwan, BH	187	385
2	Munger, BH	182	356
3	Ghaziabad, UP	178	647
4	Chhapra, BH	174	300
5	Delhi, DL	170	515
6	Kishanganj, BH	168	344
7	Faridabad, HR	161	532
8	Buxar, BH	159	353
9	Muzaffarpur, BH	152	270
10	Manesar, HR	152	380
11	Bagpat, UP	151	391
12	Noida, UP	150	601
13	Purnia, BH	150	312
14	Katihar, BH	150	270
15	Bettiah, BH	150	334
16	Darbhanga, BH	149	291
17	Gurugram, HR	145	495
18	Meerut, UP	143	395
19	Hapur, UP	142	407
20	Hisar, HR	142	406
21	Saharsa, BH	141	254
22	Bulandshahr, UP	140	481
23	Bhagalpur, Bh	140	229
24	Bhagalpur, BH	140	237
25	Muzaffarnagar, UP	140	313
26	Greater Noida, UP	137	558
27	Rajgir, BH	136	252
28	Sasaram, BH	135	282
29	Bhiwadi, RJ	134	419
30	Jind, HR	133	442
31	Motihari, BH	131	307
32	Bahadurgarh, HR	131	314
33	Ballabgarh, HR	131	341
34	Rohtak, HR	123	307
35	Charkhi Dadri, HR	123	505
36	Bihar Sharif, BH	121	305
37	Patna, BH	116	250
38	Singrauli, MP	115	239
39	Firozabad, UP	115	495
40	Moradabad, UP	114	284
41	Dharuhera, HR	111	307
42	Vrindavan, UP	110	422
43	Yamuna Nagar, HR	110	234
44	Bhiwani, HR	107	363
45	Durgapur, WB	103	197
46	Kurukshetra, HR	102	258
47	Ankleshwar, GJ	101	233
48	Kanpur, UP	99	308
49	Kaithal, HR	98	278
50	Howrah, WB	98	183
51	Agra, UP	97	395
52	Gaya, BH	96	176
53	Ambala, HR	95	205
54	Katni, MP	93	164
55	Lucknow, UP	92	298
56	Hajipur, BH	92	167
57	Panipat, HR	90	243
58	Vapi, GJ	89	261
59	Narnaul, HR	89	263
60	Jodhpur, RJ	88	203
61	Kota, RJ	88	257
62	Fatehabad, HR	88	235
63	Kalyan, MH	86	145

Rank	City	Winter PM2.5 average (µg/m^3)	Peak 24hr value (µg/m^3)
64	Prayagraj, UP	85	273
65	Karnal, HR	83	214
66	Kolkata, WB	83	155
67	Guwahati, AS	81	179
68	Jaipur, RJ	81	208
69	Mandi Gobindgarh, PB	80	187
70	Jabalpur, MP	78	145
71	Bhopal, MP	78	407
72	Gwalior, MP	78	263
73	Gorakhpur, UP	77	256
74	Navi Mumbai, MH	77	148
75	Agartala, TR	77	155
76	Asansol, WB	77	156
77	Patiala, PB	74	177
78	Udaipur, RJ	73	176
79	Sonipat, HR	72	220
80	Ludhiana, PB	72	169
81	Varanasi, UP	72	200
82	Rupnagar, PB	71	143
83	Indore, MP	71	162
84	Vatva, GJ	70	196
85	Jalandhar, PB	69	197
86	Panchkula, HR	69	192
87	Khanna, PB	69	162
88	Sirsa, HR	67	165
89	Mumbai, Mh	67	120
90	Pithampur, MP	66	119
91	Chandigarh, CH	65	141
92	Ahmedabad, GJ	64	199
93	Amritsar, PB	63	164
94	Mandideep, MP	62	158
95	Chandrapur, MH	62	115
96	Ujjain, MP	62	142
97	Damoh, MP	62	167
98	Pali, RJ	62	112
99	Pune, GJ	61	149
100	Mandikhera, HR	60	196
101	Gandhinagar, GJ	59	150
102	Kalaburagi, KA	58	127
103	Haldia, WB	58	113
104	Hyderabad, TS	58	89
105	Visakhapatnam, AP	57	114
106	Nashik, MH	57	111
107	Talcher, OD	56	106
108	Ajmer, RJ	54	125
109	Alwar, RJ	52	106
110	Siliguri, WB	52	96
111	Dewas, MP	51	115
112	Gadag, KA	50	497
113	Rajamahendravaram, AP	50	102
114	Bhatinda, PB	49	227
115	Ratlam, MP	48	104
116	Raichur, KA	48	127
117	Sagar, MP	46	203
118	Amaravati, AP	46	121
119	Palwal, HR	45	144
120	Hubballi, KA	45	108
121	Nagpur, MH	44	95
122	Yadgir, KA	42	103
123	Gummidipoondi, TN	42	598
124	Chikkaballapur, KA	41	80
125	Bengaluru, KA	40	90
126	Tirupati, AP	39	93
127	Kochi, KL	39	131
128	Coimbatore, TN	39	71

Rank	City	Winter PM2.5 average (µg/m³)	Peak 24hr value (µg/m³)
129	Solapur, MH	39	80
130	Kollam, KL	38	50
131	Kolar, KA	37	71
132	Kannur, KL	37	83
133	Ramnagara, KA	35	73
134	Davanagere, KA	35	74
135	Hassan, KA	35	68
136	Brajrajnagar, OD	33	51
137	Maihar, MP	33	104
138	Thrissur, KL	32	60
139	Chennai, TN	31	121
140	Thiruvananthapuram, KL	29	69
141	Puducherry, PY	29	125
142	Kohima, NL	29	66
143	Bagalkot, KA	28	57
144	Mangalore, KA	28	78
145	Bilaspur, CG	27	46
146	Srinagar, JK	26	75
147	Nandesari, GJ	26	57
148	Kozhikode, KL	26	37
149	Madikeri, KA	25	54
150	Naharlagun, AR	24	41
151	Mysuru, KA	22	44
152	Bhilai, CG	22	38
153	Shivamogga, KA	22	28
154	Satna, MP	21	40
155	Vijaypura, KA	21	45
156	Koppal, KA	21	50
157	Chikkamagaluru, KA	21	50
158	Aurangabad, MH	19	21
159	Chamarajanagar, KA	17	34
160	Shillong, ML	11	23
161	Aizwal, MZ	7	18

Note: Winter average of a city is based on mean of daily $PM_{2.5}$ values recorded at CAAQM stations in the city that have minimum 75 per cent data for this winter. Winter peak of a city is based on mean of the highest daily $PM_{2.5}$ value recorded at CAAQM stations in the city that meet the data completeness requirement.
Source: CSE analysis of CPCB's real time air quality data.

Air pollution in North India: Moving beyond Delhi-NCR to unlock bigger pollution picture

Anumita Roychowdhury and Avikal Somvanshi
Research contribution: Sharanjeet Kaur

Centre for Science and Environment, New Delhi, December 16, 2021

Centre for Science and Environment (CSE) has analyzed air quality trends so far in North India with special focus on cities outside Delhi and National Capital Region (NCR). It is not Delhi and NCR alone that are wrapped in smog, but the entire northern plains. This land locked region is most vulnerable to smog build-up during winter when inversion, cool and calm conditions entrap air and pollution.

This year too there has been curiosity about the smog pattern in the northern belt especially in the smaller cities and towns in the larger region. The focus is on Punjab, Haryana, Uttar Pradesh, Rajasthan, Delhi and NCR. Therefore, as part of its air quality tracker initiative, the Urban Data Analytics Lab of CSE has carried out an assessment of annual and seasonal trends in PM2.5 concentration for the period 1 January 2019 to 30 November 2021. This helps to understand the pollution profile across the northern states and locates Delhi within the larger context of North India related to seasonal variation and annual trends in particulate pollution.

While capturing the regional trend in urban pollution, it has also put a specific spotlight on the emerging trends in key cities of the region that are spread across Punjab, Haryana, Uttar Pradesh, Delhi and NCR. This shows the magnitude of reduction needed in the annual average level of PM2.5 in each city, how daily pollution trends are changing and the trend in winter pollution.

This analysis is based on the real time data available from the current working air quality monitoring stations in North India. 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 137 continuous ambient air quality monitoring stations (CAAQMS) spread across 56 cities in Punjab, Chandigarh, Haryana, Delhi, Rajasthan, and Uttar Pradesh. 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 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).

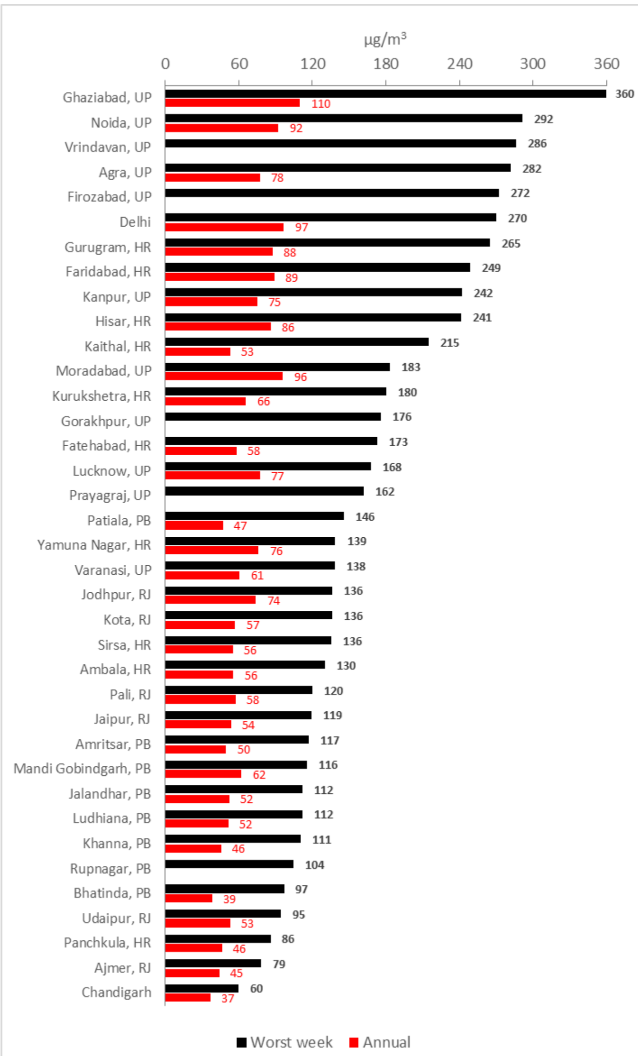
North region has been divided into five sub-regions for analysis sake in this study. Sub-regions have been defined as Punjab & Chandigarh, NCR (includes Delhi and 26 other cities/towns that fall inside NCR), Haryana (excluding cities in NCR), Uttar Pradesh (excluding cities in NCR), and Rajasthan (excluding cities in NCR).

Key findings: Highlights

i) Winter pollution pattern in key cities of the North

During a smog episode pollution levels in otherwise cleaner smaller towns can exceed the levels reported in Delhi: Most smaller towns have considerably lower annual average PM2.5 level but during early winter when farm stubble fire also peaks entire region gets engulfed by smog, smaller towns report level comparable to Delhi. For instance, smaller cities like Vrindavan, Agra and Firozabad have comparatively lower annual average of PM2.5 than Delhi. But during the early winter of 2021 their weekly average PM2.5 levels exceeded that of Delhi. While the annual average level of Delhi is 97 µg/m3 that of Agra is 78 µg/m3, 20 per cent lower. But during early winter this year the weekly average PM2.5 level in Agra was 282 µg/m3 and exceeded by 5 per cent that of Delhi which stood at 270 µg/m3. Similarly, weekly average of Vrindavan has been 286 µg/m3 and that of Firozabad 272 µg/m3. (See *Graph 1: Weekly PM2.5 levels vs annual level among North Indian Cities*). Ghaziabad and Nodia had the worst weekly average this winter.

Graph 1: Weekly PM2.5 levels vs annual level among North Indian Cities

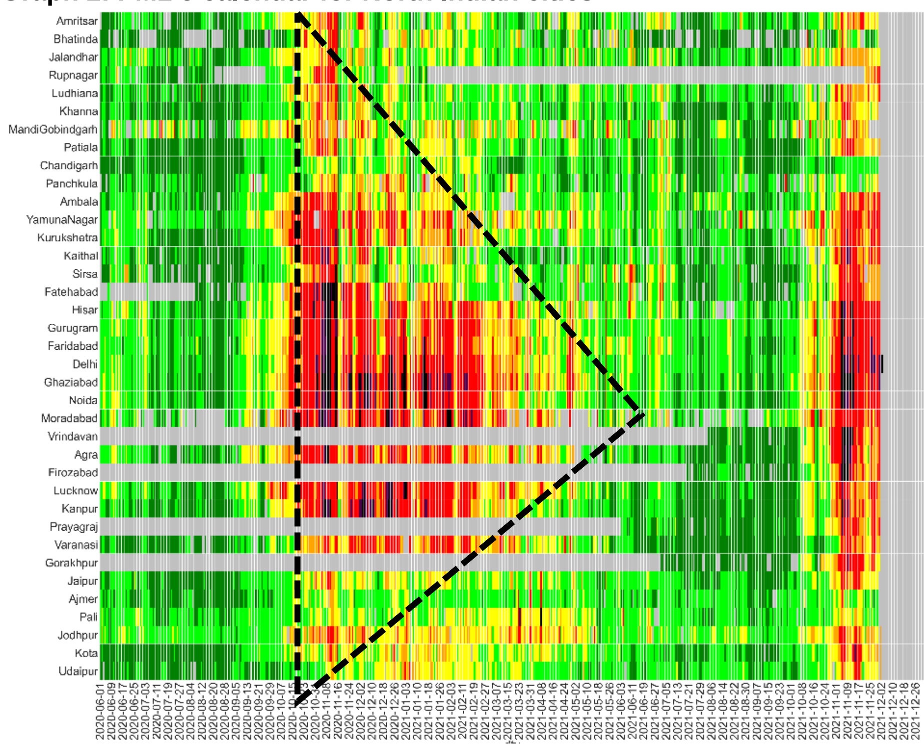


Note: PM2.5 values for cities with more than one monitoring stations is based on average of all stations that have continuous and adequate data for complete assessment period. Data up till 30 November 2021.
Source: CSE analysis of realtime data from CPCB portal

Early winter smog synchronise across the region but lasts longer in Delhi-NCR: Normally the smog episodes of November synchronise across the northern region. But it lingers longer only in Delhi, NCR and UP during rest of the winter. 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 of Punjab and North Haryana post stubble fire season but it remains in very poor category in NCR and UP till February (See *Graph 2: PM2.5 calendar for North Indian cities*). In fact, air quality in these two sub-regions do not clean up to satisfactory levels until arrival of monsoon. Rajasthan cities also show impact of smoke but to a lesser degree with relatively less polluted air during rest of the winter.

Graph 2: PM2.5 calendar for North Indian cities

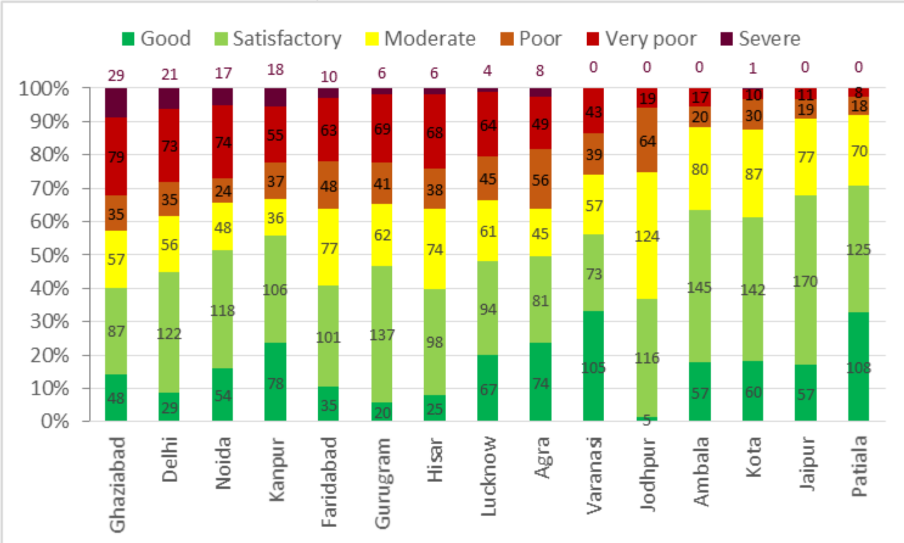


Note: PM2.5 values for cities with more than one monitoring stations is based on average of all stations that have continuous and adequate data for complete assessment period. Cell colours are based on the official AQI category colours. Data up till 30 November 2021.
Source: CSE analysis of realtime data from CPCB portal

Number of days with air quality in very poor and severe category is significantly higher in cities of NCR and UP: Delhi and NCR cities lead the chart for most severe days in 2021. Delhi recorded 94 days with very poor or severe air quality this year by end of November. It was only topped by Ghaziabad that recorded 108 days of very poor and severe air quality. Faridabad and Gurugram are not any cleaner with 75 days and 73 days of very poor and severe days respectively. UP cities outside NCR including Kanpur (73 days of very poor and severe), Lucknow (68 days of very poor and severe) and Agra (57 days of very poor and severe) are not much behind Delhi-NCR. Air quality monitoring is limited in UP cities and therefore it is not possible to capture the full magnitude of the problem. Even in larger Haryana, small city like Hisar has recorded 74 days of very poor and severe air quality in 2021 so far.

Good news is that the available information shows that this year 24hr standard for PM2.5 has been met in most cities in the region for more than half of the year, recorded mostly during monsoon and summer. An interesting observation is that cities in the arid regions of Rajasthan, Haryana and Punjab have on average recorded lesser days with good air quality compared to cities in the plains of UP. Chandigarh and Punjab cities have the most numbers of satisfactory and good air quality days (See *Graph 3: PM2.5 AQI categorization of days for major cities in North India*).

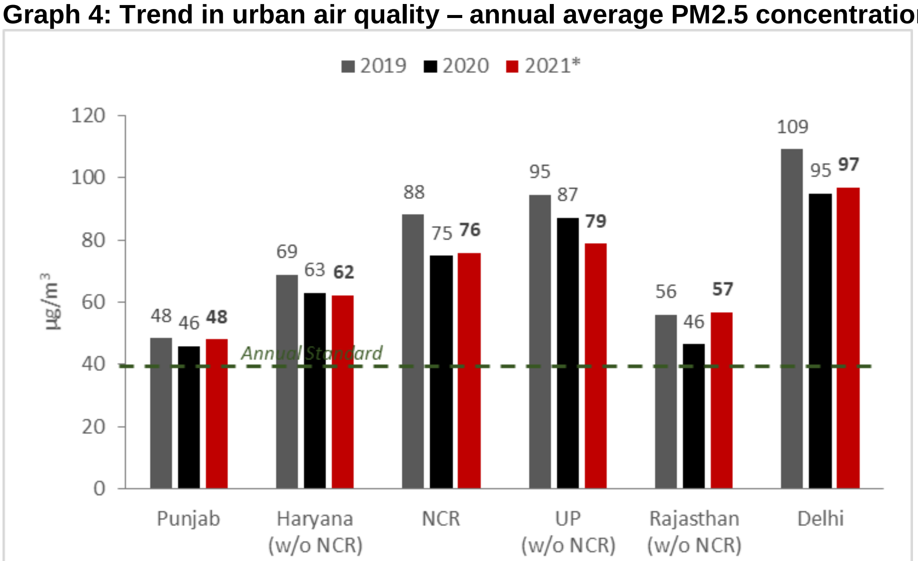
Graph 3: PM2.5 AQI categorization of days for major cities in North India



Note: PM2.5 values for cities with more than one monitoring stations is based on average of all stations that have continuous and adequate data for complete assessment period. Data up till 30 November 2021.
Source: CSE analysis of realtime data from CPCB portal

Overall trend in urban concentration of PM2.5 in most cities of Northern states is declining or has stabilised: Based on the data available for the limited number of cities in north India it is possible to construct a trend in urban air quality in Delhi-NCR, UP, Haryana, Punjab and Rajasthan. This shows a declining and a stabilised trend though the annual average levels are still way above the national ambient air quality standard for PM2.5 in most monitored cities of the sub regions. Data for 2021 is until November 30th (See *Graph 4: Trend in urban air quality – annual average PM2.5 concentration in North India*). The high annual average levels also explain why pollution build up is so high in the region when atmospheric conditions change during winter.

Graph 4: Trend in urban air quality – annual average PM2.5 concentration in North India



Note: PM2.5 values for sub-regions are based on the average of citywide values of all the cities in that region. PM2.5 values for cities with more than one monitoring stations is based on average of all stations that have continuous and adequate data for complete assessment period. Data up till 30 November 2021.
Source: CSE analysis of realtime data from CPCB portal

Average PM2.5 concentration in cities of Uttar Pradesh (UP) and Delhi are among the highest in North India: While the entire north India is vulnerable to pollution build up, the overall annual average of Delhi and NCR is among the highest in the region. Also the average of the urban concentration in UP outside NCR is 8 per cent higher than NCR (includes Delhi and 26 other cities/towns that fall in NCR). In fact, Delhi has lower annual average than many cities of UP. This year (2021) Ghaziabad has been the most polluted city in the region with the average of 2021 as high as 110 µg/m^3 (uptill November 30). Moradabad is the most polluted city outside NCR with PM2.5 level of 96 µg/m^3.

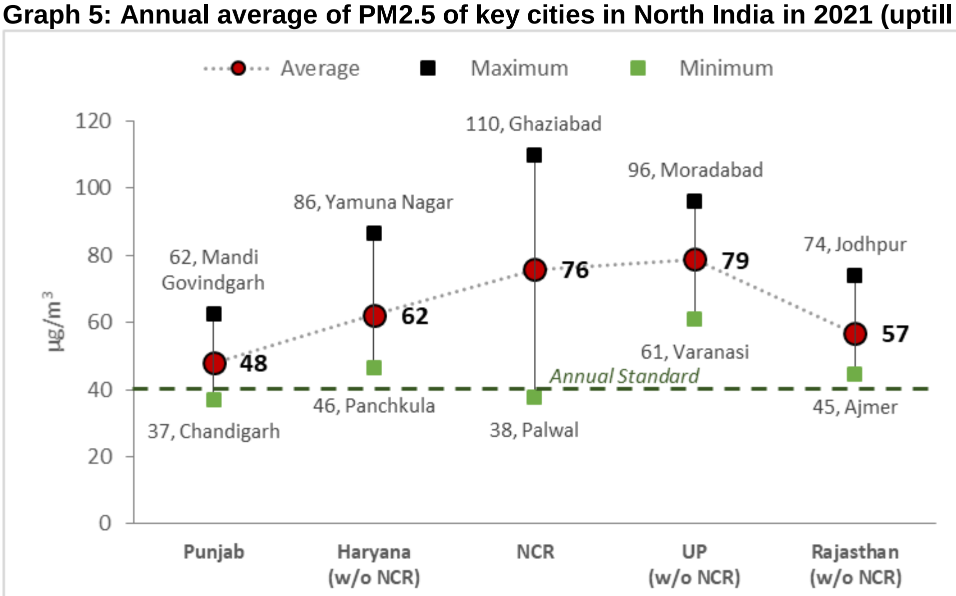
Haryana (excluding NCR sub region) was the third most polluted state with PM2.5 average of 62 µg/m^3 and Yamuna Nagar was its most polluted city with PM2.5 level of 86 µg/m^3.

Rajasthan with average of 57 µg/m^3 was lower than others. Jodhpur has been the dirtiest city in the desert state with a PM2.5 level of 74 µg/m^3 during early winter of 2021.

Punjab which is the hotbed of farm stubble burning has the lowest sub-regional PM2.5 level of 48 µg/m^3. Mandi Govindgarh was the most polluted city in the state with PM2.5 level at 62 µg/m^3. Chandigarh with PM2.5 level of 37 µg/m^3 was the cleanest city in whole of North India. Bhatinda, Panchkula, Palwal, Varanasi, and Ajmer were comparatively the least polluted cities in their respective sub-regions.

Average PM2.5 levels in 2021 (up till November 30) has already crossed the regional 2019 annual average in Punjab and Rajasthan indicating worsening of air beyond pre-Covid levels in these two states. (See *Graph 5: Annual average of PM2.5 of key cities in North India in 2021 (uptill November 30, 2021)*)

Graph 5: Annual average of PM2.5 of key cities in North India in 2021 (uptill November 30, 2021)

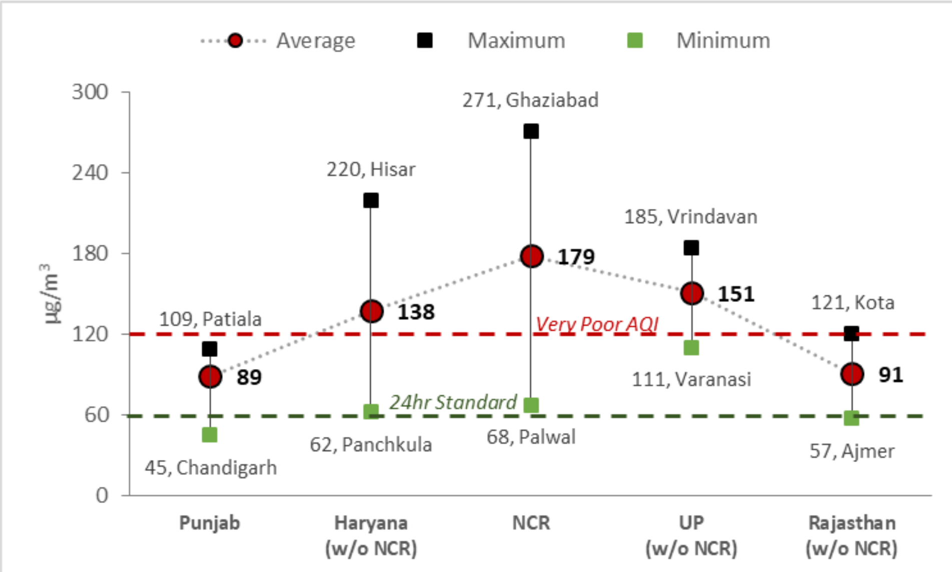


Note: PM2.5 values for sub-regions are based on the average of citywide values of all the cities in that region. PM2.5 values for cities with more than one monitoring stations is based on average of all stations that have continuous and adequate data for complete assessment period. Data up till 30 November 2021.
Source: CSE analysis of realtime data from CPCB portal

Advantage of prolonged monsoon lost quickly with onset of winter: PM2.5 rose by 2.4-5.4 times from clean monsoon level in November among the sub-regions. Air quality deteriorated most in UP where PM2.5 level rose by 5.4 times from monsoon average of 28 µg/m3 to reach 151 µg/m^3 in the month of November. NCR with November average of 179 µg/m3 was the most polluted sub-region. Air quality deteriorated by 3.6 times in Haryana, 2.8 times in Punjab and 2.4 times in Rajasthan between monsoon and November (See *Graph 6: November PM2.5 levels among sub-regions of North India*).

During November Ghaziabad (271 µg/m^3) in NCR was the most polluted in the region. Patiala (109 µg/m^3) in Punjab, Hisar (220 µg/m^3) in Haryana, Vrindavan (185 µg/m^3) in UP and Kota (121 µg/m^3) in Rajasthan were the most polluted cities in each of the sub-regions. Chandigarh was the least polluted city in the region with November average of 45 µg/m^3.

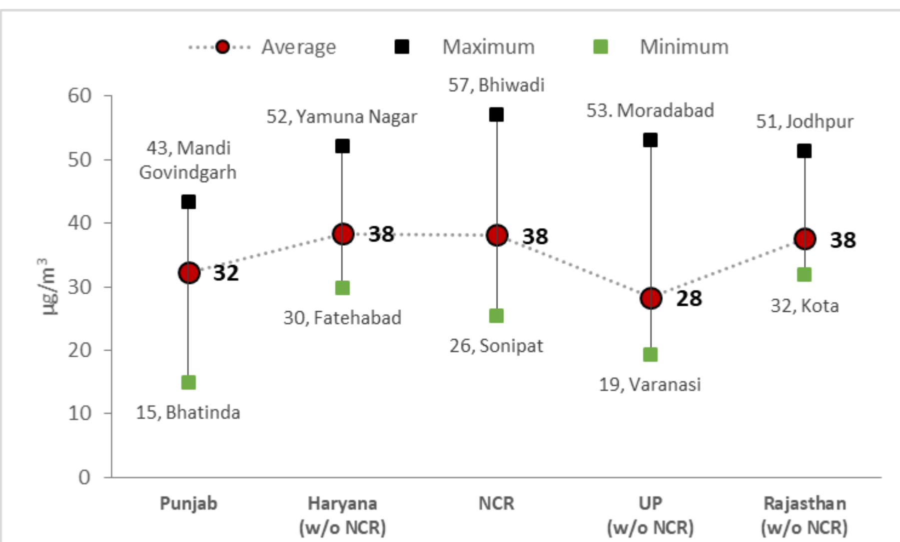
Graph 6: November PM2.5 levels among sub-regions of North India



Note: PM2.5 values for sub-regions are based on the average of citywide values of all the cities in that region. PM2.5 values for cities with more than one monitoring stations is based on average of all stations that have continuous and adequate data for complete assessment period. Data up till 30 November 2021.
Source: CSE analysis of realtime data from CPCB portal

Industrial towns remain vulnerable throughout the year - even during monsoon: The heavy and prolonged monsoon this year brought down PM2.5 level substantially across the region. The average of UP cities (outside NCR) registered the lowest sub-regional level at 28 µg/m^3 followed by Punjab at 32 µg/m^3. NCR, Haryana, and Rajasthan had 38 µg/m^3 each (See *Graph 7: Monsoon PM2.5 levels among sub-regions of North India*). Even though the overall pollution in the region was low during monsoon period, the levels in industrial cities in the region were comparatively higher than other cities during monsoon. Mandi Govindgarh (43 µg/m^3) in Punjab, Yamuna Nagar (52 µg/m^3) in Haryana, Bhiwadi (57 µg/m^3) in NCR, Moradabad (53 µg/m^3) in UP and Jodhpur (51 µg/m^3) in Rajasthan were the most polluted.

Graph 7: Monsoon PM2.5 levels among sub-regions of North India, 2021 (1 June - 15th October)



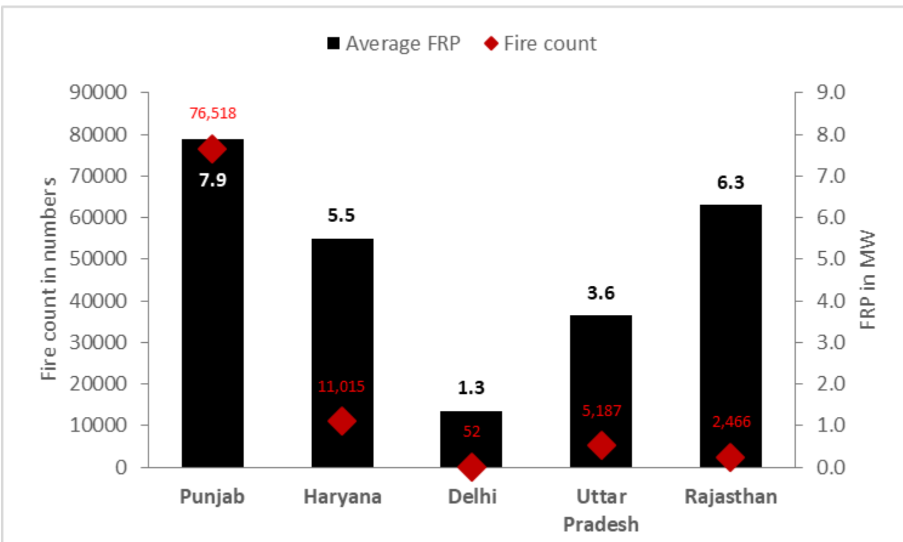
Note: PM2.5 values for sub-regions are based on the average of citywide values of all the cities in that region. PM2.5 values for cities with more than one monitoring stations is based on average of all stations that have continuous and adequate data for complete assessment period. Data up till 30 November 2021.
Source: CSE analysis of realtime data from CPCB portal

Problem of farm fire remains obstinate: One of the major pollution event which spikes pollution in the entire region every November is seasonal farm stubble burning. This time two level of analysis has been carried out – daily trend in fire count and trend in average Fire Radiative Power (FRP) reported by NASA satellites. FRP is the rate of emitted radiative energy by the fire at the time of observation that is reported in MW (megawatts). FRP is considered a better measure of emissions from bio-mass burning as intensity of FRP indicates the quantum of biomass being burned that has bearing on emissions. It is not only the number of fires but also the quantum of biomass burned that determine the intensity of smoke and pollution.

This year, Punjab has noted the maximum number of fires with a combined count 76,518 during October and November (See *Graph 8: Comparison of fire instances and average Fire Radiative Power among North Indian states*). Haryana recorded 11,015 incidences, UP 5,187, Rajasthan 2,466 and Delhi 52.

But the average FRP of a fire incidences in Punjab during October-November, 2021 stood at 7.9 MW -- highest in the region. The average FRP in Rajasthan has been 6.3 MW; Haryana of 5.5 MW; UP 3.6 MW and Delhi 1.3 MW. This indicates that not only the overall fire count in Punjab has been high but also the quantum of biomass burnt has also been high compared to the rest of the region.

Graph 8: Comparison of fire instances and average Fire Radiative Power among North Indian states

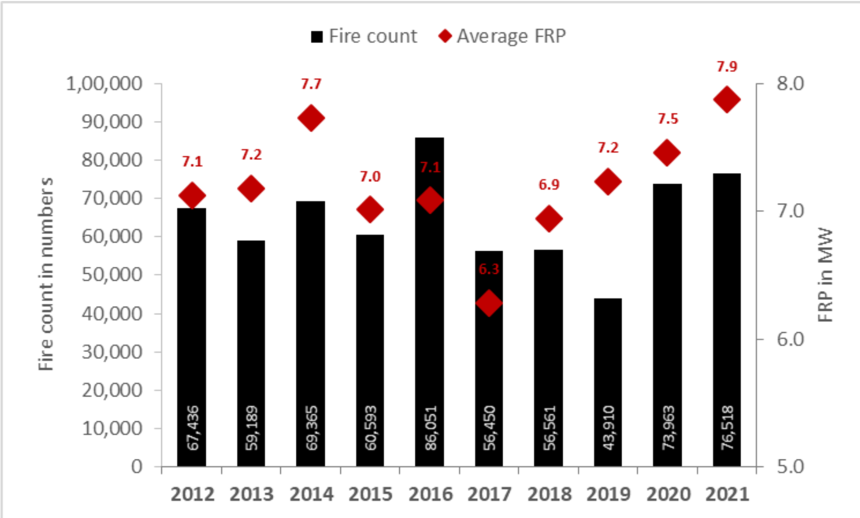


Source: CSE analysis of NASA FIRMS data

Long term trend analysis shows that average FRP in Punjab has been increasing since 2017 and this season's average is highest since monitoring started in 2012 (See *Graph 9: Trend in fire instances and average Fire Radiative Power in Punjab*). This coupled with overall increase in fire count in Punjab may have also contributed to the increased severity of smog this year. Meanwhile, both fire count and average FRP that have been declining in Haryana since 2016 but this year the trend broke and state reported doubling of fire count with minor increase in FRP as well (See *Graph 10: Trend in fire instances and average Fire Radiative Power in Haryana*).

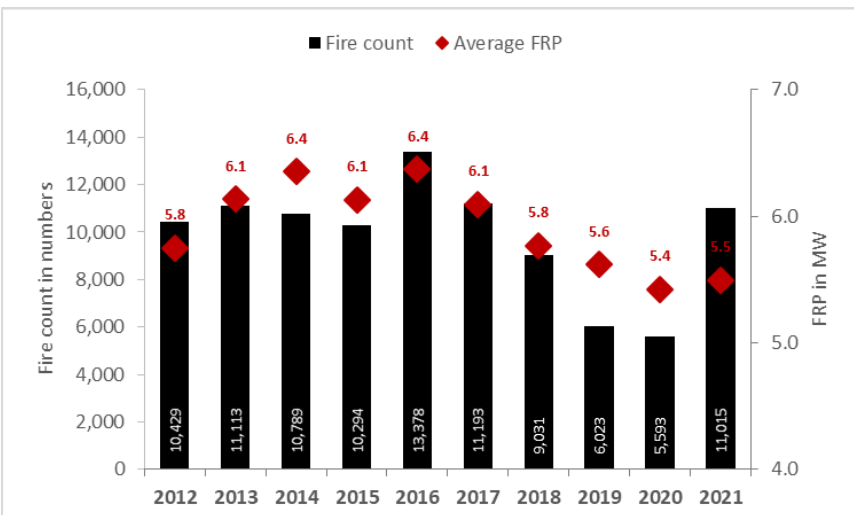
Fire count during winter in UP and Rajasthan are insignificant compared to Punjab and Haryana. Both have reported three-fold more instances of fire during summer compared to winter. However, due to summer meteorological conditions that allow more efficient pollution dispersion do not have similar effect on air quality of the region.

Graph 9: Trend in fire instances and average Fire Radiative Power in Punjab



Source: CSE analysis of NASA FIRMS data

Graph 10: Trend in fire instances and average Fire Radiative Power in Haryana

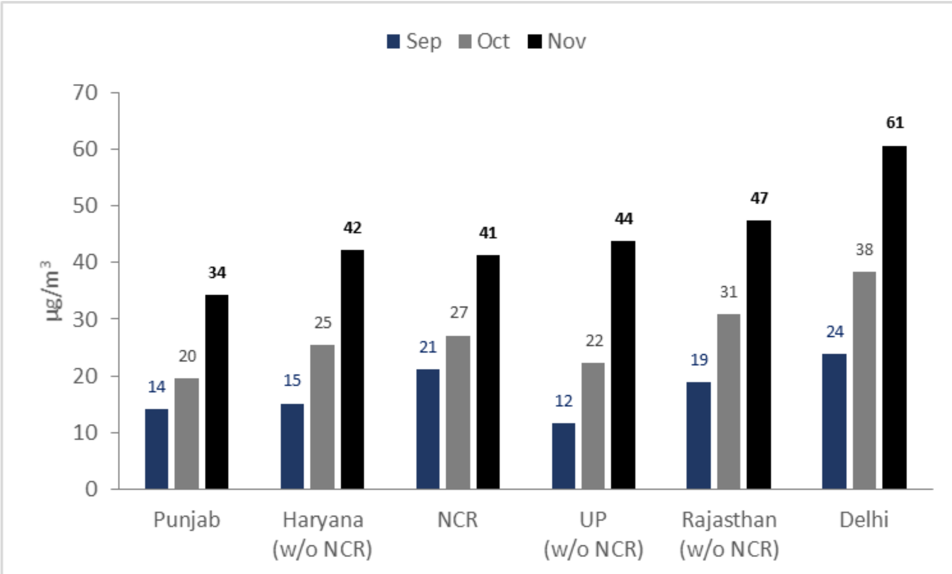


Source: CSE analysis of NASA FIRMS data

Nitrogen dioxide (NO2) levels rise two-fold during November: There is significant increase in amount of NO2 in air during November compared to October and September. NO2 comes entirely from combustion sources and significantly from vehicles. UP cities (outside NCR) have registered 3.7 times increase -- maximum build-up of NO2 between September and November. NCR cities saw two-fold rise in NO2 levels. Punjab and Rajasthan cities have registered 2.5 times increase while Haryana cities saw 2.8 times jump in sub-regional NO2 from September to November (See *Graph 11: Trend in NO2 levels among sub-regions of North India*).

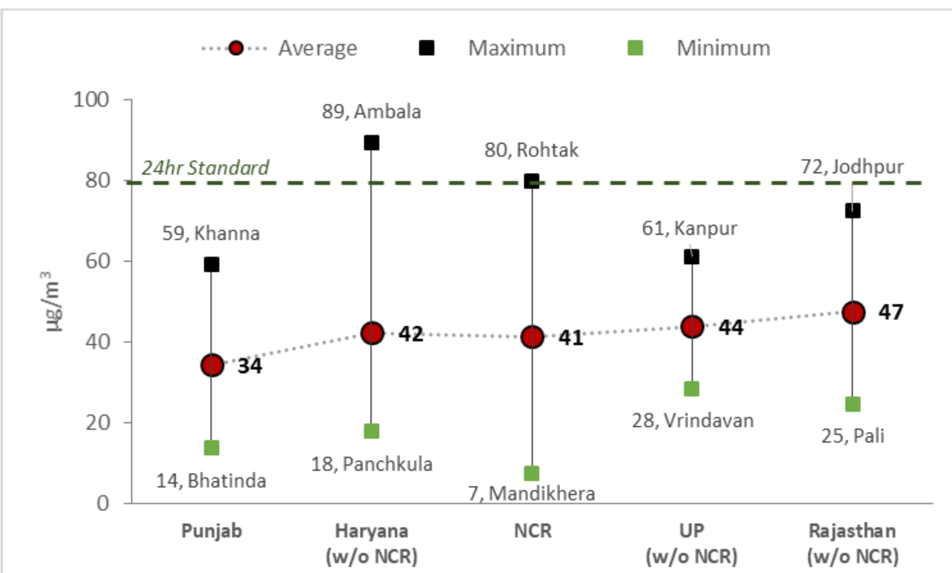
In absolute concentration term, Rajasthan cities (outside NCR) registered the highest sub-regional average of 47 µg/m^3 (See *Graph 12: November NO2 levels among sub-regions of North India*). Among Punjab cities Ambala with monthly average of 89 µg/m^3 was the most polluted in the region. Khanna (59 µg/m^3) in Punjab, Rohtak (80 µg/m^3) in NCR, Kanpur (61 µg/m^3), and Jodhpur (72 µg/m^3) were the most polluted with NO2 in each of the sub-regions.

Graph 11: Trend in NO2 levels among sub-regions of North India



Note: NO2 values for sub-regions are based on the average of citywide values of all the cities in that region. NO2 values for cities with more than one monitoring stations is based on average of all stations that have continuous and adequate data for complete assessment period. Data up till 30 November 2021.
Source: CSE analysis of realtime data from CPCB portal

Graph 12: November NO2 levels among sub-regions of North India



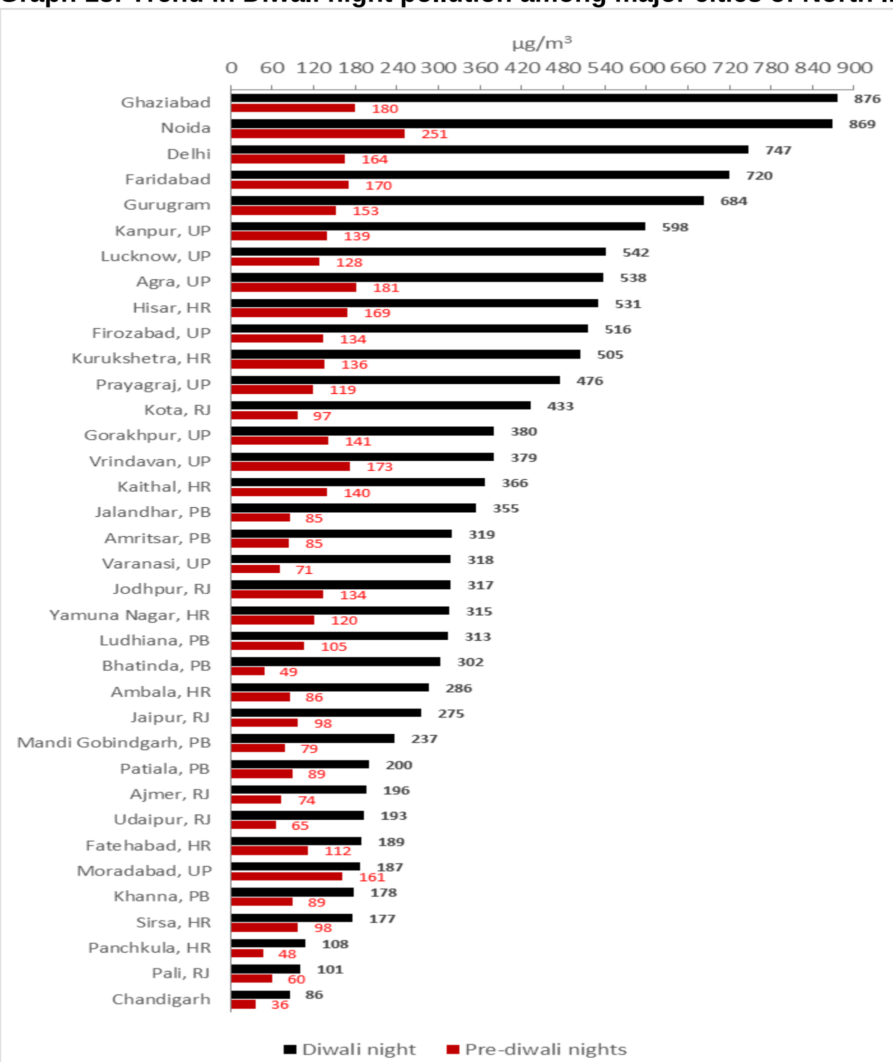
Note: NO2 values for sub-regions are based on the average of citywide values of all the cities in that region. NO2 values for cities with more than one monitoring stations is based on average of all stations that have continuous and adequate data for complete assessment period. Data up till 30 November 2021.
Source: CSE analysis of realtime data from CPCB portal

Diwali continues to be a mega pollution event: Despite the ban on bursting firecrackers in Delhi NCR by the Supreme Court Diwali night still got extremely toxic. Pollution level on Diwali night (8pm to 8am) in cities shot up by 1.2-6.1 times the average level recorded seven nights preceding Diwali (See *Graph 13: Diwali night pollution among cities of North India*). The range is wide -- Bhatinda recorded 6.1 times jump in PM2.5 level on Diwali night and Moradabad noted just 20 per cent spike.

In absolute concentration terms, Delhi's 747 µg/m³ level for Diwali night is only matched by its big four satellite towns; Ghaziabad (876 µg/m³), Noida (869 µg/m³), Faridabad (720 µg/m³), and Gurugram (684 µg/m³). Outside NCR, UP cities dominate the list of most polluted Diwali nights. Kanpur and Lucknow topped the list with Diwali night PM2.5 levels recording levels as high as 598 µg/m³ and 543 µg/m³ respectively. Agra, Firozabad, Prayagraj, Gorakhpur, and Vrindavan are other UP cities in the top 10 list of most polluted Diwali night outside NCR. Hisar and Kurukshetra in North Haryana and Kota in Rajasthan also feature in top ten. Chandigarh had the least polluted Diwali night in the region.

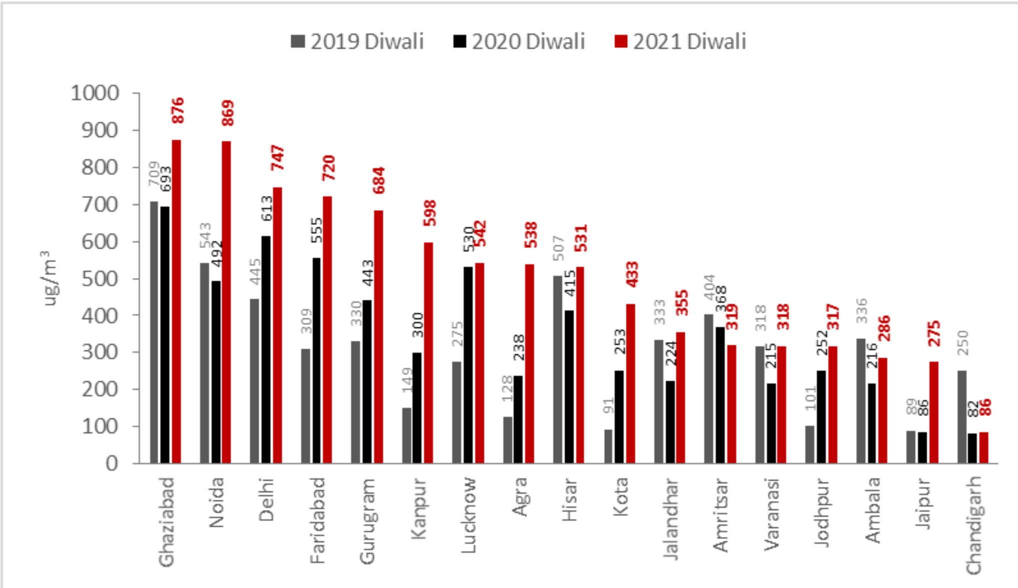
This Diwali had the worst air quality in last three years for all major cities in the region except Amritsar, Ambala and Chandigarh. Cities of UP and Rajasthan had seen the maximum increase on Diwali night (See *Graph 14: Trend in Diwali night pollution among major cities of North India*).

Graph 13: Trend in Diwali night pollution among major cities of North India



Note: PM2.5 values for cities with more than one monitoring stations is based on average of all stations that have continuous and adequate data for complete assessment period. Diwali night is considered from 8.00PM November 4 to 8.00AM November 5. Pre-diwali night is average of seven nights (8.00PM-8.00AM) preceding Diwali.
Source: CSE analysis of realtime data from CPCB portal

Graph 14: Trend in Diwali night pollution among major cities of North India



Note: PM2.5 values for cities with more than one monitoring stations is based on average of all stations that have continuous and adequate data for complete assessment period. Diwali night is considered from 8.00PM November 4 to 8.00AM on 27 October 2019, 14 November 2020 and 4 November 2021.
Source: CSE analysis of realtime data from CPCB portal

PART II

Winter pollution in individual cities of North

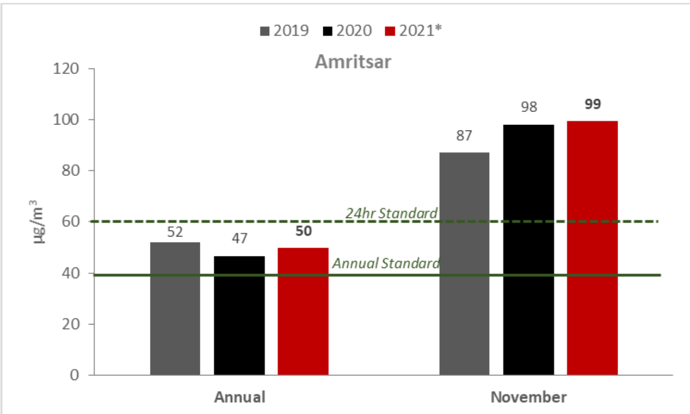
Punjab: Amritsar

City has a stable annual average since last three years but it does not meet the annual standard for PM2.5 (See *Graph 15: PM2.5 annual and winter trend in Amritsar*). It needs to cut pollution level by 20 per cent to meet the standard.

Pollution level during winter has been on rise. AQI categorisation of days shows that the city's air quality has not deteriorated to severe level in last three years but number of days with poor and very poor air quality have remained the same (See *Graph 16: PM2.5 AQI trend in Amritsar*).

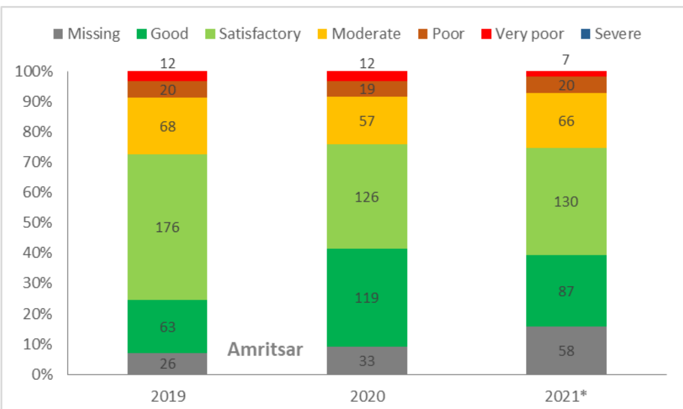
But this city only has only one monitoring station located at Golden Temple Complex (cleanest spot in the city) and not representative of air quality of the entire city. Improved monitoring network can help to understand the air quality profile of the city better.

Graph 15: PM2.5 annual and winter trend in Amritsar



Note: PM2.5 values is based on stations that have continuous and adequate data for complete assessment period. Data up till 30 November 2021.
Source: CSE analysis of realtime data from CPCB portal

Graph 16: PM2.5 AQI trend in Amritsar



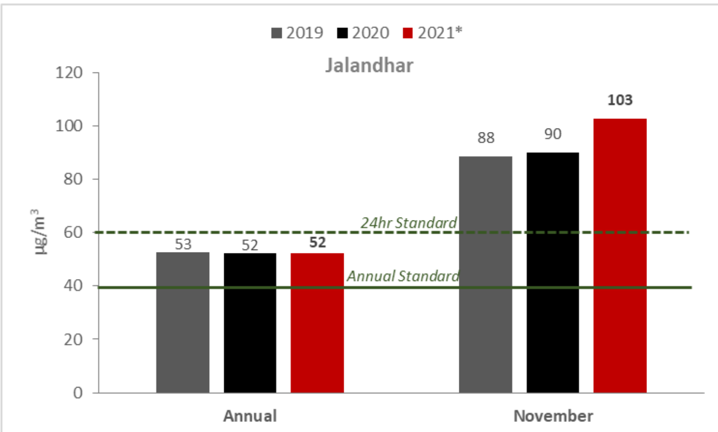
Note: PM2.5 value is based on stations that have continuous and adequate data for complete assessment period. AQI is based on PM2.5 sub-category only. Data up till 30 November 2021.
Source: CSE analysis of realtime data from CPCB portal

Punjab: Jalandhar

City has a stable annual average since last three year but it doesn't meet the annual standard for PM2.5 (See *Graph 17: PM2.5 annual and winter trend in Jalandhar*). It needs to cut pollution level by 20 per cent to meet the standard.

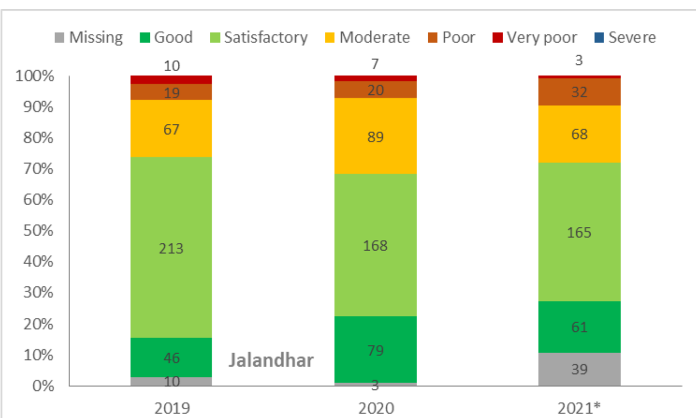
Pollution level during winter is rising. Analysis of days as per AQI categorisation shows that the city's air quality has not deteriorated to severe level in last three years but number of days with poor and very poor air quality have shown increase this year (See *Graph 18: PM2.5 AQI trend in Jalandhar*).

Graph 17: PM2.5 annual and winter trend in Jalandhar



Note: PM2.5 values is based on stations that have continuous and adequate data for complete assessment period. Data up till 30 November 2021.
Source: CSE analysis of realtime data from CPCB portal

Graph 18: PM2.5 AQI trend in Jalandhar



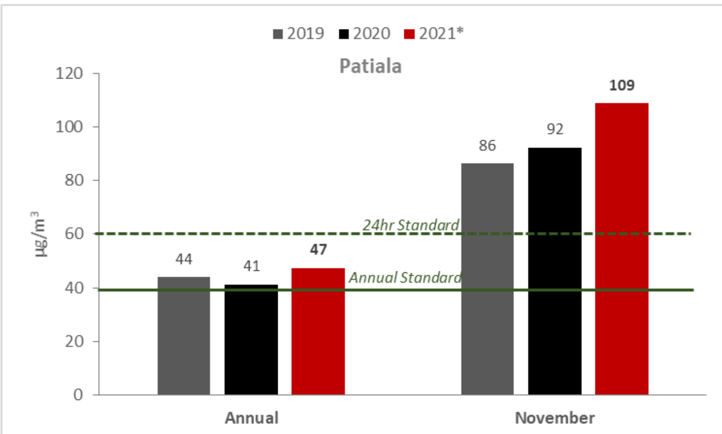
Note: PM2.5 value is based on stations that have continuous and adequate data for complete assessment period. AQI is based on PM2.5 sub-category only. Data up till 30 November 2021.
Source: CSE analysis of realtime data from CPCB portal

Punjab: Patiala

City has a stable annual average since last three year but it doesn't meet the annual standard for PM2.5 (See *Graph 19: PM2.5 annual and winter trend in Patiala*). It needs to cut pollution level by 15 per cent to meet the standard. Further, pollution level during winter has been on rise.

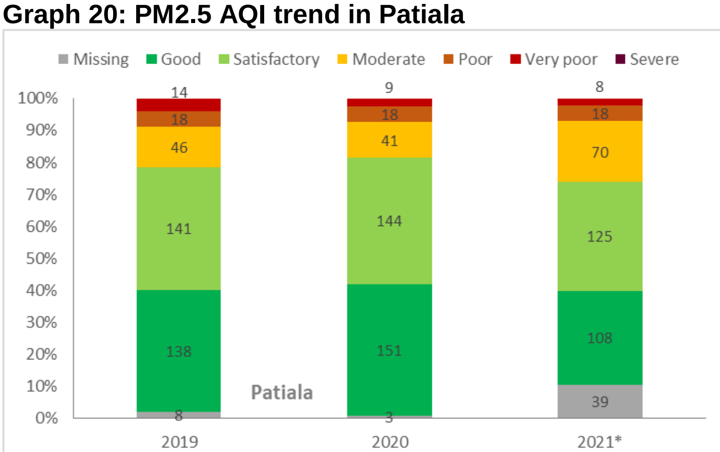
Analysis of days as per AQI categorisation shows that the city's air quality has not deteriorated to severe level in last three years but number of days with poor and very poor air quality have shown increase this year (See *Graph 20: PM2.5 AQI trend in Patiala*). There is a 40 days drop in number good and satisfactory days in the city this year compared to 2019.

Graph 19: PM2.5 annual and winter trend in Patiala



Note: PM2.5 values is based on stations that have continuous and adequate data for complete assessment period. Data up till 30 November 2021.
Source: CSE analysis of realtime data from CPCB portal

Graph 20: PM2.5 AQI trend in Patiala



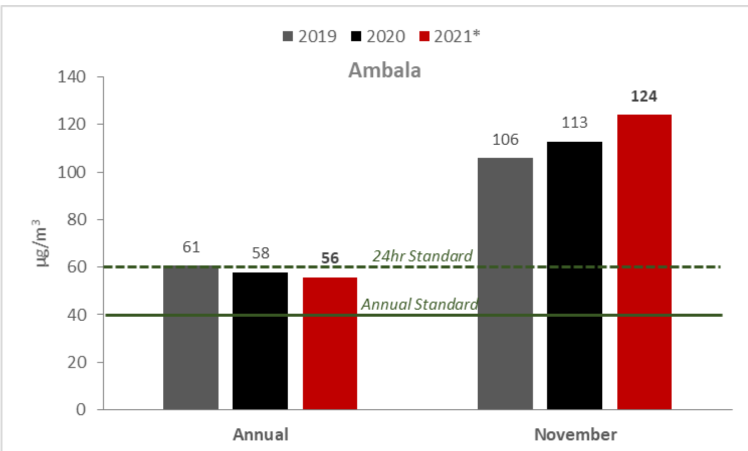
Note: PM2.5 value is based on stations that have continuous and adequate data for complete assessment period. AQI is based on PM2.5 sub-category only. Data up till 30 November 2021.
Source: CSE analysis of realtime data from CPCB portal

Haryana: Ambala

City has a stable annual average since last three year but it doesn't meet the annual standard for PM2.5 (See *Graph 21: PM2.5 annual and winter trend in Ambala*). It needs to cut pollution level by 31 per cent to meet the standard.

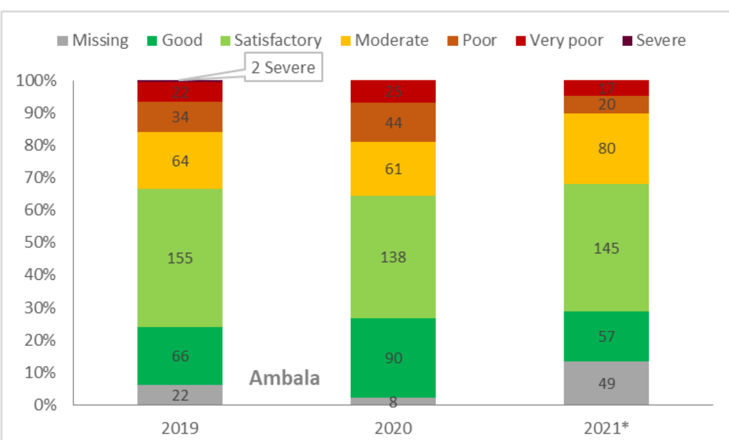
Pollution level during winter is rising. Analysis of days as per AQI categorisation shows that the city's air quality has not deteriorated to severe level since 2019 when it had two severe days and number of days with poor and very poor air quality so far are also lower this year (See *Graph 22: PM2.5 AQI trend in Ambala*). But there is a drop in number good days in the city this year compared to 2019 and 2020. This year there has been only 57 good days -- down from 90 good days in 2020 and 66 good days in 2019.

Graph 21: PM2.5 annual and winter trend in Ambala



Note: PM2.5 values is based on stations that have continuous and adequate data for complete assessment period. Data up till 30 November 2021.
Source: CSE analysis of realtime data from CPCB portal

Graph 22: PM2.5 AQI trend in Ambala



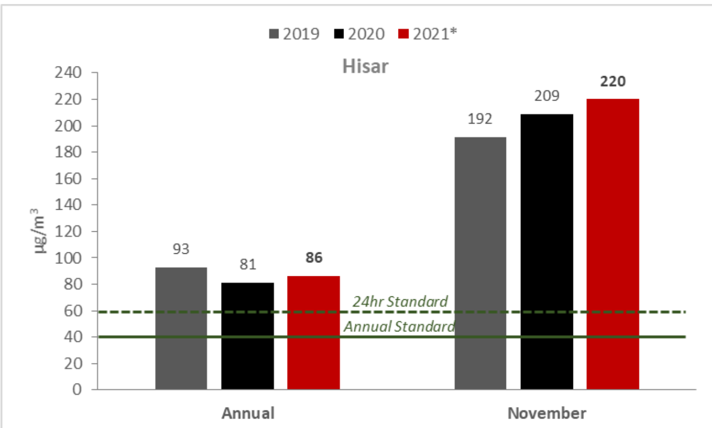
Note: PM2.5 value is based on stations that have continuous and adequate data for complete assessment period. AQI is based on PM2.5 sub-category only. Data up till 30 November 2021.
Source: CSE analysis of realtime data from CPCB portal

Haryana: Hisar

City has a stable annual average since last three year but it doesn't meet the annual standard for PM2.5 (See *Graph 23: PM2.5 annual and winter trend in Hisar*). It needs to cut pollution level by over 50 per cent to meet the standard. Further, pollution level during winter has been on rise.

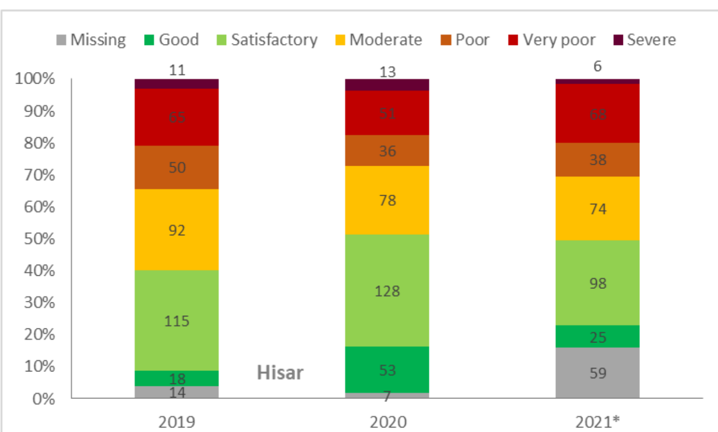
Analysis of days as per AQI categorisation shows that the city's air quality has 6-13 severe days each year and city has already clocked similar number of very poor or worse air days this year so far. As air quality in the city mostly remains in very poor category in December therefore 2021 might end as more polluted than 2019 (See *Graph 24: PM2.5 AQI trend in Hisar*).

Graph 23: PM2.5 annual and winter trend in Hisar



Note: PM2.5 values is based on stations that have continuous and adequate data for complete assessment period. Data up till 30 November 2021.
Source: CSE analysis of realtime data from CPCB portal

Graph 24: PM2.5 AQI trend in Hisar



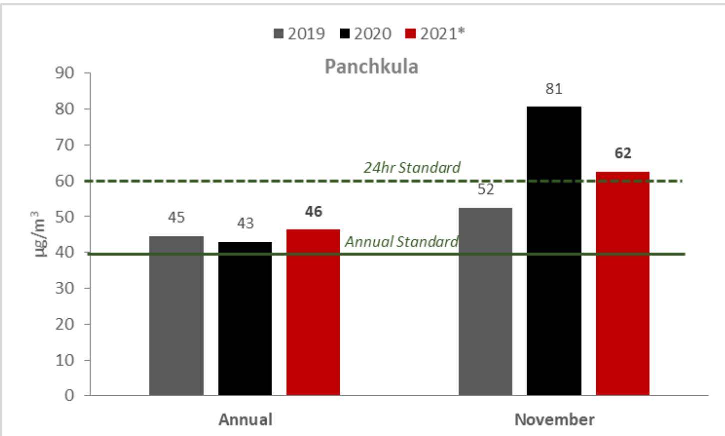
Note: PM2.5 value is based on stations that have continuous and adequate data for complete assessment period. AQI is based on PM2.5 sub-category only. Data up till 30 November 2021.
Source: CSE analysis of realtime data from CPCB portal

Haryana: Panchkula

City's annual average has risen this year despite have a relatively less polluted winter so far compared to last winter (See *Graph 25: PM2.5 annual and winter trend in Panchkula*). It needs to cut pollution level by over 13 per cent to meet the standard.

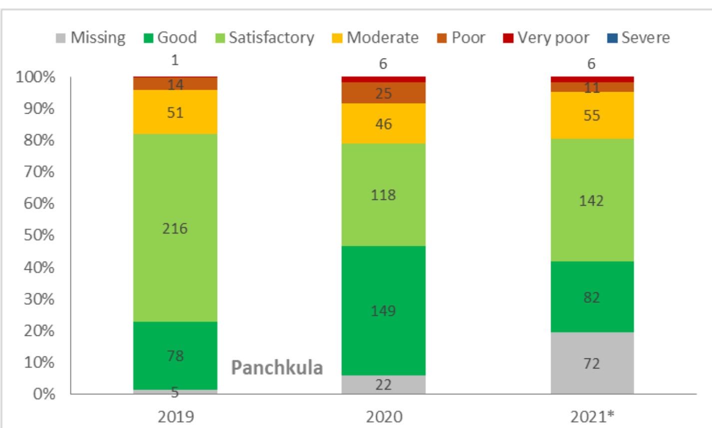
Analysis of days as per AQI categorisation shows that the city's air quality has not deteriorated to severe in last three year (See *Graph 26: PM2.5 AQI trend in Panchkula*). But there is a drop in number good and satisfactory days in the city this year compared to 2019 and 2020. This year there has been 224 good and satisfactory days down from 267 good days in 2020 and 294 good days in 2019.

Graph 25: PM2.5 annual and winter trend in Panchkula



Note: PM2.5 values is based on stations that have continuous and adequate data for complete assessment period. Data up till 30 November 2021.
Source: CSE analysis of realtime data from CPCB portal

Graph 26: PM2.5 AQI trend in Panchkula



Note: PM2.5 value is based on stations that have continuous and adequate data for complete assessment period. AQI is based on PM2.5 sub-category only. Data up till 30 November 2021.
Source: CSE analysis of realtime data from CPCB portal

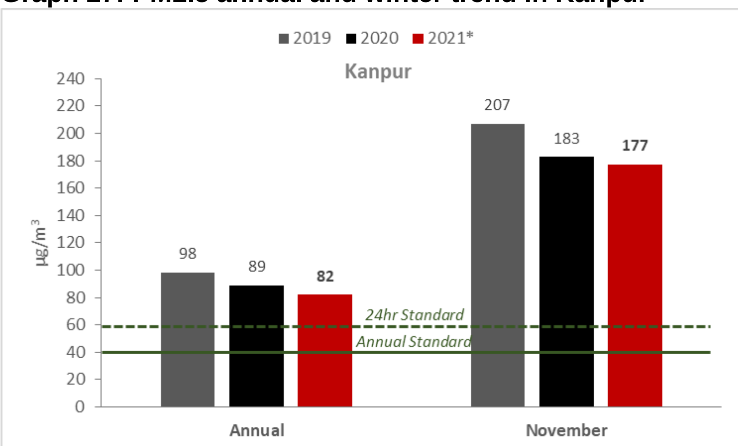
Uttar Pradesh (UP): Kanpur

City has a stable annual average since last three year and this year might have same annual average as 2020 (See *Graph 27: PM2.5 annual and winter trend in Kanpur*). It needs to cut pollution level by over 50 per cent to meet the standard.

Analysis of days as per AQI categorisation shows that the city's air quality has 25-26 severe days in 2019 and 2020 and this year there has been 18 severe days so far. It has already clocked similar number of very poor or worse air days this year so far. As air quality in the city mostly remains in very poor category in December therefore 2021 might end as more polluted than 2019 (See *Graph 28: PM2.5 AQI trend in Kanpur*).

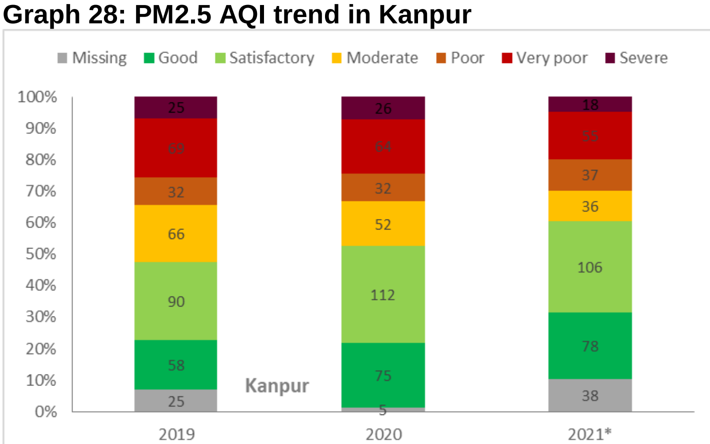
City has added three new monitoring stations this year to its long term station at Nehru Nagar. November average at these new stations show that there is considerable variation in PM2.5 levels within the city (See *Graph 29: November PM2.5 level among city stations in Kanpur*). IIT Kanpur station has worst air with November average of 190 µg/m3, while station at Kidwai Nagar is least polluted with November average of 118 µg/m3.

Graph 27: PM2.5 annual and winter trend in Kanpur



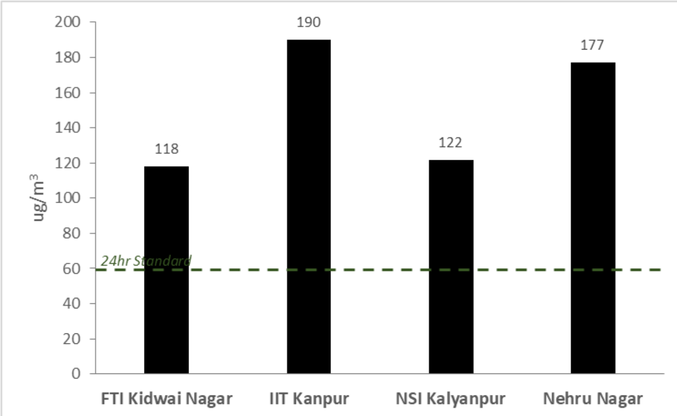
Note: PM2.5 values is based on stations that have continuous and adequate data for complete assessment period. Data up till 30 November 2021.
Source: CSE analysis of realtime data from CPCB portal

Graph 28: PM2.5 AQI trend in Kanpur



Note: PM2.5 value is based on stations that have continuous and adequate data for complete assessment period. AQI is based on PM2.5 sub-category only. Data up till 30 November 2021.
Source: CSE analysis of realtime data from CPCB portal

Graph 29: November PM2.5 level among city stations in Kanpur



Source: CSE analysis of realtime data from CPCB portal

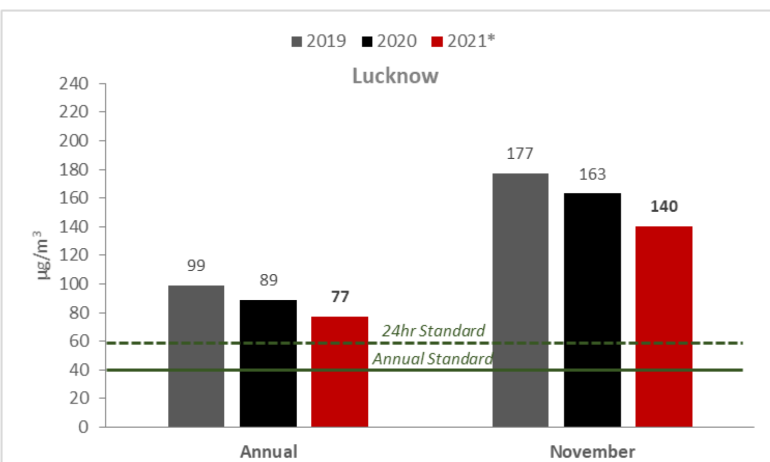
UP: Lucknow

City has a declining annual average trend and this year might have lower annual average than 2020 (See *Graph 30: PM2.5 annual and winter trend in Lucknow*). It needs to cut pollution level by over 50 per cent to meet the standard.

Further, pollution level during winter stable. Analysis of days as per AQI categorisation shows that the city has seen no significant reduction is number of days with very poor and severe days in last three years (this year included). But there has been considerable increase in number of good air days this year which is improving the annual average of the city. 2021 so far has clocked 67 good air days up from 42 in 2020 and 31 in 2019 (See *Graph 31: PM2.5 AQI trend in Lucknow*).

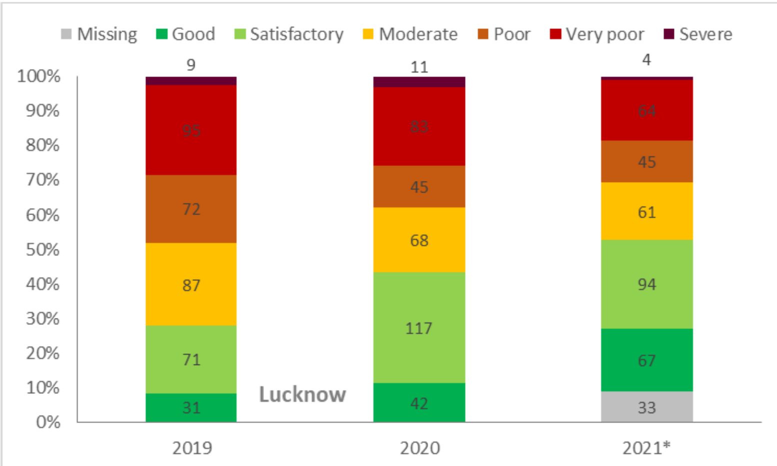
City has added two new monitoring stations (Ambedkar University and Kukrail) this year to its four long term stations at Central School, Gomti Nagar, Lalbagh, and Talkatora. November average at these stations show that there is considerable variation in PM2.5 levels within the city (See *Graph 32: November PM2.5 level among city stations in Lucknow*). Talkatora station has worst air with November average of 192 µg/m^3, while station at Gomit Nagar is least polluted with November average of 98 µg/m^3.

Graph 30: PM2.5 annual and winter trend in Lucknow



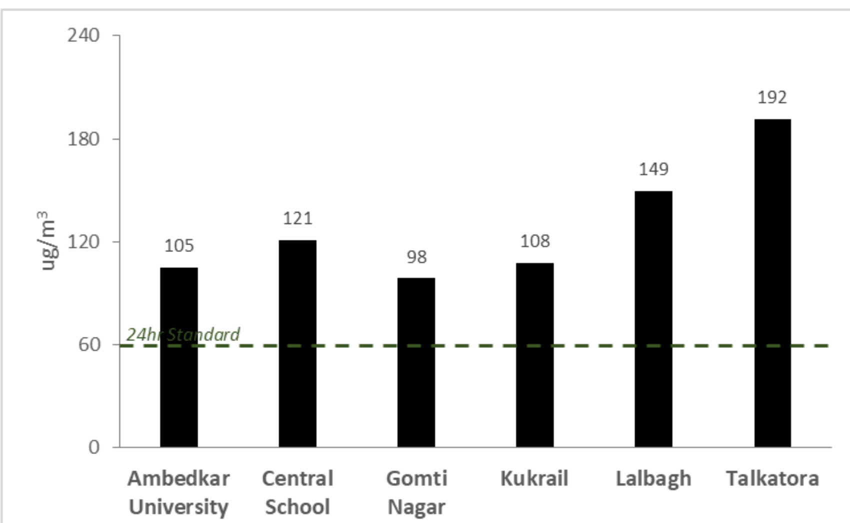
Note: PM2.5 values is based on stations that have continuous and adequate data for complete assessment period. Data up till 30 November 2021.
Source: CSE analysis of realtime data from CPCB portal

Graph 31: PM2.5 AQI trend in Lucknow



Note: PM2.5 value is based on stations that have continuous and adequate data for complete assessment period. AQI is based on PM2.5 sub-category only. Data up till 30 November 2021.
Source: CSE analysis of realtime data from CPCB portal

Graph 32: November PM2.5 level among city stations in Lucknow



Source: CSE analysis of realtime data from CPCB portal

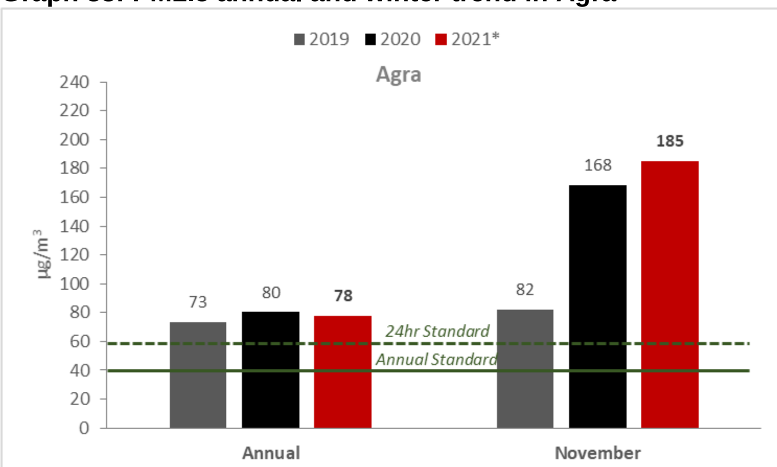
UP: Agra

Agra has recorded rising annual average level over the last three years with 2020 registering higher annual average than 2019 despite the pandemic lockdowns. 2021 might have same or higher annual average than 2020 (See *Graph 33: PM2.5 annual and winter trend in Agra*). It needs to cut pollution level by over 50 per cent to meet the standard.

Further, pollution level during winter has been on rise as well. Analysis of days as per AQI categorisation shows that the city this year already has had 8 severe days which is higher than 2019 (5 severe days) and 2020 (6 severe days). There is an overall increase in number of days with poor or worse air quality in the city compared to previous two years (See *Graph 34: PM2.5 AQI trend in Agra*). The city has also registered 74 good air days this year which in a significant improvement from 2020 and 2019 when it had 50 and 36 good air days respectively.

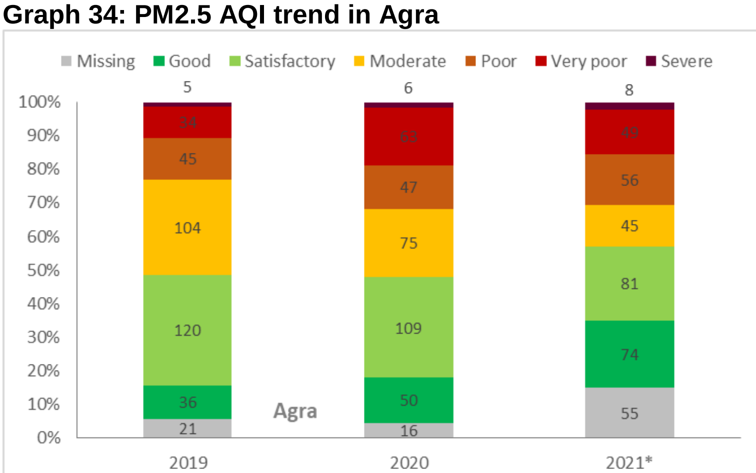
City has added four new monitoring stations this year to its long term station at Sanjay Palace. November average at these new stations show that there is considerable variation in PM2.5 levels within the city (See *Graph 35: November PM2.5 level among city stations in Agra*). Avas Vikas Colony station has worst air with November average of 202 µg/m³, while station at Shastripuram is least polluted with November average of 160 µg/m³.

Graph 33: PM2.5 annual and winter trend in Agra



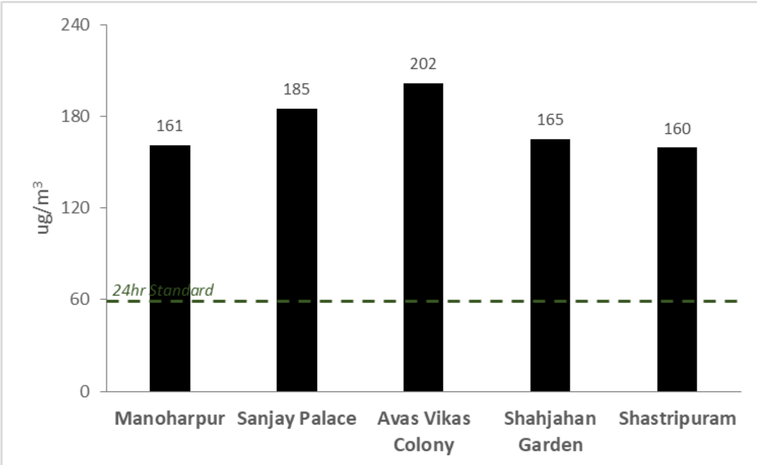
Note: PM2.5 values is based on stations that have continuous and adequate data for complete assessment period. Data up till 30 November 2021.
Source: CSE analysis of realtime data from CPCB portal

Graph 34: PM2.5 AQI trend in Agra



Note: PM2.5 value is based on stations that have continuous and adequate data for complete assessment period. AQI is based on PM2.5 sub-category only. Data up till 30 November 2021.
Source: CSE analysis of realtime data from CPCB portal

Graph 35: November PM2.5 level among city stations in Agra



Source: CSE analysis of realtime data from CPCB portal

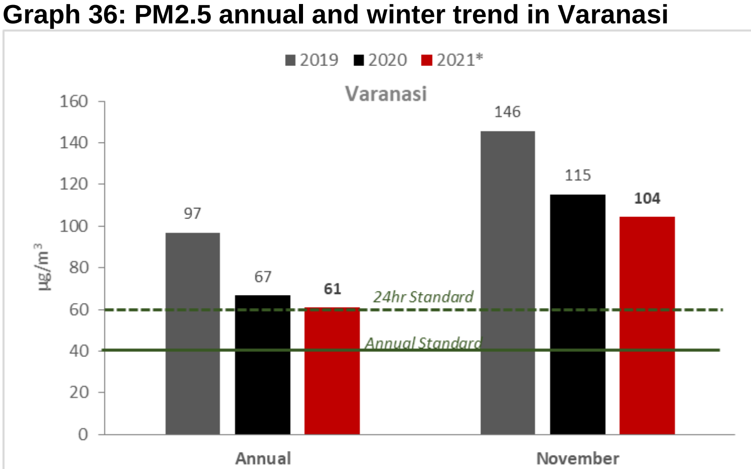
UP: Varanasi

City has a declining annual average trend and this year might have lower annual average than 2020 (See *Graph 36: PM2.5 annual and winter trend in Varanasi*). It needs to cut pollution level by over 35 per cent to meet the standard.

Further, pollution level during winter has been decreasing as well. Analysis of days as per AQI categorisation shows that the city's has significant reduction is number of days with very poor and severe days in last three years (this year included). There has been an increase in number of good air days this year which is improving the annual average of the city. 2021 so far has clocked 105 good air days up from 94 in 2020 and 29 in 2019 (See *Graph 37: PM2.5 AQI trend in Varanasi*).

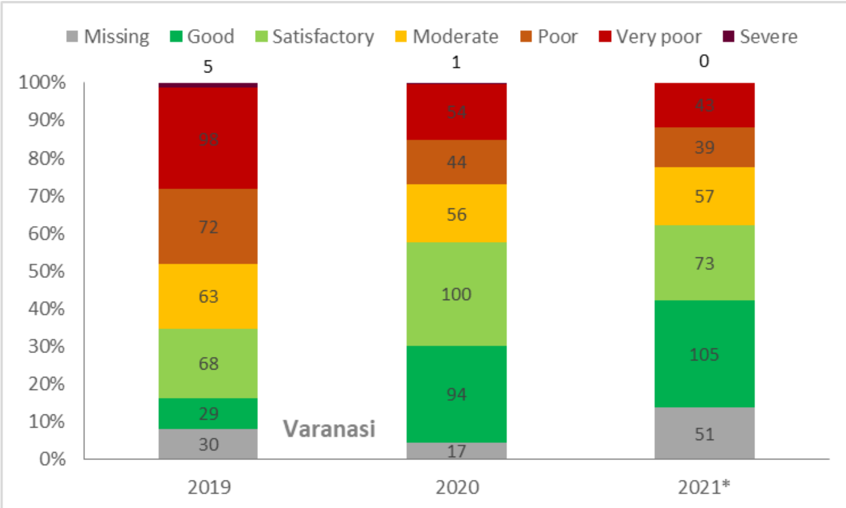
City has added three new monitoring stations this year to its long term station at Ardhali Bazar. November average at these new stations show that there is considerable variation in PM2.5 levels within the city (See *Graph 38: November PM2.5 level among city stations in Varanasi*). Maldahiya station has worst air with November average of 129 µg/m^3, while station at BHU is least polluted with November average of 98 µg/m^3.

Graph 36: PM2.5 annual and winter trend in Varanasi



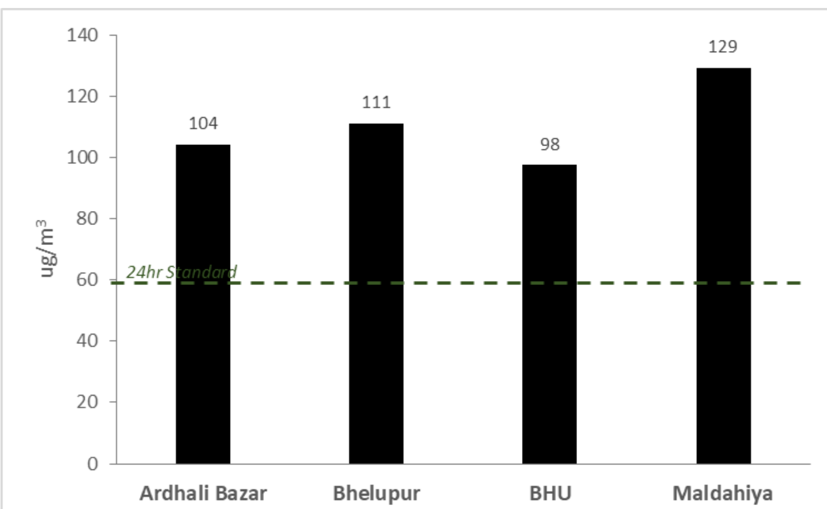
Note: PM2.5 values is based on stations that have continuous and adequate data for complete assessment period. Data up till 30 November 2021.
Source: CSE analysis of realtime data from CPCB portal

Graph 37: PM2.5 AQI trend in Varanasi



Note: PM2.5 value is based on stations that have continuous and adequate data for complete assessment period. AQI is based on PM2.5 sub-category only. Data up till 30 November 2021.
Source: CSE analysis of realtime data from CPCB portal

Graph 38: November PM2.5 level among city stations in Varanasi



Source: CSE analysis of realtime data from CPCB portal

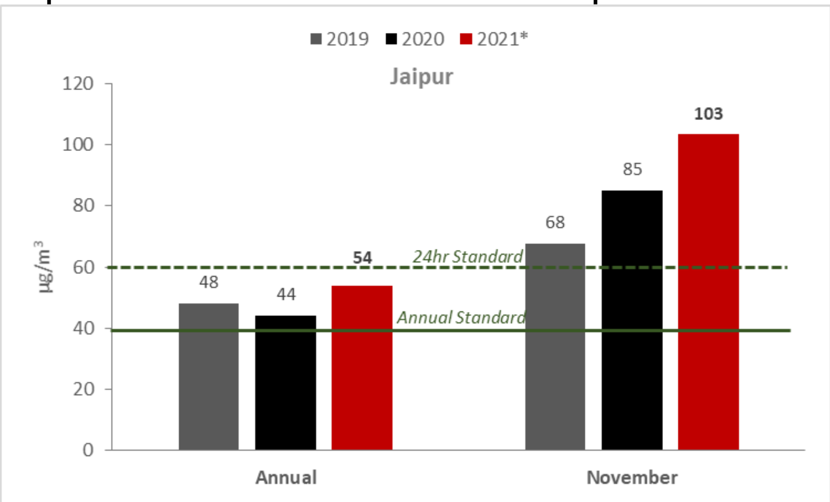
Rajasthan: Jaipur

City has a rising annual average over last three year and with 2021 might considerably higher (12 per cent) annual average than 2019 (See *Graph 39: PM2.5 annual and winter trend in **J**aipur*). It needs to cut pollution level by over 25 per cent to meet the standard.

Further, pollution level during winter has been on rise as well. Analysis of days as per AQI categorisation shows that the city this year already has had 11 very poor days which is higher than 2019 (4 very poor days) and 2020 (5 very poor days). There is an overall increase in number of days with poor or worse air quality in the city compared to previous two years (See *Graph 40: PM2.5 AQI trend in Jaipur*). Interestingly, the city has similar good air days this year as observed in 2019.

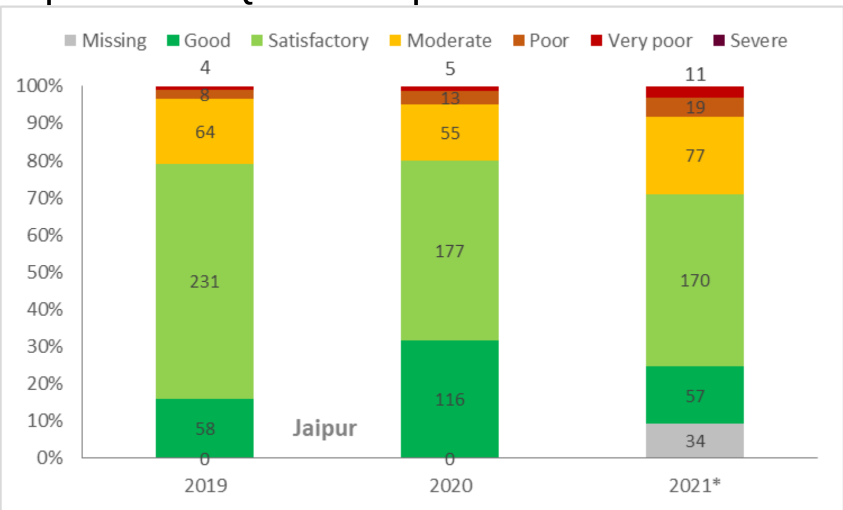
City has three monitoring stations at Adarsh Nagar, Police Commissionerate and Shastri Nagar. November average at these stations show that there is not a considerable variation in PM2.5 levels among them (See *Graph 41: November PM2.5 level among city stations in Jaipur*). This is due to relatively close by siting of these stations. Police Commissionerate station has worst air with November average of 113 µg/m^3, while station at Shastri Nagar is least polluted with November average of 95 µg/m^3.

Graph 39: PM2.5 annual and winter trend in Jaipur



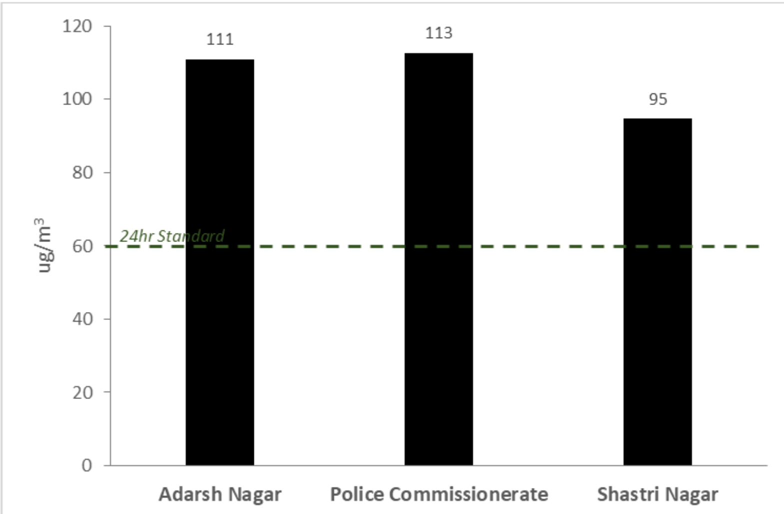
Note: PM2.5 values is based on stations that have continuous and adequate data for complete assessment period. Data up till 30 November 2021.
Source: CSE analysis of realtime data from CPCB portal

Graph 40: PM2.5 AQI trend in Jaipur



Note: PM2.5 value is based on stations that have continuous and adequate data for complete assessment period. AQI is based on PM2.5 sub-category only. Data up till 30 November 2021.
Source: CSE analysis of realtime data from CPCB portal

Graph 41: November PM2.5 level among city stations in Jaipur



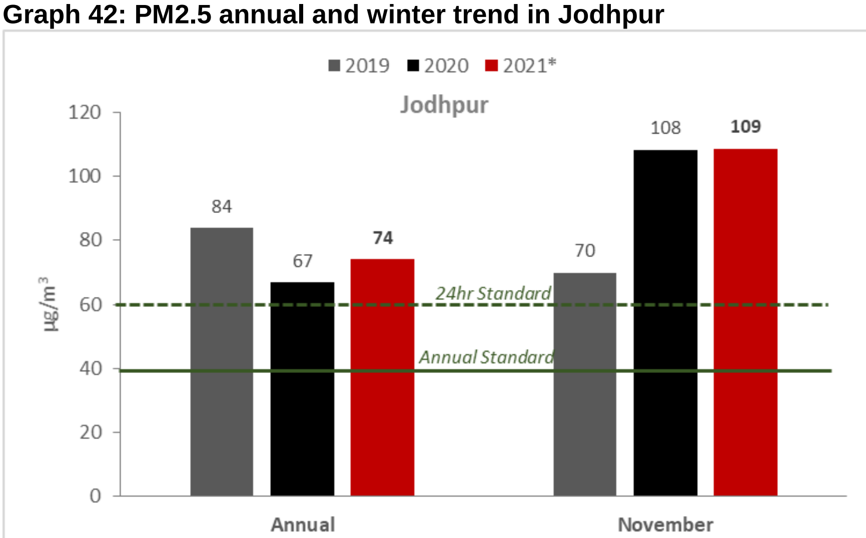
Source: CSE analysis of realtime data from CPCB portal

Rajasthan: Jodhpur

City has a stabilizing annual average over last three year and with 2021 average projected to settle higher 2020 but lower than 2019 (See *Graph 42: PM2.5 annual and winter trend in Jodhpur*). It needs to cut pollution level by over 45 per cent to meet the standard.

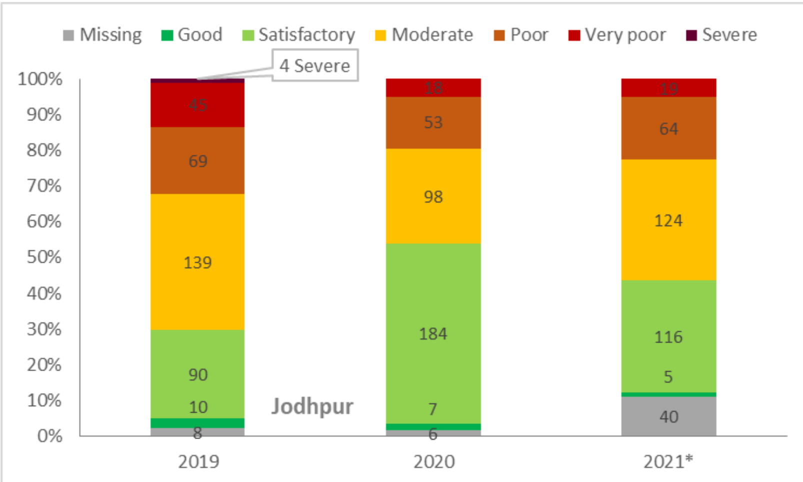
Further, pollution level during winter has been on rise with 2021 November being dirtier than 2019 and 2020 Novembers. Analysis of days as per AQI categorisation shows that the city has not had severe days since 2019 when it had 4 severe days. Overall number of days with poor or worse air quality in the city have returned to 2019 levels (See *Graph 43: PM2.5 AQI trend in Jodhpur*). Interestingly, the city has very low number of good air days and it has been on decline with this year registering just 5 good days down from 10 observed in 2019.

Graph 42: PM2.5 annual and winter trend in Jodhpur



Note: PM2.5 values is based on stations that have continuous and adequate data for complete assessment period. Data up till 30 November 2021.
Source: CSE analysis of realtime data from CPCB portal

Graph 43: PM2.5 AQI trend in Jodhpur



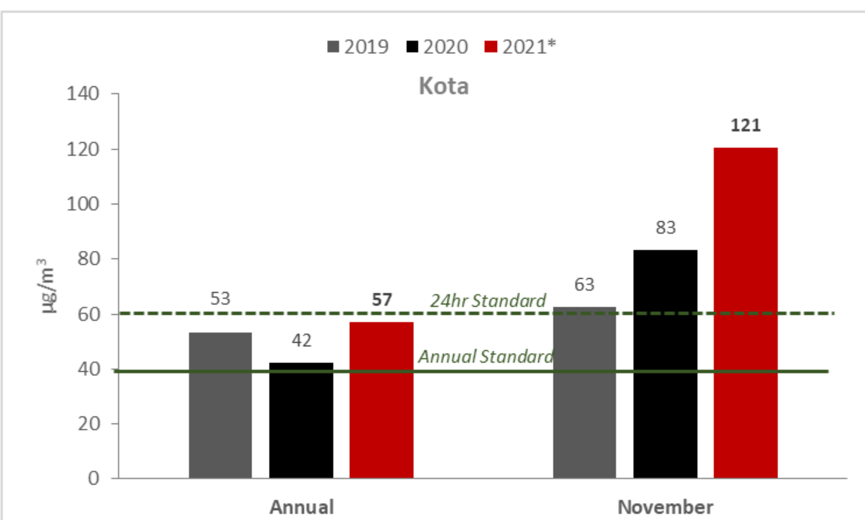
Note: PM2.5 value is based on stations that have continuous and adequate data for complete assessment period. AQI is based on PM2.5 sub-category only. Data up till 30 November 2021.
Source: CSE analysis of realtime data from CPCB portal

Rajasthan: Kota

City has a rising annual average over last three year and with 2021 average projected to settle higher than 2019 (See *Graph 44: PM2.5 annual and winter trend in Kota*). It needs to cut pollution level by over 30 per cent to meet the standard.

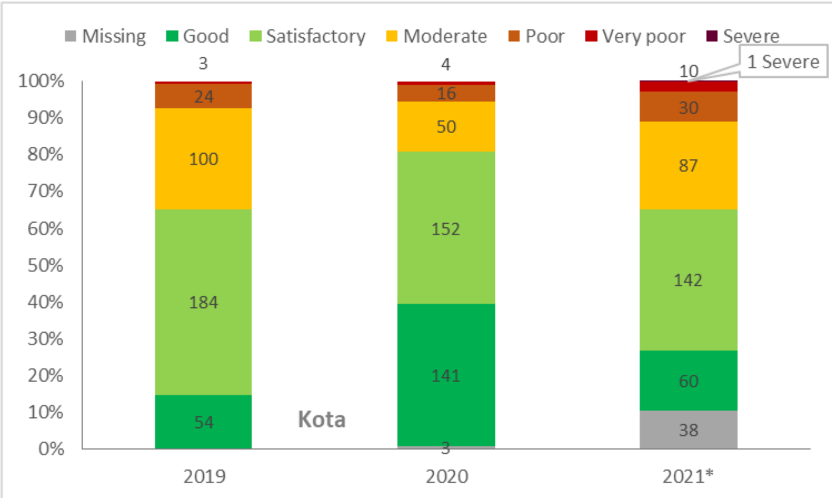
Further, pollution level during winter has been on rise with 2021 November being significantly dirtier than 2019 and 2020 Novembers. Analysis of days as per AQI categorisation shows that the city had it first severe day this year since 2019. Overall number of days with poor or worse air quality in the city have surpassed 2019 count by 4 days with December still left to go (See *Graph 45: PM2.5 AQI trend in Kota*).

Graph 44: PM2.5 annual and winter trend in Kota



Note: PM2.5 values is based on stations that have continuous and adequate data for complete assessment period. Data up till 30 November 2021.
Source: CSE analysis of realtime data from CPCB portal

Graph 45: PM2.5 AQI trend in Kota



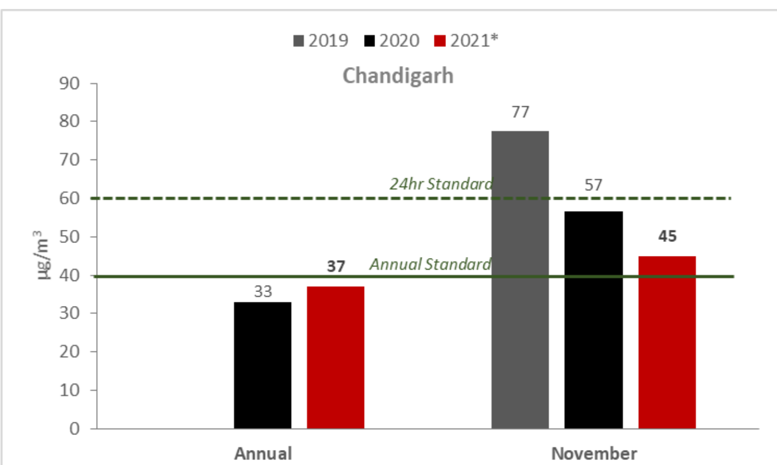
Note: PM2.5 value is based on stations that have continuous and adequate data for complete assessment period. AQI is based on PM2.5 sub-category only. Data up till 30 November 2021.
Source: CSE analysis of realtime data from CPCB portal

Chandigarh

City started monitoring its air only in winter of 2019 therefore it is not possible to establish annual trend for the city. Its annual average for 2021 would be higher than its 2020 average but it'll still be under the annual standard (See *Graph 46: PM2.5 annual and winter trend in Chandigarh*).

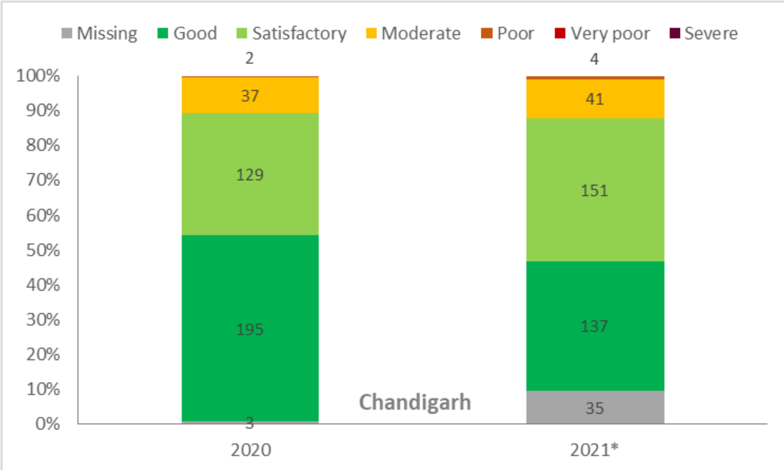
Further, pollution level during winter has been on decline with 2021 November average being significantly under the 24-hr standard. Analysis of days as per AQI categorisation shows that the city registered four days of poor air quality this year which is increase from two poor air days observed last year. There has been significant drop in number of good air days I the city. This year so far 137 good air days have been registered down from 195 good air days observed in 2020 (See *Graph 47: PM2.5 AQI trend in Chandigarh*).

Graph 46: PM2.5 annual and winter trend in Chandigarh



Note: PM2.5 values is based on stations that have continuous and adequate data for complete assessment period. Data up till 30 November 2021.
Source: CSE analysis of realtime data from CPCB portal

Graph 47: PM2.5 AQI trend in Chandigarh



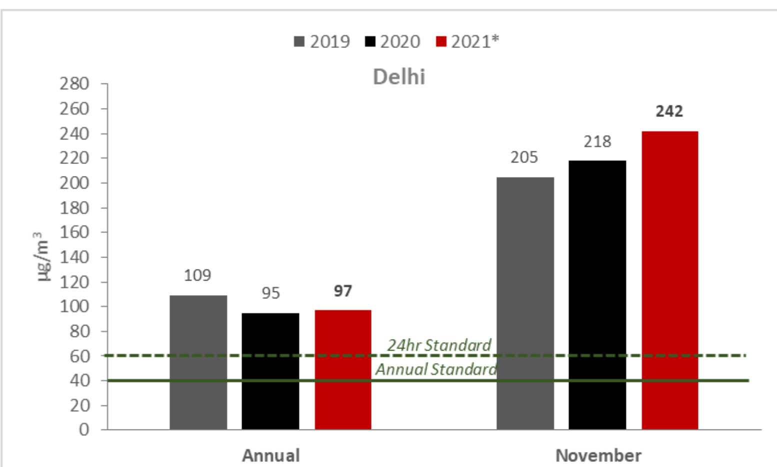
Note: PM2.5 value is based on stations that have continuous and adequate data for complete assessment period. AQI is based on PM2.5 sub-category only. Data up till 30 November 2021.
Source: CSE analysis of realtime data from CPCB portal

NCR: Delhi

City has a declining annual average over last three year and with 2021 average projected to settle lower than 2019 (See *Graph 48: PM2.5 annual and winter trend in Delhi*). It needs to cut pollution level by 59 per cent to meet the standard.

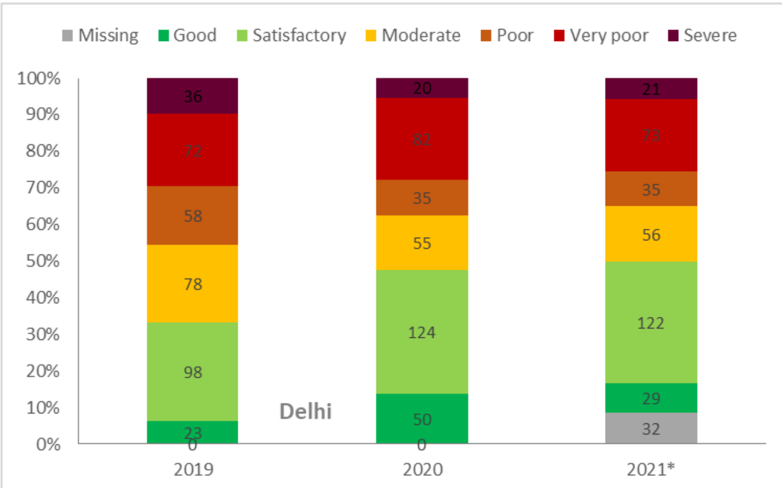
But pollution level during winter has been on rise with 2021 November being significantly dirtier than 2019 and 2020 Novembers. Analysis of days as per AQI categorisation shows that the number of very poor and severe days this year might be same as observed in 2019. Overall number of days with good and satisfactory air quality in the city this year (2021) have surpassed 2019 count even without hard lockdowns which had increased their count in 2020 (See *Graph 49: PM2.5 AQI trend in Delhi*).

Graph 48: PM2.5 annual and winter trend in Delhi



Note: PM2.5 values is based on stations that have continuous and adequate data for complete assessment period. Data up till 30 November 2021.
Source: CSE analysis of realtime data from CPCB portal

Graph 49: PM2.5 AQI trend in Delhi



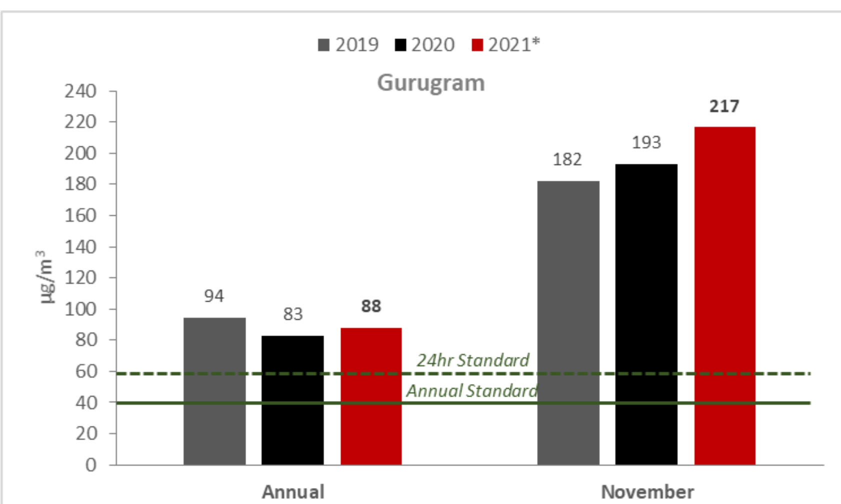
Note: PM2.5 value is based on stations that have continuous and adequate data for complete assessment period. AQI is based on PM2.5 sub-category only. Data up till 30 November 2021.
Source: CSE analysis of realtime data from CPCB portal

NCR: Gurugram

City has a declining annual average over last three year and with 2021 average projected to settle lower than 2019 (See *Graph 50: PM2.5 annual and winter trend in Gurugram*). It needs to cut pollution level by 55 per cent to meet the standard.

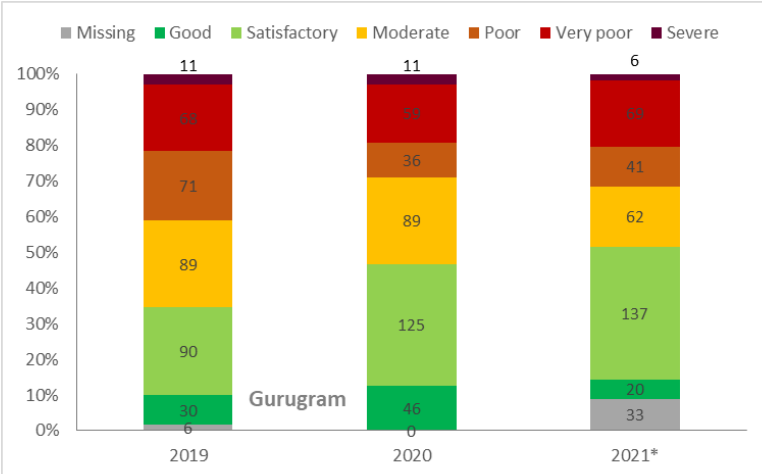
But pollution level during winter has been on rise with 2021 November being significantly dirtier than 2019 and 2020 Novembers. Analysis of days as per AQI categorisation shows that the number of very poor and severe days this year might be same as observed in 2019. Overall number of days with good and satisfactory air quality in the city this year (2021) have surpassed 2019 count even without hard lockdowns which had increased their count in 2020 (See *Graph 51: PM2.5 AQI trend in Gurugram*).

Graph 50: PM2.5 annual and winter trend in Gurugram



Note: PM2.5 values is based on stations that have continuous and adequate data for complete assessment period. Data up till 30 November 2021.
Source: CSE analysis of realtime data from CPCB portal

Graph 51: PM2.5 AQI trend in Gurugram



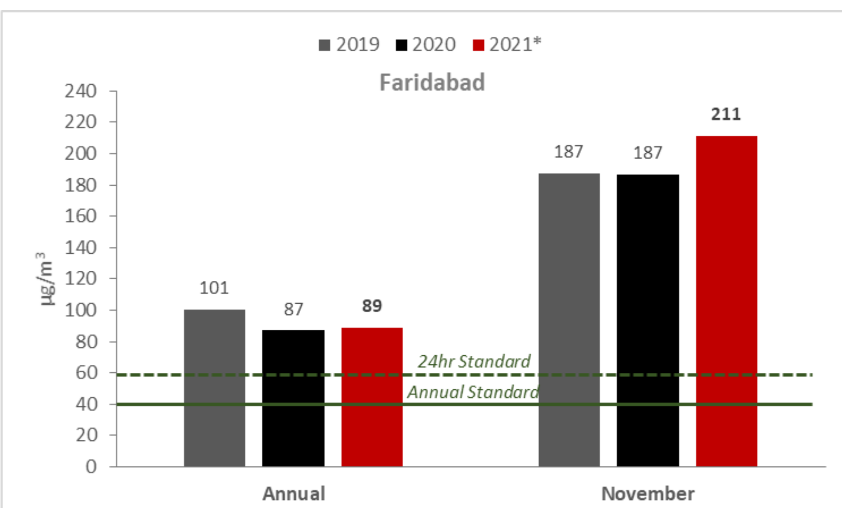
Note: PM2.5 value is based on stations that have continuous and adequate data for complete assessment period. AQI is based on PM2.5 sub-category only. Data up till 30 November 2021.
Source: CSE analysis of realtime data from CPCB portal

NCR: Faridabad

City has a declining annual average over last three year and with 2021 average projected to settle lower than 2019 (See *Graph 52: PM2.5 annual and winter trend in Faridabad*). It needs to cut pollution level by 55 per cent to meet the standard.

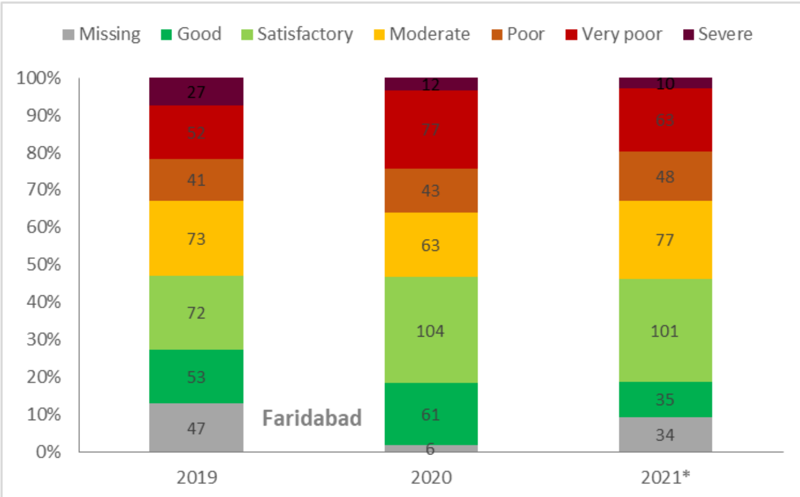
But pollution level during winter has been on rise with 2021 November being significantly dirtier than 2019 and 2020 Novembers. Analysis of days as per AQI categorisation shows that the number of very poor and severe days this year might be same as observed in 2019. Overall number of days with good and satisfactory air quality in the city this year (2021) have surpassed 2019 count even without hard lockdowns which had increased their count in 2020 (See *Graph 53: PM2.5 AQI trend in Faridabad*).

Graph 52: PM2.5 annual and winter trend in Faridabad



Note: PM2.5 values is based on stations that have continuous and adequate data for complete assessment period. Data up till 30 November 2021.
Source: CSE analysis of realtime data from CPCB portal

Graph 53: PM2.5 AQI trend in Faridabad



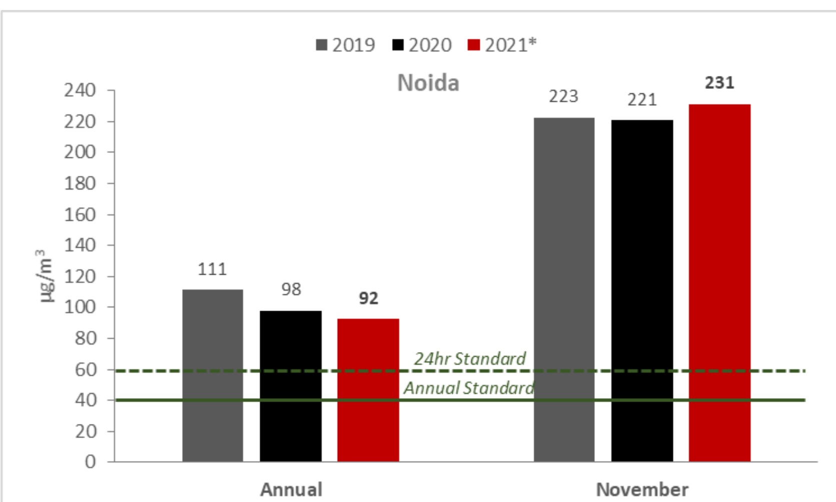
Note: PM2.5 value is based on stations that have continuous and adequate data for complete assessment period. AQI is based on PM2.5 sub-category only. Data up till 30 November 2021.
Source: CSE analysis of realtime data from CPCB portal

NCR: Noida

City has a declining annual average over last three year and with 2021 average projected to settle lower than 2019 (See *Graph 54: PM2.5 annual and winter trend in Noida*). It needs to cut pollution level by 58 per cent to meet the standard.

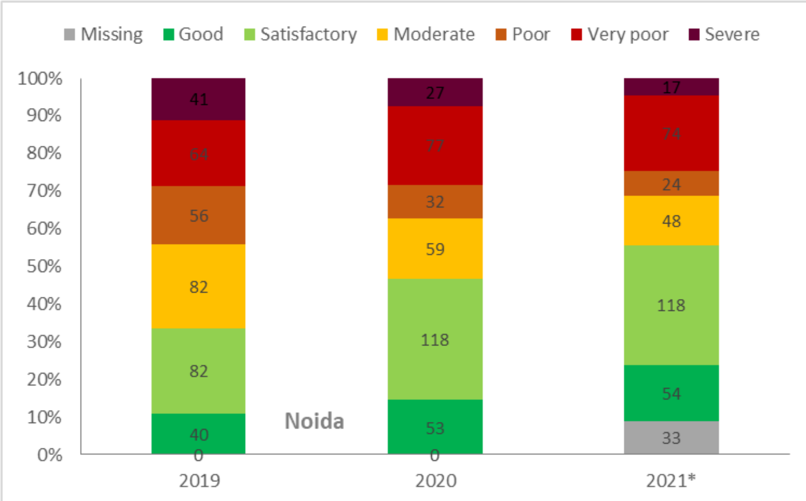
But pollution level during winter has been on rise with 2021 November being significantly dirtier than 2019 and 2020 Novembers. Analysis of days as per AQI categorisation shows that the number of very poor and severe days this year might be same as observed in 2019. Overall number of days with good and satisfactory air quality in the city this year (2021) have surpassed 2020 count even without hard lockdowns which had increased their count in 2020 (See *Graph 55: PM2.5 AQI trend in Noida*).

Graph 54: PM2.5 annual and winter trend in Noida



Note: PM2.5 values is based on stations that have continuous and adequate data for complete assessment period. Data up till 30 November 2021.
Source: CSE analysis of realtime data from CPCB portal

Graph 55: PM2.5 AQI trend in Noida



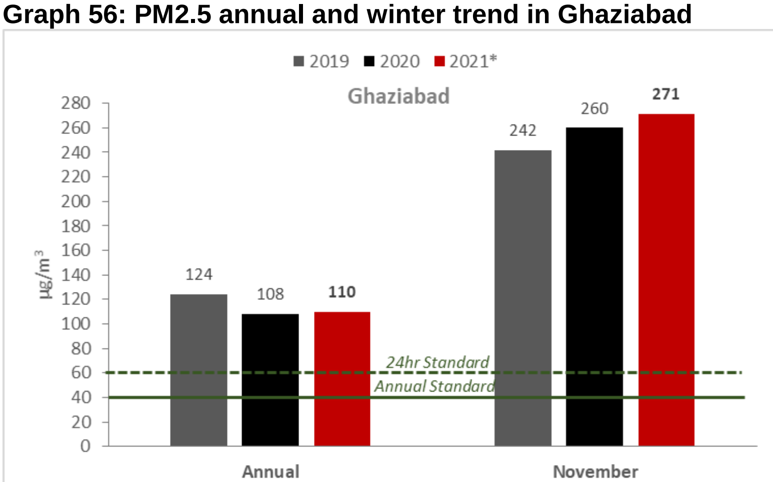
Note: PM2.5 value is based on stations that have continuous and adequate data for complete assessment period. AQI is based on PM2.5 sub-category only. Data up till 30 November 2021.
Source: CSE analysis of realtime data from CPCB portal

NCR: Ghaziabad

City has a declining annual average over last three year and with 2021 average projected to settle lower than 2019 (See *Graph 56: PM2.5 annual and winter trend in Ghaziabad*). It needs to cut pollution level by 63 per cent to meet the standard.

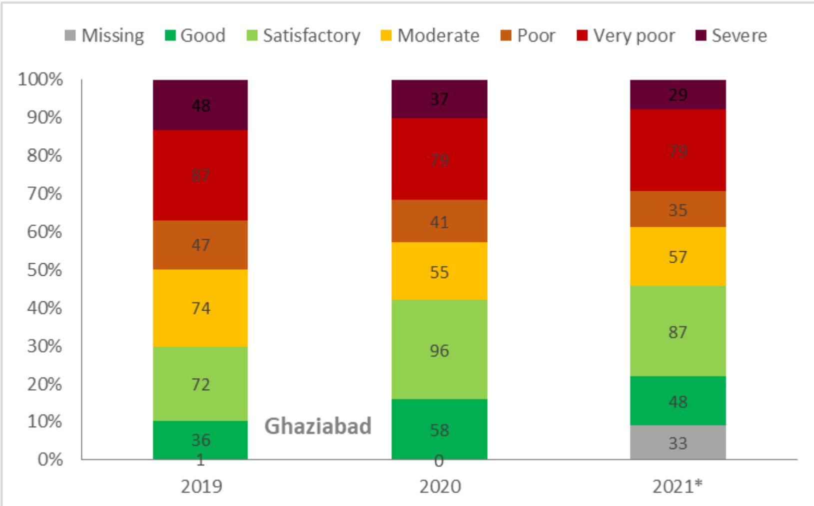
But pollution level during winter has been on rise with 2021 November being significantly dirtier than 2019 and 2020 Novembers. Analysis of days as per AQI categorisation shows that the number of very poor and severe days this year might be same as observed in 2019. Overall number of days with good and satisfactory air quality in the city this year (2021) have surpassed 2019 count even without hard lockdowns which had increased their count in 2020 (See *Graph 57: PM2.5 AQI trend in Ghaziabad*).

Graph 56: PM2.5 annual and winter trend in Ghaziabad



Note: PM2.5 values is based on stations that have continuous and adequate data for complete assessment period. Data up till 30 November 2021.
Source: CSE analysis of realtime data from CPCB portal

Graph 57: PM2.5 AQI trend in Ghaziabad



Note: PM2.5 value is based on stations that have continuous and adequate data for complete assessment period. AQI is based on PM2.5 sub-category only. Data up till 30 November 2021.
Source: CSE analysis of realtime data from CPCB portal

Annexure: List of cities included in the study

S. No.	City	November 2021 average (µg/m³)
	Punjab	
1	**Amritsar**	99
2	**Bhatinda**	61
3	**Jalandhar**	103
4	**Khanna**	94
5	**Ludhiana**	103
6	**Mandi Gobindgarh**	101
7	**Patiala**	109
8	**Rupnagar**	104
	Chandigarh	
1	**Chandigarh**	45
	Haryana (w/0 NCR)	
1	**Ambala**	124
2	**Fatehabad**	140
3	**Hisar**	220
4	**Kaithal**	156
5	**Kurukshetra**	146
6	**Panchkula**	62
7	**Sirsa**	121
8	**Yamuna Nagar**	131
	Uttar Pradesh (w/0 NCR)	
1	***Moradabad***	160
2	**Agra**	176
3	**Firozabad**	179
4	**Gorakhpur**	142
5	**Kanpur**	147
6	**Lucknow**	129
7	**Prayagraj**	132
8	**Varanasi**	111
9	**Vrindavan**	185
	Rajasthan (w/0 NCR)	
1	***Ajmer***	57
2	***Jaipur***	103
3	***Jodhpur***	109
4	***Kota***	121
5	***Pali***	69
6	***Udaipur***	86
	NCR (Delhi)	
1	**Delhi**	242
	NCR (Haryana)	
1	**Bahadurgarh**	195
2	**Ballabgarh**	171
3	**Bhiwani**	153
4	**Charkhi Dadri**	206
5	**Dharuhera**	145
6	**Faridabad**	211
7	**Gurugram**	217
8	**Jind**	225
9	**Karnal**	124
10	**Mandikhera**	90
11	**Manesar**	202
12	**Narnaul**	128
13	**Palwal**	69
14	**Panipat**	107
15	**Rohtak**	181
16	**Sonipat**	144
	NCR (Rajasthan)	
1	**Alwar**	68
2	**Bhiwadi**	195
	NCR (UP)	
1	**Bagpat**	228
2	**Bulandshahr**	206
3	**Ghaziabad**	271
4	**Greater Noida**	211
5	**Hapur**	223
6	**Meerut**	202
7	**Muzaffarnagar**	175
8	**Noida**	231
	Regional values	
No. of cities		*November average*
59	***North India***	147

Source: CSE

Winter Air pollution in the states of North East

Anumita Roychowdhury, Avikal Somvanshi and Sharanjeet Kaur

Centre for Science and Environment, New Delhi, December 17, 2021

The growing problem of air pollution challenges the public impression of pristine blue sky in the cities of ecologically sensitive north east region. The current obsession with high pollution concentration in the Indo-Gangetic Plain and overall northern India overshadows and side lines the early signs of the crisis in north eastern states in the national discourse on air pollution and public health. This has emerged from the new analysis of the Centre for Science and Environment (CSE).

Weak and inadequate air quality monitoring and paucity of data do not allow proper assessment of risk. But even the limited evidence shows several cities – especially the state capitals, are already vulnerable to poor air quality and winter smog. Growing pollution from uncontrolled motorisation, use of dirty and solid fuels, industrial sources, open burning of waste and biomass, and continuous urban construction are contributing to the crisis.

Big gaps in data as well as limited air quality monitoring infrastructure makes it difficult to construct reliable air quality trends for the cities to inform action in the region. Signs of worsening of air quality in this region has not drawn adequate public attention. Winter air quality in Guwahati can be almost as bad as what we see in NCR and UP cities. Smaller cities like Agartala and Kohima have begun to experience high pollution days.

The Centre for Science and Environment (CSE) has analyzed urban air quality status in the states of Assam, Meghalaya, Tripura, Nagaland, Mizoram, and Arunachal Pradesh. This is part of the air quality tracker initiative of the Urban Data Analytics Lab of CSE started last winter. The objective of this new analysis is to understand the magnitude and trend in winter pollution in major cities of the region which have recently started realtime air quality monitoring.

This is an assessment of annual and seasonal trends in PM2.5 concentration for the period 1 January 2019 to 7th December 2021. This analysis is based on the real time data available from the currently functioning air quality monitoring stations in North East India. 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 seven continuous ambient air quality monitoring stations (CAAQMS) spread across six cities in five states: two stations in Guwahati and one station each in Shillong, Agartala, Kohima, Aizwal and Naharlagun.

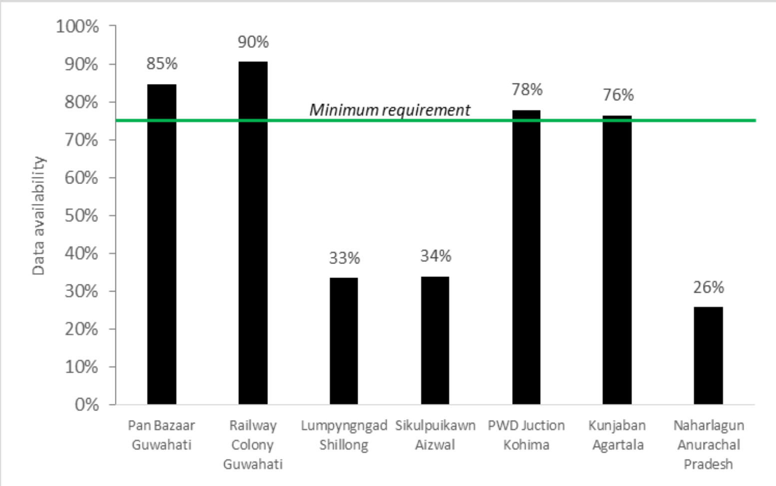
The data is limited. Guwahati in Assam and Shillong in Meghalaya have data available for over two years. Real time monitors in Agartala (Tripura), Kohima (Nagaland) and Aizwal (Mizoram) became operational only near the end of 2020 which limits the possibility of doing long term trend analysis for these cities. Naharlagun in Arunachal Pradesh got its real time monitor in March 2021. Due to excessive amount of missing data from this station any meaningful analysis is not possible.

Key highlights

Data quality remains poor despite setting up of automatic real time air quality monitoring stations: The region has historically been low on monitoring due to hilly terrain and limited infrastructure and resources. With introduction of automated monitoring in the region under CAAQMS program of CPCB, it was expected that air quality data generation would improve. But even this online system is plagued with data gaps. Data availability calculated as number of days with adequate data for commutation of a valid 24hr-average has been low in three of the six cities in the region. In last six month (May to November) data availability at Naharlagun station of Anurachal Pradesh has been just 26 per cent. Stations at Shillong in Meghalaya, and Aizwal in Mizoram fare just marginally better with 33 per cent and 34 per cent data availability (See *Graph 1: Data availability at stations May-Nov, 2021*).

Stations at Kohima in Nagaland, Agartala in Tripura and Guwahati in Assam meet the minimum 75 per cent data availability requirement. In contrast the CAAQMS stations in Delhi-NCR have over 95 per cent data availability. It is not clear why these stations have such poor data availability but it probably has to do with poor electricity and internet connectivity in the region.

Graph 1: Data availability at stations May-Nov, 2021

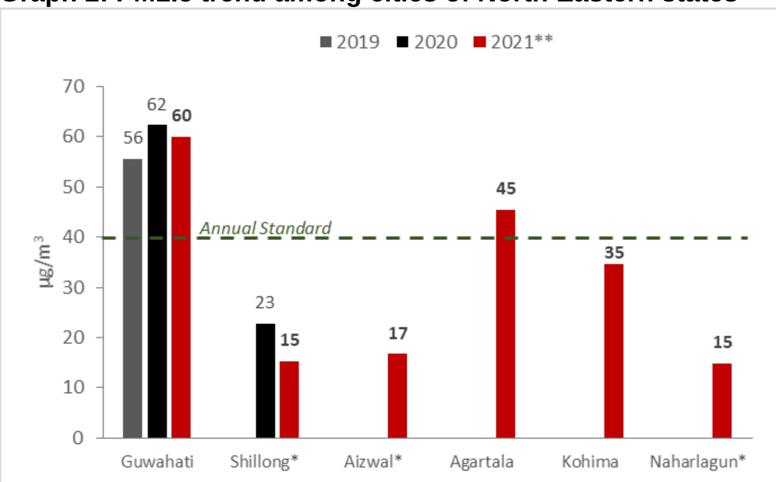


Note: Data availability calculated as number of days with adequate data for commutation of a valid 24hr-average for 1 May-7 Dec 2021.
Source: CSE analysis of real time data from CPCB website

Guwahati has the most polluted air in North Eastern region: Average PM2.5 levels in 2021 (uptill 30th November) has already surpassed the 2019 annual average in Guwahati. The city's 2020 annual average was also higher than its 2019 average which indicates continuous worsening of air in the city. Shillong is the only other city in the region that has a station generating data for over two year but due to poor data availability its annual averages cannot be considered credible. Nevertheless, the city's average is considerably below the annual standard (See *Graph 2: PM2.5 trend among cities of North-Eastern states*).

In contrast to northern India, the overall pollution level is low and several of them currently meet the national ambient air quality standards. But it is possible to grade them based on their annual trends. Among other cities meeting minimum data availability requirements, Agartala with 2020 average of 45 µg/m³ is second most polluted city in the region. Kohima with 2020 average of 35 µg/m³ is the third most polluted city in the region. Aizwal and Naharlagun do not meet the minimum data availability requirement but the limited data available indicates that these two would most probably be meeting the annual standard.

Graph 2: PM2.5 trend among cities of North Eastern states

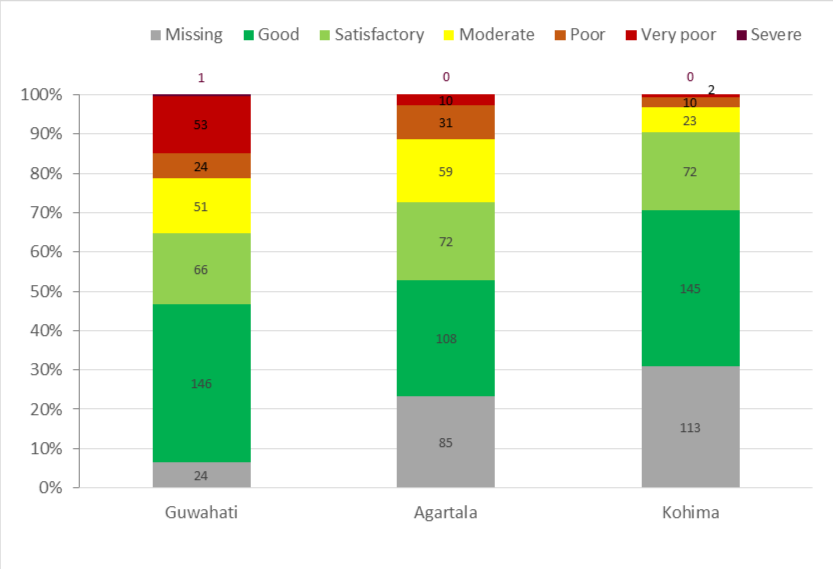


Note: PM2.5 values for sub-regions are based on the average of citywide values of all the cities in that region. PM2.5 values for Guwahati with more than one monitoring stations is based on average of all stations that have continuous and adequate data for complete assessment period. Data up till 30 November 2021.
Source: CSE analysis of real time data from CPCB website

Guwahati has almost two months of very poor air quality days: This year so far number of days with air quality in very poor or severe category stands at 54 days in Guwahati city (See *Graph 3: PM2.5 AQI categorization of days for major cities in North-East India*).

This is comparable to cities of North India which is more polluted compared to North-Eastern states. In other cities good and satisfactory days dominate but poor and very poor days have begun to emerge. Agartala registered 10 very poor days while Kohima two very poor days. There is considerable number of days in these cities for which AQI could not be calculated due to poor data availability. All three cities meet the 24hr standard for about half of the days in 2021 so far. AQI chart for Shillong, Aizwal, and Naharlagun were not made as these cities don't have enough data.

Graph 3: PM2.5 AQI categorization of days for major cities in North East India

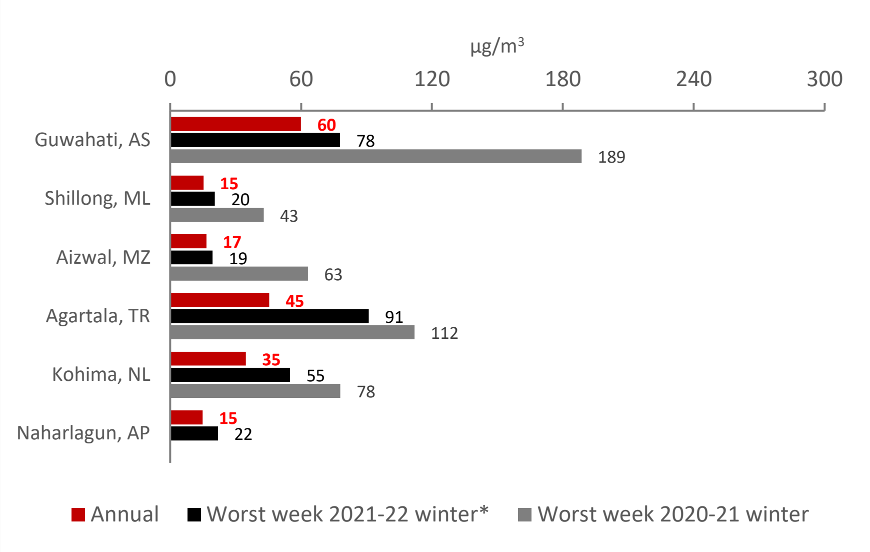


Note: PM2.5 values for cities with more than one monitoring stations is based on average of all stations that have continuous and adequate data for complete assessment period. Data up till 30 November 2021.
Source: CSE analysis of real time data from CPCB website

High pollution episode common during winters despite low annual levels: Except Guwahati, rest of the cities in the states in north east have low annual PM2.5 levels but during winter episodes of high pollution are common. Weekly PM2.5 levels can go as high as 189 µg/m^3 in Guwahati (as recorded in week ending on 17 Jan 2021). This winter so far the highest weekly level has been reported from Agartala when it hit 91 µg/m^3 (as recorded in week ending on 28 Nov 2021). Last winter it had gone upto 112 µg/m^3 (as recorded in week ending on 10 Jan 2021). Similarly highly pollutions have been recorded in Aizwal and Kohima (*See Graph 4: Weekly PM2.5 levels vs annual level among Cities of North East India*).

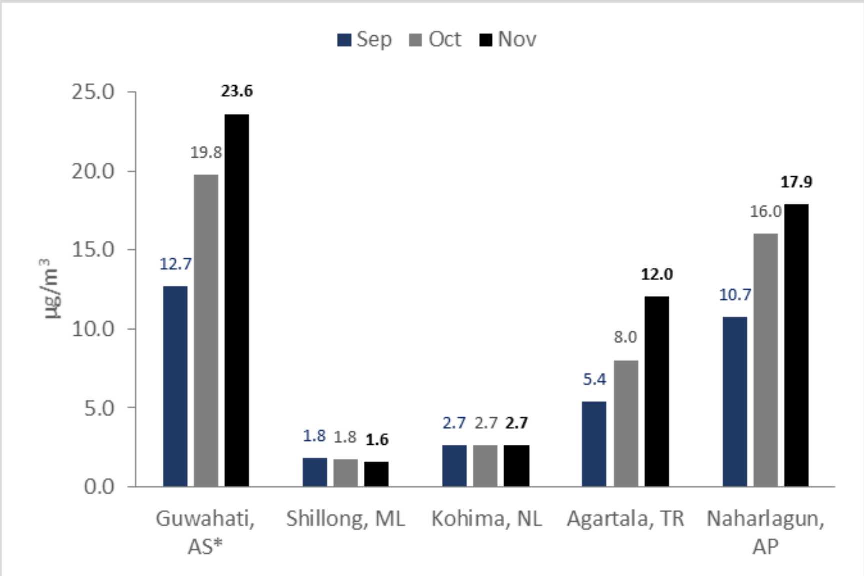
Guwahati, Agartala and Naharlagun show elevated NO2 levels in winter: There is a significant increase in amount of NO2 in air of Agartala and Naharlagun during November compared to October and September, 2021. Agartala registered 124 per cent jump in monthly NO2 level while Naharlagun registered a 67 per cent increase (See *Graph 5: Monthly trend in NO2 levels in cities of North East India*). In other cities including Shillong, Kohima, and Guwahati, there seems to be a problem with the monitors as the data points are showing an almost flat line. This implies their NO2 monitors might not be working properly. Guwahati's data for this year is reporting almost flat-line since May 2021. But in 2020 NO2 level in Guwahati had increased as winter progressed -- there was a 85 per cent jump in monthly NO2 levels between September and November. Aizwal has not reported NO2 data since May 2021.

Graph 4: Weekly PM2.5 levels vs annual level among cities of North East India



Note: Worst week for Guwahati were weeks ending on 17 Jan 2021 and 7 Nov 2021; Agartala were weeks ending on 10 Jan 2021 and 28 Nov 2021; Kohima and Aizwal have both their worst weeks ending on 17 Jan 2021 and 5 Feb 2021; Shillong were weeks ending on 17 Jan 2021 and 28 Nov 2021; Naharlagun were weeks ending on 5 Dec 2021.
Source: CSE analysis of real time data from CPCB portal

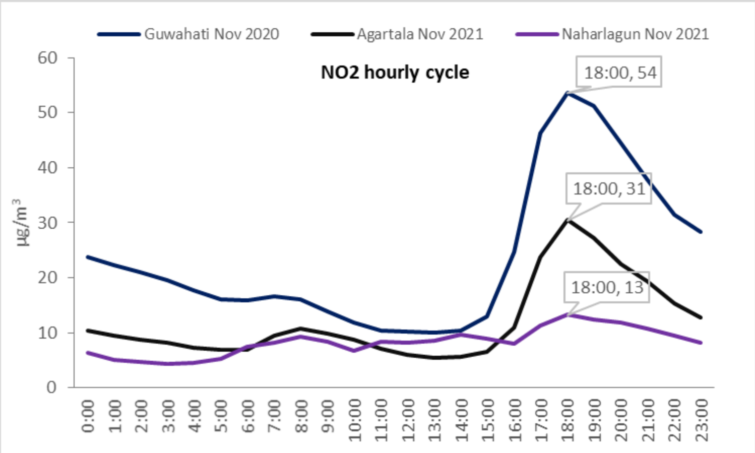
Graph 5: Monthly trend in NO2 levels in cities of North East India



Note: NO2 values for cities with more than one monitoring stations is based on average of all stations that have continuous and adequate data for complete assessment period. Data up till 30 November 2021.
Source: CSE analysis of real time data from CPCB website

Daily NO2 peaks with traffic peaks: Only three cities have reliable NO2 data and all of them show peaking of hourly NO2 concentration at 6pm which coincides with evening rush hour in the cities. Hourly NO2 in Guwahati and Agartala increases 5-folds between 1pm and 6pm (See *Graph 6: Hourly NO2 cycle for November in Guwahati, Agartala and Naharlagun*). NO2 cycle is not as sharp in Naharlagun but still 40 per cent increase in noted at 6pm from 1pm. All three cities have a morning NO2 peak around 7-8am but is relatively smaller to evening peak. In Guwahati, night time NO2 is high indicating impact of night-time truck movement in the city.

Graph 6: Hourly NO2 cycle for November in Guwahati, Agartala and Naharlagun

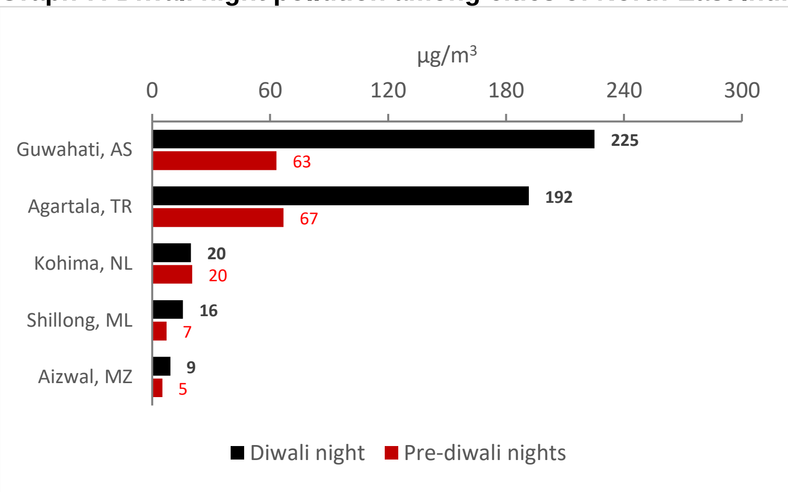


Note: Average NO2 concentration is based on mean of hourly values that have continuous and adequate data for complete assessment period. Data up till 30 November 2021.
Source: CSE analysis of real time data from CPCB website

Diwali is a mega pollution event for Guwahati and Agartala: Pollution level on Diwali night (8pm to 8am) in cities shot up by 1.0 - 3.6 times the average level recorded seven nights preceding Diwali (See *Graph 7: Diwali night pollution among cities of North-East India*). Guwahati had the greatest pollution build-up on Diwali night, with a 3.6-fold increase in night-time PM2.5, while Kohima had no impact of Diwali on its air quality. Naharlagun had no data for Diwali night while Kohima, Shillong and Aizwal registered very low PM2.5 levels with negligible impact of Diwali.

In absolute concentration terms, Guwahati dominate the list of most polluted Diwali nights with 225 µg/m³ PM2.5 level. Agartala with Diwali night PM2.5 level 192 µg/m³ enters the AQI categorization of very poor level.

Graph 7: Diwali night pollution among cities of North-East India



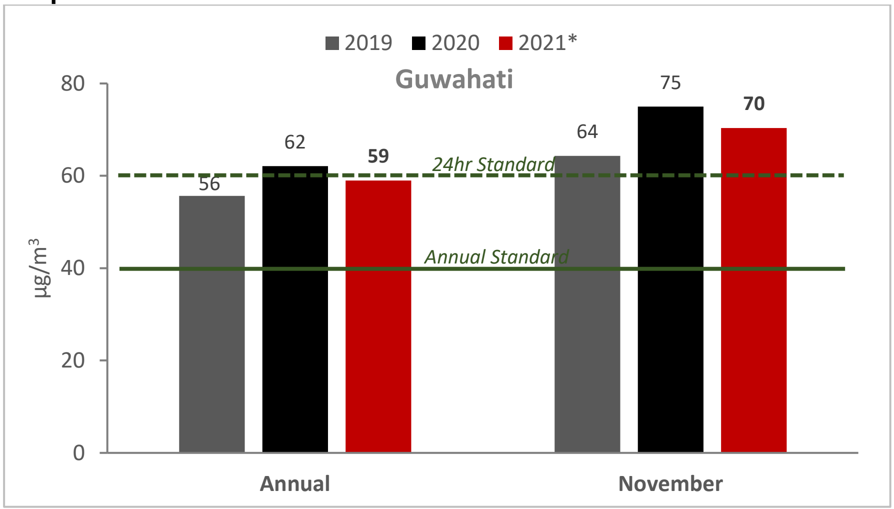
Note: PM2.5 values for cities with more than one monitoring stations is based on average of all stations that have continuous and adequate data for complete assessment period. Diwali night is considered from 8.00PM November 4 to 8.00AM November 5. Pre-Diwali night is average of seven nights (8.00PM-8.00AM) preceding Diwali.
Source: CSE analysis of real time data from CPCB website

Spotlight on Guwahati

Guwahati has comparatively better data set that allows more insights into the pollution behaviour in the city. This city has a stable annual average of PM2.5 since last three year but it does not meet the annual standard for PM2.5 (See *Graph 8: PM2.5 annual and winter trend in Guwahati*). It needs to cut pollution level by 33 per cent to meet the standard.

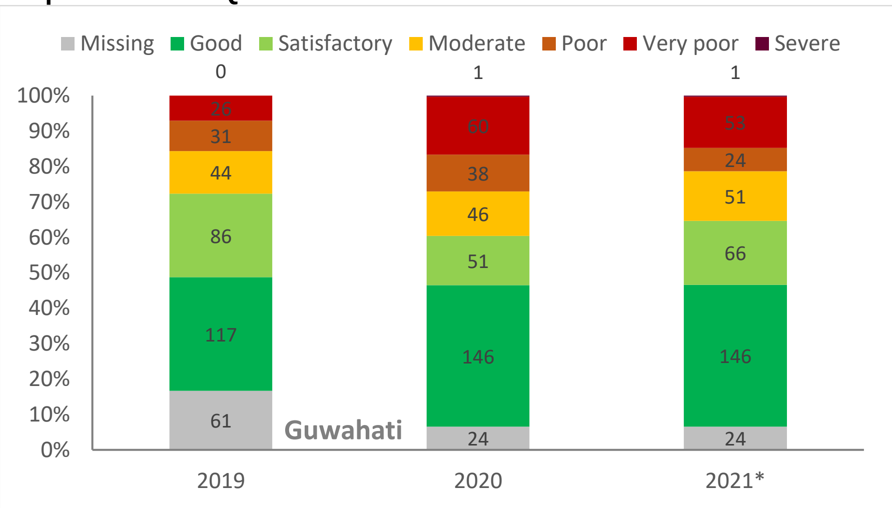
Further, November pollution this year is lesser compared to last two Novembers. But most polluted months for the city are December and January. Analysis of days as per the categorisation of the national air quality index shows that the city is experiencing increasingly higher number of days with poor or worse air quality, and most of these days are concentrated during winter months. Number of days with good air quality has remained same in last two years (See *Graph 9: PM2.5 AQI trend in Guwahati*).

Graph 8: PM2.5 annual and winter trend in Guwahati



Note: PM2.5 values is based on stations that have continuous and adequate data for complete assessment period. Data up till 30 November 2021.
Source: CSE analysis of real time data from CPCB portal

Graph 9: PM2.5 AQI trend in Guwahati



Note: PM2.5 value is based on stations that have continuous and adequate data for complete assessment period. AQI is based on PM2.5 sub-category only. Data up till 30 November 2021.
Source: CSE analysis of real time data from CPCB portal

Way forward

Sparse and limited air quality data underrates the magnitude of the problem in cities. Though overall pollution in the region is low, air pollution is increasing in several cities. Cities like Guwahati needs to cut annual average PM2.5 levels by 33 per cent to meet the standard. High pollution episode is becoming common during winter despite low annual levels. Guwahati in Assam, Agartala in Tripura, Kohima in Nagaland, and Aizwal in Mizoram experience high pollution days. These are the early signs of growing public health crisis in the hilly terrains and valleys.

Cities of north eastern states need urgent support under the National Clean Air Programme to implement locally appropriate clean air action and robust air quality monitoring network for proper risk assessment. This is urgently needed to cut pollution from growing motorisation and congestion, use of solid fuels and open burning, and dispersed industrial sources at the early stages to prevent worsening of the public health crisis in this ecologically vulnerable region.

Winter Air pollution in cities of Madhya Pradesh and Chhattisgarh

Anumita Roychowdhury, Avikal Somvanshi

Centre for Science and Environment, New Delhi, December 23, 2021

It is not only the North India that is in grip of severe winter pollution. Several cities in other regions such as Central India -- Madhya Pradesh and Chhattisgarh, are experiencing worsening of winter pollution, finds the latest analysis of the centre for Science and Environment (CSE).

Even though the real time air quality data is extremely limited in this region, the emerging jigsaw of real time data from only 17 cities of these two big states indicates a growing crisis and vulnerability to winter smog. This demands early and stronger multi-sector action at a regional scale to meet the clean air targets.

Gaps in air quality data and lack of quality control of data make it difficult to construct reliable air quality trends and do proper risk assessment. The worsening of air quality in the region has not drawn adequate public attention. In winter, air quality of cities like Singrauli, Gwalior, Jabbalpur, Katna among others can be nearly three times worse than their annual average level.

CSE has analyzed air quality status in cities of Madhya Pradesh (MP) and Chhattisgarh. This is continuation of the air quality tracker initiative of the Urban Data Analytics Lab of CSE that was started last winter. The objective of this new analysis has been to understand the trend and magnitude of the winter pollution in major cities of different regions that have real time air quality monitoring systems.

This is an assessment of annual and seasonal trends in PM2.5 concentration for the period 1 January 2019 to 12th December 2021. This analysis is based on the real time data available from the current working air quality monitoring stations in Central India. 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 18 continuous ambient air quality monitoring stations (CAAQMS) spread across 17 cities in two states: two stations in Gwalior and one station each in Bhopal, Damoh, Dewas, Indore, Jabalpur, Katni, Maihar, Mandideep, Pithampur, Ratlam, Sagar, Satna, Singrauli, Ujjain, Bhilai, and Bilaspur.

Air quality monitoring is still very limited in the central region. MP cities have data available for over two years. Bur real time monitors in Chhattisgarh became operational only in later half of this year which limits the possibility of assessing long term trend. Therefore data is indicative of the current status of air quality and seasonal variation in particulate pollution in medium and smaller cities.

Analysis shows that air pollution during winter is a problem in all the cities in these two states with Gwalior and Singrauli having the worst air quality, as bad the winter air quality of NCR and UP cities.

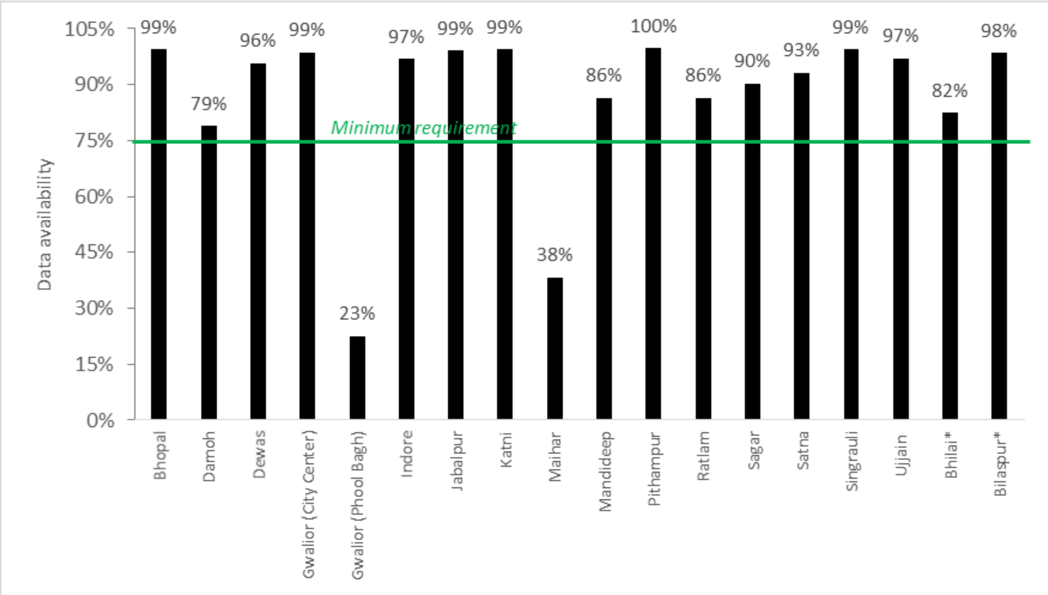
Even gases have begun to raise the ugly heads. Nitrogen dioxide (NO2) pollution is also high in these cities with Indore recording the highest among the cities of this region. The limited air quality data in the region indicates that it has not changed much from the 2020 level. But due to limited historical data it is difficult to comment on the regional air quality trend.

Summary highlights

Data quality remains poor despite automation: This central region has 18 real time monitors, 13 are operated by state pollution control boards while five are operated by private entities: Bhilai by Bhilai Steel Plant, Satna by Birla Cement, Maihar by KJS Cement, Ratlam by IPCA Lab, and Phool Bagh Gwalior by Mondelez Ind. Food. Most stations meet the minimum data availability of 75 per cent for this winter season this year (1 Jan – 12 Dec, 2021) (See *Graph 1: Data availability at stations in 2021*). Only stations that do not meet the minimum requirement are at Maihar (38 per cent) and Phool Pagh Gawlior (23 per cent). These are operated by private entities. Stations in Chhattisgarh only started operating in September (Bilaspur) and November (Bhilai) but they have reported data for more than 75 per cent of days since becoming operational.

Quick examination of data indicates that stations operated by industry actors tend to report very low concentration numbers or have massive data gaps compared to stations operated by state pollution control board. Station at Satna operated by Birla Cement especially stands out for uncannily low values, in fact annual average for 2020 for this particular station works out to be about 50 per cent lower than what is reported by two manual stations of the city in annual NAMP report. It is not clear why such deviation occurs in Satna's realtime monitor data.

Graph 1: Data availability at stations in 2021

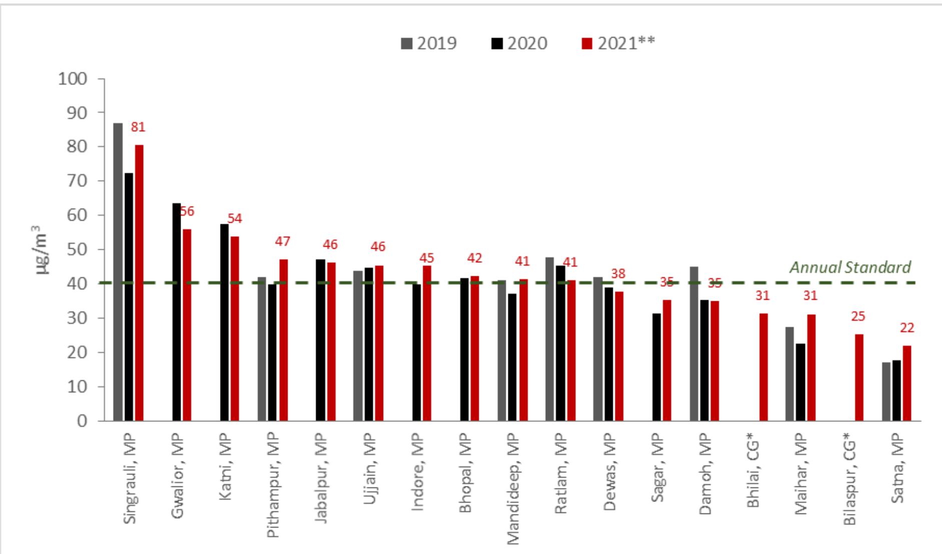


Source: CSE analysis of real time data from CPCB website

Singrauli and Gawlior have the most polluted air in Central India: Singrauli, a small town in eastern MP but designated as critically polluted areas by the Central Pollution Control Board, has the most polluted air in the region with 2021 average of 81 µg/m^3. It is followed by Gwalior and Katni that have 2021 average of 56 µg/m^3 and 54 µg/m^3 respectively (See *Graph 2: PM2.5 trend among cities of Central India*). The 2021 average has bypassed the 2020 average in all major cities i.e. Bhopal, Indore, Jabalpur and Ujjain and they don't meet the annual standard as well. Satna has the lowest 2021 average value but quality of data from the city's only station is of suspect nature.

Bilaspur, Bhilia and Maihar do not have adequate data for computation of annual values.

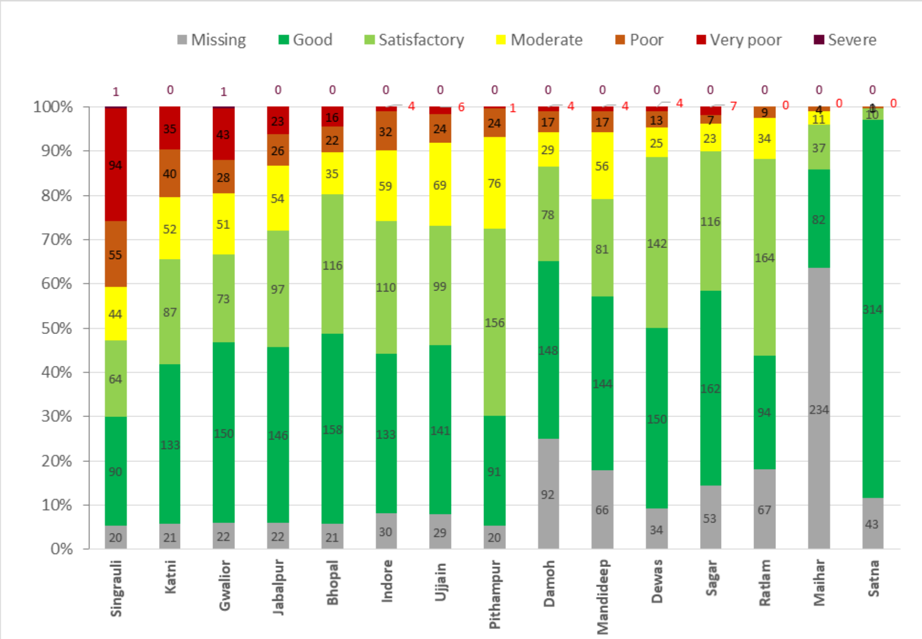
Graph 2: PM2.5 trend among cities of Central India



Note: PM2.5 values for Guwahati which has two monitoring stations is based on average of both stations. Data for only those stations is considered that have continuous and adequate data for complete assessment period. Data up till 30 November 2021.
Source: CSE analysis of real time data from CPCB website

Singrauli have had over three months of very poor air quality days this year: This year so far number of days with air quality in very poor or severe category in Singrauli city stands at 95 days which is identical to Delhi – as of November 2021 (See Graph 3: PM2.5 AQI categorization of days for major cities in Central India). Singrauli has just one severe day. There is a constant high pollution in the city but it rarely gets tipped over to severe, which generally happens due to impact of additional factors like meteorology or external pollution source. Major cities like Bhopal (38 days), Indore (36 days), Gwalior (72 days), Jabalpur (49 days) and Ujjain (30 days) have recorded over a month of poor or worse air quality in 2021 so far. These bad air quality days are concentrated during winter months (See Graph 4: PM2.5 AQI heatmap calendar for major cities in Central India). Cities in the east abutting the Indo-Gangetic Plains are dirtier compared to rest of the cities in the region.

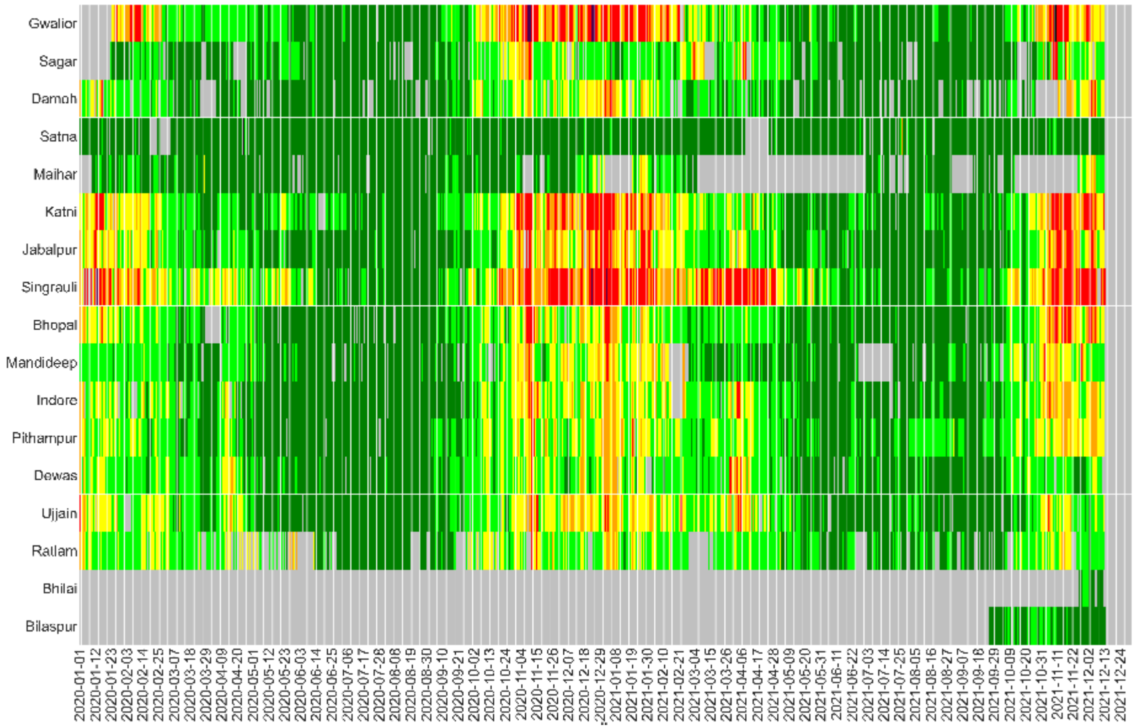
Graph 3: PM2.5 AQI categorization of days for major cities in central India



Note: PM2.5 values for cities with more than one monitoring stations is based on average of all stations that have continuous and adequate data for complete assessment period. Data up till 30 November 2021.
Source: CSE analysis of real time data from CPCB website

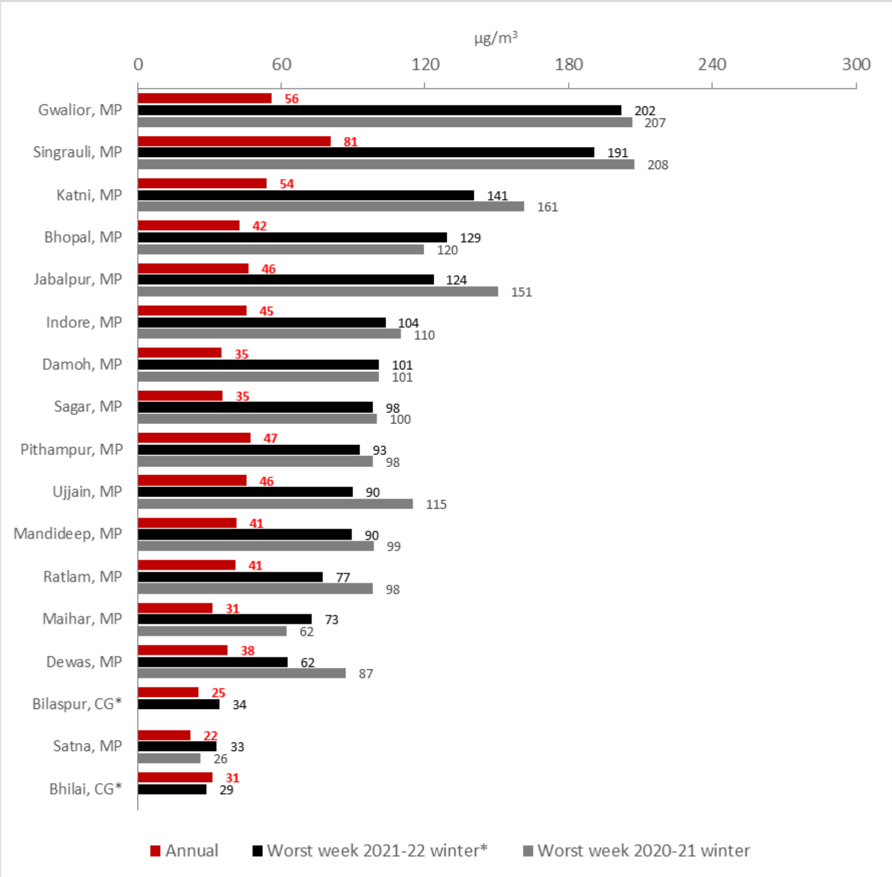
High pollution episode common during winters despite low annual levels: Except Singrauli, rest of the central Indian cities have relatively low annual PM2.5 levels (requiring less than 30 per cent reduction to meet the annual standard) but during winters episodes of high pollution are common place. During these high pollution episodes weekly PM2.5 levels can go as high as 202 µg/m^3 as recorded in Gwalior in November 2021 (See Graph 5: Weekly PM2.5 levels vs annual level among Cities of Central India). This winter so far the highest weekly level has crossed 100 µg/m^3 in Singrauli (191 µg/m^3), Katni (141 µg/m^3), Bhopal (129 µg/m^3), Jabalpur (124 µg/m^3), Indore (104 µg/m^3), and Damoh (101 µg/m^3). The levels are marginally lower this winter compared to last winter.

Graph 4: PM2.5 AQI heatmap calendar for major cities in Central India



Note: PM2.5 values for cities with more than one monitoring stations is based on average of all stations that have continuous and adequate data for complete assessment period. Cell colours are based on the official AQI category colours. Data up till 12 December 2021.
Source: CSE analysis of realtime data from CPCB portal

Graph 5: Weekly PM2.5 levels vs annual level among Cities of Central India

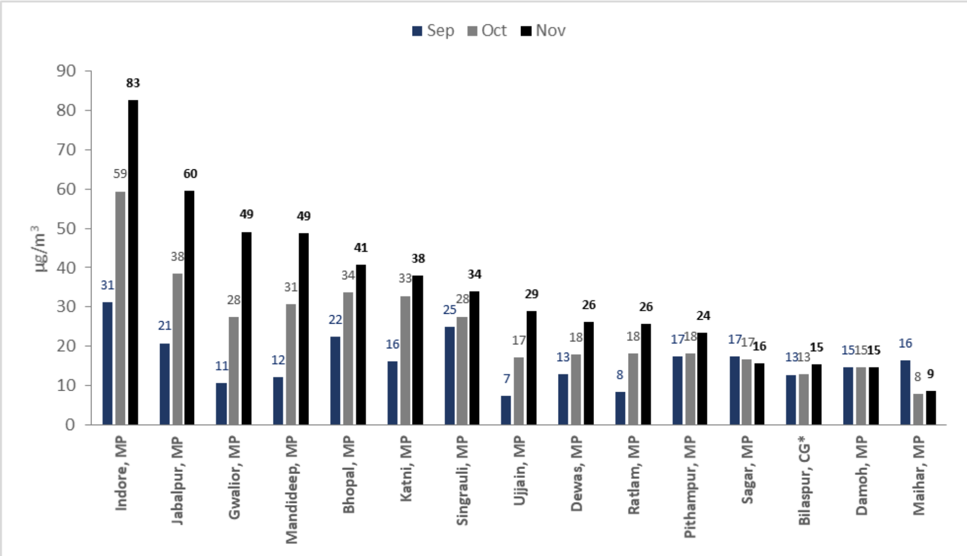


Source: CSE analysis of real time data from CPCB portal

Indore has dangerously high NO2 levels in winter: There is a significant increase in amount of NO2 in air of all cities of Central India during November compared to October and September. Gwalior registered 4.6 times jump in monthly NO2 level while Mandideep registered a 4 times increase (See *Graph 6: Monthly trend in NO2 levels in cities of Central India*).

In absolute concentration term, Indore registered the highest monthly average of 83 µg/m³ for November. This is higher than 24-hr standard for NO2. It is followed by Jabalpur (60 µg/m³) and Gwalior (49 µg/m³). Such high levels are not recorded even in North Indian cities which are more polluted.

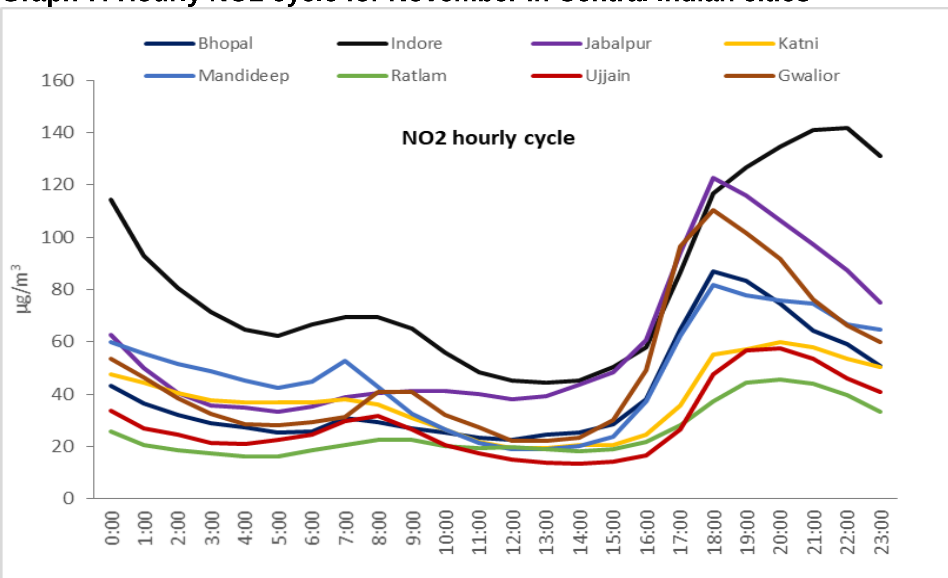
Graph 6: Monthly trend in NO2 levels in cities of Central India



Note: NO2 values for cities with more than one monitoring stations is based on average of all stations that have continuous and adequate data for complete assessment period. Data up till 30 November 2021
Source: CSE analysis of real time data from CPCB portal

Traffic is a major contributor to pollution in the cities: All cities show peaking of hourly NO2 concentration between 6pm and 8pm which coincides with evening rush hour in the cities. Hourly NO2 in Gwalior increases 5-folds between noon and 6pm (See *Graph 7: Hourly NO2 cycle for November in Central India cities*). NO2 cycle is equally as sharp among other cities with 2.5-4.3 times increase in noted at evening from afternoon. All cities have a morning NO2 peak around 7-8am but is relatively smaller to evening peak. In Indore high NO2 levels persist uptill midnight indicating presence of pollution from night-time truck movement in the city.

Graph 7: Hourly NO2 cycle for November in Central Indian cities

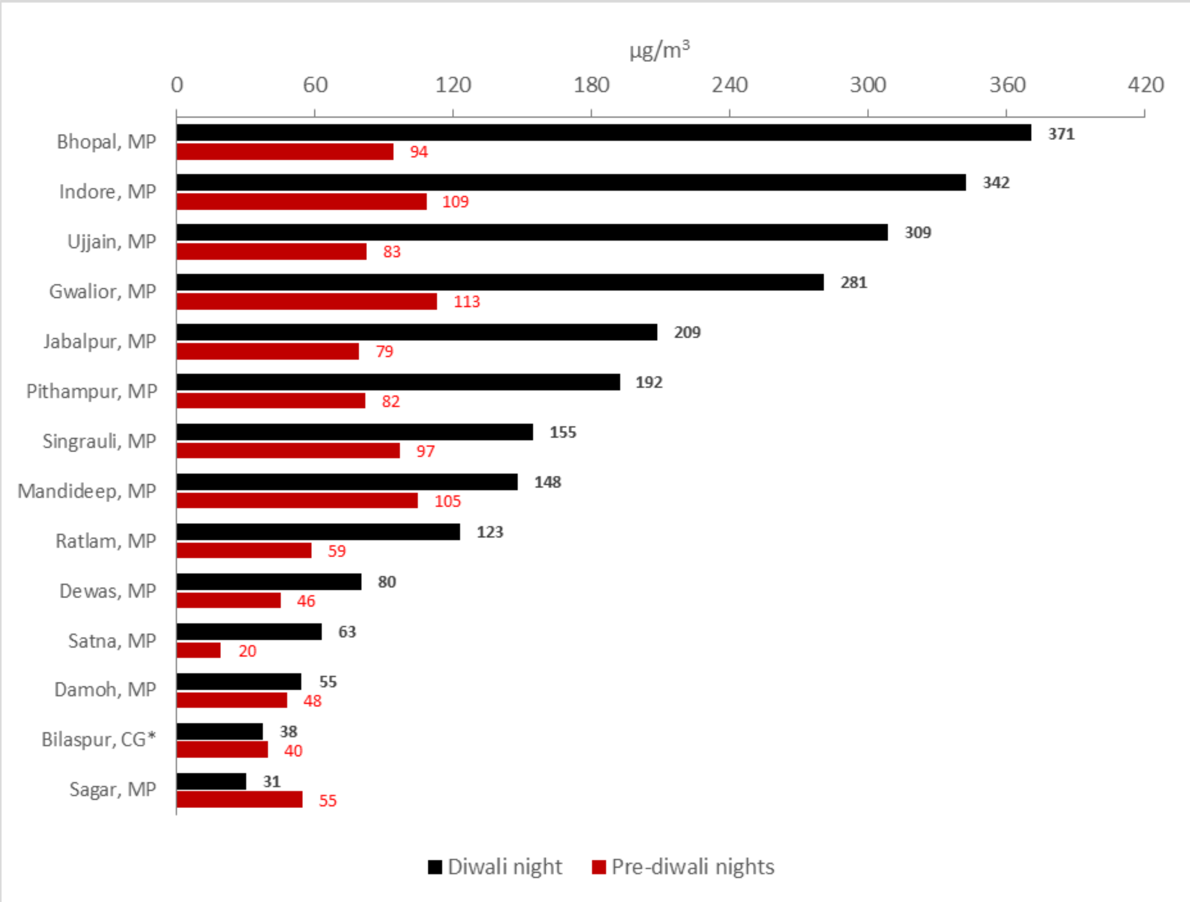


Note: Average NO2 concentration is based on mean of hourly values that have continuous and adequate data for complete assessment period. Data up till 30 November 2021.
Source: CSE analysis of real time data from CPCB website

Diwali is a mega pollution event: Pollution level on Diwali night (8pm to 8am) in cities shot up by 1.4 - 3.9 times the average level recorded seven nights preceding Diwali (See Graph 8: Diwali night pollution among cities of Central India). Bhopal had the greatest pollution build-up on Diwali night, with a 3.9-fold increase in night-time PM2.5, followed by Ujjain that saw 3.7 fold increase. Sagar, Bilaspur and Damoh registered very low PM2.5 levels with no impact of Diwali.

In absolute concentration terms, Bhopal dominate the list of most polluted Diwali nights with 371 µg/m³ PM2.5 level. Pollution was very high among all other major cities as well on Diwali night with Indore (342 µg/m³), and Ujjain (309 µg/m³), Gwalior (281 µg/m³), Jabalpur (209 µg/m³) crossing 200 µg/m³ mark.

Graph 8: Diwali night pollution among cities of Central India



Note: PM2.5 values for cities with more than one monitoring stations is based on average of all stations that have continuous and adequate data for complete assessment period. Diwali night is considered from 8.00PM November 4 to 8.00AM November 5. Pre-Diwali night is average of seven nights (8.00PM-8.00AM) preceding Diwali.
Source: CSE analysis of real time data from CPCB website

The next steps

This region that includes critically polluted industrial areas requires urgent attention under the National Clean Air Programme. While strengthening air quality monitoring network for proper risk assessment, tighten action in critically polluted areas and scale up implementation of multi-sector clean air action plan to meet time bound clean air target. This is needed to prevent worsening of the public health crisis in this region.

Winter Air pollution in cities of East India

Anumita Roychowdhury, Avikal Somvanshi and Sharanjeet Kaur

Centre for Science and Environment, New Delhi, January 07, 2022

The build-up in pollution level during winter has a clear pattern. The smog begins to engulf North India and parts of Indo Gangetic Plain during early November and then begins to extend eastward. Bihar, West Bengal and Odisha are affected mostly during December and early January when winter inversion, cool and calm conditions contribute to this trend in this region where overall trend in annual pollution level is already high.

Centre for Science and Environment (CSE) has analyzed air quality status in cities of West Bengal (WB), Bihar (BR), and Odisha (OD). This is continuation of the air quality tracker initiative of the Urban Data Analytics Lab of CSE. The objective of this new analysis has been to understand the trend and magnitude of the winter pollution in major cities of different regions that have real time air quality monitoring systems.

This is an assessment of annual and seasonal trends in PM2.5 concentration for the period 1st January 2019 to 4th January 2022. This analysis is based on the real time data available from the current working air quality monitoring stations in East India. A huge volume of data points have been cleanedand data gaps have been addressed based on USEPA method for this analysis.

This analysis covers 29 continuous ambient air quality monitoring stations (CAAQMS) spread across 12 cities in three states: West Bengal -- seven stations in Kolkata, three stations in Howrah, and one station each in Asansol, Siliguri, Durgapur, Haldia; Bihar - six stations in Patna, three stations in Gaya, three stations in Muzaffarpur and one in Hajipur; Odisha -- one real time station each in Talcher and Brajrajnagar.

Even though there are real time monitors in a few other cities of these states, those could not be considered due to data gaps and lack of quality data. This has made it difficult to construct reliable air quality trends for proper risk assessment. Moreover, in several cases the real time monitors have been set up recently and therefore long term data is not available. Several cities of Bihar have got their real time monitors between July and November 2021. There are two stations in Bhagalpur and one station each in Bettiah, Bihar Sharif, Darbhanga, Motihari, Araria, Arrah, Buxar, Chhapra, Katihar, Kishanganj, Manguraha, Munger, Purnia, Rajgir, Saharsa, Sasaram, and Siwan. But due to excessive amount of missing data from these stations meaningful analysis has not been possible. Hajipur in Bihar have data availability for over two years.

In West Bengal, real time monitors in Durgapur and Haldia became operational only near the end of 2020 which limits the possibility of doing long term trend analysis for these cities. Odisha has very limited real time monitoring. Therefore, data is indicative of the current status of airquality and seasonal variation in particulate pollution in medium and smaller cities.

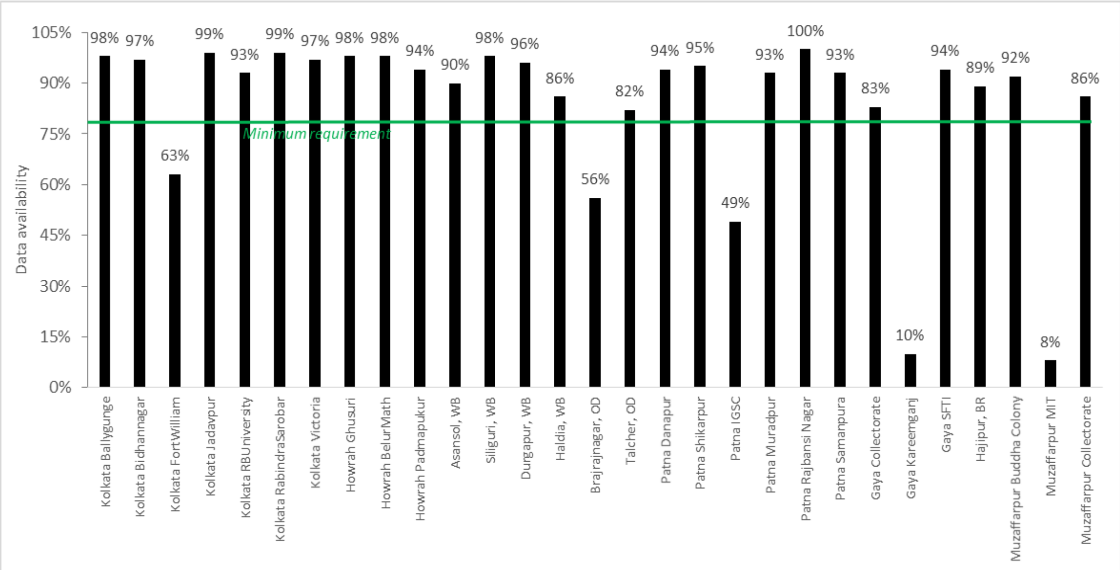
Key highlights

Data quality remains poor despite automation: Review of data availability of from the automated monitoring stations in the region under Continuous Ambient Air Quality Monitoring Stations (CAAQMS) program of CPCB, shows major data gaps. Data availability calculated as number of days with adequate data for commutation of a valid 24hr-average has been low in five of the twelve cities in the region. For the year 2021 (January to December) data availability at Kareemganj station of Gaya and MIT station of Muzaffarpur has been just 10 per cent and 8 per cent respectively. Stations at Fort William in Kolkata, Bajrajnagar in Odisha and IGSC in Patna fare marginally better with 63 per cent, 56 per cent, and 49 per cent data availability respectively (See *Graph 1: Data availability at stations in Jan-Dec, 2021*).

Stations at Talcher in Odisha, and Collectorate in Gaya meet the minimum 80 per cent data availability requirement. In contrast the CAAQMS stations at Rajbansi Nagar in Patna have 100 per cent data availability. It is not clear why these stations have such poor data availability but it probably has to do with poor electricity and internet connectivity in the region. This requires an assessment.

However, several other stations in Kolkata, Howrah, Siliguri, and Durgapur in West Bengal; and a few in Patna, Gaya, and Muzaffarpur in Bihar show between 95-100 per cent availability with some variation.

Graph 1: Data availability at stations in Jan-Dec, 2021

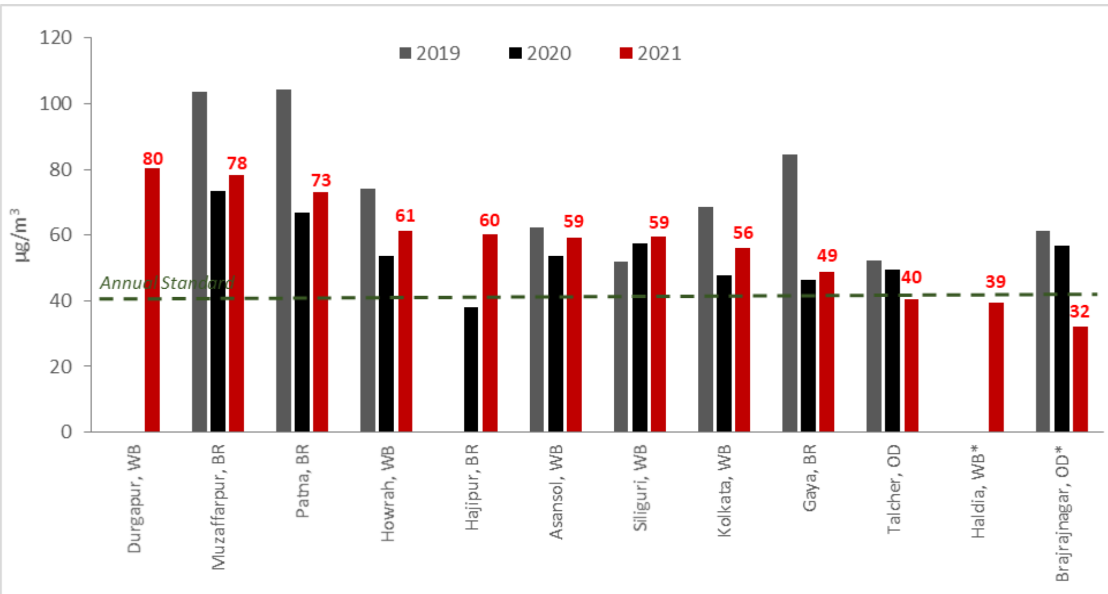


Source: CSE analysis of real time data from CPCB website

Most cities show a rising trend in annual PM2.5 level after an initial drop during 2020 with more pandemic related lockdown phases: Nearly all cities in the region show a drop in annual average PM2.5 level in 2020 that was also the year with maximum lockdown phases. But there is a rebound and a rising trend once again in 2021 though in several cases the levels are lower than the 2019 level. Durgapur, a big industrial hub of WB that is also designated as a critically polluted area by CPCB, has the most polluted air in the region with 2021 average of 80 µg/m^3. This is followed by Muzaffarpur and Patna with 2021 annual average of PM2.5 at 78 µg/m^3 and 73 µg/m^3 respectively (See *Graph 2: PM2.5 trend among cities of East India*).

Odisha is the only state where Bajrajnagar and Talcher have met the annual standard with average of 32 µg/m^3 and 40 µg/m^3. Haldia in West Bengal also meets the annual standard as well at 39 µg/m^3.

Graph 2: Long term PM2.5 trend among cities of East India

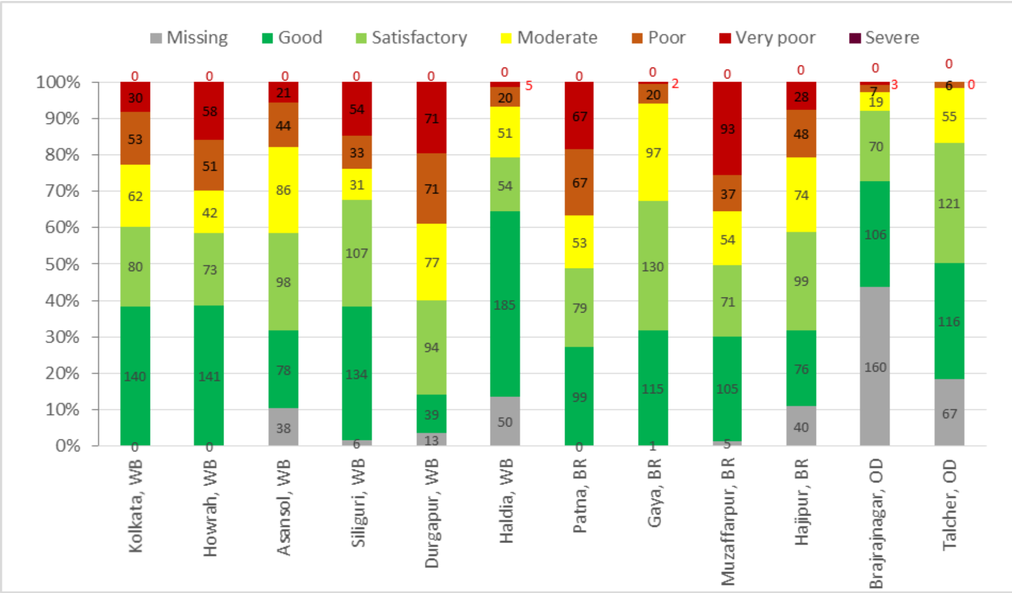


Note: PM2.5 values for Guwahati which has two monitoring stations is based on average of both stations. Data for only those stations is considered that have continuous and adequate data for complete assessment period. Data up till 31 December 2021.
Source: CSE analysis of real time data from CPCB website

This region did not experience severe days during 2021 but the share of poor and very poor days are high: Cities of Eastern region states have not recorded severe air quality day in 2021 which indicates that there is a constant high pollution in the city but it rarely gets tipped into severe, which generally happens due to impact of additional factors like meteorology or external pollution source. Major cities like Durgapur (142 days in a year), Patna (134 days), Howrah (109 days), Siliguri (87 days), Kolkata (83 days), Hajipur (76 days), and Asansol (65 days) have recorded over a two month of poor or worse air quality in 2021. These bad air quality days are concentrated during winter months (See *Graph 4: PM2.5 AQI heatmap calendar for major cities in East India*).

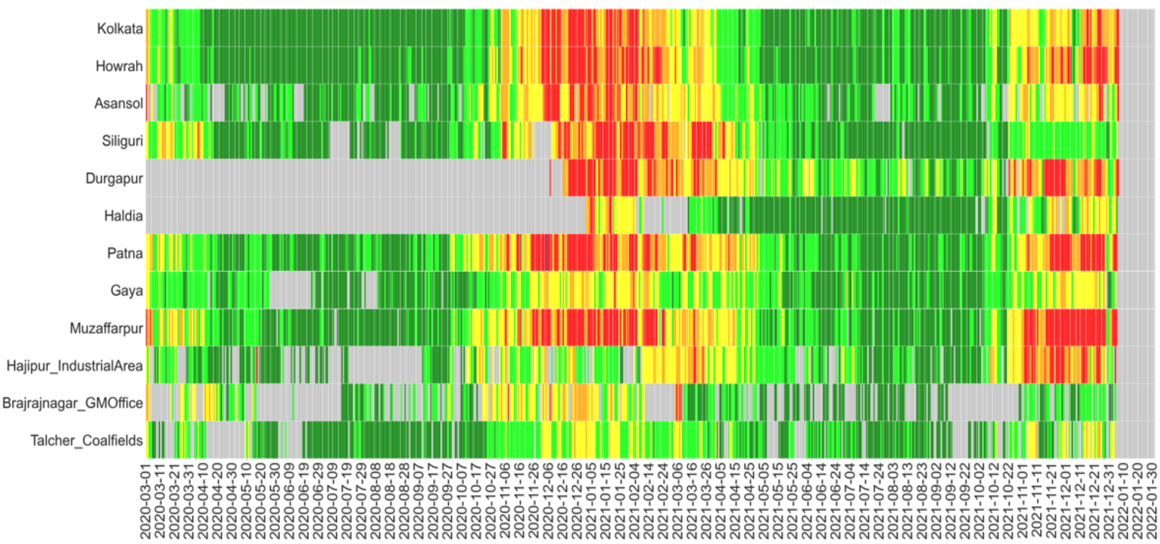
Muzaffarpur have had over three months of very poor air quality days this year. Number of days with air quality in very poor or severe category in Muzaffarpur city stands at 93 days which is identical to Delhi – as of November 2021 *(See Graph 3: PM2.5 AQI categorization of days formajor cities in East India*).

Graph 3: PM2.5 AQI categorization of days for major cities in East India – 2021 – Percentage share as well as number of days



Note: PM2.5 values for cities with more than one monitoring stations is based on average of all stations that have continuous and adequate data for complete assessment period. Data up till 31 December 2021.
Source: CSE analysis of real time data from CPCB website

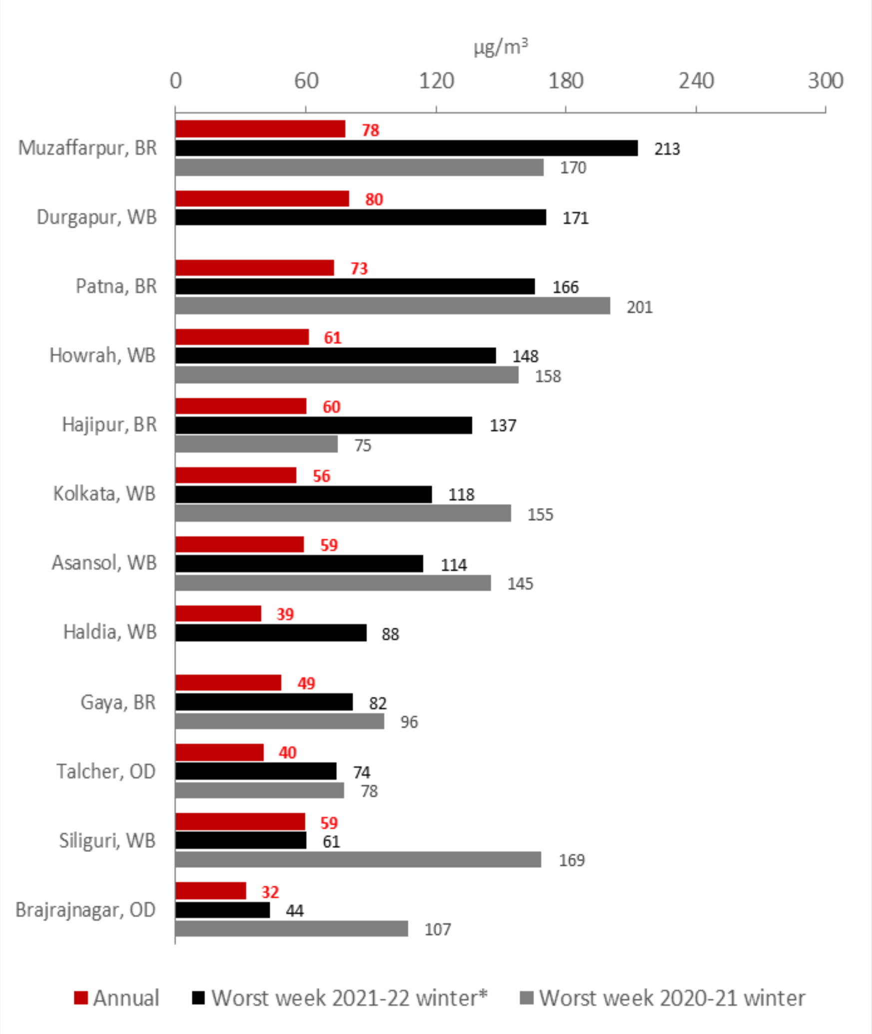
Graph 4: PM2.5 AQI heatmap calendar for major cities in East India



Note: PM2.5 values for cities with more than one monitoring stations is based on average of all stations that have continuous and adequate data for complete assessment period. Cell colors are based on the official AQI category colors. Data up till 4 January 2022.
Source: CSE analysis of real time data from CPCB portal

High weekly pollution episode during winter can be more than double the annual concentration in several cities: During the worst weekly pollution episode in winter the PM2.5 concentration can increase significantly higher than the annual PM2.5 average – about two times high in several cities. During the high pollution episodes weekly PM2.5 levels can go as high as 213 µg/m³ as recorded in Muzaffarpur in December 2021 (See *Graph 5: Weekly PM2.5 levels vs annual level among Cities of East India*). This winter so far the highest weekly level has crossed 100 µg/m³ in Durgapur (171 µg/m³), Patna (166 µg/m³), Howrah (148 µg/m³), Hajipur (137 µg/m³), Kolkata (118 µg/m³), and Asansol (114 µg/m³). The levels are marginally lower this winter compared to last winter except in Hajipur which shows 1.8 times increase comparing to previous winters.

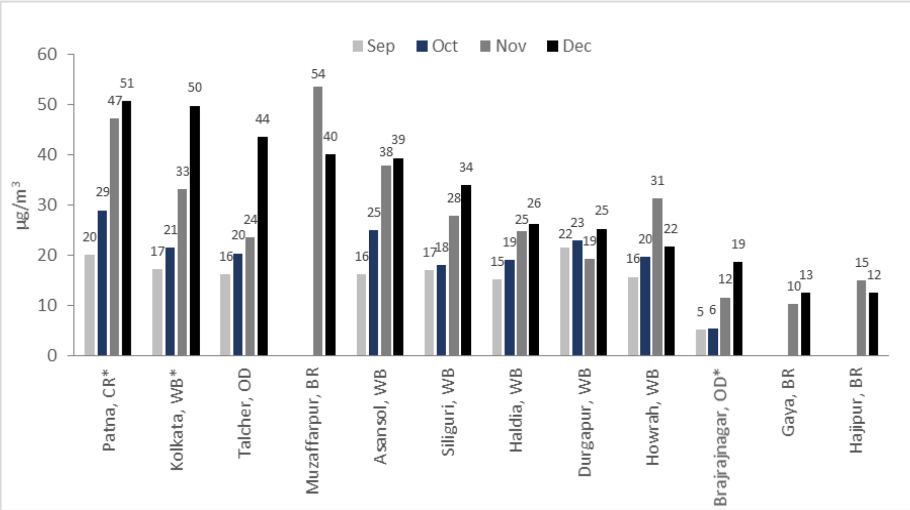
Graph 5: Weekly PM2.5 levels vs annual level among Cities of East India



Note: Worst week for Muzaffarpur were weeks ending on 26 Dec 2021 and 6 Dec 2020; Patna were weeks ending on 26 Dec 2021 and 6 Dec 2021; Gaya were weeks ending on 5 Dec 2021 and 3 Jan 2021; Hajipur were weeks ending on 28 Nov 2021 and 6 Dec 2020. Brajrajnagar were weeks ending on 26 Dec 2021 and 3 Jan 2021; Talcher were weeks ending on 19 Dec 2021 and 3 Jan 2021. Worst week for Durgapur were weeks ending on 21 Nov 2021; Howrah and Kolkata have both their worst weeks ending on 3 Jan 2021 and 26 Dec 2021; Asansol were weeks ending on 13 Dec 2021 and 26 Dec 2021; Haldia were weeks ending on 28 Nov 2021; Siliguri were weeks ending on 7 Nov 2021 and 17 Jan 2021. Data up till 4 January 2022.
Source: CSE analysis of real time data from CPCB portal

Winter pollution can be a toxic cocktail of particulate and gases: There is a significant increase in amount of nitrogen dioxide (NO2) in air of all cities of East India during December compared to November, October and September. Brajrajnagar registered 3.6 times jump in monthly NO2 level, Kolkata registered a 2.8 times increase while Patna, Talcher, and Asansol registered a 2.5 times increase (See *Graph 6: Monthly trend in NO2 levels in cities of East India*). In absolute concentration term, Patna registered the highest monthly average of 51 µg/m³ for December. It is followed by Kolkata (50 µg/m³) and Talcher (44 µg/m³). Muzaffarpur, Howrah and Hazipur showed increase in amount of NO2 in month of November as compared to December.

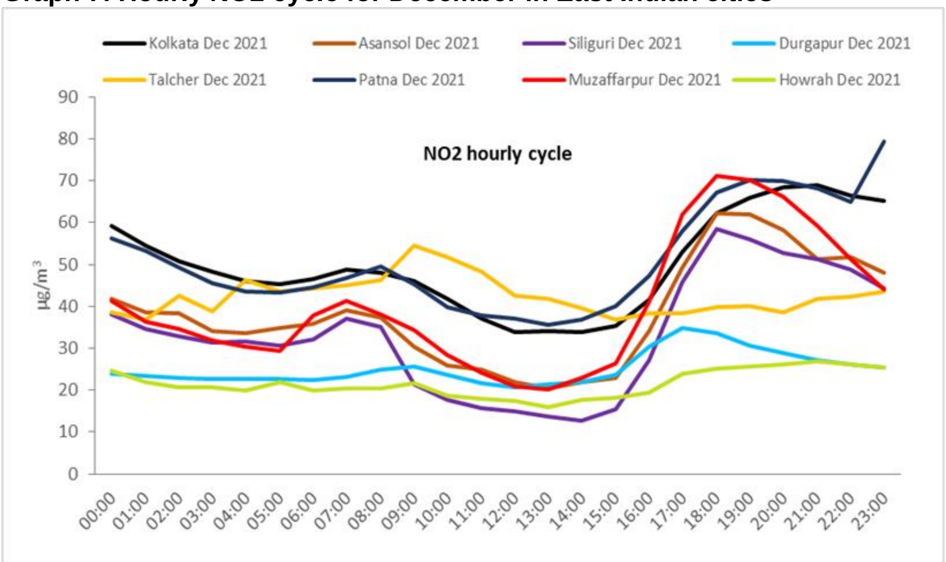
Graph 6: Monthly trend in NO2 levels in cities of East India



Note: NO2 values for cities with more than one monitoring stations is based on average of all stations that have continuous and adequate data for complete assessment period. Data up till 31 December 2021
Source: CSE analysis of real time data from CPCB portal

NO2 levels corelate well with traffic peaks in cities: All cities show peaking of hourly NO2 concentration between 6pm and 8pm which coincides with evening rush hour in the cities. Hourly NO2 in Siliguri increases 4-folds between noon and 7pm (See *Graph 7: Hourly NO2 cycle for December in East India cities*). NO2 cycle is equally as sharp in Muzaffarpur and Asansol with over 3 times increase noted at evening compared to afternoon. All cities have a morning NO2 peak around 7-8am but is relatively lower` than the evening peak. In Patna and Kolkata high NO2 levels persist uptill midnight indicating presence of pollution from night-time truck movement in the city.

Graph 7: Hourly NO2 cycle for December in East Indian cities

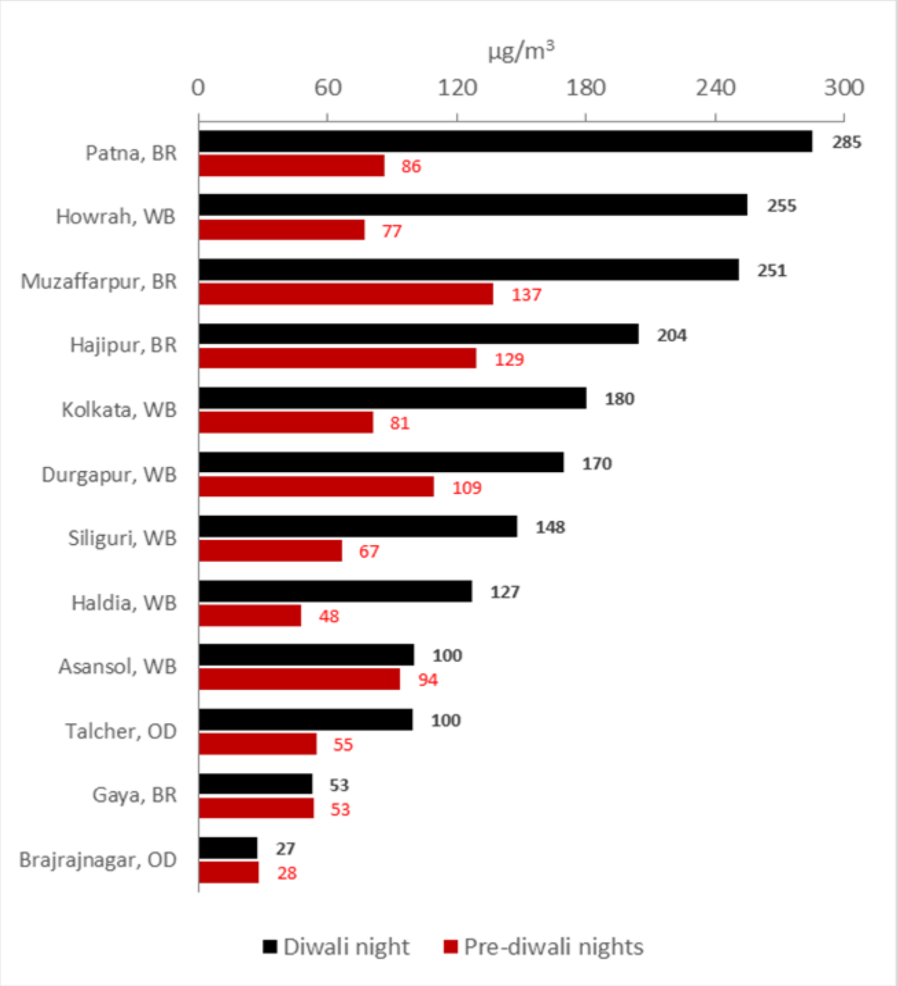


Note: Average NO2 concentration is based on mean of hourly values that have continuous and adequate data for complete assessment period. Data up till 31 December 2021.
Source: CSE analysis of real time data from CPCB website

Diwali is a mega pollution event: Pollution level on Diwali night (8pm to 8am) in cities of east shot up by 1.1 - 3.3 times the average level recorded seven nights preceding Diwali (See *Graph 8: Diwali night pollution among cities of East India*). Patna and Howrah had the greatest pollution build-up on Diwali night, with a 3.3-fold increase in night-time PM2.5, followed by Haldia that saw 2.7 fold increase. Gaya and Brajrajnagar registered very low PM2.5 levels showing little impact.

In absolute concentration terms, Patna dominate the list of most polluted Diwali nights with 285 µg/m^3 PM2.5 level. Pollution was very high among all other major cities as well on Diwali night with Howrah (255 µg/m^3), Muzaffarpur (251 µg/m^3), and Hajipur (204 µg/m^3) crossing 200 µg/m^3 mark.

Graph 8: Diwali night pollution among cities of East India



Note: PM2.5 values for cities with more than one monitoring stations is based on average of all stations that have continuous and adequate data for complete assessment period. Diwali night is considered from 8.00PM November 4 to 8.00AM November 5. Pre-Diwali night is average of seven nights (8.00PM-8.00AM) preceding Diwali.
Source: CSE analysis of real time data from CPCB website

Tracking overall and winter air pollution in cities of West Bengal

Dissecting air quality trends in different parts of Indo Gangetic Plain provides deeper insight into the emerging regional pollution pattern especially during winter. West Bengal which is considered to be part of the lower Gangetic Plains is of special interest as being closer to the sea it has comparatively more open atmospheric conditions and ventilation pattern though there is variance within the state -- inland, upland and coastal regions.

While the winter pollution build up begins early November in the states of trans-Gangetic Plain of Punjab and Haryana and the upper Gangetic Plains of Delhi, Uttarakhand and Uttar Pradesh, it extends to West Bengal towards the end of December. There is wide seasonal variation in pollution levels in this state - with monsoon and summer showing lower concentration compared to winter. However, winter concentration is certainly a reflection of high overall pollution in the region that is trapped the moment atmospheric conditions turn adverse due to inversion, cool and calm conditions.

Centre for Science and Environment (CSE) has analyzed air quality status in cities of West Bengal (Kolkata, Howrah, Asansol, Siliguri, Durgapur and Haldia). This is part of the air quality tracker initiative of the Urban Data Analytics Lab of CSE. The objective of this new analysis is to understand the quantum and nature of the winter pollution in major cities of the West Bengal which have real-time air quality monitoring. This is an assessment of annual and seasonal trends in PM2.5 concentration for the period 1 January 2019 to 2nd January 2022. This analysis is based on the real time data available from the current working air quality monitoring stations in West Bengal. 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 14 continuous ambient air quality monitoring stations (CAAQMS) spread across 6 cities: seven stations in Kolkata, three stations in Howrah and one station each in Asansol, Siliguri, Durgapur and Haldia.

Four cities – Kolkata, Howrah, Asansol and Siliguri have been selected for long term trend analysis because real time data is available for multiple years for these cities. This has analysed data recorded by 7 air quality monitoring stations in Kolkata, 3 stations in Howrah, and one station each in Asansol and Siliguri under the Continuous Ambient Air Quality Monitoring System (CAAQMS) of CPCB. Real time monitors in Durgapur and Haldia became operational only this year which limits the possibility of long term trend analysis for these cities. This is also an opportunity to understand the air pollution trend even in medium and smaller cities.

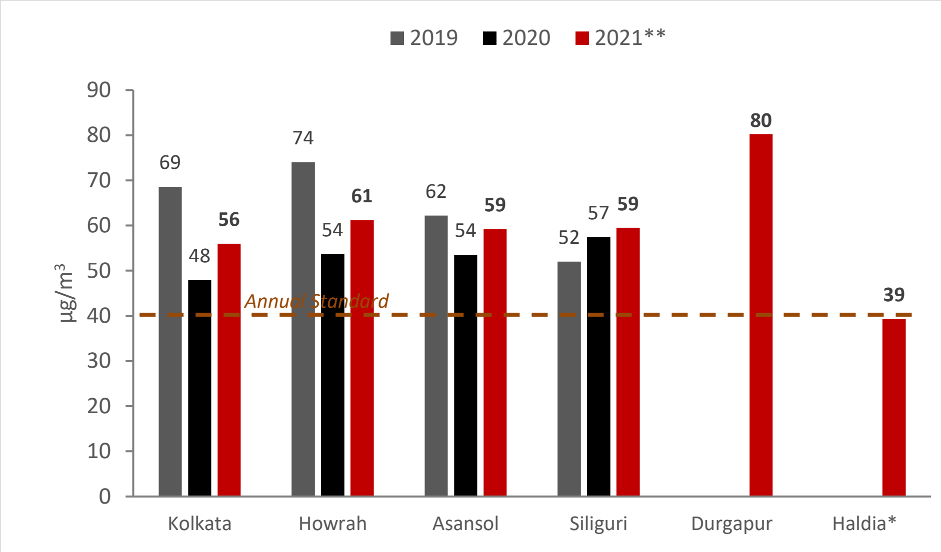
This analysis shows that air pollution during winter is a problem in all the cities with Durgapur and Howrah experiencing poor and very poor days comparable to the winter in NCR and UP cities. Winter pollution concentration is also a cocktail of tiny particles and gases such as nitrogen dioxide (NO2) that also increases during winter. Overall, the air quality in the region is slightly higher compared to the 2020 level but due to limited archival monitoring data it is difficult to comment on the trend in the Durgapur and Haldia's air quality.

Key summary findings

Annual trends dip in most cities in 2020 to rises again; Cities need to cut annual average concentration substantially to meet the clean air standard: Overall, if the data available from the real time monitors are considered as indicative of the current average baseline of PM2.5 level in cities, then Kolkata requires close to 29 per cent reduction to meet the annual average standard of 40 µg/m^3 for PM2.5; Howrah 34 per cent; Asansol 32 per cent and Durgapur 50 per cent reduction.

Moreover, the annual trend in average annual PM2.5 concentration since 2019 shows a dip in 2020 that had several pandemic linked lock down and semi lock down phases. But levels rose again in 2021. Despite the rise in 2021, the levels in Kolkata, Howrah, and Asansol are lower than the 2019 levels. But Siliguri shows levels higher than even 2019. Longer term trend for Durgapur and Haldia could not be constructed as the realtime monitors became operational near the end of 2020 only. But Durgapur which a major industrial hub of West Bengal, has the most polluted air in the region in 2021 with an average annual PM2.5 concentration of 80 µg/m^3. It is followed by Howrah, Asansol and Siliguri with 2021 annual averages of 61 µg/m^3 and 59 µg/m^3 respectively (See *Graph 9: Trend in annual average PM2.5 concentration in cities of West Bengal*). Haldia has the lowest 2021 average value of 39 µg/m^3 meeting the average annual standard.

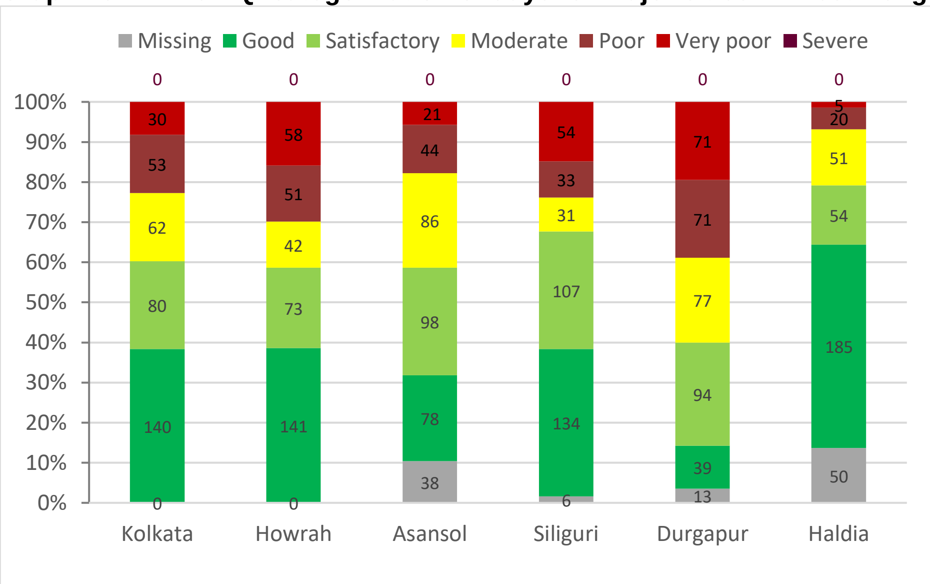
Graph 9: Trend in annual average PM2.5 concentration in cities of West Bengal



Note: PM2.5 values for Kolkata which has seven monitoring stations and Howrah which has three monitoring stations is based on average of these stations. Data for only those stations is considered that have continuous and adequate data for complete assessment period. Data up till 31 December 2021.
Source: CSE analysis of real time data from CPCB website

Bad air quality days are substantial and mostly concentrated in winter months. The combined share of days in poor and very poor category of air quality as per the air quality index classification for PM2.5 in 2021 are highest in Durgapur (close to 39 per cent), followed by Howrah (close to 30 per cent), Siliguri (about 24 per cent), Kolkata (22 per cent), Asansol (about 18 per cent) and Haldia (about 7 per cent). Very poor days are highest in Durgapur (19 per cent), followed by Howrah with about 16 per cent, Siliguri 14 per cent, Kolkata 8 per cent, Asansol about 6 per cent, Haldia 1.3 per cent. Days in 'severe' air quality have not been noticed in 2021. Durgapur have had over almost three months of very poor air quality days this year (see *Graph 10: PM2.5 AQI categorization of days for major cities in West Bengal*).

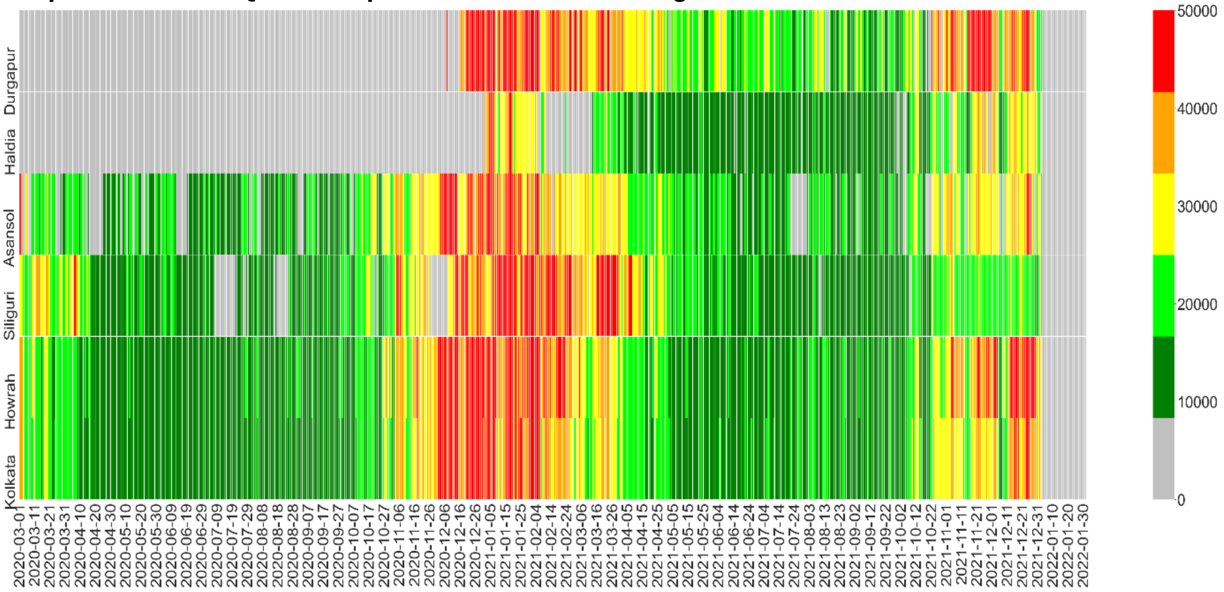
Graph 10: PM2.5 AQI categorization of days for major cities in West Bengal



Note: PM2.5 values for cities with more than one monitoring stations is based on average of all stations that have continuous and adequate data for complete assessment period. Data up till 31 December 2021.
Source: CSE analysis of real time data from CPCB website

Winter pollution build up is quite synchronised across cities but lasts longer in Siliguri and Durgapur: The pollution heatmap based on daily concentration of PM2.5 concentration shows that poor and very poor days begin to build up in December and subsides by early February in most cities except in Siliguri and Durgapur that persists further. Also Howrah ad Durgapur have more very poor days during November to December compared to Asansol and Kolkata. Kolkata and Asansol have more poor and very poor days during last week of December 2021 (See *Graph 11: PM2.5 AQI heatmap calendar for West Bengal cities*)

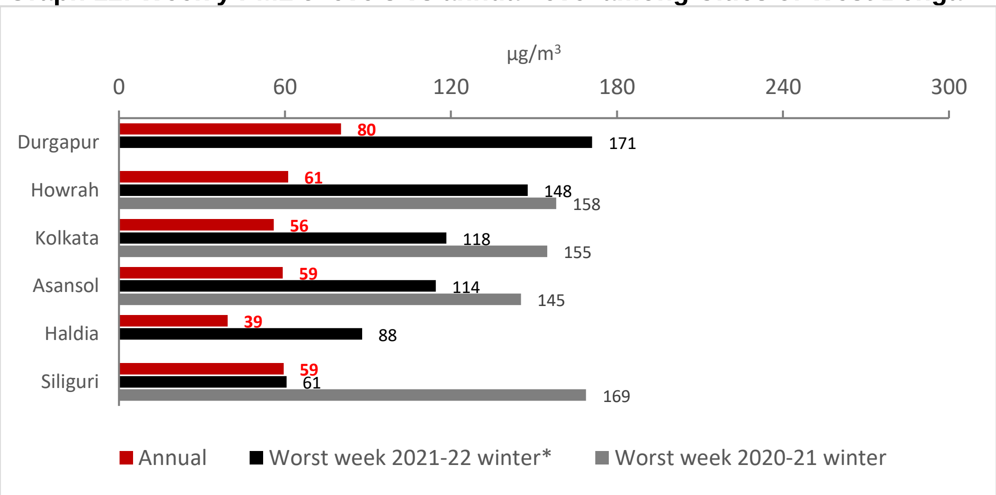
Graph 11: PM2.5 AQI heatmap calendar for West Bengal cities



Note: PM2.5 values for cities with more than one monitoring stations is based on average of all stations that have continuous and adequate data for complete assessment period. Cell colours are based on the official AQI category colours. Data up till 2 Jan 2022.
Source: CSE analysis of real time data from CPCB portal

The worst polluted week during winter is several times more polluted than the annual average concentration of the cities: The deterioration in air quality during the worst affected week in winter is substantially worse than the annual average concentration in most cities. In 2021, during the weekly pollution episodes in winter the weekly average of PM2.5 indicates that it was two times higher than the annual average in Durgapur, 2.4 times higher in Howrah, two times higher in Kolkata, 1.9 times in Asansol, and 2 times in Haldia. But in Siliguri looks the worst weekly average in 2021 winter is nearly the same as the annual average, but the 2020 worst week was 2.8 times higher (See *Graph 12: Weekly PM2.5 levels vs annual level among Cities of West Bengal*).

Graph 12: Weekly PM2.5 levels vs annual level among Cities of West Bengal

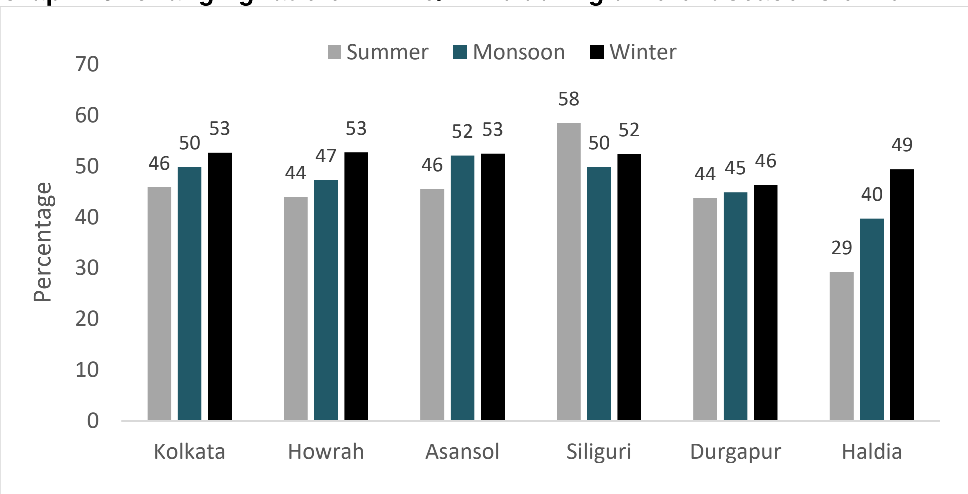


Note: Worst week for Durgapur were weeks ending on 21 Nov 2021; Howrah and Kolkata have both their worst weeks ending on 3 Jan 2021 and 26 Dec 2021; Asansol were weeks ending on 13 Dec 2021 and 26 Dec 2021; Haldia were weeks ending on 28 Nov 2021; Siliguri were weeks ending on 7 Nov 2021 and 17 Jan 2021. Data up till 2 January 2022.
Source: CSE analysis of real time data from CPCB portal

Changing ratio of PM2.5:PM10 during different seasons of 2021: The PM2.5/PM10 ratio is a useful indicator to understand the impact of coarse dust vs tinier dust from combustion sources on air quality. Higher share of smaller particles in total particle concentration makes the air more toxic. The indicative ratio for all cities show there is a seasonal variation. The share of smaller PM2.5 is higher than the coarser PM10 in monsoon and winter. The long-term variation of the PM2.5/PM10 ratio was analyzed from weekly data average for three different seasons: Summer (March - May), monsoon (June - October), and winter (November – January) (see *Graph 13: Changing ratio of PM2.5/PM10 during different seasons of 2021*).

The PM2.5/PM10 ratio in all the cities of West Bengal has an increasing slope from summer to winter except Siliguri, which is showing high percentage of PM2.5/PM10 ratio in summers with 58 per cent and then gradually dropping to 50 per cent in monsoon which again spikes to 52 per cent in winter (See *Graph 13: Changing ratio of PM2.5/PM10 during different seasons of 2021*). Mostly, the concentration of PM2.5/PM10 ratio is higher during winter's months (November to January) hovering around 53 per cent. This is indicative and there can be variation across years. However, this trend is broadly consistent with what has been noted in parts of the country.

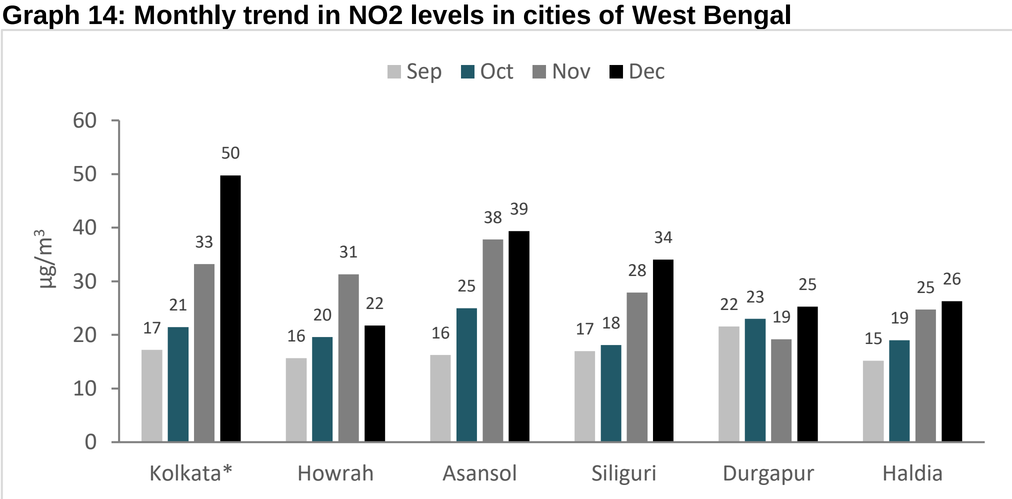
Graph 13: Changing ratio of PM2.5/PM10 during different seasons of 2021



Note: Average PM2.5 concentration for a week is based on mean of all CAAQM stations in the city. Data up till 31 December 2021.
Source: CSE analysis of CPCB's real time air quality data

Winter pollution is a cocktail of particulates and toxic gases: There is a significant increase in the NO2 concentration during winter in nearly all cities of West Bengal. Kolkata has registered 3 times jump in monthly NO2 level while Asansol has registered a 2.5 times increase (*See Graph 14: Monthly trend in NO2 levels in cities of West Bengal*). In absolute concentration term, Kolkata has registered the highest monthly average of 50 µg/m³ for December. It is followed by Asansol (39 µg/m³) and Siliguri (34 µg/m³). Howrah recorded higher NO2 levels in November.

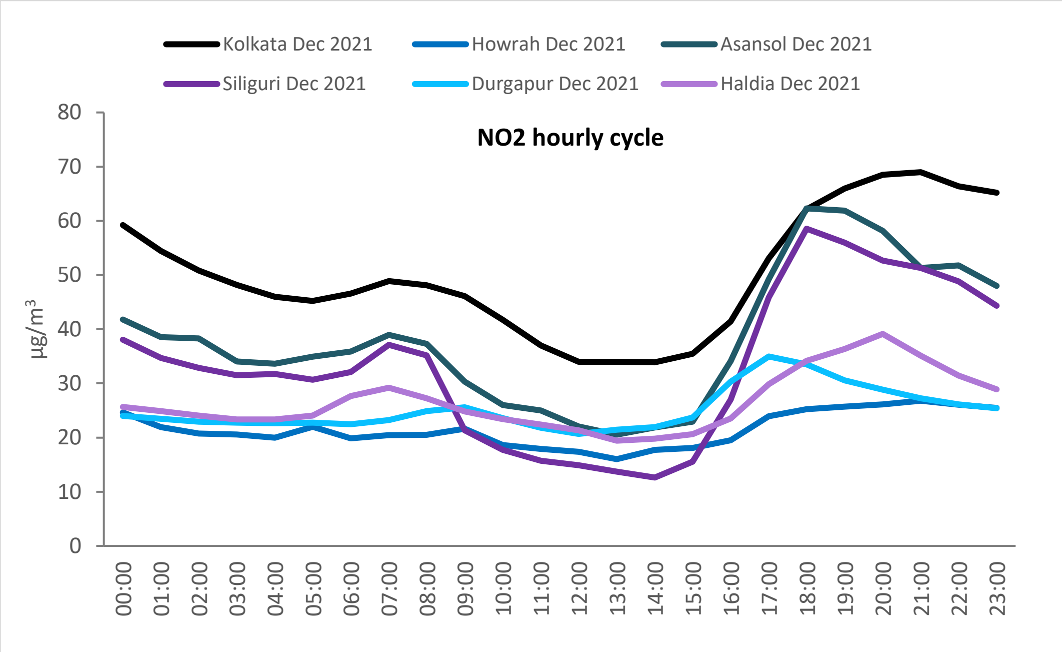
Graph 14: Monthly trend in NO2 levels in cities of West Bengal



Note: NO2 values for cities with more than one monitoring stations is based on average of all stations that have continuous and adequate data for complete assessment period. Data up till 31 December 2021
Source: CSE analysis of real time data from CPCB portal

NO2 trend corelates strongly with the traffic peaks: All cities show peaking of hourly NO2 concentration between 6pm and 8pm which coincides with evening rush hour in the cities. Hourly NO2 in Kolkata increases 2-folds between noon and 6pm (See *Graph 15: Hourly NO2 cycle for December in West Bengal cities*). NO2 cycle is equally as sharp among cities Asansol and Siliguri with 3-4 times increase in noted at evening from afternoon. All cities have a morning NO2 peak around 7-8am but is relatively smaller to evening peak. In Kolkata high NO2 levels persist up till midnight indicating presence of pollution from night-time truck movement in the city.

Graph 15: Hourly NO2 cycle for December in West Bengal cities



Note: Average NO2 concentration is based on mean of hourly values that have continuous and adequate data for complete assessment period. Data up till 31 December 2021.
Source: CSE analysis of real time data from CPCB website

City-wise trends

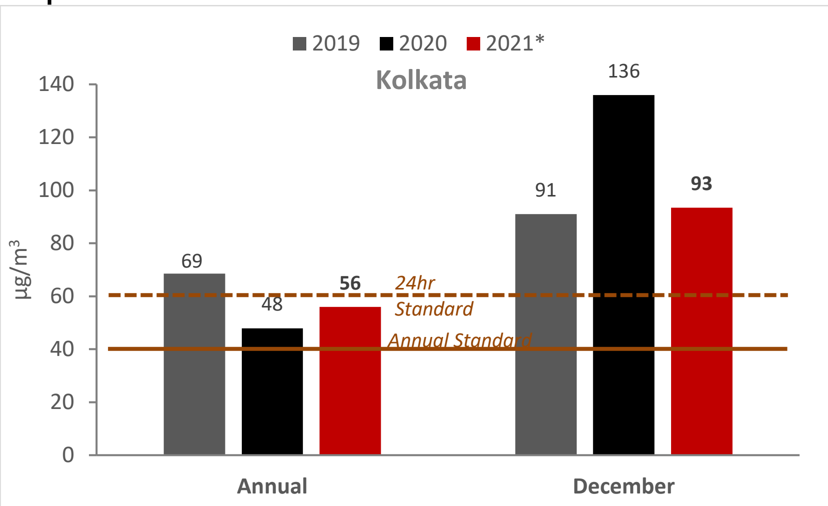
Kolkata

The annual average of PM2.5 concentration declined in 2020 to increase again in 2021 but it is still lower than 2019. The pandemic and related lockdown phases have contributed to this trend. However, It needs to cut annual average level by 28 per cent to meet the National Ambient Air Quality Standard (NAAQS) for PM2.5. (See *Graph 16: PM2.5 annual and winter trend in Kolkata*).

During winter, the average for December this year is lesser compared to 2020 December. Past record shows that the most polluted months are December and January.

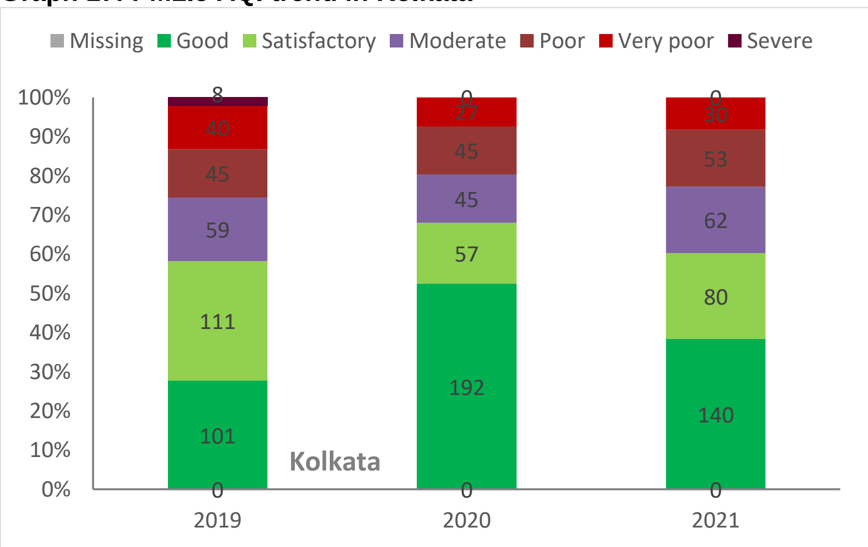
Analysis of days as per the categorization of the national air quality index related to PM2.5 shows that 8 days in severe air quality category was recorded in 2019 but not after that. The total number of poor, very poor and severe category days have reduced from 93 in 2019 to 83 in 2021. Good air quality days have increased from 101 in 2019 to 140 days in 2021. While satisfactory days (that meet the standards) have reduced from 111 to 80, poor days have increased from 45 to 53. However, 2020 was cleaner with higher number of good air quality days at 192 (See *Graph 17: PM2.5 AQI trend in Kolkata*).

Graph 16: PM2.5 annual and winter trend in Kolkata



Note: PM2.5 values is based on stations that have continuous and adequate data for complete assessment period. Data up till 31 December 2021.
Source: CSE analysis of real time data from CPCB portal

Graph 17: PM2.5 AQI trend in Kolkata



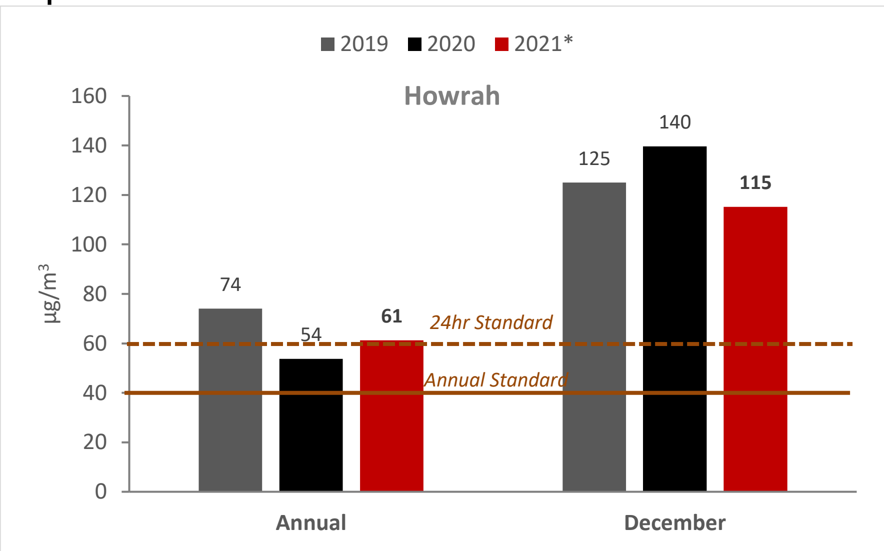
Note: PM2.5 value is based on stations that have continuous and adequate data for complete assessment period. AQI is based on PM2.5 sub-category only. Data up till 31 December 2021.
Source: CSE analysis of real time data from CPCB portal

Howrah
The annual average PM 2.5 concentration declined in 2020 compared to 2019 level but increased again in 2021 (See *Graph 18: PM2.5 annual and winter trend in Howrah*). Howrah needs to cut annual average concentration by 34 per cent to meet the annual PM2.5 standard.

The monthly average for December (when pollution level normally peak), this year is lesser compared to the corresponding last two years.

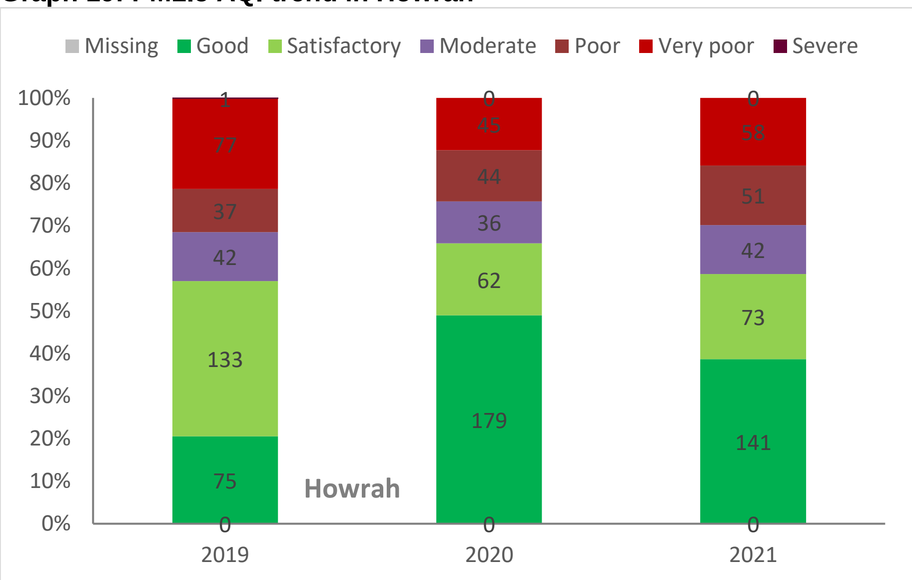
Analysis of days as per the categorization of the national air quality index related to PM2.5 shows that very poor days have declined from 77 (there was only one severe day) in 2019 to 58 very poor days in 2021. But this is an increase from 45 very poor days in 2020 which was a cleaner year. Good air days (that is 50 per cent below the standard) have also increased from 75 in 2019 to 141 in 2021 through 2020 had much higher number of good air days at 179. But the number of poor days have increased overall in Howrah. The city is experiencing increasingly higher number of days with poor air quality, and most of these days are concentrated during winter months. Also the Number of days with good air quality has declining from 179 in 2020 to 141 in 2021 (See *Graph 19: PM2.5 AQI trend in Howrah*).

Graph 18: PM2.5 annual and winter trend in Howrah



Note: PM2.5 values is based on stations that have continuous and adequate data for complete assessment period. Data up till 31 December 2021.
Source: CSE analysis of real time data from CPCB portal

Graph 19: PM2.5 AQI trend in Howrah

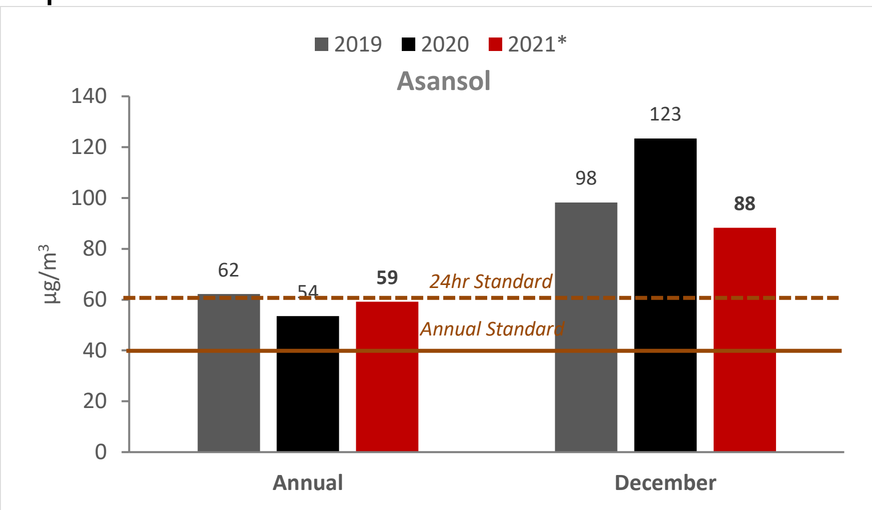


Note: PM2.5 value is based on stations that have continuous and adequate data for complete assessment period. AQI is based on PM2.5 sub-category only. Data up till 31 December 2021.
Source: CSE analysis of real time data from CPCB portal

Asansol
The annual PM2.5 levels seem to have stabilized in Asansol and is downward. But Asansol needs to cut annual average PM2.5 level by at least 32 per cent to meet the standard. (See *Graph 20: PM2.5 annual and winter trend in Asansol*). Further, December pollution this year is lesser compared to last two Decembers.

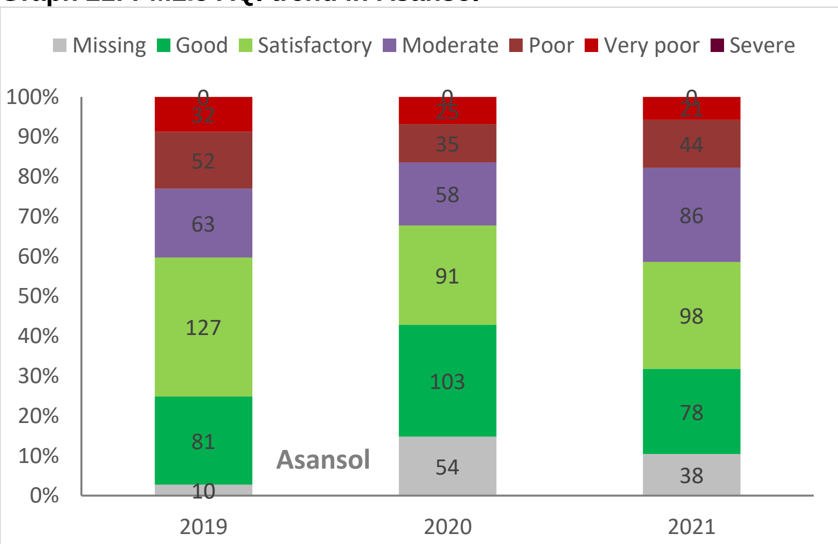
Categorization of the national air quality index shows that the city has not experienced severe levels. The number of days in very poor category has reduced from 32 in 2019 to 21 in 2021. Similarly, the number of poor air quality days have reduce from 52 in 2019 to 44 in 2021. However, there are data gaps as data is not available for 38 days in 2021. (See *Graph 21: PM2.5 AQI trend in Asansol*). 2020 was comparatively a cleaner year.

Graph 20: PM2.5 annual and winter trend in Asansol



Note: PM2.5 values is based on stations that have continuous and adequate data for complete assessment period. Data up till 31 December 2021.
Source: CSE analysis of real time data from CPCB portal

Graph 21: PM2.5 AQI trend in Asansol



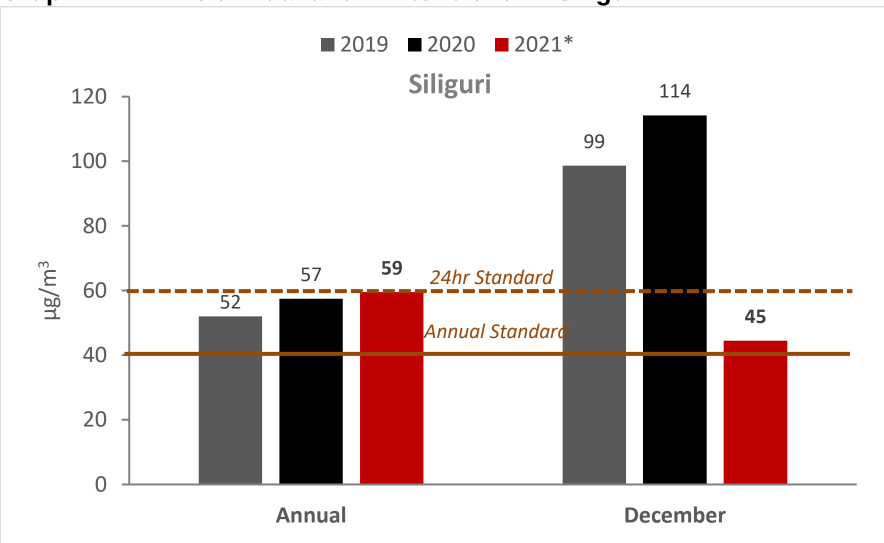
Note: PM2.5 value is based on stations that have continuous and adequate data for complete assessment period. AQI is based on PM2.5 sub-category only. Data up till 31 December 2021.
Source: CSE analysis of real time data from CPCB portal

Siliguri

The annual average level of PM2.5 is showing a rising trend in Siliguri. This has steadily increased from 52 µg/m^3 in 2019 to 59 µg/m^3 in 2021 City. It does not meet the annual standard for PM2.5. Siliguri needs to cut annual average level of PM2.5 by 32 per cent to meet the standard (See *Graph 22: PM2.5 annual and winter trend in Siliguri*). Further, December pollution this year is far lesser compared to last two Decembers.

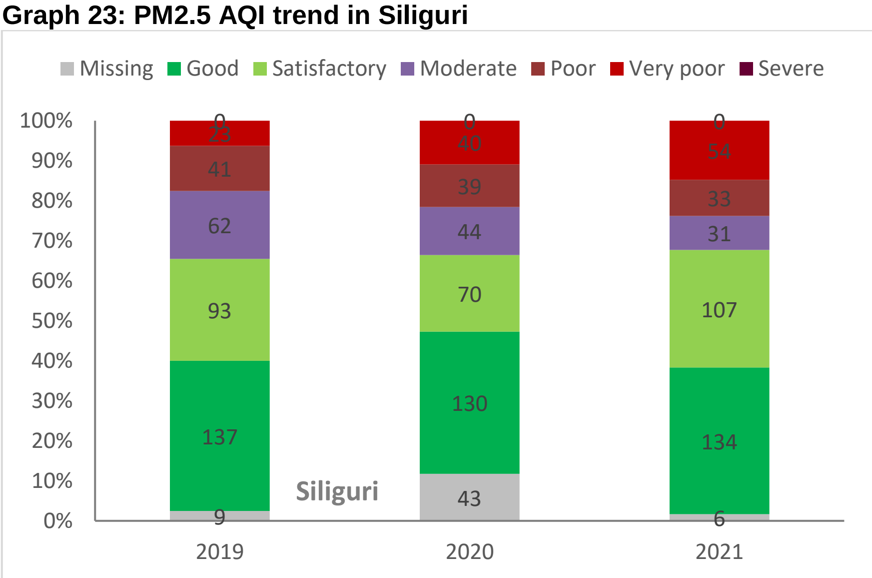
Analysis of days as per the categorization of the national air quality index shows that the number of very poor days have increased dramatically from 23 in 2019 to 54 in 2021. Even in 2020 it was on higher side at 40. (See *Graph 23: PM2.5 AQI trend in Siliguri*).

Graph 22: PM2.5 annual and winter trend in Siliguri



Note: PM2.5 values is based on stations that have continuous and adequate data for complete assessment period. Data up till 31 December 2021.
Source: CSE analysis of real time data from CPCB portal

Graph 23: PM2.5 AQI trend in Siliguri



Note: PM2.5 value is based on stations that have continuous and adequate data for complete assessment period. AQI is based on PM2.5 sub-category only. Data up till 31 December 2021.
Source: CSE analysis of real time data from CPCB portal

Tracking overall and winter air pollution in the western region -- cities of Maharashtra and Gujarat

Anumita Roychowdhury, Avikal Somvanshi and Sharanjeet Kaur

Centre for Science and Environment, New Delhi, January 12, 2022

When the winter inversion triggers smog episode and engulfs entire North India, the western region by contrast looks cleaner. But air pollution is a matter of concern in the western states of Maharashtra and Gujarat too. Winter pollution sets in these states during late December and early January when cooler and calmer conditions trap local pollution that is high. Even though the trapping of winter pollution in the western region is not as high as that of the Indo Gangetic plain due to its proximity to the sea and improved ventilation, the levels increase despite the geographical advantages and favorable meteorology, finds the latest analysis by the Centre for Science and Environment (CSE).

This analysis of real time air quality data for the period 2019-2021 shows that the downward dip in pollution that was induced by the hard lockdown phases of the pandemic in 2020 is threatening to bounce back with the levels in 2021 already rising. Also in many cases the levels are even higher than 2019. Number of bad air days in Mumbai have doubled between 2019 and 2021, good days are down by 20 per cent. This underscores the urgency of scaling up action across all sectors to prevent further worsening and to arrest the trend in this region.

Even though real time air quality monitoring has begun to expand in these states to provide more up to date and real time information on air quality, there are serious concerns around missing data and gaps that makes proper risk assessment difficult. In some stations of Maharashtra and Gujarat, data availability is so low that the trend cannot be assessed. Quality control of data is necessary.

This has emerged from the new analysis of real time pollution data by CSE as part of the air quality tracker initiative of the Urban Data Analytics Lab of CSE. The objective of this new analysis is to understand the trend and magnitude of pollution in different regions that have real time air quality monitoring systems. This is an assessment of annual and seasonal trends in PM2.5 concentration for the period 1st January 2019 to 9th January 2022. This analysis is based on the real time data available from the current working air quality monitoring stations. 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 56 continuous ambient air quality monitoring stations (CAAQMS) spread across 15 cities in two states: Maharashtra -- one station each in Aurangabad, Kalyan, Nagpur, Nashik and Solapur, two stations in Chandrapur, four stations in Navi Mumbai, eight stations in Pune, and 21 stations in Mumbai; Gujarat - one station each in Ankleshwar, Nandesari, Vapi, and Vatva, four stations in Gandhi Nagar, and eight stations in Ahmedabad.

Even though there are multiple real time monitors in a few cities of these states but many could not be considered for long term analysis due to data gaps and lack of quality data. Moreover, in several cases the real time monitors have been set up recently and therefore long term data is not available. Several cities of Gujarat have got their real time monitors in June 2021. Many stations in Maharashtra have got their real time monitors in June 2019 and November 2020. Thane station stopped reporting PM2.5 data in early 2019, therefore it could not be included in this analysis.

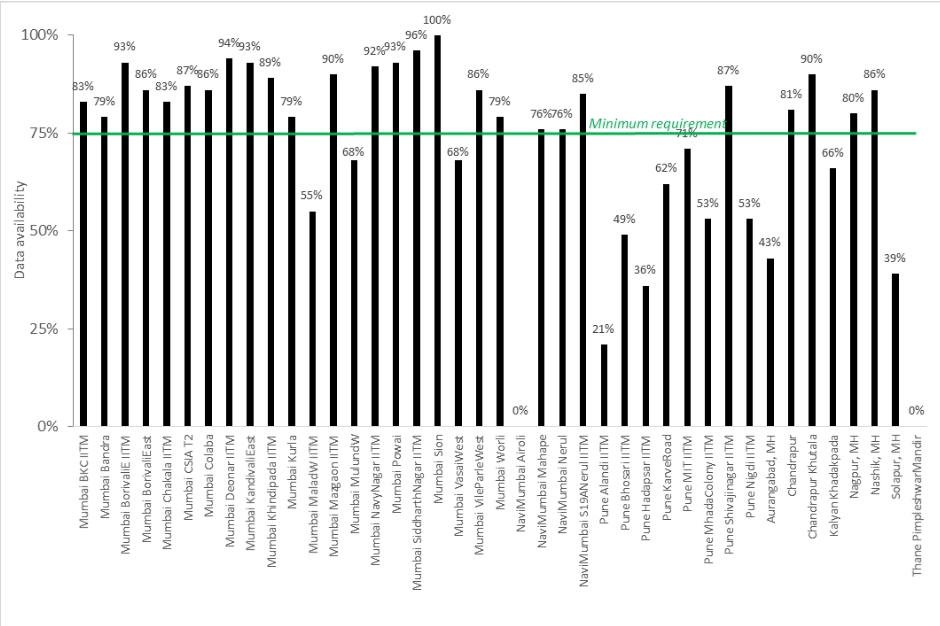
Key highlights

Challenge of data gaps and quality despite automation: Review of data availability from the automated monitoring stations in the region under Continuous Ambient Air Quality Monitoring Stations (CAAQMS) program of CPCB, shows major data gaps. Data availability calculated as number of days with adequate PM2.5 data for computation of a valid 24hr-average has been low in five of the twelve cities in the region. For the year 2021 (June to December) data availability at Airoli station of Navi Mumbai and Pimpleshwar Mandir station of Thane has zero per cent of data availability. Alandi & Hadapsar station of Pune has been just 21 and 36 per cent and Solapur station has just 39 per cent respectively.

Among Mumbai stations Kurla has only 55 per cent data while Malad West in Mumbai with 68 per cent. Kalyan and Aurangabad are data poor as well with 66 per cent and 43 per cent data availability respectively. Only one out of eight stations of Pune meet the minimum requirement as they have data availability of less than 75 per cent (See *Graph 1: Data availability at real time monitoring stations of Maharashtra in June-Dec, 2021*). It is not clear why these stations have such poor data availability despite minimal problems of electricity and internet connectivity in the region. This requires an assessment.

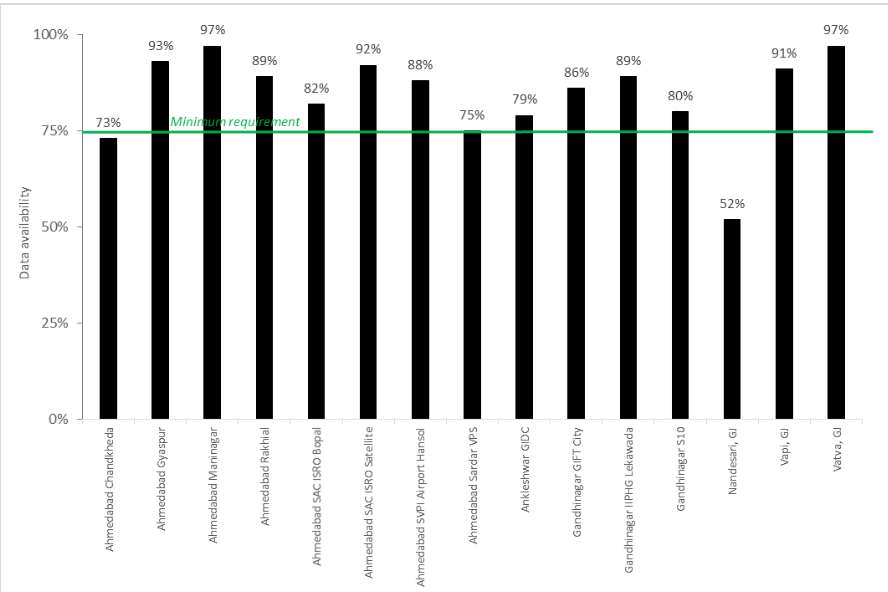
In contrast most stations of Gujarat perform better as they have data availability of more than 85 per cent (See *Graph 2: Data availability at real time monitoring stations of Gujarat in June-Dec, 2021*). Only stations at Chandkheda in Ahmedabad, and Nandesari are below the minimum 75 per cent data availability requirement.

Graph 1: Data availability at real time monitoring stations of Maharashtra in June-Dec, 2021



Source: CSE analysis of real time data from CPCB website

Graph 2: Data availability at real time monitoring stations of Gujarat in June-Dec, 2021



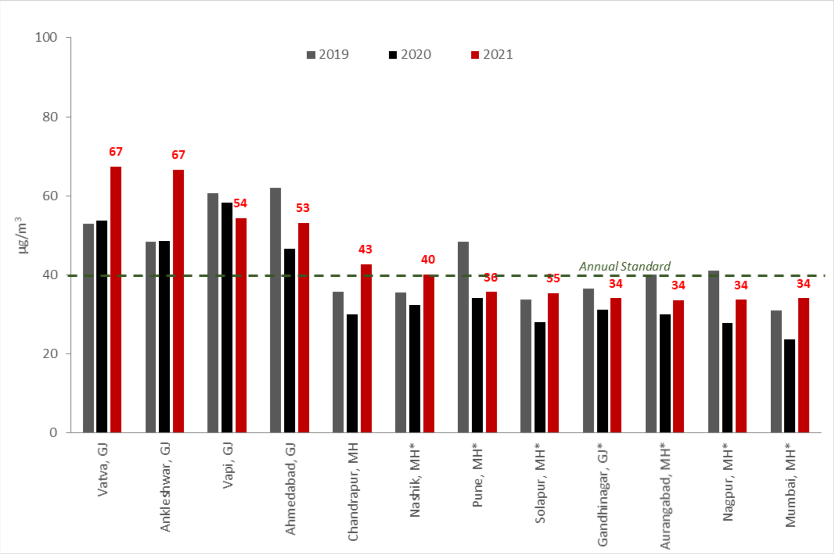
Source: CSE analysis of real time data from CPCB website

Most cities show a rising trend in annual PM2.5 level after an initial drop during 2020 with more pandemic related lockdown phases: Nearly all cities in the region show a drop in annual average PM2.5 level in 2020 that was also the year with maximum lockdown phases. But there is a rebound and a rising trend once again in 2021. Gujarat cities are much more polluted than Maharashtra. Vatva and Ankleshwar in Gujarat, has the most polluted air in the region with 2021 average at 67 µg/m³. This is followed by Vapi and Ahmedabad with 2021 annual average of PM2.5 at 54 µg/m³ and 53 µg/m³ respectively (See *Graph 3: PM2.5 trend among cities of Maharashtra and Gujarat – 2019-2021*).

In Maharashtra, Chandrapur, an industrial city has recorded levels marginally above the annual standard at 43 µg/m³. Other stations have met the annual standard though all of them are showing a rising trend in 2021 after the dip in 2020.

If the real time data is taken as an indicator, in Gujarat, Vatva and Ankleshwar needs to reduce annual average PM2.5 by 40 per cent to meet the annual PM2.5 standard, Vapi 25 per cent, and Ahmedabad Maninagar 24 per cent.

Graph 3: Long term PM2.5 trend among cities of Maharashtra and Gujarat (2019-2021)

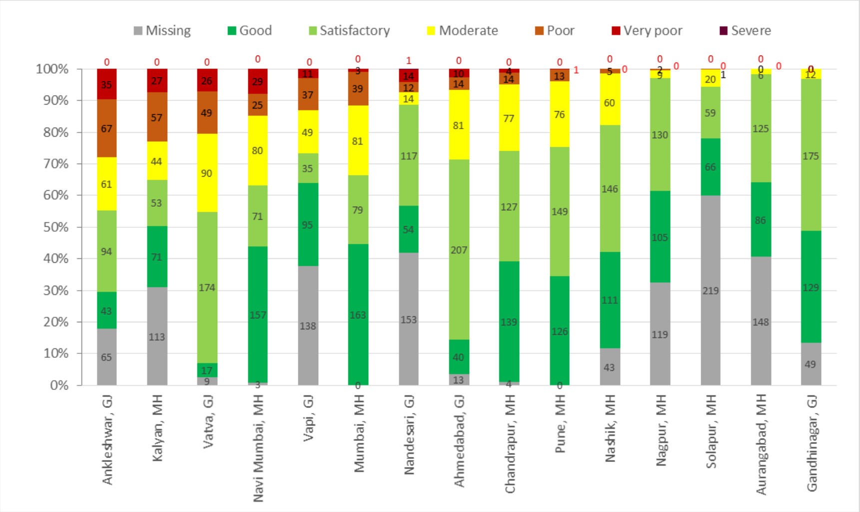


Note: PM2.5 values for Chandrapur which has two monitoring stations is based on average of both stations. Data for only those stations is considered that have continuous and adequate data for complete assessment period. Data up till 31 December 2021. Source: CSE analysis of real time data from CPCB website

Despite low annual levels cities of Maharashtra experience high number of days with 'poor' and 'very poor' AQI: With 102 days of poor and very poor AQI Ankleshwar, Gujarat has the unhealthiest days in the region. It is followed by Kalyan with 84 days, Vatva with 75 days, and Navi Mumbai with 54 days. Vapi has 48 days of poor and very poor AQI. However, data is missing for 138 days (mainly for winter months). Mumbai has registered 42 days of poor and very poor AQI despite meeting the annual standard (See *Graph 4: PM2.5 based AQI categorization of days for major cities in Maharashtra and Gujarat – 2021*).

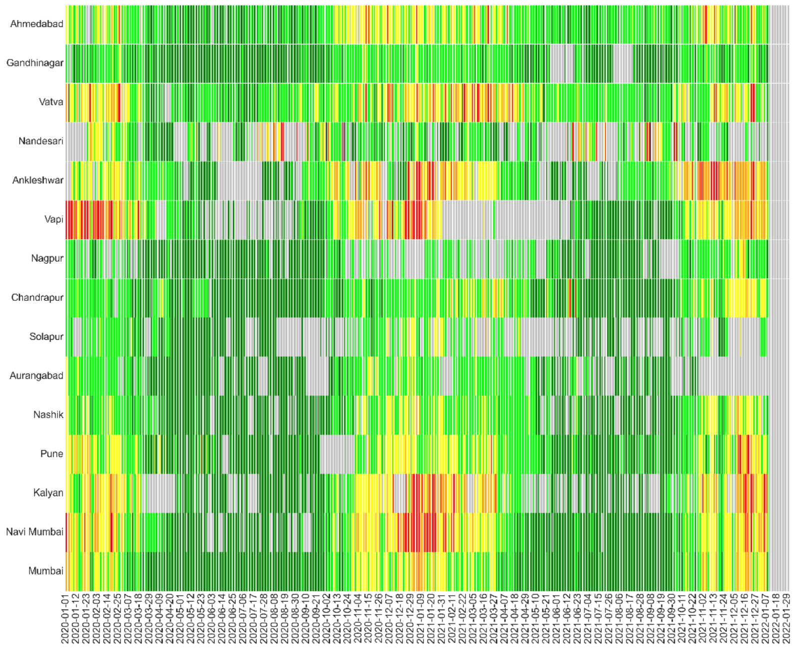
Bad air days begin to build up around the same time in the cities of western states during end of December and persists till end of January. Cities in the Mumbai Metropolitian Region show more pronounced impact of winter pollution compared to cities of other regions. Industrial towns show bad air days across the year but there is some clustering during winter (See *Graph 5: Heatmap based on days classified as per PM2.5 air quality index for major cities Maharashtra and Gujarat*).

Graph 4: PM2.5 based AQI categorization of days for major cities in Maharashtra and Gujarat – 2021 – (Percentage share and number of days)



Note: PM2.5 values for cities with more than one monitoring stations is based on average of all stations that have continuous and adequate data for complete assessment period. Data up till 31 December 2021. Source: CSE analysis of real time data from CPCB website

Graph 5: Heatmap based on days classified as per PM2.5 air quality index for major cities in Maharashtra and Gujarat

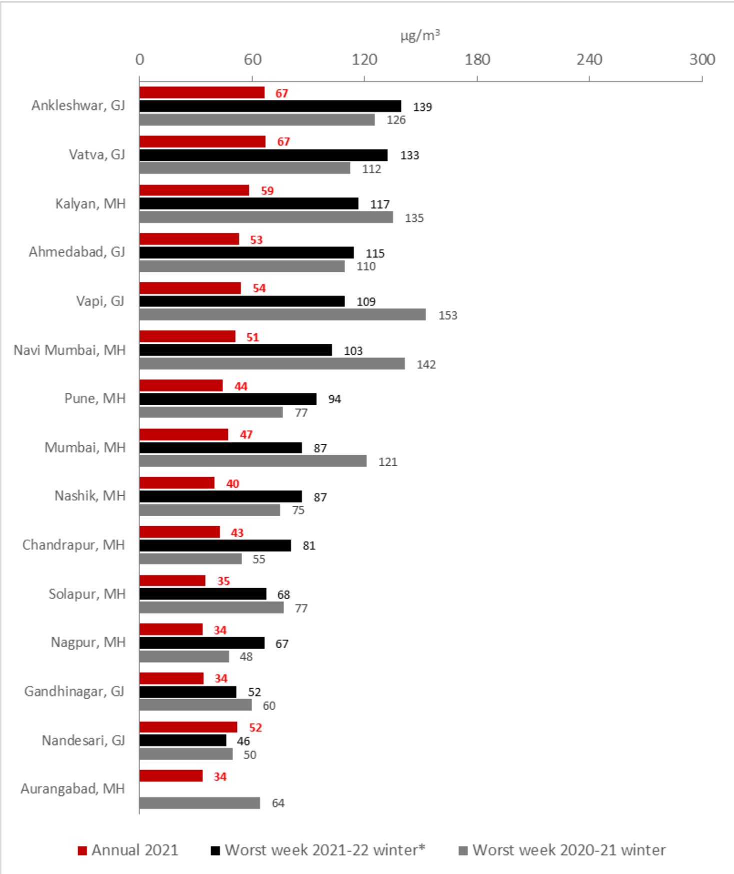


Note: PM2.5 values for cities with more than one monitoring stations is based on average of all stations that have continuous and adequate data for complete assessment period. Cell colors are based on the official AQI category colors. Data up till 9 January 2022. Source: CSE analysis of real time data from CPCB portal

The levels during high weekly pollution episode in winter can be more than double the annual concentration in several cities: During the worst weekly pollution episode in winter the PM2.5 concentration can increase significantly higher than the annual PM2.5 average – about two times high in several cities.

During the high pollution episodes weekly PM2.5 levels can go as high as 139 µg/m³ as recorded in Ankleshwar in December 2021 (See *Graph 6: Weekly PM2.5 levels vs annual level among in cities of Maharashtra and Gujarat*). This winter so far the highest weekly level was 133 µg/m³ in Vatva, 117 µg/m³ in Kalyan, 115 µg/m³ in Ahmedabad Maninagar, 109 µg/m³ Vapi, and 103 µg/m³ in Navi Mumbai. The levels are marginally higher this winter compared to last winter with Chandrapur being the highest which shows 1.5 times increase comparing to previous winters.

Graph 6: Comparison of worst weekly PM2.5 levels with annual average level in cities of Maharashtra and Gujarat



Note: Worst week for Ahmedabad Maninagar were weeks ending on 7 Nov 2021 and 15 Nov 2020; Ankleshwar were weeks ending on 14 Nov 2021 and 1 Nov 2020; Gandhinagar S10 were weeks ending on 26 Dec 2021 and 15 Nov 2020; Vapi were weeks ending on 26 Dec 2021 and 10 Jan 2021. Vatva were weeks ending on 26 Dec 2021 and 24 Jan 2021; Nandesari were weeks ending on 26 Dec 2021 and 10 Jan 2021. Worst week for Kalyan were weeks ending on 26 Dec 2021 and 10 Jan 2021; Navi Mumbai were weeks ending on 19 Dec 2021 and 24 Jan 2021; Mumbai were weeks ending on 19 Dec 2021 and 10 Jan 2021; Pune were weeks ending on 14 Nov 2021 and 27 Dec 2020. Nashik were weeks ending on 12 Dec 2021 and 3 Jan 2021; Nagpur and were weeks ending on 19 Dec 2021 and 31 Jan 2021; Solapur were weeks ending on 12 Dec 2021 and 3 Jan 2021; Chandrapur were weeks ending on 19 Dec 2021 and 31 Jan 2021. Data up till 9 January 2022. Source: CSE analysis of real time data from CPCB portal

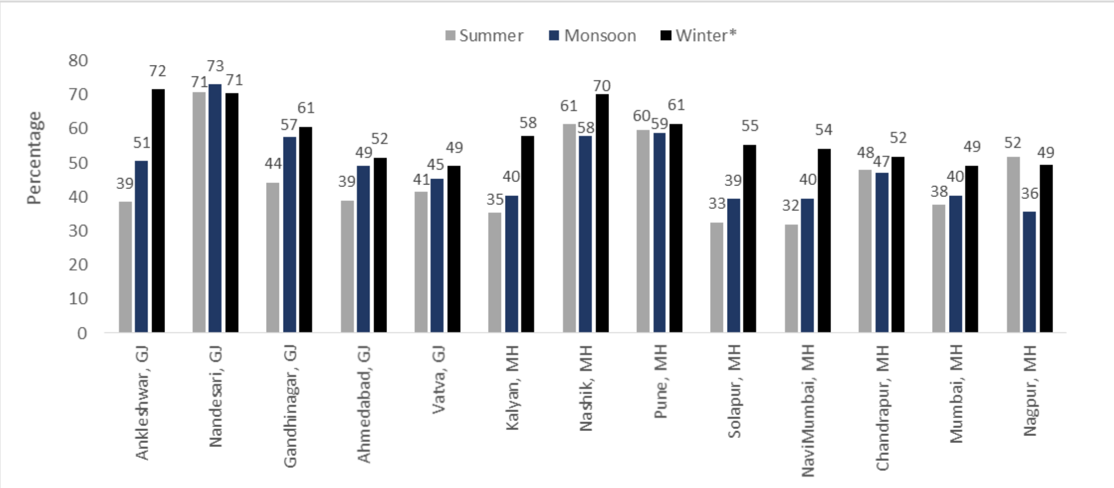
Changing ratio of PM2.5/PM10 during different seasons of 2021: The PM2.5/PM10 ratio is a useful indicator to understand the impact of coarse dust vs tinier dust from combustion sources on air quality. Higher share of smaller particles in total particle concentration makes the air more toxic. The indicative ratio for all cities show there is a seasonal variation. The share of smaller PM2.5 is higher than the coarser PM10 in monsoon and winter. The long-term variation of the PM2.5/PM10 ratio was analyzed from weekly data average for three different seasons: Summer (March - May), monsoon (June - October), and winter (November – January). (See *Graph 7: Changing ratio of PM2.5/PM10 during different seasons of 2021*).

The PM2.5/PM10 ratio in all the cities of these states has an increasing slope from summer to winter except Nagpur, which is showing high percentage of PM2.5/PM10 ratio in summers with 52 per cent and then gradually dropping to 36 per cent in monsoon which again spikes to 49 per cent in winter (See Graph 7: Changing ratio of PM2.5:PM10 during different seasons of 2021). Mostly, the concentration of PM2.5/PM10 ratio is higher during winter's months (November to January) hovering between 50 to 60 per cent. This is indicative and there can be variation across years. However, this trend is broadly consistent with what has been noted in parts of the country.

In Gujarat, Nandesari has the highest PM2.5/PM10 ratio in all the three seasons with the PM2.5 share as high as 71 per cent in winter. Ankleshwar is showing high percentage of PM2.5/PM10 ratio in winters with 72 percent. The highest percentage of PM2.5/PM10 ratio in monsoon was at 73 percent in Nandesari Overall in Gujarat the concentration of PM2.5/PM10 ratio is higher during winter (November to January).

Nasik in Maharashtra recorded the highest percentage of PM2.5/PM10 ratio in winters with 70 percent. Vapi in Gujarat and Aurangabad in Maharashtra has data gaps for the month for summer and winter season. Therefore, these stations has not been included in this analysis (See *Graph 7: Changing ratio of PM2.5/PM10 during different seasons of 2021*).

Graph 7: Changing ratio of PM2.5/PM10 during different seasons of 2021

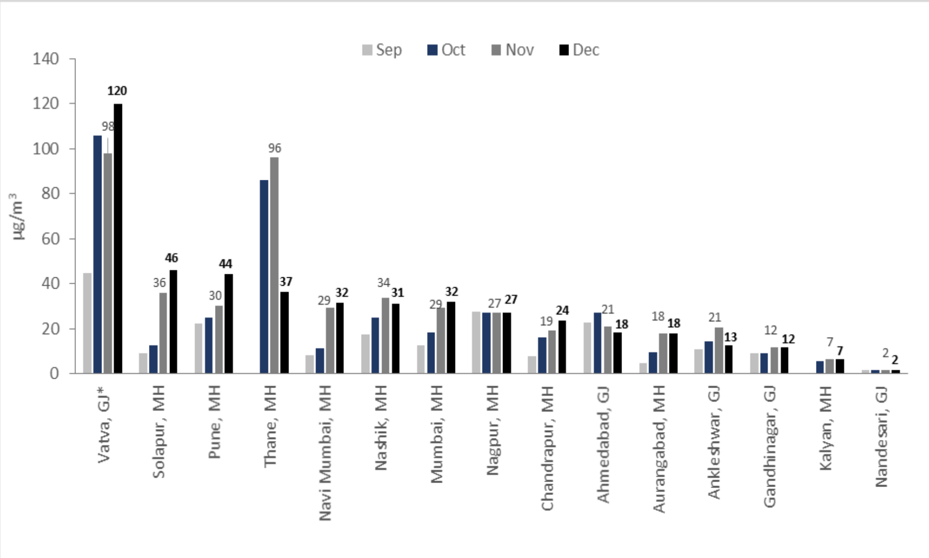


Note: Average PM2.5 concentration for a week is based on mean of all CAAQM stations in the city. Data up till 9 January 2022. Source: CSE analysis of CPCB's real time air quality data

Winter pollution can be a toxic cocktail of particulate and gases: There is a significant increase in amount of nitrogen dioxide (NO2) in air of all cities of western states during December compared to the previous months of November, October and September. Solapur registered 4.9 times jump in monthly NO2 level, Navi Mumbai registered a 3.9 times increase while Aurangabad with 3.6 times increase, Chandrapur with 3 times increase, Vatva with 2.7 times increase and Mumbai registered a 2.5 times increase (See *Graph 8: Monthly trend in nitrogen dioxide levels in cities of Maharashtra and Gujarat*).

In absolute concentration term, Vatva registered the highest monthly average of 120 µg/m^3 for December. This is higher than 24-hr standard for NO2. It is followed by Solapur (46 µg/m^3) and Pune (44 µg/m^3). Such high levels are not recorded even in North Indian cities. Thane showed a dramatic increase in amount of NO2 in month of November and October as compared to December. It has a missing data for the month September (See *Graph 8: Monthly trend in nitrogen dioxide levels in cities of Maharashtra and Gujarat*). Vapi station in Gujarat is not included in the analysis due to data gaps.

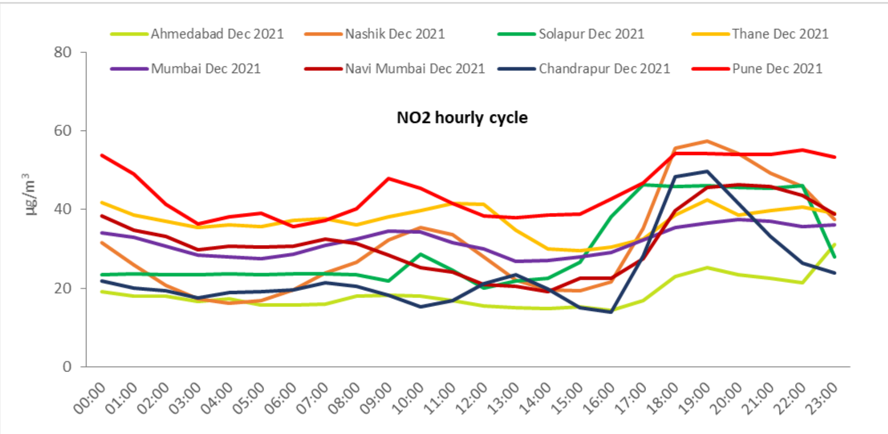
Graph 8: Monthly trend in nitrogen dioxide levels in cities of Maharashtra and Gujarat



Note: NO2 values for cities with more than one monitoring stations is based on average of all stations that have continuous and adequate data for complete assessment period. Data up till 31 December 2021. Source: CSE analysis of real time data from CPCB portal

NO2 levels correlate well with traffic peaks in cities: All cities show peaking of hourly NO2 concentration between 6pm and 8pm which coincides with evening rush hour in the cities. Hourly NO2 in Vatva increases 3.4-folds between noon and 7pm (See *Graph 9: Hourly NO2 cycle for December in cities of Maharashtra and Gujarat*). NO2 cycle is equally as sharp in Nashik and Navi Mumbai with 2.6-2.2 times increase noted at evening compared to afternoon. All cities have a morning NO2 peak around 7-8am but is relatively lower` than the evening peak. In Pune, Mumbai, and Ahmedabad high NO2 levels persist uptill midnight indicating presence of pollution from night-time truck movement in the city.

Graph 9: Hourly NO2 cycle for December in cities of Maharashtra and Gujarat



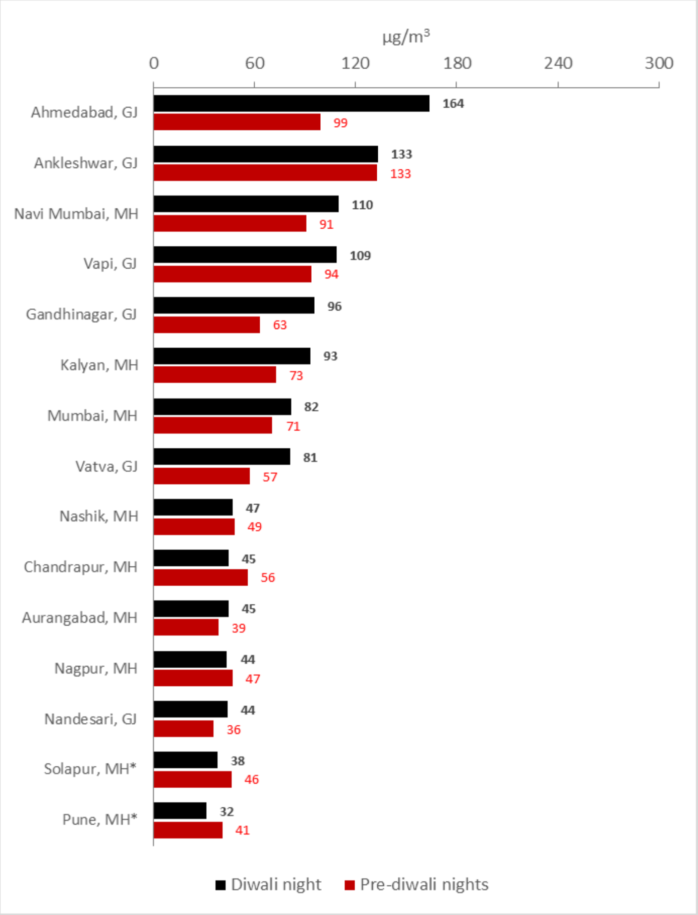
Note: Average NO2 concentration is based on mean of hourly values that have continuous and adequate data for complete assessment period. Data up till 31 December 2021. Source: CSE analysis of real time data from CPCB website

Diwali is a mega pollution event: Pollution level on Diwali night (8pm to 8am) in cities of east shot up by 0.8 – 1.6 times the average level recorded seven nights preceding Diwali (See *Graph 10: Diwali night pollution among cities of Maharashtra and Gujarat*). Ahmedabad had the greatest pollution build-up on Diwali night with a 1.6-fold increase in night-time PM2.5, followed by Ankleshwar that saw 1 fold increase i.e, it is almost same on Diwali and seven night preceding Diwali.

Chandrapur, Nagpur, Nashik, Solapur, and Pune registered low PM2.5 levels on Diwali night comparing to seven night preceding Diwali. Solapur and Pune registered very low PM2.5 levels on Diwali showing little impact, and also met the annual average standard.

In absolute concentration terms, Ahmedabad dominate the list of most polluted Diwali nights with 164 µg/m³ PM2.5 level. Pollution was very high among all other major cities as well on Diwali night with Ankleshwar (133 µg/m³), Navi Mumbai (110 µg/m³), and Vapi (109 µg/m³) crossing 100 µg/m³ mark.

Graph 10: Diwali night pollution among cities of Maharashtra and Gujarat

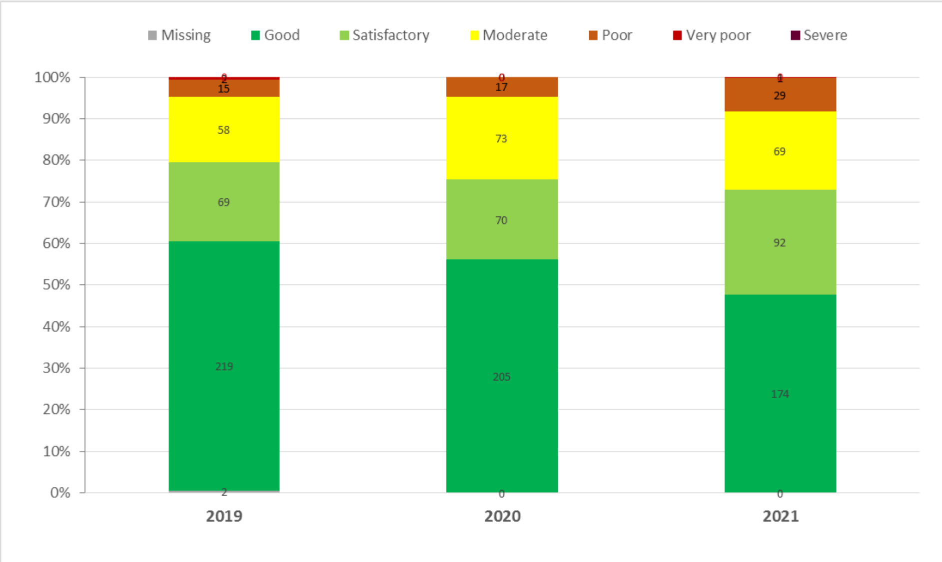


Note: PM2.5 values for cities with more than one monitoring stations is based on average of all stations that have continuous and adequate data for complete assessment period. Diwali night is considered from 8.00PM November 4 to 8.00AM November 5. Pre-Diwali night is average of seven nights (8.00PM-8.00AM) preceding Diwali. Source: CSE analysis of real time data from CPCB website

Spotlight on Mumbai

Number of bad air quality days are increasing in Mumbai: Over the years the air quality in Mumbai seems to be declining. Daily AQI analysis based on 10 oldest stations shows 20 per cent drop in number of good AQI days in the city between 2019 and 2021. While days with poor or very poor AQI have doubled (See *Graph 11: Trend in PM2.5 AQI in Mumbai 2019-21*).

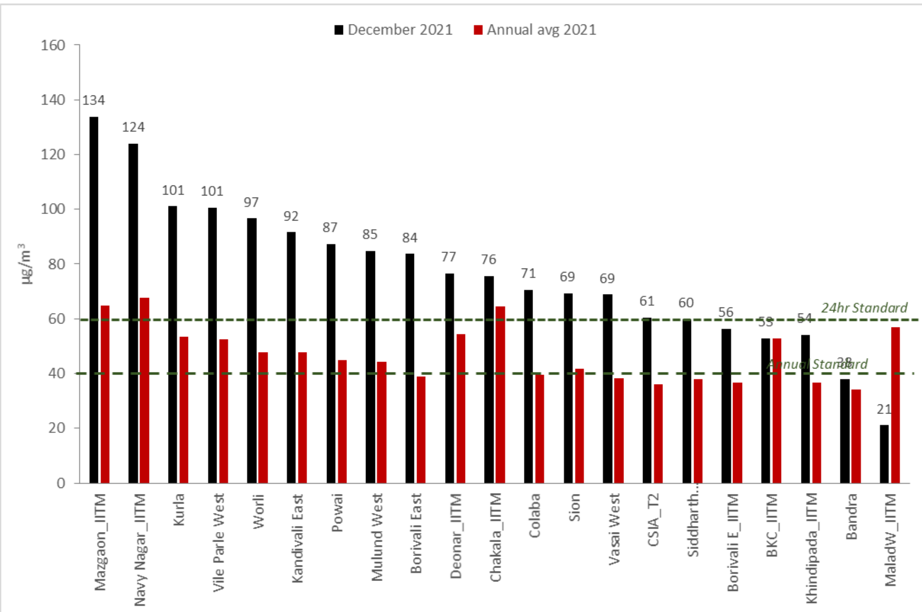
Graph 11: Trend in PM2.5 AQI in Mumbai 2019-21



Note: PM2.5 values for Mumbai is based on average of 10 oldest stations that have continuous and adequate data for complete assessment period. Data up till 31 December 2021. Source: CSE analysis of real time data from CPCB website

South Mumbai has the worst air within the city during winter: The stations in the south Mumbai report significantly higher PM2.5 levels compared to rest of the city this past December. Mazgaon with monthly average of 134 µg/m³ was the most polluted neighborhood of the city followed by Navy Nagar-Colaba (124 µg/m³), Kurla (101 µg/m³), Vile Parle West (101 µg/m³) and Worli (97 µg/m³). Khindipada at the edge of Sanjay Gandhi National Park in the suburbs with monthly average of 54 µg/m³ was the least polluted neighborhood. Bandra and Malad West report low numbers but the values are not considered valid due to significantly large amount of missing data from these two stations. (See *Graph 12: Station wise PM2.5 levels within Mumbai*).

Graph 12: Station wise PM2.5 levels within Mumbai



Source: CSE analysis of real time data from CPCB website

Way ahead

The western region has its own unique challenges and will have to be addressed. Pollution trapping can be high during adverse winter conditions as the overall pollution level in cities are high. The region is already experiencing rebound of pollution after the temporary dip in 2020 due to the pandemic linked hard lockdown phases. Key industrial towns and clusters are located in these two states that require attention. Maharashtra is among the states with highest number of non-attainment cities under the national clean air programme.

Stronger multi-sector interventions are needed to reduce pollution in a time bound manner and to meet the national ambient air quality standards and prevent further worsening of the trend. This requires massive scaling up of the access to clean fuel and technology in industry and power plants, transformation of public transport, walking and cycling at a scale, renewal of vehicle fleet, rapid electrification of new vehicle fleet, amendment of municipal bylaws based on central waste management rules and regulations and scaling up of infrastructure for management and recycling of all waste streams, elimination of solid fuels for cooking, controlling dust from construction sector and adopting greening and afforestation strategy for dust control. This agenda is non-negotiable to meet the clean air target.

Tracking overall and winter air pollution in the southern region -- cities of Andhra Pradesh, Kerala, Karnataka, Tamil Nadu and Telangana

Anumita Roychowdhury, Avikal Somvanshi and Sharanjeet Kaur

Centre for Science and Environment, New Delhi, January 19, 2022

Even though the states in the southern region of India have some of the cleanest cities in the country, it still comes under some influence of winter inversion and elevated pollution levels. The levels increase despite the geographical advantages and favorable meteorology due to its proximity to the sea and improved ventilation. At the same time the annual average level of PM2.5 that was downward in 2020 has risen again in most cities of the southern states during 2021. This has emerged from the recent air quality analysis of the Centre for Science and Environment (CSE) for the period 2019-2021.

However, unlike the states in other regions, the air quality gains are not completely lost. In most cities the levels are still lower than 2019. This signals towards early preventive action to prevent further worsening in the coming years. This requires urgent scaling up of across all sectors to arrest the trend in this region.

Even though real time air quality monitoring has begun to expand in these states to provide more up to date and real time information on air quality, there are serious concerns around missing data and gaps that makes proper risk assessment difficult. In some stations of Karnataka, Hyderabad and Tamil Nadu, data availability is so low that the trend cannot be assessed. Quality control of data is necessary.

This is evident from the new analysis of real time pollution data as part of the air quality tracker initiative of the Urban Data Analytics Lab of CSE. The objective of this new analysis is to understand the trend and magnitude of pollution in different regions that have real time air quality monitoring systems. This is an assessment of annual and seasonal trends in PM2.5 concentration for the period 1st January 2019 to 9th January 2022. This analysis is based on the real time data available from the current working air quality monitoring stations. 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 63 continuous ambient air quality monitoring stations (CAAQMS) spread across 39 cities in five states and a union territory: Andhra Pradesh -- one station each in Amravati, Tirupati, Vijaywada, Rajamahendravaram, and Visakhapatnam; Kerela -- three stations in Kochi, two stations in Thiruvananthapuram, and one station each in Kollam, Kannur, Kozhikode, and Thrissur; Karnataka -- ten stations in Bengaluru and one station each in Bagalkot, Bidar, Chamarajanagar, Chikkaballapur, Chikkamagaluru, Davanagere, Gadag, Hassan, Hubballi, Kalaburagi, Kolar, Koppal, Madikeri, Mangalore, Mysuru, Raichur, Ramnagara, Shivamogga, Udupi, Vijaypura, and Yadgir; Tamil Nadu -- eight stations in Chennai, and one station each in Coimbatore, Gummidipoondi, and Thoothukudi; Telangana – six stations in Hyderabad; Puducherri – one station at Pondicherry.

Even though there are multiple real time monitors in a few cities of these states but many could not be considered for long term analysis due to data gaps and lack of quality data. Moreover, in several cases the real time monitors have been set up recently and therefore long term data is not available. Several cities of southern region have got their real time monitors in November 2020. Chennai got 4 out of their 8 real time monitors only in Jan 2021. Vijaywada station stopped reporting PM2.5 data after October 2019, and Sanegurava Halli station in Bengaluru stopped reporting PM2.5 data early 2019.

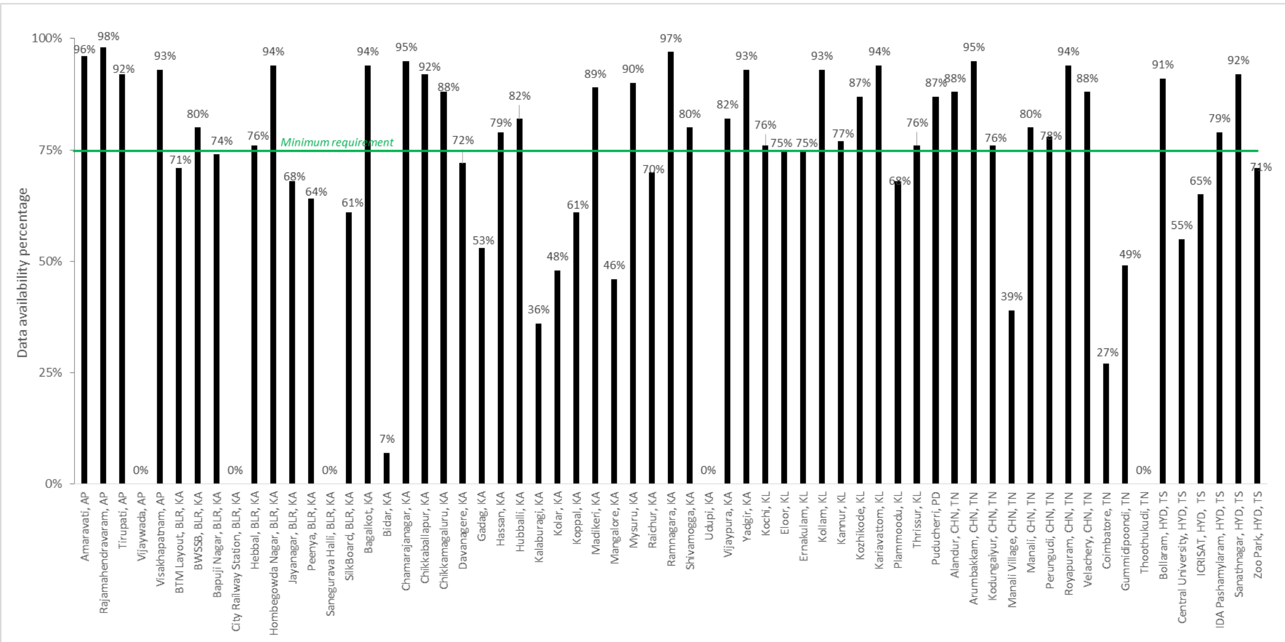
Key highlights

Challenge of data gaps and data quality despite automation in Tamil Nadu and Karnataka, situation relatively better in Andhra Pradesh, Telengana and Kerela: Review of data availability from the automated monitoring stations in the region under Continuous Ambient Air Quality Monitoring Stations (CAAQMS) program of CPCB, shows major data gaps. Data availability calculated as number of days with adequate PM2.5 data for computation of a valid 24hr-average has been low in 19 of 39 cities in the region. For the second half of the year 2021 (June to December) data availability at Vijaywada station of Andhra Pradesh, City Railway Station and Sanegurava Halli stations of Bengaluru, Thoothukudi station of Tamil Nadu, and Udupi station of Karnataka has been zero per cent. Coimbatore station of Tamil Nadu, Kalaburagi station and Bidar station of Karnataka has just 27 per cent, 39 per cent, and 7 per cent data availibility respectively. Velachery and Manali Village stations of Chennai also reported data only for 27 per cent and 36 per cent of days respectively.

Among Bengaluru stations, Silk board has only 61 per cent data while Peenya and Jayanagar with 64 per cent and 68 percent. Gummidipoondi station of Tamil Nadu and Central University of Hyderabad are data poor as well with 49 per cent and 55 per cent data availability respectively. Only twelve out of twenty one stations of Karnataka outside Bengaluru meet the minimum requirement of 75 per cent (See *Graph 1: Data availability at real time monitoring stations of South India region in June-Dec, 2021*). It is not clear why these stations have such poor data availability, this requires additional assessment which is not in the scope of this study.

In contrast most stations of Andhra Pradesh and Kerala perform better as they have data availability of more than 75 per cent. Only station at Plammoodu in Thiruvananthapuram, Kerala is below the minimum 75 per cent data availability requirement.

Graph 1: PM2.5 data availability at real time monitoring stations of South India for June-Dec, 2021

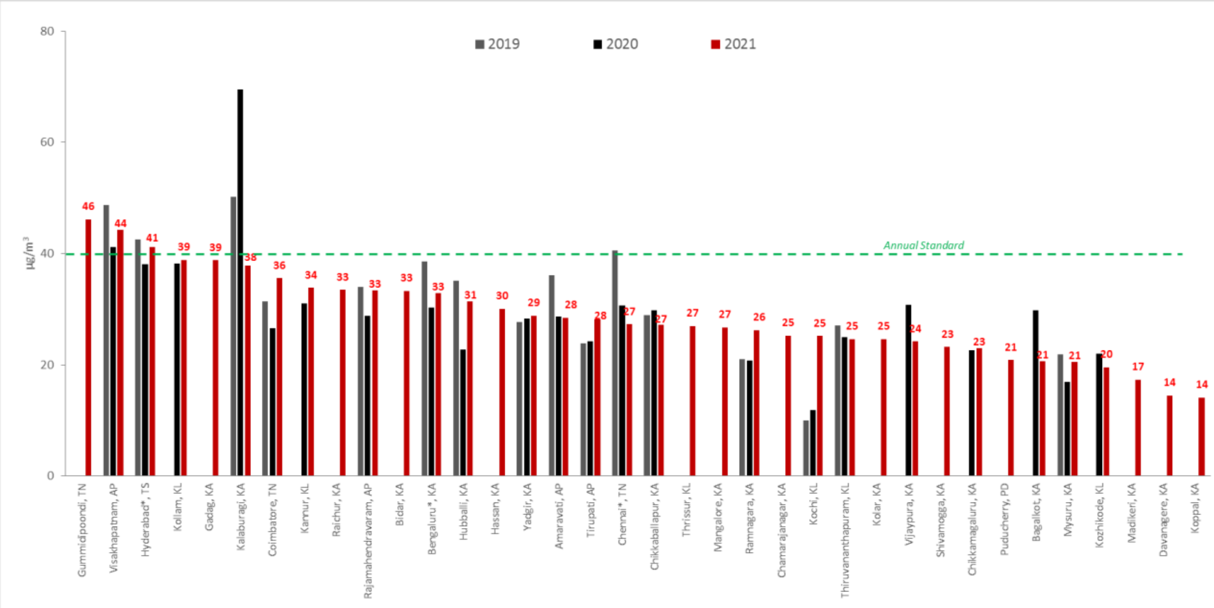


Source: CSE analysis of real time data from CPCB website

Many cities show a rising trend in annual PM2.5 level after an initial drop during 2020 with more pandemic related lockdown phases: Among all the regions, cities of South India have shown least of a rebound and a rising trend once again in 2021 after significant drop due to maximum pandemic lockdowns of 2020. But there is still a rebound and it should be seen as a warning signal. 22 cities have adequate data for both 2020 and 2021 for annual average computation. 16 of these cities show increase in their annual PM2.5 average while six show further improvement. Kochi has registered doubling of its annual PM2.5 average between 2020 and 2021. Cities that show improvement are Chennai, Kalaburagi, Chikkaballapur, Vijaypura, Chikkmangaluru, and Kozhikode.

Industrial town Gummidipoondi near Chennai in Tamil Nadu, had the most polluted air in the region with 2021 average at 46 µg/m³. This is followed by Visakhapatnam and Hyderabad with 2021 annual average of PM2.5 at 44 µg/m³ and 41 µg/m³ respectively (See *Graph 2: PM2.5 trend among cities of South India states 2019-2021*). In contrast, all other cities in the southern region have met the annual standard with average.

Graph 2: Long term PM2.5 trend among cities of South India states (2019-2021)

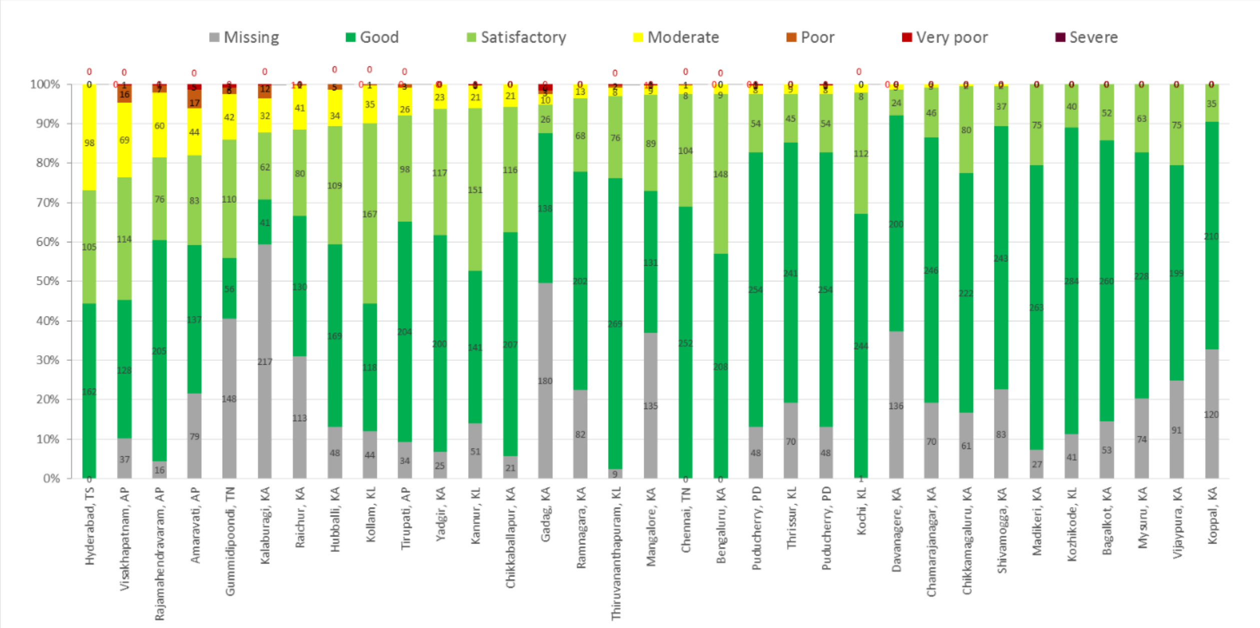


Note: PM2.5 values for cities with more than one monitoring stations is based on average of all stations that have continuous and adequate data for complete assessment period. Data up till 31 December 2021.
Source: CSE analysis of real time data from CPCB website

Cities of Andhra Pradesh and Telangana have worst air among the Southern states: Hyderabad with 98 days of bad air (AQI of moderately polluted or worse) is the city with most unhealthy days in Southern states. It is closely followed by Andhra cities; Visakhapatnam with 86 days, Rajamahendravaram with 68 days, and Amravati with 66 days of bad air. Smaller industrial towns of Karnataka namely Gadag and Kalaburagi also report significant bad air days, in fact AQI in these cities can cross into very poor AQI category but due to massive amount of missing data it is unclear how long these bad air episodes actually last. Gummidipoondi has the most bad air days in Tamil Nadu while Kollam in Kerela (See *Graph 3: PM2.5 based AQI categorization of days for major cities in South Indian states – 2021*).

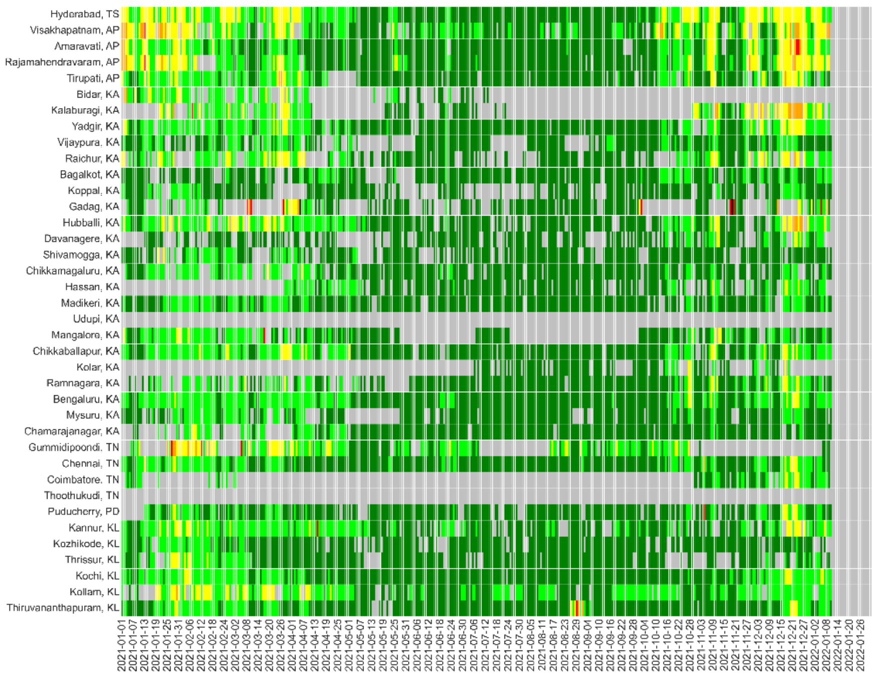
Bad air days begin to build up around the end of December in the cities of south Indian states and tend to increase till end of March. Hyderabad and cities in the Andhra Pradesh show more pronounced impact of winter pollution compared to other cities of the region (See *Graph 4: Heatmap based on days classified as per PM2.5 air quality index for major cities of South Indian states*).

Graph 3: PM2.5 based AQI categorization of days for major cities in South Indian states 2021 – (Percentage share and number of days)



Note: PM2.5 values for cities with more than one monitoring stations is based on average of all stations that have continuous and adequate data for complete assessment period. Data up till 31 December 2021.
Source: CSE analysis of real time data from CPCB website

Graph 4: Heatmap based on days classified as per PM2.5 air quality index for major cities of South Indian states

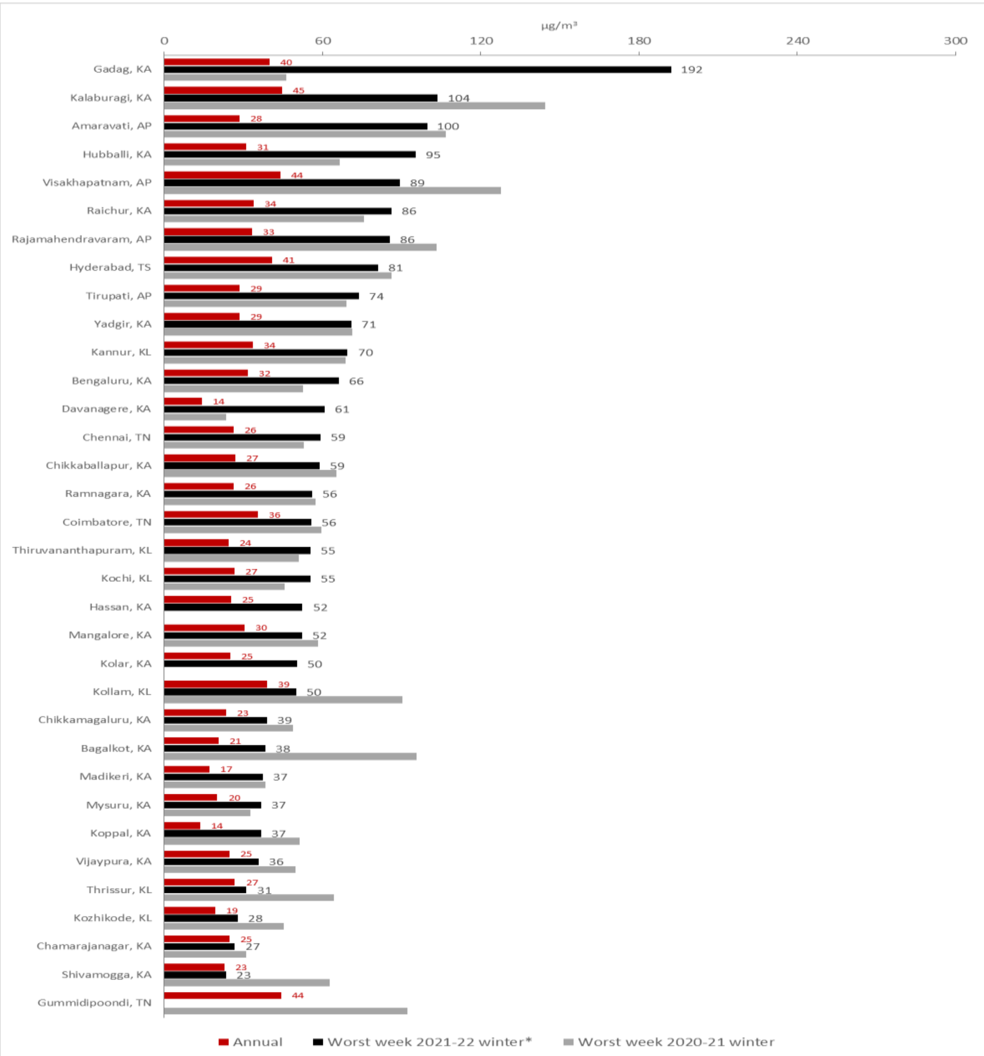


Note: PM2.5 values for cities with more than one monitoring stations is based on average of all stations that have continuous and adequate data for complete assessment period. Cell colors are based on the official AQI category colors. Data up till 9 January 2022. Source: CSE analysis of real time data from CPCB portal

High weekly pollution episode during winter can be more than double the annual concentration in several cities: During the worst weekly pollution episode in winter the PM2.5 concentration can increase significantly higher than the annual PM2.5 average – about two times high in several cities. Worst episodes are noted in the industrial towns of Karnataka where Gadag registered a shocking weekly average of 192 µg/m³ (almost five times its annual average). Similarly, Kalaburagi recorded a weekly average of 104 in mid-December.

Among non-industrial cities, during the high pollution episodes weekly PM2.5 levels can go as high as 100 ug/m3 as recorded in Amravati in December 2021 (See *Graph 5: Weekly PM2.5 levels vs annual level among in cities of South Indian states*). This winter so far the highest weekly level has recorded 95 µg/m³ in Hubbali, 89 µg/m³ in Visakhapatnam, 86 µg/m³ in Rajamahendravaram, and 81 µg/m³ in Hyderabad.

Graph 5: Comparison of worst weekly PM2.5 levels with annual average level in Cities of South Indian states



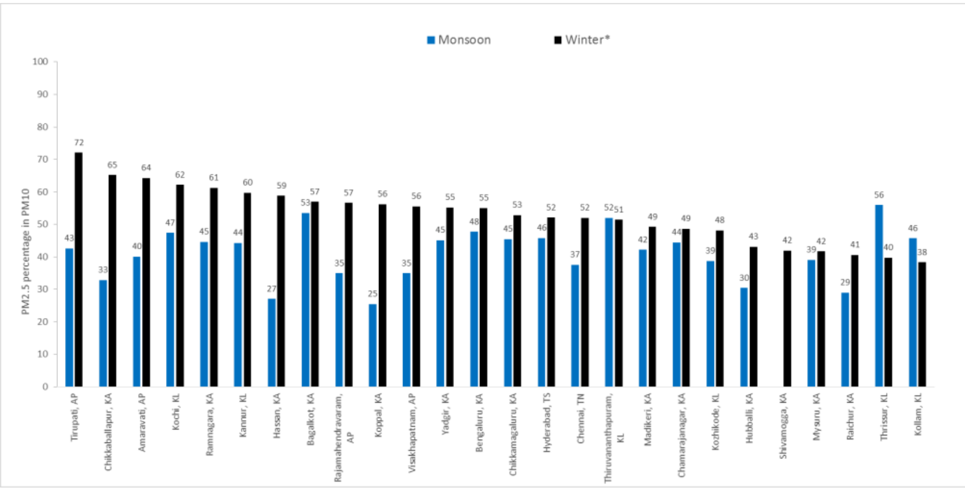
Note: Worst week for Amravati were weeks ending on 26 Dec 2021 and 27 Dec 2020; Hubbali were weeks ending on 26 Dec 2021 and 27 Dec 2020; Visakhapatnam were weeks ending on 26 Dec 2021 and 27 Dec 2020; Rajamahendravaram were weeks ending on 26 Dec 2021 and 3 Jan 2021. Hyderabad were weeks ending on 26 Dec 2021 and 3 Jan 2021; Tirupati were weeks ending on 26 Dec 2021 and 27 Dec 2020. Worst week for Yadgir were weeks ending on 26 Dec 2021 and 3 Jan 2021; Kannaur were weeks ending on 26 Dec 2021 and 27 Dec 2020; Bengaluru were weeks ending on 26 Dec 2021 and 31 Jan 2021; Chennai were weeks ending on 26 Dec 2021 and 27 Dec 2020. Chikkaballapur were weeks ending on 26 Dec 2021 and 24 Jan 2021; Ramnagara and were weeks ending on 26 Dec 2021 and 1 Nov 2020; Kochi were weeks ending on 19 Dec 2021 and 31 Jan 2021; Thiruvananthapuram were weeks ending on 26 Dec 2021 and 31 Jan 2021; Kollam were weeks ending on 2 Jan 2022 and 1 Nov 2020; Chikkamagaluru were weeks ending on 26 Dec 2021 and 1 Nov 2020; Bagalkot and were weeks ending on 9 Jan 2022 and 1 Nov 2020; Mysuru were weeks ending on 26 Dec 2021 and 1 Nov 2020; Vijaypura were weeks ending on 19 Dec 2021 and 8 Nov 2020; Thrissur were weeks ending on 12 Dec 2021 and 31 Jan 2021; Kozhikode were weeks ending on 9 Jan 2022 and 27 Dec 2020. Data up till 9 January 2022.
Source: CSE analysis of real time data from CPCB portal

Changing ratio of PM2.5:PM10 during different seasons of 2021 – PM2.5 share increase during winter making air more toxic: The PM2.5/PM10 ratio is a useful indicator to understand the impact of coarse dust vs tinier dust from combustion sources on air quality. Higher share of smaller particles in total particle concentration makes the air more toxic. The indicative ratio for all cities show there is a seasonal variation. The share of smaller PM2.5 is higher than the coarser PM10 in monsoon and winter. The long-term variation of the PM2.5/PM10 ratio was analyzed from weekly data average for two different seasons: Monsoon (June - October) and winter (November – January). (See *Graph 6: Changing ratio of PM2.5/PM10 during different seasons of 2021*).

The PM2.5/PM10 ratio in all the cities of southern states has an increasing slope in winters comparing to monsoon except Thrissur and Kollam in Kerela, which is showing high percentage of PM2.5/PM10 ratio in monsoon compared to winter. Mostly, the concentration of PM2.5/PM10 ratio is higher during winter's months (November to January) hovering between 50 to 70 per cent. This is indicative and there can be variation across years. However, this trend is broadly consistent with what has been noted in other regions of the country.

In Andhra Pradesh, Tirupati is showing high percentage of PM2.5/PM10 ratio in winters with 72 percent. It is followed by Chikkaballapur in Karnataka with 65 percent. Kochi in Kerala with 62 percent. Overall in southern India region, the concentration of PM2.5/PM10 ratio is higher during winter (November to January) (See *Graph 6: Changing ratio of PM2.5/PM10 during different seasons of 2021*).

Graph 6: Changing ratio of PM2.5/PM10 during different seasons of 2021

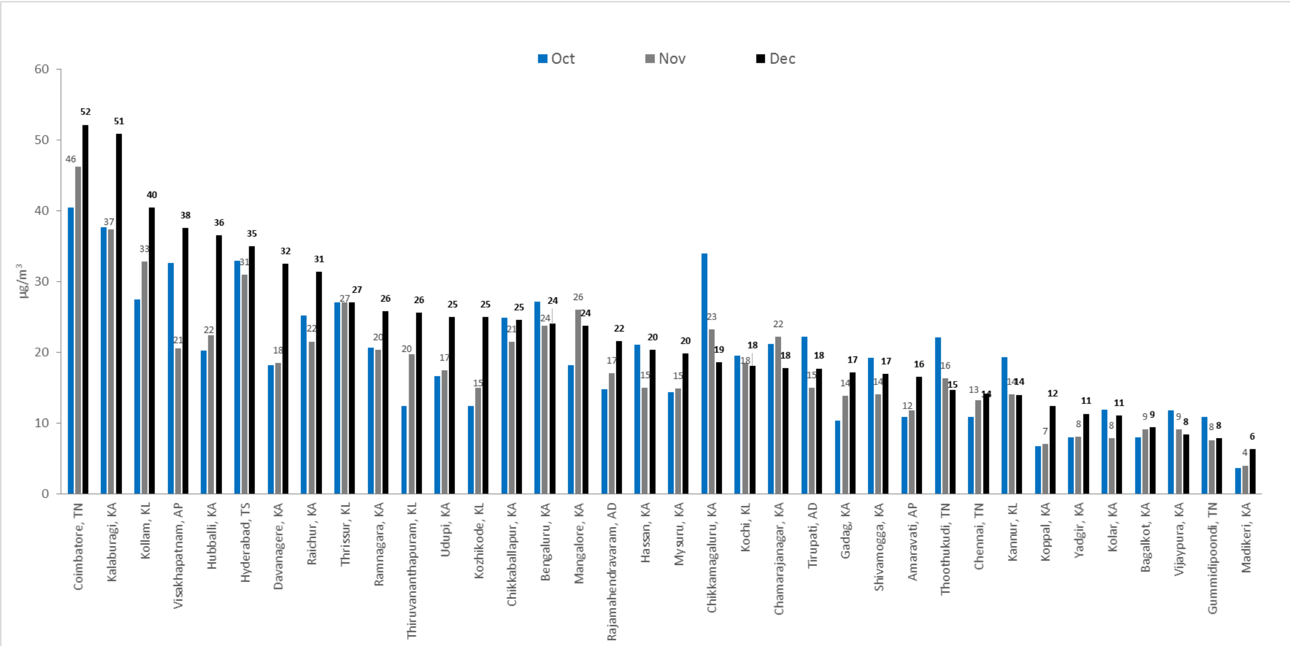


Note: Average PM2.5 concentration for a week is based on mean of all CAAQM stations in the city. Data up till 9 January 2022. Source: CSE analysis of CPCB's real time air quality data

Nitrogen oxide (NO2) that comes largely from vehicles increase during winter: There is a significant increase in amount of nitrogen dioxide (NO2) in air of all cities of southern states during December compared to the previous months of November, October and September in most cities of South India. Coimbatore with 52 µg/m³ monthly NO2 average for December is the highest in the region. It is followed by Kalaburagi (51 µg/m³), Kollam (40 µg/m³), and Visakhapatnam (38 µg/m³).

As for the seasonal increase in NO2 concentration smaller cities led the list. Kalaburagi registered 5.8 times jump in monthly NO2 level, Thoothukudi registered a 4 times increase, while Kozhikode with 3.8 times increase, Hubballi with 3.3 times increase, and Thiruvananthapuram registered a 2.2 times increase (See *Graph 7: Monthly trend in nitrogen dioxide levels in cities of Southern states*).

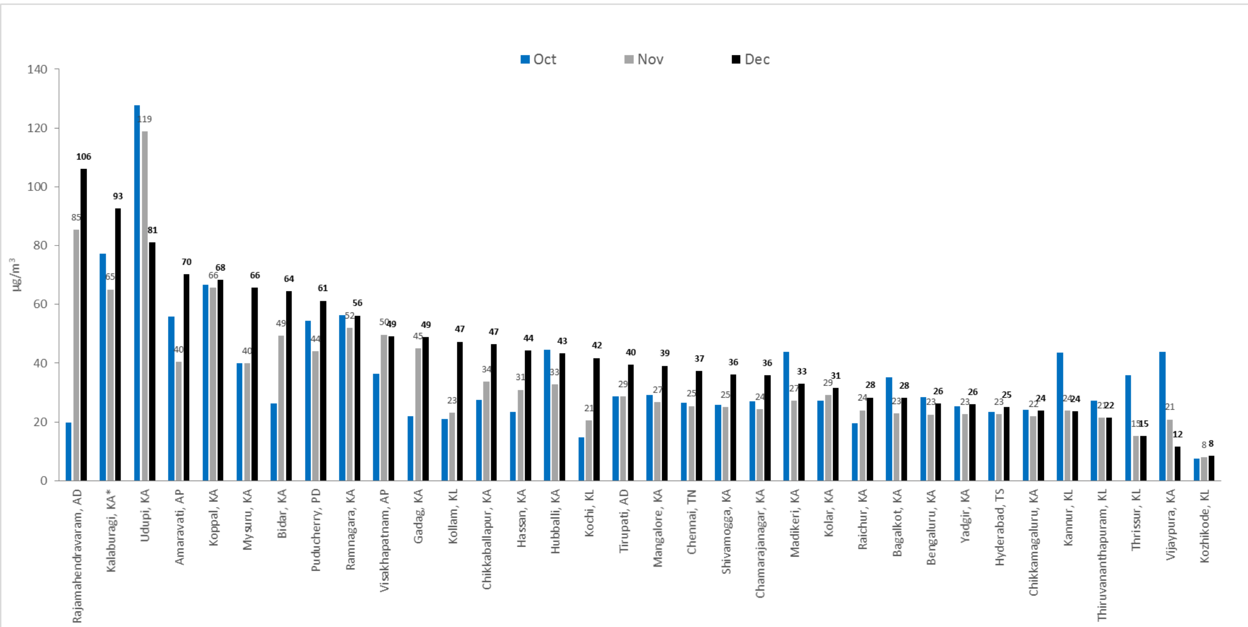
Graph 7: Monthly trend in nitrogen dioxide levels in cities of South Indian states



Note: NO2 values for cities with more than one monitoring stations is based on average of all stations that have continuous and adequate data for complete assessment period. Data up till 31 December 2021. Source: CSE analysis of real time data from CPCB portal

Surface ozone increase during winter making air more toxic: There is a significant increase in amount of surface ozone (O3) in air of all cities of western states during December compared to the previous months of November, October and September in most cities in the South. Rajamahendravaram with 106 µg/m^3 monthly O3 average for December is the highest in the region. Which means ozone exceeded the standard in the city on almost everyday of December. It is followed by Kalaburagi (93 µg/m^3), Udipi (81 µg/m^3), and Amravati (70 µg/m^3). The problem is especially acute among smaller cities (See *Graph 8: Monthly trend in ozone levels in cities of South Indian states*). It is also interesting to note that surface ozone has been relatively lower this winter compared to previous winter for almost all cities.

Graph 8: Monthly trend in nitrogen dioxide levels in cities of South Indian states

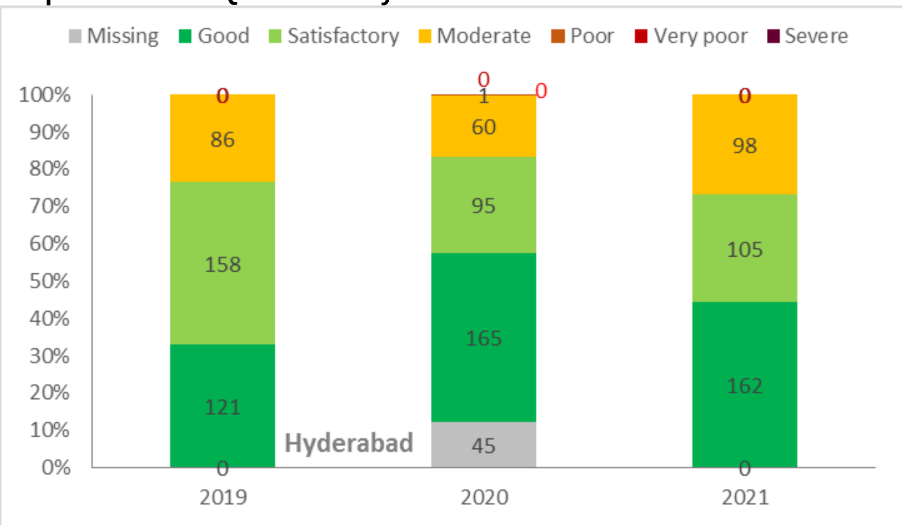


Note: Surface ozone values for cities with more than one monitoring stations is based on average of all stations that have continuous and adequate data for complete assessment period. Data up till 31 December 2021. Source: CSE analysis of real time data from CPCB portal

Pollution profile of individual cities

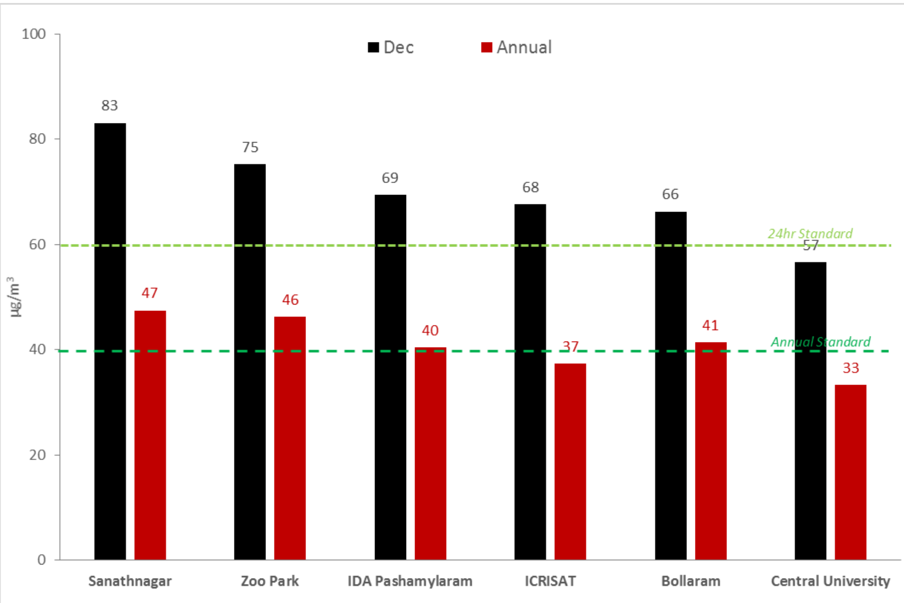
Hyderabad: Analysis of days as per AQI categorisation shows that the Hyderabad city's air quality is declining. Number of days recording AQI level worse than satisfactory has increased to 98 days in 2021 from 60 days in 2020 and 86 days in 2019 (See *Graph 9: PM2.5 AQI trend in Hyderabad*). In Hyderabs, the location Sanathnagar is worst air with its December average hitting 83 µg/m³. Ths is followed by Central University at 57 µg/m³ monthly average for December (See *Graph 10: Variation in PM2.5 level among city stations of Hyderabad*).

Graph 9: PM2.5 AQI trend in Hyderabad



Note: PM2.5 values is based on average of all stations that have continuous and adequate data for complete assessment period. Data up till 31 December 2021.
Source: CSE analysis of real time data from CPCB website

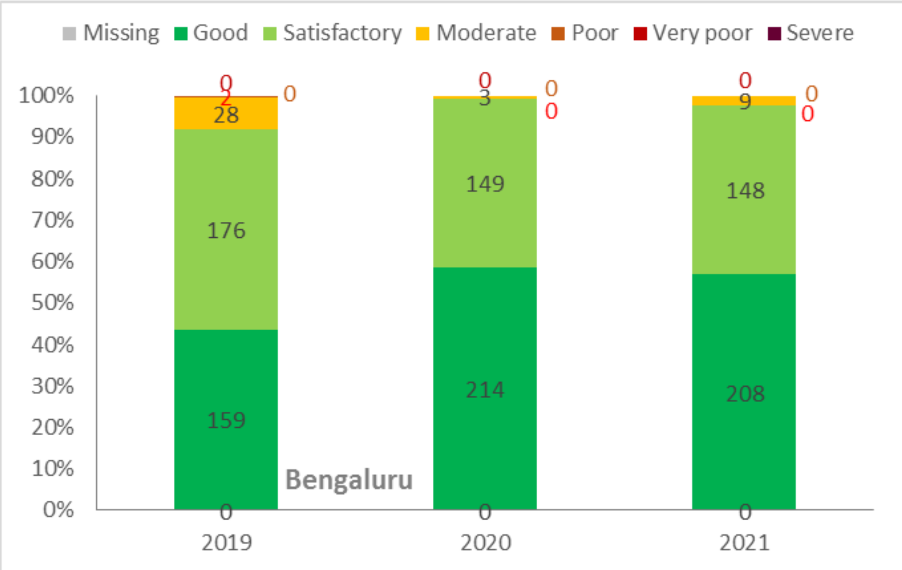
Graph 10: Variation in PM2.5 level among city stations of Hyderabad



Source: CSE analysis of real time data from CPCB website

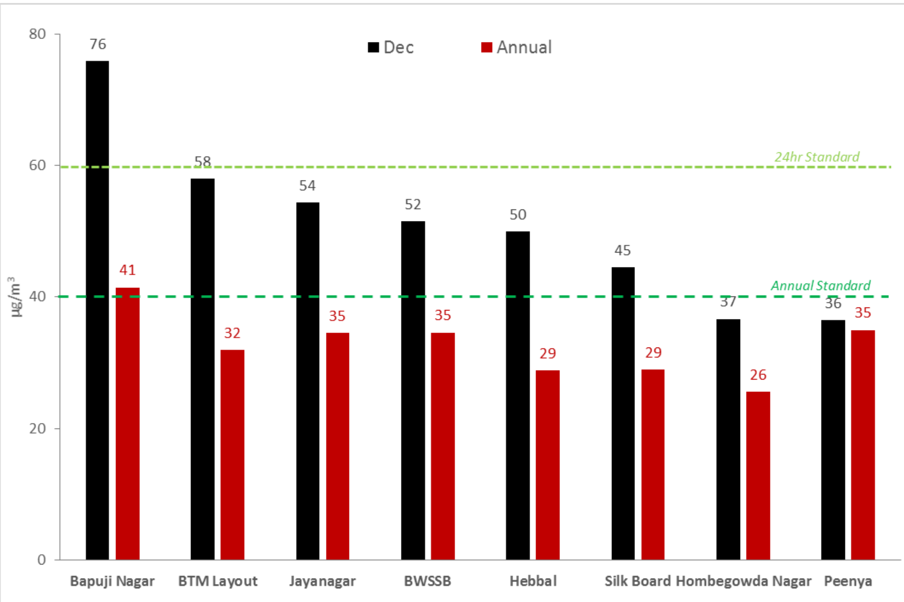
Bengaluru: Analysis of days as per AQI categorisation shows that Bengaluru city has been able to hold on to most of air quality gains made during 2020 with most hard lockdown days. The number of days with the AQI worse than satisfactory (or meeting the standard) was 9 in 2021; this is more than 3 days in 2020 and much less than 22 days in 2019 (See *Graph 11: PM2.5 AQI trend in Bengaluru*). Number of "good" AQI days in 2021 stood at 208 days, which is just marginally lower from 214 good AQI days recorded in 2020. It is an improvement of over 30 per cent from 2019. Within the city Bapuji Nagar was the worst hit with its December average recording 76 µg/m³. Pennya has least polluted air with 36 µg/m³ monthly average for December (See *Graph 12: Variation in PM2.5 level among city stations of Bengaluru*).

Graph 11: PM2.5 AQI trend in Bengaluru



Note: PM2.5 values is based on average of all stations that have continuous and adequate data for complete assessment period. Data up till 31 December 2021.
Source: CSE analysis of real time data from CPCB website

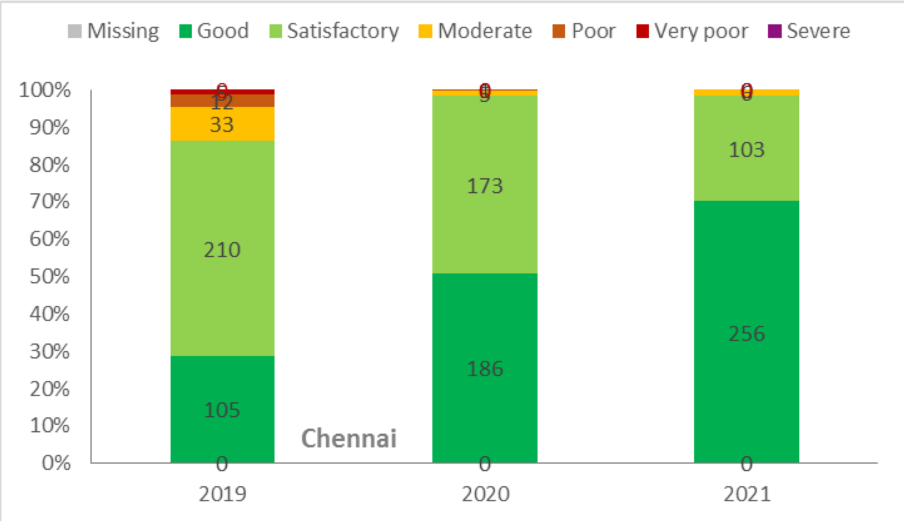
Graph 12: Variation in PM2.5 level among city stations of Bengaluru



Source: CSE analysis of real time data from CPCB website

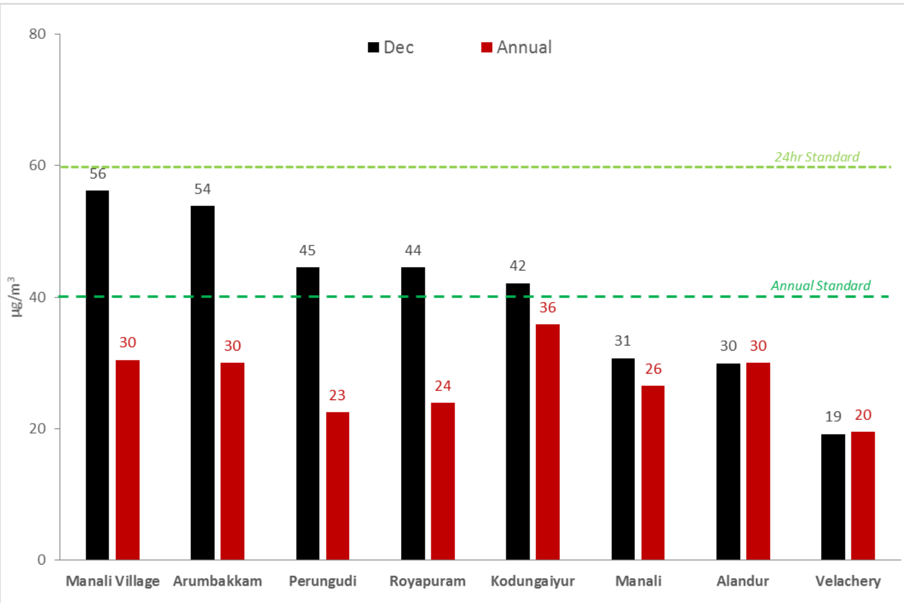
Chennai: Analysis of days as per AQI categorisation shows that the Chennai city has been able to hold on to most of air quality gains during 2020 with maximum lockdown days. Number of days when the AQI was worse than satisfactory was 6 in 2021, same as 2020. But 2019 had witnessed 50 days (See *Graph 13: PM2.5 AQI trend in Chennai*). Within the city, Manali Village has the worst air with its December average adding up to 56 µg/m³ closely followed by Arumbakam with 54 µg/m³. Velachery has least polluted air with 19 µg/m³ monthly average for December (See *Graph 14: Variation in PM2.5 level among city stations of Chennai*).

Graph 13: PM2.5 AQI trend in Chennai



Note: PM2.5 values is based on average of all stations that have continuous and adequate data for complete assessment period. Data up till 31 December 2021.
Source: CSE analysis of real time data from CPCB website

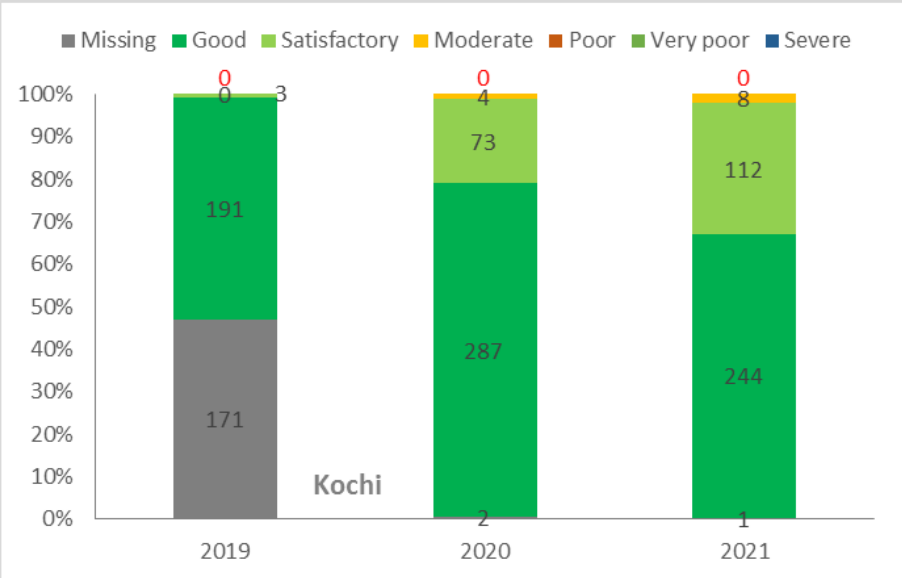
Graph 14: Variation in PM2.5 level among city stations of Chennai



Source: CSE analysis of real time data from CPCB website

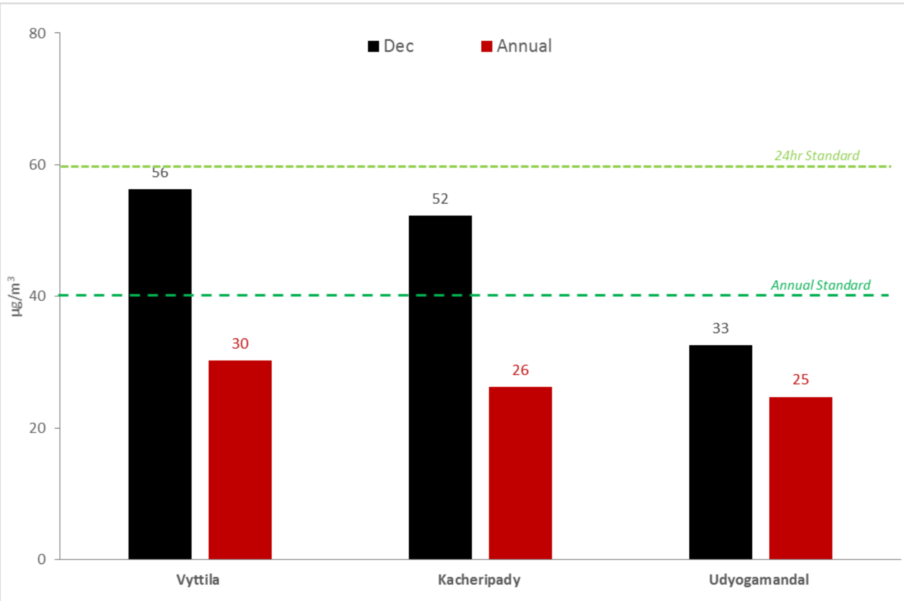
Kochi: Analysis of days as per AQI categorisation shows that Kochi city has not been able to sustain the air quality gains of 2020. Number of days when the AQI was worse than satisfactory level was 8 in 2021, - up by 4 days in 2020. But 2019 had witnessed 50 days above the satisfactory category (see *Graph 15: PM2.5 AQI trend in Kochi*). Most significant reduction is noted among "good" AQI days which are down by 43. Within the city Vyttila has the worst air with its December average adding up to 56 µg/m³. Udyogamandal has least polluted air with 33 µg/m³ monthly average for December (see *Graph 16: Variation in PM2.5 level among city stations of Kochi*).

Graph 15: PM2.5 AQI trend in Kochi



Note: PM2.5 values is based on average of all stations that have continuous and adequate data for complete assessment period. Data up till 31 December 2021.
Source: CSE analysis of real time data from CPCB website

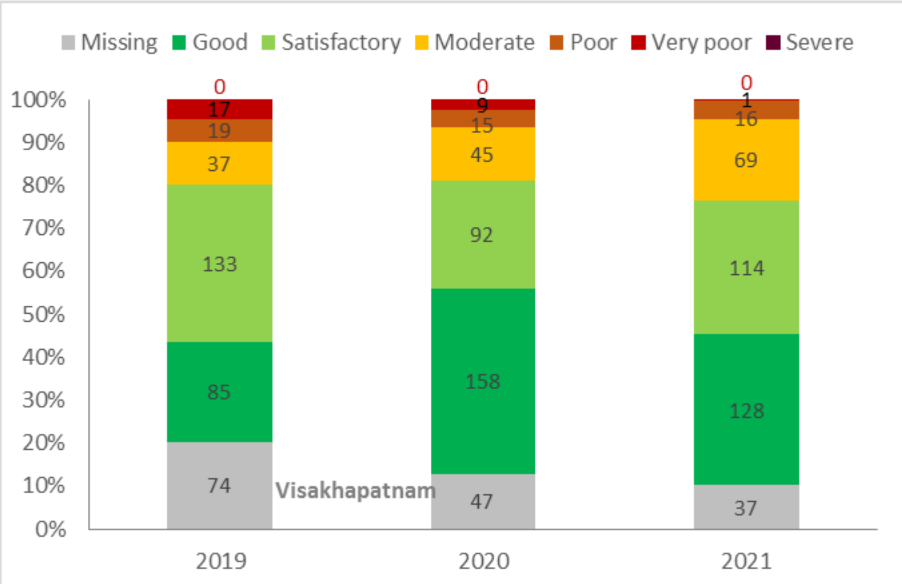
Graph 16: Variation in PM2.5 level among city stations of Kochi



Source: CSE analysis of real time data from CPCB website

Visakhapatnam: Analysis of days as per AQI categorisation shows that Visakhapatnam city has not been able to sustain air quality gains of 2020. Number of days when the AQI was worse than satisfactory has risen to 86 days in 2021, in contrast to 69 days in 2020 and 73 days in 2019 (See *Graph 17: PM2.5 AQI trend in Visakhapatnam*). Though number of days with very poor AQI has come down but this overall increase in bad air days is alarming.

Graph 17: PM2.5 AQI trend in Visakhapatnam



Note: Data up till 31 December 2021.
Source: CSE analysis of real time data from CPCB website

Next steps

States in southern India have unique locational advantage with sea and well ventilated atmosphere and more moderate climate that prevents pollution build up during winter like it happens in North India. But this region is at the risk of losing the air quality gains of pandemic though it has not yet reached the pre-pandemic levels. However, doubling of pollution during winter also indicates high local pollution and exposure that normally is not well captured in the annual average trends. This indicates the need for urgent action across all sectors to control pollution from vehicles, industry, power plants, waste burning, construction, and solid fuel use in households in all the states to meet the clean air standards throughout the year.

Winter is coming:
Understanding pre-winter air pollution baseline in Delhi-NCR

Anumita Roychowdhury and Avikal Somvanshi

Centre for Science and Environment, New Delhi, October 20, 2021

At the onset of winter, Centre for Science and Environment (CSE) has analyzed air quality trends so far in Delhi and the National Capital Region (NCR) and also in the larger Indo-Gangetic Plains (IGP). The objective has been to understand the starting line of the onset of the winter pollution season or pre-winter levels in this region. This also helps to locate the winter season within the longer term context of seasonal variation and annual trends in particulate pollution.

This is an assessment of annual and seasonal trends in $PM_{2.5}$ concentration for the period 1 January 2018 to 15 October 2021. This captures three successive winter seasons, pre-winter trends and pre and pandemic era including stages of lockdown in Delhi and the National Capital Region. This analysis is based on the real time data available from the current working air quality monitoring stations in Delhi-NCR and larger Indo Gangetic Plain. 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 156 continuous ambient air quality monitoring stations (CAAQMS) spread across 67 cities in Punjab, Chandigarh, Haryana, Delhi, Rajasthan, Uttar Pradesh, Bihar and West Bengal. 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 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).

The pre-winter phase this year is quite unusual given the ongoing pandemic disruption combined with the unusual meteorological conditions. This year has witnessed one of the wettest monsoons in many decades. The monsoon period and the phase of extended rains cover the period from 1 July to 15 October. In the analysis winter season is considered from 15 October to 15 February based on dates referred in Delhi's Graded Response Action Plan (GRAP). Summer season is considered from 16 February to 30 June.

Even though the seasonal PM2.5 average was lowest compared to all other seasons, it still shows how tough it will be for this region to go down further to meet the new and more stringent threshold that has been set by the WHO for particulate pollution recently.

The 2021 winter is starting with a cleaner threshold compared to the previous years. It is now awaited to see how soon and how intensely the winter pollution will bounce back this year. This demands very stringent advanced action to minimize local pollution across Delhi and National Capita Region (NCR) and the Indo Gangetic Plains (IGP) and also leveraging of winter action for more sustained air quality gains.

Inputs: Shambhavi Shukla

Key highlights

1. Delhi

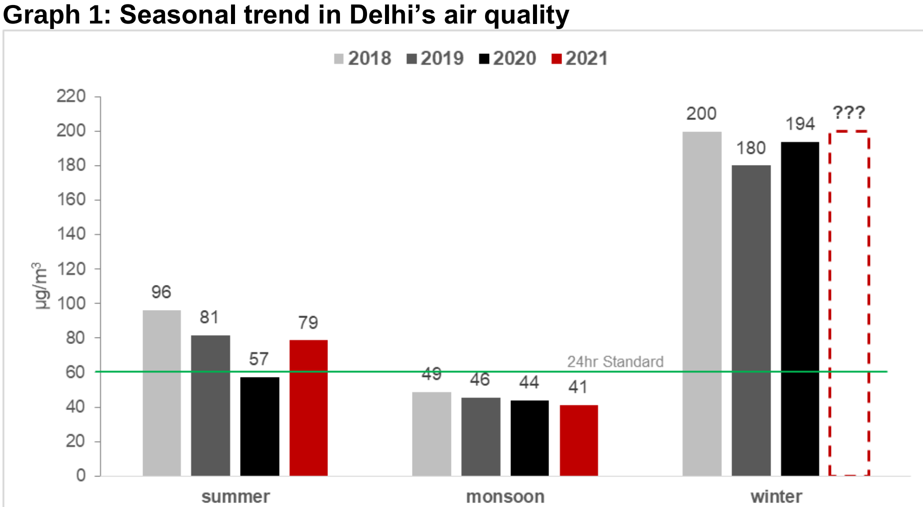
Cleanest monsoon season in last four years: The extraordinarily wet monsoon season also translated into the cleanest monsoon season for Delhi. The citywide average for the monsoon this year stood at 41 µg/m³ with 96 days meeting the 24hr standard for $PM_{2.5}$. The corresponding seasonal average in 2020 was 44 µg/m³ with 84 days meeting the 24hr standard. Monsoon season has noted progressive increase in the number of cleaner days with an average 6 per cent annual improvement since 2018 (See *Graph 1: Seasonal trend in Delhi's air quality*). The rainfall has not been of equal intensity in all the monsoons. Even though the 2019 monsoon had registered 40 per cent lesser rain compared to 2018 monsoon, the seasonal $PM_{2.5}$ average improved from 49 µg/m³ to 46 µg/m³ (See *Graph 2: Relationship between Delhi's seasonal air quality and rainfall*).

In Delhi, Dr. Karni Singh Shooting Range has recorded the lowest seasonal average of 33 µg/m³, while the National Stadium had 100 days that met the daily standard. Anand Vihar with seasonal average of 61 µg/m³ had lesser number of days – 54, meeting the standard and was the worst hotspot in the city.

Summer pollution – rising trend: Lockdowns were effective in bringing down $PM_{2.5}$ levels during 2020 summer, with seasonal average of 57 µg/m³ and about 90 days meeting the 24hr standard. But this advantage was lost during 2021 summer with seasonal average climbing to 79 µg/m³ and the number of days meeting standard plummeting to 51 from 90 in summer of 2020 (See *Graph 1: Seasonal trend in Delhi's air quality*). In fact, $PM_{2.5}$ levels this summer have almost returned to 2019 summer level despite partial lockdowns that were in place during much of April and May of this year due to the second wave of corona.

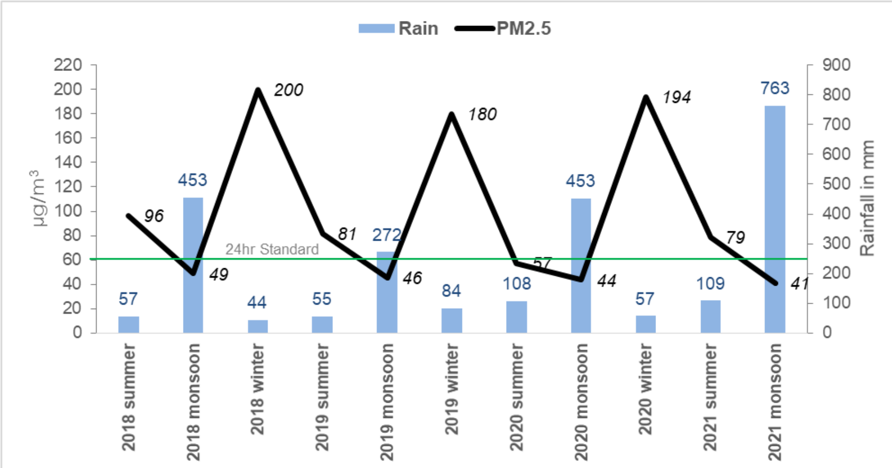
In Delhi, Aya Nagar had cleanest summer average of 54 µg/m³, while the National Stadium and Sri Aurobindo Marg had 76 days meeting the daily standard. Bawana with seasonal average of 111 µg/m³ was the most polluted spot during summer. DTU, ITO and Mundaka were other spots in the city that registered seasonal average higher than 100 µg/m³.

Graph 1: Seasonal trend in Delhi's air quality



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

Graph 2: Relationship between Delhi's seasonal air quality and rainfall



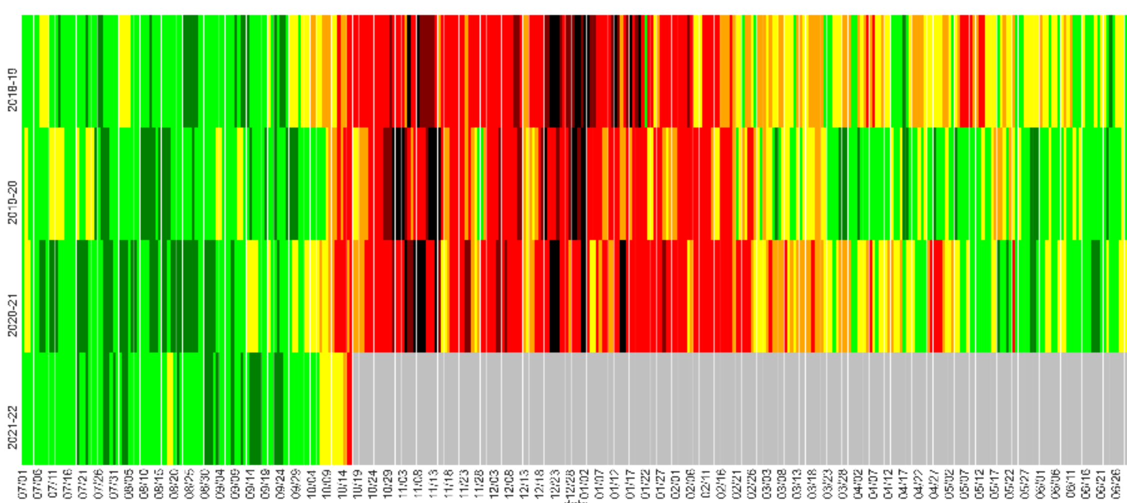
Note: Average $PM_{2.5}$ concentration is based on mean of daily values recorded at 36 CAAQM stations in the city that have adequate data for all four years.
Source: CSE analysis of CPCB's real time air quality data and IMD rainfall data from Palam weather station

2. Delhi-NCR

Annual heat map of daily $PM_{2.5}$ in Delhi and NCR: Daily $PM_{2.5}$ levels have been further classified according to the air quality index sub-categories for the years 2018, 2019, 2020, and 2021. The number of days in the 'very poor' AQI $PM_{2.5}$ sub-category dramatically increased in Feb-March of 2021 (See *Graph 3: Heatmap of Delhi's daily $PM_{2.5}$ AQI sub-category*). There were 27 days of 'very poor' days this Feb-March compared to 17 in 2020 and 12 in 2019. Days meeting the standard also plummeted this spring with just two days on record. 2020 had 16 and 2019 had 6 days when the standard was met.

Monsoon season this year has relatively lesser 'good' air days compared to 2020 monsoon but due to prolonged rain-spells this year that delayed onset of bad air days that overall seasonal average is lower. The heatmap also shows that the onset of days with 'very poor' air quality has not shifted despite the prolonged rains, even this year it happened around mid-October.

Graph 3: Heatmap of Delhi's daily $PM_{2.5}$ AQI sub-category



Note: Average $PM_{2.5}$ concentration is based on mean of daily values recorded at 36 CAAQM stations in the city that have adequate data for all four years. Cell colour is based on the official colour-scheme of AQI sub-categories.
Source: CSE analysis of CPCB's real time air quality data

Start of bad air days is linked to monsoon retreat: As is logically expected the start of monsoon retreat date almost perfectly coincides with the start of bad air days in Delhi (i.e. daily $PM_{2.5}$ average breaching the standard and mostly remaining above for rest of the season). The pollution build-up is triggered by retreating monsoon winds, and made worse by cool and calm winter condition and the inversion. While this process had started early in September for 2018 and 2020, it was delayed to October in 2019 and 2021 (See *Table 1: Relationship between monsoon withdrawal process and exceedance of daily standard for $PM_{2.5}$*).

Table 1: Relationship between monsoon withdrawal process and exceedance of daily standard for $PM_{2.5}$

	Onset of Monsoon Retreat	Onset of bad air days	Withdrawal Completion	First severe day
2018	29-Sep	27-Sep	21-Oct	30-Oct
2019	9-Oct	9-Oct	16-Oct	28-Oct
2020	28-Sep	28-Sep	28-Oct	31-Oct
2021	6-Oct	7-Oct	??	??

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

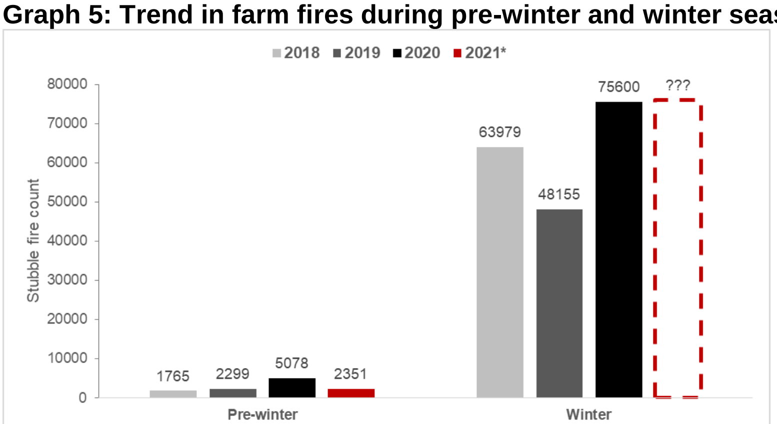
3. Farm stubble fire and early winter smog in Delhi

Normally the first phase of winter smog is often triggered by large scale stubble burning in the region. The contribution of farm stubble fire this year started roughly around October 10, same as 2018 and 2020. This was delayed by a week in 2019. Peak contribution this year so far was registered on October 16 when 14 per cent of Delhi's $PM_{2.5}$ was attributed to stubble fire smoke by SAFAR. Heavy rains following days washed out the first build-up of the season. The smoke season generally peaks around cusp of October and November with contribution spiking over 40 per cent on worst days. (See *Graph 4: Daily trend in $PM_{2.5}$, Rainfall, Farm stubble fires during pre-winter and winter season*)

The last year burning season (1-Oct to 29-Nov) saw on an average 12.2 per cent contribution per day. This was considerably higher than previous years. In 2019, contributions stood at 8.9 per cent per day, while it stood at 10.9 per cent per day in 2018. (The average contribution of stubble fire to Delhi's daily $PM_{2.5}$ concentration increased by 36 per cent from last year and 12 per cent from 2018.)

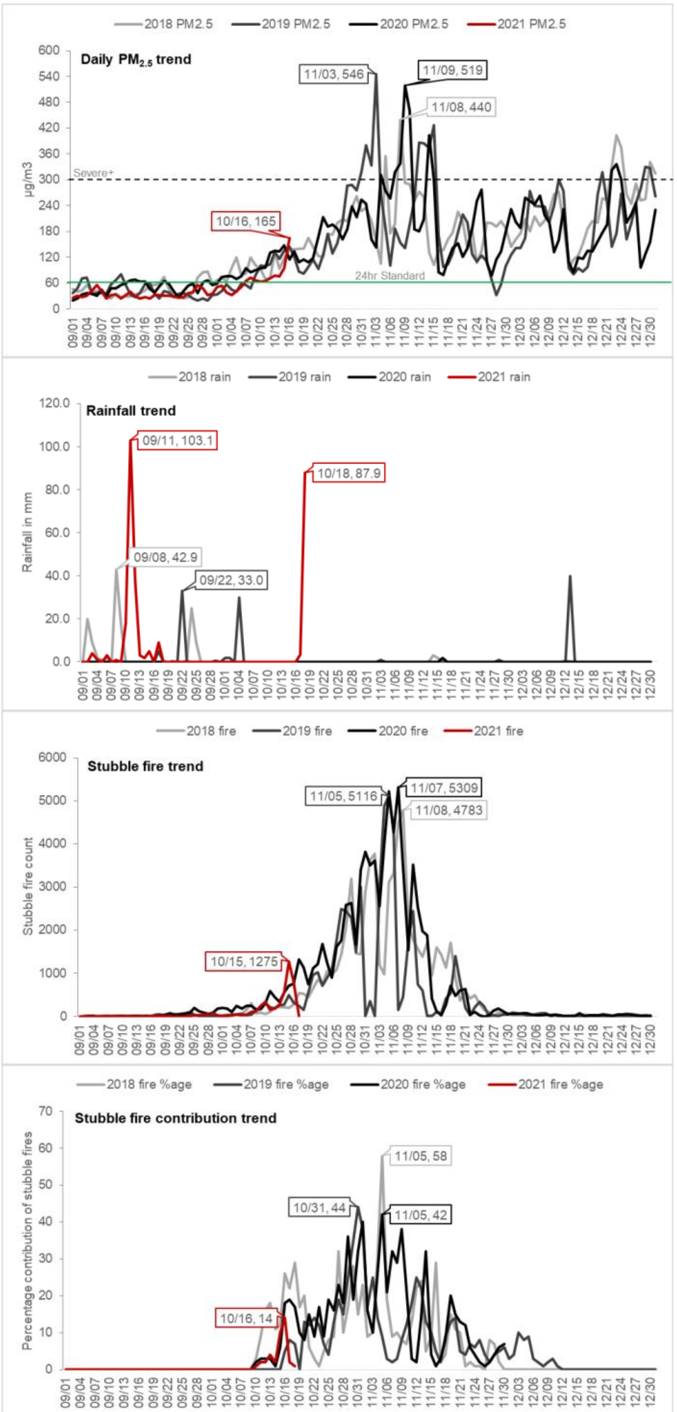
Trend in fire count during pre-winter of 2021: The farm fire count during the pre-winter season of 2021 has been less than half of the number recorded last year (See *Graph 5: Trend in farm fires during pre-winter and winter season*). But this can be due to multiple rain spells this year. Lower count reported by satellite imagery can also be due to increased cloud cover which hinders spotting of fires by the satellites. Nevertheless, lower fire count during pre-winter correlates well with the lower pollution level in Delhi-NCR.

Graph 5: Trend in farm fires during pre-winter and winter season



Note: Farm fire data is aggregate for Punjab and Haryana fires only.
Source: CSE analysis of fire count data from NASA's VIIRS product

Graph 4: Daily trend in $PM_{2.5}$, Rainfall, Farm stubble fires during pre-winter and winter season (2018-2021)



Note: Average $PM_{2.5}$ concentration is based on mean of daily values recorded at 36 CAAQM stations in the city that have adequate data for all four years. Farm fire data is aggregate for Punjab and Haryana fires only.
Source: CSE analysis of CPCB's real time air quality data, IMD rainfall data from Palam weather station, fire count data from NASA's VIIRS satellite, and smoke contribution data from SAFAR.

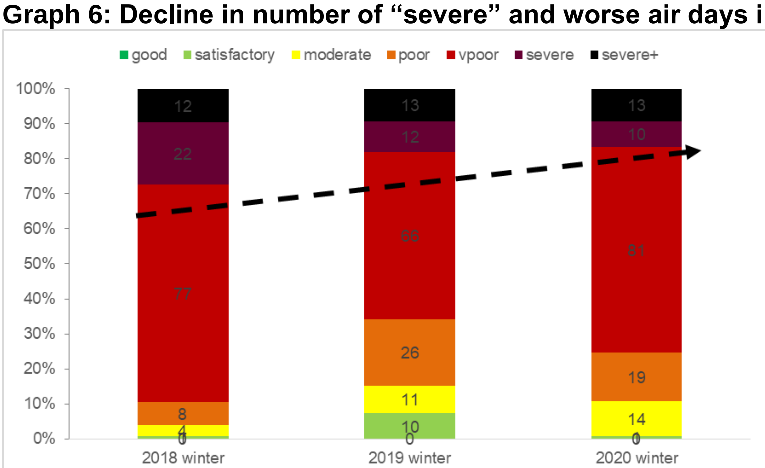
4. Winter trend in PM2.5

It is not possible to predict the trend during this winter. The pre-winter months of September and October have been one of the cleanest over the last four years. But going by the experience of past four years cleaner starting point is no guarantee for cleaner winter. During 2020-21 winter, $PM_{2.5}$ seasonal average was 8 per cent higher than the 2019 winter average. Also 2020-21 winter had an early onset of bad air days and also received lesser rain than 2019 winter. All that advantage of lockdown and monsoon was lost during winter. However, it is helpful to understand the more nuanced variation in winter $PM_{2.5}$ trend since 2018.

Number of days with severe concentration of $PM_{2.5}$ declined and duration of smog episodes were shorter during 2020-21 winter: During the winter of 2020-21, 23 days had citywide average of $PM_{2.5}$ concentration in “severe’ or worse AQI sub-category, - this is down from 25 such days in 2019-20 winter and 34 days in 2018-19 winter. (See *Graph 6: Decline in number of “severe” and worse air days in Delhi*). Technically, a smog episode is defined for the purpose of implementing emergency action under the Graded Response Action Plan when the levels of $PM_{2.5}$ remain in “severe” category for three consecutive days. From this perspective, during 2020-21 winter there were two continuous smog episodes. The first episode was of longer duration that started on 3rd November and lasted for 7 days. The second started on 22nd December and lasted for 3 days (See *Graph 7: Map of smog episode in Delhi*). Thus the continuous smog episodes are fewer and shorter compared to previous winters. 2019-20 winter had three smog episodes of 8 days, 6 days and 5 days durations. 2018-19 winter had four smog episodes of 10 days, couple of 6 days and a 3 days durations.

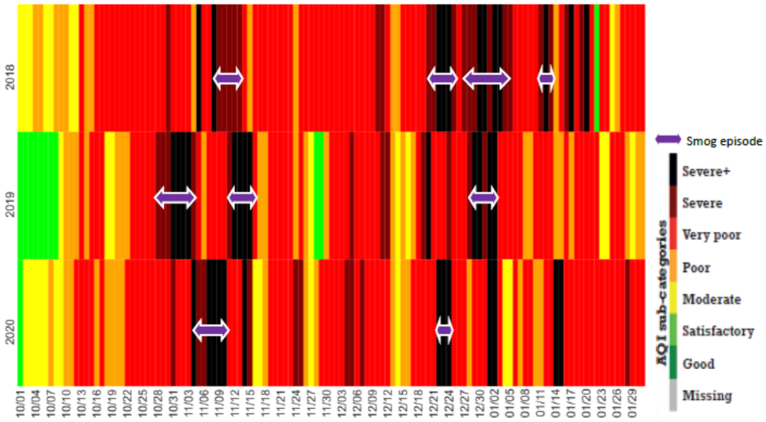
Relatively faster dissipation of smog episodes without any major rainfall or pollution control-emergency action during 2020-21 pointed towards downward trend in the annual average concentration (perhaps residual impact of lockdown). This period also coincides with the gradual unlocking of economy and travel in the air shed. But still persistent high level suggest impact of local pollution.

Graph 6: Decline in number of “severe” and worse air days in Delhi (15 Oct– 15 Feb)



Note: Average $PM_{2.5}$ concentration is based on mean of daily values recorded at 36 CAAQM stations in the city that have adequate data for all three winters. Cell colour is based on the official colour-scheme of AQI sub-categories.
Source: CSE analysis of CPCB’s real time air quality data

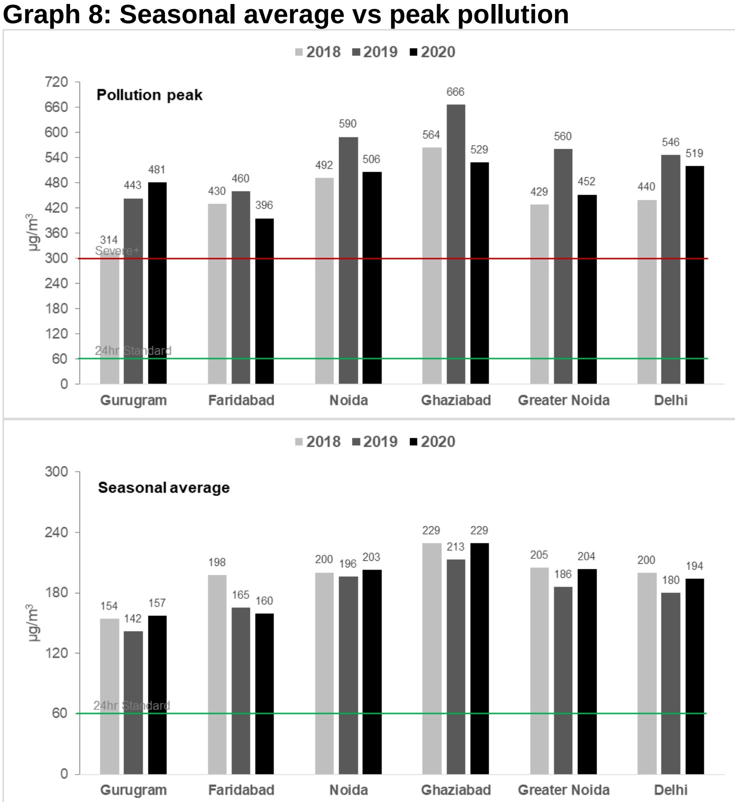
Graph 7: Map of smog episodes based on PM2.5 concentration during winter in Delhi



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

$PM_{2.5}$ winter trend in NCR: On an average 2020-21 winter season was 5 per cent worse among the major NCR cities and Delhi compared to 2019-20 season but the peak pollution on average was 13 per cent lower (See *Graph 8: Seasonal average vs peak pollution*). Delayed start of the season with multiple spurts of rain that marked 2019-20 is similar to the conditions prevailing this year. Given the experience of 2019-20, it can be expected that smog episode this year might have higher peak pollution if special steps are not taken to reduce the pollution from the sources.Even though the average level during the earlier winter of 2019-20 was lesser than other winters, the peak daily pollution was considerably higher across all major NCR cities. This can be attributed to September-October rains that pushed and concentrated the farm stubble burning towards the end of October and start of November when winter conditions were turning more adverse.

Graph 8: Seasonal average vs peak pollution



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

5. Pollution hotspots in Delhi and NCR

City hotspots record higher $PM_{2.5}$ levels compared to the city and regional average even during monsoon: There is a broad classification of hotspots. Originally, hotspots were defined as those with annual average levels higher than the mean value of the city – that is any case is much worse than the national ambient air quality standards.

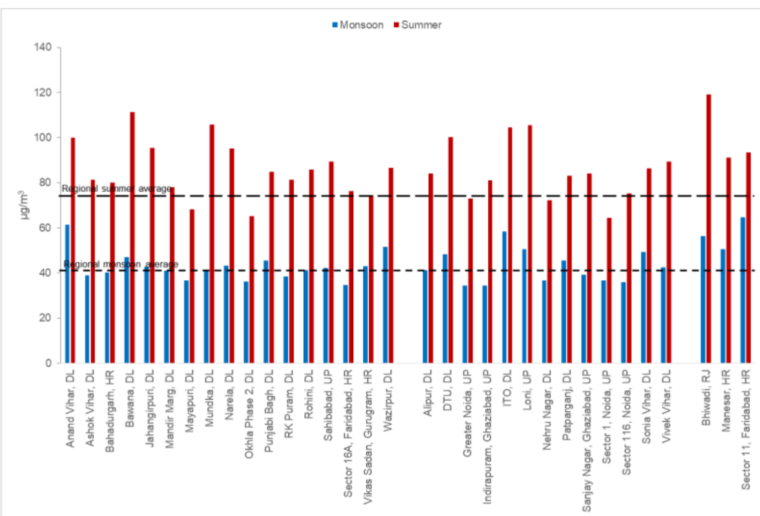
However, there is considerable seasonal variation and in the shifting nature of pollution across hotspots. 11 of 18 recognized hotspot registered higher seasonal average than the city and the region. But only two hotspots (Anand Vihar and Punjabi Bagh) show worsening of air quality during 2021 monsoon compared to 2020 monsoon.

Among 14 new locations in NCR identified last winter by CSE as emerging hotspots half registered lower levels this monsoon compared to city and regional averages. Three more locations have emerged this monsoon as potential hotspots i.e. Bhiwadi (Rajasthan), Manesar (Haryana), and Sector 11 Faridabad (Haryana). These location show significantly higher season average compared to rest of the region. In fact, with 64 µg/m³ Sector 11 Faridabad had the worst air during this monsoon in the NCR (See *Graph 9: Pollution at hotspots during monsoon*).

From this list of 35 recognized and emerging hotspots only three locations (Mayapuri, Okhla Phase 2, and Sanjay Nagar) had their summer average below the regional average of 75 µg/m³.

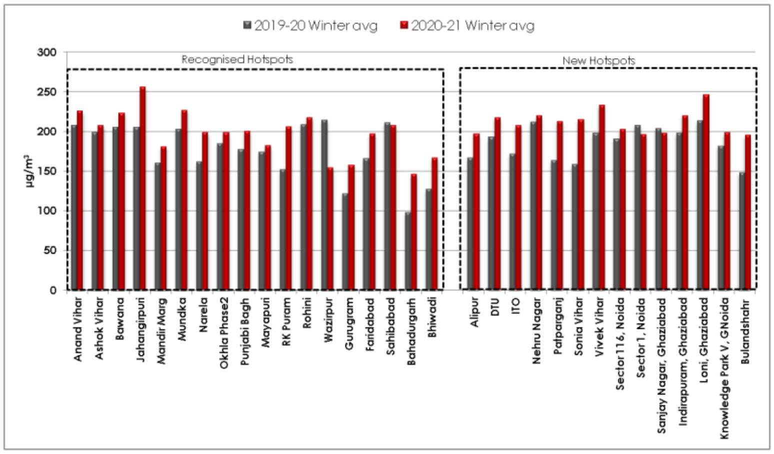
Earlier in the winter 16 of 18 recognized hotspot registered worsening of air (See Graph 10: Winter pollution at hotspots). Two hotspots that showed improvement were Wazirpur and Sahibabad.

Graph 9: Pollution at hotspots during monsoon



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 monsoon. 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 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

6. Trend in $PM_{2.5}$ concentration in Indo Gangetic plain

Indo Gangetic plain (IGP) wide phenomena: Winter is problematic throughout the IGP. Tracking all the 67 monitored cities in the region makes it very clear that air quality dips to poor and worse categories as the monsoon retreats. For most of the northern plains from Punjab to central UP, the start of bad air quality days is almost perfectly synchronized. Eastern plains witness the onset of pollution almost 3-4 weeks later. It is interesting to note that air cleans up in Punjab much earlier than rest of IGP, while pollution lingers on longer in NCR and adjoining western UP.

In the lower IGP (Bihar and West Bengal) cleaning of air starts earlier than NCR. General observation form the data is that Northern Plains (up till central UP) are much severely impacted farm stubble fire smoke during the start of winter season but high levels seen later in the season are due to inversion and local pollution. Meanwhile, winter build-up in eastern plains is driven almost exclusively by inversion and local pollution with limited impact of farm stubble fires. (See *Graph 11: Heatmap of air quality in IGP cities (1.1.2019 to 15.10.2021)*).

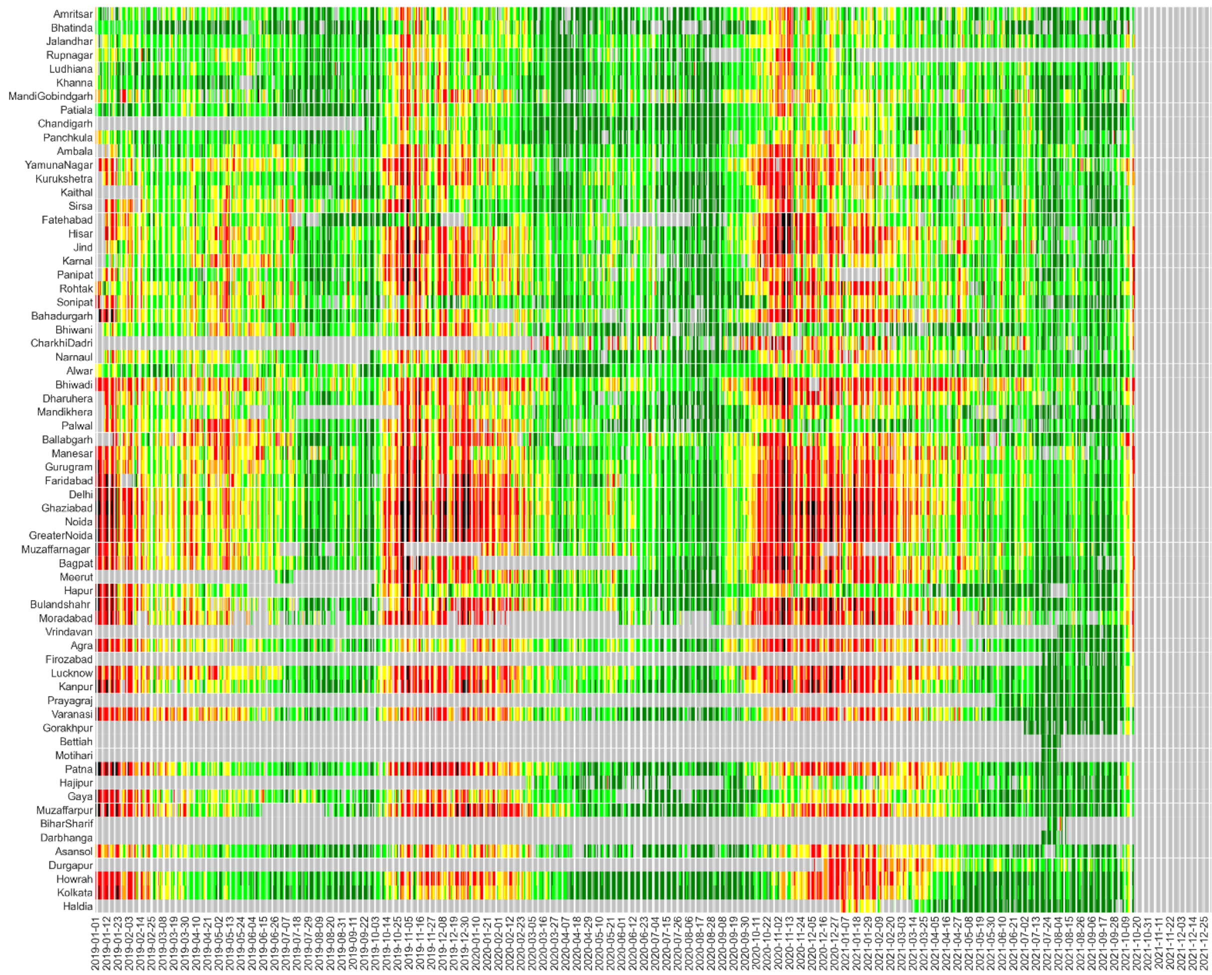
Monsoon season average is a good indicator of extent of local pollution among cities. The weather conditions actively wash down pollution. Therefore, cities reporting higher seasonal averages ought to have bigger local pollution problem. Therefore, it is no a surprise that industrial towns of Bhiwadi, Moradabad, and Yumuna Nagar are at the bottom of the list of least polluted cities in IGP during this monsoon season. It is interesting to note that cities in Delhi-NCR and its adjoining region are also concentrated at the bottom third of the list, indicating problem of local pollution. In fact, within Delhi there are locations like Anand Vihar that report as bad air as Bhiwadi the worst city on the list (See *Annexure 1: Seasonal $PM_{2.5}$ averages of IGP cities*).

Bhatinda and Haldia were the cleanest cities in IGP during this monsoon season.

Also despite the heavier than usual monsoon many cities in IGP actually recorded increase in PM2.5 level this monsoon compared to last monsoon. Bhiwani (16 per cent), Narnaul (14 per cent), Rohtak (10 per cent), Kolkata (9 per cent), Gaya (6 per cent), and Sirsa (5 per cent) saw increase of over 5 per cent.

Most improvement was noted in Charkhi Dadri (25 per cent), Mandi Gobindgarh (20 per cent), Agra (20 per cent), Fatehabad (17 per cent), Lucknow (17 per cent), Meerut (16 per cent), Bulandshahr (13 per cent) and Bagpat (12 per cent). (See annex 1: Seasonal PM2.5 averages of IGP cities).

Graph 11: Heatmap of air quality in IGP cities (1.1.2019 to 15.10.2021)



Note: Average $PM_{2.5}$ concentration is based on mean of daily values recorded at all CAAQM stations in the city. Cell colour is based on the official colour-scheme of AQI sub-categories.
Source: CSE analysis of CPCB's real time air quality data

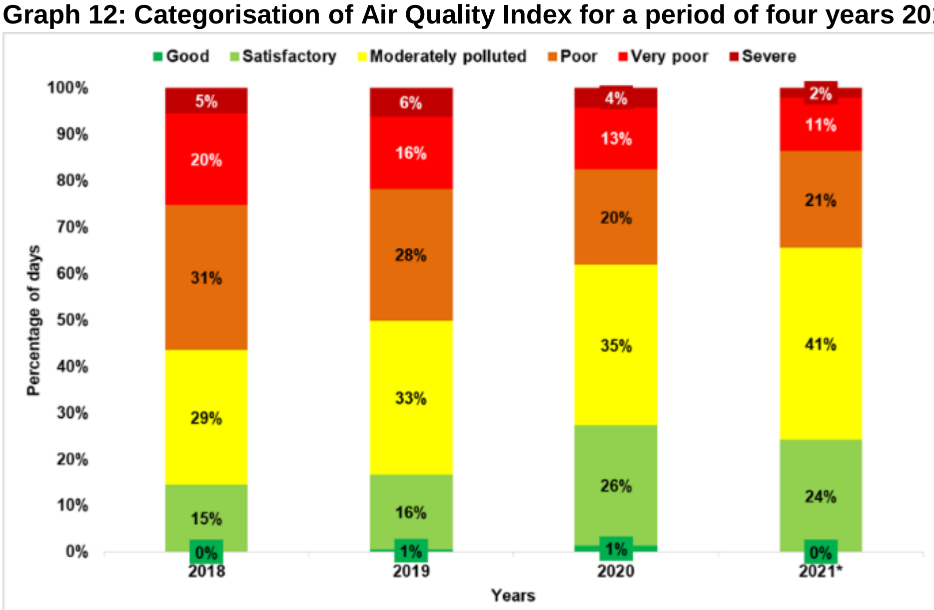
7. What is composite Air Quality Index (AQI) signaling in Delhi

In addition to the analysis of PM2.5 concentration as a key indicator of change in air quality, an additional effort has also been made to understand the trend in the daily reporting of Air Quality Index (AQI) in Delhi. The general public follows the AQI as this is a tool for communication of air quality status. It translates complex air quality data (concentrations) of various pollutants into a single number (index value), nomenclature and colour. This classifies the air quality as Good, Satisfactory, Moderately polluted, Poor, Very Poor, and Severe. Each category is decided based on ambient concentration values of air pollutants and their likely health impacts. AQI for each pollutant type is computed independently, and these are called sub-index. The highest AQI among all the pollutant types becomes the main AQI and the pollutant type associated with it is labelled as predominant pollutant at the location. The sub-index are expected to consider all regulated pollutants (PM10, PM2.5, NO2, SO2, CO, O3, NH3, and Pb (upto 24-hours and 8-hours for CO and O3). The daily AQI is reported based on the lead pollutant of the day with highest sub-index. This kind of represents the composite air quality of the city.

However, all the eight pollutants may not be monitored at all the locations. Therefore, the overall AQI is calculated only if data is available for a minimum of three pollutants, out of which one should necessarily be either PM2.5 or PM10. Else, data is considered insufficient for calculating AQI. Similarly, a minimum of 16 hours of data is considered necessary for calculating the sub-index. AQI thus reflects the composite air quality of the city.

CSE's analysis of the daily AQI for the period 2018-2021 (until October 15th) shows that number of 'good' days are still very negligible in Delhi. From zero good days in 2018 about three days in 2019 and five days in 2020 have been recorded. There are none so far in 2021. However, there has been a steady increase in the number of 'satisfactory' and 'moderately polluted' days. On the other hand, the number of days in 'very poor' and 'severe' categories, have somewhat decreased over the past four years indicating stabilization and even bending of the curve. The data for the year 2021 is till 15 October, so the worst days are yet to come. (See *Graph 12: Categorisation of Air Quality Index for a period of four years 2018–2021*).

Graph 12: Categorisation of Air Quality Index for a period of four years 2018–2021



Note: Data for 2021 is till 15 October
Source: CSE's analysis based on CPCB AQI data

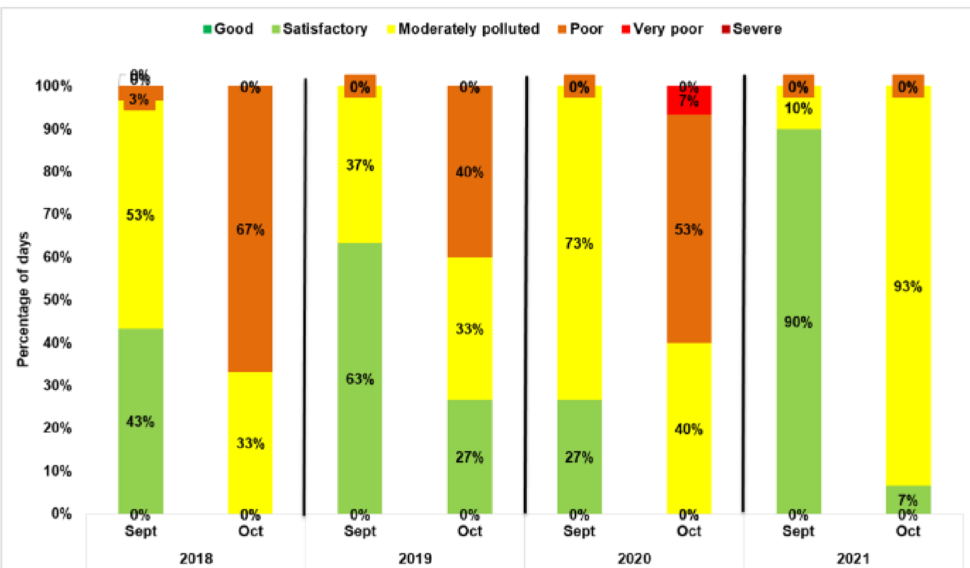
The AQI during pre-winter months and the changing pattern of lead pollutant: The months of September and October which is the transition period from monsoon to winter show that the number of days in 'satisfactory' category has increased from 43 per cent in 2018 to 90 per cent in 2021. In 2020 however, this came down to 27 per cent. A similar pattern is seen in the 'moderately polluted' category.

In September 2021 has not recorded any 'poor' day. In October, 2021, the number of days in 'poor' category has reduced from 67 per cent in 2018 to zero per cent in 2021. In 2020, there was a slight increase with 53 per cent of days in 'poor' category. (See *Graph 13: Month-wise categorisation of Air Quality Index for September and October (till 15th) from 2018–2021*)

Normally particulate pollution dominate the daily pollution in Delhi. However, during pre-winter months primarily due to the wash out effect of rains, other gaseous pollutants have often became the lead pollutants along with particulate pollution of the day. In 2021, out of the 45 days (September 1 –October 15), division of the days based on the prominent pollutant are as follow.

- PM10 = 5 days
- PM2.5 + PM10 = 10 days
- PM10 + O3 = 1 day
- PM10 + CO = 15 days
- PM10 + CO + O3 = 5 days
- PM10 + PM2.5 + O3 = 4 days
- PM10 + PM2.5 + CO = 4 days
- PM2.5 + CO + O3 = 1 day

Graph 13: Month-wise categorisation of Air Quality Index for September and October (till 15th) from 2018–2021



Note: Data for 2021 is till 15 October
Source: CSE's analysis based on CPCB AQI data

Annexure: Seasonal $PM_{2.5}$ averages of IGP cities

Rank	City	Monsoon 2021	Summer 2021	Winter 2020
1	Bhatinda	15	43	71
2	Haldia	18	23	85
3	Gorakhpur	20	-	-
4	Siliguri	21	71	106
5	Varanasi	23	62	125
6	Howrah	24	48	109
7	Kolkata	25	45	103
8	Firozabad	25	-	-
9	Prayagraj	25	29	
10	Sonipat	26	51	91
11	Patiala	26	43	73
12	Vrindavan	27	-	-
13	Muzaffarpur	27	60	123
14	Patna	27	68	127
15	Chandigarh	28	36	58
16	Mandikhera	28	50	84
17	Agra	28	74	149
18	Gaya	28	44	70
19	Meerut	28	69	161
20	Asansol	29	54	98
21	Palwal	29	36	49
22	Kanpur	29	55	166
23	Fatehabad	30	53	147
24	Alwar	30	40	56
25	Hapur	31	27	63
26	Khanna	31	42	66
27	Bulandshahr	32	75	198
28	Hajipur	32	63	58
29	Kaithal	33	37	100
30	Sirsa	33	57	82
31	Bagpat	34	80	177
32	Lucknow	35	69	168
33	Greater Noida	35	72	204
34	Noida	36	70	203
35	Karnal	36	50	96
36	Panipat	36	57	101
37	Bhiwani	36	24	45
38	Amritsar	37	46	73
39	Panchkula	37	42	77
40	Narnaul	37	61	102
41	Jalandhar	38	49	69
42	Ludhiana	38	49	71
43	Kurukshetra	39	55	122
44	Bahadurgarh	40	80	151
45	Ghaziabad	41	88	229
46	Ambala	41	48	92
47	Delhi	41	78	192
48	Charkhi Dadri	42	61	125
49	Faridabad	42	78	160
50	Muzaffarnagar	42	57	141
51	Dharuhera	43	70	155
52	Hisar	43	77	156
53	Jind	43	74	156
54	Mandi Gobindgarh	43	64	83
55	Ballabgarh	44	67	112
56	Durgapur	44	75	136
57	Gurugram	44	73	157
58	Rohtak	47	72	154
59	Manesar	51	91	128
60	Yamuna Nagar	52	68	133
61	Moradabad	53	93	183
62	Bhiwadi	56	119	168
-	Rupnagar	-	-	72

Note: Seasonal value is based on average of 24hr averages in the season. Minimum 75 per cent data completeness is required in each season to assign a valid seasonal value. Cities with multiple monitoring station, average of all stations meeting the data completeness requirements in all three season is used to represent the city. Monsoon 2021 is 1.7,2021 to 14.10.2021; Summer 2021 is 16.2.2021 to 30.6.2021; Winter 2020 is 15.10.2020 to 15.2.2021.
Source: CSE analysis of CPCB's real time air quality data

First smog episode of the season: Decoding this year's smog

Anumita Roychowdhury and Avikal Somvanshi

Centre for Science and Environment, New Delhi, November 10, 2021

The first severe smog episode has hit Delhi and the National Capital Region (NCR) and is expected to last for another two days. The smog has engulfed the entire Indo-Gangetic Plain, shows a new analysis by Centre for Science and Environment (CSE). The region is in the grip of a public health emergency and requires urgent and drastic measure to shave off the pollution peak.

Predictably, the season's first episode has been triggered by the combined effect of unfavourable weather conditions (cool and calm winds and inversion), stubble burning and firecrackers. But even though the seasonal smog in Delhi is intense, the average daily contribution of smoke from farm stubble fires from the middle of October to November 8, 2021 has been the lowest in last four years. But since November 6, its contribution has peaked to reach 48 per cent on November 7, and it is still elevated.

While very high concentrations of PM2.5 have hogged attention, the levels of gases – ozone, CO or NO2 -- have remained elevated during this smog episode. Also, the ratio of SO2 to NO2 increased on Diwali night indicating increased pollution load from firecrackers. The PM2.5 concentration on Diwali night (8 PM to 8 AM) has been the most intense since 2017.

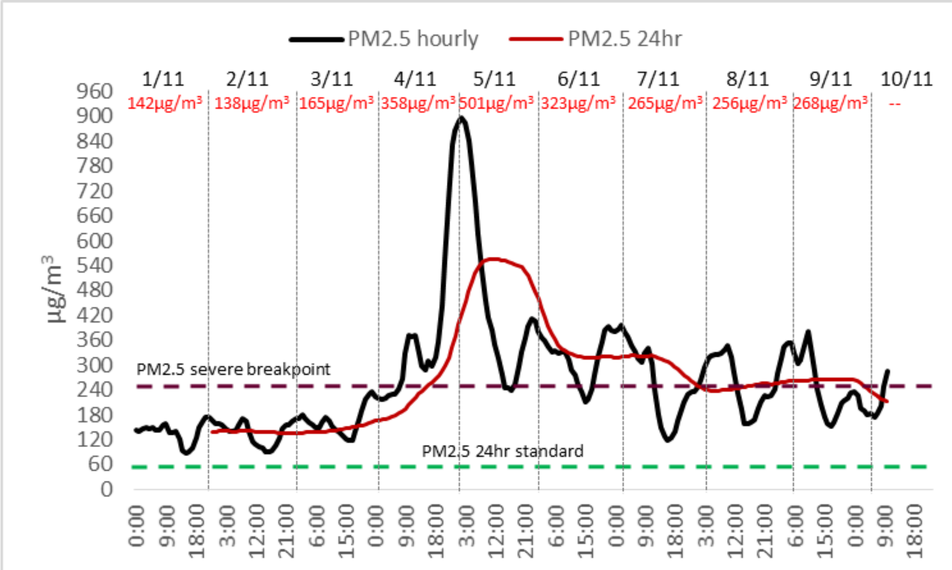
This analysis is based on the real time data available from the current working air quality monitoring stations in Delhi-NCR and the larger Indo-Gangetic Plain. For this analysis, a huge volume of data points have been cleaned and data gaps addressed, based on the USEPA methodology. This analysis covers 156 continuous ambient air quality monitoring stations (CAAQMS) spread across 67 cities in Punjab, Chandigarh, Haryana, Delhi, Rajasthan, Uttar Pradesh, Bihar and West Bengal. Meteorological data for the analysis has been sourced from the Palam weather station of India Meteorological Department (IMD). Fire count data has been sourced from NASA's Fire Information for Resource Management System, specifically, the Visible Infrared Imaging Radiometer Suite (VIIRS) product has been used. Estimates of contribution of farm stubble fire smoke to Delhi's air quality has been sourced from Ministry of Earth Science's System of Air Quality and Weather Forecasting and Research (SAFAR).

Key highlights

Season's first smog: PM2.5 concentration in Delhi skyrocketed beyond 250 µg/m^3 (breakpoint for severe AQI category) on Nov 4th and is still hovering over it seven days on. It hit its peak concentration of 501 µg/m^3 on 5th November then gradually receded to 256 µg/m^3 on 8th November. Since it has started to climb again and stood at 264 µg/m^3 on 9th November. Hourly levels are again rising on 10th of November (checked up to 10AM) and if weather conditions don't improve even 10th November might end-up with 24-hr average higher than 250 µg/m^3. It should be noted that CSE assessment is based on monitoring in Delhi alone and daily average is considered from midnight to midnight, which is different from CPCB's methodology. CPCB for its trend counter used for GRAP uses average of all stations in Delhi and NCR towns, while CPCB AQI bulletin uses 4PM to 4PM as measure of its daily value.

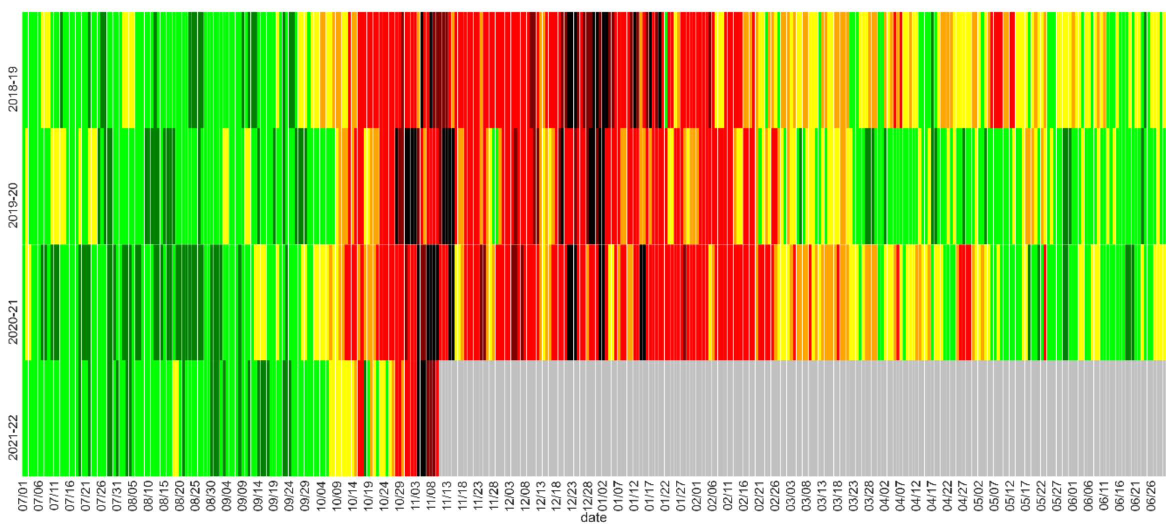
Compared to the first smog episode of previous four years, current smog has matched the duration of first smog of 2018 and 2020 season both lasted 6 days. If the conditions don't improve it might over take 2019 smog lasted 8 days. Average intensity of the smog this year so far was 329 µg/m^3 per day, which is lower than 2020 smog (by 7 per cent) and 2019 smog (by 3 per cent). It is more intense than 2018 smog (about 9 per cent). Lingering on of this year's smog for longer duration despite relatively windier local conditions might be due to lack of pollution control measures in the city this year (see *Graph 1: Hourly movement of PM2.5 in Delhi during 2021 smog*).

Graph 1: Hourly movement of PM2.5 in Delhi during 2021 smog



Note: Average $PM_{2.5}$ concentration is based on mean of daily values recorded at 39 CAAQM stations in the city that have adequate data. 24-hr average is based on midnight to midnight.
Source: CSE analysis of CPCB's real time air quality data

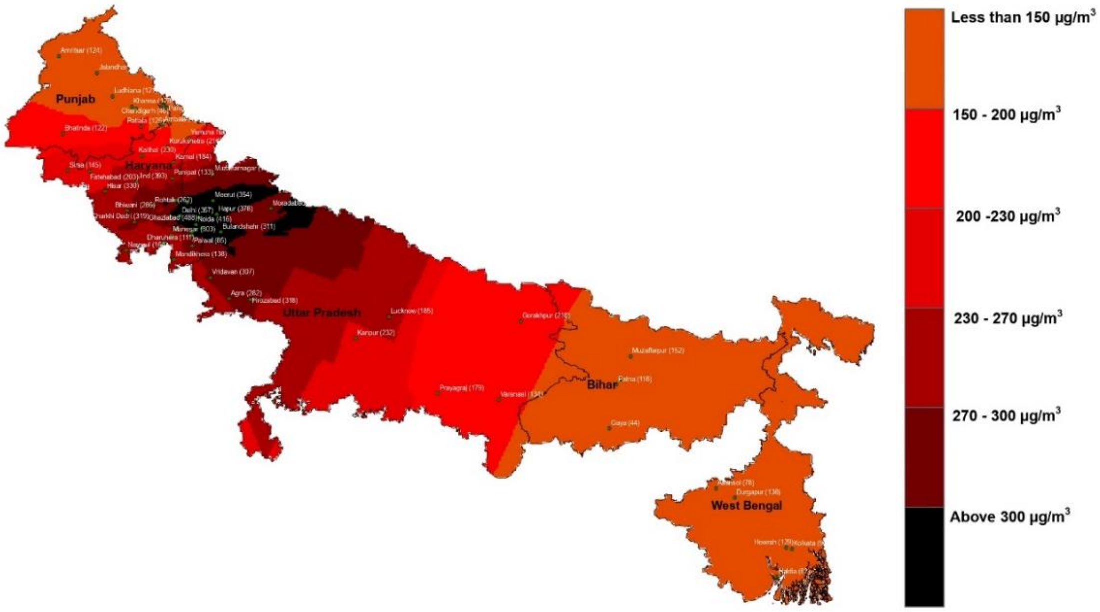
Graph 2: PM2.5 heatmap of Delhi (2018-21)



Note: Average $PM_{2.5}$ concentration is based on mean of daily values recorded at 36 CAAQM stations in the city that have adequate data for all four years. Cell colour is based on the official colour-scheme of AQI sub-categories.
Source: CSE analysis of CPCB's real time air quality data

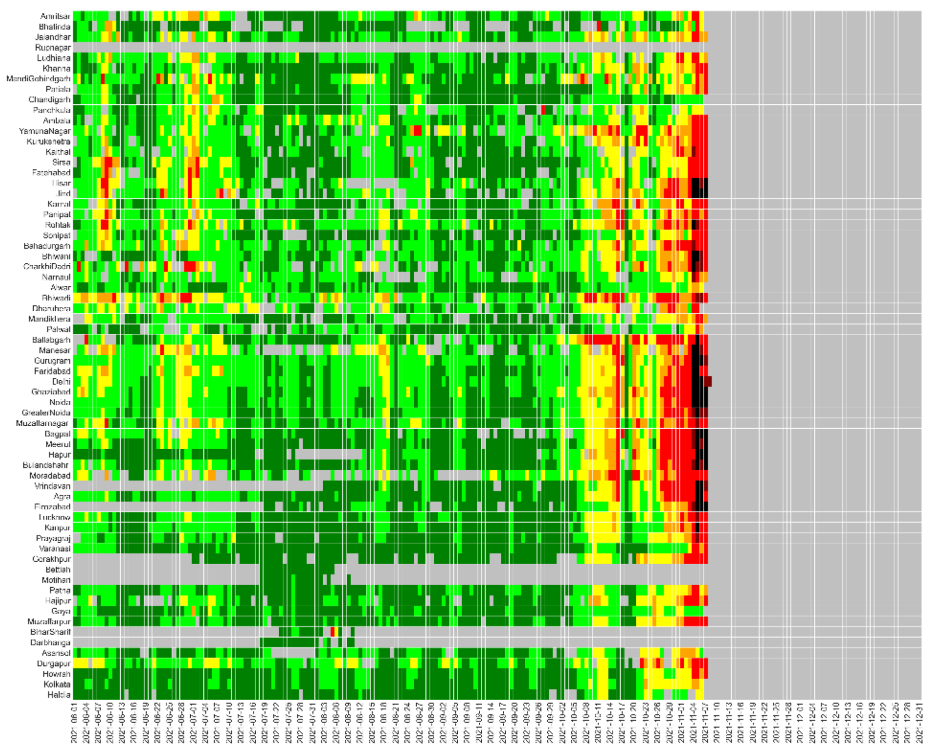
Extent of the smog: PM2.5 levels increased across all IGP cities on Diwali night as per the expectation but lingering of it for multiple days to develop into a smog episode only happened in cities Delhi-NCR and western UP. Hisar and Jind marks the northern extent of the smog while southern extent is Agra and Firozabad. Epicenter of this was Ghaziabad and Noida where daily levels reached 635 µg/m^3 and 601 µg/m^3 respectively. Smog in the rural districts of Bhiwani, Charki Dadri, Hisar and Jind in western Haryana exhibits distinct behavior from the urban centers east of them. Their peak happened on the day of Diwali instead of the day after Diwali and lesser daily fluctuation in concentrations. More research is needed to characterize smog in rural regions (see *Map 1: Smog map of IGP (4-7 November, 2021); Graph 3: PM2.5 heatmap of IGP; Table 1: Smog levels in the cities of IGP (4-7 November, 2021)*).

Map 1: Smog map of IGP (4-7 November, 2021)



Note: Average $PM_{2.5}$ concentration is based on mean of daily values recorded at CAAQM stations in the city that have adequate data. Values are based on average daily concentration of four days 4-7 November, 2021.
Source: CSE analysis of CPCB's real time air quality data

Graph 3: PM2.5 heatmap of IGP



Note: Average $PM_{2.5}$ concentration is based on mean of daily values recorded at 36 CAAQM stations in the city that have adequate data for all four years. Cell colour is based on the official colour-scheme of AQI sub-categories.
Source: CSE analysis of CPCB's real time air quality data

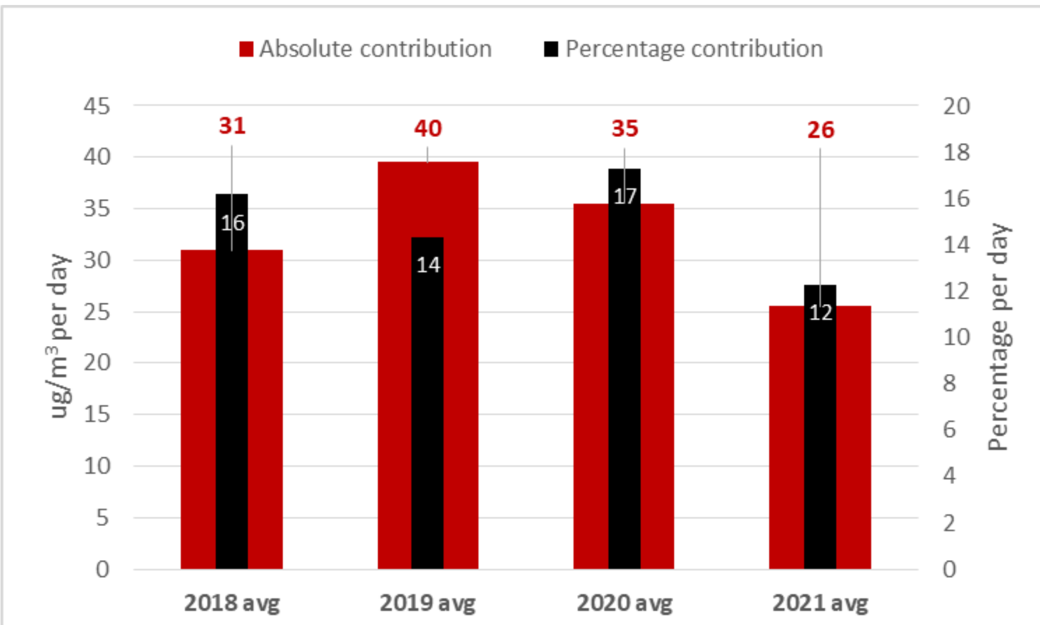
Table 1: Smog levels in the cities of IGP (4-7 November, 2021)

City	Smog intensity (ug/m3 per day)	City	Smog intensity (ug/m3 per day)
Ghaziabad	488	Lucknow	185
Noida	416	Karnal	184
Jind	393	Prayagraj	179
Hapur	378	Narnaul	164
Gurugram	371	YamunaNagar	155
Bagpat	370	Ambala	153
Delhi	357	Muzaffarpur	152
Meerut	354	Sirsa	145
Greater Noida	341	Mandi Gobindgarh	142
Hisar	330	Mandikhera	138
Faridabad	322	Durgapur	138
Charkhi Dadri	319	Varanasi	134
Firozabad	318	Panipat	133
Bulandshahr	311	Howrah	129
Vrindavan	307	Jalandhar	129
Manesar	303	Khanna	128
Bhiwani	286	Patiala	125
Agra	282	Hajipur	125
Rohtak	262	Amritsar	124
Bhiwadi	251	Bhatinda	122
Ballabgarh	246	Ludhiana	121
Bahadurgarh	246	Patna	118
Kanpur	232	Dharuhera	111
Kaithal	230	Kolkata	96
Gorakhpur	218	Palwal	85
Kurukshetra	217	Haldia	82
Sonipat	209	Asansol	78
Moradabad	205	Alwar	72
Fatehabad	203	Panchkula	70
Muzaffarnagar	196	Chandigarh	46
		Gaya	44

Note: Average $PM_{2.5}$ concentration is based on mean of daily values recorded at CAAQM stations in the city that have adequate data. Values are based on average daily concentration of four days 4-7 November, 2021.
Source: CSE analysis of CPCB's real time air quality data

Farm stubble fire smoke is lower this season: On an average contribution of smoke to Delhi's daily PM2.5 during middle of October to November 8th has been the lowest in last 4 years. So far it has recorded on an average 12 per cent per day in contrast to 17 per cent per day in 2020, 14 per cent per day in 2019, and 16 per cent per day in 2018 (as reported by SAFAR). If converted to absolute concentration then per day contribution of smoke stood at 26 µg/m^3 this year so far compared to 35 µg/m^3 in 2020, 40 µg/m^3 in 2019, and 31 µg/m^3 in 2018. However, peak contribution of smoke to Delhi's PM level was recorded on 7th November when it hit 48 per cent (see *Graph 4: Average contribution from farm stubble fire smoke to Delhi's air*). This the second highest daily contribution percentage recorded since such estimation was started by SAFAR in 2018. The highest single day contribution percentage has been 58 per cent recorded on 5th November 2018. But this unusually high percentage on 7th November, 2021 didn't spike Delhi's PM2.5 levels as on that day PM2.5 levels came down to 265 µg/m^3 from their 5th November 2021 peak of 501 µg/m^3.

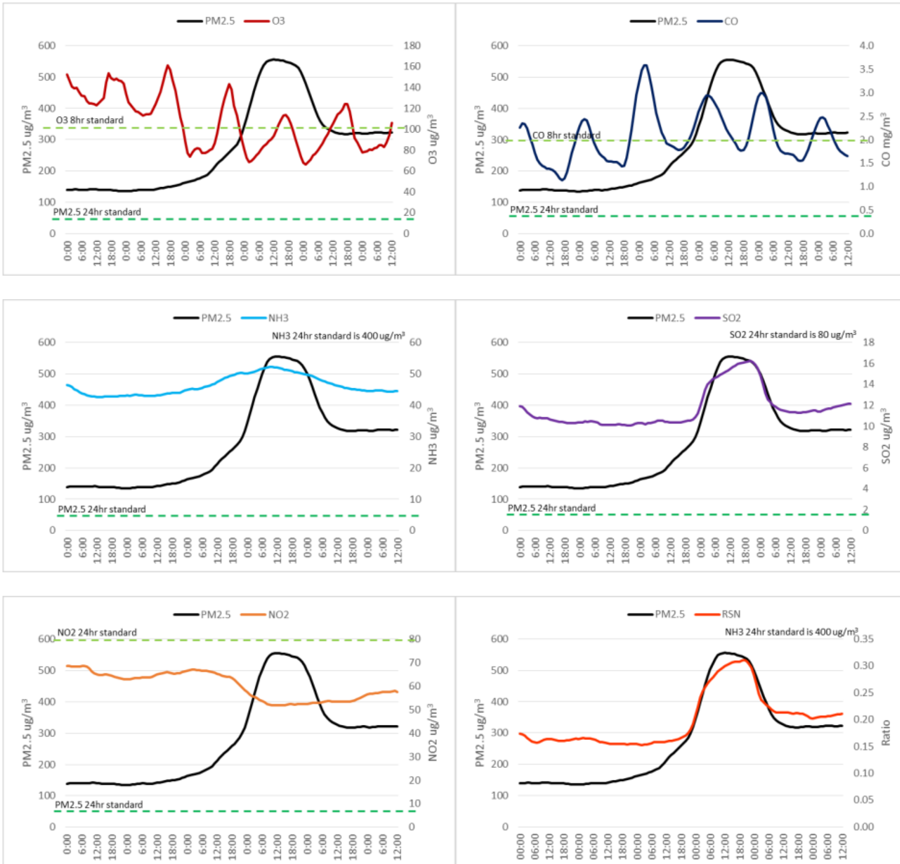
Graph 4: Average contribution from farm stubble fire smoke to Delhi's air



Source: CSE analysis of CPCB's real time air quality data and SAFAR data on farm fire contribution

Other toxic gases during smog episode: During this smog episode ozone levels have continued to breech standard at ozone hotspots in the city even during the peak smog episodes. Levels are even higher pre and post peak smog day. CO is also found to be exceeding the standard through the smog episode. SO2 levels mimic the trend of PM2.5 but it doesn't breech the standard. NO2 bucks the trend and is seen to drop in concerentrations when PM2.5 peaks (see *Graph 5: Relation of PM2.5 level with other pollutants during smog episode (1-8 Nov, 2021)*).

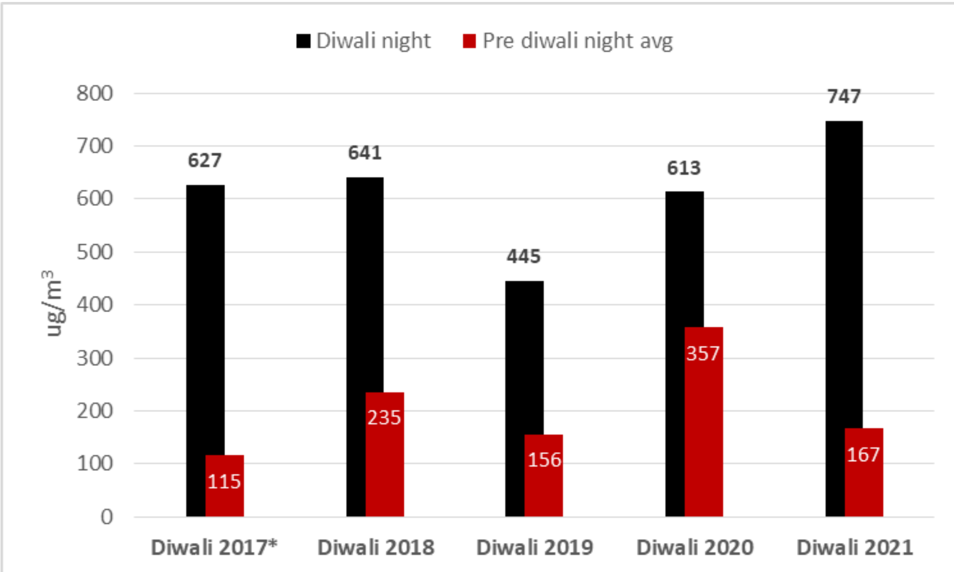
Graph 5: Relation of PM2.5 level with other pollutants during smog episode (1-8 Nov, 2021)



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

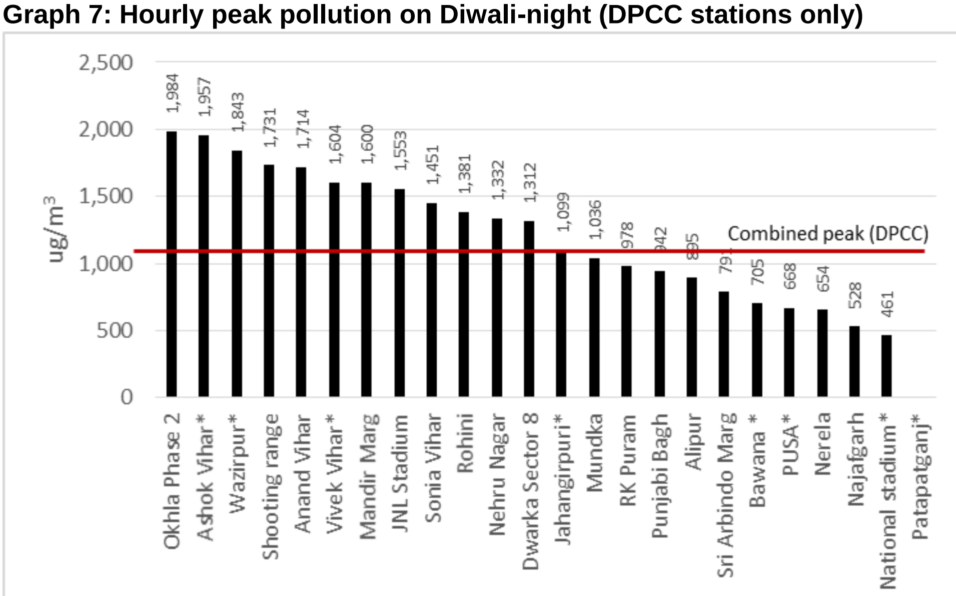
Delhi Worst Diwali night in last 5 year: PM2.5 concentration at the Diwali night (8pm to 8am) was the worst in last five years. The 12-hr night average stood at 747 µg/m^3, 22 per cent higher than 2020 Diwali night. The levels on Diwali night were 4.5 times the average night-time levels recorded in the week preceding Diwali. Please note that this Diwali night value is an undercount as CPCB caps PM2.5 data at 1,000 µg/m^3. It is noted that hourly concentrations can go beyond 1,000 µg/m^3. This year 26 of 38 operational monitoring stations hit the 1,000 µg/m^3 mark. In 2020, 23 out of 38 station had hit the 1000 µg/m^3 mark while in 2019 the number stood at 22 stations. Data on DPCC website show that hourly concentration went as high as 1,984 µg/m^3 at Okhla Phase 2 and 1,957 µg/m^3 at Ashok Vihar. The 12-hr night average for 24 DPCC stations stood at 824 ug/m3 using the uncapped data. This is 9 per cent higher than average computed from CPCB data for same 24 stations (see *Graph 6: PM2.5 levels Diwali-night (8pm-8am) vs average of nights in the week preceding Diwali; Graph 7: Hourly peak pollution on Diwali-night (DPCC stations only)*).

Graph 6: Diwali-night (8pm-8am) PM2.5 levels vs average PM2.5 level at nights in the week preceding Diwali



Note: Average concentration is based on mean of 12hr values recorded at 38 CAAQM stations in the city that have adequate data for all four years. Nighttime is 8pm to 8am. Pre-diwali night average is mean of nighttime levels of seven preceding nights.
* Based on lesser number of stations
Source: CSE analysis of CPCB's real time air quality data

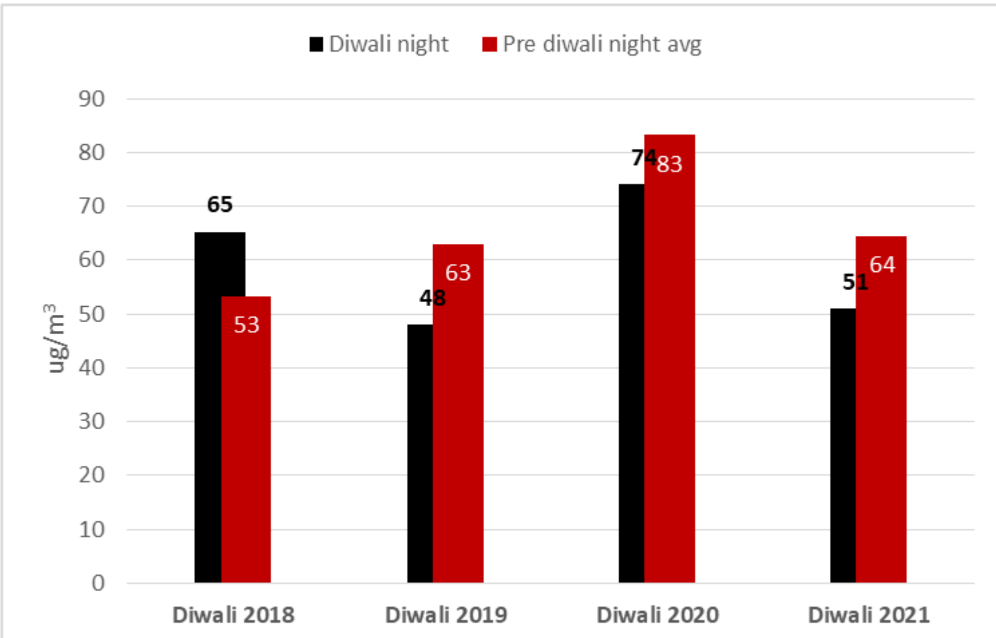
Graph 7: Hourly peak pollution on Diwali-night (DPCC stations only)



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

Diwali traffic shows up as elevated NO2 levels: Diwali night this year had lower NO2 levels compared 2020 Diwali night. NO2 level in last three years have been lower on Diwali night compared to nights preceding it, which is indicative of congestion and high traffic conditions in the city leading to the festival night. And also reflective of less traffic on Diwali night itself. DTU had highest NO2 levels in the city with night-time average of 154 µg/m^3. Dwarka Sector 8 and Anand Vihar with 107 µg/m^3 and 103 µg/m^3 were the other NO2 hotspot on Diwali night. Rohini with just 2 µg/m^3 of NO2 was the least affected area in the city followed by Nerala (5 µg/m^3) and JNL Stadium (10 µg/m^3) (see *Graph 8: Diwali-night (8pm-8am) NO2 levels vs average NO2 level at nights in the week preceding Diwali*).

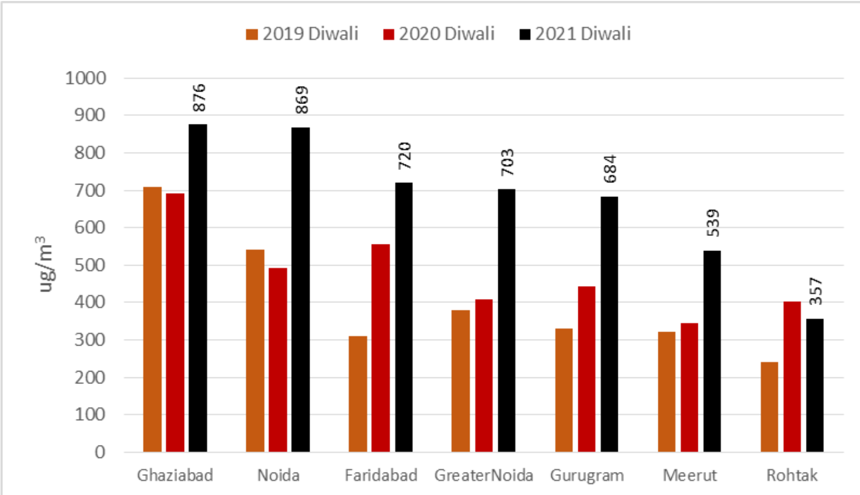
Graph 8: Diwali-night (8pm-8am) NO2 levels vs average NO2 level at nights in the week preceding Diwali



Note: Average concentration is based on mean of 12hr values recorded at 38 CAAQM stations in the city that have adequate data for all four years. Nighttime is 8pm to 8am. Pre-diwali night average is mean of nighttime levels of seven preceding nights.
* Based on lesser number of stations
Source: CSE analysis of CPCB's real time air quality data

This year Diwali night in most NCR cities was dirtiest in last three years: This year Diwali night in most NCR cities was dirtiest in last three years: Ghaziabad had the most polluted Diwali night among NCR cities and towns. With the night average of 876 µg/m^3 it was 26 per cent higher than 2020 Diwali night and 23 per cent higher than 2019 Diwali night. Noida was only marginally better at night average of 869 µg/m^3 with 77 per cent jump from 2020 level. Faridabad at 720 ug/m3, Greater Noida at 703 µg/m^3, Gurugram at 684 µg/m^3 and Meerut at 539 µg/m^3 were not any better. Rohtak was only major NCR city which saw lower pollution level this Diwali compared to previous year, its 357 µg/m^3 was 11 per cent lower than 2020 Diwali night level (see *Graph 9: Diwali night pollution in major NCR cities*).

Graph 9: Diwali night pollution in major NCR cities.



Note: Average concentration is based on mean of 12hr values recorded at CAAQM stations in the city that have adequate data for all three years. Nighttime is 8pm to 8am.
Source: CSE analysis of CPCB's real time air quality data

Act now

The ongoing smog episode is a public health emergency. This requires urgent emergency action on key combustion sources (vehicles, industry, and waste burning) and dust sources (construction and roads) to prevent further trapping of pollution when there is no wind to blow this away. We need pollution-source-wise and hotspot-wise status of action. CSE has called for leveraging this to speed up longer term action for scaling up integrated public transport systems, walking and cycling; eliminate dirty fuels from all industrial units while tightening emissions control measures; and strengthen the municipal systems and infrastructure for segregated collection and recycling of waste.

Another toxic winter: Air pollution crisis in Delhi-NCR

Anumita Roychowdhury and Avikal Somvanshi
Reseach contribution: Sharanjeet Kaur

Centre for Science and Environment, March 29, 2022

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.

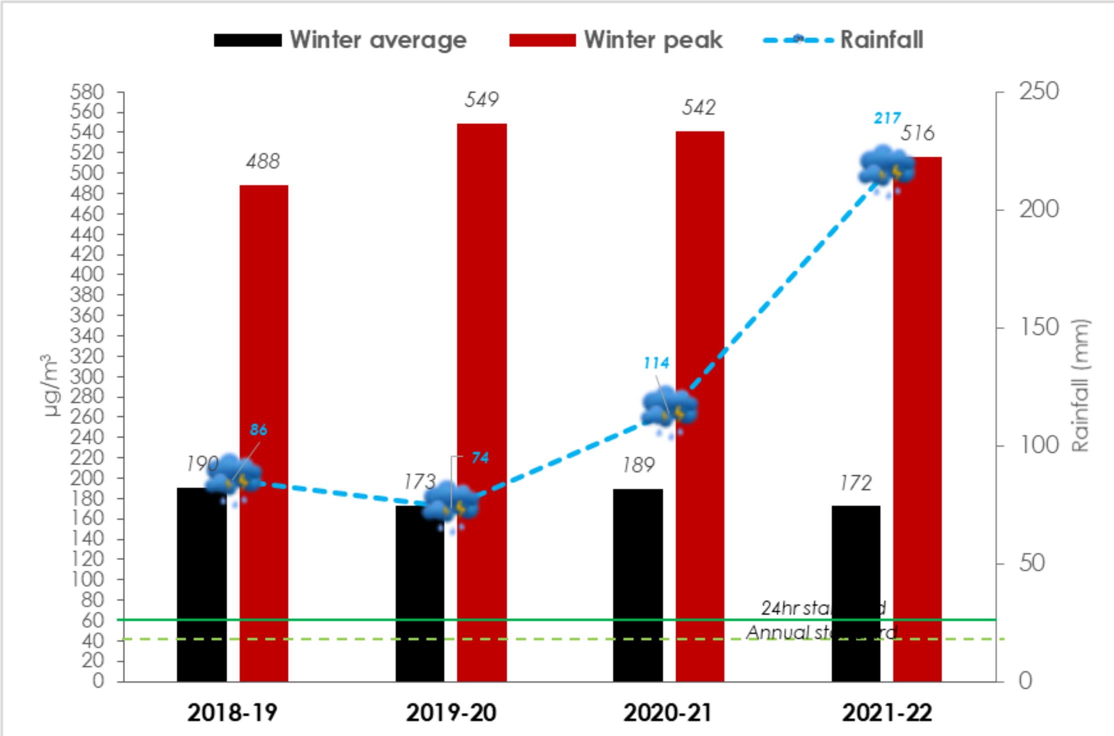
Key highlights

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.

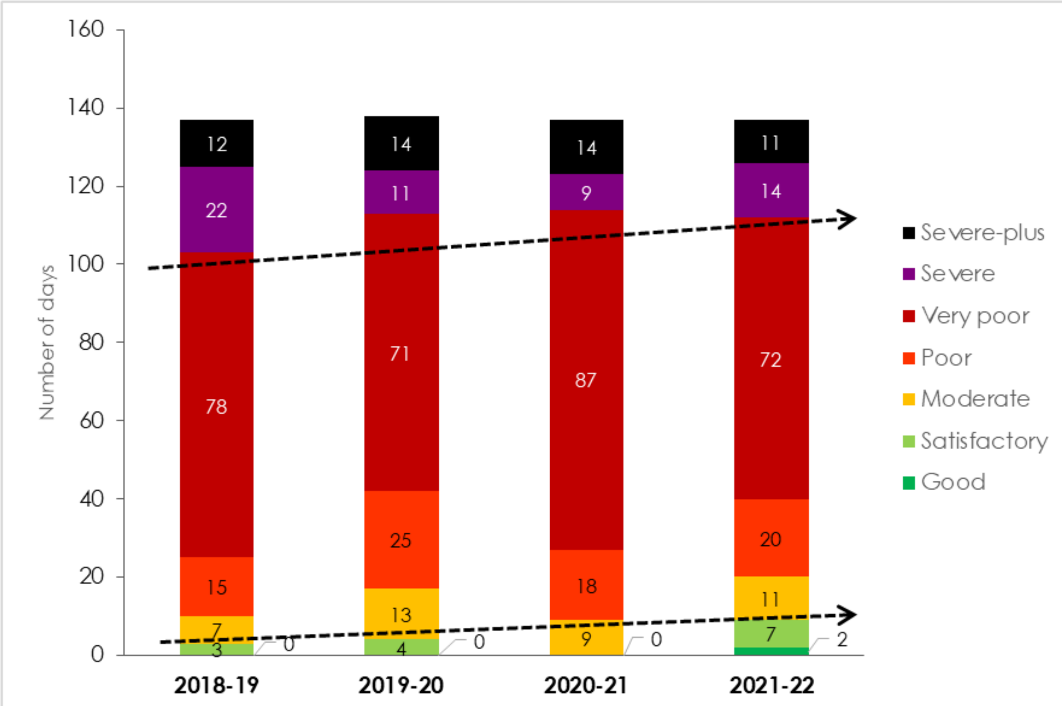
Graph 1: Trend on winter pollution in Delhi



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

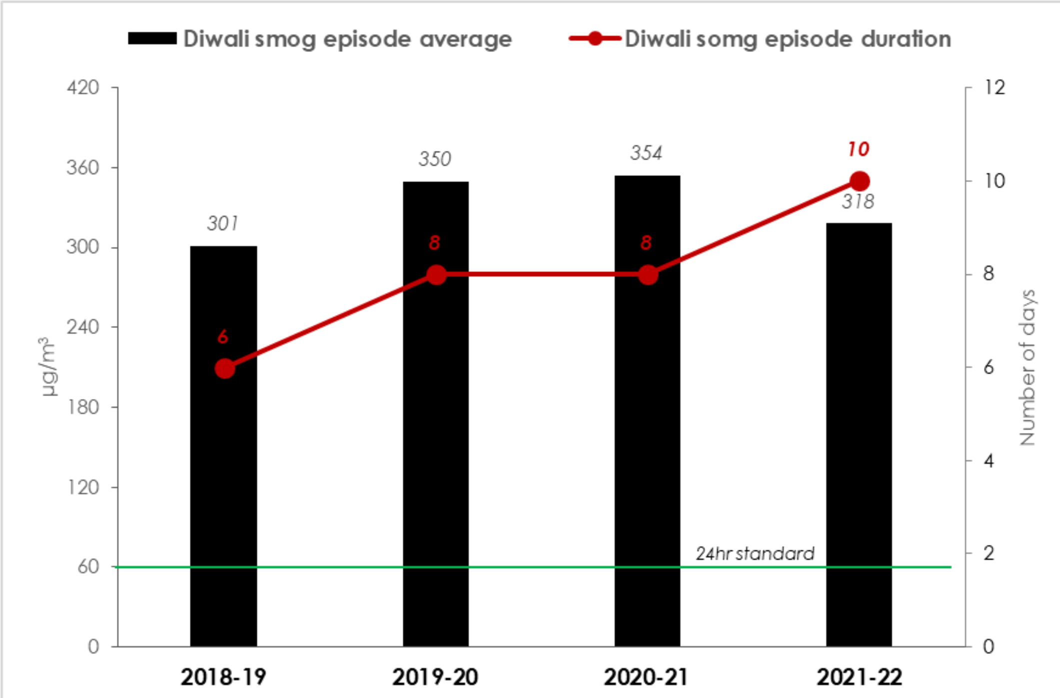


Note: Average $PM_{2.5}$ concentration is based on mean of daily values recorded at 38 CAAQM stations in the city that have adequate data for all four winters.
Source: CSE analysis of CPCB's real time air quality data

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.

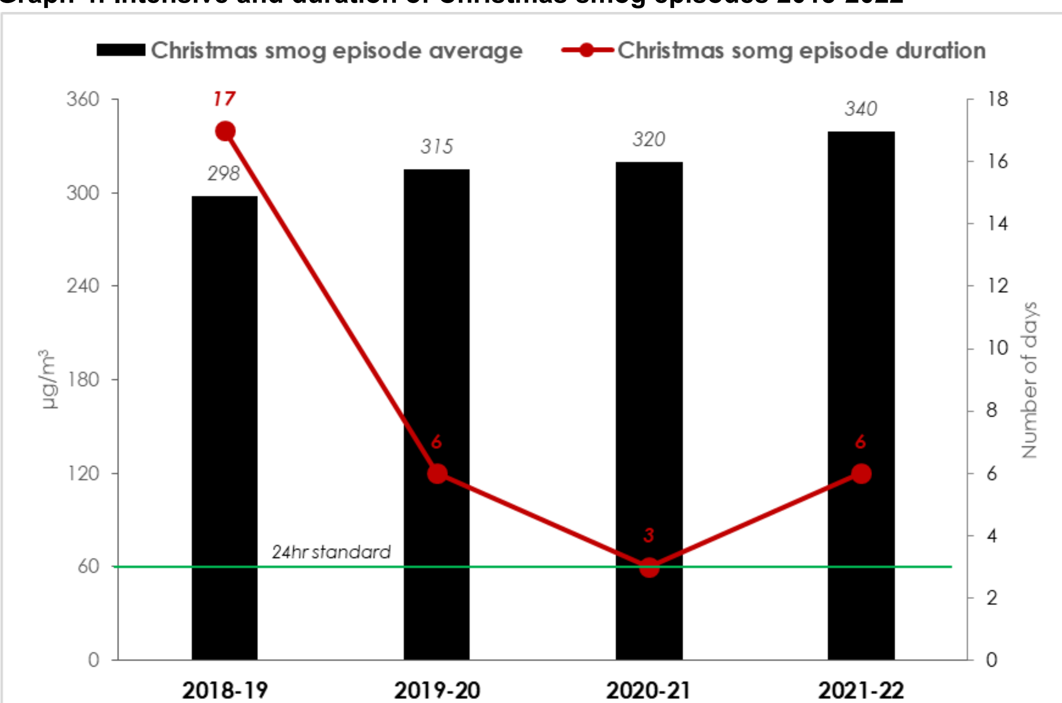
Similarly, the late winter smog this year started on 21st Dec and lasted 9 days with intensity of 340 ug/m3 per day (See *Graph 4: Intensive and duration of Christmas smog episodes 2018-2022*). This was both longer and more intense compared to previous Christmas smog which started 22nd Dec and last only 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

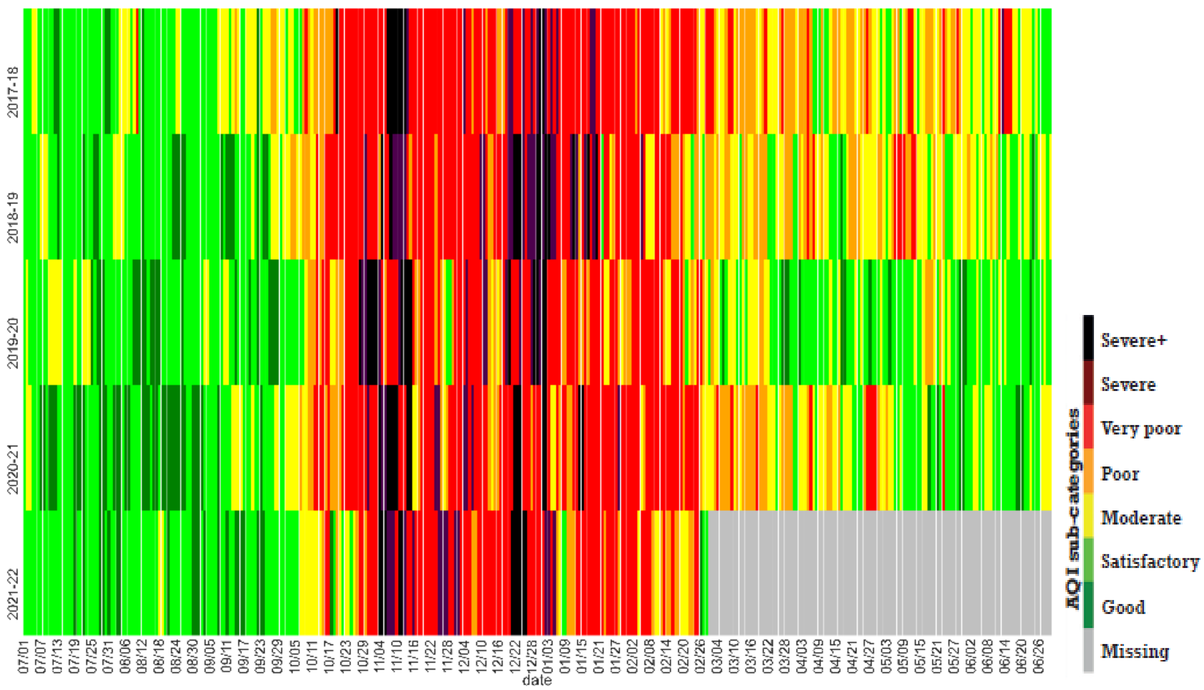
Graph 4: Intensive and duration of Christmas smog episodes 2018-2022



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 4[rd] Nov and lasted 10 days, second started on 25[th] Nov and last 4 days, and third started on 21[st] 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.

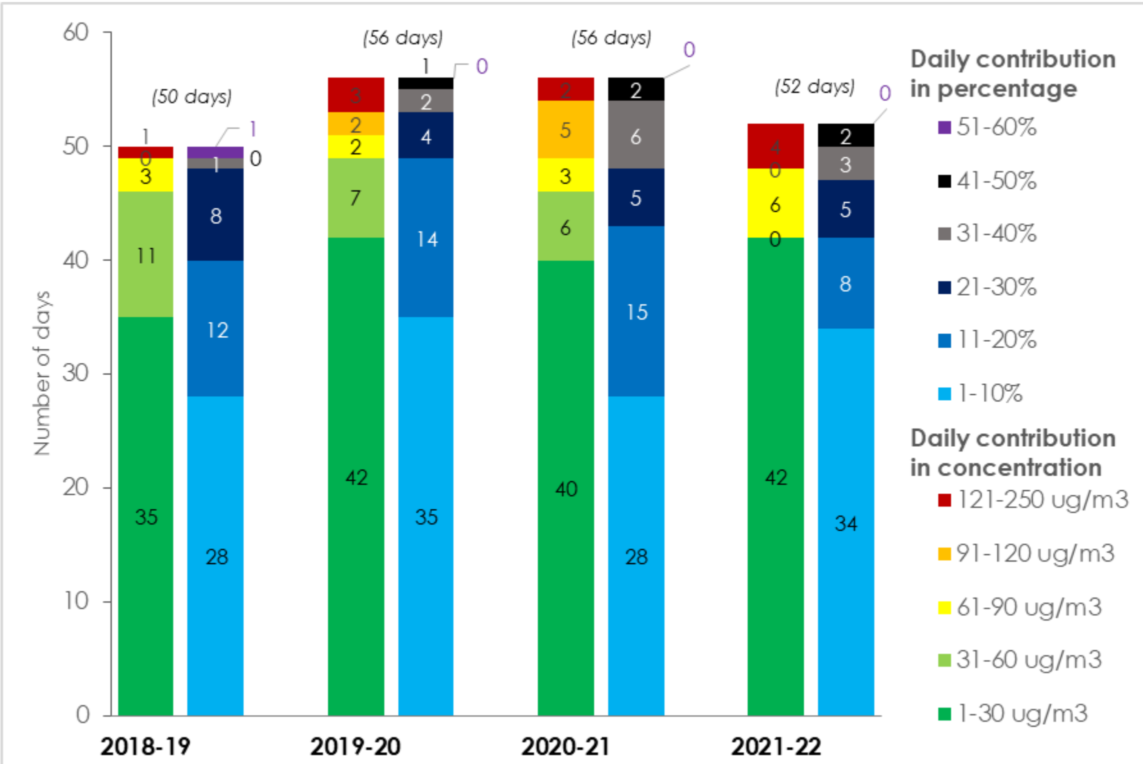
Graph 5: Map of smog episode in Delhi



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.

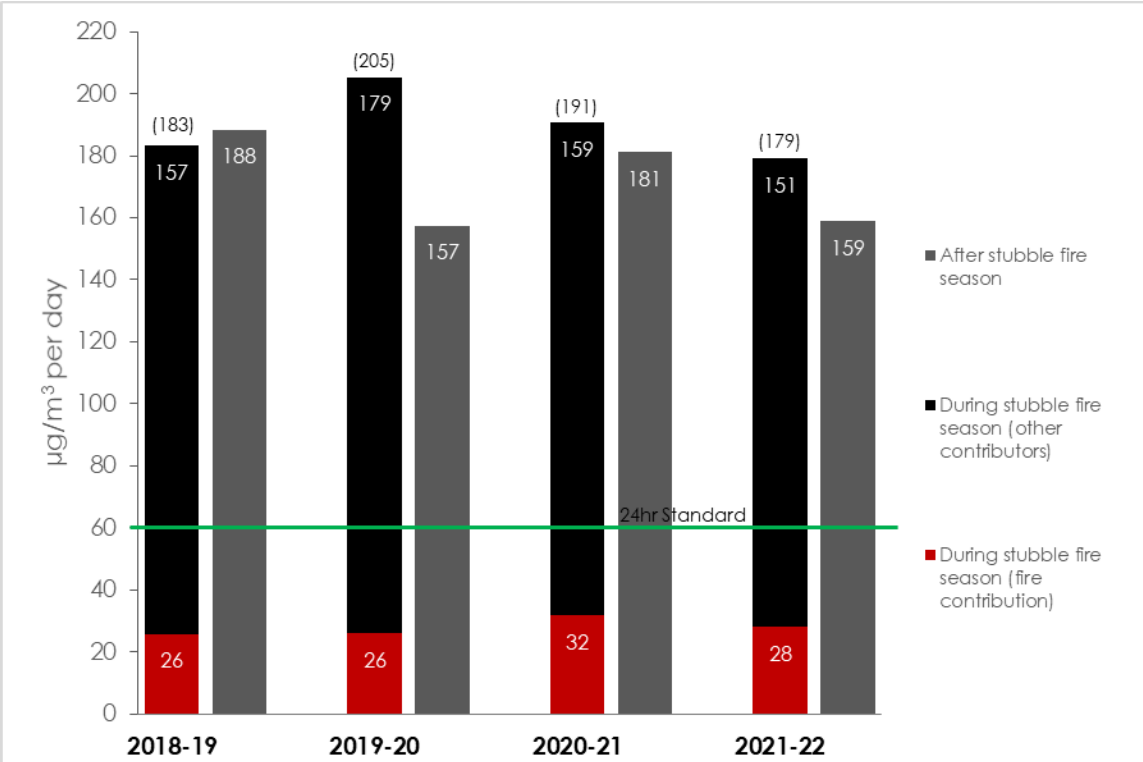
Graph 6: Daily distribution of stubble fire smoke contribution to Delhi's air



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.

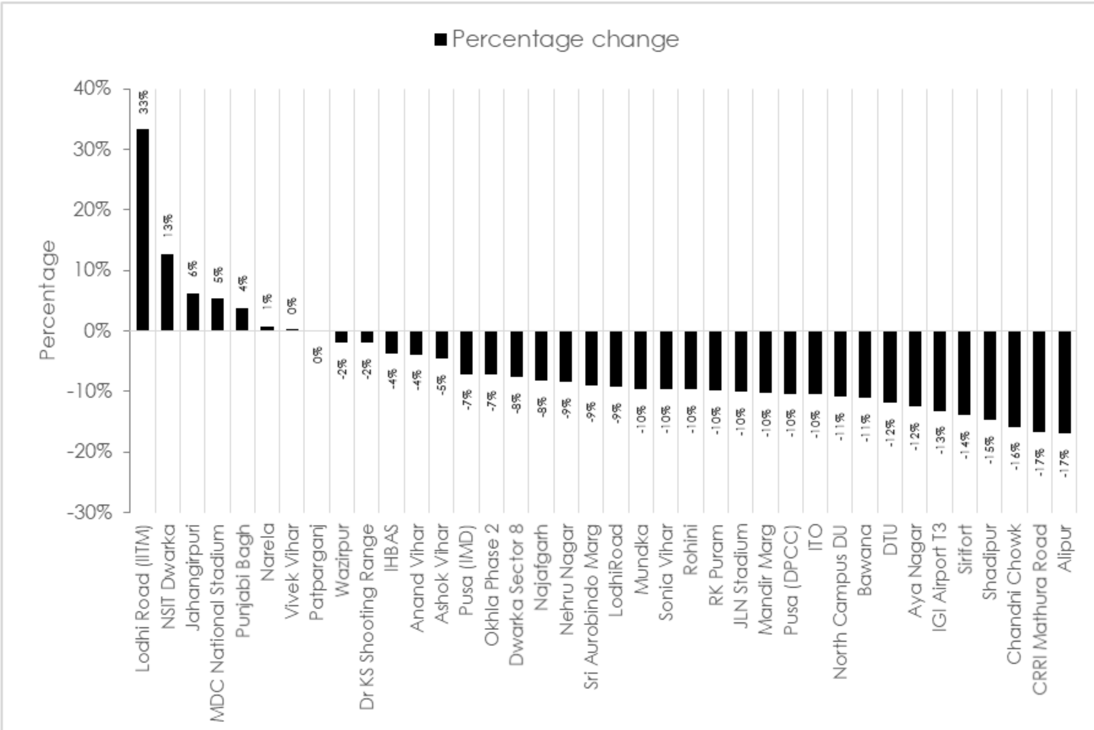
Graph 7: Seasonal distribution of stubble fire smoke contribution to Delhi's air



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

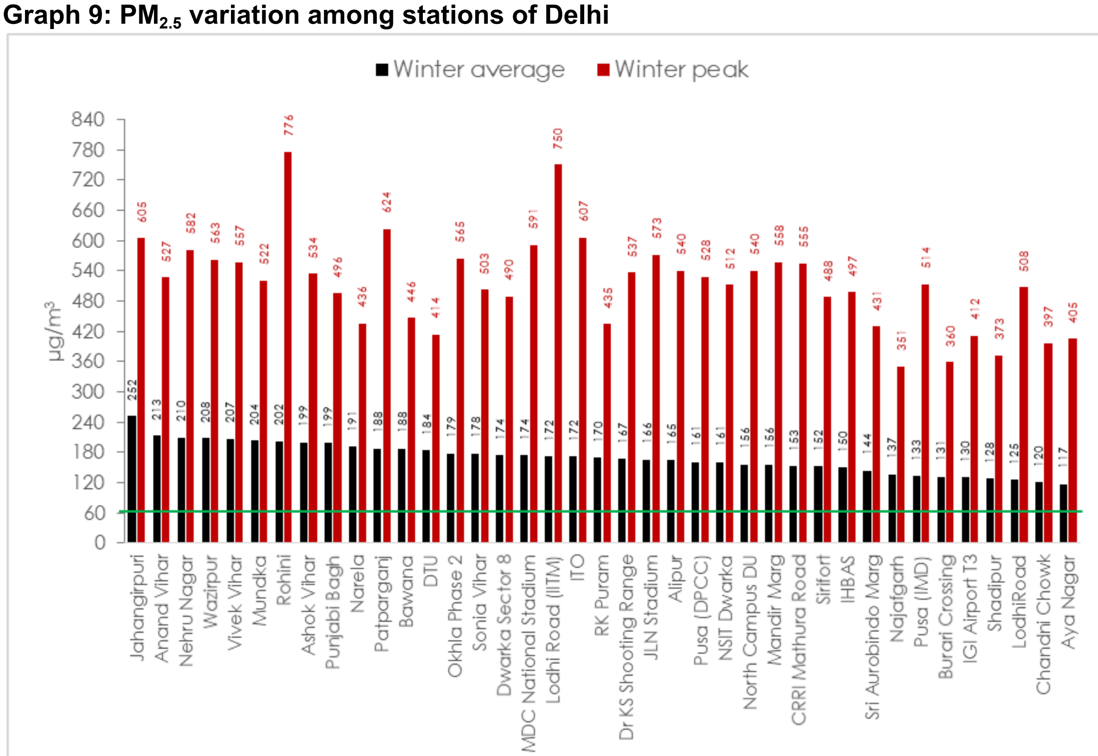
Variation among city's stations remain significant, indicating dominance of local pollution sources, influence of micro climate and level of action: 30 out of 38 stations saw improvement in their seasonal average over last year. Most improvement was noted at Alipur and CRRI Mathura Road which registered 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

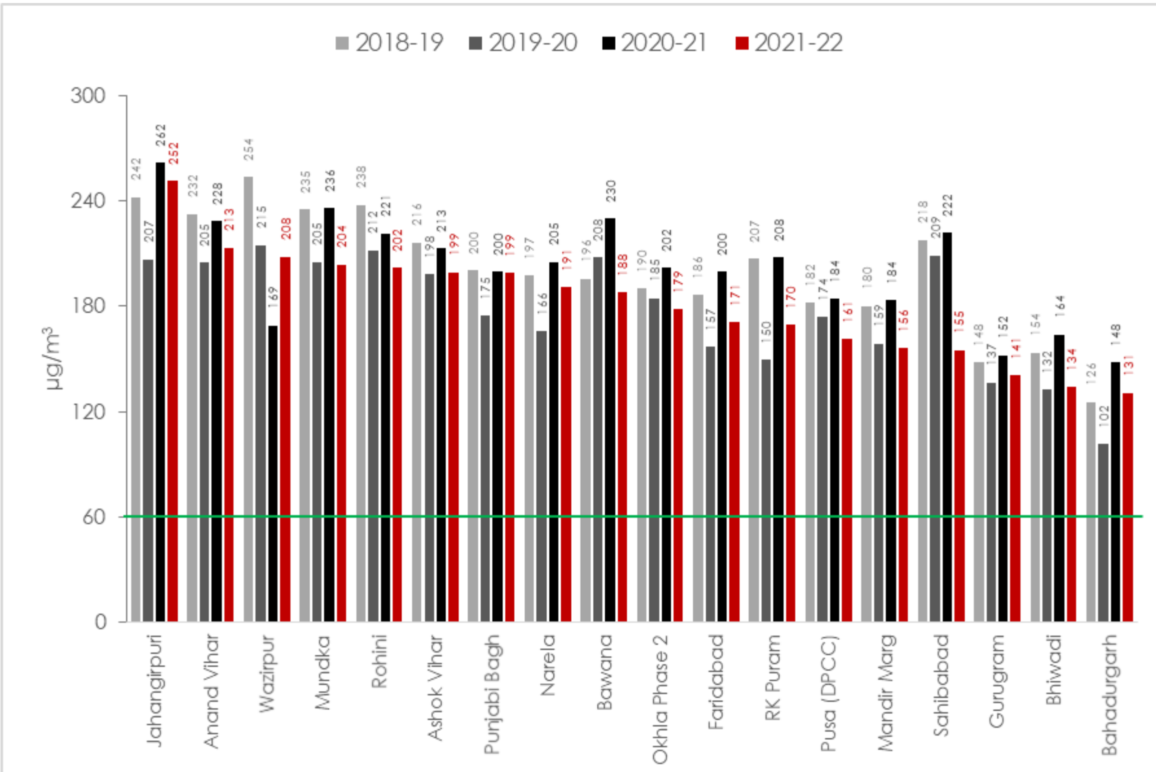
Graph 9: $PM_{2.5}$ variation among stations of Delhi



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

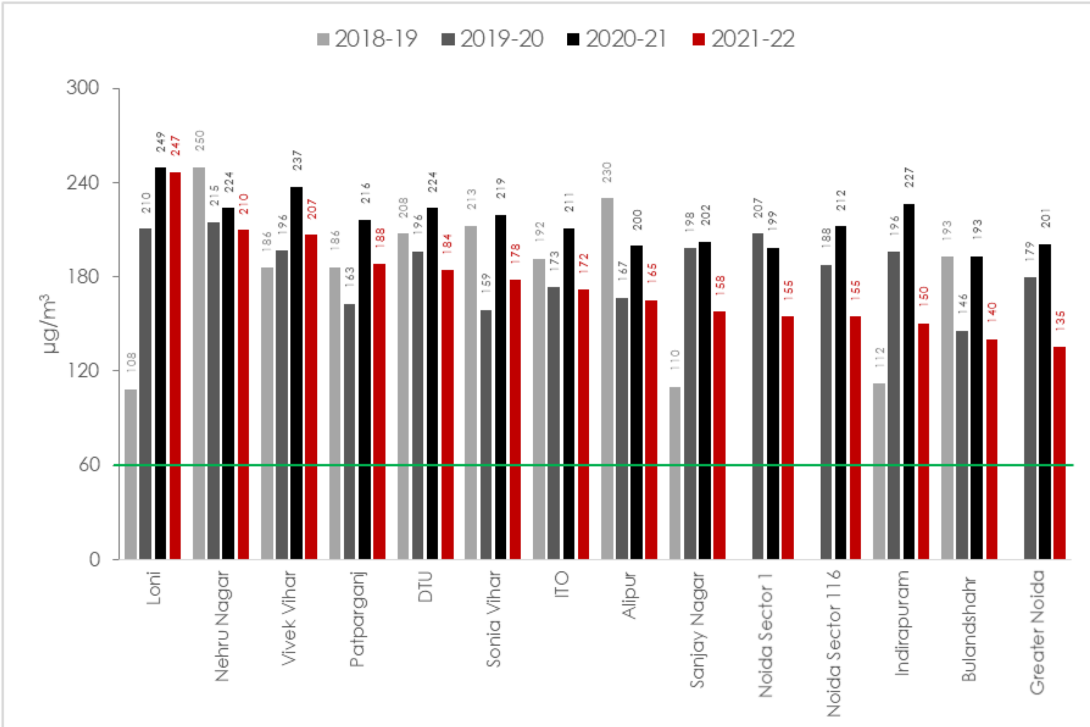
Wizirpur was the only recognized hotspot that registered worsening of air: Except Wazirpur, all the locations on Delhi-NCR pollution hotspot list saw decline in the seasonal PM2.5 level compared to last winter. Bahadurgarh with seasonal average of 131 ug/m3 continues to be the least polluted of the hotspots (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

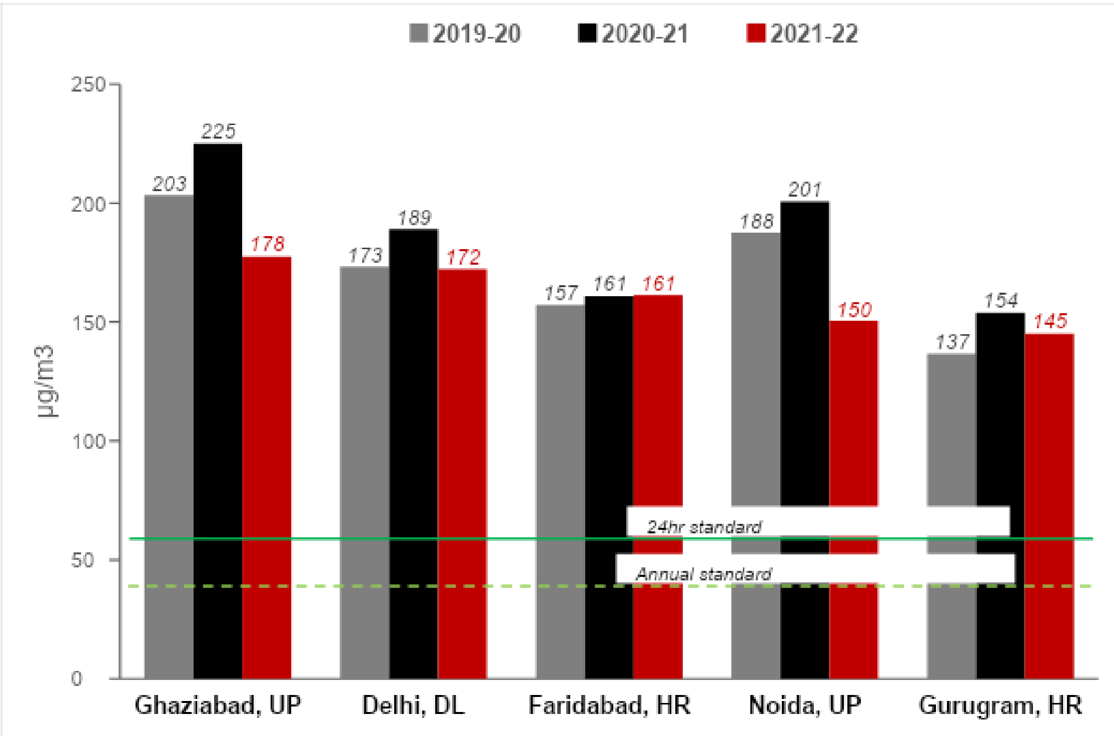


Source: CSE analysis of CPCB's real time air quality data

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

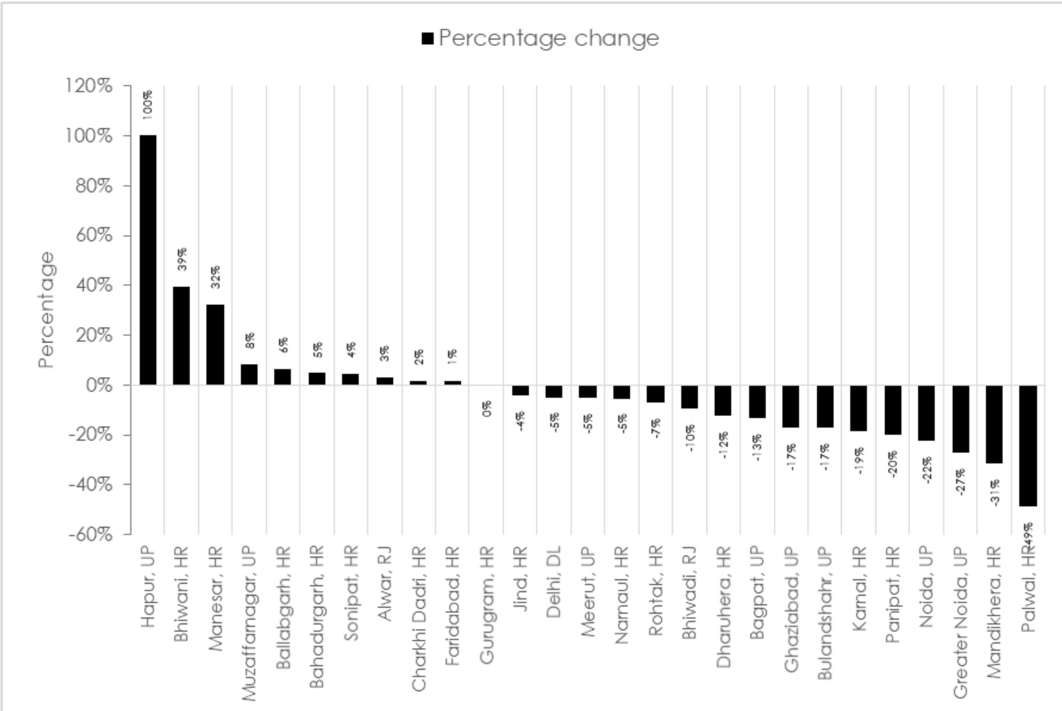


Note: Average $PM_{2.5}$ concentration is based on mean of daily values recorded at CAAQM stations in the city that have adequate data for all three winters.
Source: CSE analysis of CPCB's real time air quality data

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*).

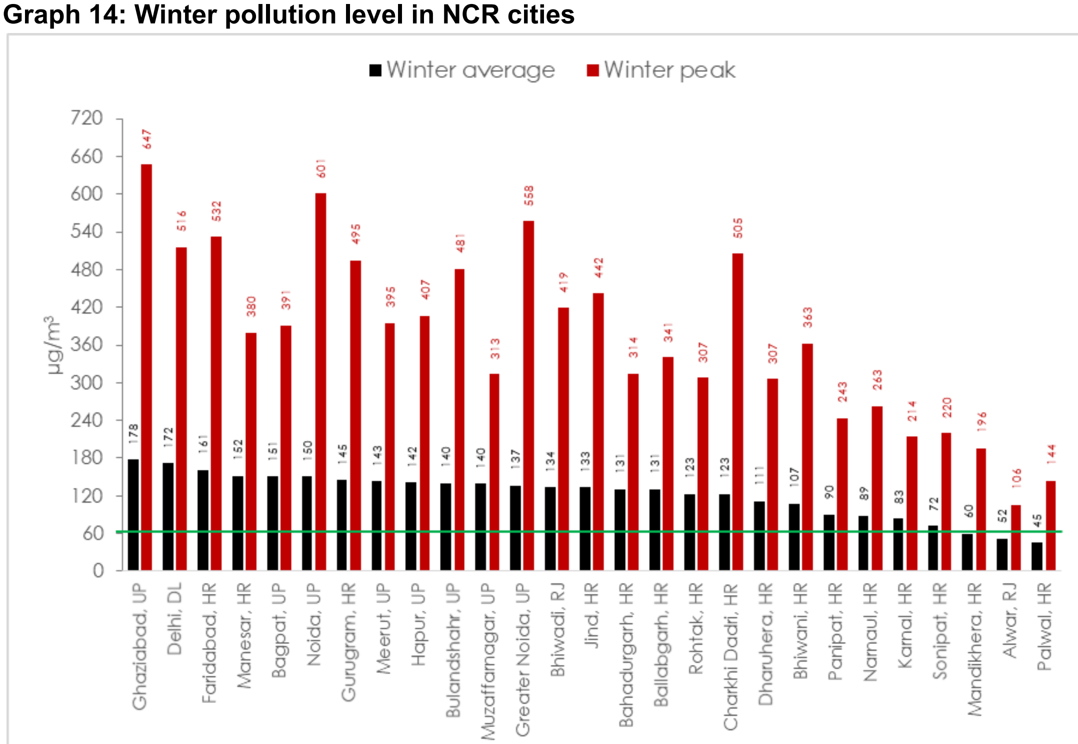
Big cities of NCR continue to be the most polluted with highest seasonal average and peak pollution levels but smaller towns are not far behind. Predictably, Ghaziabad, Delhi and Faridabad were the most polluted cities in the NCR this winter. But Manesar and Bagpat with seasonal average over 150 ug/m3 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

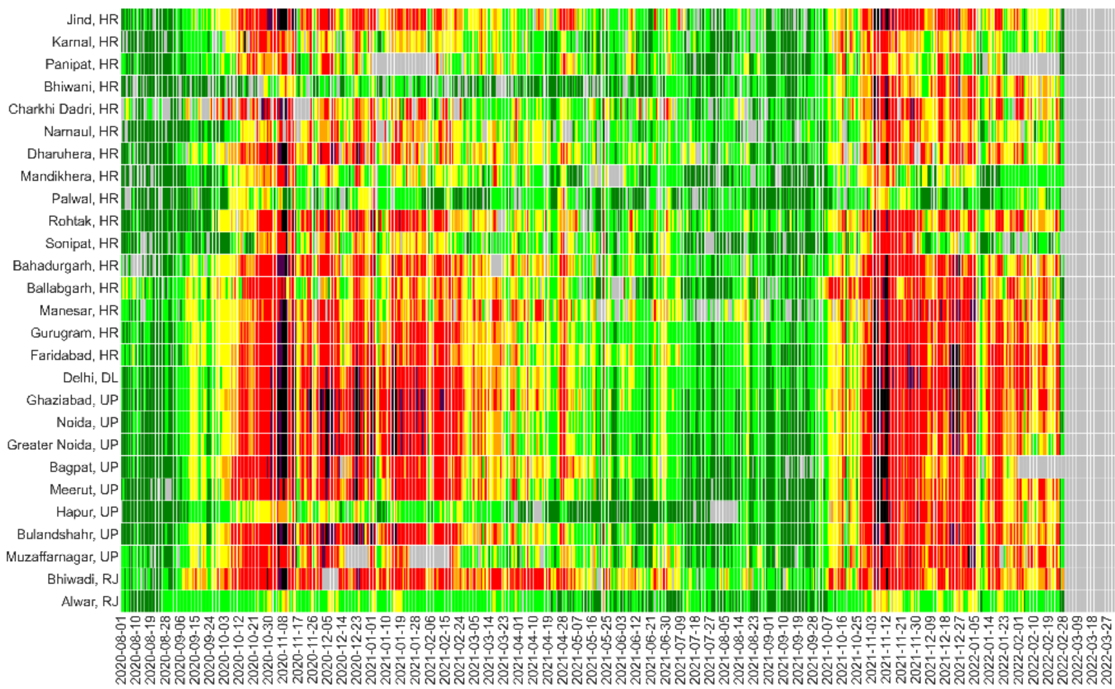


Note: Average $PM_{2.5}$ concentration is based on mean of daily values recorded at CAAQM stations in the city that have adequate data

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*).

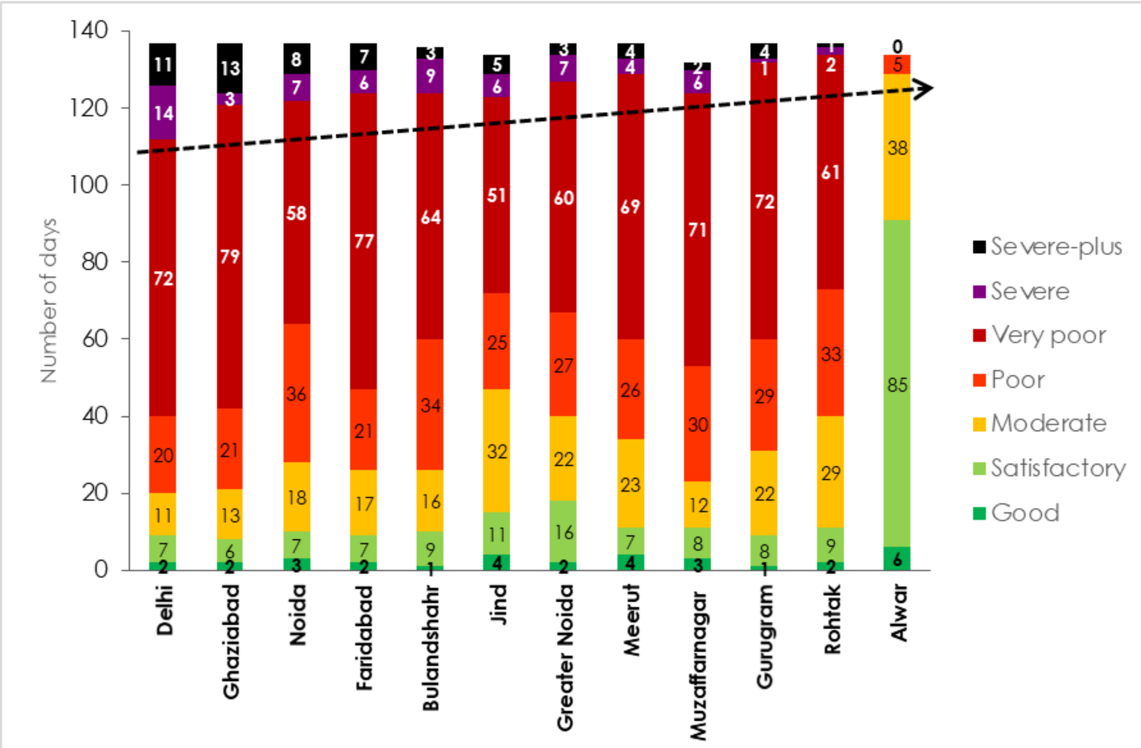
Graph 15: PM2.5 calendar for NCR cities



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.