Winter pollution in megacities: The growing crisis outside Delhi

Anumita Roychowdhury, Avikal Somvanshi and Sharanjeet Kaur

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As the winter season comes to a close, an analysis of PM2.5 trends in five megacities in comparison to Delhi has been conducted by the Urban Lab at the Centre for Science and Environment (CSE). All mega cities, despite being located in different geo climatic zones, have faced the challenge of worsening PM2.5 levels during this winter season. While the levels in Delhi that is located in the land locked northern plains, has been the highest among all mega cities, the rest have also experienced very poor to worsening trends.

This has emerged from the analysis of real time PM2.5 data in Delhi, Kolkata-Howrah, Mumbai, Hyderabad, Bengaluru and Chennai for the winter period (October 1- February 28), by the Urban Lab at the Centre for Science and Environment (CSE). The objective of this analysis has been to assess the peer megacities for longer term seasonal variation and annual trends in particulate pollution. All five megacities registered higher seasonal PM2.5 average this winter compared to the previous winter. Which is opposite of Delhi which registered its least polluted winter compared to previous 4 four winters. This is the challenge of sprawling urbanization and rapid motorization.

While Delhi's winter air quality hogs all attention, the rising winter air pollution in other mega cities including Kolkata, Mumbai, Hyderabad, Bengaluru and Chennai, do not get adequate attention. While Delhi has bent its seasonal pollution curve, winter air quality is high or on the rise in most other megacities. These cities outside the northern plains may have more favourable meteorological conditions to contain the peaking of pollution during the winter, but their overall city average and levels across locations inside cities can cause very high exposures. This demands round the year action to control emissions in cities that are motorizing and urbanizing rapidly.

Winter season presents a serious challenge in all megacities despite them being located in different geo climatic zones with varying meteorological and topographical conditions. The PM2.5 levels remain elevated and also the levels peak during winter in all megacities. This winter several mega cities (excluding Delhi) have recorded higher seasonal PM2.5 average compared to their previous winter. This clearly indicates that the overall emissions are high or may be rising in those cities.

Data used in the analysis: This is an assessment of annual and seasonal trends in PM2.5 concentration for the period 1 October to 28 February for 2019-20, 2020-21, 2021-22 and 2022-23. This analysis is based on the real time data available from the current working air quality monitoring stations in Delhi, Kolkata-Howrah, Mumbai, Chennai, Hyderabad and Bengaluru. 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 106 continuous ambient air quality monitoring stations (CAAQMS) spread across metro cities. Delhi (40), Kolkata (7), Howrah (3), Mumbai (21), Hyderabad (14), Bengaluru (12), and Chennai (9) 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 have been functional for the defined study period.

Key highlights

Among the mega cities, Kolkata and Mumbai are the most polluted after Delhi, while air quailty has worsened fastest in Bengaluru and Chennai: Delhi with winter average PM2.5 of 151 µg/m³ remains the most polluted megacity by a large margin but it has shown improvement over the past few years. But in other five megacities, the average PM2.5 level this winter (October to Feburary) stood at 80 µg/m³ for Kolkata and at 77 µg/m³ for Mumbai both higher than 24-hour standard for PM2.5 (*See Graph 1: Winter pollution in megacities*). Hyderabad's winter average of 59 µg/m³ is just under the 24-hour standard. Bengaluru with 44 µg/m³ and Chennai µg/m³ with 42 were comfortably under the 24-hour standard but breeached the annual standard for PM2.5.

-- Compared to winter of 2021-22 only Delhi has shown improvement in winter air quality and its winter air is 9 per cent less polluted than previous winter. But the winter avegare of PM2.5 average has increased in rest of the five megacities.
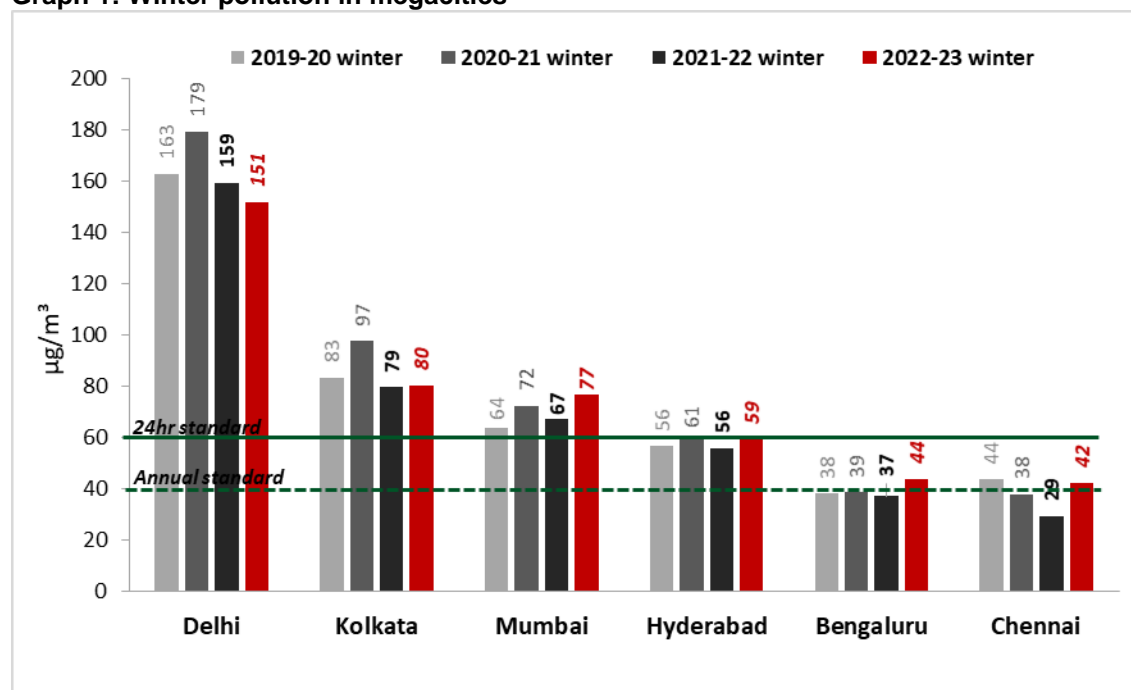
-- When PM2.5 level of the current winter is compared with the average for the previous three winters, Bengaluru and Chennai's performance is the worst as their winter air is 15 per cent more polluted than average of their previous three winters.

-- Mumbai's winter air is 14 per cent and Hyderabad's winter air is 3 per cent more polluted.

-- Kolkata's overall winter average of PM2.5 has improved compared to previous three years but is stagnating since last year. Kolkata's winter air is 7 per cent less polluted compared to the average of previous three winters, but this winter's pollution level is identical to last winter level showing a stagnant trend.

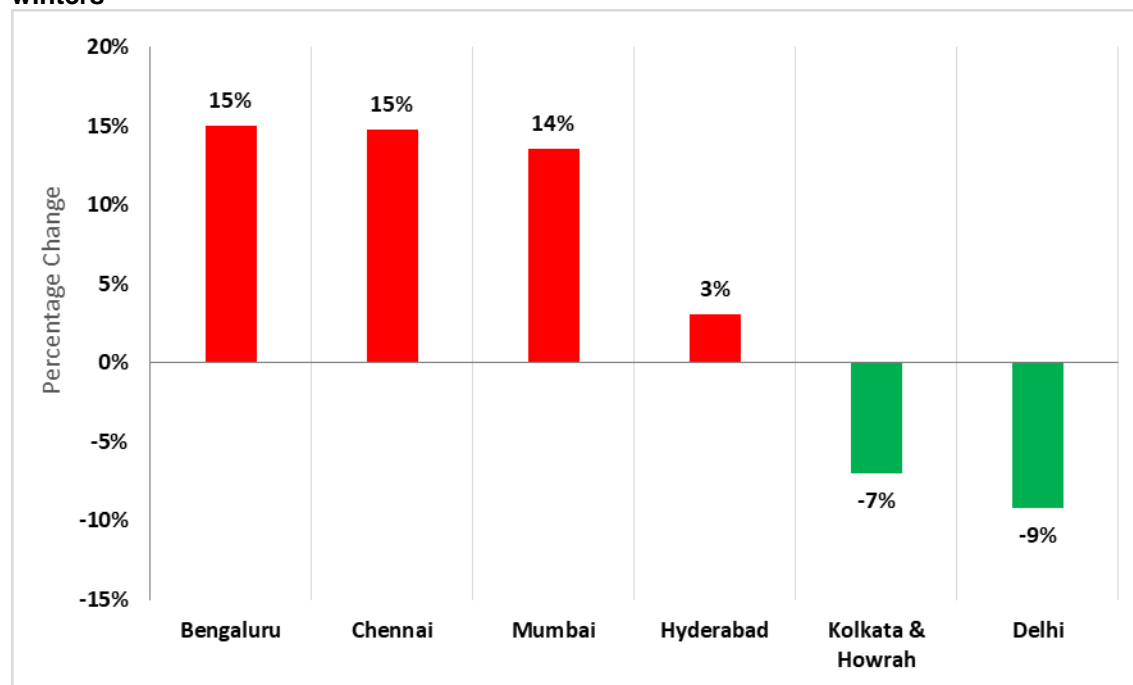(See Graph 2: Change in winter PM2.5 level among megacities compared to mean of previous three winters).

Graph 1: Winter pollution in megacities

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

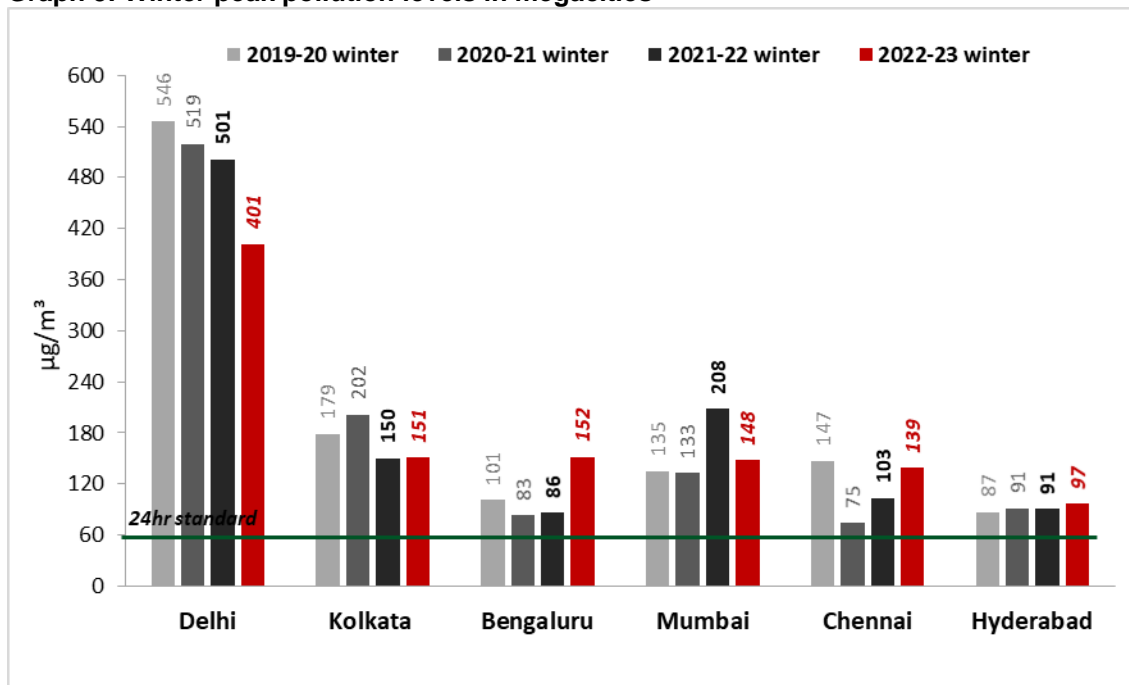**Graph 2: Change in winter PM$_{2.5}$ level among megacities compared to mean of previous three winters**

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

Peak winter pollution in Bengaluru and Hyderabad is worst in last four years: On 27 January 2023, daily PM2.5 level in Bengaluru hit 152 µg/m³ which was highest 24-hour PM2.5 average recorded in the city since 2019. Similarly, Hyderabad registered its highest 24-hour PM2.5 average since 2019 this winter when on 23 Feburary 2023 when daily average reached 97 µg/m³. Peak daily value this winter for Kolkata, Mumbai and Chennai was not as high as their previous winter peaks but still in the "very poor" AQI category (See *Graph 3: Winter peak pollution levels in megacities*).. Kolkata's winter peak stood at 151 µg/m³ registered on 21 January 2023, for Mumbai it stood at 148 µg/m³ registered on 18 January 2023, and for Chennai it stood at 139 µg/m³ registered on 24 October 2022. Delhi's peak pollution this winter stood at 401 µg/m³ and it was registered on 3 November 2022.
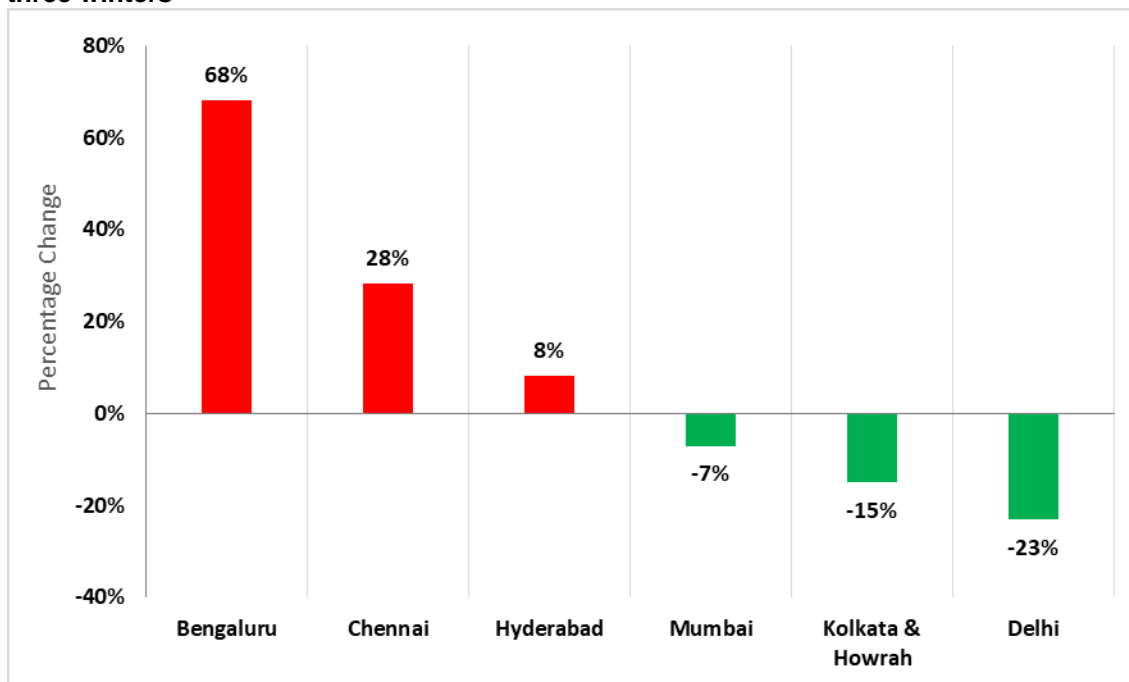
When PM2.5 peak level of the current winter is compared to the average for previous three winters, Bengaluru's performance works out to be the worst as its winter peak was 68 per cent higher than average of its previous three winter peaks. Simlarly, Chennai's winter peak was 28 per cent higher, and Hyderabad's winter peak was 8 per cent higher (See *Graph 4: Change in winter PM2.5 peak level among megacities compared to mean of previous three winters*).

Delhi, Kolkata and Mumbai had lower peaks compared to the average of previous three winter peaks. Mumbai's winter peak was 7 per cent lower, Kolkata's winter peak was 15 per cent lower and Delhi's winter peak was 23 per cent lower than the average of previous three winter peaks.

Graph 3: Winter peak pollution levels in megacities

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 4: Change in winter PM2.5 peak level among megacities 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

Monthly air quality pattern varies across the megacities: Unlike Delhi which has two pollution crests during the winter season (November and January), other megcities have just one crest. November is the worst air quality month for Hyderabad and Bengaluru. Worst month for Mumbai and Chennai has been January (See *Graph 5: Monthly pollution levels in megacities*). Kolkata's worst month is December. Kolkata was most polluted megacity (excluding Delhi) for months of November, December and January. In Feburary, Mumbai overtook Kolkata as the most polluted megacity (excluding Delhi).

Graph 5: Monthly pollution levels in megacities

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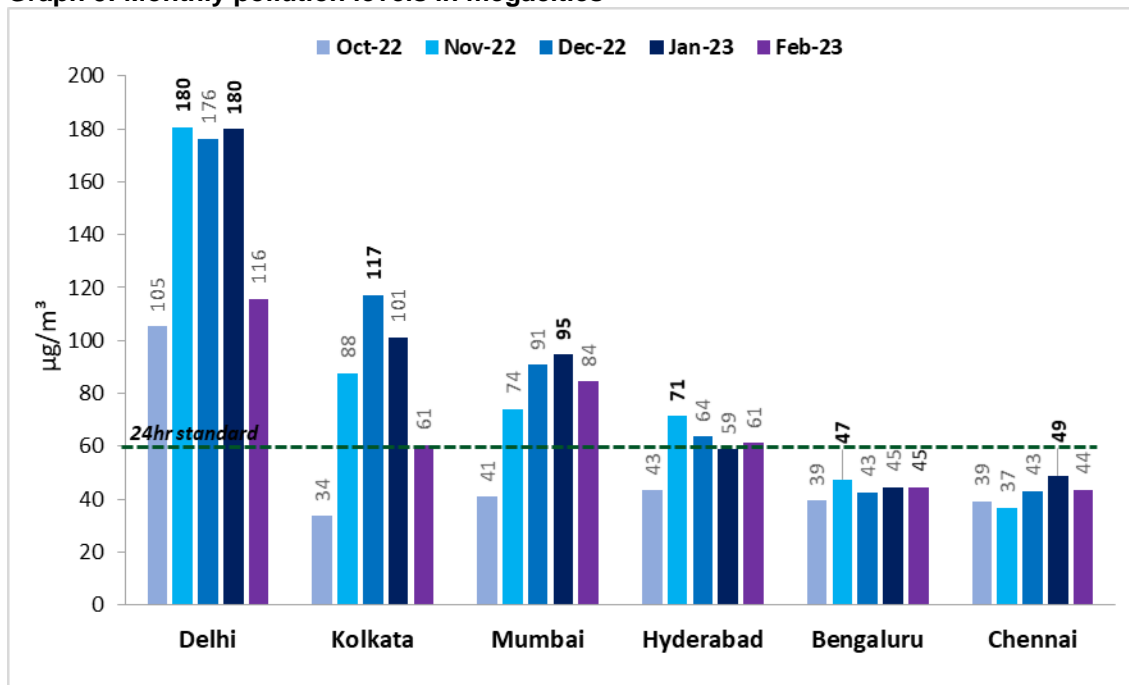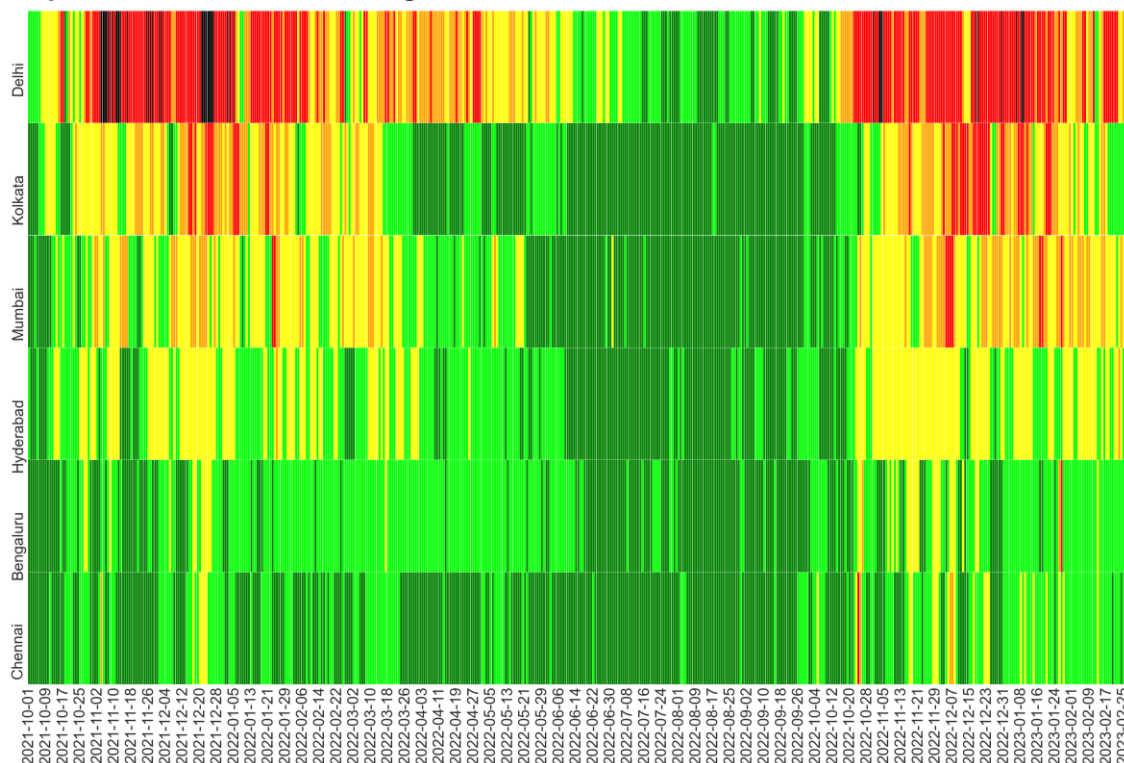Source: CSE analysis of CPCB's real time air quality data

Winter is problematic season for all megacities but intensity of the problem varies: The days with bad air quality occurred in clusters during the winter season in the megacities. The clustering of bad air days was longer in Delhi, Kolkata, Mumbai and Hyderabad, but of shorter duration in Bengaluru and Chennai (See *Graph 6: PM2.5 calendar for megacities*). Intensity and duration of these bad air days was long enough in Delhi to get classified as a smog episode (See *Graph 7: Daily pollution levels in megacities*). Other thn Delhi, compared to previous winter, the number of bad air days were more in other megacities.

Graph 6: PM2.5 calendar for megacities

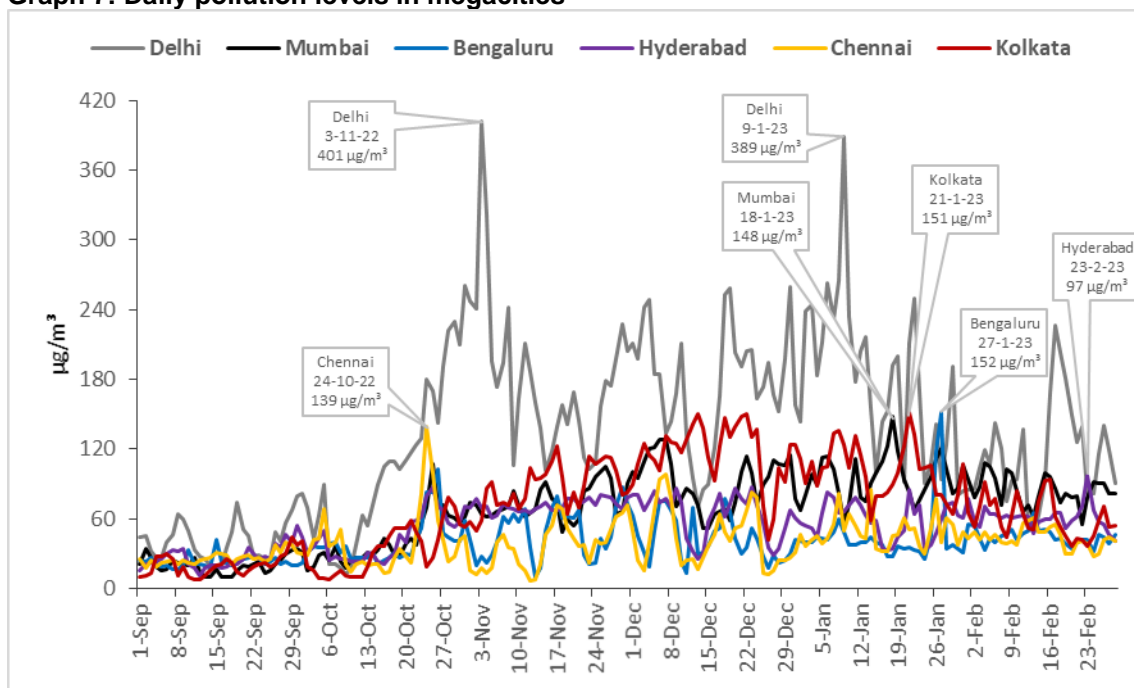Note: Average PM2.5 concentration is based on mean of daily values recorded at all CAAQM stations in the city that have adequate data for the winter. Cell colour is based on the official colour-scheme of AQI sub-categories. Blue loops mark smog episodes.
Source: CSE analysis of CPCB's real time air quality data

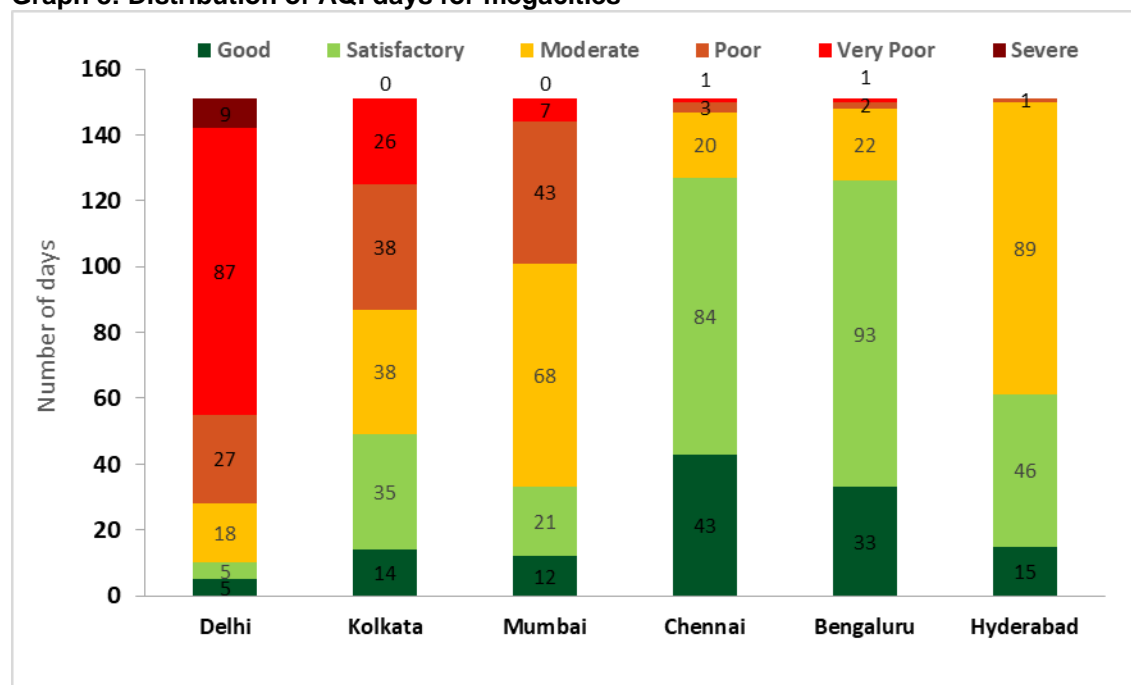**Graph 7: Daily pollution levels in megacities**

Note: Average PM2.5 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

Kolkata's longer term seasonal PM2.5 trend was lower but had the highest number of "very poor" AQI days; Mumbai had least number of "good"AQI days among the megacities (excluding Delhi): Kolkata registered 26 days of "very poor" AQI this winter which is second only to Delhi. It was followed by Mumbai that had seven days of "very poor" AQI. Chennai and Bengaluru registered just one day of "very poor" AQI while Hyderabad registerd zero days with "very poor" AQI (see Graph 8: Distribution of AQI days for megacities).

Mumbai had only 12 days of "good" AQI which is lower than Kolkata (14 "good" AQI days) despite having relatively lower number of bad air days. Chennai (43 "good" AQI days) and Bengaluru (33 "good" AQI days) had most "good" AQI days among the megacities. Hyderabad had only 15 "good" AQI days. Delhi was the worst megacities with 9 "severe" AQI days, 87 "very poor" days and 5 "good" AQI days.
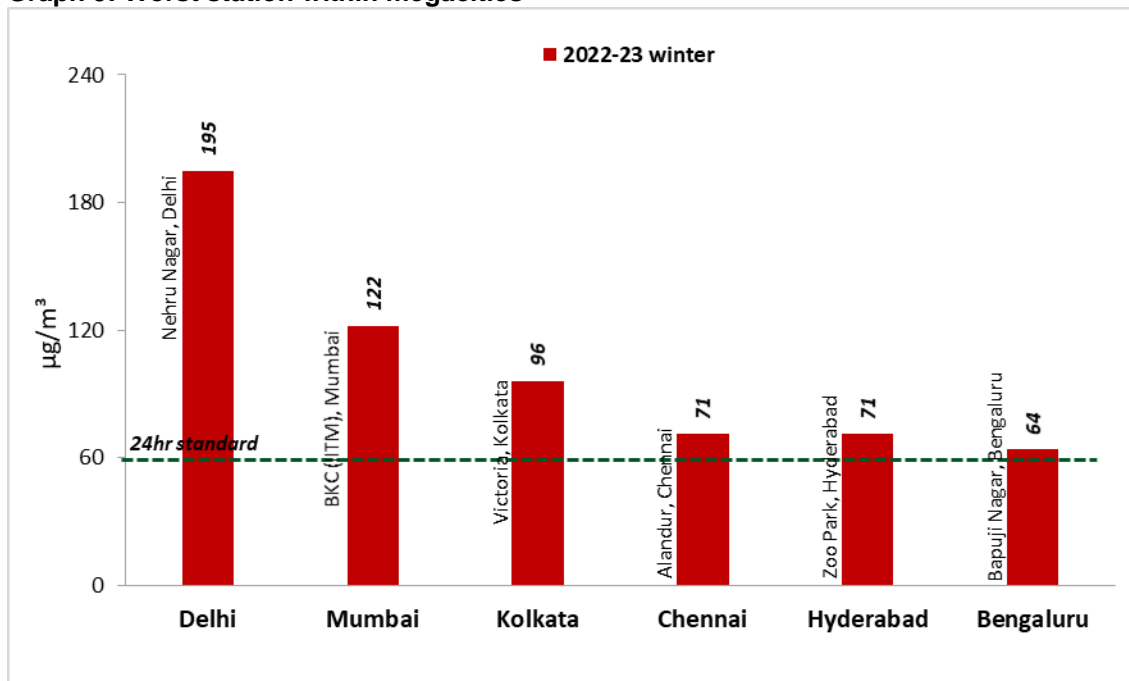
Graph 8: Distribution of AQI days for megacities

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

Worst affected locations within megacities have pollution levels 50 per cent higher than citywide average: There is considerable variation in air quality among the locations of each megacity with worst locations being considerabily more polluted than citywide average. In Mumbai the worst air quality was recorded at Bandra-Kurla Complex (BKC) whose seasonal average stood at 122 µg/m³. In fact five of the six most pollutioned locations among the 66 monitoring stations among the five megacities are in Mumbai. For Kolkata the most polluted location was Victoria with the winter average of 96 µg/m³. Neighbouring twin city of Howarh has been worse off with Ghusuri in Howrah recording the winter average of 128 µg/m³. Alandur was the most polluted location in Channai with seasonal average of 71 µg/m³. Zoo Park was the most pollution location in Hyderabad with seasonal average of 71 µg/m³. In Bengaluru most polluted location was Bapuji Nagar and its seasonal average was 64 µg/m³ (See *Graph 9: Worst station within megacities & Annexure 1: October-February PM2.5 level at station levels)*

Graph 9: Worst station within megacities

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

Way forward

The winter period is a special challenge in all cities as adverse meteorological conditions trap pollution and increase concentration and exposures. The impact is worse if the overall pollution in the city is high and is worsening. This demands stringent action round the year as well as emergency action during the bad-air days to bring down the overall pollution levels. This demands stringent action to reduce emissions from vehicles, industry, waste burning, construction, solid fuels in households among others. This is also needed to meet the new target of 40 per cent reduction in particulate pollution under the National Clean Air Programme.

Annexure 1: October-February PM2.5 level at station levels

	Station name	2022-23 winter PM2.5 level in µg/m³
	Mumbai citywide average	**77**
1	BKC (IITM), Mumbai	122
2	Deonar (IITM), Mumbai	121
3	Mazgaon (IITM), Mumbai	109
4	Navy Nagar (IITM), Mumbai	107
5	Chakala (IITM), Mumbai	97
6	Vile Parle West, Mumbai	89
7	Borivali East (IITM), Mumbai	83
8	Sion, Mumbai	82
9	Mulund West, Mumbai	82
10	Khindipada (IITM), Mumbai	77
11	Powai, Mumbai	71
12	Kandivali East, , Mumbai	68
13	Borivali East, Mumbai	60
14	Colaba, Mumbai	60
15	Worli, Mumbai	59
16	Siddharth Nagar (IITM), Mumbai	57
17	CSI Airport T2, Mumbai	57
18	Vasai West, Mumbai	54
19	Malad West (IITM), Mumbai	48

20	Kurla, Mumbai	38
21	Bandra, Mumbai	
Hyderabad citywide average		**59**
1	Zoo Park, Hyderabad	71
2	Sanathnagar, Hyderabad	67
3	IDA Pashamylaram, Hyderabad	62
4	Bollaram, Hyderabad	60
5	ICRISAT, Hyderabad	59
6	Somajiguda, Hyderabad*	48
7	Central University, Hyderabad	44
8	Nacharam TSIICIALA, Hyderabad*	39
9	Ramachandrapuram, Hyderabad*	38
10	Kokapet, Hyderabad*	37
11	New Malakpet, Hyderabad*	37
12	IITH Kandi, Hyderabad*	36
13	Kompally Municipal Office, Hyderabad*	33
14	ECIL Kapra, Hyderabad*	30
Bengaluru citywide average		**47**
1	Bapuji Nagar, Bengaluru	64
2	RVCE, Bengaluru*	54
3	Silk Board, Bengaluru	45
4	Hebbal, Bengaluru	44
5	Jayanagar, Bengaluru	44
6	BTM Layout, Bengaluru	41
7	Shivapura, Bengaluru*	40
8	Peenya, Bengaluru	40
9	Hombegowda Nagar, Bengaluru	31
10	BWSSB, Bengaluru	
11	City Railway Station, Bengaluru**	
12	Sanegurava Halli, Bengaluru	
Chennai citywide average		**42**
1	Alandur, Chennai	71
2	Manali Village, Chennai	63
3	Gandhi Nagar Ennore, Chennai*	46
4	Royapuram, Chennai	44
5	Perungudi, Chennai	44
6	Arumbakkam, Chennai	42
7	Manali, Chennai	41
8	Velachery, Chennai	32
9	Kodungaiyur, Chennai	21
Delhi citywide average		**151**
1	Nehru Nagar, Delhi	195
2	Jahangirpuri, Delhi	187
3	Anand Vihar, Delhi	184
4	Vivek Vihar, Delhi	177
5	Wazirpur, Delhi	175
6	Mundka, Delhi	174
7	Patparganj, Delhi	173
8	NSIT Dwarka, Delhi	172
9	Shadipur, Delhi	171
10	Rohini, Delhi	170
11	Bawana, Delhi	169
12	Burari Crossing, Delhi	168
13	Narela, Delhi	168
14	ITO, Delhi	167
15	RK Puram, Delhi	166
16	Sonia Vihar, Delhi	165
17	Dwarka Sector 8, Delhi	164
18	Punjabi Bagh, Delhi	163
19	Alipur, Delhi	161
20	Ashok Vihar, Delhi	160
21	National Stadium, Delhi	159

22	Pusa (DPCC), Delhi	156
23	Okhla Phase 2, Delhi	155
24	JLN Stadium, Delhi	153
25	Dr KS Shooting Range, Delhi	150
26	Sirifort, Delhi	147
27	North Campus DU, Delhi	144
28	Sri Aurobindo Marg, Delhi	139
29	CRRI Mathura Road, Delhi	137
30	Mandir Marg, Delhi	131
31	IGI Airport T3, Delhi	124
32	Pusa (IMD), Delhi	121
33	Najafgarh, Delhi	121
34	IHBAS, Delhi	112
35	Aya Nagar, Delhi	111
36	DTU, Delhi	108
37	Lodhi Road, Delhi	108
38	Lodhi Road (IITM), Delhi*	179
39	Chandni Chowk (IITM), Delhi*	102
40	East Arjun Nagar, Delhi**	
Kolkata citywide average		**80**
1	Ghusuri, Howrah*	128
2	Victoria, Kolkata	96
3	R.B. University, Kolkata	91
4	Jadavpur, Kolkata	90
5	Bidhannagar, Kolkata	85
6	Ballygunge, Kolkata	85
7	Padmapukur, Howrah*	78
8	Belur Math, Howrah*	78
9	Rabindra Sarobar, Kolkata	64
10	Fort William, Kolkata	57

Note: October-February average of a city is based on mean of daily PM$_{2.5}$ values recorded at CAAQM stations in the city that have adequate data for all winters. * Station does not have adequate data for previous winters and therefore not included in citywide average calculation. ** Station does not have PM2.5 monitor.
Source: CSE analysis of CPCB's real time air quality data.