VISUALISING THE IMPACT OF
AIR POLLUTION DURING THE MONTHS OF 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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BACKGROUND

Air pollution is ranked as the 2nd 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[i]. 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.

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

Despite these, cities across India witnessed high pollution episodes. These were extensively covered via media reporting, particularly for Delhi. The deteriorating air quality levels and limited reference grade monitors beyond Delhi NCR, lead to the dearth of air quality data.

LOW-COST AIR QUALITY MONITORING ACROSS INDIAN CITIES

To bridge this data gap, Respirer 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 burning and Diwali firecrackers on the pollution levels in the vicinity of deployed monitors.

The assessment period spans across 45 days, from 15 October to 30 November 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 deployment locations.

In the Northern part of India, monitors were installed **in Delhi, Varanasi, Patna, Kanpur, Jaipur, Dehradun and Chandigarh.** In the Central Indian region, monitors 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 colour-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 05 - Nov 09).

Colour-Coded Index

Our Code	GOOD		MODERATE		POOR	
PM2.5	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, 2018 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 were next in line to be the most polluted out of the nine cities monitored for PM2.5 levels.

Delhi recorded 49 percent "Poor" and "Very Poor" days and 21 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.

Table summarizing the percentage of "Good", "Moderate" and "Poor" air quality across nine cities ranked based on the maximum "Poor" air quality days:

RANK	CITY	GOOD	MODERATE	POOR
1	PATNA	00%	30%	**70%**
2	VARANASI	11%	19%	**70%**
3	KANPUR	02%	28%	**70%**
4	DELHI	19%	30%	**51%**
5	JAIPUR	15%	**66%**	19%
6	RAIPUR	17%	**77%**	06%
7	RANCHI	21%	**75%**	04%
8	AHMEDABAD	30%	**66%**	04%
9	DEHRADUN	**52%**	43%	05%

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 PM2.5 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.

North india | Daily PM2.5 Avg

City	Value
Kanpur	449
Patna	271
Delhi	232
Varanasi	198
Dehradun	194

Kanpur | Diwali 2018 PM2.5 Avg.

Date	Value
6th	185
7th	355
8th	449
9th	305
10th	253
11th	246
12th	229
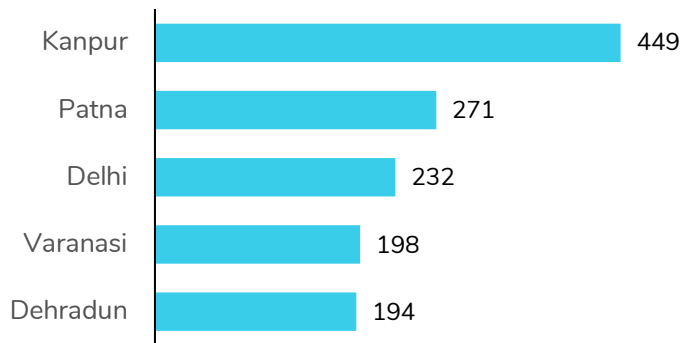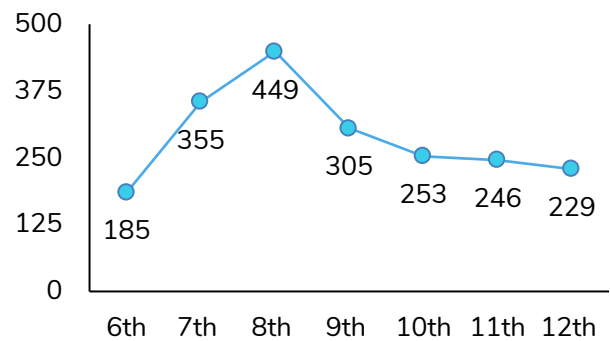
Central India
Ranchi, Ahmedabad and Raipur

Central India | Daily PM2.5 Avg.

City	Value
Ahmedabad	145
Ranchi	163
Raipur	139
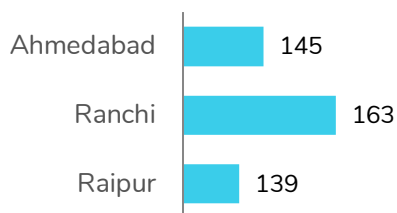
In the cities across central India however, Ranchi topped the charts with Ahmedabad and Raipur after it.

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 NINE CITIES

Varanasi has witnessed the maximum PM levels amongst nine 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 Organisation's safe air standards by 18-20 times. The monitors spread across central Indian cities had lower air pollution levels with PM2.5 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.

	Dehradun	Delhi	Jaipur	Kanpur	Patna	Varanasi	Ahmeda..	Raipur	Ranchi
OCTOBER	20	116	6	16	25	3	20	457	373
NOVEMBER	16	141	4	65	47	30	47	752	436
DECEMBER	52	198	3	21	75	312	32	1007	405
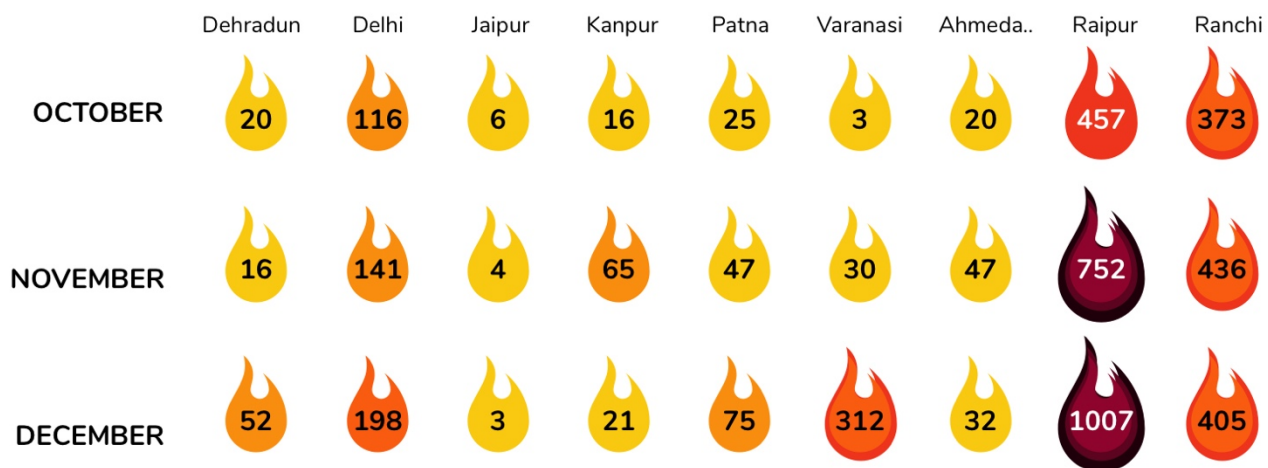
The data are obtained from the medium resolution sensor Visible Infrared Imaging Radiometer Suite (VIIRS), which measures radiation in the middle and thermal infrared wavelength at 375 m spatial resolution. Although 750 m resolution data is also available from VIIRS, the 375 m resolution data is suitable 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][ii].

Daily Average of PM2.5 Levels

AHMEDABAD|GANDHINAGAR

The city of 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% 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 PM2.5 on a 24Hr basis.

Ahmedabad | Diwali 2018 PM2.5 Avg.
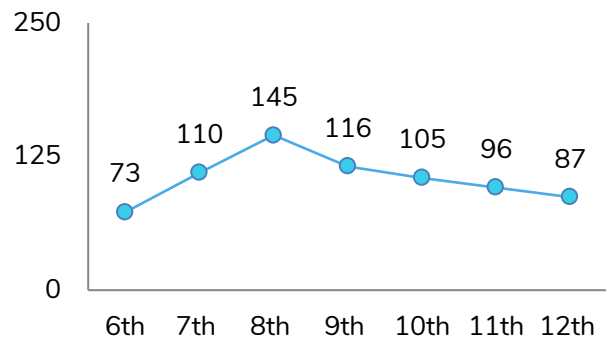
The city of Ahmedabad recorded the maximum number of moderate air quality days in comparison to the other cities, 55 percent of the monitored days were found to be in the moderate category.

| Day									
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:** 04%

DEHRADUN

The hill city of Dehradun despite its proximity to Delhi has fared to be the least polluted among the 9 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 PM2.5, 2-3 times the Indian Safety limits on a 24hr basis.

Dehradun | Diwali 2018 PM2.5 Avg.
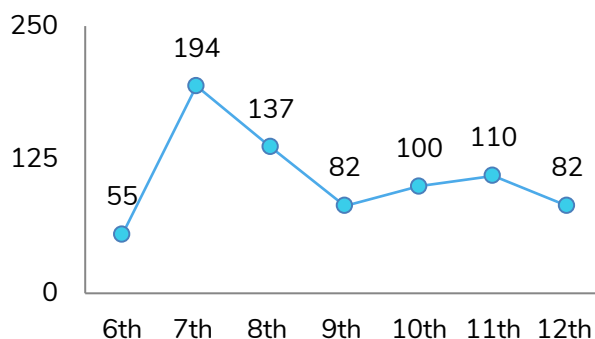
Sun	– 30	– 07	– 14	44 21	58 28	38 04	110 11	64 18	82 25	
Mon	– 01	– 08	– 15	44 22	59 29	51 05	81 12	69 19	55 26	
Tue	– 02	– 09	– 16	45 23	61 30	55 06	74 13	88 20	61 27	
Wed	– 03	– 10	– 17	37 24	60 31	194 07	72 14	79 21	37 28	
Thu	– 04	– 11	45 18	38 25	39 01	137 08	74 15	72 22	32 29	
Fri	– 05	– 12	46 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:** 05%

DELHI

India's capital city isn't the most polluted among the list, while it retains its position in the top five for having the maximum number of poor air quality days, it is only so after Patna, Kanpur and Varanasi. 72% of the days monitored were found to be in the poor and very poor category with PM2.5 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 Govt.

Delhi | Diwali 2018 PM2.5 Avg.
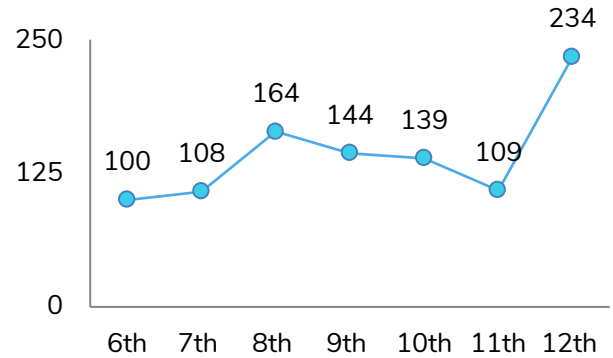
Sun	- 30	- 07	- 14	49 21	131 28	56 04	109 11	162 18	130 25	
Mon	- 01	- 08	111 15	25 22	118 29	199 05	234 12	189 19	211 26	
Tue	- 02	- 09	55 16	53 23	118 30	100 06	226 13	232 20	170 27	
Wed	- 03	- 10	74 17	43 24	105 31	108 07	139 14	195 21	179 28	
Thu	- 04	- 11	63 18	55 25	106 01	164 08	136 15	121 22	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				

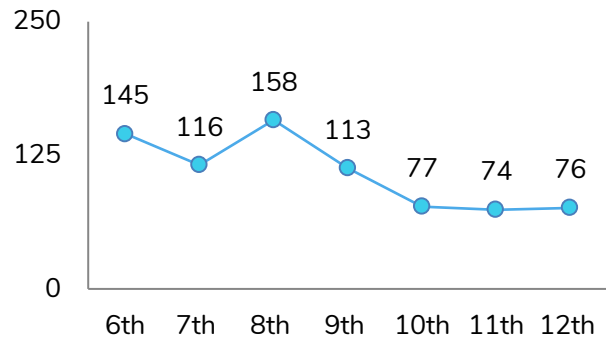**Good Days:** 19%   **Moderate Days:** 30%   **Poor Days:** 51%

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 PM2.5 value for 24hr on the 8th of November post Diwali at 158 micrograms per cubic meter which is equivalent to 2.5times the Indian safe limit.

Jaipur | Diwali 2018 PM2.5 Avg.

Line chart values: 145 (6th), 116 (7th), 158 (8th), 113 (9th), 77 (10th), 74 (11th), 76 (12th). Y-axis: 0, 125, 250.

|									
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 24hr value for PM2.5 is noted in Kanpur at 449 micrograms per cubic meter, more than 7.2 times the Indian safety limit.

Kanpur | Diwali 2018 PM2.5 Avg.

6th	7th	8th	9th	10th	11th	12th
185	355	449	305	253	246	229
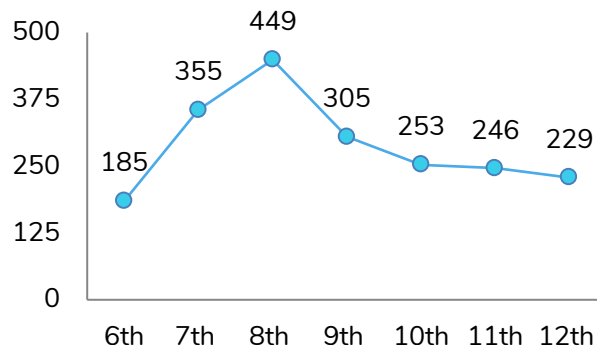
|									
Sun	- 30	- 07	- 14	67 (21)	155 (28)	122 (04)	246 (11)	230 (18)	169 (25)
Mon	- 01	- 08	102 (15)	68 (22)	127 (29)	148 (05)	229 (12)	198 (19)	230 (26)
Tue	- 02	- 09	96 (16)	121 (23)	73 (30)	185 (06)	153 (13)	217 (20)	206 (27)
Wed	- 03	- 10	89 (17)	115 (24)	125 (31)	355 (07)	130 (14)	220 (21)	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: 02%   **Moderate Days:** 28%   **Poor Days:** 70%

PATNA

Patna remains the most polluted of the 9 cities monitored as it recorded the maximum number of poor air quality days with 98% of the total monitored days in poor to severe category. The city also recorded 'zero' good air days with the daily PM2.5 averages ranging between 140 to 270 micrograms per cubic meter for most days in November.

Patna | Diwali 2018 PM2.5 Avg.
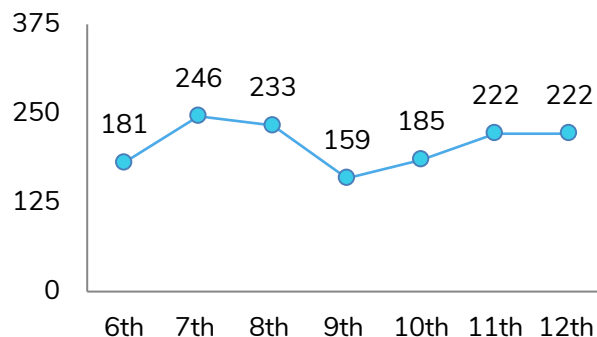
The maximum PM2.5 value was recorded on 19th November at 271. The levels consistently crossed the India safe limits for PM2.5 by 4-5 times.

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	
	October					November				

**Good Days:** 00%   **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 45percent of its monitored days with poor air quality, the maximum PM2.5 concentration was observed on the day of Diwali at 139 micrograms per cubic meter.

Raipur | Diwali 2018 PM2.5 Avg.

	6th	7th	8th	9th	10th	11th	12th
	74	139	117	116	118	117	113
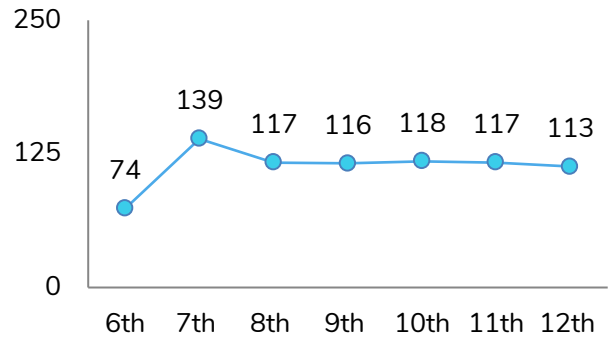
|								
Sun	- 30	- 07	- 14	79 21	56 28	71 04	117 11	83 18	57 25
Mon	- 01	- 08	63 15	79 22	82 29	81 05	113 12	92 19	64 26
Tue	- 02	- 09	74 16	96 23	80 30	74 06	113 13	72 20	61 27
Wed	- 03	- 10	67 17	73 24	50 31	139 07	107 14	73 21	104 28
Thu	- 04	- 11	60 18	98 25	45 01	117 08	92 15	78 22	134 29
Fri	- 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:** 06%

RANCHI

Ranchi ranked 7th out of the 9 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% of the monitored days were found to have moderate air quality. The city recorded its highest daily value for PM2.5 on the day of Diwali at 163 micrograms per cubic meter, 2.5 times the Indian safety limits.

Ranchi | Diwali 2018 PM2.5 Avg.
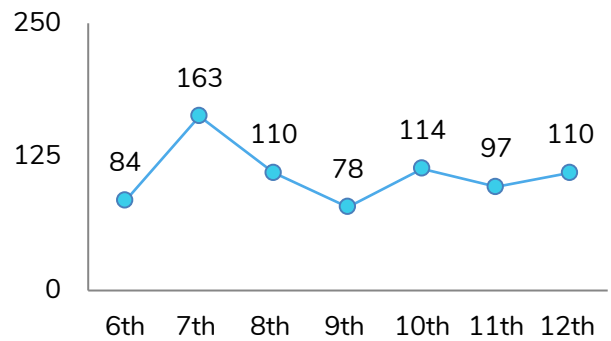
Sun	- 30	- 07	- 14	54 21	79 28	113 04	97 11	90 18	82 25
Mon	- 01	- 08	51 15	64 22	103 29	91 05	110 12	85 19	104 26
Tue	- 02	- 09	60 16	67 23	64 30	84 06	118 13	61 20	101 27
Wed	- 03	- 10	49 17	54 24	88 31	163 07	88 14	53 21	101 28
Thu	- 04	- 11	49 18	48 25	79 01	110 08	67 15	80 22	126 29
Fri	- 05	- 12	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:** 04%

VARANASI

The country's spiritual capital remained one of the most unsafe city to live in with very poor to poor PM2.5 levels being recorded for 89% 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 of November at 200 micrograms per cubic meter, exceeding the Indian safe air limits by 3.5times.

Varanasi | Diwali 2018 PM2.5 Avg.
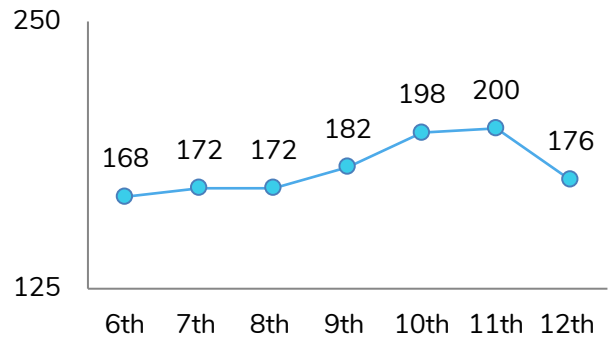
Sun	- 30	- 07	- 14	25 [21]	142 [28]	109 [04]	200 [11]	156 [18]	111 [25]
Mon	- 01	- 08	110 [15]	105 [22]	157 [29]	145 [05]	176 [12]	138 [19]	122 [26]
Tue	- 02	- 09	110 [16]	103 [23]	131 [30]	168 [06]	160 [13]	132 [20]	140 [27]
Wed	- 03	- 10	25 [17]	112 [24]	125 [31]	172 [07]	141 [14]	137 [21]	138 [28]
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%

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