VISUALIZING THE IMPACT OF

EPISODIC AIR POLLUTION DURING OCTOBER & NOVEMBER 2018

IN INDIAN CITIES

Project Title: Measurement & dissemination of air quality data using low cost monitors in 10 cities

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atmos
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Respirer Living Sciences

SHAKTI
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ACKNOWLEDGEMENT

Respirer Living Sciences Pvt. Ltd. would like to thank Shakti Sustainable Energy Foundation for providing funding and strategic assistance in the establishment of Atmos network in 10 Indian cities. The analyses this report presents is premised on the data from the Atmos monitors.

Shakti Sustainable Energy Foundation (Shakti) works to facilitate India's transition to a sustainable energy future by aiding the design and implementation of policies in the following sectors: clean power, energy efficiency, sustainable urban transport, climate policy and clean energy finance.

DISCLAIMER

DATA ACCESS

All data used in this report is freely available to view & download via the realtime dashboard at – http://atmos.urbansciences.in

For feedback, suggestions, $PM_{2.5}$ datasets and API access to the data, email – research@urbansciences.in

TABLE OF CONTENTS

BACKGROUND

Air pollution is ranked as the second highest public health risk in India (second only to heart disease). The Indo-Gangetic Plain has grabbed global headlines for severe and persistent pollution levels, making India the pollution capital of the world.

The Indo-Gangetic Plain suffers from an inherent disadvantage of being landlocked. During winters, the quality worsens due to slow moving winds and temperature inversions that trap particulate matter, leading to a toxic accumulation of smog[1]. In addition, two key events – seasonal fires and burning of firecrackers during Diwali – cause an exponential spike in pollution levels during the winter months across the region. Whilst vehicular and industrial emissions contribute their fair share throughout the year, winter-time episodes, however, remain the most toxic.

Several measures have been taken: a Supreme Court verdict ahead of Diwali restricted the sale and use of polluting fireworks of a particular grade and category. The state and central government introduced alternative methods that incentivize farmers to curb crop burning. Nevertheless, the cities across Northern India continued to reel under severe pollution levels.

Despite these, cities across India witnessed high pollution episodes. These were extensively covered via media reporting, particularly for Delhi. Additionally, limited reference grade monitors in cities other than Delhi NCR have meant a dearth of air quality data.

November 7th 2018, New Delhi (Picture Courtesy – The Times of India)

LOW-COST AIR QUALITY MONITORING ACROSS INDIAN CITIES

To bridge this vital data gap, Respirer Living Sciences, as part of their UrbanSciences initiative and IIT Kanpur with support from Shakti Sustainable Energy Foundation (SSEF) is deploying 50 low cost air quality monitors (Atmos) across Indian cities. These monitors were calibrated against reference grade monitors (E-BAM) and are primarily being deployed in residential and office buildings. This report seeks to assess the impact of agricultural fire-burning and Diwali

[1] http://web.iitd.ac.in/~sagnik/Chapter.pdf

firecrackers on the pollution levels in the vicinity of deployed monitors. The assessment period spans 45 days, from October 15 to November 30, 2018, during which the episodes were witnessed.

METHODOLOGY

The analyzed data has been derived from low-cost Atmos monitors manufactured and deployed by UrbanSciences.

Cities	No. of Monitors
Chandigarh*	5
Dehradun	5
Delhi	2
Jaipur	4
Kanpur	5
Patna	5
Varanasi	5
Ahmedabad	5
Raipur	5
Ranchi	5
Bhopal*	4

*Devices yet to be installed at final locations.

In northern India, monitors were installed **in Delhi, Varanasi, Patna, Kanpur, Jaipur and Dehradun.** In the Central Indian region they were installed in **Ahmedabad, Ranchi and Raipur**.

24-hour averages have been analyzed for Particulate Matter 2.5 ($PM_{2.5}$) to understand the pollution trends over a period of 45 days. The 24-hour $PM_{2.5}$ averages have been further categorized into a color-coded index based on the levels of pollution on that particular day. A week-long trend has been derived for all the cities during Diwali (Nov 5 - Nov 9, 2018).

Color-Coded Index

Our Code	GOOD		MODERATE		POOR	
$PM_{2.5}$	0-30	31-60	61-90	91-120	121-250	250+
Air Quality	Good	Satisfactory	Moderate	Poor	Very Poor	Severe

SUMMARY OF THE FINDINGS

During the period from October 15 to November 30, 2018, Patna, Varanasi and Kanpur recorded the worst air quality, with 70 percent “Poor” and “Very Poor” air quality days.

Patna had ZERO “Good” air quality days, Kanpur a close second with only 2 percent and Varanasi marginally better at 11 percent.

Following these three cities, Delhi and Jaipur were next in line to be the most polluted out of the nine cities monitored for $PM_{2.5}$ levels.

Delhi recorded 51 percent “Poor” and “Very Poor” days and 19 percent “Good” air quality days. It is important to note that the monitors located in Delhi and other cities are not located at major traffic junctions, as in the case of regulatory grade monitors but are located across residential blocks, balconies of individual homes and roof tops.

The table below summarizes the percentage of “Good”, “Moderate” and “Poor” air quality days across nine cities. The ranking is based on the maximum “Poor” air quality days.

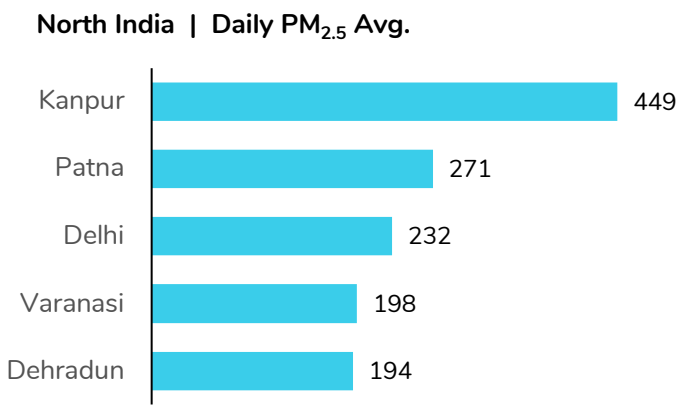
RANK	CITY	GOOD	MODERATE	POOR
1	PATNA	0%	30%	70%
2	VARANASI	11%	19%	70%
3	KANPUR	2%	28%	70%
4	DELHI	19%	30%	51%
5	JAIPUR	15%	66%	19%
6	RAIPUR	17%	77%	6%
7	RANCHI	21%	75%	4%
8	AHMEDABAD	30%	66%	4%
9	DEHRADUN	52%	43%	5%

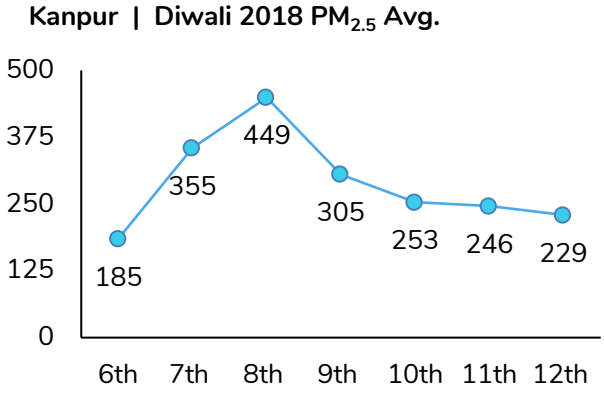
HIGHEST DAILY AVERAGES OR MAXIMUM VALUES RECORDED

Northern India: Kanpur, Patna, Delhi, Varanasi, Dehradun

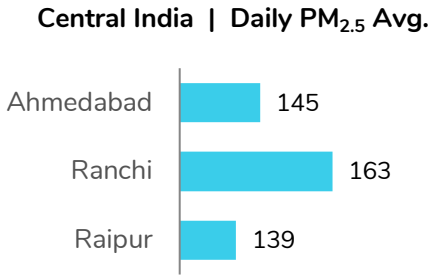
While the above rankings indicate the various category of days based on the air quality index for the $PM_{2.5}$ levels, the highest daily averages were recorded in the cities of Kanpur, Patna, Delhi, Varanasi and Dehradun during the Diwali week.

Kanpur in particular had several severe air quality days during Diwali with persistent pollution levels peaking at 355, 449 and 305 micrograms per cubic meter.





Central India: Ranchi, Ahmedabad and Raipur



In the cities across central India however, Ranchi topped the charts with Ahmedabad and Raipur after it.

The peaks experienced in these cities were significantly lower in comparison to most cities in the Northern part of the country.

RANKING BASED ON 45-DAY AVERAGES FOR VARIOUS STATIONS ACROSS THE TEN CITIES

Varanasi has witnessed the maximum $PM_{2.5}$ levels amongst the cities. The city consistently topped the charts for poor air quality for more than a couple of weeks in a row, indicating a persistent problem of poor air quality across the city.

Contrary to the popular opinion in the media and in the general public, most monitoring locations spread across cities in the Indo-Gangetic Plain have recorded averages higher than that of Delhi and Gurugram. The top five locations were identified to be in Varanasi, Kanpur and Patna.

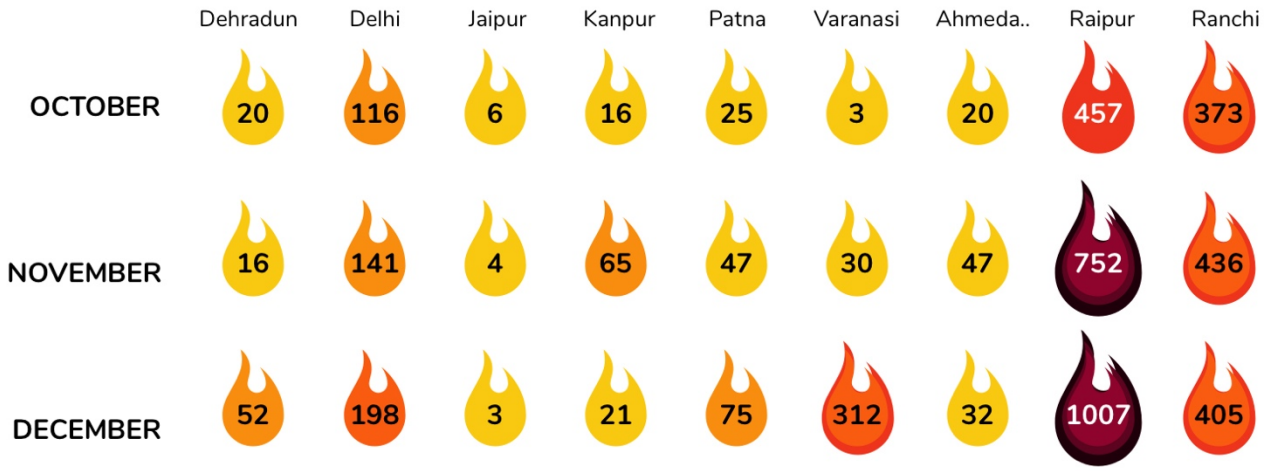
Rank	City	Area	$PM_{2.5}$
1	Varanasi	Kamachcha	208
2	Kanpur	Govind Nagar	189
3	Kanpur	Naubasta	188
4	Patna	Phulwari Sharif	169
5	Patna	Mithapur	168
6	Delhi	Sector 30, Gurugram	166
7	Kanpur	Chunniganj	166
8	Patna	CEECC ADRI	153
9	Kanpur	Indira Nagar	146
10	Kanpur	Surendra Nagar	122
11	Raipur	Bharat Mata School	110
12	Jaipur	Malviya Nagar	100
13	Ahmedabad	IIM	89
14	Delhi	Munirka Phase III	86
15	Raipur	SHRC	85

All the monitors spread across these cities recorded $PM_{2.5}$ averages in the “Very Poor” and “Severe” category with air pollution levels exceeding the Indian Safety norms by 4-5 times the annual limit and the World Health Organization’s safe air standards by 18-20 times. The monitors spread across central Indian cities had lower air pollution levels with $PM_{2.5}$ averages not reaching the “Very Poor” category but remaining in “Moderate” to “Poor” air quality range. This however does not mean that the severity of air pollution is to be downplayed in the cities of Raipur,

Ahmedabad and Ranchi. It is important to note that among the two stations cited in the ranking below for Raipur, both the stations vary greatly in terms of the prevailing pollution levels. Therefore, this demands more monitoring and a better understanding of air quality across cities in India to comprehensively understand the extent of the problem concerning ambient air quality.

FIRECOUNT DATA ACROSS INDIAN CITIES

The "Firecount" data is computed using an instrument on-board a polar satellite. The data presented gives the total number of fires occurring in a particular month.



The data are obtained from the medium resolution sensor Visible Infrared Imaging Radiometer Suite (VIIRS), which measures radiation in the middle and thermal infrared wavelength at 375 m spatial resolution. Although 750 m resolution data is also available from VIIRS, the 375 m resolution data is suitable for studies at point locations such as cities. An additional advantage of VIIRS is the measurement of fires both during day and night time. Comparison of VIIRS data with airborne and Landsat-8 data showed high level of agreement [Schroeder et al, 2014][2].

[2] Wilfrid Schroeder, Patricia Oliva, Louis Giglio, Ivan A. Csiszar (2014), The New VIIRS 375 m active fire detection data product: Algorithm description and initial assessment, Remote Sens. Environ., doi:10.1016/j.rse.2013.12.008.

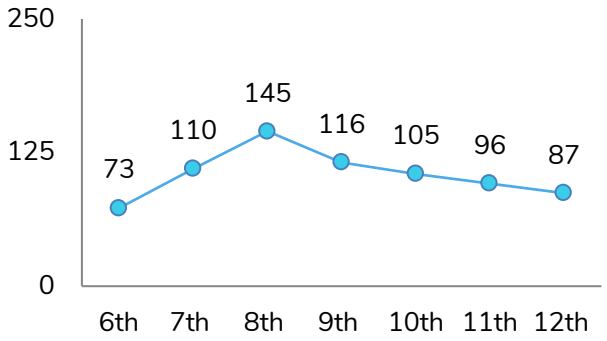
CITY-WISE ANALYSIS

Daily Average of $PM_{2.5}$ Levels

AHMEDABAD - GANDHINAGAR

Ahmedabad recorded a 45-day average of 89 micrograms per cubic meter which falls into the moderate air pollution category. The monitoring exercise spread across three different locations yielded 29 percent of the total monitored days for air quality to be in poor category with peak pollution during Diwali reaching 2.5 times the Indian Safe limits for $PM_{2.5}$ on a 24-hour basis.

Ahmedabad | Diwali 2018 $PM_{2.5}$ Avg.



Ahmedabad recorded the maximum number of moderate air quality days in comparison to the other cities, 55 percent of the monitored days were found to be in the moderate category.

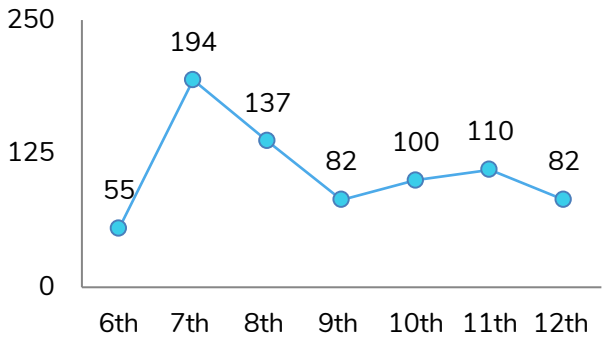
Sun	- 30	- 07	- 14	43 21	54 28	94 04	96 11	113 18	64 25	
Mon	- 01	- 08	37 15	53 22	55 29	88 05	75 12	91 19	74 26	
Tue	- 02	- 09	47 16	84 23	55 30	78 06	93 13	83 20	62 27	
Wed	- 03	- 10	61 17	52 24	57 31	131 07	94 14	88 21	73 28	
Thu	- 04	- 11	54 18	67 25	66 01	154 08	71 15	87 22	109 29	
Fri	- 05	- 12	48 19	54 26	68 02	119 09	76 16	62 23	119 30	
Sat	- 06	- 13	53 20	72 27	87 03	107 10	87 17	59 24	- 01	
	October				November					

Good Days: 30% Moderate Days: 66% Poor Days: 4%

DEHRADUN

Despite its proximity to Delhi, the hill city of Dehradun has fared to be the least polluted among the 10 cities. It recorded 50 percent of the monitored days to be in the good/safe air quality limit. It also has the least number of poor air quality days with an exception of Diwali on the 6th and 7th of November where the city saw the season's maximum levels of $PM_{2.5}$, 2-3 times the Indian Safety limits on a 24-hour basis.

Dehradun | Diwali 2018 $PM_{2.5}$ Avg.

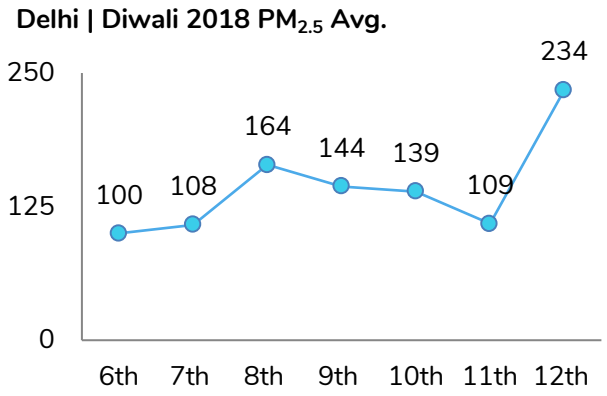


Sun	- 30	- 07	- 14	44 21	58 28	38 04	110 11	64 18	82 25					
Mon	- 01	- 08	- 15	44 22	59 29	51 05	81 12	69 19	55 26					
Tue	- 02	- 09	- 16	45 23	61 30	55 06	74 13	88 20	61 27					
Wed	- 03	- 10	- 17	37 24	60 31	194 07	72 14	79 21	37 28					
Thu	- 04	- 11	45 18	38 25	39 01	137 08	74 15	72 22	32 29					
Fri	- 05	- 12	46 19	48 26	33 02	82 09	73 16	71 23	51 30					
Sat	- 06	- 13	51 20	39 27	30 03	100 10	74 17	71 24	- 01					
	October				November									

Good Days: 52% Moderate Days: 43% Poor Days: 5%

DELHI

India's capital city isn't the most polluted among the list even as it retains its position in the top five for having the maximum number of poor air quality days, after Patna, Kanpur and Varanasi. 72 percent of the days monitored were found to be in the poor and very poor category with $PM_{2.5}$ values consistently being close to and above 200 micrograms per cubic meter for three consecutive weeks in the month of November. 234 is the highest recorded daily average for Delhi which is equivalent to 3.5 times the daily safe limit set by Indian government.



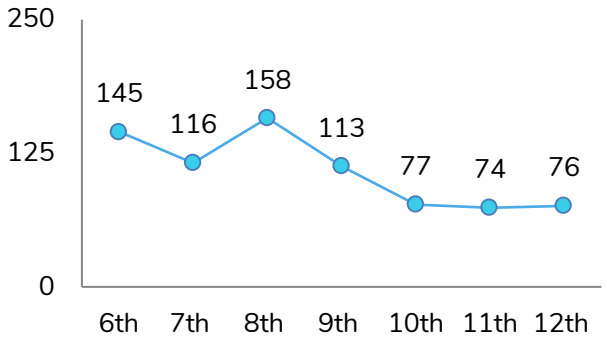
Sun	- 30	- 07	- 14	49 21	131 28	56 04	109 11	162 18	130 25					
Mon	- 01	- 08	111 15	25 22	118 29	199 05	234 12	189 19	211 26					
Tue	- 02	- 09	55 16	53 23	118 30	100 06	226 13	232 20	170 27					
Wed	- 03	- 10	74 17	43 24	105 31	108 07	139 14	195 21	179 28					
Thu	- 04	- 11	63 18	55 25	106 01	164 08	136 15	121 22	201 29					
Fri	- 05	- 12	43 19	47 26	106 02	144 09	171 16	183 23	221 30					
Sat	- 06	- 13	73 20	133 27	87 03	139 10	154 17	112 24	- 01					
	October					November								

Good Days: 19% Moderate Days: 30% Poor Days: 51%

JAIPUR

Rajasthan's capital Jaipur recorded a similar percentage of good, moderate and poor air quality days to that of Raipur. With 45 percent of days in poor category and 40 percent in moderate category, the city recorded its maximum $PM_{2.5}$ value for 24-hour on the 8th of November post Diwali at 158 micrograms per cubic meter which is equivalent to 2.5 times the Indian safe limit.

Jaipur | Diwali 2018 $PM_{2.5}$ Avg.

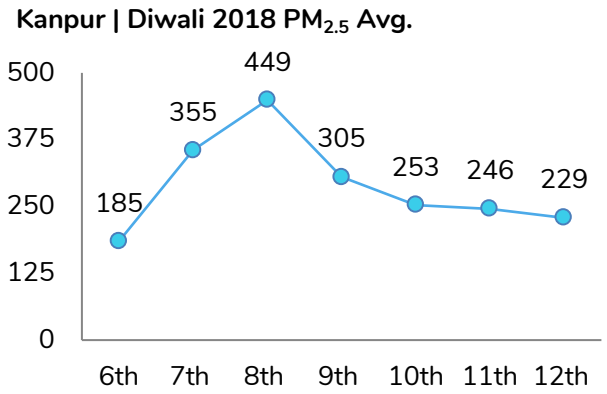


Sun	- 30	- 07	- 14	65 21	105 28	115 04	74 11	76 18	71 25					
Mon	- 01	- 08	62 15	46 22	116 29	72 05	76 12	68 19	66 26					
Tue	- 02	- 09	47 16	45 23	125 30	145 06	61 13	63 20	96 27					
Wed	- 03	- 10	41 17	45 24	111 31	116 07	63 14	125 21	142 28					
Thu	- 04	- 11	45 18	49 25	102 01	158 08	130 15	93 22	129 29					
Fri	- 05	- 12	66 19	67 26	74 02	113 09	152 16	106 23	129 30					
Sat	- 06	- 13	62 20	83 27	72 03	77 10	107 17	102 24	- 01					
	October				November									

Good Days: 15% Moderate Days: 66% Poor Days: 19%

KANPUR

Kanpur scored third after Patna and Varanasi for having the maximum number of poor air quality days. The city recorded very poor pollution averages for the whole of November with some of the days even recording severe air quality for three to four days in a row. The maximum 24-hour value for $PM_{2.5}$ is noted in Kanpur at 449 micrograms per cubic meter, more than 7.2 times the Indian safety limit.



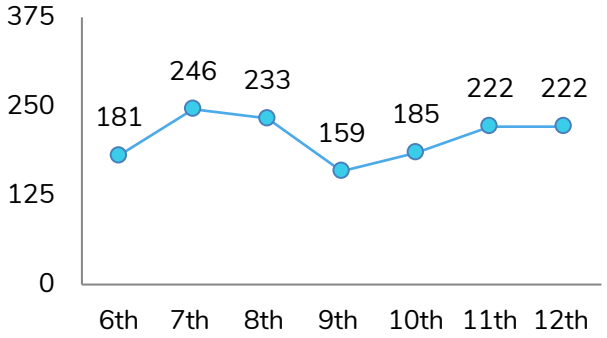
Sun	- 30	- 07	- 14	67 21	155 28	122 04	246 11	230 18	169 25					
Mon	- 01	- 08	102 15	68 22	127 29	148 05	229 12	198 19	230 26					
Tue	- 02	- 09	96 16	121 23	73 30	185 06	153 13	217 20	206 27					
Wed	- 03	- 10	89 17	115 24	125 31	355 07	130 14	220 21	207 28					
Thu	- 04	- 11	117 18	112 25	146 01	449 08	155 15	196 22	136 29					
Fri	- 05	- 12	46 19	107 26	149 02	305 09	115 16	175 23	170 30					
Sat	- 06	- 13	64 20	137 27	110 03	253 10	167 17	131 24	- 01					
	October				November									

Good Days: 2% Moderate Days: 28% Poor Days: 70%

PATNA

Patna remains the most polluted of the 10 cities monitored as it recorded the maximum number of poor air quality days with 98 percent of the total monitored days in poor to severe category. The city also recorded 'zero' good air days with the daily $PM_{2.5}$ averages ranging between 140 to 270 micrograms per cubic meter for most days in November 2018.

Patna | Diwali 2018 $PM_{2.5}$ Avg.



The maximum $PM_{2.5}$ value was recorded on 19th November at 271. The levels consistently crossed the India safe limits for $PM_{2.5}$ by 4-5 times.

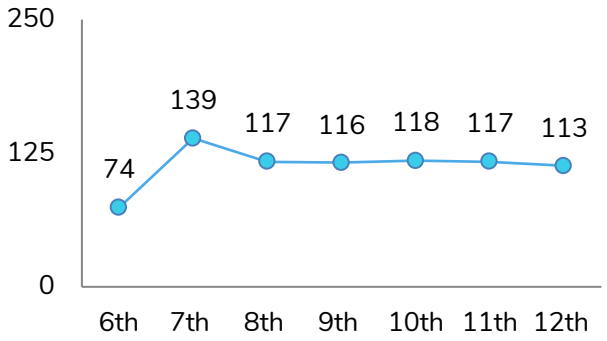
	October					November				
Sun	- 30	- 07	- 14	122 21	132 28	140 04	222 11	186 18	256 25	
Mon	- 01	- 08	95 15	136 22	120 29	161 05	222 12	271 19	253 26	
Tue	- 02	- 09	95 16	121 23	107 30	181 06	207 13	267 20	195 27	
Wed	- 03	- 10	99 17	103 24	89 31	246 07	189 14	268 21	160 28	
Thu	- 04	- 11	115 18	135 25	116 01	233 08	158 15	192 22	190 29	
Fri	- 05	- 12	96 19	143 26	120 02	159 09	98 16	209 23	196 30	
Sat	- 06	- 13	117 20	128 27	130 03	185 10	118 17	205 24	- 01	

Good Days: 0% Moderate Days: 30% Poor Days: 70%

RAIPUR

The central Indian city of Raipur fared at number 6 for having the maximum number of poor air quality days. The average values derived for the 45-day period for two different monitoring locations varied from poor to moderate. The city recorded close to 45 percent of its monitored days with poor air quality; the maximum $PM_{2.5}$ concentration was observed on the day of Diwali at 139 micrograms per cubic meter.

Raipur | Diwali 2018 $PM_{2.5}$ Avg.



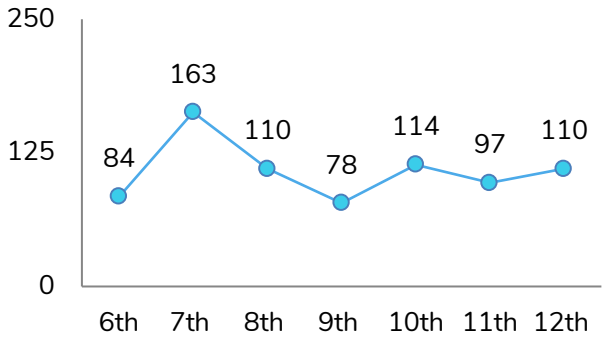
Sun	- 30	- 07	- 14	79 21	56 28	71 04	117 11	83 18	57 25					
Mon	- 01	- 08	63 15	79 22	82 29	81 05	113 12	92 19	64 26					
Tue	- 02	- 09	74 16	96 23	80 30	74 06	113 13	72 20	61 27					
Wed	- 03	- 10	67 17	73 24	50 31	139 07	107 14	73 21	104 28					
Thu	- 04	- 11	60 18	98 25	45 01	117 08	92 15	78 22	134 29					
Fri	- 05	- 12	71 19	80 26	64 02	116 09	75 16	55 23	134 30					
Sat	- 06	- 13	85 20	79 27	60 03	118 10	72 17	51 24	- 01					
	October				November									

Good Days: 17% Moderate Days: 77% Poor Days: 6%

RANCHI

Ranchi ranked 7th out of the 10 cities for the number of poor air quality days. It is one of the cities after Ahmedabad to record the maximum number of moderate air quality days. 49 percent of the monitored days were found to have moderate air quality. The city recorded its highest daily value for $PM_{2.5}$ on the day of Diwali at 163 micrograms per cubic meter, 2.5 times the Indian safety limits.

Ranchi | Diwali 2018 $PM_{2.5}$ Avg.



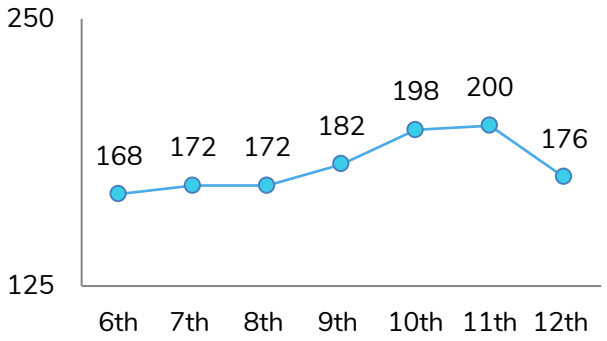
Sun	- 30	- 07	- 14	54 21	79 28	113 04	97 11	90 18	82 25					
Mon	- 01	- 08	51 15	64 22	103 29	91 05	110 12	85 19	104 26					
Tue	- 02	- 09	60 16	67 23	64 30	84 06	118 13	61 20	101 27					
Wed	- 03	- 10	49 17	54 24	88 31	163 07	88 14	53 21	101 28					
Thu	- 04	- 11	49 18	48 25	79 01	110 08	67 15	80 22	126 29					
Fri	- 05	- 12	46 19	79 26	74 02	78 09	67 16	94 23	117 30					
Sat	- 06	- 13	43 20	69 27	77 03	114 10	77 17	87 24	- 01					
	October				November									

Good Days: 21% Moderate Days: 75% Poor Days: 4%

VARANASI

The country's spiritual capital remained one of the most unsafe city to live in with very poor to poor $PM_{2.5}$ levels being recorded for 89 percent of the days monitored. The city consistently recorded very poor air quality levels from the third week of October and remained so till the end of November. The peak levels were recorded on the 11th November at 200 micrograms per cubic meter, exceeding the Indian safe air limits by 3.5 times.

Varanasi | Diwali 2018 $PM_{2.5}$ Avg.



Sun	- 30	- 07	- 14	25 21	142 28	109 04	200 11	156 18	111 25
Mon	- 01	- 08	110 15	105 22	157 29	145 05	176 12	138 19	122 26
Tue	- 02	- 09	110 16	103 23	131 30	168 06	160 13	132 20	140 27
Wed	- 03	- 10	25 17	112 24	125 31	172 07	141 14	137 21	138 28
Thu	- 04	- 11	23 18	136 25	128 01	172 08	190 15	116 22	143 29
Fri	- 05	- 12	19 19	128 26	132 02	182 09	149 16	132 23	166 30
Sat	- 06	- 13	24 20	106 27	129 03	198 10	136 17	123 24	- 01
	October				November				

Good Days: 11% Moderate Days: 19% Poor Days: 70%