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).

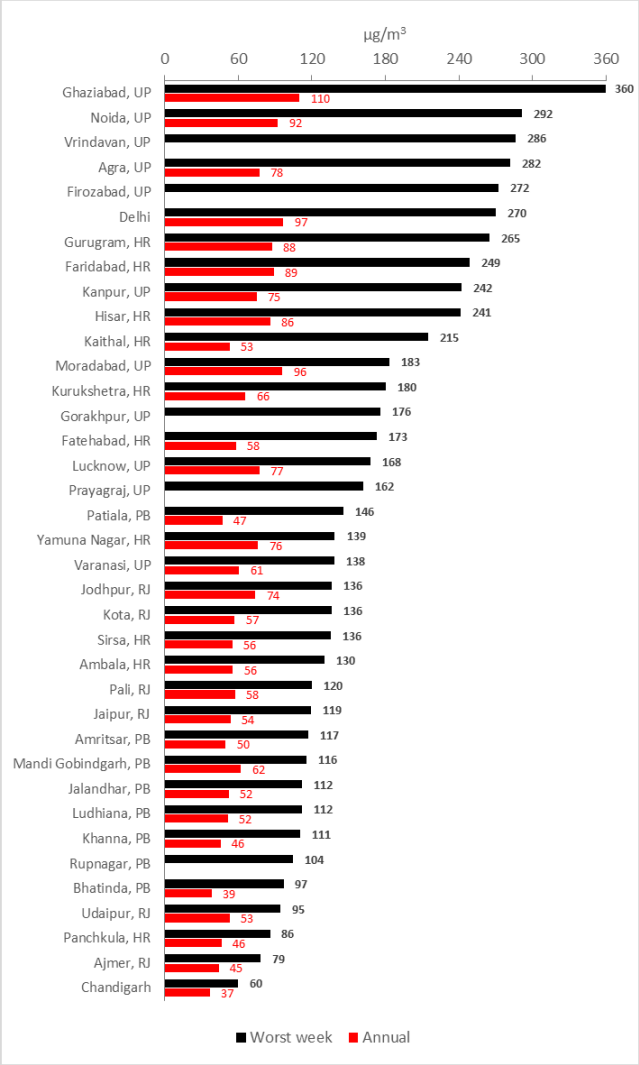
North region has been divided into five sub-regions for analysis sake in this study. Sub-regions have been defined as Punjab & Chandigarh, NCR (includes Delhi and 26 other cities/towns that fall inside NCR), Haryana (excluding cities in NCR), Uttar Pradesh (excluding cities in NCR), and Rajasthan (excluding 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 ug/m3 that of Agra is 78 ug/m3, 20 per cent lower. But during early winter this year the weekly average PM2.5 level in Agra was 282 ug/m3 and exceeded by 5 per cent that of Delhi which stood at 270 ug/m3. Similarly, weekly average of Vrindavan has been 286 ug/m3 and that of Firozabad 272 ug/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

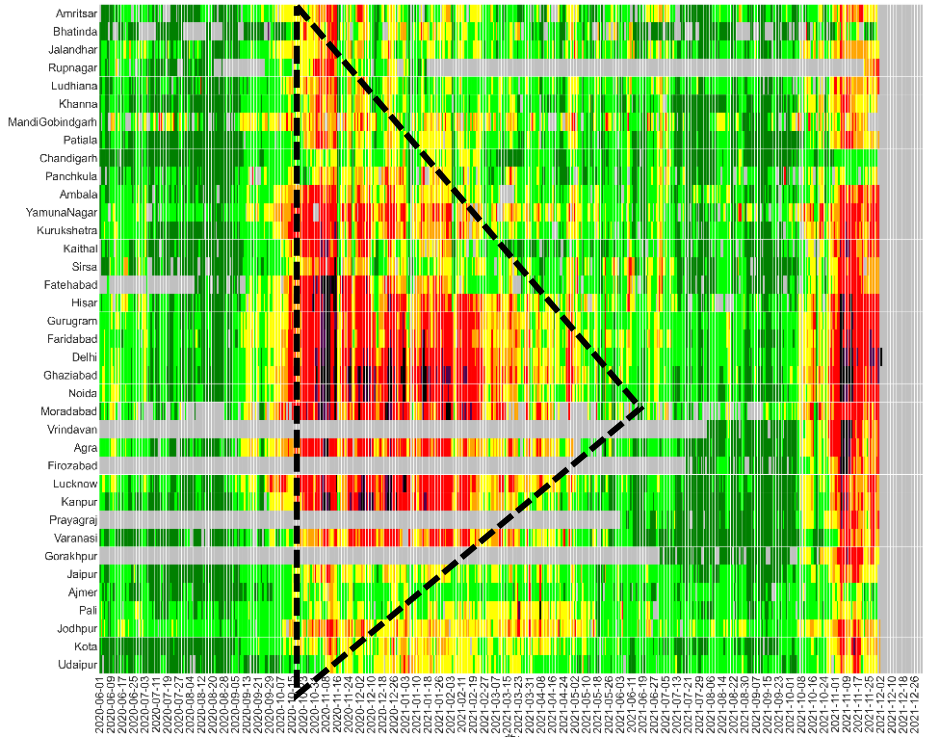


Note: PM2.5 values for cities with more than one monitoring stations is based on average of all stations that have continuous and adequate data for complete assessment period. Data up till 30 November 2021.
Source: CSE analysis of realtime data from CPCB portal

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



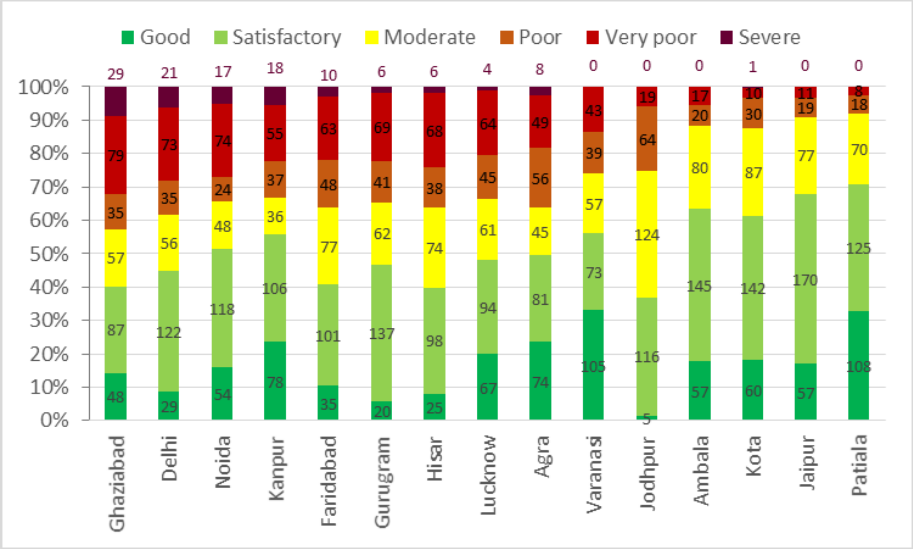
Note: PM2.5 values for cities with more than one monitoring stations is based on average of all stations that have continuous and adequate data for complete assessment period. Cell colours are based on the official AQI category colours. Data up till 30 November 2021.
Source: CSE analysis of realtime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

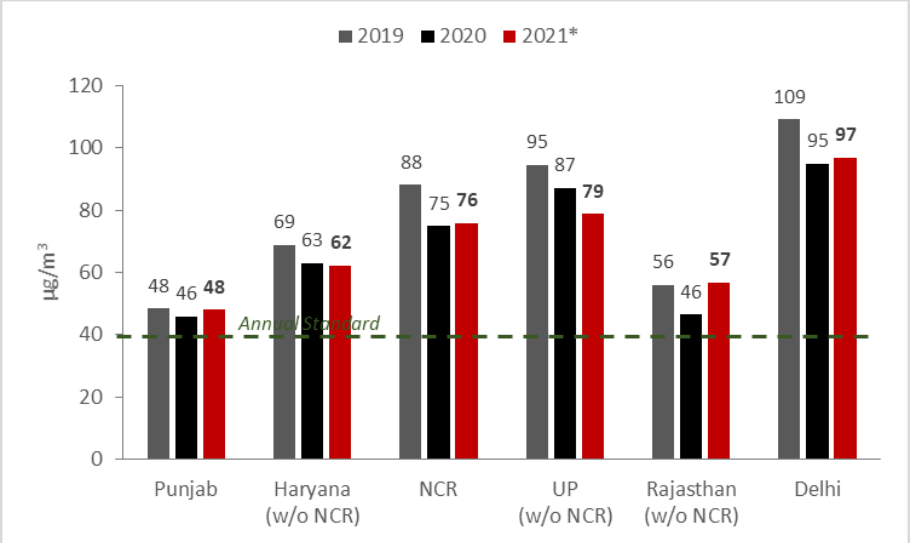
Graph 3: PM2.5 AQI categorization of days for major cities in North India



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 ug/m3 (uptill November 30). Moradabad is the most polluted city outside NCR with PM2.5 level of 96 ug/m3.

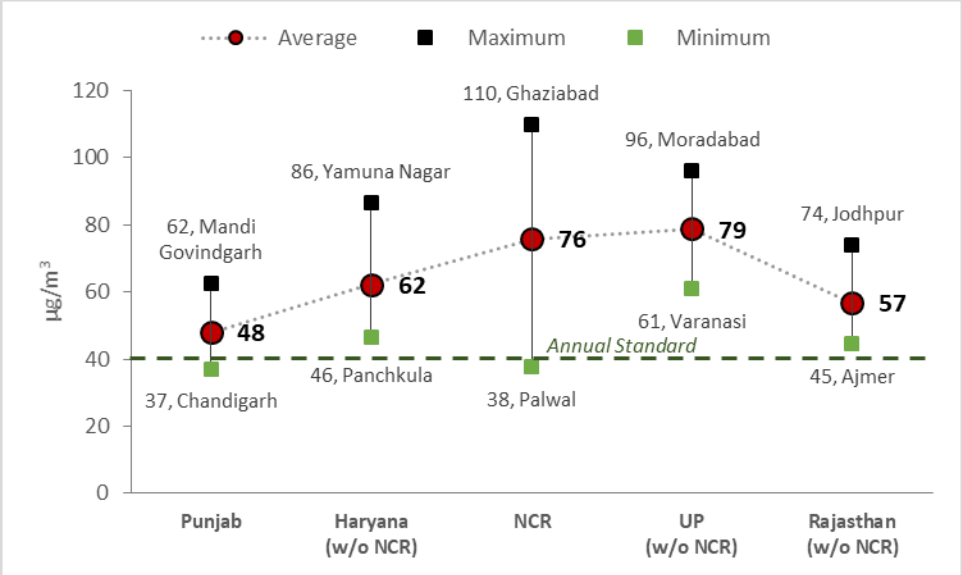
Haryana (excluding NCR sub region) was the third most polluted state with PM2.5 average of 62 ug/m3 and Yamuna Nagar was its most polluted city with PM2.5 level of 86 ug/m3.

Rajasthan with average of 57 ug/m3 was lower than others. Jodhpur has been the dirtiest city in the desert state with a PM2.5 level of 74 ug/m3 during early winter of 2021.

Punjab which is the hotbed of farm stubble burning has the lowest sub-regional PM2.5 level of 48 ug/m3. Mandi Govindgarh was the most polluted city in the state with PM2.5 level at 62 ug/m3. Chandigarh with PM2.5 level of 37 ug/m3 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)

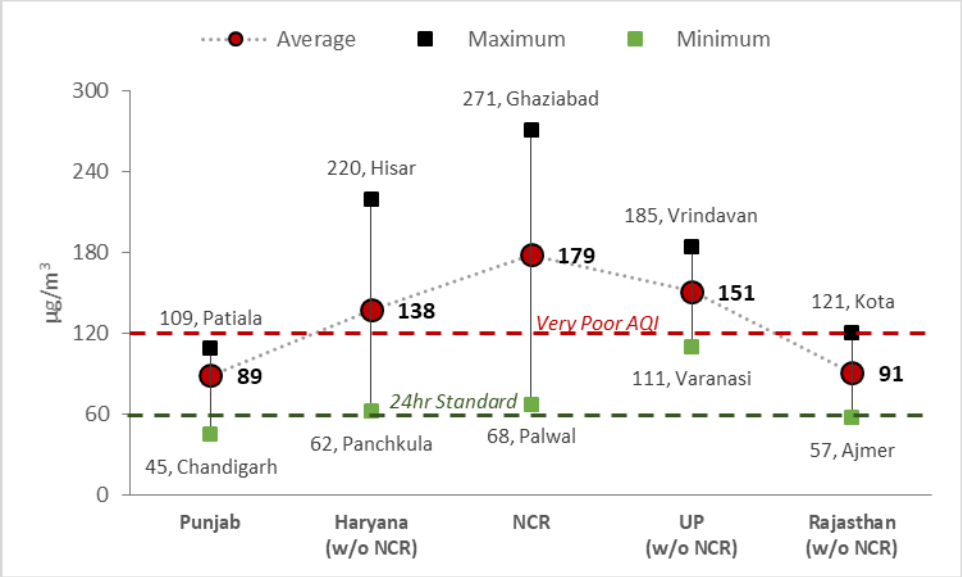


Note: PM2.5 values for sub-regions are based on the average of citywide values of all the cities in that region. PM2.5 values for cities with more than one monitoring stations is based on average of all stations that have continuous and adequate data for complete assessment period. Data up till 30 November 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 ug/m3 to reach 151 ug/m3 in the month of November. NCR with November average of 179 ug/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 ug/m3) in NCR was the most polluted in the region. Patiala (109 ug/m3) in Punjab, Hisar (220 ug/m3) in Haryana, Vrindavan (185 ug/m3) in UP and Kota (121 ug/m3) 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 ug/m3.

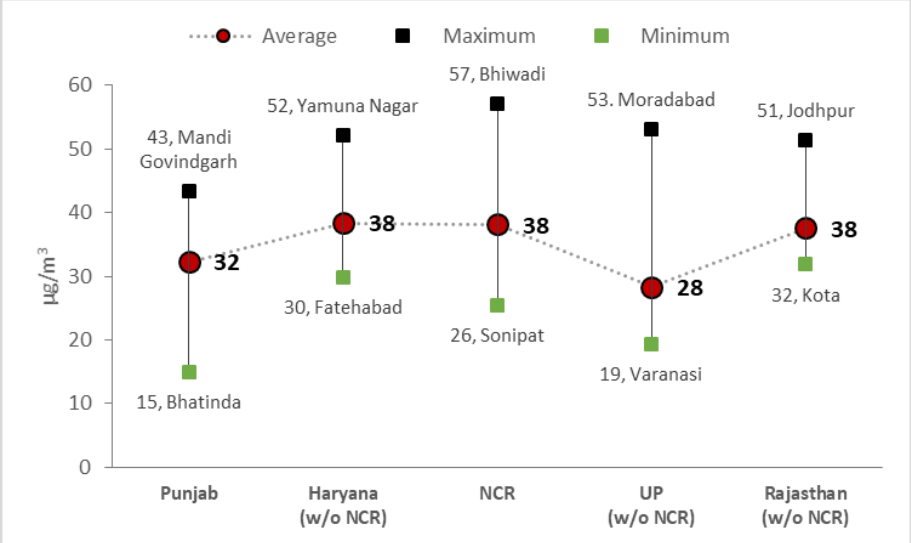
Graph 6: November PM2.5 levels among sub-regions of North India



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 ug/m3 followed by Punjab at 32 ug/m3. NCR, Haryana, and Rajasthan had 38 ug/m3 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 ug/m3) in Punjab, Yamuna Nagar (52 ug/m3) in Haryana, Bhiwadi (57 ug/m3) in NCR, Moradabad (53 ug/m3) in UP and Jodhpur (51 ug/m3) 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.

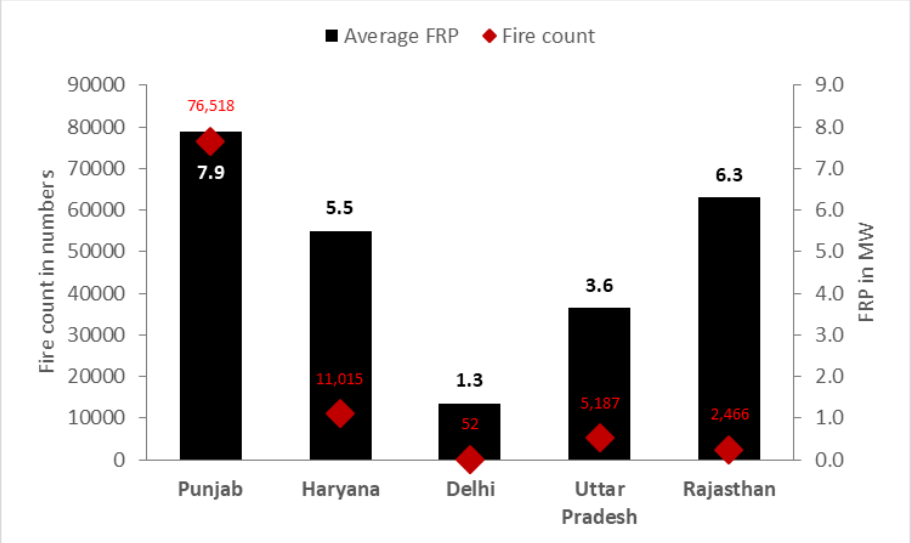
This year, Punjab has noted the maximum number of fires with a combined count 76,518 during October and November (See Graph 8: Comparison of fire instances and average Fire Radiative Power among North Indian states). Haryana recorded 11,015 incidences, UP 5,187, Rajasthan 2,466 and Delhi 52.

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.

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).

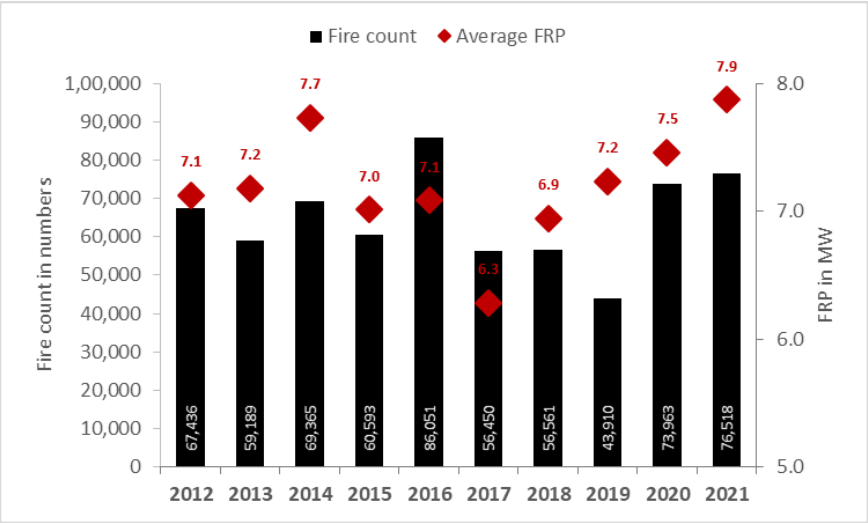
Fire count during winter in UP and Rajasthan are insignificant compared to Punjab and Haryana. Both have reported three-fold more instances of fire during summer compared to winter. However, due to summer meteorological conditions that allow more efficient pollution dispersion do not have similar effect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

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



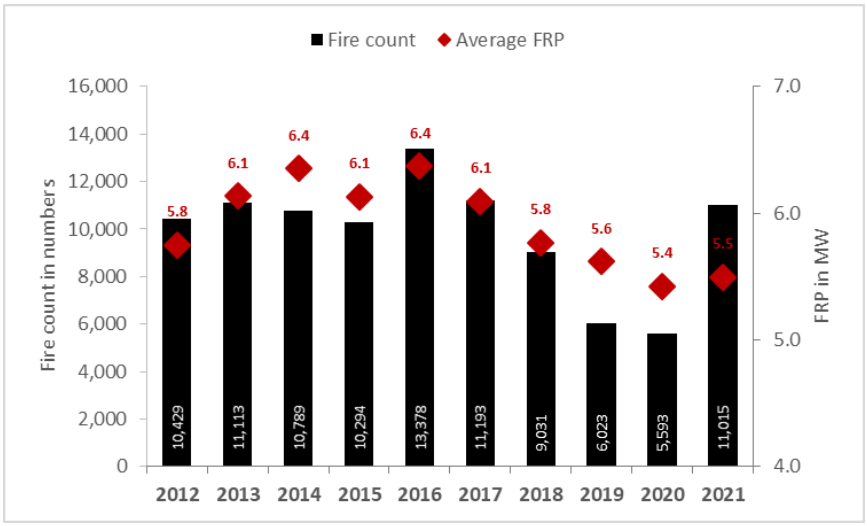
Source: CSE analysis of NASA FIRMS data

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

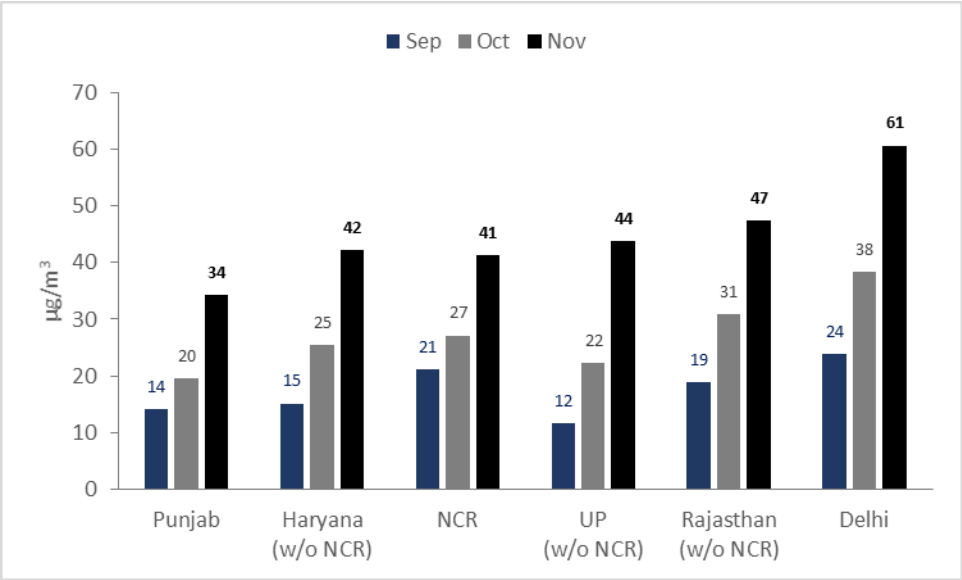


Source: CSE analysis of NASA FIRMS data

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).

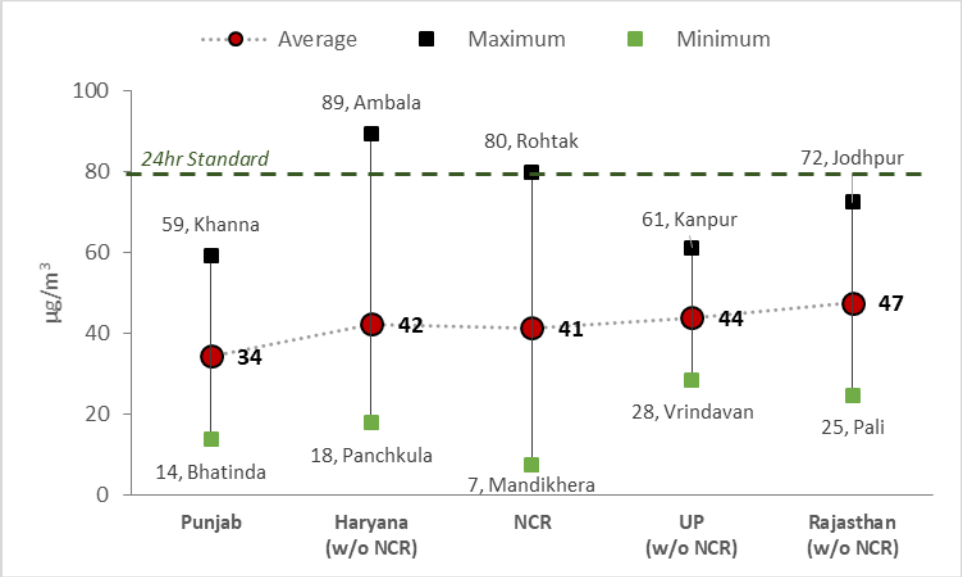
In absolute concentration term, Rajasthan cities (outside NCR) registered the highest sub-regional average of 47 ug/m3 (See Graph 12: November NO2 levels among sub-regions of North India). Among Punjab cities Ambala with monthly average of 89 ug/m3 was the most polluted in the region. Khanna (59 ug/m3) in Punjab, Rohtak (80 ug/m3) in NCR, Kanpur (61 ug/m3), and Jodhpur (72 ug/m3) 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



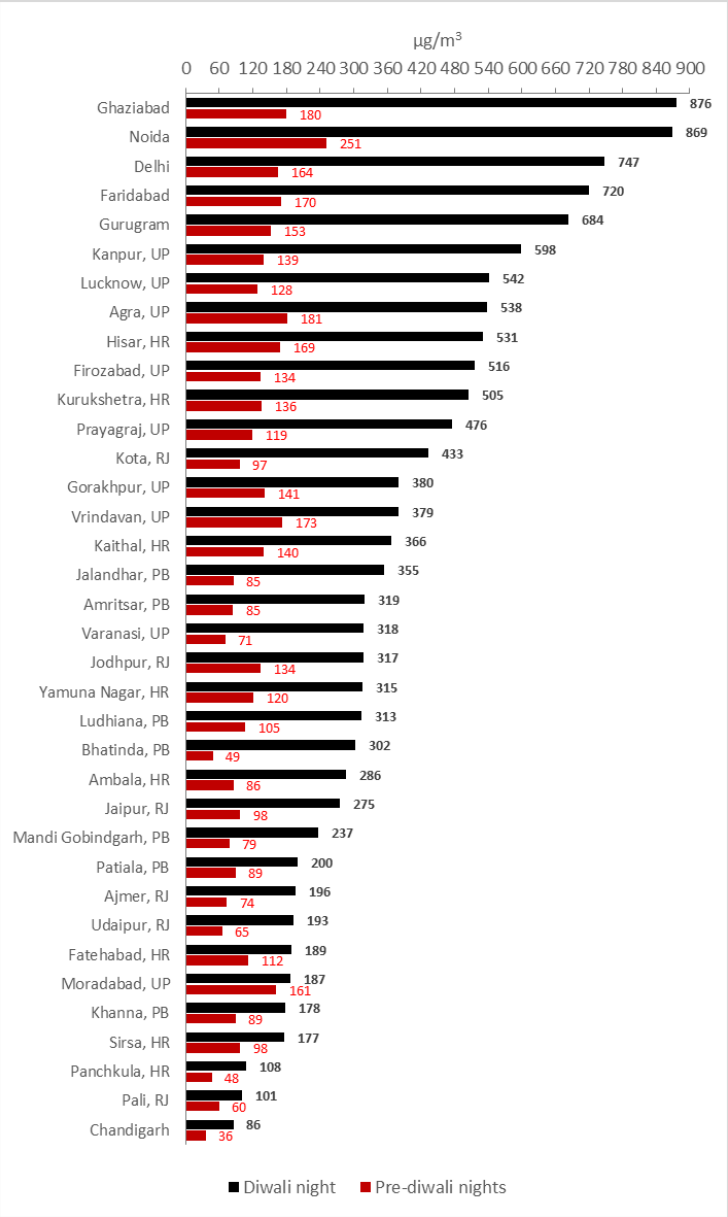
Note: NO2 values for sub-regions are based on the average of citywide values of all the cities in that region. NO2 values for cities with more than one monitoring stations is based on average of all stations that have continuous and adequate data for complete assessment period. Data up till 30 November 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 ug/m3 level for Diwali night is only matched by its big four satellite towns; Ghaziabad (876 ug/m3), Noida (869 ug/m3), Faridabad (720 ug/m3), and Gurugram (684 ug/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 ug/m3 and 543 ug/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.

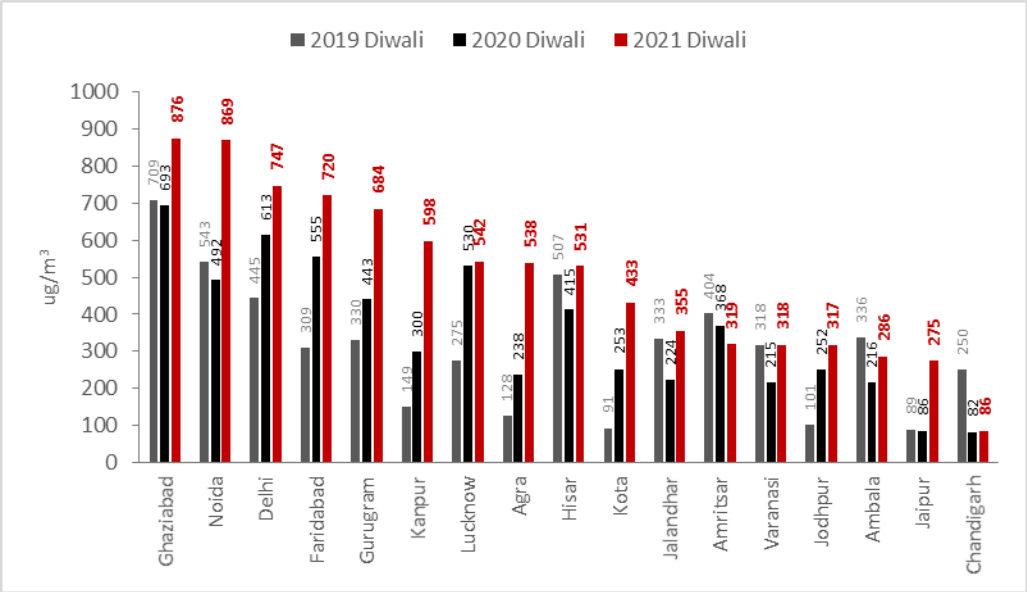
This Diwali had the worst air quality in last three years for all major cities in the region except Amritsar, Ambala and Chandigarh. Cities of UP and Rajasthan had seen the maximum increase on Diwali night (See Graph 14: Trend in Diwali night pollution among major cities of North India).

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

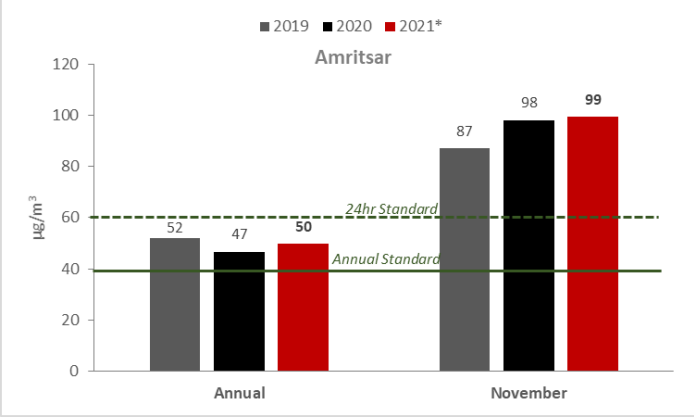
Punjab: Amritsar

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).

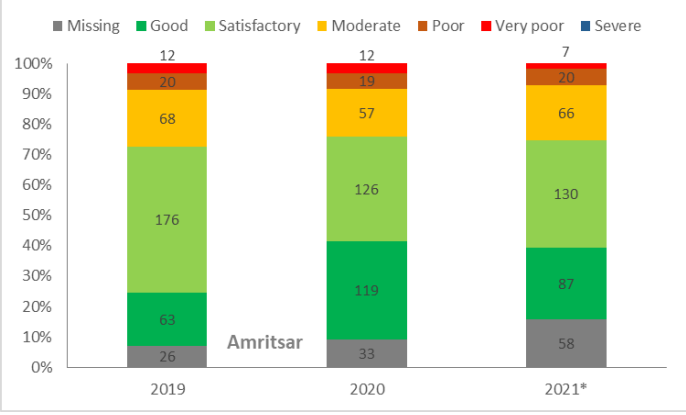
But this city only has only one monitoring station located at Golden Temple Complex (cleanest spot in the city) and not representative of air quality of the entire city. Improved monitoring network can help to understand the air quality profile of the city better.

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



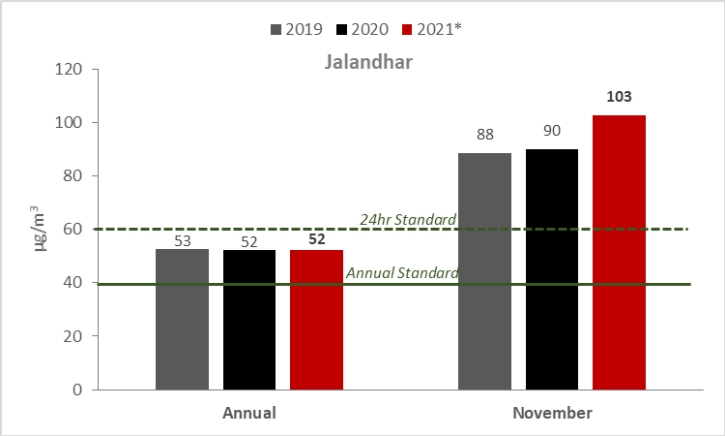
Note: PM2.5 value is based on stations that have continuous and adequate data for complete assessment period. AQI is based on PM2.5 sub-category only. Data up till 30 November 2021.
Source: CSE analysis of realtime data from CPCB portal

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.

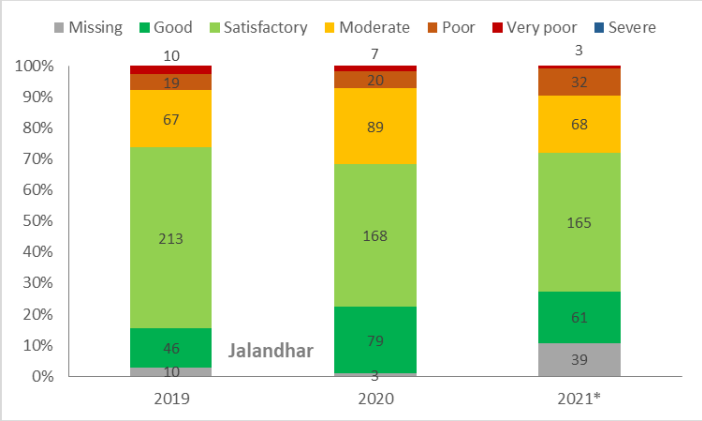
Pollution level during winter is rising. Analysis of days as per AQI categorisation shows that the city's air quality has not deteriorated to severe level in last three years but number of days with poor and very poor air quality have shown increase this year (See Graph 18: PM2.5 AQI trend in Jalandhar).

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



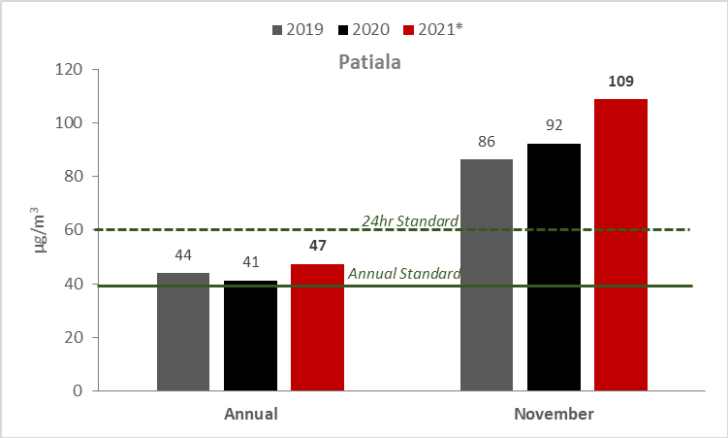
Note: PM2.5 value is based on stations that have continuous and adequate data for complete assessment period. AQI is based on PM2.5 sub-category only. Data up till 30 November 2021.
Source: CSE analysis of realtime data from CPCB portal

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.

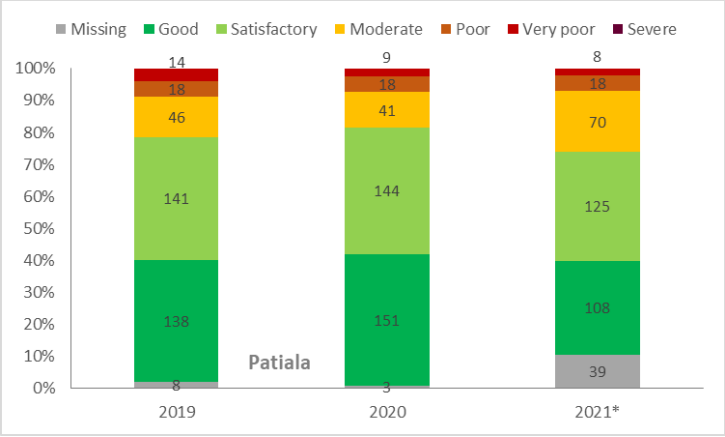
Analysis of days as per AQI categorisation shows that the city's air quality has not deteriorated to severe level in last three years but number of days with poor and very poor air quality have shown increase this year (See Graph 20: PM2.5 AQI trend in Patiala). There is a 40 days drop in number good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



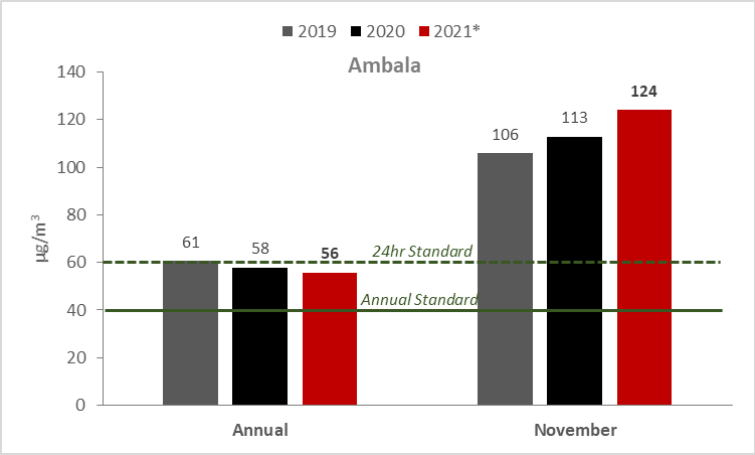
Note: PM2.5 value is based on stations that have continuous and adequate data for complete assessment period. AQI is based on PM2.5 sub-category only. Data up till 30 November 2021.
Source: CSE analysis of realtime data from CPCB portal

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.

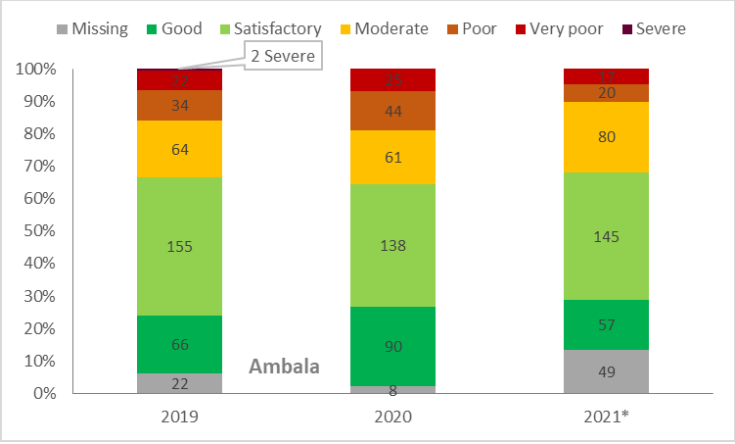
Pollution level during winter is rising. Analysis of days as per AQI categorisation shows that the city's air quality has not deteriorated to severe level since 2019 when it had two severe days and number of days with poor and very poor air quality so far are also lower this year (See Graph 22: PM2.5 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



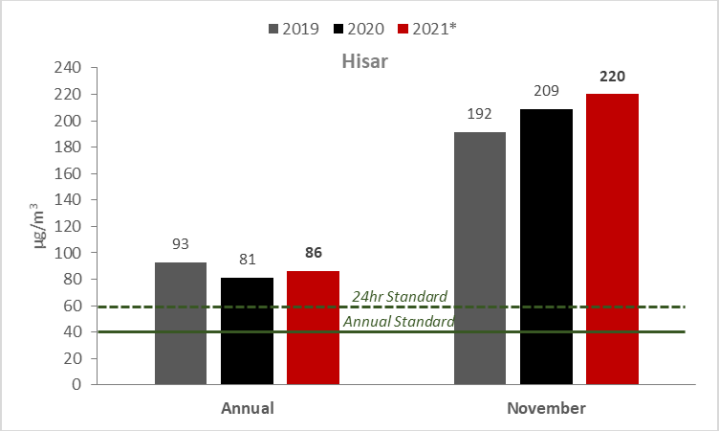
Note: PM2.5 value is based on stations that have continuous and adequate data for complete assessment period. AQI is based on PM2.5 sub-category only. Data up till 30 November 2021.
Source: CSE analysis of realtime data from CPCB portal

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.

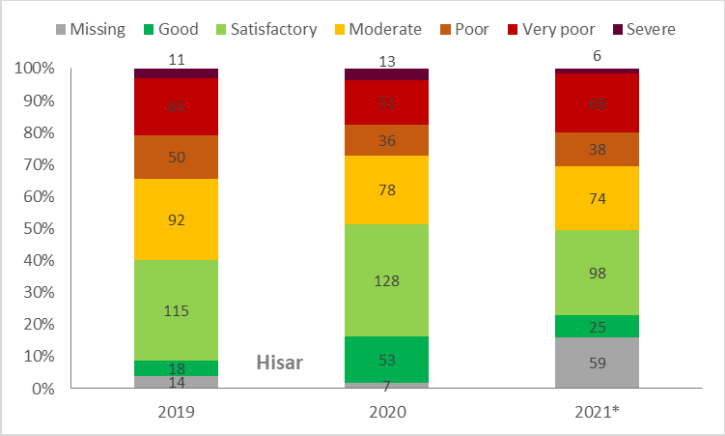
Analysis of days as per AQI categorisation shows that the city's air quality has 6-13 severe days each year and city has already clocked similar number of very poor or worse air days this year so far. As air quality in the city mostly remains in very poor category in December therefore 2021 might end 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



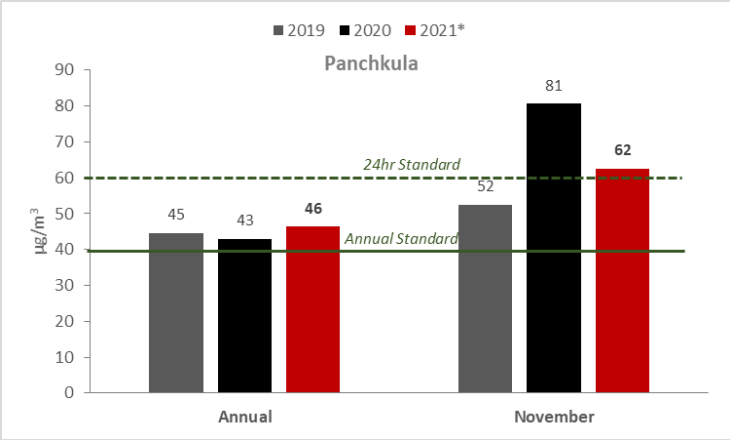
Note: PM2.5 value is based on stations that have continuous and adequate data for complete assessment period. AQI is based on PM2.5 sub-category only. Data up till 30 November 2021.
Source: CSE analysis of realtime data from CPCB portal

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.

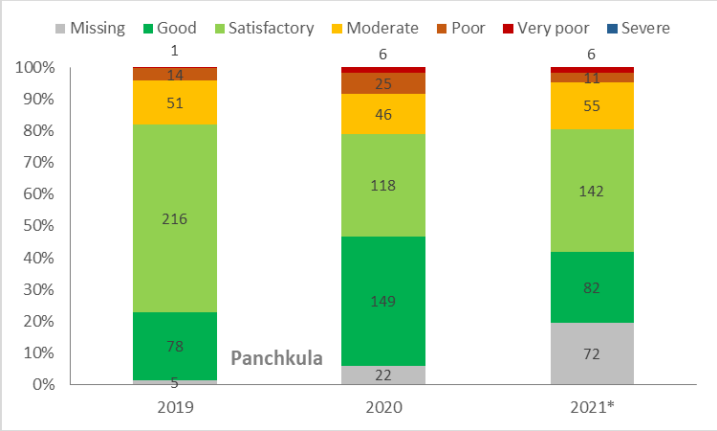
Analysis of days as per AQI categorisation shows that the city's air quality has not deteriorated to severe in last three year (See Graph 26: PM2.5 AQI trend in Panchkula). But there is a drop in number good and satisfactory days in the city this year compared to 2019 and 2020. This year there has been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

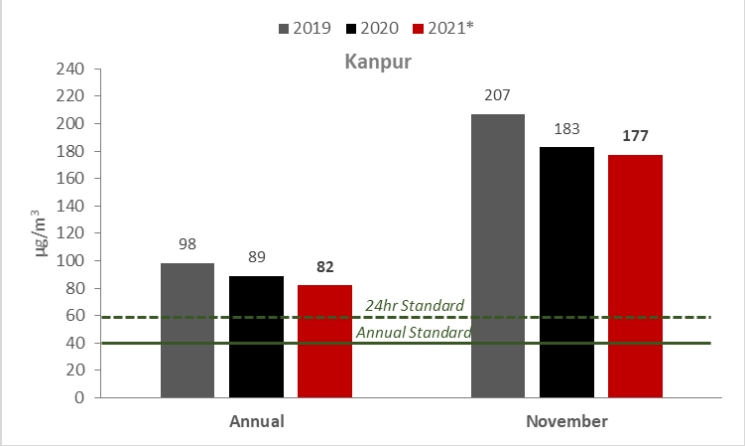
Uttar Pradesh (UP): Kanpur

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).

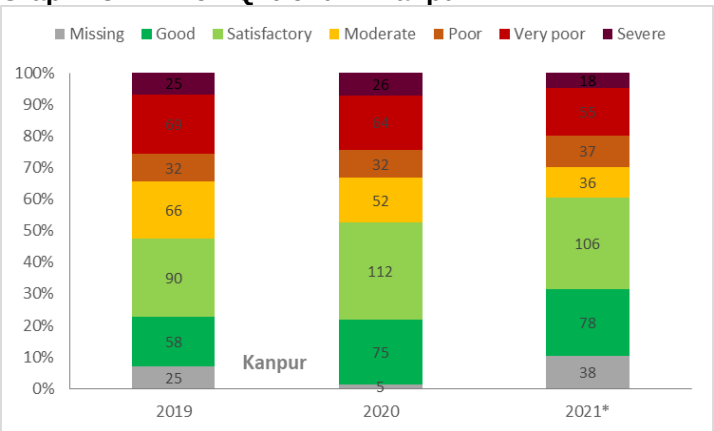
City has added three new monitoring stations this year to its long term station at Nehru Nagar. November average at these new stations show that there is considerable variation in PM2.5 levels within the city (See Graph 29: November PM2.5 level among city stations in Kanpur). IIT Kanpur station has worst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

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



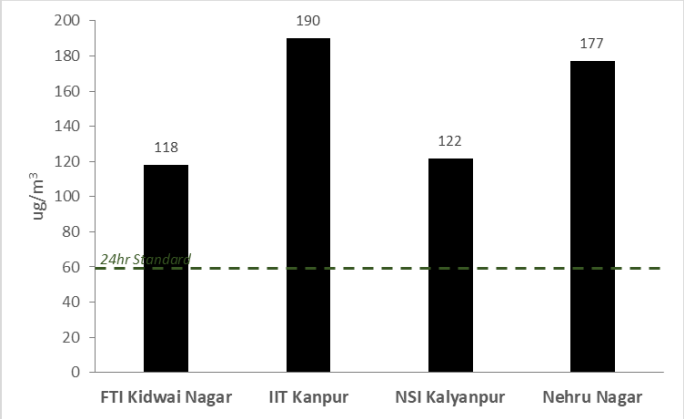
Note: PM2.5 values is based on stations that have continuous and adequate data for complete assessment period. Data up till 30 November 2021.
Source: CSE analysis of realtime data from CPCB portal

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

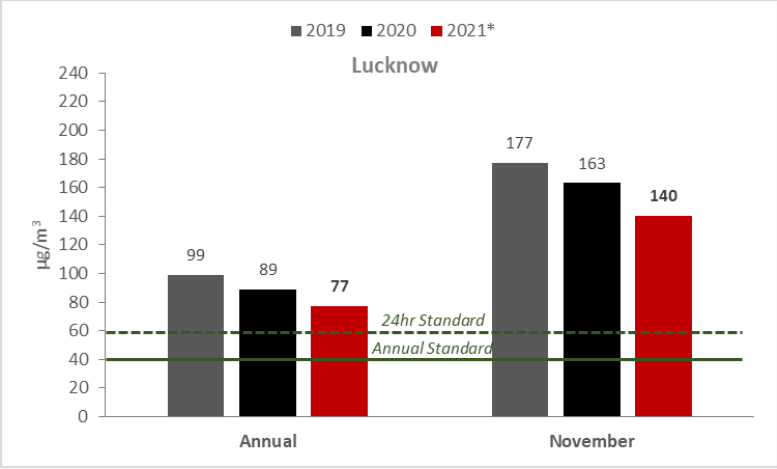
UP: Lucknow

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).

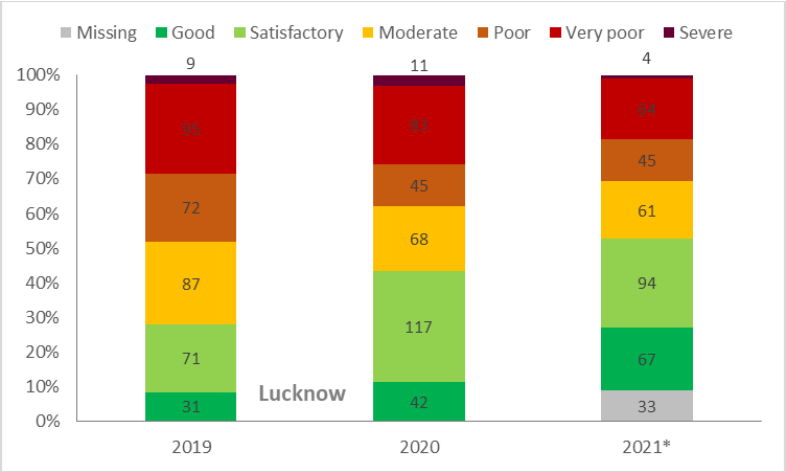
City has added two new monitoring stations (Ambedkar University and Kukrail) this year to its four long term stations at Central School, Gomti Nagar, Lalbagh, and Talkatora. November average at these stations show that there is considerable variation in PM2.5 levels within the city (See Graph 32: November PM2.5 level among city stations in Lucknow). Talkatora station has worst air with November average of 192 ug/m3, while station at Gomit Nagar is least polluted with November average of 98 ug/m3.

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



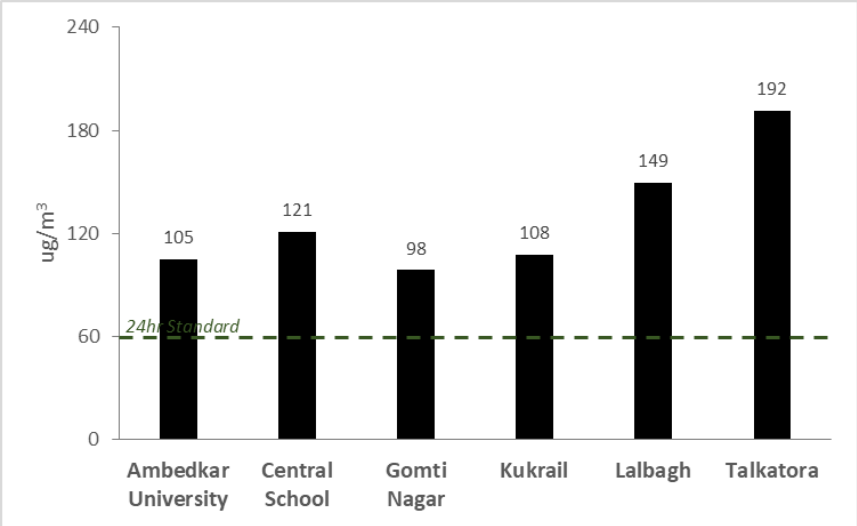
Note: PM2.5 values is based on stations that have continuous and adequate data for complete assessment period. Data up till 30 November 2021.
Source: CSE analysis of realtime data from CPCB portal

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

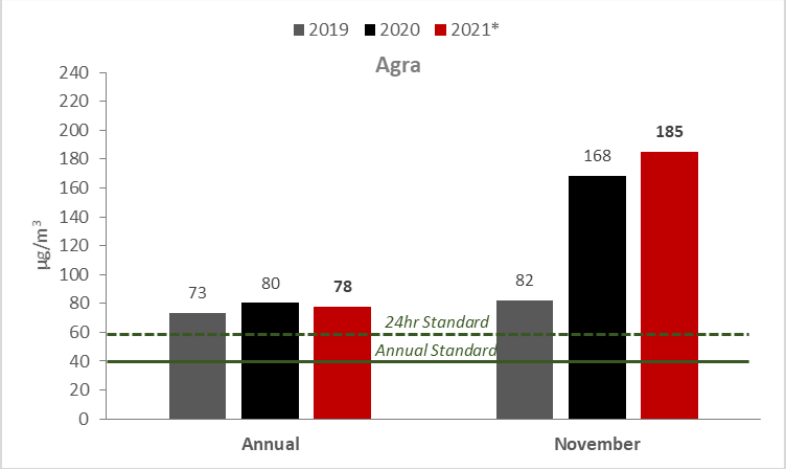
UP: Agra

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.

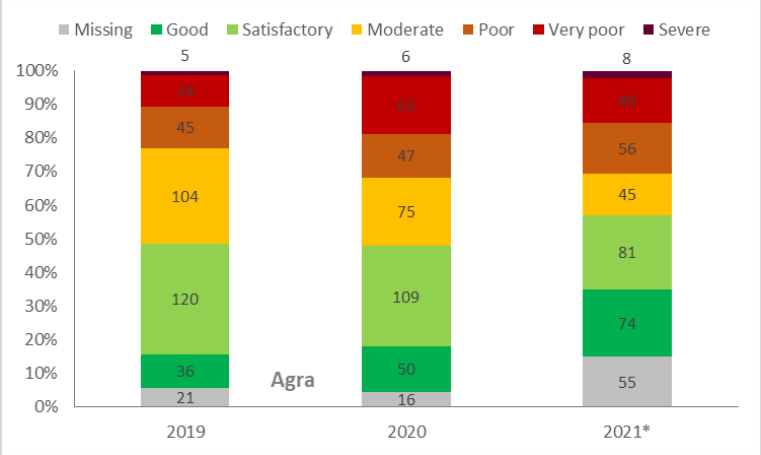
City has added four new monitoring stations this year to its long term station at Sanjay Palace. November average at these new stations show that there is considerable variation in PM2.5 levels within the city (See Graph 35: November PM2.5 level among city stations in Agra). Avas Vikas Colony station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

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



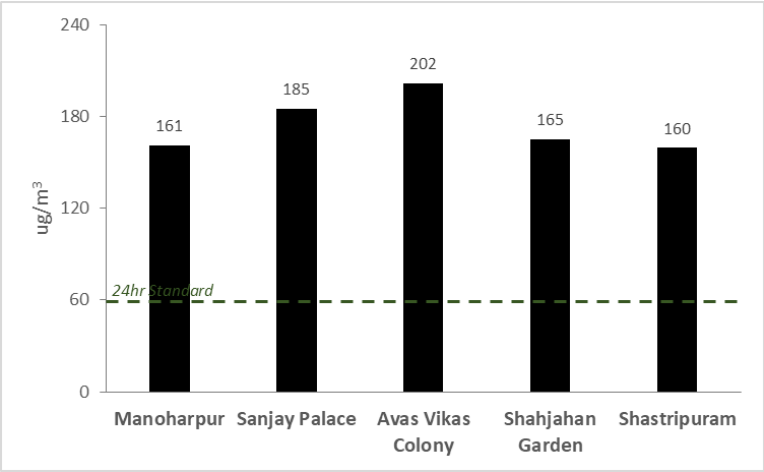
Note: PM2.5 values is based on stations that have continuous and adequate data for complete assessment period. Data up till 30 November 2021.
Source: CSE analysis of realtime data from CPCB portal

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

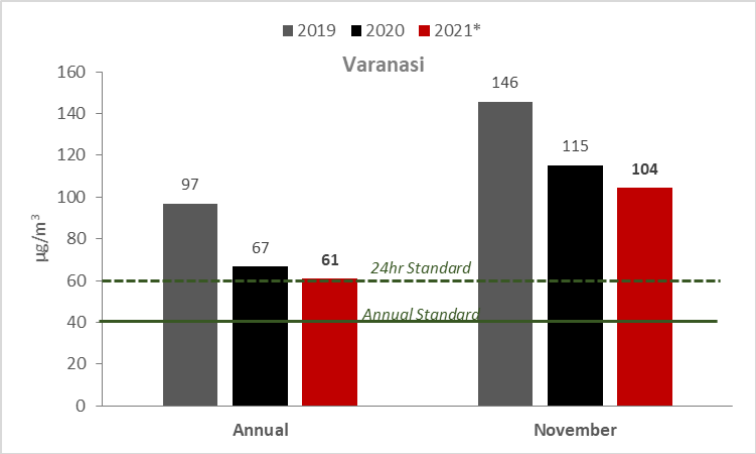
UP: Varanasi

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).

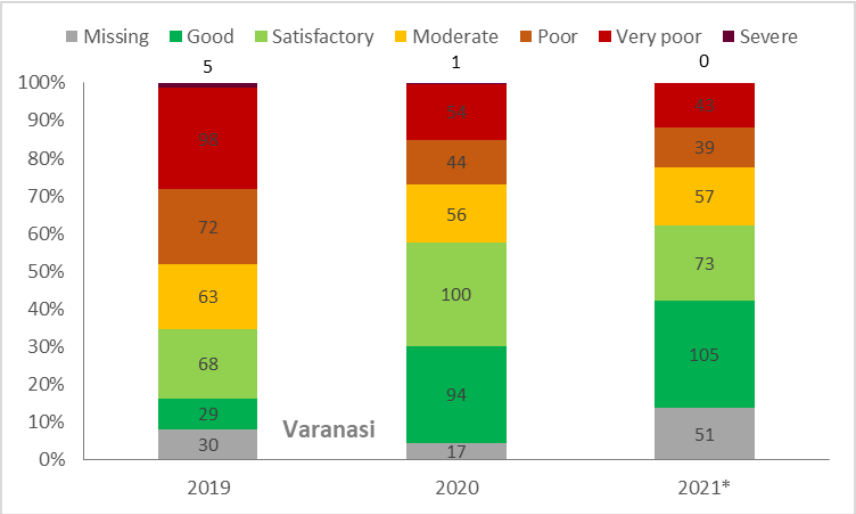
City has added three new monitoring stations this year to its long term station at Ardhali Bazar. November average at these new stations show that there is considerable variation in PM2.5 levels within the city (See Graph 38: November PM2.5 level among city stations in Agra). Maldahiya station has worst air with November average of 129 ug/m3, while station at BHU is least polluted with November average of 98 ug/m3.

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



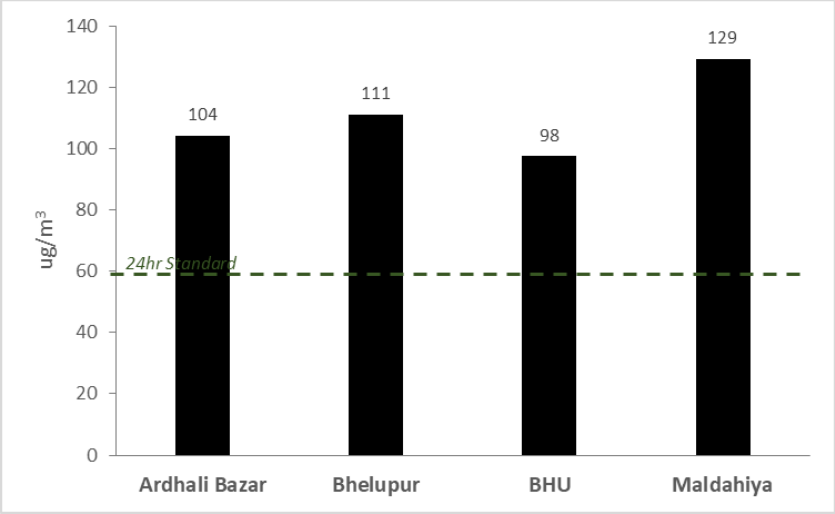
Note: PM2.5 values is based on stations that have continuous and adequate data for complete assessment period. Data up till 30 November 2021.
Source: CSE analysis of realtime data from CPCB portal

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 Agra



Source: CSE analysis of realtime data from CPCB portal

Rajasthan: Jaipur

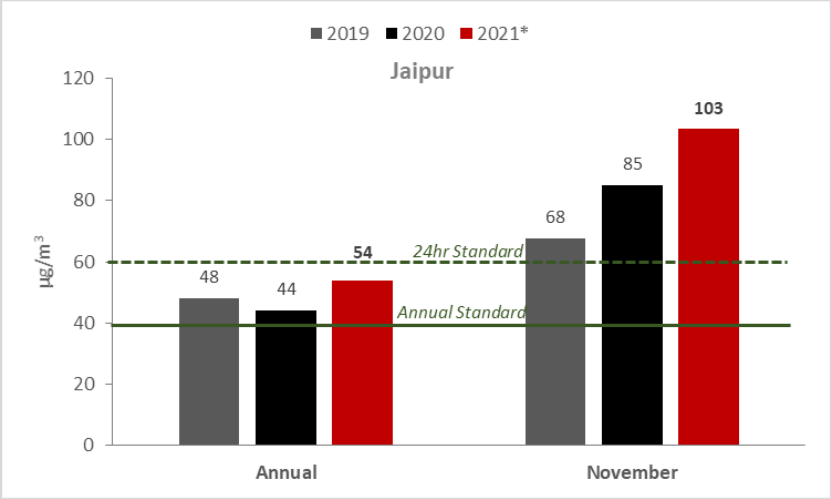
City has a rising annual average over last three year and with 2021 might considerably higher (12 per cent) annual average than 2019 (See Graph 39: PM2.5 annual and winter trend in **J**aipur). It needs to cut pollution level by over 25 per cent to meet the standard.

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.

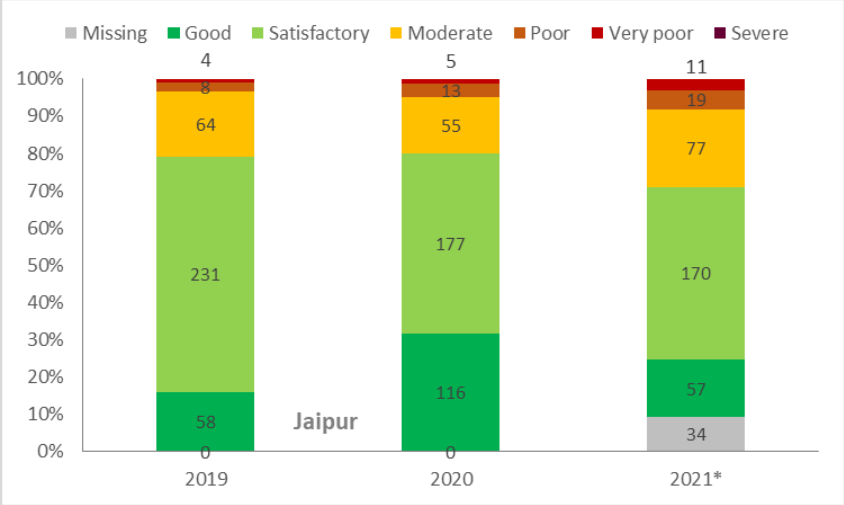
City has three monitoring stations at Adarsh Nagar, Police Commissionerate and Shastri Nagar. November average at these stations show that there is not a considerable variation in PM2.5 levels among them (See Graph 41: November PM2.5 level among city stations in **J**aipur). This is due to relatively close by siting of these stations. Police Commissionerate station has worst air with November average of 113 ug/m3, while station at Shastri Nagar is least polluted with November average of 95 ug/m3.

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



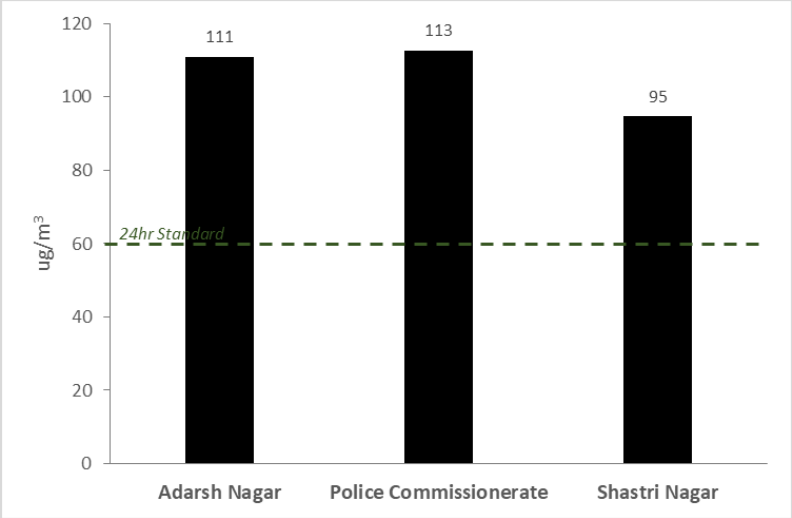
Note: PM2.5 values is based on stations that have continuous and adequate data for complete assessment period. Data up till 30 November 2021.
Source: CSE analysis of realtime data from CPCB portal

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



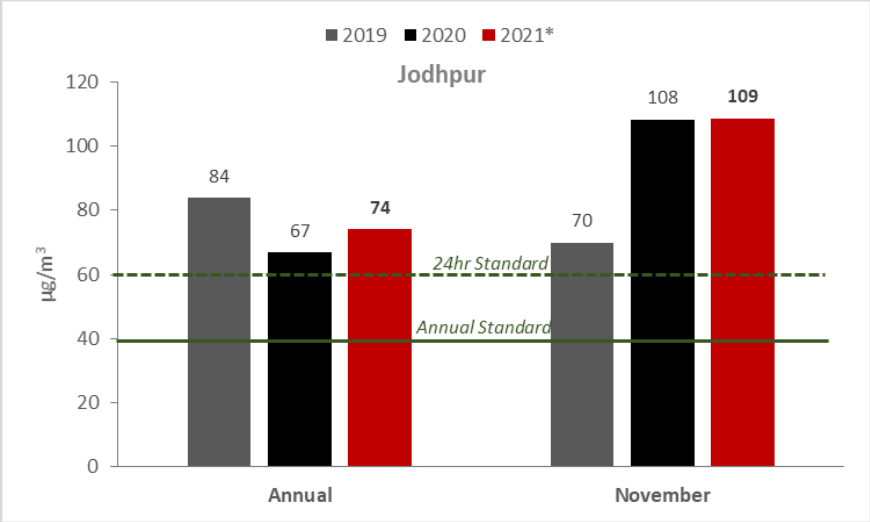
Source: CSE analysis of realtime data from CPCB portal

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.

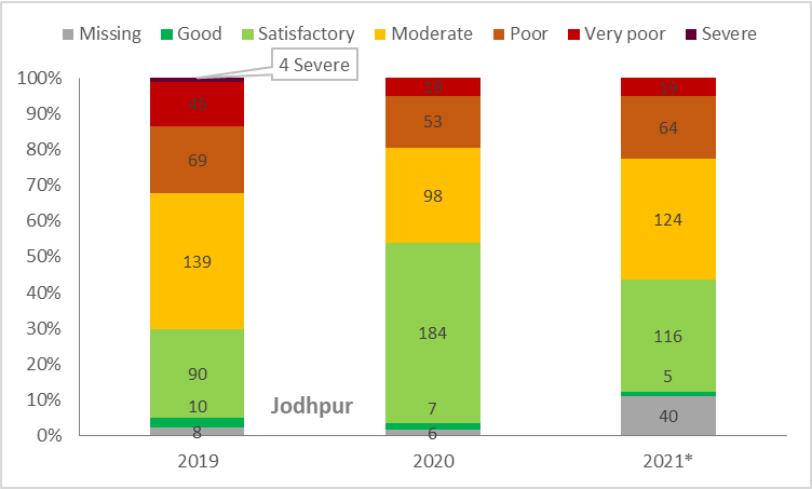
Further, pollution level during winter has been on rise with 2021 November being dirtier than 2019 and 2020 Novembers. Analysis of days as per AQI categorisation shows that the city has not had severe days since 2019 when it had 4 severe days. Overall number of days with poor or worse air quality in 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



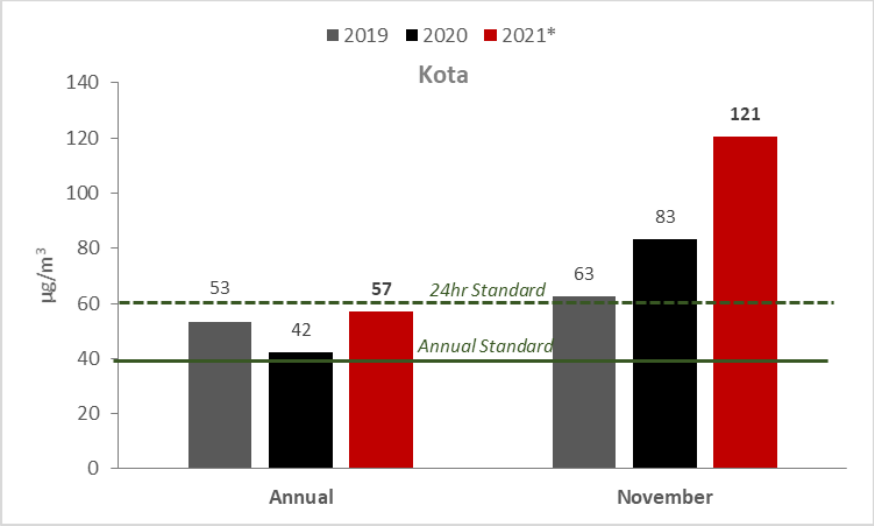
Note: PM2.5 value is based on stations that have continuous and adequate data for complete assessment period. AQI is based on PM2.5 sub-category only. Data up till 30 November 2021.
Source: CSE analysis of realtime data from CPCB portal

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.

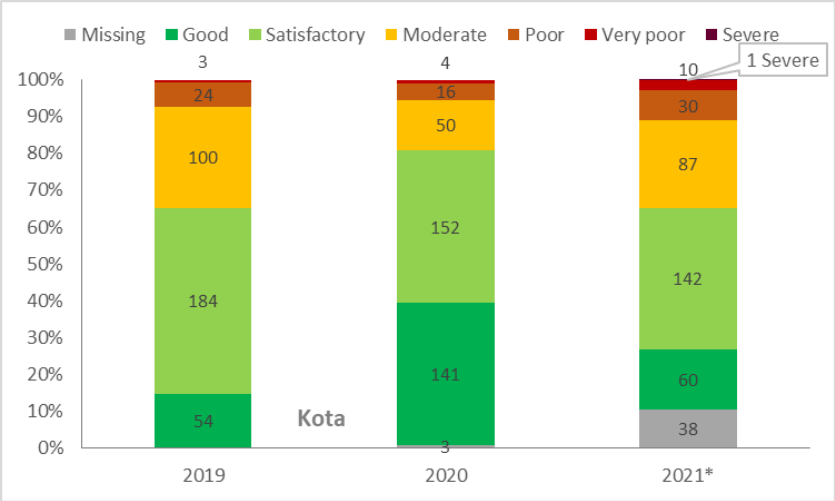
Further, pollution level during winter has been on rise with 2021 November being significantly dirtier than 2019 and 2020 Novembers. Analysis of days as per AQI categorisation shows that the city had it first severe day this year since 2019. Overall number of days with poor or worse air quality in the 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



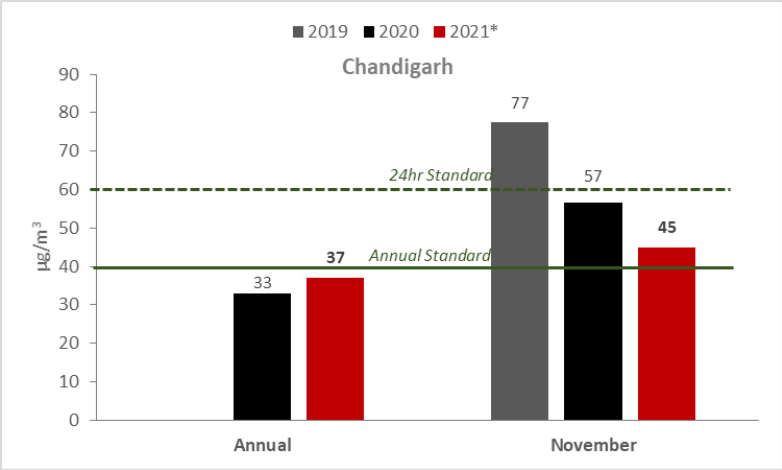
Note: PM2.5 value is based on stations that have continuous and adequate data for complete assessment period. AQI is based on PM2.5 sub-category only. Data up till 30 November 2021.
Source: CSE analysis of realtime data from CPCB portal

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).

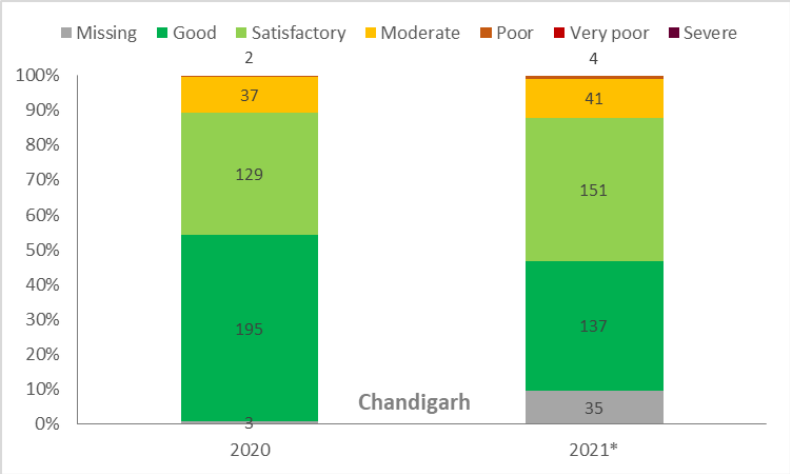
Further, pollution level during winter has been on decline with 2021 November average being significantly under the 24-hr standard. Analysis of days as per AQI categorisation shows that the city registered four days of poor air quality this year which is increase from two poor air days observed last 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



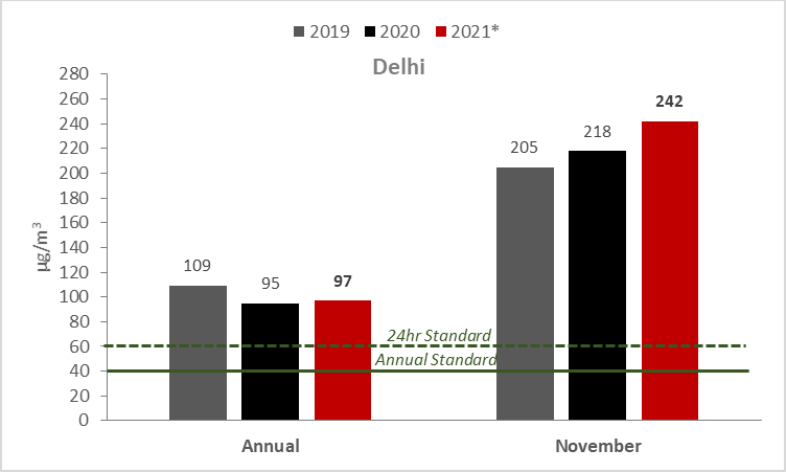
Note: PM2.5 value is based on stations that have continuous and adequate data for complete assessment period. AQI is based on PM2.5 sub-category only. Data up till 30 November 2021.
Source: CSE analysis of realtime data from CPCB portal

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.

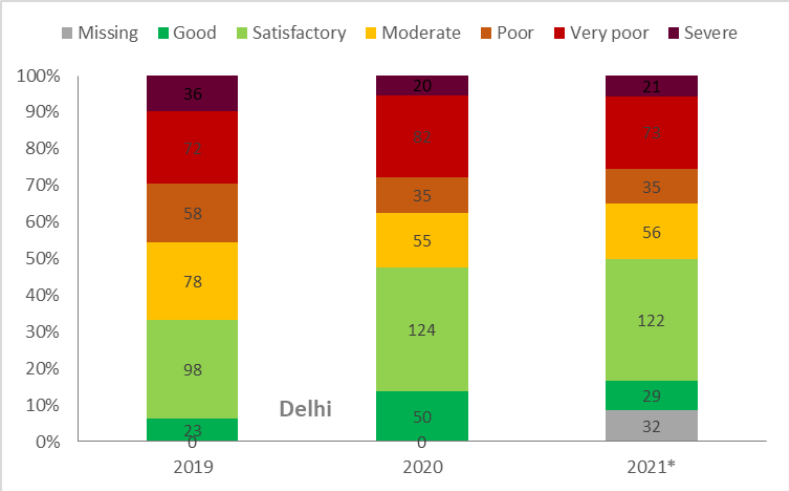
But pollution level during winter has been on rise with 2021 November being significantly dirtier than 2019 and 2020 Novembers. Analysis of days as per AQI categorisation shows that the number of very poor and severe days this year might be same as observed in 2019. Overall number of days with good and 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



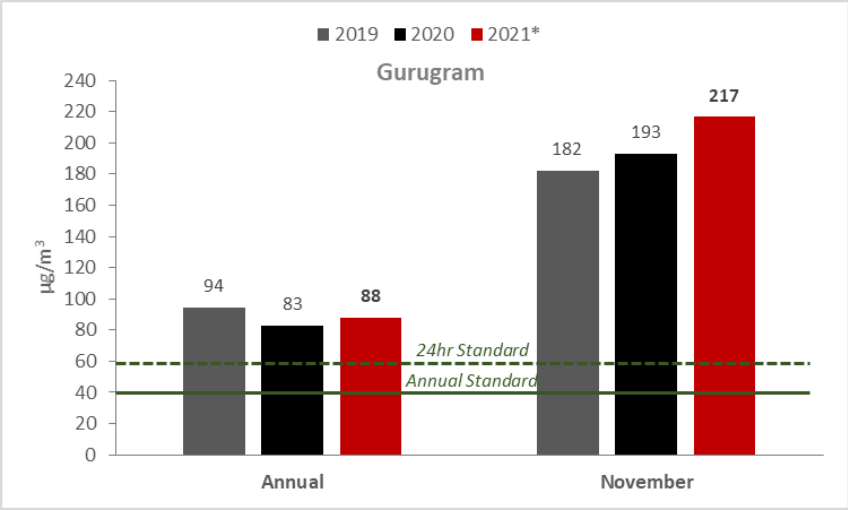
Note: PM2.5 value is based on stations that have continuous and adequate data for complete assessment period. AQI is based on PM2.5 sub-category only. Data up till 30 November 2021.
Source: CSE analysis of realtime data from CPCB portal

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.

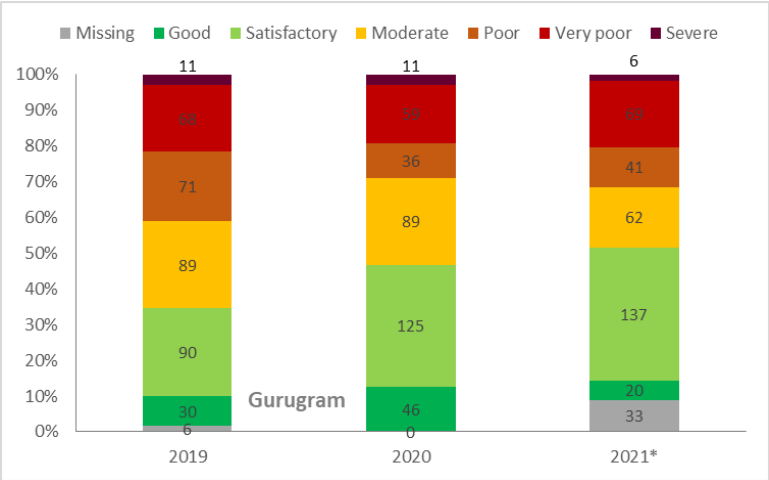
But pollution level during winter has been on rise with 2021 November being significantly dirtier than 2019 and 2020 Novembers. Analysis of days as per AQI categorisation shows that the number of very poor and severe days this year might be same as observed in 2019. Overall number of days with good and 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



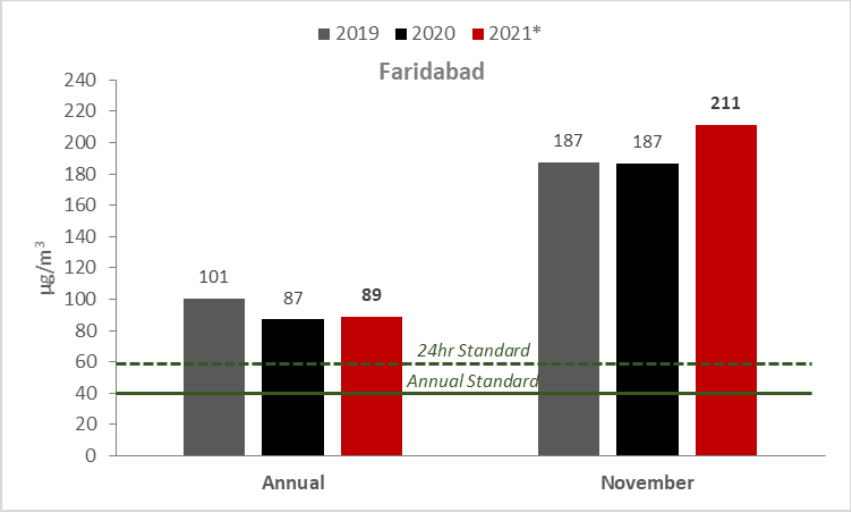
Note: PM2.5 value is based on stations that have continuous and adequate data for complete assessment period. AQI is based on PM2.5 sub-category only. Data up till 30 November 2021.
Source: CSE analysis of realtime data from CPCB portal

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.

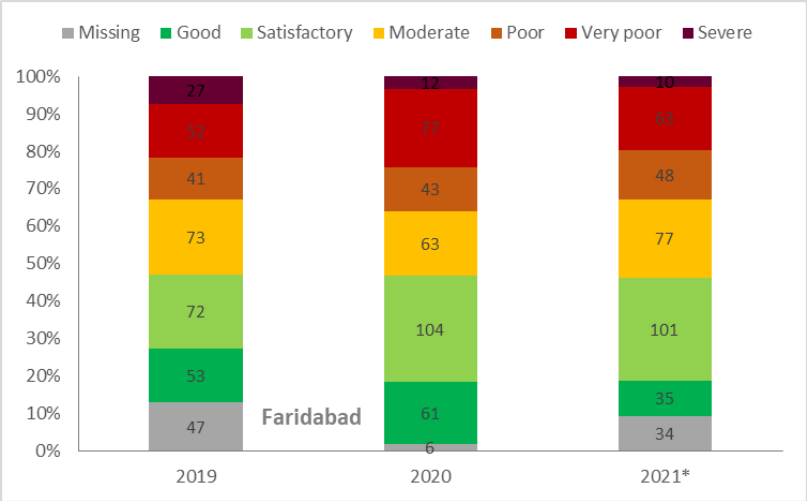
But pollution level during winter has been on rise with 2021 November being significantly dirtier than 2019 and 2020 Novembers. Analysis of days as per AQI categorisation shows that the number of very poor and severe days this year might be same as observed in 2019. Overall number of days with good and 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



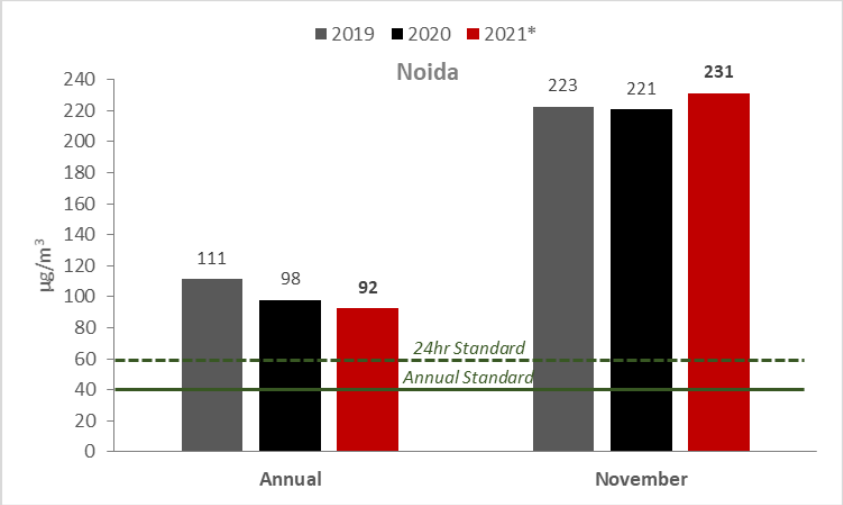
Note: PM2.5 value is based on stations that have continuous and adequate data for complete assessment period. AQI is based on PM2.5 sub-category only. Data up till 30 November 2021.
Source: CSE analysis of realtime data from CPCB portal

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.

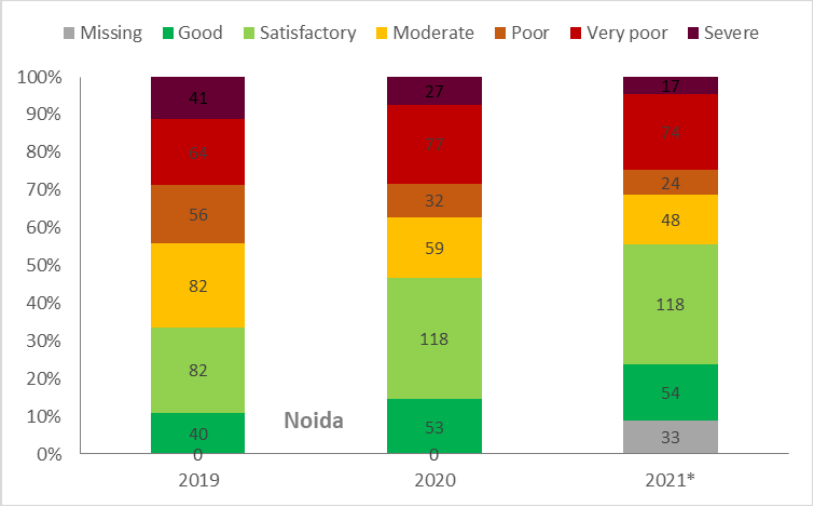
But pollution level during winter has been on rise with 2021 November being significantly dirtier than 2019 and 2020 Novembers. Analysis of days as per AQI categorisation shows that the number of very poor and severe days this year might be same as observed in 2019. Overall number of days with good and 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



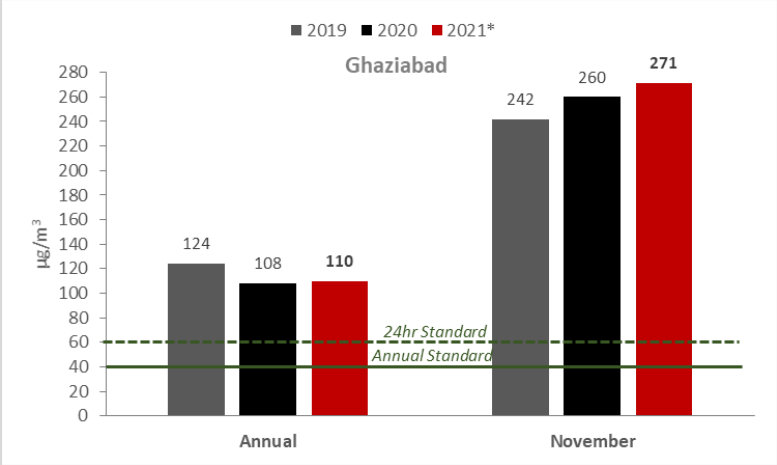
Note: PM2.5 value is based on stations that have continuous and adequate data for complete assessment period. AQI is based on PM2.5 sub-category only. Data up till 30 November 2021.
Source: CSE analysis of realtime data from CPCB portal

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.

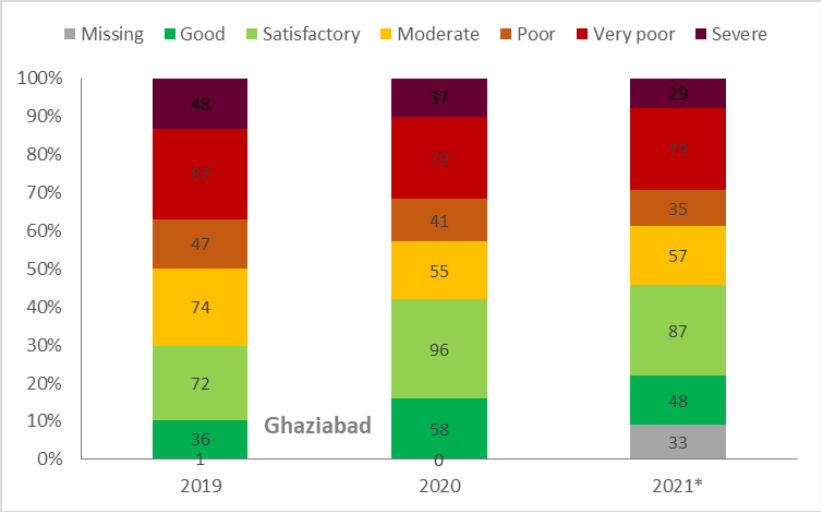
But pollution level during winter has been on rise with 2021 November being significantly dirtier than 2019 and 2020 Novembers. Analysis of days as per AQI categorisation shows that the number of very poor and severe days this year might be same as observed in 2019. Overall number of days with good and 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

List of cities included in the study

S. No.	City	November 2021 average (µg/m^3)
	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