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Technical Report

Delhi's PM2.5 Levels (2017-2023)
Probabilistic Analysis of Air Quality and AQI Categories for Personal and Community Interventions

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Introduction

Air pollution is a significant environmental issue in Delhi, with particulate matter ($PM_{2.5}$) being one of the primary pollutants affecting air quality and public health. The pathways air pollution impacts public health include pulmonary and systemic inflammation, increased coagulation and vasoconstriction and increased sympathetic tone in the nervous system. Sensitive groups include those having chronic respiratory or cardiovascular disease or those whose detoxification capacity is impaired, especially unborn and young children and older populations.

This report examines $PM_{2.5}$ levels across four key locations in Delhi — Sirifort, IHBAS Dilshad Garden, Sonia Vihar, and Mandir Marg (Figure 1) — over the period from 2017 to 2023. This report focuses on scientific evidence around PM2.5's seasonal and temporal behaviour to derive personal and community interventions. This will help to alleviate some of the negative health impacts of PM2.5 by advising means to avoid exposure during critical times of the year.

If in a rush, the reader will derive the most value from the Inference and Recommendation sections at the end of the report.

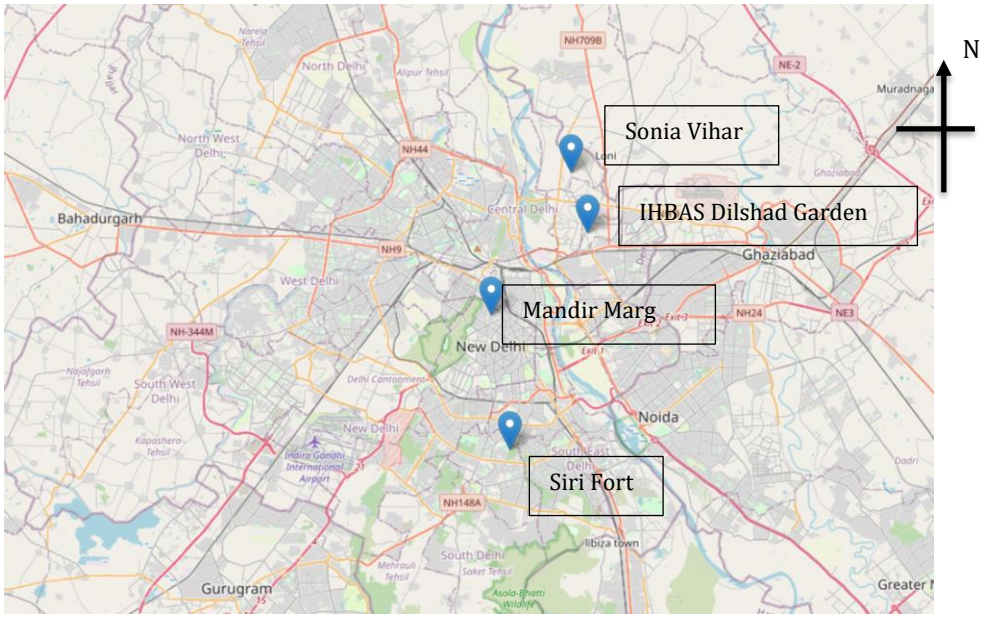

Figure 1: Sampling Sites for Data Analysis

Data Snapshot

In Figure 2, the count is the number of observations from the particular AQ station during the study period (2017-2023), followed by mean observation in $\mu g/m^3$, the standard deviation in $\mu g/m^3$ and the 25th %ile, 50th %ile and 75th %ile values for PM2.5

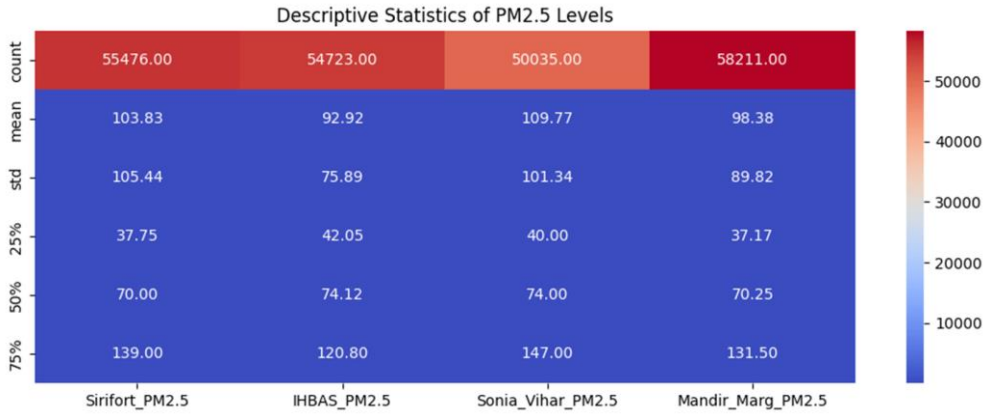

Figure 2: Snap Shot of Data Statistics

Methodology

By analyzing descriptive statistics of PM2.5 concentrations, as visualized in the accompanying figures, this study aims to highlight the variations and distribution of pollution levels across these areas. Then, the statistics are used to model the probability of poor air quality due to PM2.5 across time frames.

This report focuses on the Air Quality Index (AQI), which is calculated by averaging the concentrations of pollutants over a period of time. The National Ambient Air Quality Standards (CPCB 2009) are notified for 12 pollutants but for AQI for 8 parameters – PM10, PM2.5, NO_2, SO_2, CO, O_3, NH_3 and Pb are considered. The AQI for a location is the worst-performing pollutant being monitored represented on a scale from 0 to 500 (Table 1). Along with PM2.5 concentrations, AQI due to PM2.5 and its trends have also been analyzed. Understanding the spatial and temporal trends in PM2.5 concentrations is crucial for designing targeted air quality interventions and safeguarding public health in urban areas like Delhi.

Table 1: Air Quality Index and Concentration Cut-off (µg/m3 except for CO) (Source: CPCB Report CUPS/82/2014-15)

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	0.6 –1.0
Moderate (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	10.1-17	381-800	801-1200	2.1-3.0
Very poor (301-400)	351-430	121-250	281-400	209-748*	17.1-34	801-1600	1201-1800	3.1-3.5
Severe (401-500)	430 +	250+	400+	748+*	34+	1600+	1800+	3.5+

Table 2 shows the effects of various levels of AQI on the health of individuals. For AQIs higher than 151, sensitive groups like people with heart or respiratory ailments along with children and the elderly, risks go up. Above 201, everyone is at risk.

AQI Category and Color	Index Value	Description of Air Quality
Good Green	0 to 50	Air quality is satisfactory, and air pollution poses little or no risk.
Moderate Yellow	51 to 100	Air quality is acceptable. However, there may be a risk for some people, particularly those who are unusually sensitive to air pollution.
Unhealthy for Sensitive Groups Orange	101 to 150	Members of sensitive groups may experience health effects. The general public is less likely to be affected.
Unhealthy Red	151 to 200	Some members of the general public may experience health effects; members of sensitive groups may experience more serious health effects.
Very Unhealthy Purple	201 to 300	Health alert: The risk of health effects is increased for everyone.
Hazardous Maroon	301 and higher	Health warning of emergency conditions: everyone is more likely to be affected.

Table 2: AQI and relation to health effects (Source: CPCB Report CUPS/82/2014-15)

Observations

Monthly Trends in PM2.5 Levels

The analysis of monthly PM2.5 levels across Sirifort, IHBAS Dilshad Garden, Sonia Vihar, and Mandir Marg reveals clear seasonal trends in air quality. Figure 3 shows a pronounced increase in PM2.5 concentrations during the winter months, particularly in October, November, and December, when levels peak across all stations.

In contrast, the summer months, from April to August, exhibit significantly lower PM2.5 levels, likely due to atmospheric conditions such as increased wind and precipitation, which help disperse pollutants. These findings emphasize the importance of targeted interventions during the high-pollution winter period to mitigate health risks and improve air quality in Delhi.

It becomes of utmost importance that community and personal interventions happen during this time. We provide recommendations in the end.

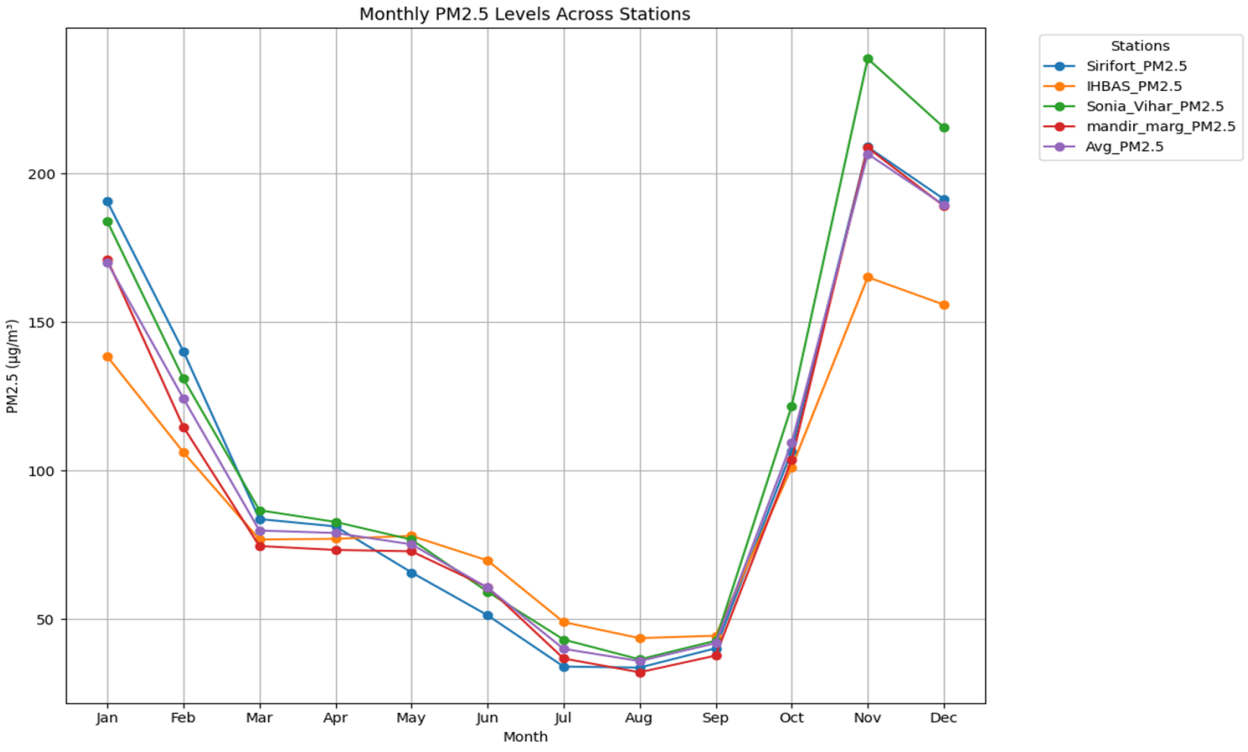

Fig. 3: Monthly Trends in PM2.5 levels (24-hr average can be much higher)

Probability Percentage of Severe Hours by Month and Hour of the Day

Figure 4 illustrates the percentage of hours with PM2.5 levels exceeding 250 µg/m^3 across different months and hours of the day, indicating the severe AQI category. Notably, November, December, and January experience the highest percentages of severe PM2.5 pollution, especially during late night and early morning hours **(10:00 PM to 11:00 AM)**.

As the year progresses, these occurrences decrease significantly during the spring and summer months, suggesting seasonal fluctuations. The early morning and late evening hours are particularly affected, likely due to lower temperatures and limited atmospheric dispersion. This pattern underscores the critical need for air quality control measures, especially during winter months when the concentration of pollutants is at its peak.

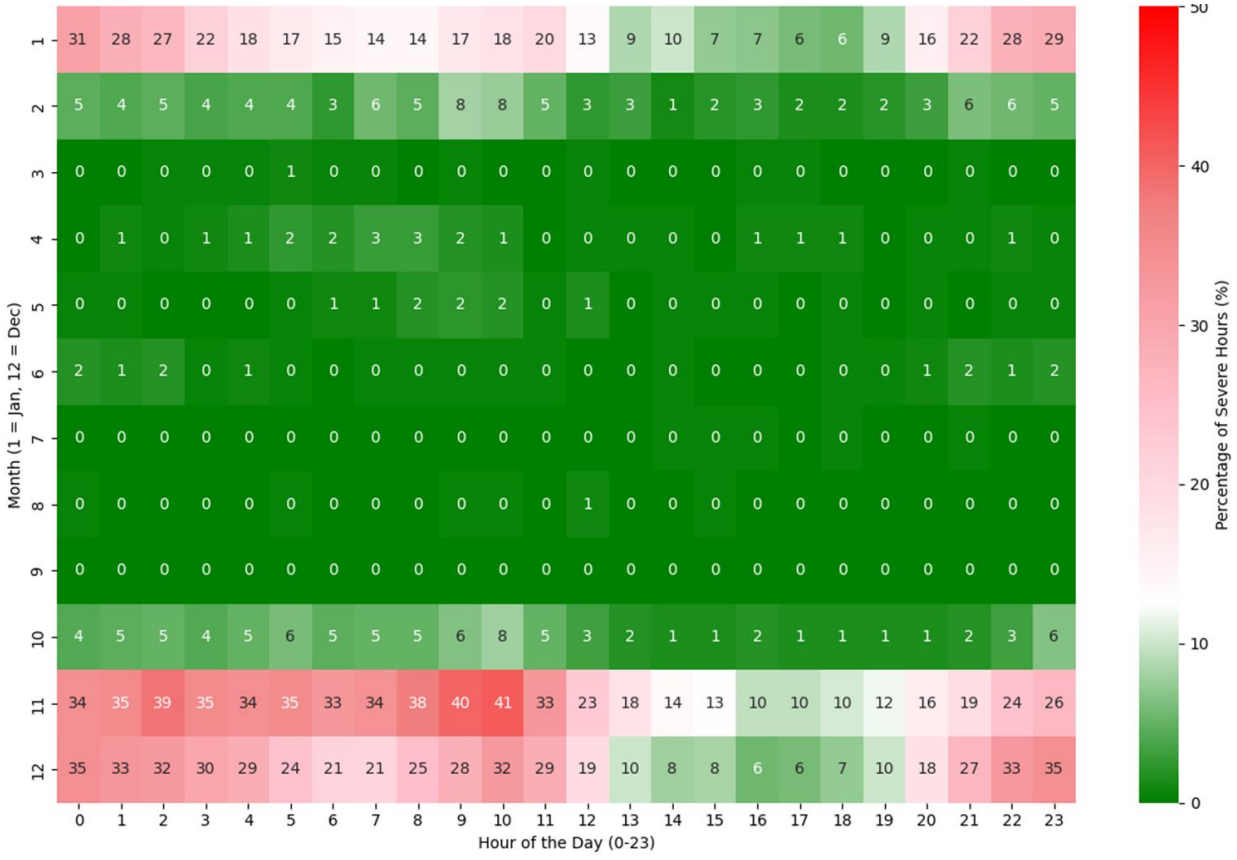

Fig. 4: Probability percentage of occurrence of an hour to be severe (Avg PM2.5 > 250 µg/m^3), Month vs Hour

The number inside each box is the probability of having severe air quality at that particular hour. The colour gradient makes it easier to visualise the numbers by hour.

Probability Percentage of Very Poor to Severe AQI by Month and Hour of the Day

Figure 5 focuses on the percentage of hours where PM2.5 levels are above 120 µg/m^3, indicating very poor air quality. The data shows a consistent pattern of high percentages in January and December, with almost continuous very poor conditions throughout the day. However, during summer months, very poor air quality hours are much less frequent, especially during the daytime when atmospheric conditions are more conducive to pollutant dispersion. This seasonal trend further emphasizes the need for targeted measures during winter to address the prolonged exposure to unhealthy air quality.

It is also to be noted that it's after sunset that air quality deteriorates rapidly and it is harder to access medical services at night.

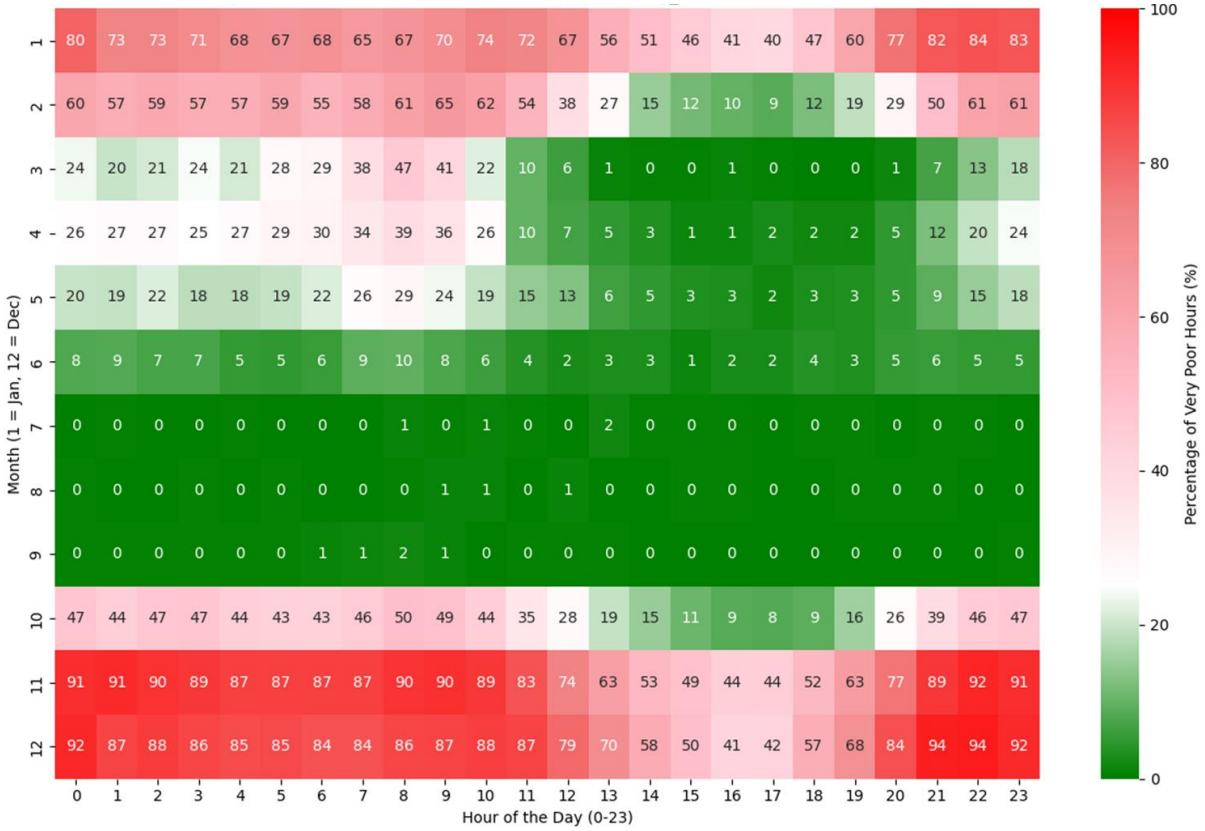

Fig. 5 Probability percentage of occurrence of an hour to be very poor to severe AQI (Avg PM2.5 > 120 µg/m^3), Month vs Hour

Probability Percentage of Severe Pollution Hours by Month-Week and Hour of the Day

Figure 6 breaks down severe pollution hours on a weekly basis, from October to January. It is to be noted that pollution starts to pick up in Week 4 of October and the highest severity is observed in the second and third weeks of November. The pattern continues into December, where pollution remains high, particularly during the late night and early morning hours.

The takeaway from the figure is that time, particularly between 1:00 PM and 7:00 PM, is best suited if one has to be exposed outdoors for unavoidable tasks.

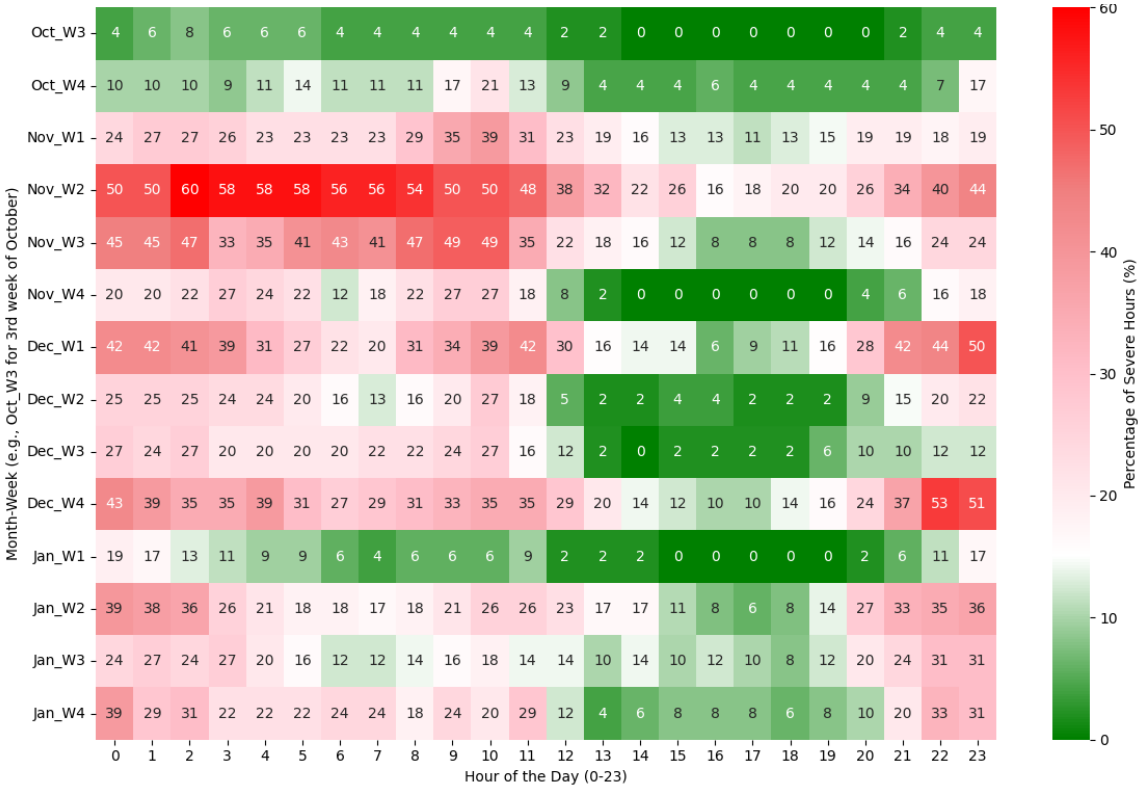

Figure 6 Probability percentage of occurrence of an hour to be severe (Avg PM2.5 > 250 µg/m^3), Month-Week vs Hour

Probability Percentage of Very Poor to Severe AQI by Month-Week and Hour of the Day

Figure 7 provides a detailed look at very poor air quality across weekly segments from October through January. Notably, the weeks from mid-November through December exhibit the most consistent very poor conditions. The conditions ease slightly in January but still show elevated levels compared to October.

These insights suggest that late November to December is the period of greatest concern for air quality, warranting intensified air pollution mitigation efforts during these weeks. The administration can be stricter in the week before known weeks with poor quality to improve public health and reduce the load on the health infrastructure caused by it.

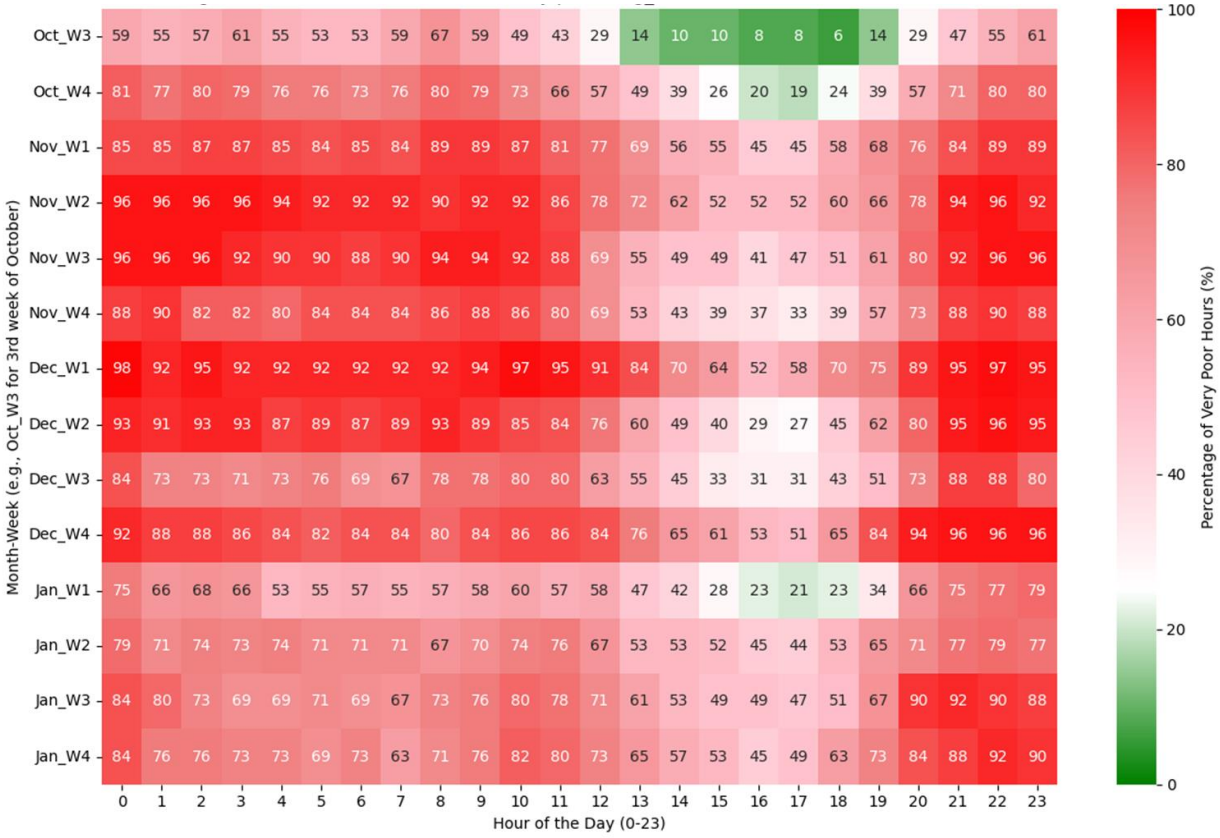

Figure 7: Probability percentage of occurrence of an hour to be Very Poor to Severe (Avg PM2.5 > 120 µg/m^3), Month-Week vs Hour

Inferences

The following inferences summarize the findings of the study –

1. PM2.5 pollution is the highest in the months from October to January.
2. In particular, pollution rises from week 3 of October and peaks around week 3 of November with a slight lull in weeks 2 and 3 of December and week 1 of January.
3. By hour, from 10:00 PM to 11:00 AM is the worst time for PM2.5 pollution owing to atmospheric conditions.
4. There is a high probability of severe AQI episodes returning in the last week/1st week of January for a few days.

Recommendations

We recommend a public advisory for October to January to ensure better public health and lesser stress on public infrastructure due to pollution-triggered health issues. These are in the order of prevention to adaptation. The following may be the content of the advisory –

1. Children and the elderly are advised not to step out for non-essential tasks during the night. Unavoidable outdoor exposure is best done between 1:00 PM and 6:00 PM.
2. Keep an N95 face mask or equivalent handy during excursions.
3. Exercising is best done in indoor environments at this time and exercise should not be avoided completely.
4. The use of balconies and keeping windows open should only be done in the afternoon hours. Keeping balcony doors and windows closed is preferred at night.
5. School breaks, vacations and trips outside Delhi are best planned in the first two weeks of November.
6. If possible, keep effective air purifiers in your homes and workplaces. They are most crucial in the night hours.
7. Communities may be urged to delay non-essential constructions in winter and start them after February.
8. The use of EVs and electric public transport must be encouraged at this time of the year.
9. If possible, working from home and conducting meetings online is advised.
10. While walking on a sloping road, always walk on a downward gradient side of the road (vehicle emissions are much lower) and avoid traffic-congested areas for shopping or other activities.

11. Those with known respiratory or heart ailments are advised to have emergency medicines ready at night-time and have handy access to the doctor.
12. Hospitals may prepare separate emergency rooms for pollution-triggered illnesses, particularly at night.
13. The administration can help mitigate such periods by being more stringent about existing traffic and construction norms in the week before a known bad week.
14. School vacations or timings can be planned according to Figure 6 and avoid exposure to the severe AQI category.