2023 – the crossroad: Yearend analysis of PM2.5 pollution in Delhi

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Centre for Science and Environment, New Delhi, 31December 2023

The gradual long term improvement in annual PM2.5 levels since 2015-17 is halted in 2023. This has happened despite cleaner than usual summer and monsoon seasons, and much lower ingress of smoke from farm stubble fires in northern states. But this winter has witnessed unusually low surface wind speed that has trapped local pollution that is already high.

Due to the impact of the unusual winter levels the overall annual levels have plateaued and even worsened undoing the gains of the long term downward trend. Even with the contribution of stubble burning to Delhi's pollution going down this year, with more rains in November and less severe cold winter conditions, the annual level should have improved further. Instead, the worsening of meteorology - lowering of wind speed has tilted the scale adversely simply because the local pollution is still very high. Delhi needs more aggressive emissions reduction to meet the national ambient air quality standard.

Interestingly, summer and monsoon months in 2023 were unusually cleaner than the previous years. But winter levels turned out to be one of the worst due to very slow surface wind speed observed. This has impeded dispersion of pollution and further aggravated trapping of pollution and spiked the levels. This trapping of local pollution from all sides has made this winter exceptionally bad despite lesser smoke from farm stubble fires. The meteorology also explains lowerpollution peaks and relatively uniform bad air quality with minimal fluctuations in PM2.5 concentration throughout the season.

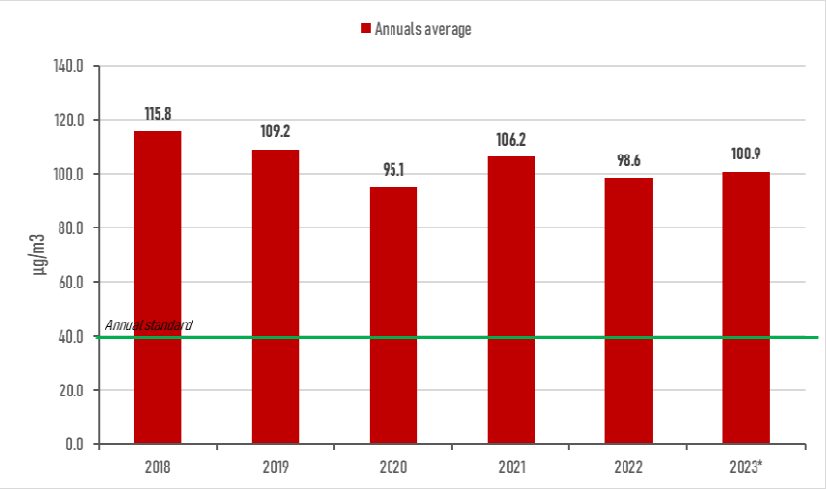
This has emerged from the latest winter pollution analysis of the Urban Lab at Centre for Science and Environment (CSE). The objective has been to understand the trend and the starting line of the onset of the winter pollution season in this region. This is the first analysis of the fourth edition of Urban Lab's Air Quality Tracker Initiative which was started in 2020-21 winter to study the impact of pandemic lockdown on air quality of Delhi and NCR.

Key Highlights

2023 annual average PM2.5 levels worse than 2022 – but not as high as it used to be: Delhi has been witnessing a gradual yet consistent decline in its annual PM2.5 level since 2015-17 with 2020 being the only outlier due to massive disruption caused by pandemic lockdowns. But this downward movement is halted in 2023. Delhi's PM2.5 annual average for 2023 (up till 29 December 2023) stood at 100.9 µg/m^3. This is an increase of 2 per cent compared to 2022 annual level and 6 per cent higher than exceptionally clean 2020 (See Graph 1: Trend in annual PM2.5 for Delhi). It's higher than last winter but levels are not as high as it used to be earlier. Average of 2018-22 winters is higher that winter of 2023.

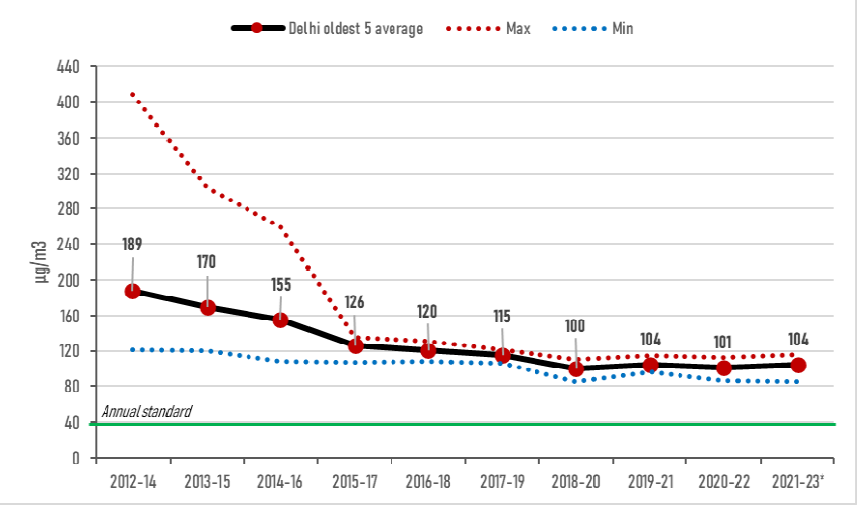
Long-term 3-yr average trend among the five oldest CAAQMS stations of the city (ITO, IHBAS, Mandir Marg, Punjabi Bagh and RK Puram) also shows similar pattern. This 2021-23 average has settled almost 3 per cent higher than 2020-22 average (See Graph 2: Long-term 3-yr average trend among 5 oldest Delhi stations).

Graph 1 : Trend in annual PM2.5 for Delhi



Note: 36 station average includes all the Delhi stations except Lodhi Road IITM, Chandni Chowk IITM and East Arjun Nagar. 24-hour averages are calculated from midnight to midnight. Data up till 30 Dec 2023.
Source: CSE analysis of CPCB realtime data

Graph 2: Long-term 3-yr average trend among 5 oldest Delhi stations

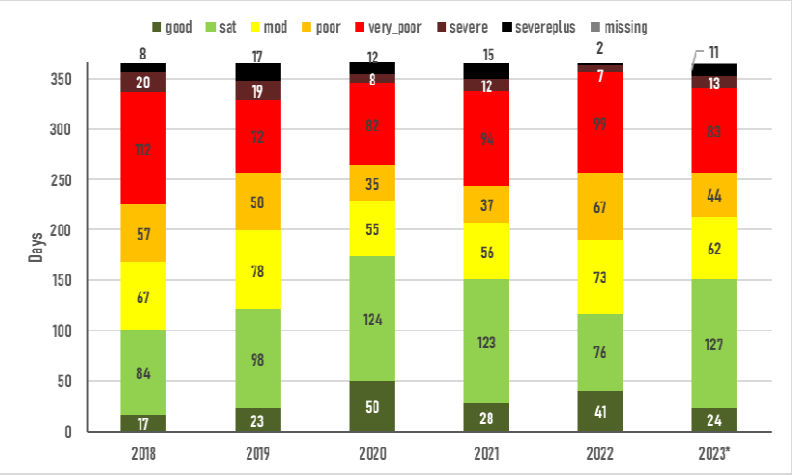


Note: Based on average of 5 oldest CAAQMS stations in Delhi, namely ITO, IHBAS, Mandir Marg, RK Puram and Punjabi Bagh. Source: CSE analysis of CPCB's real time air quality data

Winter condition has affected the 2023 trend - summer is getting progressively cleaner: In 2023, about 151 days have met the National Ambient Air Quality Standard which is similar to the 2021 trend and second only to 2020 lockdown year when 174 days had met the standards (See Graph 3: Annual trend in PM2.5 sub-AQI distribution). In 2022 only 117 such days had met the standard. Almost all of these cleaner days are observed during summer and monsoon seasons (See Graph 4: Heatmap calendar of PM2.5 sub-AQI distribution).

But there is significant fall in the number of good air quality days (when levels are 50 per cent below the standard) this year which stood at 24 days compared to 41 days in 2022. Meanwhile, in 2023 number of days with PM2.5 concentration in the very poor or worse categories (as per air quality index classification) stood at 107 days including 24 days with severe levels (until December 30, 2023). In 2022 there were 106 very poor or worse days but severe days were just 9 in number which is less than half of that of 2023.

Graph 3: Annual trend in PM2.5 sub-AQI distribution



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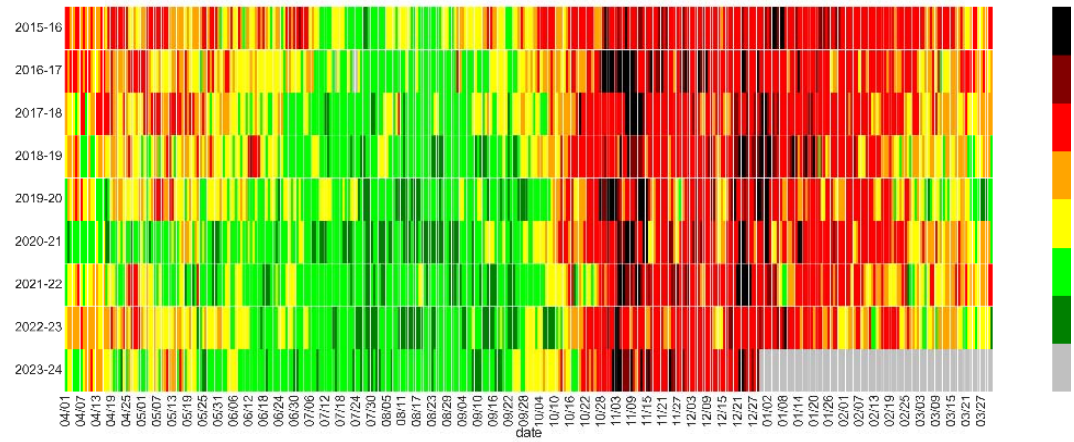
Source: CSE analysis of CPCB realtime data

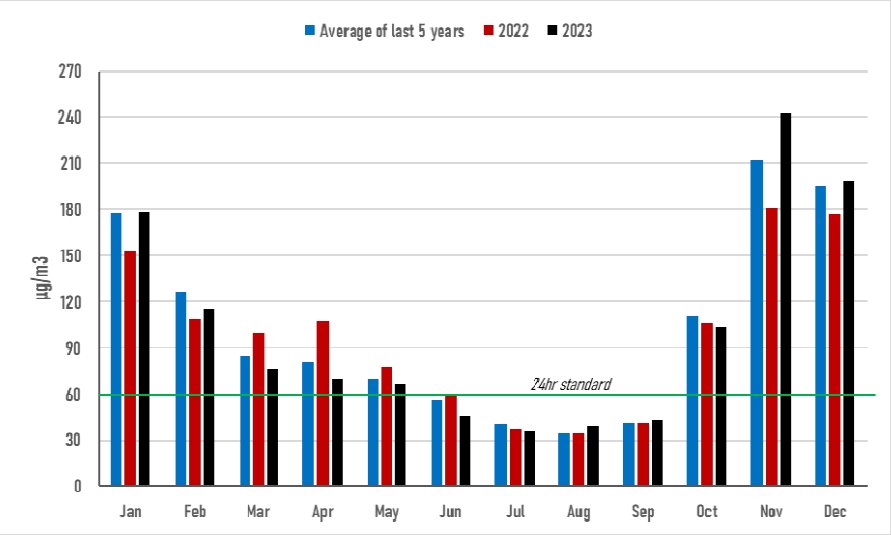
Graph 4: Heatmap calendar of PM2.5 sub-AQI distribution



Note: PM2.5 24-hr average for each station is calculated based on USEPA methodology. 24-hour is defined as midnight to midnight. Citywide PM2.5 concentration is based on mean of daily values recorded at 36 CAAQM stations in the city that have adequate and continuous data from 2018 to 2021. AQI categorization is based on CPCB's Indian AQI formula. Cell color is based on the official colour-scheme of Indian AQI sub-categories. Data is up till 30 Dec 2023.
Source: CSE analysis of CPCB's real time air quality data

Summer is cleaner but winter is worse: In 2023, summer months including March, April, May and June were significantly lesserpolluted (14-36 per cent)than 2022. But winter months of January, August, November and December are significantly more polluted in 2023 (12-34 per cent)compared to 2022 (See Graph 5: Change in monthly PM2.5 levels). The transition season including February, July, September and October do not show much change which might be due to the fact that the monsoon months are already very clean.

Graph 5: Change in monthly PM2.5 levels



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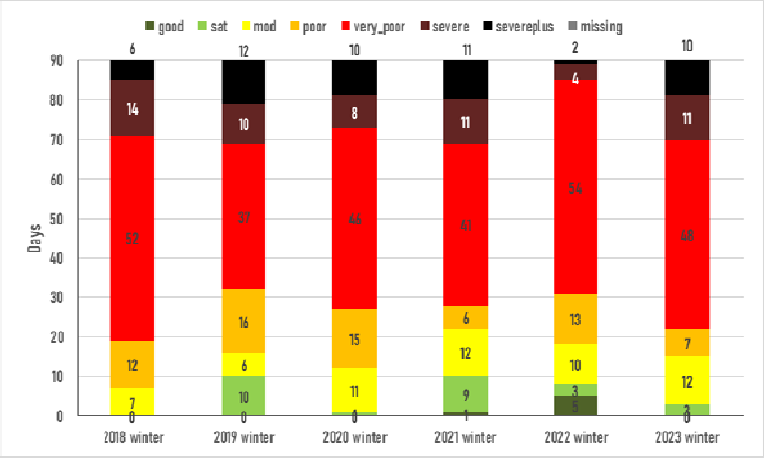
Source: CSE analysis of CPCB realtime data

What went wrong this winter?

Though the number of days with very poor and severe PM2.5 concentration has increased, peak pollution is down: Between 1 October and 29 December, there were 3 days of satisfactory air quality and zero days of good air quality. There were more days of satisfactory and good air quality in the same period in the previous two years.

Number of severe+ days is similar to 2019, 2020 and 2021 winter but the peak intensity is down (See Graph 6: Winter trend in PM2.5 sub-AQI distribution). The peak this year was 349 µg/m3 that happened on 13th November (day after Diwali) followed by 339 µg/m3 that was observed on 4th November. This is much lower than the peaks recorded in previous years. In 2022 the peak was 401 g/m3 while in 2019 it went up to 546 µg/m3 (See Graph 7: Trend in peak PM2.5 levels).

Graph 6: Winter trend in PM2.5 sub-AQI distribution



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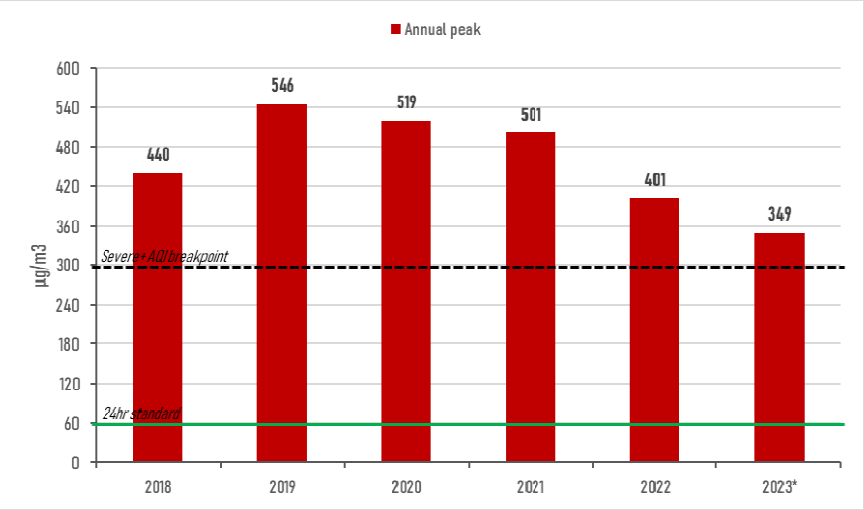
Source: CSE analysis of CPCB realtime data

Graph 7: Trend in peak PM2.5 levels



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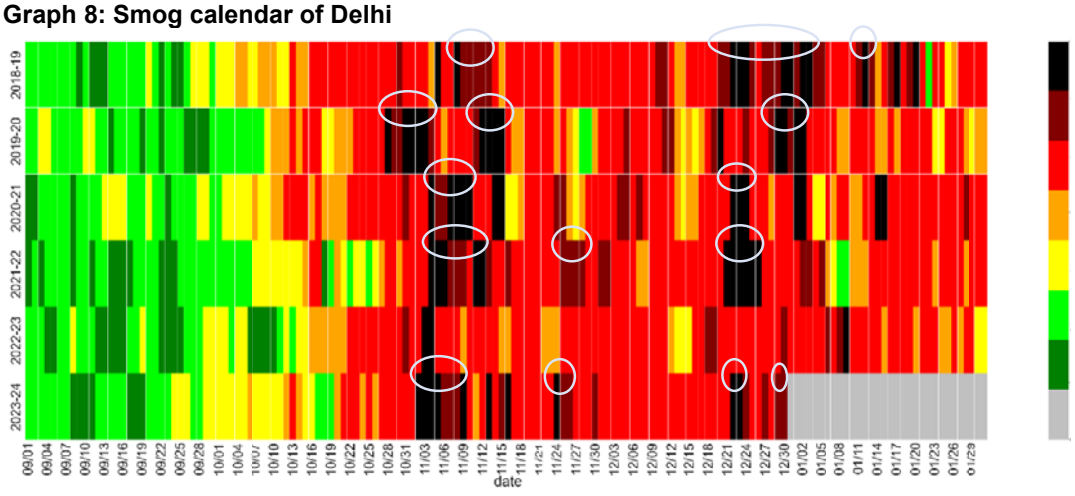
Source: CSE analysis of CPCB realtime data

Highest number of smog episodes observed this season in last six winters: Delhi usually experiences two smog episodes (smog episode defined as at least three minimum continuous days and more with air quality in severe category) in the months of November and December. This year there have been three episodes by December 24 and as of December 30thit is third day of continuous severe AQI whichis likely turn into the fourth smog episode.

This is the highest number of smog episodes observed in a season in last six winters (See Graph 8: Smog calendar of Delhi). Overall this winter seems to have had the most consistently bad air compared to last six winters. This time there has been minimal fluctuation in daily PM2.5 level. Data also clearly shows that it is the longest spell of very poor or worse air in last six years.

Graph 8: Smog calendar of Delhi



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

Slow surface winds seems to be the main contributory factor to the winter trend this year: The farm stubble fire smoke is generally perceived as the main contributor to the heightened PM2.5 levels

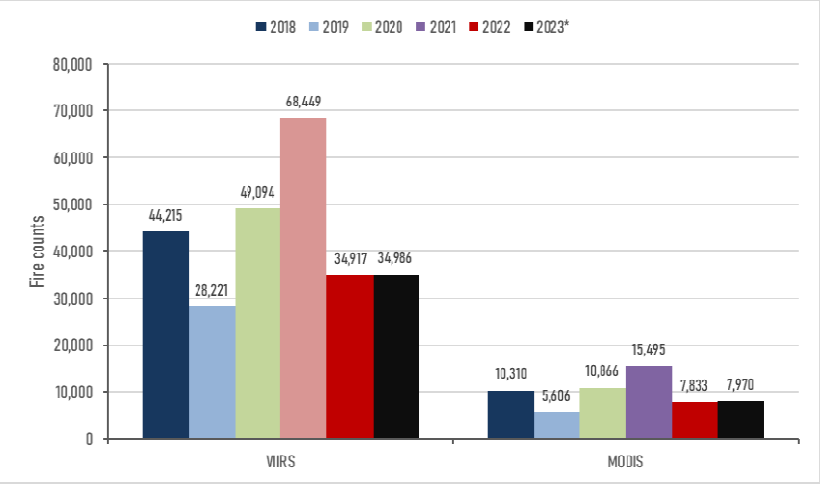
during the first half of the winter season. But this year, the number of fires in Punjab and Haryana have been nearly identical to the last year's number of incidences.

Data from both MODIS and VIIRS satellites shows that there is not a significant difference between fire instances of 2023 and 2022 (See Graph 9: Trend in fire counts in Punjab, Haryana and Delhi). The contribution of fires to PM2.5 in November only adds up to 1.48 tonnes (calculated based on SAFAR's Decision Support System estimates) which is lowest in last six years. This winter has also recorded maximum rainfall in last six years. The cold conditions this winter is also lesser than usual. All these factors should have led to a cleaner winter. But this was undone by the lack of surface wind.

This November the average surface wind speed in Delhi has been 9.8 m/s which is the lowest in last six years (See Graph 10: Trend in November wind, rain, smoke contribution and fire counts). It is a good 21 per cent less than the wind speed in the November of 2022. This seems to be the driving factor for poor air quality this season.

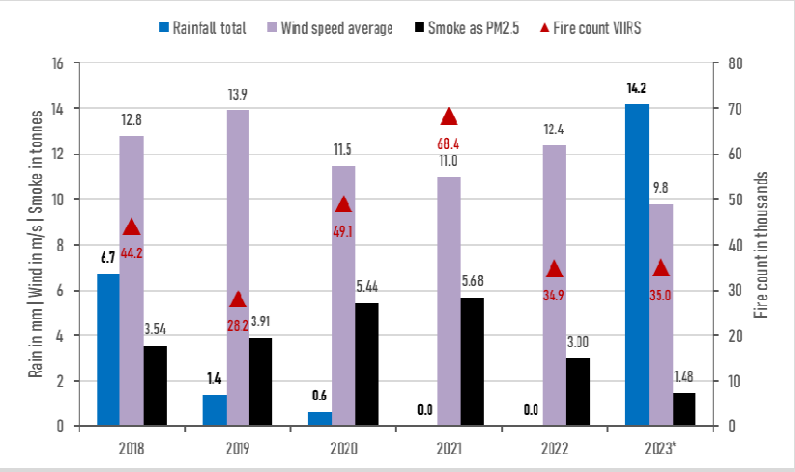
Low wind speed means that local pollution dispersion is horizontally restricted while vertical dispersion is already restricted because of winter inversion phenomenon. This trapping of local pollution from all sides has made this winter exceptionally bad despite lesser smoke from farm stubble fires. This also explains low peaks and relatively uniform bad air quality with minimal fluctuations in PM2.5 concentration throughout the season. It must also be noted that heavy rains in November had insignificant impact on air quality.

Graph 9: Trend in fire counts in Punjab, Haryana and Delhi



Source: CSE analysis of NASA data

Graph 10: Trend in November wind, rain, smoke contribution and fire counts



Source: CSE analysis of NASA, IMD and SAFAR data

Take away

This winter is the lasting reminder of the fact that Delhi despite succeeding to bend the long term pollution curve downward over the last few years, has not achieved deeper cuts in emissions to sustain a more aggressive reduction to meet the National Ambient Air Quality Standards and prevent winter spikes. This requires sustained action for:

- Significant reduction in emissions from vehicles with massive scaling up of zero emissions electric vehicle programme and public transport strategy.
- Clean fuel transition in all segments of industries with stringent compliance with emissions targets and replacement of solid fuels in households and eateries.
- Elimination of waste burning with a comprehensive waste management system ensuring 100 per cent segregated collection, material recovery and remediation of legacy waste.
- Stringent action in the construction sector.