GRAPPLING WITH AIR POLLUTION

How the Graded Response Action Plan (GRAP) has failed to clean up the air

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SUMMARY

India's effort to control air pollution is centred around two major plans—National Clean Air Plan (NCAP) and the Graded Response Action Plan (GRAP). NCAP focuses on the country as a whole while GRAP focuses on the National Capital Region of Delhi (NCR). GRAP was initiated in response to the seasonal increase in the level of air pollution in the NCR. The fundamental basis of GRAP is that strict and urgent measures for varied sources of pollution are key to bringing down air pollution. GRAP assumes that if a set of measures are taken, the level of pollution with respect to particulate matter will reduce and be within the acceptable standards.

GRAP was implemented for the first time in January 2017 and has since been implemented from autumn to winter season in the NCR. Data from the four years of GRAP implementation clearly shows that it has failed to improve air quality. Our analysis reveals that the implementation of GRAP has been largely a `cosmetic exercise since there has been no improvement in the air quality in NCR region. To clarify, GRAP does not consider all the air pollutants—it only considers particulate matters, i.e. $PM_{2.5}$ and PM_{10}. Thus, if the level of pollutants such as SO_2 or NO_X increases, GRAP does not come into effect. Further, the number of days when the air quality can be categorised as "good" has not increased ever since GRAP has been implemented.

It is clear that the level of particulate matters is high throughout the year, in which case GRAP as it exists today, needs to be implemented round the year. If one sees the measures under GRAP, it is clear that they will be impossible to implement with the same vigour round the year.

In such a situation, our study finds that GRAP, in its current form, is a futile plan to clean up the air in NCR. It serves only one purpose—to give an impression to the public that the government and its agencies are serious in tackling air pollution when there is episodic rise in its levels. GRAP is faulty in terms of both its design and implementation. It cannot be corrected by improving implementation because many of its action are impractical to be followed throughout the year.

The NCR requires an effective year-round, long-term plan to improve its air quality. It should move beyond the exclusive focus on particulate matter and must focus, at the very least, on all the pollutants listed in the Air Quality Index if not on all those in the National Ambient Air Quality Standards, 2009.

KEY FINDINGS

- There have been no "good" air days even after the implementation of GRAP for the last four years in NCR.
- GRAP has been operationalised only in the winter months, whereas data shows that $PM_{2.5}$ and PM_{10} are beyond the acceptable standards even during the summer months.
- Data shows that the level of $PM_{2.5}$ and PM_{10} remains high throughout the year.
- GRAP has ignored the Air Quality Index which provides a more comprehensive status of the air quality and is limited only to particulate matters. Thus, even if the particulate matter levels are within limit, air quality can still be bad since non-particulate pollutants such as lead, NO_2, SO_2, ozone and others may still be high.

1. INTRODUCTION

The National Capital Region of Delhi (NCR) is spread across 55,083 km^2, which includes Delhi and parts of Haryana, Rajasthan and Uttar Pradesh[1]. It harbours the most number of polluted cities in the world, a result of what has been termed as "meteorological misfortune" or unplanned urban expansion.

The Graded Response Action Plan (GRAP) has been notified under the Environment (Protection) Act, 1986[2]. The notification, which came into effect from January 12, 2017, specifically states that the GRAP "aims to address different levels of air pollution as per the Air Quality Index (AQI)", which has been formulated in India[3]. The National Clean Air Plan (NCAP) states the following with respect to GRAP:

> *The graded measures according to AQI are listed from public health emergency level to downward. The measures are cumulative. Emergency and Severe levels include cumulatively all other measures listed in the lower levels of AQI including Very Poor, Poor and Moderate.*

It is clear from both the notifications that GRAP aims to focus on the AQI. This is where the first major shortcoming of GRAP is—in simple terms, the focus of GRAP is not on improving or bringing down the levels of all the air pollutants. It aims only at reducing the concentration of particulate matters i.e. $PM_{2.5}$ and PM_{10}. In fact, GRAP is inconsistent in terms of air quality parameters for which daily average standard is given in National Ambient Air Quality Standard (NAAQS), 2009 and monitored through Continuous Ambient Air Monitoring System (CAAQMS) or considered in National Air Monitoring Programme (NAMP) or daily AQI calculation. A comparison of parameters of NAAQS, CAAQMS, AQI, NAMP and GRAP is given in Table-1.

Table 1: A comparison of parameters used in various air quality measures.

Parameters	NAAQS	CAAQMS	AQI	NAMP	GRAP
$PM_{2.5}$	Yes	Yes	Yes	Yes	Yes
PM_{10}	Yes	Yes	Yes	Yes	Yes
SO_2	Yes	Yes	Yes	Yes	No
NO_2	Yes	Yes	Yes	Yes	No
O_3	Yes	Yes	Yes	No	No
CO	Yes	Yes	Yes	No	No
NH_3	Yes	Yes	Yes	No	No
Pb	Yes	No	No	No	No

It is evident that GRAP focuses on the least number of pollutants i.e. $PM_{2.5}$ and PM_{10}, while ignoring most of the other significant pollutants included under either NAAQS 2009, NAMP and AQI. GRAP is based on the faulty premise that particulate matter in itself is the sole basis to judge the air quality of an area, and reduction in its levels would mean that the air quality has improved.

Therefore, the present study has been undertaken to analyse the level of atmospheric concentration of $PM_{2.5}$ or PM_{10} between January 12, 2017 to January 31, 2021 in Delhi and four other cities of NCR i.e. Faridabad, Ghaziabad, Gurugram and Noida since the implementation of GRAP to assess its effectiveness in making air clean.

1. National Capital Region Planning Board (ncrpb.nic.in)
2. It is important to highlight that while GRAP has been notified under the Environment (Protection) Act, 1986, the National Clean Air Plan is notified under the Air (Prevention and Control of Pollution) Act, 1981.
3. https://cpcb.nic.in/uploads/GRAP_Notification.pdf

2. METHODOLOGY

The 24-hourly average concentration of $PM_{2.5}$ and PM_{10} were taken from the CPCB website for CAAQMS located in Delhi, Faridabad, Ghaziabad, Gurugram including Manesar, and Noida[4]. The locations of 57 CAAQMS in these five cities is shown in Figure-1.

The 24-hourly data of all CAAQMS between January 12, 2017 to January 31, 2021 were grouped on a daily basis and as per the seasons[5] to undertake season-wise statistical analysis. One-way Analysis of Variance (ANOVA) was performed to test the mean equality on season and financial year (FY) basis. Post-Hoc range tests using Tukey's-b method was undertaken for pair-wise multiple comparison to determine which means differ at 0.05 significance level. Statistical test was performed for following scenarios for mean concentration of $PM_{2.5}$ and PM_{10} observed during the study period:

- Overall difference in mean of each FY and season during the study period
- Season-wise difference in mean concentration of $PM_{2.5}$ and PM_{10} in each financial year

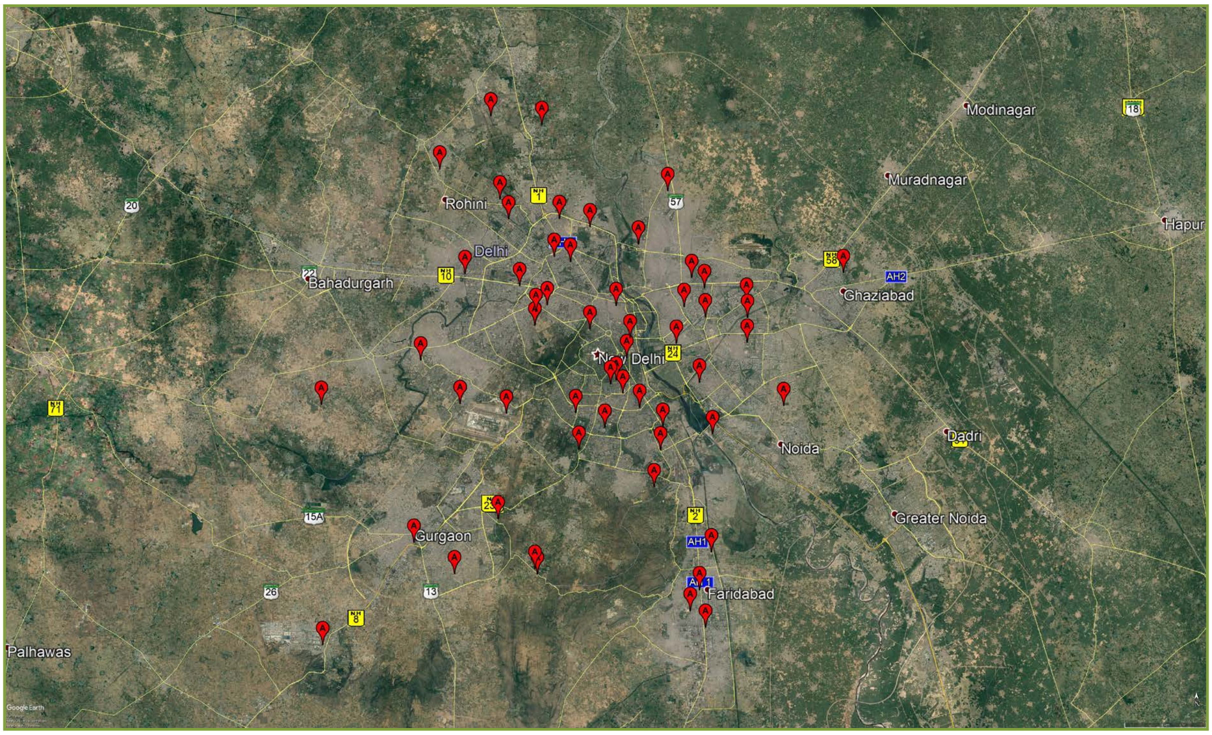

Figure-1: Location of CAAQMS in Delhi and surrounding cities of the National Capital Region

Apart from the detailed statistical analysis, daily mean concentration of $PM_{2.5}$ and PM_{10} for winter seasons was grouped as per GRAP categories to find the number of days falling in good category in various FYs. This was done to evaluate the effectiveness of suggested mitigation measures in bringing down the concentration of target pollutants.

4. https://app.cpcbccr.com/ccr/#/caaqm-dashboard-all/caaqm-landing/data
5. http://delhitourism.gov.in/delhitourism/aboutus/seasons_of_delhi.jsp

3. RESULT AND DISCUSSION

The ANOVA test is a statistical method of finding out data reliability. By this technique, we tried to see significant difference in the mean concentration of PM_{10} and $PM_{2.5}$ within and between the groups at 0.05 significance level i.e. 95%. Once it was found that difference in mean concentration of PM_{10} and $PM_{2.5}$ exists, then Post-Hoc range tests using Tukey's-b method was undertaken to determine true difference between the mean value between the groups.

3.1 OVERALL YEAR- AND SEASON-WISE DIFFERENCE IN MEAN OF PM_{10} AND $PM_{2.5}$

The statistical analysis shows that mean concentration of PM_{10} and $PM_{2.5}$ differed significantly ($PM_{2.5}$: F: 253.504, $p < 0.001$; PM_{10}: F: 370.063, $p<0.001$) across the years. However, the mean concentration of $PM_{2.5}$ did not differ significantly between 2019-20 and 2020-21 (Tukey's Post-Hoc test: $p = 0.113$) and there was no significant difference in PM_{10} concentration between 2016-17 and 2017-18 (Tukey's Post-Hoc test: $p= 0.808$). The highest annual mean concentration of $PM_{2.5}$ (139.37 μgm^{-3}) was in FY 2018-19 and the lowest was in FY 2020-21 (100.51 μgm^{-3}). However, mean concentration of $PM_{2.5}$ of FY 2019-20 and 2020-21 forms a homogenous group. Contrary to $PM_{2.5}$, the mean concentration of PM_{10} in FY 2016-17 and 2017-18 forms a homogenous group and its lowest concentration is in FY 2017-18. The homogenous subset obtained through Post-Hoc multiple comparison is given in Table-2. Overall mean concentration of both $PM_{2.5}$ and PM_{10} shows an increasing trend as we tread from monsoon to winters. This increasing trend may be attributed to meteorological[6, 7, 8] and other factors which are not within the scope of this study.

Table-2: Tukey's Post-Hoc test for $PM_{2.5}$ and PM_{10} concentration (μgm^{-3}) across various FYs

Parameter	FY	N	Subset for alpha = 0.05			
			1	2	3	4
$PM_{2.5}$	2020-21	15700	100.512			
	2019-20	17500	102.938			
	2018-19	14804		116.823		
	2016-17	881			126.710	
	2017-18	6139				139.372
	Sig		**0.814**	**1.000**	**1.000**	**1.000**
PM_{10}	2020-21	14755	193.106			
	2019-20	15647		206.955		
	2018-19	12937			239.027	
	2016-17	363				259.457
	2017-18	3951				267.587
	Sig		**0.814**	**1.000**	**1.000**	**0.448**

Means for groups in homogeneous subsets are displayed.
a. Harmonic Mean Sample Size for $PM_{2.5}$ = 3363.938 and PM_{10} = 1554.290
b. The group sizes are unequal. The harmonic mean of the group sizes is used.

The season-wise pooled data shows significant difference in the mean concentration of both the $PM_{2.5}$ (F: 7386.805, $p < 0.001$) and PM_{10} (F: 4706.611, $p < 0.001$) between the seasons. However, the homogenous subset obtained through Tukey's Post-Hoc test does not form any group in case of $PM_{2.5}$ concentrations but in case of PM_{10} the mean concentration of summer and spring seasons forms a similar group (Table-3). Overall mean concentration of both $PM_{2.5}$ and PM_{10} shows an increasing trend as we tread from monsoon to winters. However, statistical test shows that unlike $PM_{2.5}$, the mean concentration of PM_{10} does not differ significantly between summer and spring season thus forming a same group in Tukey's Post-Hoc test.

6 https://doi.org/10.3155/1047-3289.58.4.543
7 http://dx.doi.org/10.1155/2013/264046
8 The relationships between meteorological parameters and air pollutants in an urban environment (gjesm.net)

Table-3: Tukey's Post-Hoc test for season wise $PM_{2.5}$ and PM_{10} mean concentration (μgm^{-3}) across the entire study period

Parameter	Season	N	Subset for alpha = 0.05				
			1	2	3	4	5
$PM_{2.5}$	Monsoon	11163	40.573				
	Summer	12749		73.103			
	Spring	8470			100.038		
	Autumn	12073				148.797	
	Winter	10569					193.725
	Sig	**1.000**	**1.000**	**1.000**	**1.000**	**1.000**	**1.000**
PM_{10}	Monsoon	9822	98.114				
	Summer	10804		200.610			
	Spring	7087		202.288			
	Autumn	10698			271.774		
	Winter	9242				309.361	
	Sig		**1.000**	**0.862**	**1.000**	**1.000**	

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size $PM^{2.5}$ = 10786.818 and PM10 = 9308.368
b. The group sizes are unequal. The harmonic mean of the group sizes is used.

3.2 SEASON-WISE MEAN CONCENTRATION OF $PM_{2.5}$ IN DIFFERENT FINANCIAL YEARS

Season-wise Post-Hoc multiple test shows significant difference ($p<0.001$) in the mean concentration of $PM_{2.5}$ only for the summer and spring seasons across all FYs, hence not forming a homogenous subset obtained through the Tukey test (Table-4). It is interesting to note that when GRAP is implemented during the winter month of FY 2016-17, no significant difference in the mean concentration in the winter season of FY 2017-18, 2019-20 and 2020-21 is observed. The highest mean concentration for winter season is observed in the FY 2018-19. The significantly low winter season mean concentration ($p<0.001$) in FY 2016-17 may be due to the very small dataset for FY 2016-17 i.e. 20 days. The non-significant difference in the mean concentration of $PM_{2.5}$ in FY 2016-17 winter season with the other FYs i.e. 2017-18, 2019-20 and 2020-21, clearly shows the ineffectiveness of mitigation measures suggested in GRAP to bring down the concentration to safe level i.e. 60 μgm^{-3}.

Plate 1: Diesel generators have been identified as a source of pollution in NCR.

Table-4: Tukey's Post-Hoc test for season-wise $PM_{2.5}$ mean concentration (μgm^{-3}) during study period

Season	Financial Year	N	Subset for alpha = 0.05			
			1	2	3	4
Summer	2020-21	4471	49.147			
	2019-20	4173		79.788		
	2018-19	3260			87.753	
	2017-18	845				110.316
	Sig.		**1**	**1**	**1**	**1**
Monsoon	2020-21	3911	33.475			
	2019-20	3669		42.159		
	2018-19	3036		44.141		
	2017-18	547			60.880	
	Sig.		**1**	**0.338**	**1**	
Autumn	2019-20	3699	139.326			
	2020-21	4008		148.767		
	2018-19	3137		149.202		
	2017-18	1229			176.369	
	Sig.		**1**	**0.999**	**1**	
Winter	2016-17	215	179.232			
	2019-20	2976	181.121	181.121		
	2020-21	3310	190.673	190.673		
	2017-18	1367		192.973		
	2018-19	2701			212.885	
	Sig.		**0.104**	**0.084**	**1**	
Spring	2019-20	2983	86.955			
	2018-19	2670		99.741		
	2016-17	666			109.755	
	2017-18	2151				115.543
	Sig.		**1**	**1**	**1**	**1**

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size Summer = 2047.628, Monsoon = 1489.327, Autumn = 2420.883, Winter = 782.343 and Spring = 1494.675.
b. The group sizes are unequal. The harmonic mean of the group sizes is used.

Figure-2 shows that except in monsoon season when relative humidity in the atmosphere remains high, the mean concentration of $PM_{2.5}$ never reaches the safe level of 60 μgm^{-3}. The monsoon mean concentration of $PM_{2.5}$ was observed between "moderate" to "good" categories for most days, except for five days of FY 2017-18 when it was in "very poor" category[9]. The mean $PM_{2.5}$ concentrations below 60 μgm^{-3} during the summer season of FY 2020-21 can be attributed to country-wide lockdown due to COVID-19 pandemic.

During the entire winter season of FY 2018-19, the mean $PM_{2.5}$ concentrations was within "good" category for one day only (Figure-2). The mean $PM_{2.5}$ concentration remained within "very poor" to "emergency" for majority of the days in winter months, which shows the ineffectiveness of GRAP.

9. The exact reasons for very poor $PM_{2.5}$ concentrations for five days in the monsoon month of FY 2017-18 cannot be ascertained due to paucity of meteorological data of all the CAAQMS.

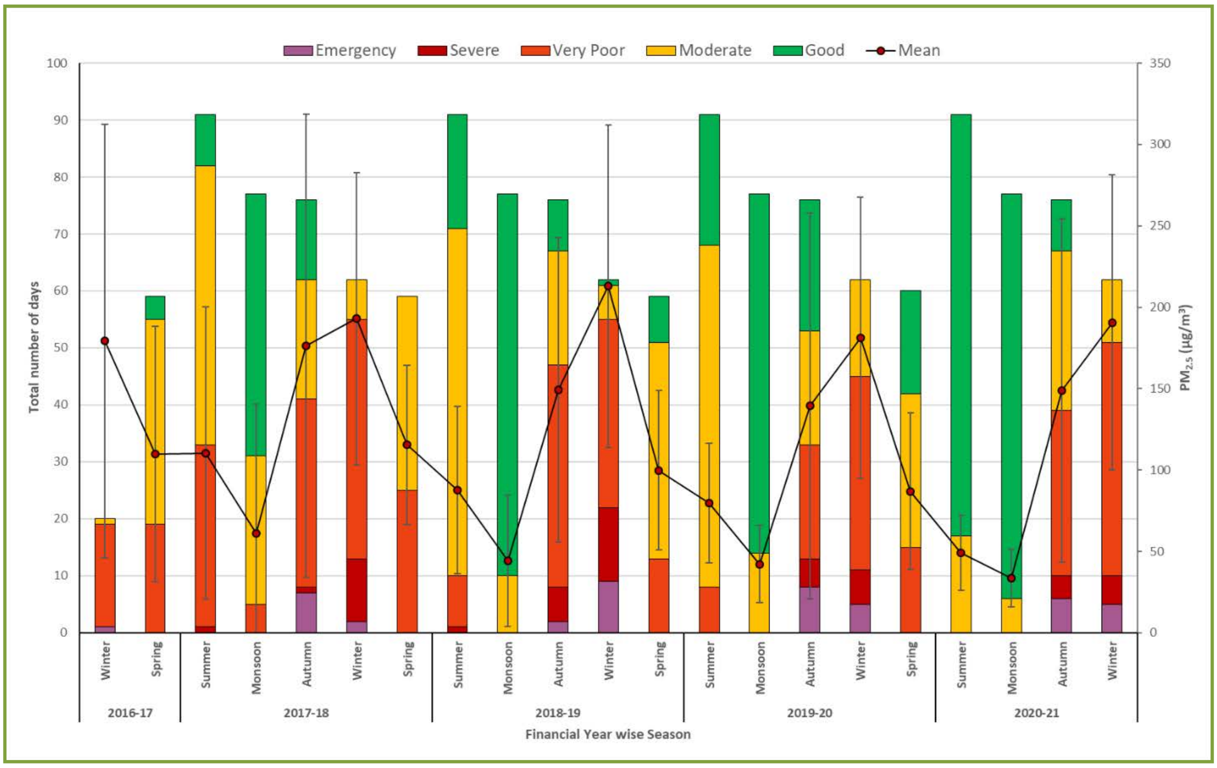

Figure-2: Season-wise number of days falling in various category of GRAP and mean concentration of $PM_{2.5}$ (μgm^{-3}) with standard deviation on secondary axis

The Figures 3 to 7 highlight the ineffectiveness of GRAP during winter months when the mean $PM_{2.5}$ concentrations do not show a decline to “moderate” or “good” category on subsequent days after having “very poor”, “serve” or “emergency” levels. This clearly shows the failure of mitigation measures adopted under GRAP during the winter seasons in NCR.

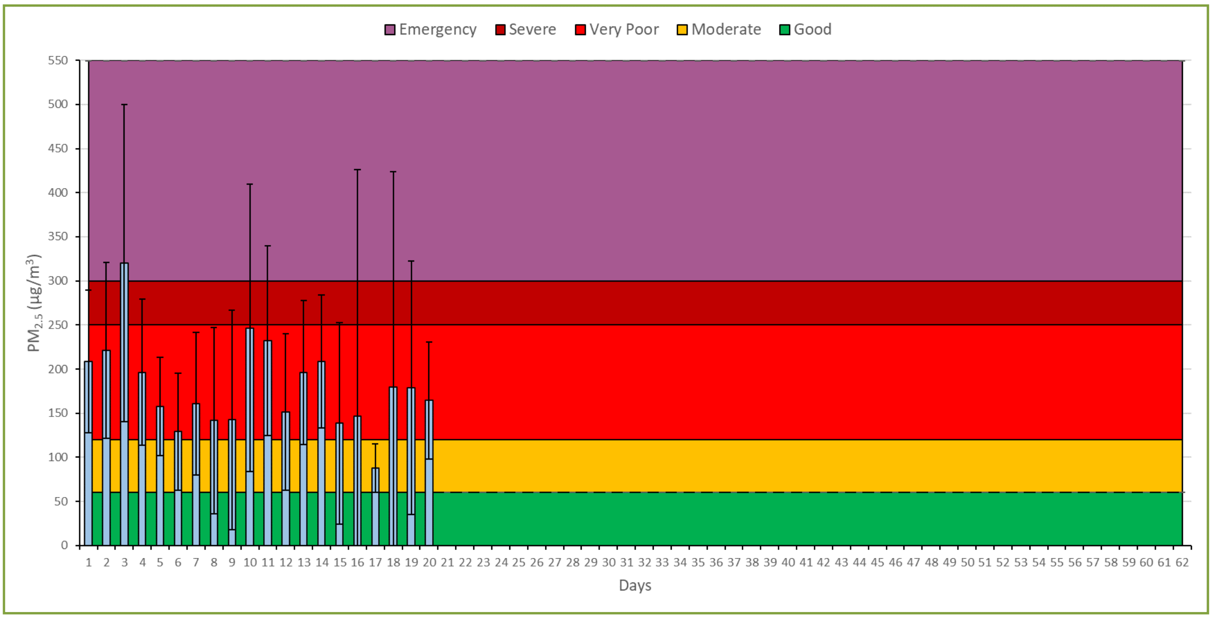

Figure-3: Day-wise mean concentration of $PM_{2.5}$ (μgm^{-3}) with standard deviation during winter months in financial year 2016-17

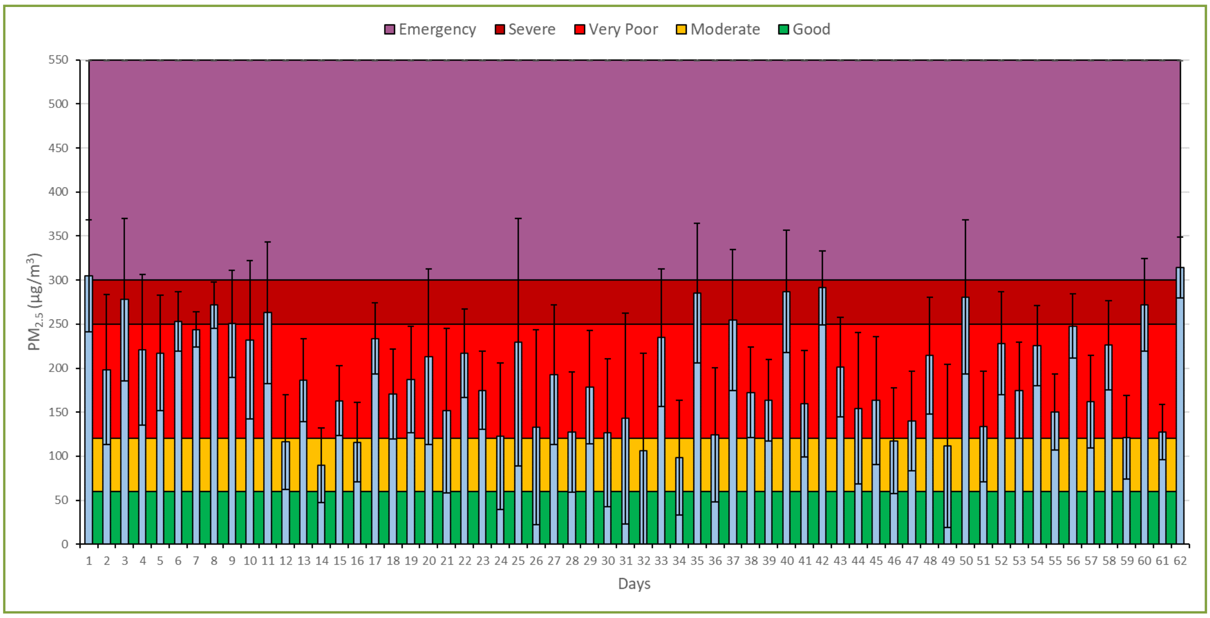

Figure-4: Day wise mean concentration of $PM_{2.5}$ (μgm^{-3}) with standard deviation during winter months in financial year 2017-18

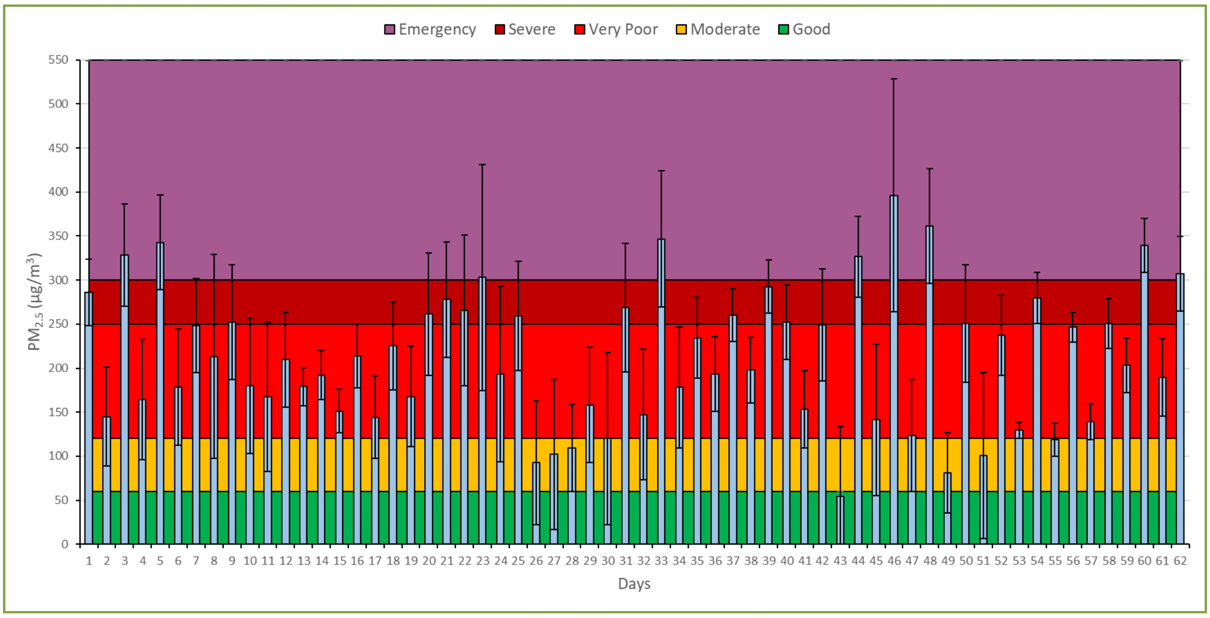

Figure-5: Day-wise mean concentration of $PM_{2.5}$ (μgm^{-3}) with standard deviation during winter months in financial year 2018-19

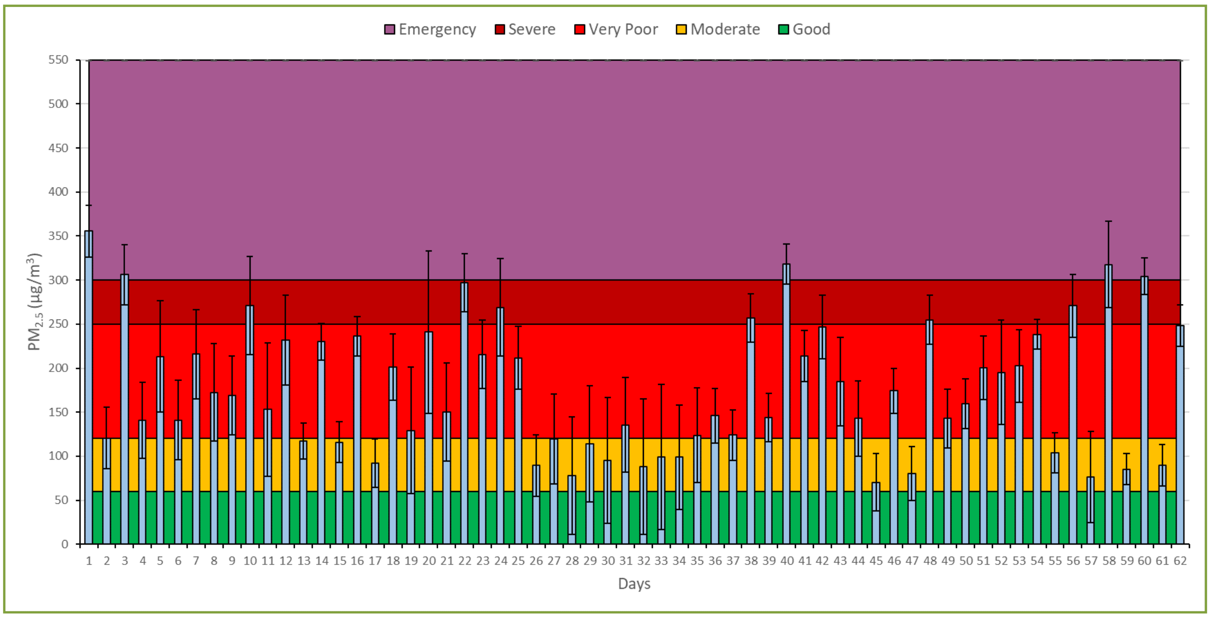

Figure-6: Day-wise mean concentration of $PM_{2.5}$ (μgm^{-3}) with standard deviation during winter months in financial year 2019-20

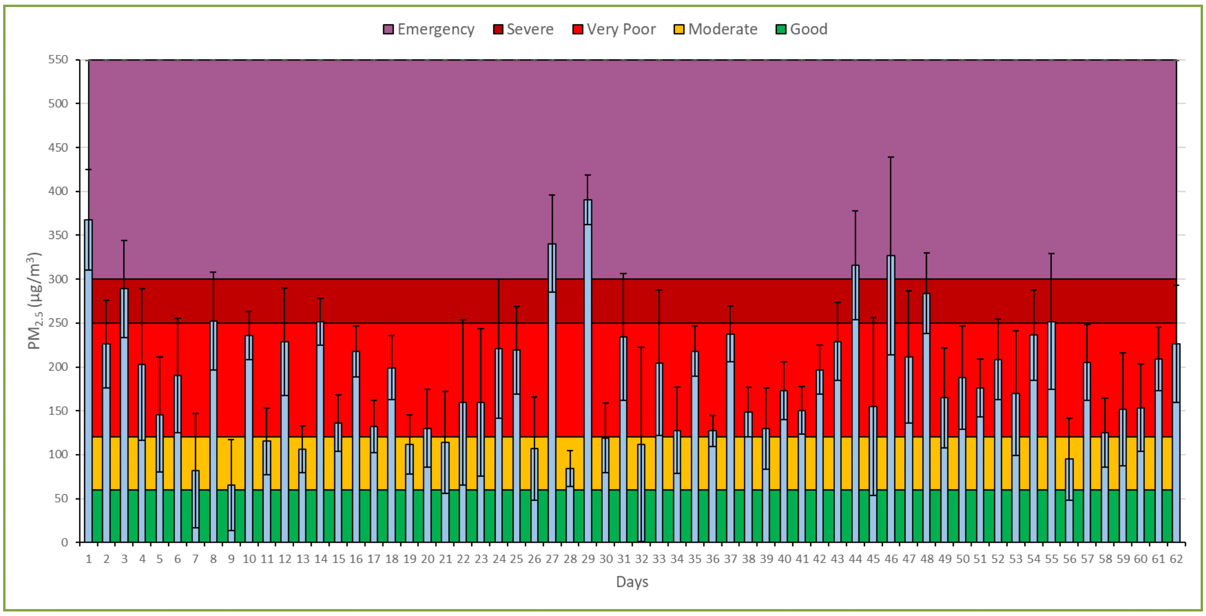

Figure-7: Day-wise mean concentration of $PM_{2.5}$ (μgm^{-3}) with standard deviation during winter months in financial year 2020-21

3.3 SEASON-WISE MEAN CONCENTRATION OF PM_{10} IN DIFFERENT FINANCIAL YEARS

Season-wise Post-Hoc multiple test shows significant differences ($p>0.001$) in the mean PM_{10} concentrations for summer seasons across all financial years, hence, homogenous subset was not obtained through the Tukey test (Table-5). However, unlike $PM_{2.5}$, the mean concentration of PM_{10} did not come to level of NAAQS i.e. 100 μgm^{-3} even during country-wide lockdown in COVID-19 pandemic in the summer season of FY 2020-21.

The winter mean concentration was observed to be the highest during the FY 2018-19 and was significantly different than the mean concentration of other FYs. The non-significant difference in the mean concentration of PM_{10} for FY 2016-17 winter season with other FYs of 2017-18, 2019-20 and 2020-21, clearly shows the ineffectiveness of GRAP mitigation measures in bringing down the concentrations to a safe level i.e. 100 μgm^{-3}.

Table-5: Tukey's Post-Hoc test for season wise PM_{10} mean concentration (μgm^{-3}) in during study period

Seasons	Financial Year	N	Subset for alpha = 0.05			
			1	2	3	4
Summer	2020-21	3964	124.244			
	2019-20	3704		236.298		
	2018-19	2807			252.688	
	2017-18	329				274.582
	Sig.		**1.000**	**1.000**	**1.000**	**1.000**
Monsoon	2020-21	3738	77.055			
	2017-18	137		93.029		
	2018-19	2657			109.463	
	2019-20	3290			113.086	
	Sig.		**1.000**	**1.000**	**0.779**	
Autumn	2019-20	3318	242.561			
	2020-21	3867		281.978		
	2017-18	754		282.159		
	2018-19	2759		289.765		
	Sig.		**1.000**	**0.398**		
Winter	2016-17	86	274.122			
	2019-20	2652	275.069			
	2020-21	3186		307.075		
	2017-18	932		317.396		
	2018-19	2386			348.659	
	Sig.		**1.000**	**0.813**	**1.000**	
Spring	2019-20	2683	170.189			
	2018-19	2328		197.937		
	2017-18	1799			247.689	
	2016-17	277			254.904	
	Sig.		**1.000**	**1.000**	**0.35**	

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size Summer = 1020.925, Monsoon = 485.018, Autumn = 1778.810, Winter = 362.032 and Spring = 805.114.

b. The group sizes are unequal. The harmonic mean of the group sizes is used.

The season-wise number of days having mean PM_{10} concentration in "good" category of GRAP is only one day each in the winter seasons of FY 2016-17 and 2020-21 (Figure-8). It is observed that on most days the mean concentration of PM_{10} in winter months remained in "moderate" to "severe" categories. The mean concentration of PM_{10} reached "emergency" levels in the winter months for six and two days during the FY 2018-19 and 2020-21 respectively. **However, it is surprising to note that the mean PM_{10} concentration also reached up to "severe" or "emergency" levels in the summer and autumn seasons of all the years, except in FY 2020-21 when there was a country-wide lockdown (Figure-8). It is also clear from Figure-8 that only in the monsoon seasons the mean concentration of PM_{10} remained between "moderate" to "good" category in most days, except for two days of FY 2019-20 when it was in the "very poor" category.**

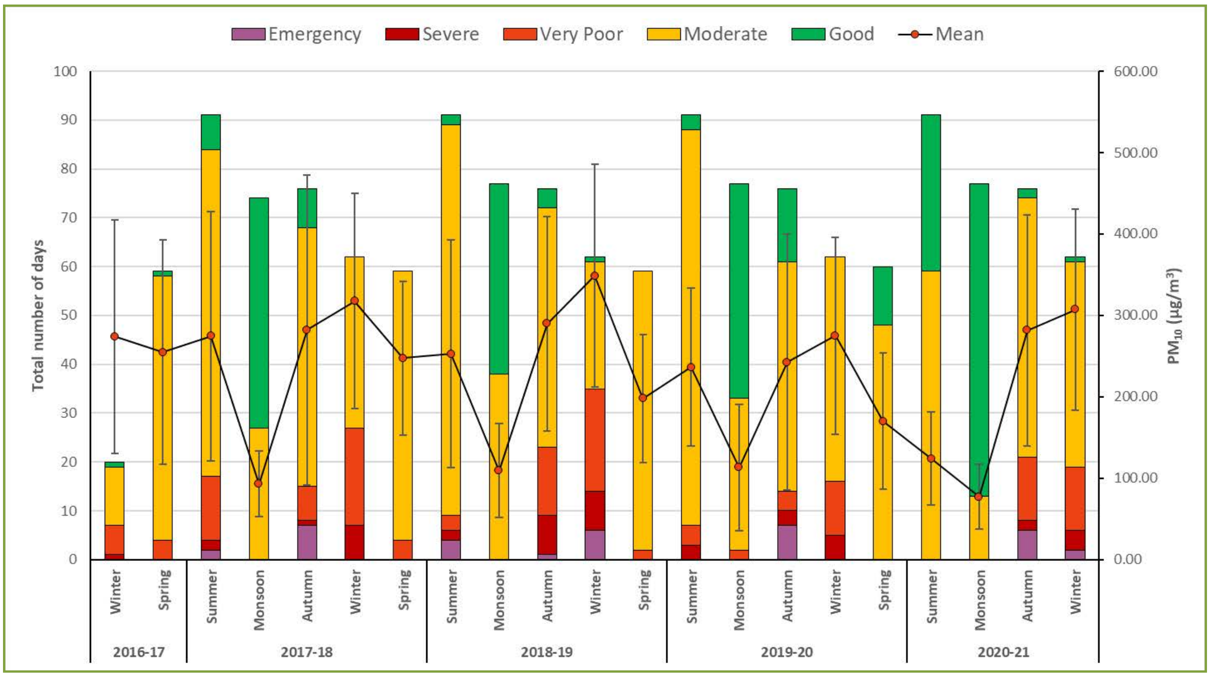

Figure-8: Season-wise number of days falling in various category of GRAP and mean concentration of PM_{10} (μgm^{-3}) with standard deviation on secondary axis.

The Figures 9 to 13 show that despite the implementation of GRAP during winter months, the mean PM_{10} concentration did not come down to "good" category in the days following "very poor", "serve" or "emergency" levels. This trend clearly shows failure of GRAP mitigation measures adopted during winter months in NCR.

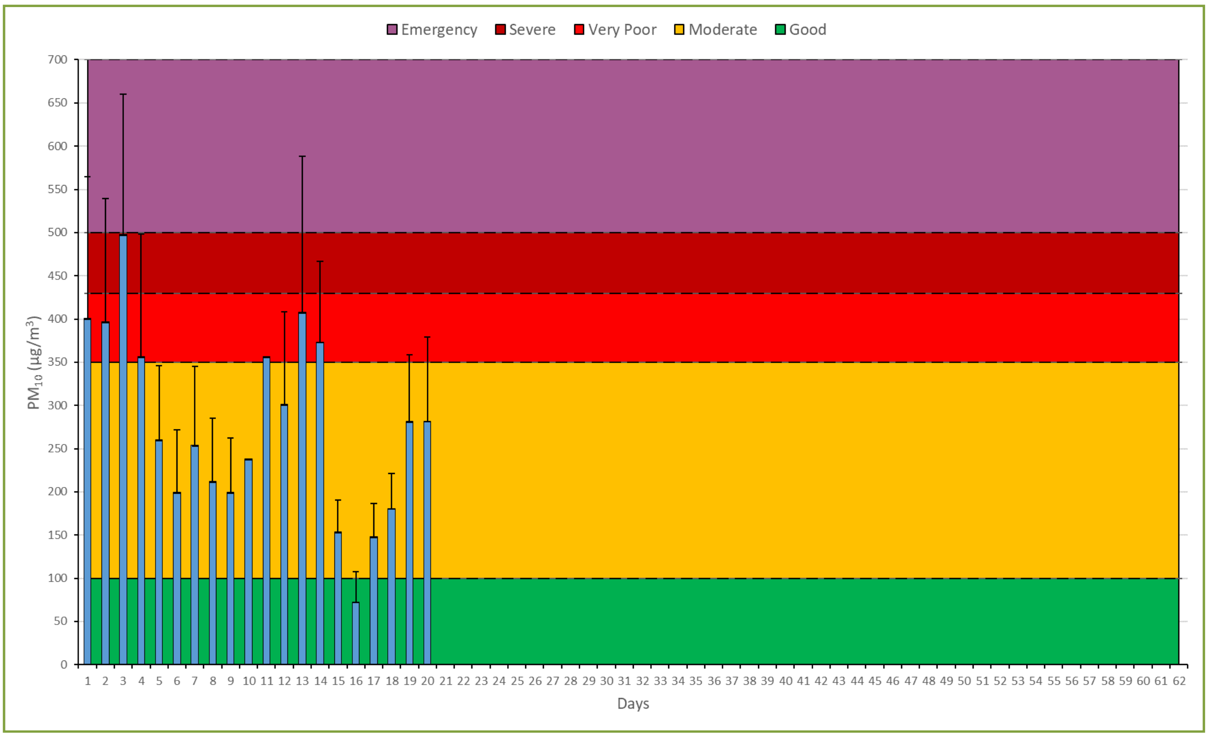

Figure 9: Day-wise mean concentration of PM_{10} with standard deviation during winter months in financial year 2016-17

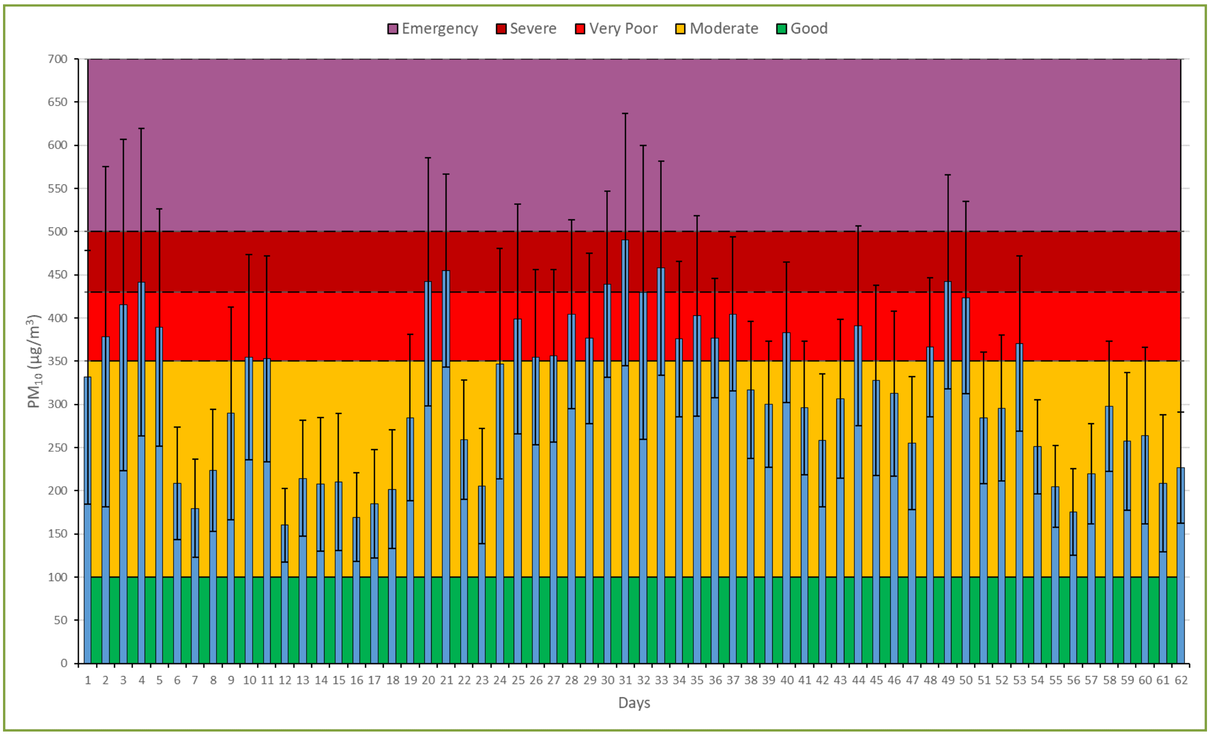

Figure-10: Day-wise mean concentration of PM_{10} with standard deviation during winter months in financial year 2017-18

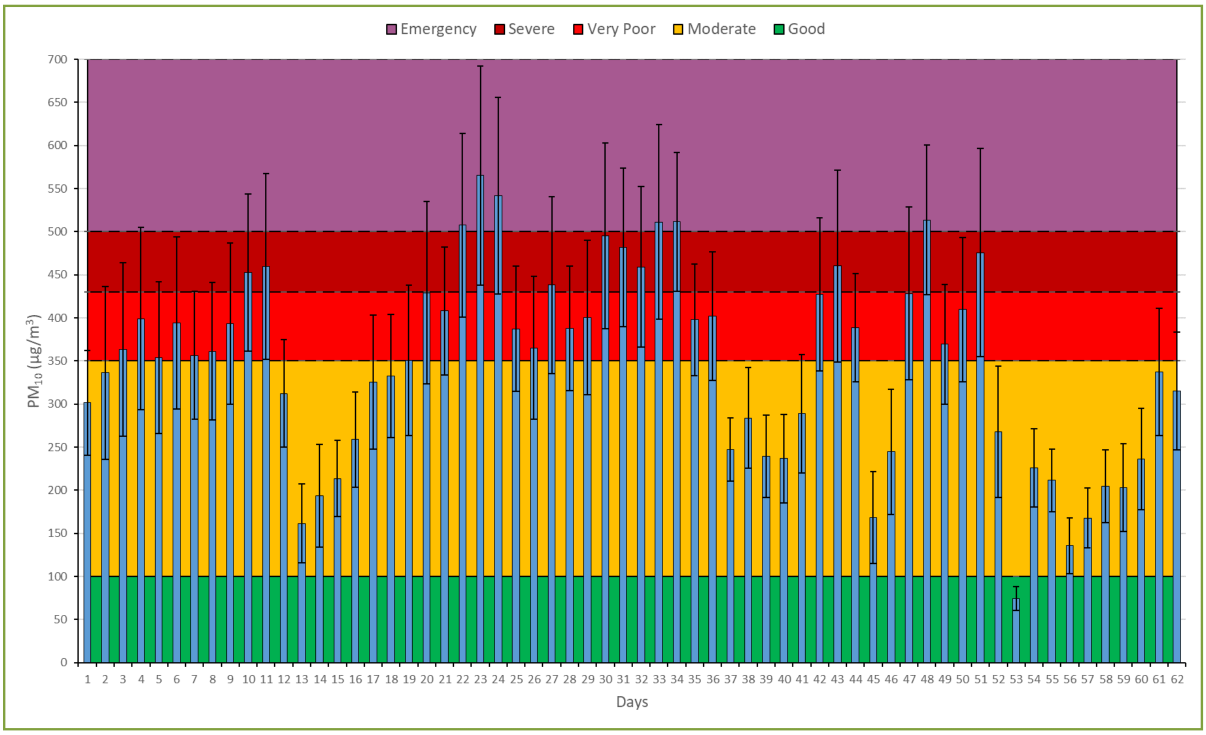

Figure-11: Day-wise mean concentration of PM_{10} with standard deviation during winter months in financial year 2018-19

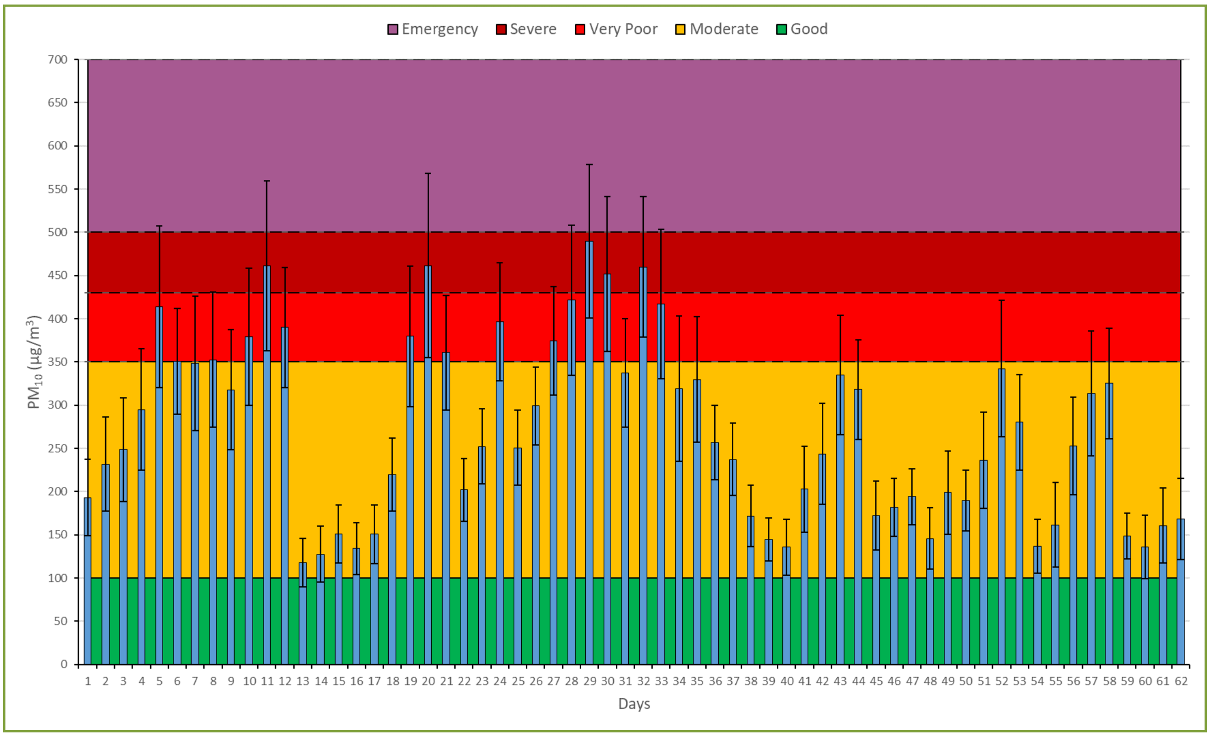

Figure-12: Day-wise mean concentration of PM_{10} with standard deviation during winter months in financial year 2019-20

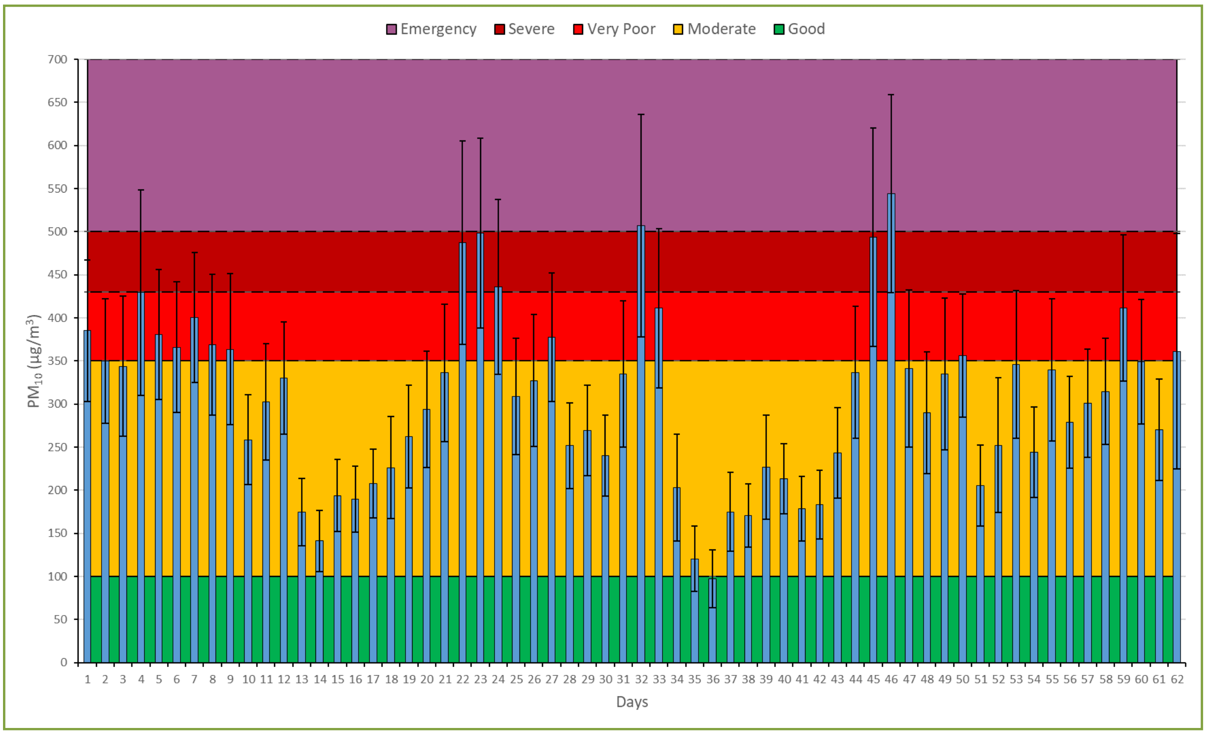

Figure-13: Day-wise mean concentration of PM_{10} with standard deviation during winter months in financial year 2020-21

5. CONCLUSION

GRAP, as the name suggests, comes into effect in a graded manner. Thus, if the level of $PM_{2.5}$ exceeds 121 μgm^{-3}, the plan mandates a complete stoppage of use of diesel generator sets and an increase in parking fees by three to four times. It is evident from our analysis that the level of $PM_{2.5}$ remains higher than 120 μgm^{-3} for almost every single day in NCR. By implication this would mean that no diesel generators should be allowed in Delhi, Noida, Ghaziabad, Gurugram and other parts of NCR. The parking fees should be higher by at least three times.

Similarly, if the $PM_{2.5}$ value exceeds 250 μgm^{-3}, all brick kilns, stone crushers and hot mix plants are required to be closed. The analysis of $PM_{2.5}$ data shows that it exceeds this figure for most of days in the year. If that is the case, all these activities ought to be closed throughout the year, except for a brief period during the monsoons when there is a dip in particulate matter levels.

Overall, our findings show that GRAP has not led to any change in air quality. There has been no increase in the number of "good" air days. This is despite more than four years of its implementation. GRAP is not about improvement in air quality: even if the levels of carbon monoxide, SO_2, NO_2, ozone, ammonia and other pollutants increase, the air can still be regarded as clean as per GRAP, so long as the levels of particulate matters remain within limits. This focus on particulate matter implies that GRAP is not a comprehensive plan to clean up the air. The other serious concern is the impracticality of most of its action point: it is practically impossible to implement many of the action points since they are not grounded in reality. GRAP essentially serves as a cosmetic purpose—to give an impression to the public that the governments and its different agencies are serious in tackling the issue of air pollution. Our analysis shows that the levels of particulate matters remain high all through the four seasons and therefore proactive efforts need to be taken throughout the year to control air pollution. Making efforts to control particulate matter during the onset of winter serves no effective purpose. In fact, the very fact that GRAP could not ensure even a single "good" air day is a good enough reason to thoroughly review its objective and efficacy. Unless that is done, there is little benefit by implementing GRAP in its current form.

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