Mumbai's unusually high air pollution levels in February 2023: An Analysis

Key Highlights

1. Most areas in Mumbai had PM2.5 levels exceeding the safe limits set by the CPCB in February 2023, except for a few locations that saw some improvement compared to previous years. This highlights the need for measures to control air pollution in the city. (NOTE: Daily permissible levels of PM2.5 is 60 ug/m^3)
2. In February 2020, half of the monitoring stations in Mumbai did not report PM2.5 data. PM2.5 levels exceeded the permissible limit at 8 locations, emphasizing the need for improved monitoring and measures to control air pollution.
3. In February 2021, all 21 monitoring stations in Mumbai reported PM2.5 data, with an average uptime of 83.02%. While some stations reported lower uptime, PM2.5 levels at 7 locations were below the permissible limit, but the average PM2.5 level remained high at 69.44 ug/m^3.
4. In February 2022, 20 monitoring stations in Mumbai reported PM2.5 data, with only one station having 0% uptime. While some stations reported low uptime, PM2.5 levels at 8 locations were below the permissible limit, but the highest level recorded was 2.39x the permissible limit at Mazgaon (IITM).
5. In February 2023, all 20 active monitoring stations reported data, with an average uptime of 80.5%, and only 3 stations had PM2.5 levels within permissible limits. The average PM2.5 levels for the 20 stations was 83.41 ug/m^3, considerably higher than the previous year, and the lowest level was recorded at Kurla (MPCB) station with an uptime of 92.75%.
6. Increase in PM2.5 levels observed in Feb 2023 as compared to the previous year, with 16 out of 21 locations showing an increase. Certain locations show more than double the increase as compared to last year. Kurla (MPCB), Malad (IITM), and Mazgaon (IITM) are the only locations reporting a decrease in PM2.5 levels. However, Mazgaon's monitor had an uptime of mere 31.96% in February 2023. Borivali East (MPCB) shows marginal increase and PM2.5 levels have remained similar to Feb 2022.
7. The distribution of PM2.5 levels in Mumbai during February 2023 reveals that BKC, Deonar, Chakala, Khindipada, and Navi Mumbai have higher levels compared to other locations, while Kurla (MPCB) and Borivali (MPCB) are found to have lower levels that meet the CPCB standard of 60 ug/m^3.
8. Mumbai recorded 27 POOR category days ($PM_{2.5}$ between 90 to 120 ug/m3) in the Jan/Feb 2023 period as compared to 6 POOR days in the same period for 2022. There were ZERO good days ($PM_{2.5}$ under 30 ug/m3). Good/Poor/Very Poor/Severe are as per CPCB prescribed norms for $PM_{2.5}$ concentrations.
9. The Hysplit back-trajectory model was used in Mumbai to identify sources of air pollutants, and found changes in emission sources and dispersion patterns over time. The NCEP runs computer analyses and forecasts for air quality modeling, with archived data available at ARL. The heat map shows a decrease in particulate matter concentration in the fourth week of February.

Based on the data and analysis presented, it is evident that air pollution levels in Mumbai during February 2023 were considerably higher than the previous year, with only a few monitoring stations recording levels within the permissible limit. The Hysplit back-trajectory model and the NCEP GDAS system provide valuable tools for understanding the sources and dispersion of pollutants, which can help identify areas where policy interventions are needed. The findings suggest that urgent action is required to reduce emissions from various sources, including vehicular traffic, industrial activities, and construction sites. Some possible policy solutions include promoting the use of public transportation, imposing stricter emission standards on industries and vehicles, and increasing green cover in the city. Addressing the issue of air pollution is crucial for protecting public health, improving quality of life, and achieving sustainable development in Mumbai.

Trends

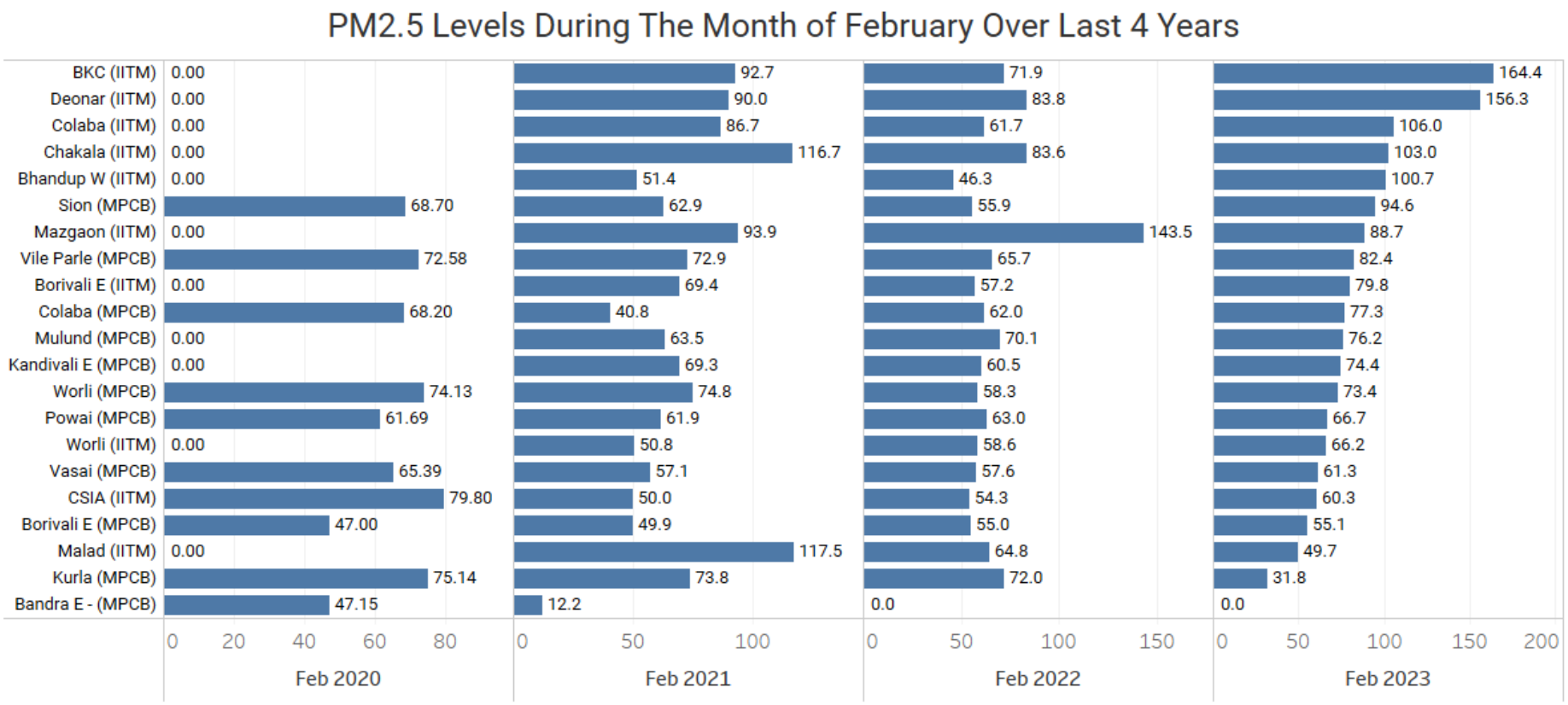
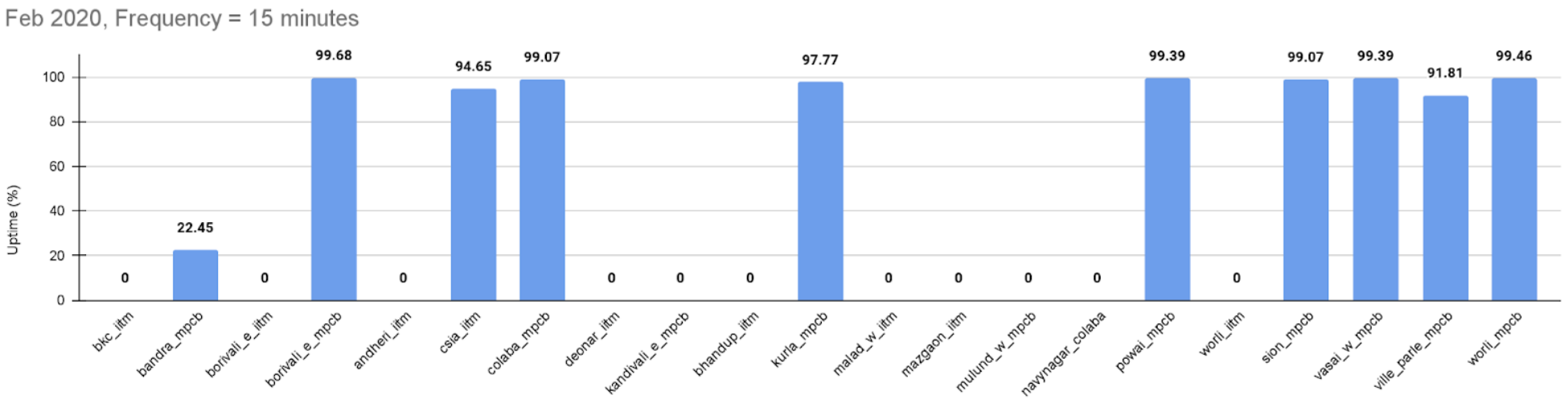
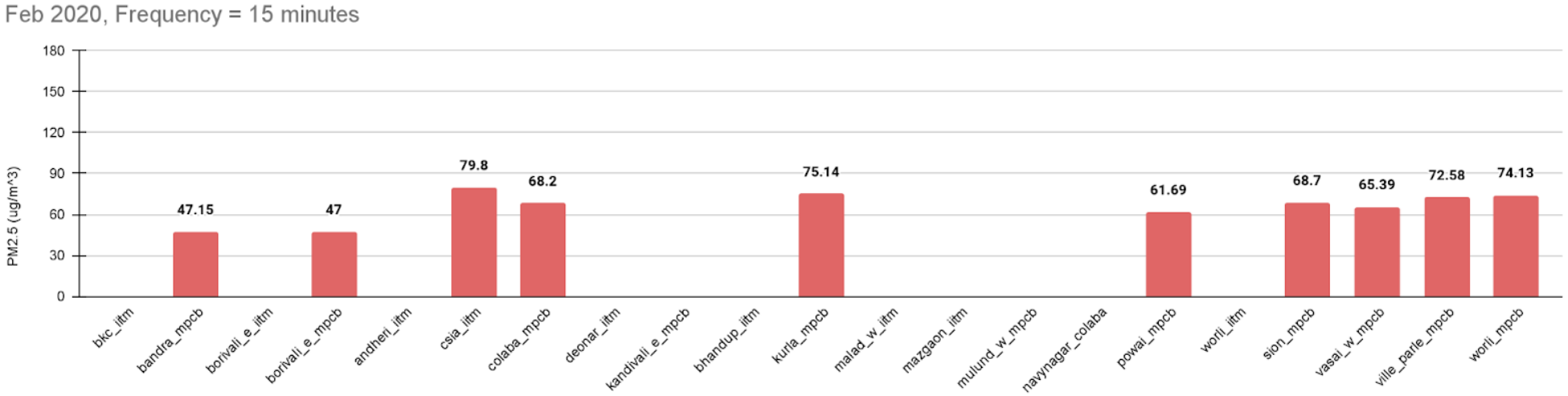


Figure1: Location wise daily avg. data for mumbai city from 2020, 2021, 2022, and 2023 (February).
Data source:https://airquality.cpcb.gov.in/ccr/#/caaqm-dashboard-all/caaqm-landing

Some locations like **Malad, Kurla and Vile Parle witnessed improvements in PM2.5 levels** in the month of February 2023 in comparison to previous years in the same month; most locations see a spike ranging from 60.3 ug/m3 at CSIA (IITM) to 164.4 ug/m3 at BKC (IITM). The Central Pollution Control Board's (CPCB) daily average safe limit for PM2.5 level is 60 ug/m3, which is much higher than the World Health Organisation's (WHO) prescribed limit of 15 ug/m3. However, **apart from Borivali East, Malad, Kurla and Bandra East, all other 17 monitoring stations had a monthly average higher than CPCB's prescribed safety limits** for the coastal city.

- **Feb 2020**



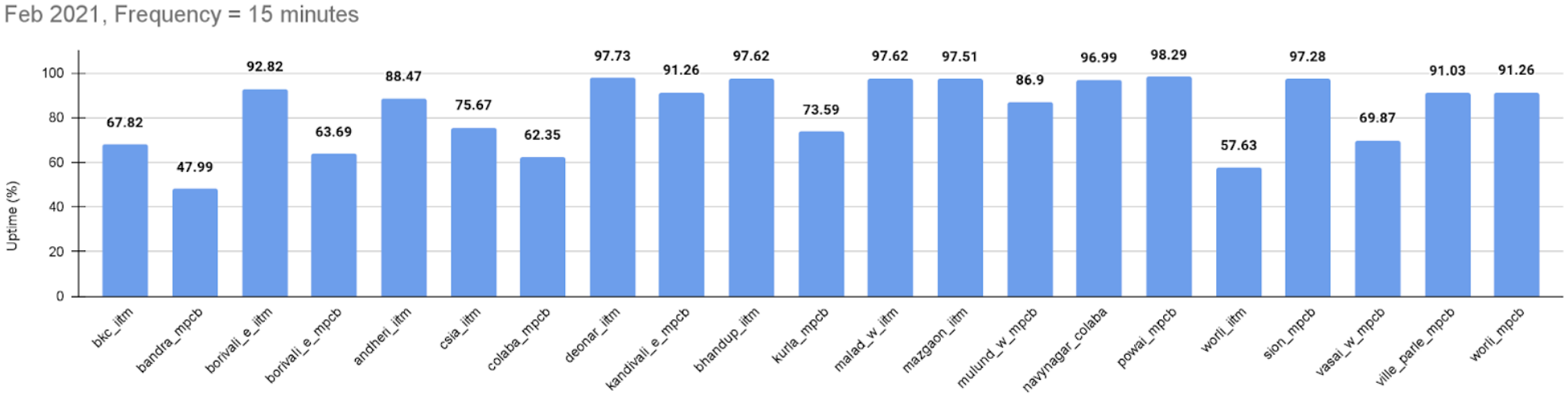


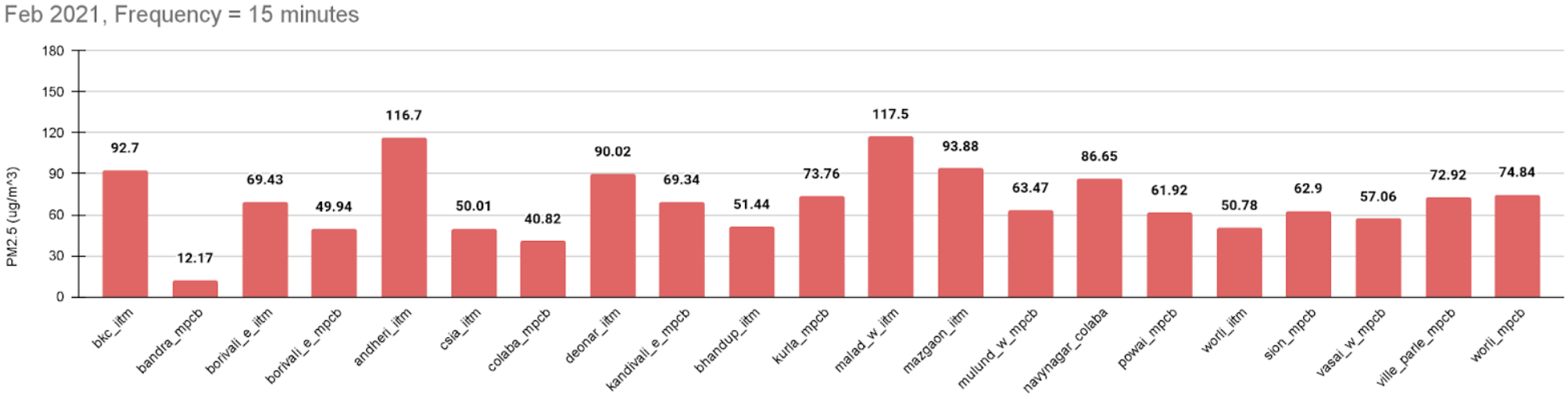
Data source:https://airquality.cpcb.gov.in/ccr/#/caaqm-dashboard-all/caaqm-landing

During February 2020, only **10 out of 21 operational sites have reported PM2.5 data, the rest have an uptime of 0% (data is not available)**. Within these 10 sites, **Bandra Mumbai (MPCB) site has an uptime of 22.45%** while the remaining **9 sites registered an uptime of more than 90%**. The average uptime of monitoring stations is 42.99% and the PM2.5 levels **exceeded the permissible limit of 60 ug/m^3 at 8 of these locations**. The highest was recorded by **CSIA (IITM) at 79.80 ug/m^3** while the lowest was recorded for

Borivali East (MPCB) at 47 ug/m^3. It should be noted that the 2nd lowest levels of **47.15 ug/m^3 recorded at Bandra Mumbai (MPCB) has the lowest uptime (22.45%)** among the monitoring stations where data is available. The average level of PM2.5, considering all 10 operational sites, is 65.98 ug/m^3.

- **Feb 2021**



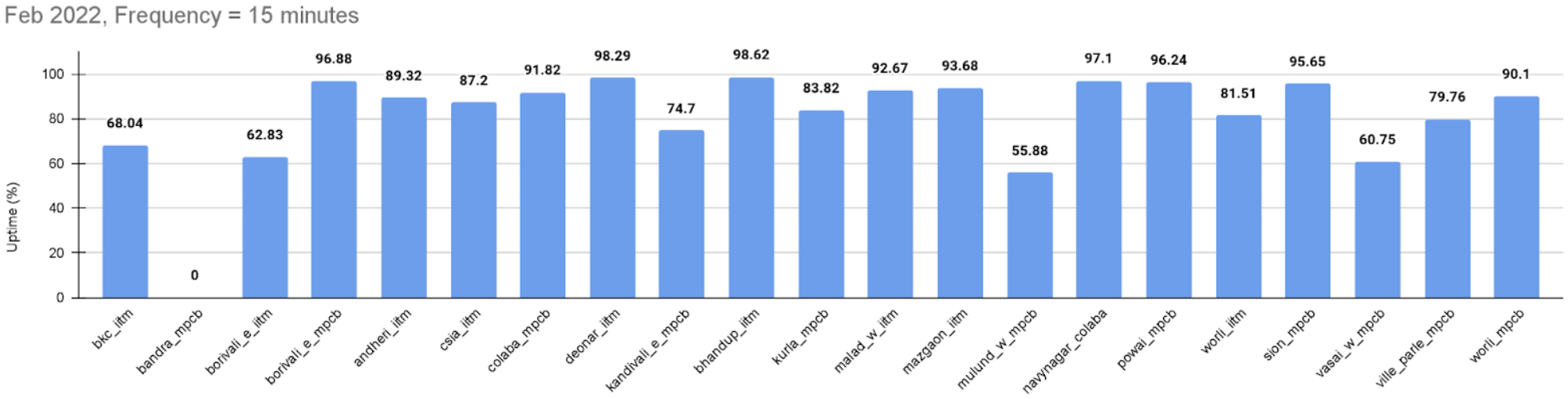


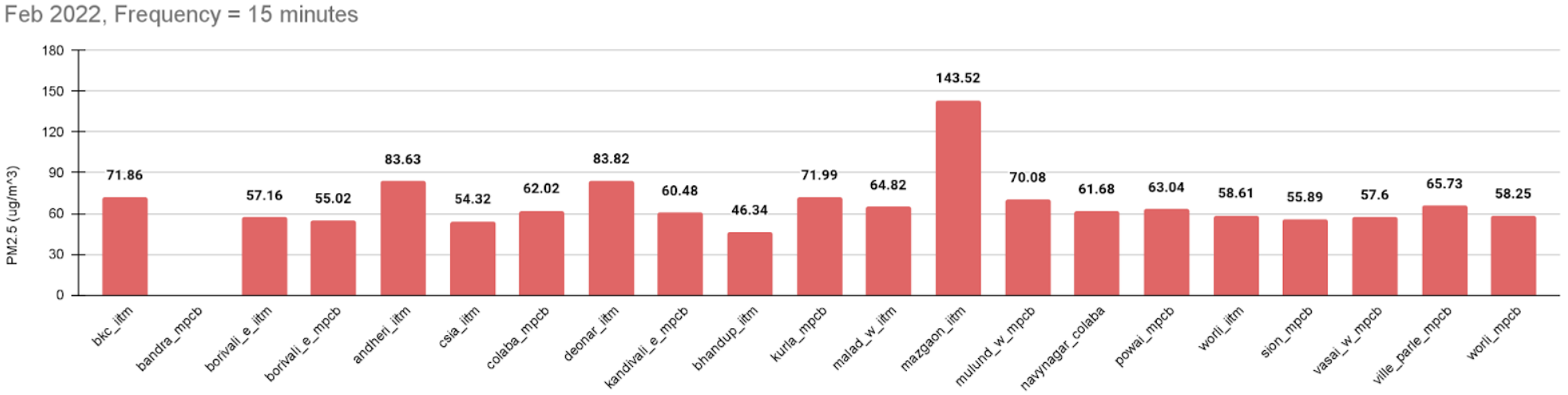
Data source:https://airquality.cpcb.gov.in/ccr/#/caaqm-dashboard-all/caaqm-landing

All 21 monitoring sites reported data in the month of Feb 2021, with an average uptime of 83.02% - better availability of data as compared to the previous year. **Bandra Mumbai (MPCB) was again amongst the stations reporting lower uptime (47.99%)**, while **11 stations reported uptime of more than 90%**. The PM2.5 levels at **7 out of 21**

locations are reported below the permissible limit of 60 ug/m^3 with the **highest of 117.5 ug/m^3 and the lowest of 12.17 ug/m^3 reported at Malad (IITM) and Bandra East (MPCB)** respectively. Similarly, **Worli (IITM) has recorded PM2.5 levels of 50.78 ug/m^3 but has the second lowest uptime of 57.63%**. Overall the average PM2.5 level is 69.44 ug/m^3 which is slightly higher near the previous year.

- **Feb 2022**



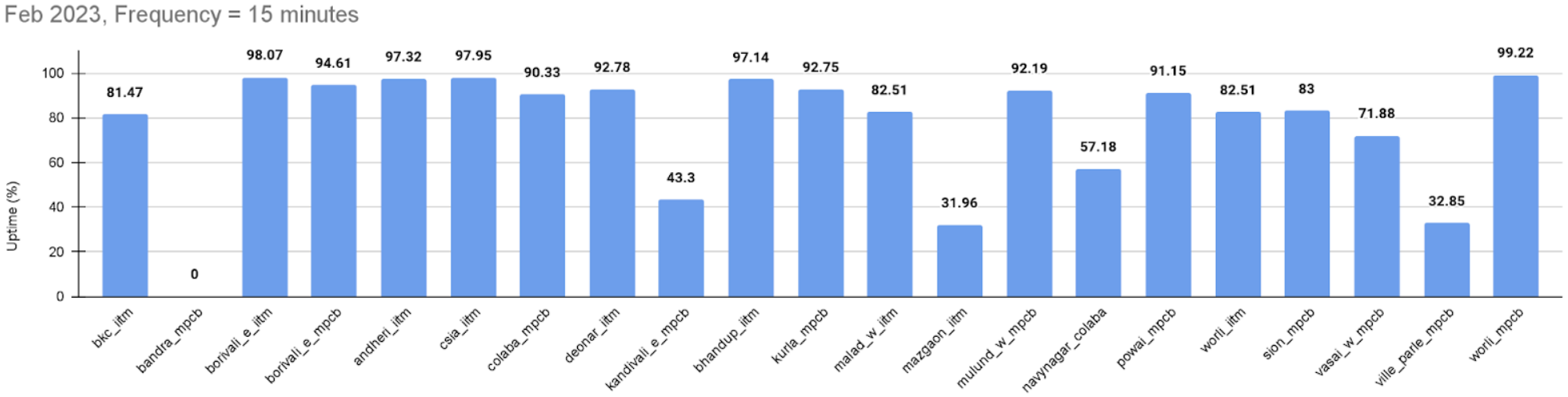


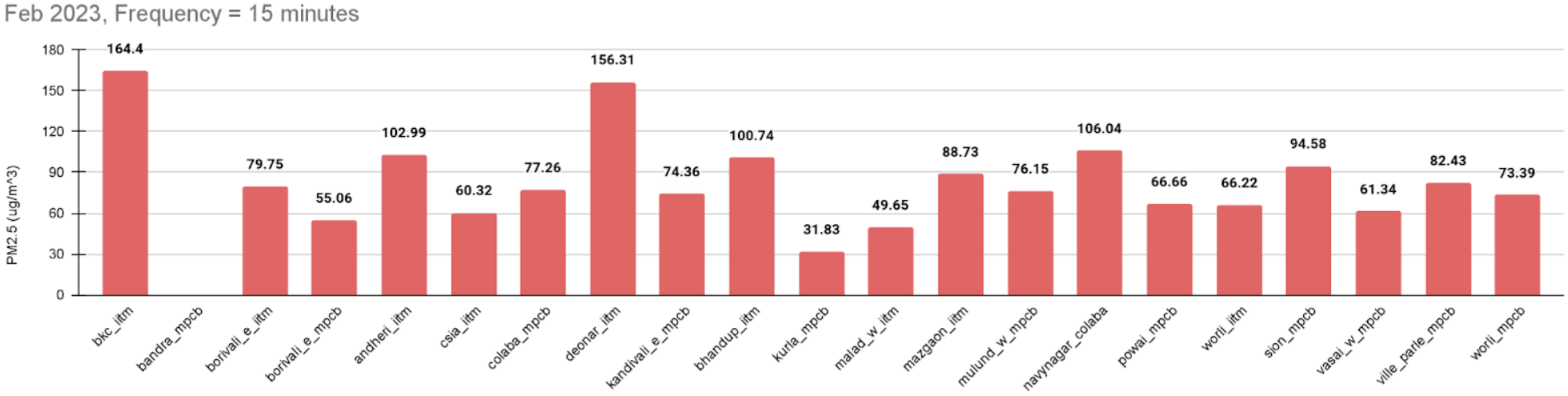
Data source:https://airquality.cpcb.gov.in/ccr/#/caaqm-dashboard-all/caaqm-landing

A total of 20 monitoring sites were active in the month of Feb 2022, and only **Bandra Mumbai (MPCB) reported 0% uptime or had no data reported.** The average

uptime of 20 stations is 84.74% and the **Mulund West (MPCB) station reported the lowest uptime of 55.88%.** The PM2.5 levels at **8 out of 20 locations are below the permissible levels** while the rest exceeded the limit of 60 ug/m^3. The **lowest levels of PM2.5, 46.34 ug/m^3, is at Bhandup West (IITM) with an uptime of 98.62%**. The **highest level of PM2.5 is 143.52 ug/m^3 at Mazgaon (IITM)** and the monitoring station has **recorded 93.68% uptime**. Notably, the **PM2.5 levels at Mazgoan (IITM) is 2.39x the permissible levels** and 2.13x the city average of 67.29 ug/m^3.

- **Feb 2023**





Data source:https://airquality.cpcb.gov.in/ccr/#/caaqm-dashboard-all/caaqm-landing

All 20 active monitoring stations reported data in February 2023 with the **lowest uptime of 31.96% recorded at Mazgaon (IITM).** The average uptime of 20 stations, 80.5%, is also less than the previous year. Only **3/20 stations have PM2.5 levels that are lower than the permissible limit**. The **lowest PM2.5 levels recorded is 31.83 ug/m^3 at Kurla (MPCB)** and the **highest is 164.4 ug/m^3 at BKC (IITM)**. Importantly, **diverging from the trend**, the **average levels of PM2.5 for 20 stations is 83.41 ug/m^3**- which is considerably higher (1.23x) than the previous year observation. The PM2.5 levels recorded at Kurla (MPCB) station, 31.83 ug/m^3, is considerably lower than the previous year levels of 71.99 ug/m^3 and the station has an uptime of 92.75%.

Table 1: Heatmap for PM2.5 Levels in Mumbai In the Month of February

Data source:https://airquality.cpcb.gov.in/ccr/#/caaqm-dashboard-all/caaqm-landing

Location	Feb-20	Feb-21	Feb-22	Feb-23
BKC (IITM)	0	92.7	71.86	164.4
Bandra E - (MPCB)	47.15	12.17	0	0
Borivali E (IITM)	0	69.43	57.16	79.75
Borivali E (MPCB)	47	49.94	55.02	55.06
Chakala (IITM)	0	116.7	83.63	102.99
CSIA (IITM)	79.8	50.01	54.32	60.32
Colaba (MPCB)	68.2	40.82	62.02	77.26
Deonar (IITM)	0	90.02	83.82	156.31
Kandivali E (MPCB)	0	69.34	60.48	74.36
Bhandup W (IITM)	0	51.44	46.34	100.74
Kurla (MPCB)	75.14	73.76	71.99	31.83
Malad (IITM)	0	117.5	64.82	49.65
Mazgaon (IITM)	0	93.88	143.52	88.73
Mulund (MPCB)	0	63.47	70.08	76.15
Colaba (IITM)	0	86.65	61.68	106.04
Powai (MPCB)	61.69	61.92	63.04	66.66
Worli (IITM)	0	50.78	58.61	66.22
Sion (MPCB)	68.7	62.9	55.89	94.58

Vasai (MPCB)	65.39	57.06	57.6	61.34
Vile Parle (MPCB)	72.58	72.92	65.73	82.43
Worli (MPCB)	74.13	74.84	58.25	73.39

Figure 2: A calendar heatmap of Mumbai city in the month of **February 2023** using average PM2.5 levels
Data source: https://airquality.cpcb.gov.in/ccr/#/caaqm-dashboard-all/caaqm-landing)

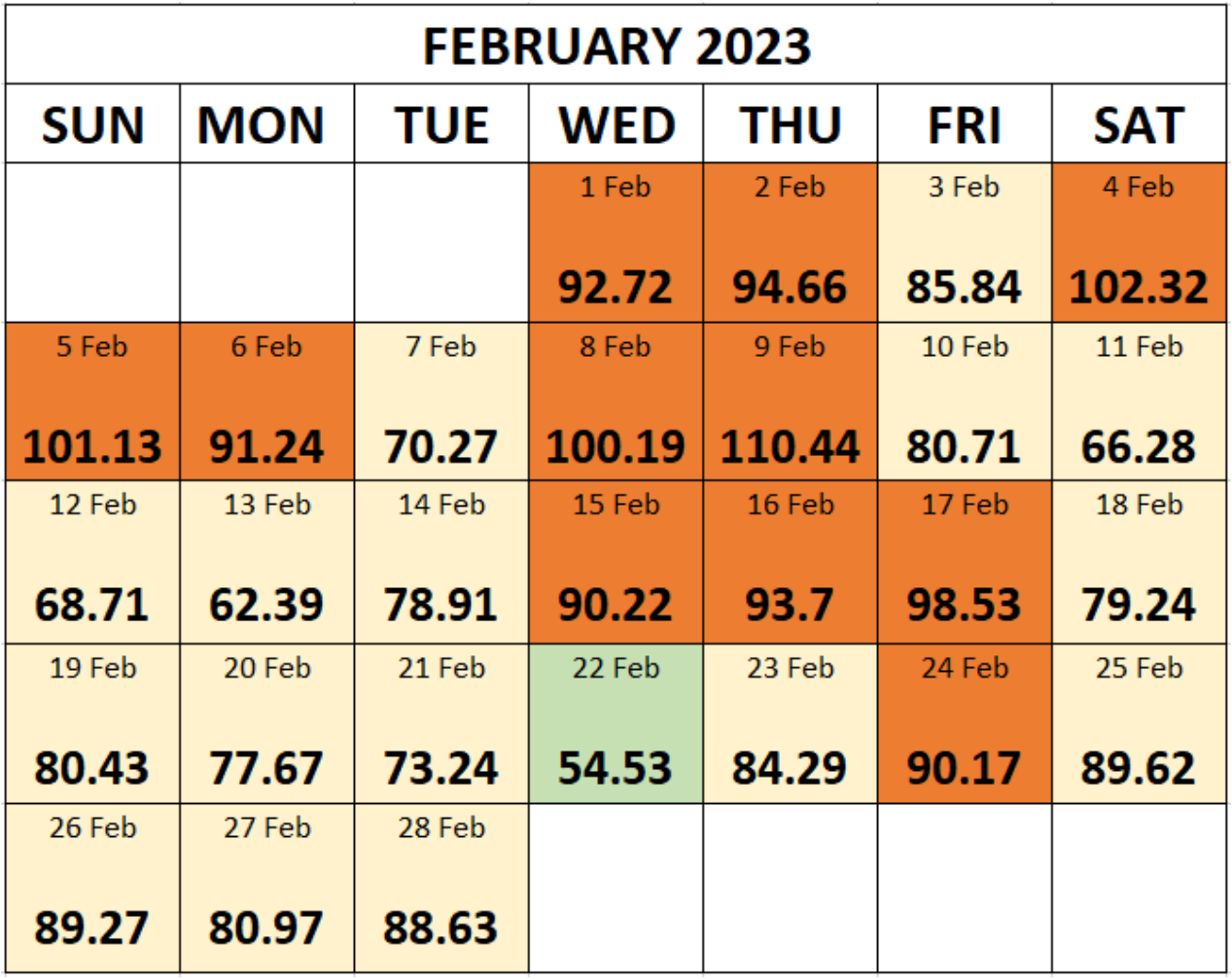
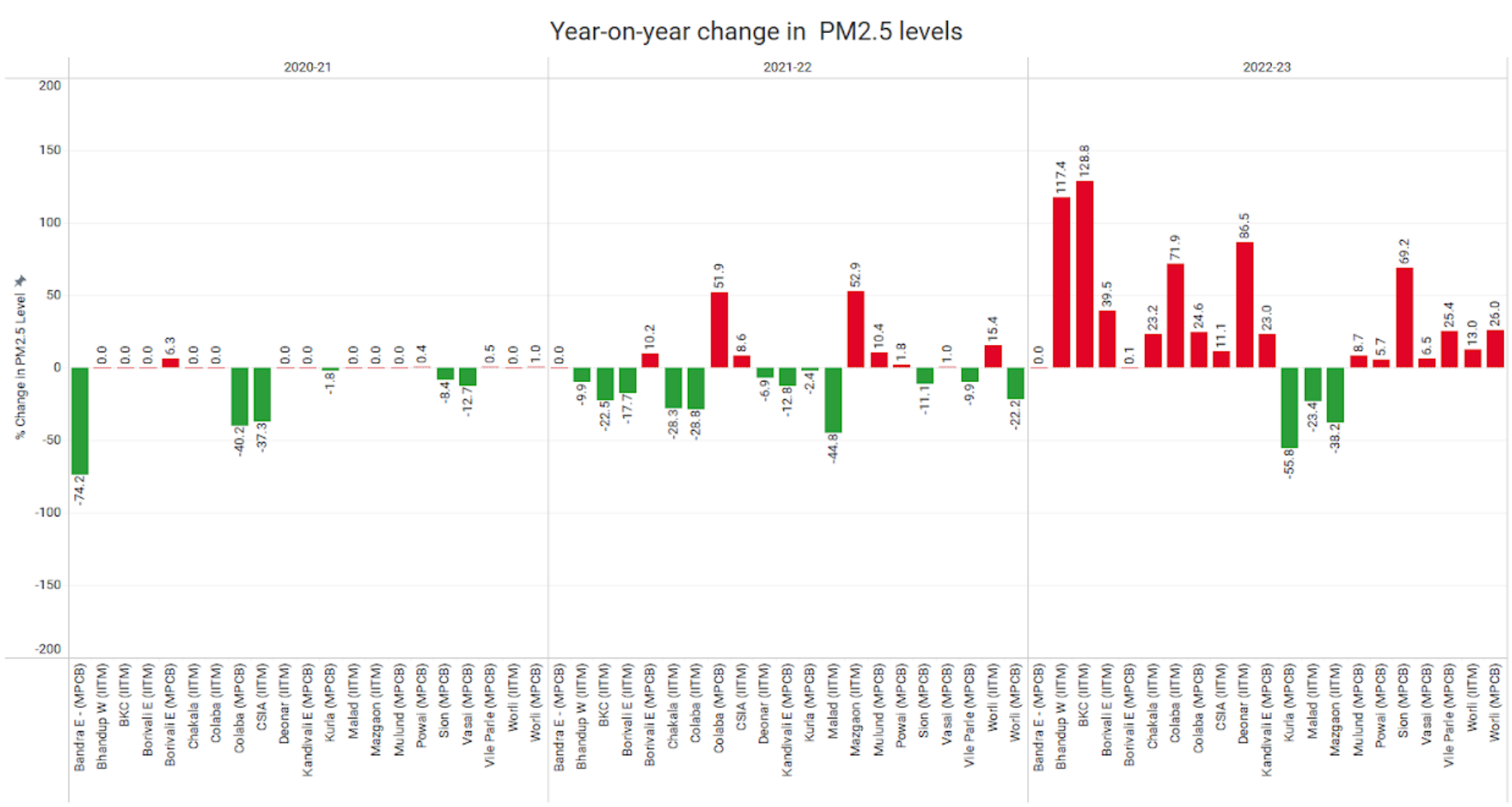


Figure3: Year to year PM2.5 percentage change at Mumbai city in the month of **February**
Data source:https://airquality.cpcb.gov.in/ccr/#/caaqm-dashboard-all/caaqm-landing)



The **increase in PM2.5 levels in the month of Feb 2023** is evident from the **% change in the levels** as compared to the previous year. **8 out of 21 locations show an increase in levels for Feb 2022** (as compared to Feb 2021) and **16 out of 21 locations show an increase in Feb 2023** (as compared to Feb 2022). The rise in levels is **more than double at certain locations like Bhandup West (IITM) and BKC (IITM) for Feb 2023**. The locations showing a decrease in PM2.5 levels are Kurla (MPCB), Malad (IITM), and Mazgoan (IITM). However, the Mazgoan (IITM) station reported an uptime of only 31.96% as compared to 93.68% in Feb 2022. In Feb 2023, Borivali East (MPCB) showed only a marginal increase of 0.1%, therefore the PM2.5 levels have remained similar as compared to Feb 2022.

Box plot

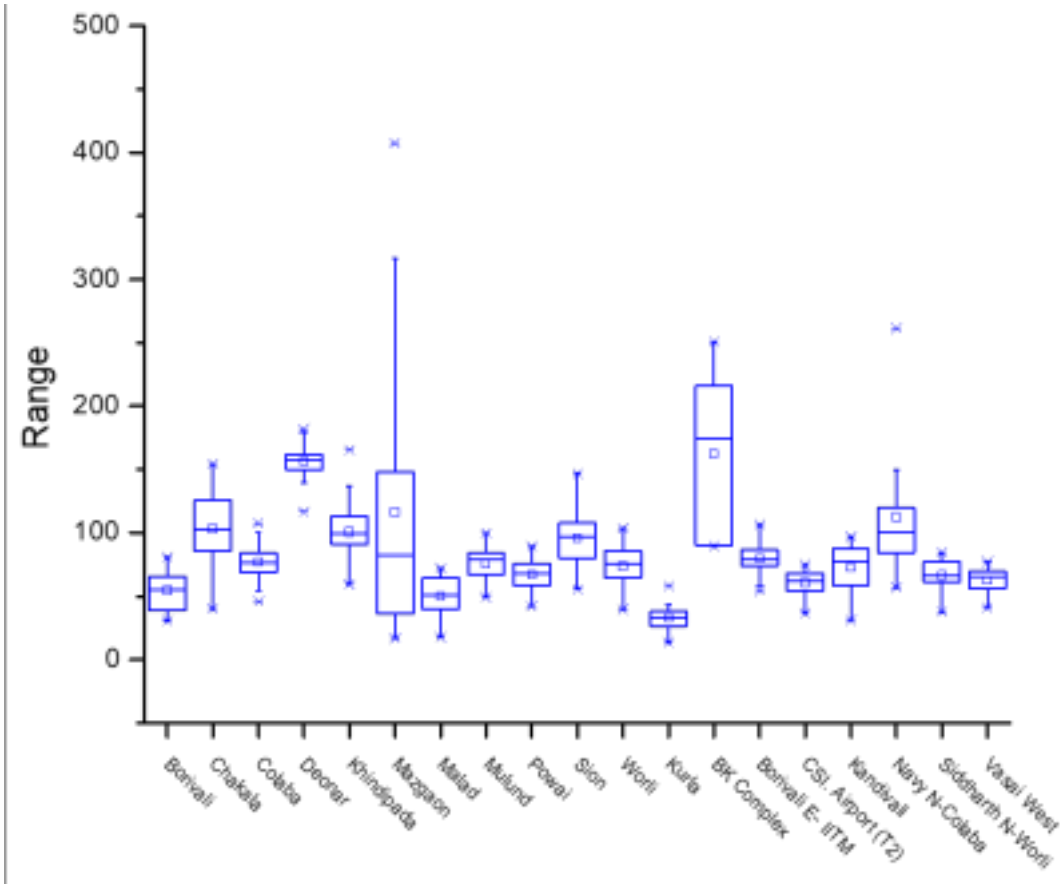
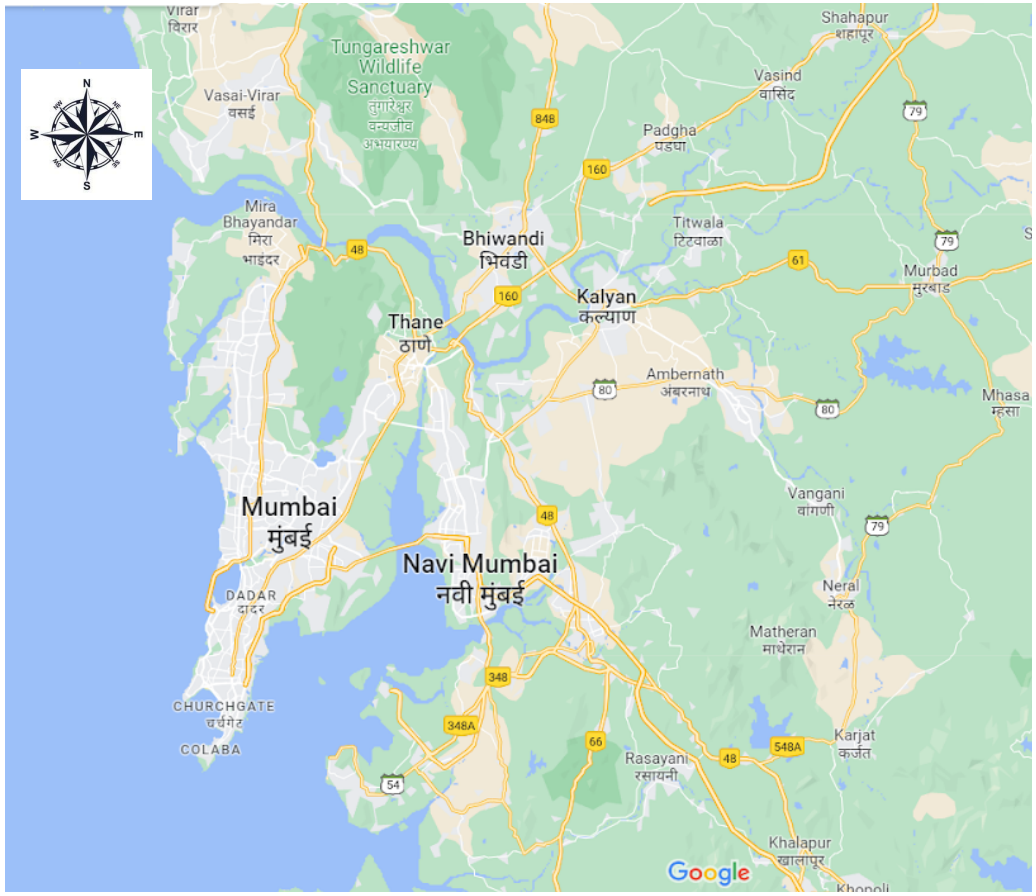


Figure 4: Box plot of PM2.5 for February 2023 at mumbai city
Data source:https://airquality.cpcb.gov.in/ccr/#/caaqm-dashboard-all/caaqm-landing

Box plots are a useful tool for visualizing the distribution of a dataset, including its central tendency, variability, and potential outliers. The box plot of PM2.5 concentrations in Mumbai during February 2023 shows higher values for BKC, Deonar, Chakala, Khindipada, and Navi Mumbai compared to the other locations in the city. Meanwhile, Kurla and Borivali are found to have lower concentrations that meet the Central Pollution Control Board (CPCB) standard of 60 ug/m3.

HYSPLIT Analysis

The Hysplit back-trajectory model is a widely used air pollution modeling system that can be used to study the dispersion and transport of air pollutants. In this particular case, the model was run in Mumbai city in February 2023, and it uses a fixed three-dimensional grid as a reference to compute the concentration of pollutants in the air. The simulation was able to identify multiple hotspots where the concentrations of particulate matter were high, which can indicate the sources of emissions that lead to the emergence of pollutants. By tracing the concentrations of particulate matter from the source to the receptor areas where pollution concentrations are retained, the simulation can provide insights into how pollutants are dispersed. During the period of the simulation, the origin of particulate matter mass concentration was found to be in the *north, north east, and east* direction in the first three weeks, and then changed to a *westerly* direction in the fourth week. This suggests that there were changes in the sources of emissions during this period, which may have contributed to the changes in the direction of the particulate matter dispersion. Overall, the Hysplit back-trajectory model provides a valuable tool for understanding the dispersion of pollutants in urban areas like Mumbai and can help identify sources of emissions that contribute to air pollution.



The National Centers for Environmental Prediction (NCEP) (part of NOAA of the US Government) runs computer analyses and forecasts. One system is the Global Data Assimilation System (GDAS). At NOAA's Air Resources Laboratory (ARL), NCEP model output is used for air quality modeling. ARL archives both EDAS(Eta Data Assimilation System) and GDAS output. Both archives contain basic fields such as wind components, temperature, and humidity. The 3-hourly archive data comes from NCEP's GDAS which is run 4 times a day i.e., at 00, 06, 12, and 18 UTC.

Furthermore, the heat map indicates that the concentration of particulate matter was lower in the fourth week of February compared to the previous three weeks. This could be due to a change in weather patterns or other factors that affected the dispersion of particulate matter in the atmosphere.

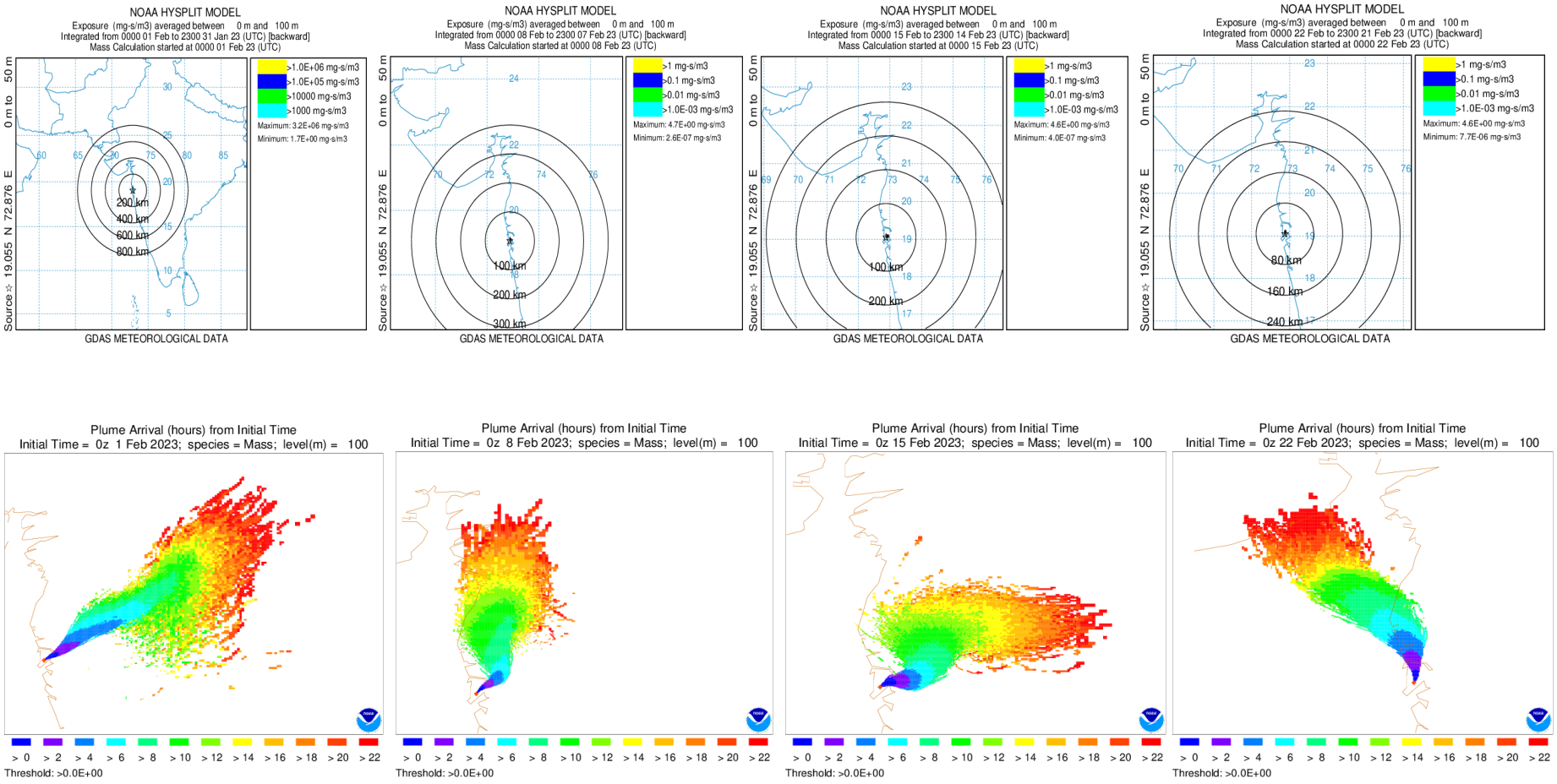


Figure 5: Mumbai city mass trajectory analysis using hysplit model during the Feb 2023 (first to fourth week). https://www.ready.noaa.gov/READYtransp.php, **Meteorological data source**: https://www.emc.ncep.noaa.gov/gmb/gdas/

ANNEXURE 1:

Revised National Ambient Air Quality Standards (NAAQS)

[NAAQS Notification dated 18th November, 2009]

S. No.	Pollutants	Time Weighted Average	Concentration in Ambient Air		Methods of Measurement
			Industrial, Residential, Rural and other Areas	Ecologically Sensitive Area (notified by Central Government)	
1	Sulphur Dioxide (SO_2), µg/m³	Annual*	50	20	1. Improved West and Gaeke 2. Ultraviolet Fluorescence
		24 Hours**	80	80	
2	Nitrogen Dioxide (NO_2), µg/m³	Annual*	40	30	1. Modified Jacob & Hochheiser 2. Chemiluminescence
		24 Hours**	80	80	
3	Particulate Matter (Size <10µm) or PM_{10} µg/m³	Annual*	60	60	1. Gravimetric 2. TEOM 3. Beta attenuation
		24 Hours**	100	100	
4	Particulate Matter (Size <2.5 µm) or $PM_{2.5}$ µg/m³	Annual*	40	40	1. Gravimetric 2. TEOM 3. Beta attenuation
		24 Hours **	60	60	
5	Ozone (O_3), µg/m³	8 hours**	100	100	1. UV photometric 2. Chemiluminescence 3. Chemical Method
		1 hours **	180	180	
6	Lead (Pb), µg/m³	Annual *	0.50	0.50	1. AAS/ICP Method after sampling using EPM 2000 or equivalent filter paper 2. ED-XRF using Teflon filter
		24 Hour**	1.0	1.0	
7	Carbon Monoxide (CO), mg/m³	8 Hours **	02	02	Non dispersive Infra Red (NDIR) Spectroscopy
		1 Hour**	04	04	
8	Ammonia (NH_3), µg/m³	Annual*	100	100	1. Chemiluminescence 2. Indophernol blue method
		24 Hour**	400	400	
9	Benzene (C_6H_6) , µg/m³	Annual *	05	05	1. Gas chromatography based continuous analyzer 2. Adsorption and Desorption followed by GC analysis
10	Benzo(a)Pyrene (BaP)-particulate phase only, ng/m³	Annual*	01	01	Solvent extraction followed by HPLC/GC analysis
11	Arsenic (As), ng/m³	Annual*	06	06	AAS/ICP method after sampling on EPM 2000 or equivalent filter paper
12	Nickel (Ni), ng/m³	Annual*	20	20	AAS/ICP method after sampling on EPM 2000 or equivalent filter paper

** Annual Arithmetic mean of minimum 104 measurements in a year at a particular site taken twice a week 24 hourly at uniform interval.** 24 hourly 08 hourly or 01 hourly monitored values, as applicable shall be complied with 98% of the time in a year. 2% of the time, they may exceed the limits but not on two consecutive days of monitoring.*

NOTE: Whenever and wherever monitoring results on two consecutive days of monitoring exceed the limits specified above for the respective category, it shall be considered adequate reason to institute regular or continuous monitoring and further investigation.

Source: National Ambient Air Quality Status & Trends in 2019, Central Pollution Control Board

ANNEXURE 2:

AQI Category, Pollutants and Health Breakpoints								
AQI Category (Range)	PM_{10} 24-hr	$PM_{2.5}$ 24-hr	NO_2 24-hr	O_3 8-hr	CO 8-hr (mg/m^3)	SO_2 24-hr	NH_3 24-hr	Pb 24-hr
Good (0-50)	0-50	0-30	0-40	0-50	0-1.0	0-40	0-200	0-0.5
Satisfactory (51-100)	51-100	31-60	41-80	51-100	1.1-2.0	41-80	201-400	0.5 –1.0
Moderately polluted (101-200)	101-250	61-90	81-180	101-168	2.1- 10	81-380	401-800	1.1-2.0
Poor (201-300)	251-350	91-120	181-280	169-208	10-17	381-800	801-1200	2.1-3.0
Very poor (301-400)	351-430	121-250	281-400	209-748*	17-34	801-1600	1200-1800	3.1-3.5
Severe (401-500)	430 +	250+	400+	748+*	34+	1600+	1800+	3.5+

One hourly monitoring (for mathematical calculations only)

AQI	Associated Health Impacts
Good (0–50)	Minimal Impact
Satisfactory (51–100)	May cause minor breathing discomfort to sensitive people.
Moderately polluted (101–200)	May cause breathing discomfort to people with lung disease such as asthma, and discomfort to people with heart disease, children and older adults.
Poor (201–300)	May cause breathing discomfort to people on prolonged exposure, and discomfort to people with heart disease
Very Poor (301–400)	May cause respiratory illness to the people on prolonged exposure. Effect may be more pronounced in people with lung and heart diseases.
Severe (401-500)	May cause respiratory effects even on healthy people and serious health impacts on people with lung/heart diseases. The health impacts may be experienced even during light physical activity

Source: National Ambient Air Quality Status & Trends in 2019, Central Pollution Control Board

QUOTES

Aarti Khosla, Director, Climate Trends
"This year, the city's coastal winds did not help keep air pollution levels in check which is a clear sign that Mumbai cannot continue depend on the meteorology to absorb its emissions. Across the world, there are examples of tackling bad air quality by a range of approaches towards first monitoring air quality levels closely. Mumbai could do well to implement it's tested pilot of sensor based monitoring which is being held in abeyance. The city administration must develop control strategies across sectors like industries, power, transport, and construction to reduce emissions at source. A deep dive into data during the past month shows us that several locations in the city need focused action as levels are above the city averages. Care must also be taken to ensure funds aren't spent on false solutions like smog towers."

Ronak Sutaria, **Respirer Living Sciences Pvt. Ltd.**
“Air quality conditions in Mumbai have been on the front pages of most publications this winter. A more fine grained analysis of the validated government data is essential to give us a better window into what is really happening across the city. The change in air quality levels for the month of February shows us that only 3 locations out of 20 have shown improvements this year as compared to last year (with 1 of those locations having less than 50% uptime in the month). Locations such as BKC and Deonar have shown the worst deterioration of air quality conditions this year. While BKC saw 15 VERY POOR air days and 2 SEVERE air days, Deonar saw 26 VERY POOR air days in Feb 2023. Overall Mumbai saw 11 POOR air days with the quality of air deteriorating at 11 locations since last year. This is alarming and needs immediate attention from both monitoring and mitigation perspectives.”

About NCAP Tracker

NCAP Tracker is a joint project by Climate Trends and Respirer Living Sciences to create an online hub for the latest updates on India’s clean air policy, the National Clean Air Programme (NCAP). It is designed to track India’s progress in achieving the 2024 clean air targets set under the NCAP. The NCAP Tracker enables this by compiling and evaluating various levels of air quality data and closely tracking the effectiveness of the clean air policy. The tracker compiles and analyses information on air quality and budget allocation that is publicly available or provided by the government of India.