Status of Urban and Rural air quality exposure at nation scale: A comparative analysis

Key Messages

- The analysis revealed that air pollution continues to be a significant problem in India, affecting both rural and urban populations. High levels of PM2.5, a dangerous particulate matter, were observed across the country, with variations observed between states. This indicates that air pollution is not limited to specific regions but rather a nationwide concern.

- PM 2.5 levels in the rural and urban regions across India are not very different and have witnessed a similar trend of decline over the last few years. Rural regions saw PM 2.5 levels decline by 19.1%, and urban regions recorded an 18.7% dip in PM 2.5 levels between 2017 and 2022, according to an analysis of the 1km x 1km satellite data available from IIT Delhi. So while the National Clean Air Programme is focused on cities, it is evident that air pollution is not limited to geographical boundaries.

- Despite y-o-y improvements in IGP states vs other states, the 2022 PM2.5 averages for both rural and urban areas in the country show that levels remain above the CPCB annual safe limit of 40 ug/m3. The comparison between states which have NCAP norms vs those which don’t, show a similar trend. This implies that every Indian has been living in long term exposure to air pollution which can lead to a range of health impacts.

- This highlights the need to address air pollution on a broader scale rather than focusing solely on urban areas. Efforts to mitigate air pollution should encompass a more comprehensive approach that addresses pollution sources in both rural and urban settings. Managing the air quality of entire airsheds should be the preferred policy route.

- Data shows that PM 2.5 across the rural and urban regions have plateaued over the last six years and is witnessing a consistent decline. With a reduction of 37.8% and 38.1% in urban and rural PM 2.5 levels, respectively, Uttar Pradesh has recorded the best progress from 2017 to 2022. Maharashtra was the worst performing state, with only a dip of 7.7% in its urban PM 2.5 levels, while with a decrease of 8.2% in its rural PM 2.5 levels, Gujarat made the least progress. Among all states and union territories, only With urban PM 2.5 levels up by 0.3%, Chandigarh was the only union territory to see an increase.

- The analysis also highlighted the value of satellite data in tracking air pollution trends. Satellite-derived PM2.5 levels provided comprehensive insights into both rural and urban areas, enabling a better understanding of pollution patterns and their sources. However, since rural areas are largely excluded from the air quality monitoring programme, the ground data supplied to validate the satellite-derived data results in a more homogenised outlook. A more dense rural monitoring network will help improve the quality of satellite data.

Background

India launched the National Clean Air Programme (NCAP) in 2019 to reduce particulate concentrations by 20-30% by 2024. The programme involves comprehensive planning to reduce ambient air pollution within specific time frames. However, rural areas have not been monitored yet, and air pollution remains a significant problem in these areas.

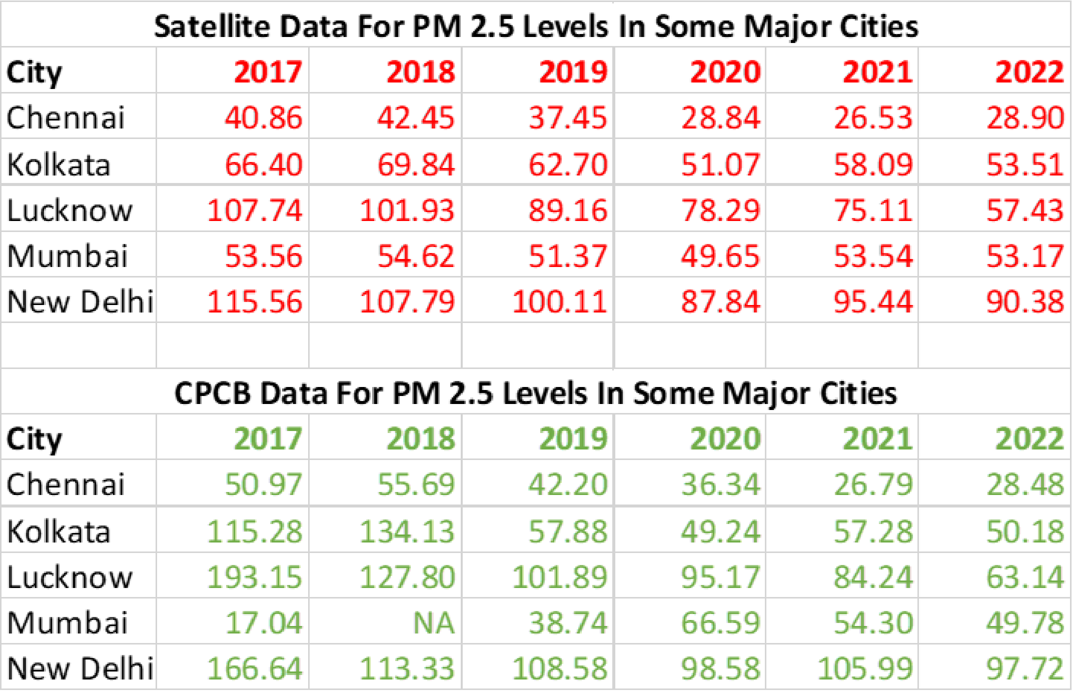
The two monitoring networks, CAAQMS (Continuous Ambient Air Quality Monitoring Stations) and NAMP (National Air Pollution Monitoring Programme) are growing, CAAQMS currently has 400 monitoring stations, while NAMP has over 800 networks in various places or cities. However, many cities in India still use only one station to measure air quality, primarily in urban areas. The national capital and other large cities monitor ambient air quality at multiple locations, with Delhi measuring air quality at 39 CAAQMS sites and six NAMP sites.

A study has suggested that India needs more than 4,000 monitoring stations to capture spatial variability. Since ground monitoring is inadequate and expensive to expand, the Central Pollution Control Board (CPCB), along with the Indian Institute of Technology, Delhi, has been exploring other hybrid approaches to address the gaps in air quality monitoring.

Scientific methods to derive surface PM2.5 from aerosol optical depth (AOD) has matured over time, and a national PM2.5 database has been developed by standardizing an algorithm for India (SAANS).

A comparison between satellite-derived PM2.5 and PM2.5 measured by the Central Pollution Control Board's (CPCB) CAAQMS network shows a high correlation (R=0.97) and low RMSE {7.2 µg/m3(micrograms per cubic metre)}, with uncertainty expected to be less than 10% at annual PM2.5 levels lower than 200 µg/m3. (Dey et al., 2020)

Figure A: Annual Average PM 2.5 (in ug/m3) levels for some major cities derived from Satellite data and CPCB's CAAQMS network.



Satellite Data For PM 2.5 Levels In Some Major Cities

City	2017	2018	2019	2020	2021	2022
Chennai	40.86	42.45	37.45	28.84	26.53	28.90
Kolkata	66.40	69.84	62.70	51.07	58.09	53.51
Lucknow	107.74	101.93	89.16	78.29	75.11	57.43
Mumbai	53.56	54.62	51.37	49.65	53.54	53.17
New Delhi	115.56	107.79	100.11	87.84	95.44	90.38

CPCB Data For PM 2.5 Levels In Some Major Cities

City	2017	2018	2019	2020	2021	2022
Chennai	50.97	55.69	42.20	36.34	26.79	28.48
Kolkata	115.28	134.13	57.88	49.24	57.28	50.18
Lucknow	193.15	127.80	101.89	95.17	84.24	63.14
Mumbai	17.04	NA	38.74	66.59	54.30	49.78
New Delhi	166.64	113.33	108.58	98.58	105.99	97.72

Figure A (given above) shows us that the annual averages, as derived from the SAANS satellite data and the CPCB's ground monitoring network, do not differ significantly in most cases. It also shows that as processes to derive satellite-based PM 2.5 levels matured, the difference between the two data sets has narrowed down. For instance, satellite-derived PM 2.5 levels and CPCB PM 2.5 levels for Chennai in 2017 were 40.86 ug/m3 and 50.97 ug/m3 in 2017. In 2022, the gap between the two datasets was down to 0.5 ug/m3. The similarity in the two datasets allows us the confidence to use satellite-derived PM 2.5 levels to analyse air pollution trends for rural and urban areas in the country.

According to the Central Pollution Control Board's National Ambient Air Quality Standards (NAAQS), the annual average safe limits for PM 2.5 are 40 ug/m3 and PM 10 are 60 ug/m3. This is well above the WHO's revised guidelines of 5 ug/m3 and 15 ug/m3 for PM 2.5 and PM 10, respectively.

Analysis

To track urban and rural pollution levels, two different datasets were used in this analysis: Dr Sagnik Dey's SAANS data from the Indian Institute of Technology, Delhi, for PM2.5 estimation and the Global Human Settlement Layer (GHSL) data for urban and rural classification. The GHSL provides information in four distinct years – 1975, 1990, 2000, and 2015.

In this analysis, the pollution level for both rural and urban areas was calculated from 2017 to 2022. Since GHSL data was not available for that period, it was assumed that the human settlement pattern did not change much from 2015 to 2022 to affect the results. The data was developed at 1-km × 1-km spatial resolution, allowing for capturing the variability of urban and rural pollution levels at a national scale. Each 1-km × 1-km grid of satellite-based PM2.5 data set was matched with GHSL data, and the urban and rural PM2.5 levels in each state and Union Territories were estimated. The analysis does not include the 'no settlement areas' (No population zone). The statistics of rural and urban pollution levels and the changes between 2017 and 2022 are reported in Tables 1 & 2. **We found that the percentage reduction of rural concentration is about 19.1 %, and urban concentration is reduced by 18.7 % for India.**

Table 1: Showing the state-level Rural PM2.5 concentration (in ug/m3) from 2017 to 2022. Percentage change is for 2022 with respect to 2017 for each state.

State	Region	2017	2018	2019	2020	2021	2022	% change
ANDAMAN & NICOBAR	South	40.7	38.4	38.4	34.2	32.6	35.1	-13.6
ANDHRA PRADESH	South	46.6	44.5	39.6	35.6	36.9	37.3	-20.1
ARUNACHAL PRADESH	East	46.8	45.4	41.1	38.8	38.5	32.4	-30.7
ASSAM	East	70.2	67.3	59.2	55.6	57.8	51.2	-27.1
BIHAR	North	92.0	87.9	76.1	62.5	65.6	74.5	-19.0
CHANDIGARH	North	58.4	53.5	50.0	45.4	48.6	54.0	-7.6
CHHATTISGARH	East	54.0	51.7	46.7	42.6	43.4	41.0	-24.0
DADRA & NAGAR HAVELI	West	53.6	52.9	47.7	45.8	48.2	49.4	-7.8
DAMAN & DIU	West	55.0	55.4	51.2	49.8	52.4	52.4	-4.6

DELHI	North	113.5	105.1	95.8	84.9	91.7	87.7	-22.7
GOA	West	42.6	42.6	37.2	34.9	35.4	38.0	-10.8
GUJARAT	West	61.0	59.8	52.5	49.5	53.0	56.0	-8.2
HARYANA	North	86.7	79.9	73.6	65.7	69.6	67.8	-21.9
HIMACHAL PRADESH	North	53.6	52.6	47.9	44.7	45.7	45.6	-14.9
JAMMU & KASHMIR	North	51.0	49.4	45.1	43.0	44.6	41.7	-18.3
JHARKHAND	East	61.9	60.2	54.5	48.3	50.3	50.7	-18.0
KARNATAKA	South	37.0	36.2	32.9	29.1	29.4	30.3	-18.1
KERALA	South	36.3	36.1	32.0	29.8	29.8	31.9	-12.2
LADAKH	North	55.2	53.8	49.0	46.0	45.6	40.7	-26.3
MADHYA PRADESH	West	55.9	54.6	48.1	45.0	47.5	47.7	-14.7
MAHARASHTRA	West	49.1	47.8	43.1	39.7	42.4	44.5	-9.5
MANIPUR	East	37.8	38.4	34.1	31.1	31.6	29.7	-21.5
MEGHALAYA	East	55.9	55.3	48.0	45.0	47.0	45.3	-19.1
MIZORAM	East	41.7	43.2	39.1	35.1	36.0	34.1	-18.3
NAGALAND	East	44.8	44.4	39.1	36.5	37.4	33.9	-24.4
ODISHA	East	56.7	55.3	49.5	44.6	44.8	47.3	-16.4
PUDUCHERRY	South	40.5	41.0	35.6	31.4	30.4	32.8	-18.9
PUNJAB	North	63.5	56.9	52.6	50.6	54.2	53.7	-15.4
RAJASTHAN	West	73.1	69.6	61.5	55.7	59.9	60.4	-17.4
SIKKIM	East	44.2	43.1	38.9	36.5	36.3	27.8	-37.2
TAMIL NADU	South	42.6	41.9	36.6	32.9	32.9	32.9	-22.7

TELANGANA	South	48.8	46.0	41.9	38.3	40.6	40.2	-17.5
TRIPURA	East	59.6	60.2	51.9	47.7	50.1	49.4	-17.1
UTTAR PRADESH	North	100.7	95.5	83.9	72.9	73.1	62.3	-38.1
UTTARAKHAND	North	66.6	65.6	59.7	54.7	56.0	52.9	-20.7
WEST BENGAL	East	69.0	67.6	59.5	53.2	56.0	58.3	-15.6

Table 2: Showing the state-level Urban PM2.5 concentration (in ug/m3) from 2017 to 2022. Percentage change is for 2022 with respect to 2017 for each state.

State	Region	2017	2018	2019	2020	2021	2022	% change
ANDAMAN & NICOBAR	South	40.4	38.2	38.1	34.1	32.3	34.0	-15.8
ANDHRA PRADESH	South	47.6	45.1	40.3	36.1	37.4	38.1	-20.0
ARUNACHAL PRADESH	East	56.3	53.7	48.6	46.1	46.5	38.2	-32.1
ASSAM	East	71.8	68.8	60.2	56.6	59.1	54.2	-24.5
BIHAR	North	92.5	88.5	76.5	63.2	66.4	77.2	-16.6
CHANDIGARH	North	56.5	51.8	49.3	43.8	47.3	56.7	0.3
CHHATTISGARH	East	55.3	52.7	47.7	43.3	44.0	41.3	-25.2
DADRA & NAGAR HAVE	West	53.0	52.4	48.1	46.3	48.7	50.4	-4.9
DAMAN & DIU	West	55.9	55.9	51.8	50.3	53.0	53.0	-5.1
DELHI	North	118.5	113.3	104.3	91.6	100.1	95.3	-19.5
GOA	West	42.1	42.4	36.8	34.7	35.3	37.4	-11.1
GUJARAT	West	60.0	58.6	51.6	48.8	52.2	54.1	-9.8

HARYANA	North	93.1	86.3	79.0	69.6	73.7	71.7	-23.0
HIMACHAL PRADESH	North	53.5	52.3	47.5	44.4	45.8	47.5	-11.2
JAMMU & KASHMIR	North	50.7	48.7	44.7	42.9	44.2	40.7	-19.6
JHARKHAND	East	64.2	62.3	56.3	49.9	52.0	52.6	-18.1
KARNATAKA	South	36.4	35.8	32.6	28.9	29.2	30.5	-16.2
KERALA	South	35.6	35.7	31.6	29.7	29.7	32.4	-9.0
LADAKH	North	51.0	49.5	45.7	42.9	43.0	36.5	-28.4
MADHYA PRADESH	West	56.4	54.9	48.5	45.1	47.2	47.5	-15.7
MAHARASHTRA	West	48.7	47.7	43.1	40.1	42.7	44.9	-7.7
MANIPUR	East	37.5	38.0	33.5	30.9	31.1	29.9	-20.3
MEGHALAYA	East	46.3	46.0	39.5	36.8	37.5	36.9	-20.2
MIZORAM	East	34.6	35.9	32.0	27.8	28.4	26.1	-24.7
NAGALAND	East	44.2	43.6	38.0	35.5	36.3	33.0	-25.3
ODISHA	East	59.6	58.0	51.6	46.6	46.5	49.7	-16.6
PUDUCHERRY	South	40.2	40.7	35.2	30.5	29.1	31.8	-20.8
PUNJAB	North	63.3	56.4	52.6	50.7	54.3	54.5	-13.9
RAJASTHAN	West	71.4	67.9	59.8	54.2	58.4	59.2	-17.0
SIKKIM	East	43.3	42.3	38.1	35.8	35.8	27.7	-35.9
TAMIL NADU	South	42.7	42.1	36.7	32.7	32.6	33.1	-22.6
TELANGANA	South	48.8	46.0	42.1	38.5	40.7	40.4	-17.3
TRIPURA	East	60.6	61.6	52.7	47.7	50.0	50.6	-16.5
UTTAR PRADESH	North	102.7	97.5	85.5	74.0	74.2	63.9	-37.8

UTTARAKHAND	North	71.6	70.2	63.8	58.5	60.0	57.8	-19.2
WEST BENGAL	East	67.3	66.8	58.9	52.2	55.2	57.2	-14.9

We present comparative statistics of urban and rural PM2.5 levels in Tables 1 & 2 for the year 2017 to 2022. The analysis reports the state-averaged changes in urban and rural exposure during this period. We observe that the urban PM2.5 exposure in Delhi decreased by 19.5% from 118.5 µg/m3 in 2017 to 95.3 µg/m3 in 2022. During the same period, the rural PM2.5 in Delhi exposure decreased by 22.7% from 113.5 µg/m3 to 87.7 µg/m3.

The NCAP was designed as a programme to address the high levels of air pollution across India’s urban centres, but we can see that the improvement is also noticeable in rural areas, and the improvement for both regions is significant. Air pollution is a transboundary problem that knows no borders. There is an urgent need to track pollution levels and develop policies for rural regions, as there is little difference in concentration levels between urban and rural areas. To better understand this, we have calculated the exposure for both urban and rural cases at a regional scale (see Figure 1).

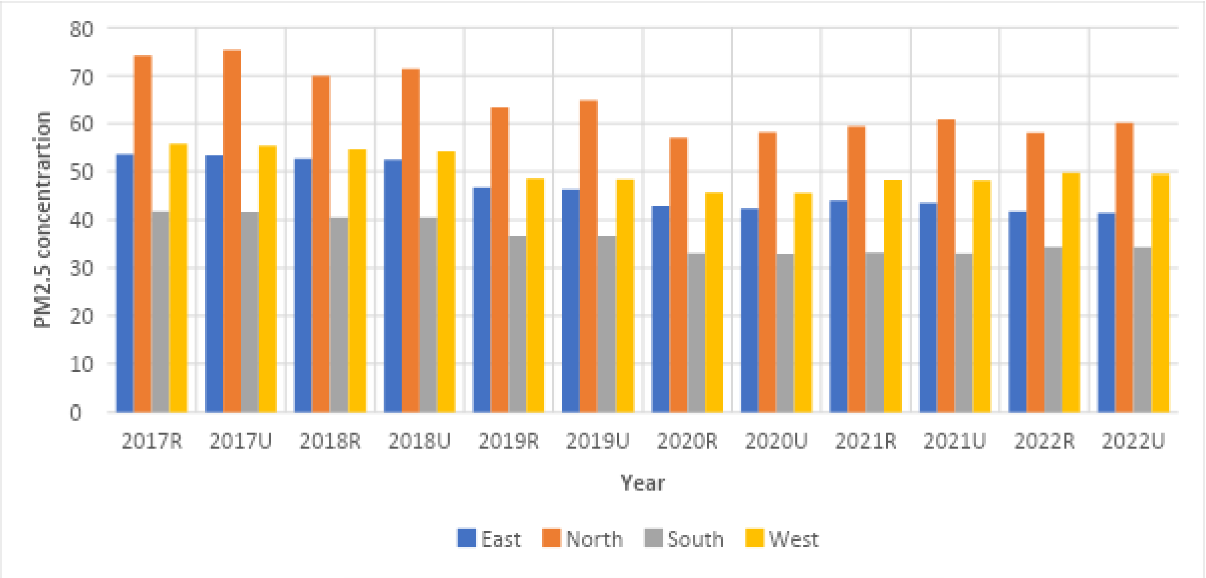


Figure 1 shows the variation of exposure at the regional scale for urban(U) and rural(R) regions. The following key conclusions can be drawn from Figure 1:

Following are the key conclusions from Table 1, Table 2 and Figure 1:

1. Satellite PM 2.5 data has been extracted for the urban-rural grid in four regions across India, and it was found that the Northern region is the most polluted one with the PM 2.5 level of 74 ug/m3 and 58 ug/m3 in the rural region and 75 ug/m3 and 60 ug/m3 in the urban region for 2017 and 2022 respectively.

2. There is little difference between urban and rural concentration for all the regions.
3. Rural concentration is higher than urban concentration in the southern region except in 2021.
4. Rural concentration is higher than urban concentration in western regions except in 2019.
5. Only the Southern region is meeting the NAAQS for both rural and urban concentration for the years 2019, 2020, 2021 and 2022.
6. The percentage change from 2017 to 2022 in western states and UTs like Maharashtra, Gujarat, Punjab, Chandigarh, Daman & Diu and Dadra and Nagar Haveli is much lower in comparison to changes in the northern and other regions for both urban and rural.
7. While the sources of air pollution vary, with almost similarly elevated levels of PM 2.5 in urban and rural regions, both groups of the population face comparable health risks. Since air pollution is typically considered an urban problem, rural India, with 70% of India's population, generally escapes attention.
8. The annual average PM 2.5 levels in rural and urban India were the highest in 2017 and lowest in 2020. Rural India's PM 2.5 levels in 2022 are 46.8 ug/m3, down by 19.1% compared to 2017. Urban India's PM 2.5 levels in 2022 are 46.4 ug/m3, down by 18.7% compared to 2017. The two continue to remain above the NAAQS annual average safe limits of 40 ug/m3.
9. Annual average PM 2.5 levels in rural and urban parts of most states have seen a similar trajectory over the last six years since 2017. The rural parts saw a greater reduction in PM 2.5 levels. For instance, Karnataka's rural PM 2.5 levels were down by 18.1%, while the urban levels were lowered by 16.2% in the same period. Similarly, West Bengal's rural PM 2.5 levels were down by 15.6% and urban PM 2.5 levels were down by 14.9%.
10. 10 states saw an upward trajectory in Urban and Rural regions since the pandemic in 2020 – Bihar, Goa, Gujarat, Kerala, Maharashtra, Telangana, West Bengal, Andaman and Nicobar, Chandigarh, and Dadra Nagar Haveli.
11. Between 2017 and 2022, twelve states saw the lowest PM 2.5 levels in 2022: Arunachal Pradesh, Assam, Chhattisgarh, Jammu and Kashmir, Ladakh, Manipur, Meghalaya, Mizoram, Nagaland, Sikkim, Uttarakhand, and Uttar Pradesh.
12. The eastern region has seen a gradual decline in PM 2.5 levels since 2017, with the lowest levels recorded last year (2022)Eastern region's urban PM 2.5 levels declined from 53.4 ug/m3 in 2017 to 41.4 ug/m3 in 2022. Its rural PM 2.5 levels dipped from 53.5 ug/m3 to 41.7 ug/m3. On the other hand, the West, North and South saw the least recorded PM 2.5 levels during the pandemic in 2020. Since then, the levels have gradually increased but yet lower than the 2017 levels. (See Table 6 for details)

13. With a reduction of 37.8% and 38.1% in Urban and Rural PM 2.5 levels, respectively, Uttar Pradesh has recorded the best progress from 2017 to 2022. Maharashtra was the worst performing state, with only a dip of 7.7% in its Urban PM 2.5 levels, while with a decrease of 8.2% in its Rural PM 2.5 levels, Gujarat made the least progress. With urban PM 2.5 levels up by 0.3%, Chandigarh was the only one to see an increase.

14. Across all regions, the rural areas saw a higher decline in PM 2.5 levels as compared to the urban levels. Northern and Eastern regions outperformed the South and West. The Western region saw only a 10.6% and 11% decrease in Urban and Rural PM 2.5 levels, respectively. Eastern Region showed the best progress with a 20.4% and 22.5% decrease in Urban and Rural PM 2.5 levels, respectively.

15. Despite progress, only 14 and 12 states brought down their urban and rural PM 2.5 levels, respectively, under the CPCB safe limits of 40 ug/m3. They are listed below:

    Urban: Andaman and Nicobar, Andhra Pradesh, Arunachal Pradesh, Goa, Karnataka, Kerala, Manipur, Mizoram, Nagaland, Puducherry, Sikkim, Tamil Nadu, Meghalaya and Ladakh. Among these, Karnataka, Kerala, Manipur, and Mizoram urban PM 2.5 levels in 2017, too, were below safe limits.

    Rural: Andaman and Nicobar, Andhra Pradesh, Arunachal Pradesh, Goa, Karnataka, Kerala, Manipur, Mizoram, Nagaland, Puducherry, Sikkim and Tamil Nadu. Of these, Karnataka, Kerala and Manipur rural PM 2.5 levels in 2017 too were below safe limits.

16. High PM2.5 in rural areas is not surprising as a large fraction of the population still relies on solid fuel for domestic use (cooking, heating, and lighting) [2]. Household sources are found to be the largest contributor to ambient PM2.5 in India [3].

Table 3: Y-o-y annual PM2.5 average for rural India vs urban from 2017 to 2022

Year	Rural	Urban
2017	57.4	57.6
2018	55.5	55.8
2019	49.8	50.1
2020	45.5	45.6
2021	47.1	47.2
2022	46.4	46.8

According to the data in **Table 3**, the PM2.5 levels in the urban and rural areas for y-o-y annual average as a whole have been almost the same, and the reduction pattern has followed each other. While rural PM2.5 averaged 57.4 ug/m3 in 2017, it averaged at 57.6 ug/m3 for urban India. Both the rural and urban areas have successfully brought down PM2.5 levels y-o-y. However, the difference between both regions is only 0.4 ug/m3 in 2022. Since 2017 rural India's PM2.5 has reduced by 11 ug/m3 in the last 6 years, coming down to 46.4 ug/m3 and by 10.8 ug/m3 for urban areas in 2022.

Other than 2021, when annual average levels escalated in comparison to those in 2020, which would be attributed to the lifting of restrictions post the COVID-19 led lockdown, PM2.5 levels have persistently reduced y-o-y from 2017 till 2022. However, the NCAP aims to reduce 20-30% of particulate matter levels by 2024, taking levels in 2017 as a base year. **This annual average reduction is 19.1% in rural and 18.7% in urban India.**

Table 4: Y-o-y annual PM2.5 average from 2017 till 2022 for all IGP states vs the Other States for both urban and rural areas

Year	Other States (Rural)	IGP States (Rural)	Other States (Urban)	IGP States (Urban)
2017	50.8	80.7	50.5	82.2
2018	49.7	75.8	49.4	77.8
2019	44.5	68.3	44.2	70.2
2020	41.2	60.4	40.9	61.8
2021	42.4	63.6	42.0	65.3
2022	41.5	63.6	41.3	66.1

According to **Table 4**, the considerable PM2.5 difference between the Indo-Gangetic Plain (IGP) states vs other states is evident from 2017 till 2022, clearly signifying why the Indo-Gangetic Plain is home to some of the most polluted cities in the world repeatedly. However, the improvement in the IGP states (rural) is 17.1 ug/m3 between 2017 levels to those in 2022, while for the urban region the improvement is 16.1 ug/m3. In comparison, the other states improved by 9.3 ug/m3 (rural) and 9.2 ug/m3 in urban areas.

The IGP states included in this analysis are Bihar, Chandigarh, Delhi, Haryana, Jharkhand, Punjab, Uttar Pradesh, and West Bengal. The urban vs rural y-o-y improvement in both IGP and Other States remains consistent. This can only signify that rural pollution is also as high as urban.

Table 5: Y-o-y annual PM2.5 average from 2017 till 2022 for all States Under NCAP vs the Other States for both urban and rural areas

Year	Other States (Rural)	Under NCAP States (Rural)	Other States (Urban)	Under NCAP States (Urban)
2017	48.5	63.1	48.5	63.4
2018	47.8	60.4	47.7	60.9
2019	43.3	54.0	43.2	54.4
2020	40.1	48.9	39.9	49.2
2021	40.8	51.1	40.7	51.3
2022	40.0	50.5	40.2	51.1

Table 5 clearly shows that levels in 2017 were higher on average in the 23 states where NCAP was enforced in comparison to the other states, both in urban and rural areas. While NCAP has been enforced in cities and urban agglomerations in these states, levels in both rural and urban areas have reduced at similar levels, signifying the need for closer ground monitoring data inspection, especially in the rural centres, to gauge improvement. NCAP states (rural) witnessed a 12.6 ug/m3 improvement in the last 6 years vs 12.3 ug/m3 in urban areas under the NCAP states.

Table 6: Y-o-y annual PM2.5 average from 2017 till 2022 for all 4 regions - East, West, North & South – for both urban and rural areas

Year	East (Rural)	North (Rural)	South (Rural)	West (Rural)	East (Urban)	North (Urban)	South (Urban)	West (Urban)
2017	53.5	74.1	41.7	55.7	53.4	75.3	41.6	55.3
2018	52.6	70.0	40.5	54.6	52.4	71.4	40.5	54.2
2019	46.8	63.3	36.7	48.7	46.4	64.8	36.6	48.5
2020	42.9	57.0	33.0	45.7	42.4	58.1	32.92	45.6
2021	44.0	59.4	33.2	48.3	43.5	60.8	32.99	48.2
2022	41.7	58.0	34.3	48.7	41.4	60.1	34.3	49.5
% difference	- 22	-21.7	-17.74	-12.5	-22.4	-20.1	-17.5	-10.4

In **Table 6,** we do not observe significant differences in PM2.5 levels for rural vs urban regions for any of the 4 zones – East, North, West and South – respectively. While most data sets have shown that levels in 2021 escalated in comparison to those in 2020 after the Covid lockdown opened up partially, this table shows that levels in the South and the West region in both urban and rural escalated in 2022 in comparison to 2021. The Western Union Territories (UTs) of Dadra & Nagar Haveli and Daman and Diu made little progress, with approximately a 4-7% decrease in PM 2.5 from 2017 to 2022. Other states like Gujarat, Maharashtra and Goa made gains of less than 10% cut in levels. On the other hand, Southern states, except Telangana, brought their PM 2.5 levels under the CPCB annual safe limits of 40 ug/m3 in 2022. States like Tamil Nadu saw a reduction of over 22% in both urban and rural PM 2.5 levels between 2017 and 2022. (see Tables 1 and 2 for details)

In India, 99.9% of people breathe unhealthy air with respect to WHO guidelines. Air pollution is now the biggest environmental risk for early death; pollution-related deaths numbered 1.67 million in 2019[4]. Decades of research have shown that air pollution increases the amount and seriousness of lung and heart disease and other health problems.

Long-term exposure to polluted air can have permanent health effects such as Accelerated ageing of the lungs, loss of lung capacity and decreased lung function, and development of other diseases such as stroke, ischaemic heart disease, chronic obstructive pulmonary disease, lung cancer, pneumonia, and cataract.

Air pollution also causes poor health conditions in children and adolescents, like low birth weight, asthma, reduced lung function, respiratory infections and allergies, as well as increased risks of adult chronic diseases.

Limitations

Satellite data has some limitations since it is retrieved from the AOD and not the direct PM2.5 monitoring. However, this 1km x 1km data set provides a holistic reference grade air quality data spread across the country, which the expensive ground-based monitoring network of CAAQMS stations cannot cover. Since rural areas in India are largely excluded from the air quality monitoring programme, the CAAQMS data supplied to validate the satellites derived data results in a more homogenised outlook between the urban and rural air pollution levels. A more dense ground-based monitoring network might reflect more nuances and differences of improvement in the rural areas, especially since the implementation of the Pradhan Mantri Ujjawala Yojana since indoor cooking fuel has been identified as one of the biggest pollution sources in India.

The analysis suggests that there has been a noticeable improvement in ambient PM2.5 levels at a regional scale, which is consistent with the data observed by ground monitors. However, it also highlights a limitation in identifying the specific sectoral contributions to this improvement. This limitation arises from the fact that the emission inventory, which provides information on pollutant sources, is only available until 2018. As a result, it is not possible to determine which sectors or activities have contributed to the observed regional improvement in PM2.5 levels.

Expert quotes:

Aarti Khosla, Director, Climate Trends

"The analysis reflects the progress being made under the National Clean Air Programme with most states and union territories seeing a dip in their PM 2.5 levels over the last few years. When divided into NCAP and non-NCAP states, we see a more significant dip in states where NCAP is being implemented. In the IGP states like Uttar Pradesh, Delhi, Haryana, and Bihar have seen a significant dip in the PM 2.5 levels indicating that the focus of the air pollution fight continues to remain in the region. However, western states like Maharashtra and Gujarat have made little progress and have seen the air pollution problem become significant in recent years.

The analysis also highlights that rural air pollution levels aren't far behind. The results show that gains come across an entire region or air shed, making a stronger case for air shed management whilst also focusing on hyper-local pollution, on the other hand. The first NCAP deadline of 2024 is close and action must move beyond cities in the programme's next phase."

Prof S N Tripathi, Civil Engineering, Indian Institute of Technology Kanpur & Steering Committee Member, National Clean Air Programme, MoEFCC

"Overall PM2.5 trends based on this analysis show state-level reductions ranging from approximately 7-38%. Improvements with levels above 10% across this timescale should be considered positive. However, anything less than 10% in the last 6 years needs to be evaluated. The projected decrease, according to the new NCAP guidelines, is up to 40% from 2019 to 2026, so every year, each state should, on average, aim to reduce 7% of their average PM2.5 levels. According to this calculation, by the end of 2022, each state should have at least 20-25% annual average PM2.5 reduction levels on the conservative side and a 30-35% reduction on the positive higher side. Anything lower than that needs to be scrutinised for the reasons for commensurate reduction.

When we are analysing long-term PM2.5 trends on the basis of the last 6 years from 2017 to 2022, we should not worry about annual fluctuations in some places. What needs to be focussed upon is how levels have changed overall during the period from the baseline year of 2017 to the levels in 2022.

Even though the satellite data remains in contest in comparison to ground-based monitoring we have to observe the consistent trend in this analysis. If any errors are there in AOD to PM2.5 conversion, that error or bias will remain for that location every year. For eg, in Delhi, if the AOD data shows PM2.5 levels at 100 ug/m3 in 2017, while the actual ground-based monitoring average is 130 ug/m3, the next year, that bias will still stay in the AOD data. That is not a random error. Therefore, the percentage trend should not get affected by any inherent bias in the data, even if issues around remain in the differences of the average between satellite AOD data vs the ground-based monitoring data.

AOD is also not a directly measured quantity, rather, it is retrieved or modelled, so it will have some errors. Satellites measure radiation and not AOD, so models are run to assess AOD, which is a columnar property to get PM2.5 levels. Therefore, if there is any error in comparative data sets for the two modes of air quality monitoring, that error will remain y-o-y. Hence in the overall trends, we can see a reduction in large states, regions and across India, which cannot be doubted.

The analysis also shows that the urban and rural levels have largely been neck to neck across states and regions, which is surprising. Satellite data remains an AOD-converted product, using ground-based data from the few stations which are available across the state. The AOD data's predictor relies hugely on ground-based monitoring data, it will have a limited ability to capture the spatial variability."

Sagnik Dey, Professor, Centre for Atmospheric Sciences, Indian Institute of Technology Delhi

"This analysis is a clear indication that India is inching towards plateauing its upward rising air pollution levels since 2016-2017. This is a positive achievement, however, the challenge now lies towards bringing the needle down further, especially as we are in the last year of the National Clean Air Programme's targets of reducing 20-30% particulate matter levels by 2024. This analysis also proves the need for a strong hybrid approach to air quality monitoring. While it is passè that air pollution is an urgent health crisis for India, monitoring data is relevant for local authorities to act on large scale and hyper-local action. The CPCB has started using satellite data for tracking air quality on a regional scale. The future lies in developing a hybrid monitoring approach for improved understanding of pollution levels in India and tracking the efficacy of the interventions at the local and regional scale."

Dr Arun Sharma, Director, ICMR-NIRCMD, Jodhpur

"This analysis is a reiteration that air pollution is not a problem of cities alone; the rural population is as much affected. Prevention and mitigation measures should be based on local conditions. Documentation of health effects is as important as exposure documentation."

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About Climate Trends

Climate Trends is a research-based consulting and capacity building initiative that aims to bring greater focus on issues of environment, climate change and sustainable development. We specialise in developing comprehensive analyses of complex issues to enable effective decision making in the private and public sector.