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An Analysis of GRAP Task Force Directions for Improved AQI in Delhi during 2018

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Abstract

Air quality has been a matter of public concern in Delhi. The concentration of Particulate Matters ($PM_{2.5}$ and PM_{10}) often surpasses the Indian National Ambient Air Quality Standards (NAAQS). This study is focused upon the evaluation of actions of Environment Pollution (Prevention and Control) Authority (EPCA) through the Graded Response Action Plan (GRAP) during 2018, in terms of $PM_{2.5}$ and NO_2. In order to control air pollution sources in National Capital Region (NCR), the EPCA directed GRAP task force to advise the local industries and other sources of pollution to close their operations on particular dates whenever Air Quality Index (AQI) showed severe level. In this study, we have analyzed 24 hourly averaged Air Quality Index (AQI) data for the period September 2017 - January 2018 and September 2018 - January 2019 at two sites i.e. Delhi Technical University (DTU) and Income Tax Office (ITO) respectively. The GRAP results showed a significant decrease in AQI values of both $PM_{2.5}$ and NO_2 after every order passed by GRAP task force. In general, the $PM_{2.5}$ AQI values were always higher during year 2017-18 as compared to 2018-19 at both the sites.

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CPCB;
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GRAP;
$PM_{2.5}$;
NO_2.

Introduction

Air Quality Standards

The issue of air quality in the National Capital. Region (NCR) Delhi is a matter of public concern. Poor air quality has various harmful effects on the environment and human health causing smog, acid rain, reduced visibility and increasing premature deaths, asthma attacks and chronic respiratory illness.[1,2,3] In general, the poor air quality of Delhi is due to high concentration, of the $PM_{2.5}$ and PM_{10} which have been reported violating the limits of National Ambient Air Quality Standards (NAAQS).[4,5] The soil dust, road dust, and construction site dust contribute to the high loadings of particulates in

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this region[6,7] other sources such as local industries, automobiles, vehicles, generator sets; brick kilns etc are also responsible for the contribution of air pollutants.[8,9] The burning of crop residues in neighboring states also adversely affects the air quality of Delhi region during post-monsoon season.[10] In the NCR, among other pollutants, it has been reported that the $PM_{2.5}$ has greater potential on health effects and respiratory system than the corresponding particles PM_{10}.[11,12] In the guideline of the World Health Organization (WHO) and the NAAQS under the USEPA, the recommended levels for $PM_{2.5}$ and PM_{10} based on 24 hourly and annual observations have already been mentioned. Several studies have considered these levels as baseline, where results have been provided by making comparison with respect to the prescribed level only. However, the need of chemical speciation of $PM_{2.5}$ has also been emphasized in order to differentiate its natural vs anthropogenic constituents.[13]

Other important pollutant is NO_2 which has been reported with increasing trends in Delhi.[14,15,16] According to reports, the levels of NO_2 are increased, primarily because of number of vehicles are increased drastically.[6] The number of vehicles is increased from 24, 32,295 in 1994 to 80, 52,508 in 2014[6] and further 10 million vehicles till March 2018.[17] The increase in NO_2 levels affects human health, acid deposition and ozone chemistry.[18] NO_2 is contributed by the combustion sources such as industrial and automobiles etc.[19,20] NO_2 causes respiratory health effects; NO_2 also has an important role in tropospheric ozone and smog formation.[21,22] Due to increase in NO_2, NO_3 concentration in rain water has been reported 11 times higher in 2011 as compare to 1994.[23]

In Indian context, the Central Pollution Control Board (CPCB, Govt. of India) has been monitoring the daily air quality and several stations which have been mandated to the monitoring purpose as well. The Indian NAAQS (under the CPCB) have already been established the prescribed levels of major air pollutants in ambient environment.[24] In the CPCB notification 2009, NAAQS limits have been prescribed for these pollutants under two categories i.e. i) industrial/ residential area and ii) ecologically sensitive areas. In general, the government has taken several measures or air pollution mitigation to improve the air quality of Delhi including the introduction of unleaded petrol, phasing out old commercial vehicles, low sulphur diesel; compressed natural gas (CNG) based vehicles etc. Other such efforts include implementation of Bharat stage-IV (BS-IV), phasing out 15 year old vehicles, ambient air fund, prohibiting burning of leaves and plastics in open, promotion of gas based thermal power plants, restriction on diesel trucks, ban on petcocks, ban on diesel generator sets etc.[9,25] The very popular mitigation step has been Odd- Even rule introduced by government of Delhi two times, first time during 1st January to 15th January 2016. The second round of Odd-Even was implemented during 15th April to 30th April 2016. All These odd even campaigns could not bring the required quality of air. However, due to less number of vehicles plying on roads, the running time was saved. Also, these campaigns were able to mobilize and encash the sentiments of people and probably, could reflect the proactivness of the government.[25]

Graded Response Action Plan (GRAP)

In order to reduce air pollution in Delhi-National Capital Region (NCR), Graded Response Action Plan (GRAP) was introduced recently directed guided by the Environment Pollution Control Authority (EPCA). Various agencies such as CPCB, the Civic Agencies and Urban Development Department, Transport Department, Pollution Control Committee of Delhi and Traffic Police are responsible to implement the plan.[17]

The task Force on Graded Response Action Plan (GRAP) holds meetings frequently. The recommended actions to be implemented in the field accordingly. Last year GRAP task force has conducted several meetings between November 2018 and January 2019 and directed for taking action. The GRAP has been notified by government for Delhi-NCR which comprises measures such as restriction on entry of trucks into Delhi; ban on construction activities, introduction of odd-even scheme for vehicles, closure of schools during severe condition, closure of brick kilns and stone crushers; ban on diesel generator sets and burning in landfills and parks.[9] The GRAP task force also ensures the enforcement of Graded Response Action Plan (GRAP) in NCR as per the pollution levels. However, stopping open burning of plastic and polythene which was source of chlorine and HCl in air, has been reported as a trigerer of ozone spikes at industrial and residential areas.[26]

Though the CPCB and other networks have been calculating AQI for various pollutants, but in order to obtain a comparative scenario, only the daily and monthly AQI data for $PM_{2.5}$ and NO_2 are considered in this study for two sites i.e. Delhi Technological University (DTU) and Income Tax Office (ITO) during the period from September 2017 to January 2018 and September 2018 to January 2019. In this study we are presenting the effectiveness of GRAP and a comparison of AQI or $PM_{2.5}$ and NO_2 at both the sites. We selected $PM_{2.5}$ and NO_2 for this study, as these two criteria pollutants are the prime indicators of air quality for Delhi region. $PM_{2.5}$ levels affect our inner bronchial region, sometimes resulting in acute and chronic respiratory diseases.[27]

Methodology

Sites Description and Methods

Figure-1 shows the map of study area i.e. Delhi Technical University (DTU) and Income Tax Office (ITO).

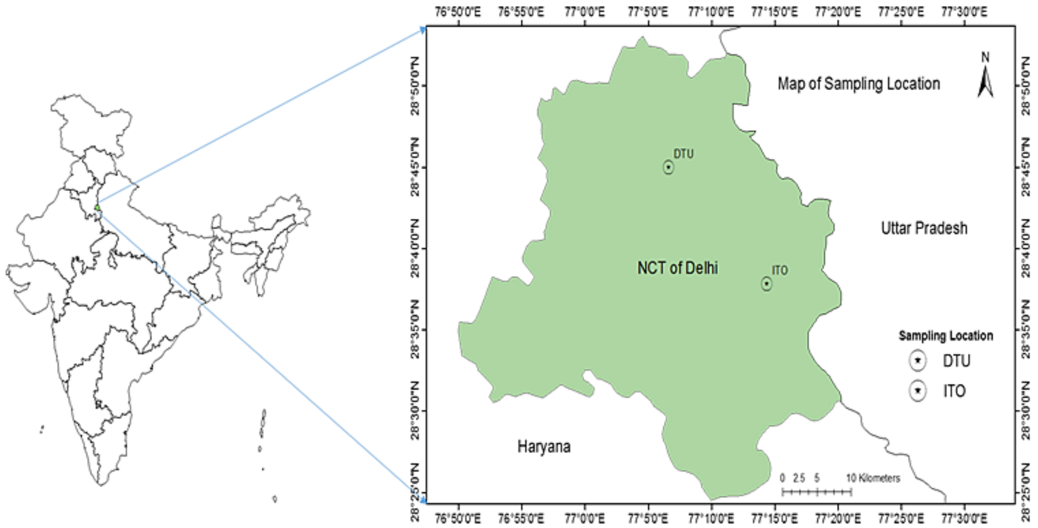

Fig. 1: Map showing the DTU and ITO sites in Delhi.

The hourly AQI data for the selected period were downloaded from the website of Central Pollution Control Board, India.[28] There are over 38 total sampling sites in Delhi out of which 24 sites are monitored by DPCC, 6 by IMD and the remaining 8 sites are monitored by CPCB. Among eight sampling sites which are, monitored by CPCB, i.e. DTU and ITO were selected for the present analysis because of their specific urban characteristics. The DTU site is located in an industrial area while the ITO site is located at a very heavy traffic junction. The monitoring protocol of the network as given on CPCB portal (cpcb.nic.in) records 8 pollutants ($PM_{2.5}$, PM_{10}, SO_2, NO-NO_2-NO_x, NH_3, CO, O_3 and BTEX), but we selected $PM_{2.5}$ and NO_2 for this study, as these two criteria pollutants are the prime air quality indicators for Delhi air.

The measurements of $PM_{2.5}$ and NO_2 along with other parameters are carried out by online analyzers. The principle of measuring $PM_{2.5}$ is based on β-ray attenuation technique through which continuous measurement of ambient particulate matters can be obtained. The, particulate matter is sampled through the inlet of the instrument and is collected on the fiberglass filter tape. The β-ray radiation value is measured by scintillation/G.M. counter before and after sampling. Internal microprocessor handles all sequences and automatically calculates the concentration of $PM_{2.5}$ (cpcb.nic.in). NO_2 measurements are carried out by using NO_X analyzer which is based on chemiluminiscence is based on. The NO_2 sampler consists of 10 ports manifold and fitted with suction pump to draw ambient air and moisture removal system.

Data Analysis Method

The downloaded hourly datasets were reformatted after which daily and monthly averaged values were computed using Microsoft excel. Descriptive statistics was applied to daily and monthly average datasets in order to determine the nature of variations and trends. It is pertinent to mention here that the descriptive statistics is useful to assess the central tendency (mean, mode etc.) and variability of the given dataset. Special attention was given to capture the variation pattern of AQI before and after GRAP (Graded Response Action Plan) orders. The variations of AQI values of the selected pollutants were shown using area graph and descriptive statistics. Date for the period of Sep-2017 to Jan-2018 (Non GRAP period i.e. 153 days of these 5 months) and Sep-2018 to Jan-2019 (GRAP period i.e. 153 days of these 5 months) of study parameters ($PM_{2.5}$ and NO_2) at various selected study sites were considered for the present study. The missing and outlier values of the downloaded datasets of pollutants were ignored and remaining data points were subjected to analysis.

Results and Discussion

AQI of $PM_{2.5}$ and NO_2 after GRAP

Table 1 gives details of GRAP task force meetings and the AQI values after the directed actions. The results showed that after the suggested actions, the AQI values reduced noticeably falling under moderate and satisfactory categories. In November 2018, EPCA conducted two Meetings on 12 and 14 November 2018 when AQI was very high under severe condition. Hence, GRAP came into an action to laid down the rules for traffic, constructions and industries for air pollution control. In response to the strict implementation of GRAP by the EPCA, significant improvement was seen in AQI. Figure-2 shows that how the values of AQI were decreased after every GRAP task force task force meeting at both the study sites. At ITO site, data of 12 November 2018 was not available for both criteria pollutants as shown in Table 1. But during remaining six dates, pollution level was noticed decreasing indicating that GRAP actions were successfully working.

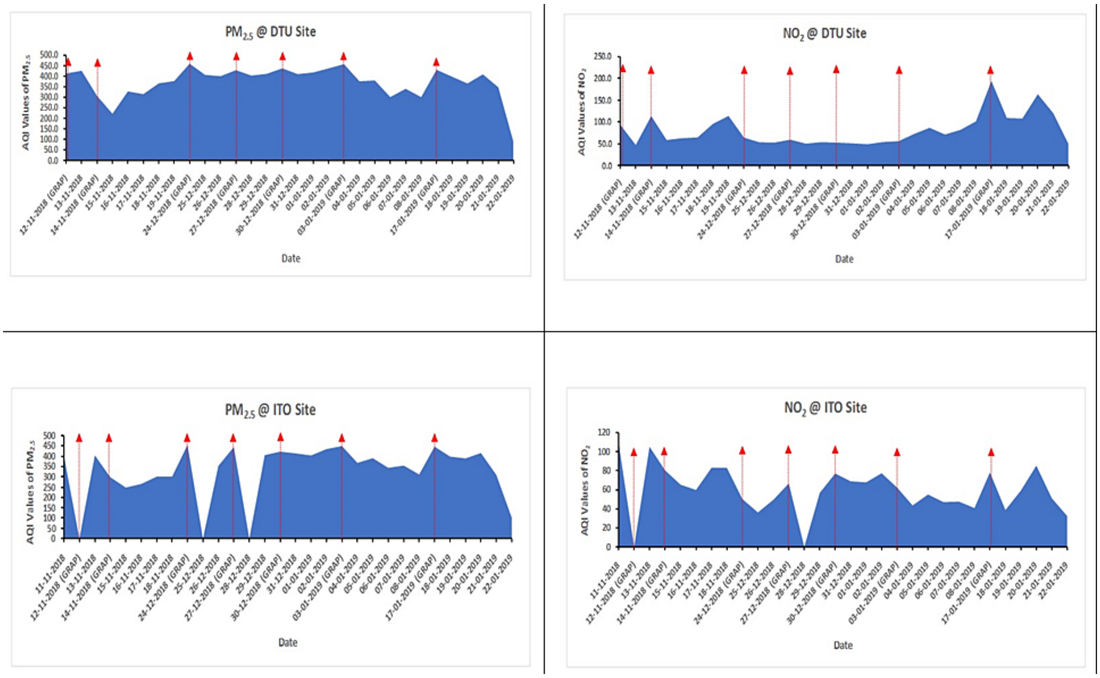

Fig. 2: Area chart of AQI during GRAP meetings for $PM_{2.5}$ and NO_2 at Selected Study Sites.

Table 1: $PM_{2.5}$ and NO_2 variations during and after GRAP meetings at DTU and ITO sites.

Dates of GRAP Order Implementation	$PM_{2.5}$						NO_2					
	DTU Site			ITO Site			DTU Site			ITO Site		
	AQI before GRAP	AQI after GRAP	% Relative difference	AQI before GRAP	AQI after GRAP	% Relative difference	AQI before GRAP	AQI after GRAP	% Relative difference	AQI before GRAP	AQI after GRAP	% Relative difference
12-11-2018	412.3	425.4	3.1	0	0	0	93.8	47.2	-49.6	0	0	0
14-11-2018	305.8	221.3	-27.6	297.5	247.1	-16.9	113.8	58.5	-48.5	80.5	65.3	-18.8
24-12-2018	458.8	405.9	-11.5	454.2	352.5	-22.3	64.2	53.3	-16.9	50.1	36.1	-27.9
27-12-2018	428.1	402.7	-5.9	444.3	404.6	-8.9	59.5	50.2	-15.6	66.6	56.7	-14.8
30-12-2018	436.9	409.4	-6.2	422.0	413.2	-2.0	52.5	51.0	-2.8	77.1	68.8	-10.7
03-01-2019	456.8	375.6	-17.7	448.6	367.0	-18.1	56.0	72.6	29.6	62.2	43.4	-30.2
17-01-2019	430.0	397.1	-7.65	446.2	397.8	-10.8	194.8	109.3	-43.8	78.3	38.6	-50.7

AQI frequency during 2017-18 and 2018-19 at DTU and ITO Sites

Table 2 describes the AQI categories used for $PM_{2.5}$ and NO_2 pollutants around the world. India has fixed the value of severe category same as China and USA. European Union (EU) has decided severe conditions for their citizens when particulate matter AQI is touched 60, and good below 10. Similarly, in case of NO_2, the lower value of AQI different for different countries i.e. 40 for India, 50 for (EU), 80 for China and there is no lower limits are set by (USA) for NO_2. The limit of severe conditions set by above mentioned countries also had a lot of variation. India and EU have decided severe conditions in case of NO_2 AQI crosses 400. The AQI value NO2 in China is 565 for severe category while in USA it is beyond 3760.

Fig. 3 shows a comparison of category wise frequency of days during period of 2017-18 and 2018-19 for the pollutants $PM_{2.5}$ and NO_2 at DTU and ITO sites. Fig. 3 shows category for pollutants with the help of range of concentration and by the color code. On the basis of concentration and color coding CPCB divided pollution in six different categories.[29] AQI of $PM_{2.5}$ from 0-30, dark green color for good category, from 31-60, light green color for satisfactory, 61-90, pink color shows moderate category, 91-120, orange color for poor category, red color and concentration between 121-250 shows pollution enters into very poor category and in last when pollution level covers concentration more than 250 it is considered in severe category which is shown in by crimson red color. In case of pollutant NO_2 the color code is same for all categories but values are different for all categories which are described below. The AQI between 0-40 for good, 41-80 for satisfactory, 81-180 for moderate, 181-280 for poor, 281-400 for very poor and more than 400 for severe condition.

Total number of days at ITO site from September 2017 to January 2018 for which data is available for pollutant $PM_{2.5}$ were 152 out of these only 21 days were found under, satisfactory and moderate categories and remaining 131 days were in poor, very poor and severe categories. According to the 131 days, data available for the period from September 2018 to January 2019, 27 days AQI showed good-moderate category while remaining 104 days the AQI was in between poor and severe categories. At DTU site, the number of days was 140 and 136 for which data was available for year 2017-18 and 2018-19. Out of these only 23 days were in good, satisfactory and moderate categories for September 2017 to January 2018 and 26 days for September 2018 to January 2019. Remaining 113 days were in poor, very poor and severe categoriesduring 2017-18 and 110 days during 2018-19.

At ITO site NO_2 data was available for 138 and 134 days during 2017-18 and 2018-19 respectively. Out of which 132 days were under moderate category and 6 were under poor and severe category for 2017-18, All 134 days were recorded under moderate category and not a single day was counted in other category during 2018-19. At DTU site 128 and 133 days data was available for the same period. Out of which all 128 days recorded under poor, very poor and severe category were during 2017-18. From September 2018 to January 2019 only two days were recorded in poor category while remaining 131 were in good, satisfactory and moderate category at DTU site.

AQI Variation of $PM_{2.5}$ and NO_2 at DTU Site

AQI of $PM_{2.5}$

Figures 4-7 show daily average AQI for $PM_{2.5}$ and NO_2 at the Delhi Technical University (DTU) and Income Tax Office (ITO) sites for the years 2017-18 and 2018-19. We noticed a large range of AQI at both the sites during all the months. During 2017 and 2018 September month at DTU site AQI values for $PM_{2.5}$ were between 20-200. In October month during 2017 and 2018, the AQI values were recorded between 200 and 400, but in the month of November again we found a huge difference between minima and maxima. In November 2017, the AQI values were recorded between 350 and 500 and for in 2018, between 200 and 425. Interestingly, during December and January months, there was no noticeable difference in the AQI of $PM_{2.5}$ between 2017-18 and 2018-19. The high particulate matter in northern India is quite obvious due to higher loadings of atmospheric dust.[6] Due to this reason Aerosol optical Depth (AOD) values has also been recorded distinctly different in south versus north India.[7]

Table 2: AQI standards used for $PM_{2.5}$ and NO_2 globally by different countries.

Country	AQI Category (Range)	$PM_{2.5}$	NO_2
India	Good	30	40
	Hazardous/Severe	250+	400
China	Good	35	80
	Hazardous/Severe	250+	565+
United States of America (USA)	Good	35	-
	Hazardous/Severe	250+	3760
European Union (EU)	Good	10*	50*
	Hazardous/Severe	60+*	400+*

*The exposure time for both $PM_{2.5}$ and NO_2 is 8 hours in European Union, while the Exposure time for remaining countries is 24 hours for both the pollutants.

$PM_{2.5}$ @ ITO Site

AQI Category for Pollutant $PM_{2.5}$	Sep-17	Sep-18	Oct-17	Oct-18	Nov-17	Nov-18	Dec-17	Dec-18	Jan-18	Jan-19
0-30	0	3	0	0	0	0	0	0	0	0
31-60	3	9	0	1	0	0	0	0	0	1
61-90	14	6	3	4	0	1	1	0	0	1
91-120	13	1	13	13	5	8	6	3	5	9
121-250	0	0	13	9	15	14	19	14	18	10
250+	0	0	1	0	10	5	5	11	8	8

NO_2 @ ITO Site

AQI Category for Pollutant NO_2	Sep-17	Sep-18	Oct-17	Oct-18	Nov-17	Nov-18	Dec-17	Dec-18	Jan-18	Jan-19
0-40	24	14	19	0	8	0	22	9	9	17
41-80	6	5	10	19	10	21	5	20	12	14
81-180	0	0	1	8	5	7	0	0	1	0
181-280	0	0	0	0	3	0	0	0	0	0
281-400	0	0	0	0	1	0	0	0	0	0
400+	0	0	0	0	2	0	0	0	0	0

$PM_{2.5}$ @ DTU Site

AQI Category for Pollutant $PM_{2.5}$	Sep-17	Sep-18	Oct-17	Oct-18	Nov-17	Nov-18	Dec-17	Dec-18	Jan-18	Jan-19
0-30	5	7	0	0	0	0	0	0	0	0
31-60	4	11	0	0	0	0	0	0	0	1
61-90	10	1	4	3	0	1	0	1	0	1
91-120	2	0	4	14	0	2	3	4	3	11
121-250	0	0	12	5	11	21	9	14	13	10
250+	0	0	8	3	19	6	18	12	15	8

NO_2 @ DTU Site

AQI Category for Pollutant NO_2	Sep-17	Sep-18	Oct-17	Oct-18	Nov-17	Nov-18	Dec-17	Dec-18	Jan-18	Jan-19
0-40	22	18	29	6	16	4	6	12	31	5
41-80	0	1	0	19	13	21	10	17	0	13
81-180	0	0	0	0	0	4	1	0	0	11
181-280	0	0	0	0	0	0	0	0	0	2
281-400	0	0	0	0	0	0	0	0	0	0
400+	0	0	0	0	0	0	0	0	0	0

Fig. 3: Number of days under various categories during 2017-18 and 2018-19 at selected sites.

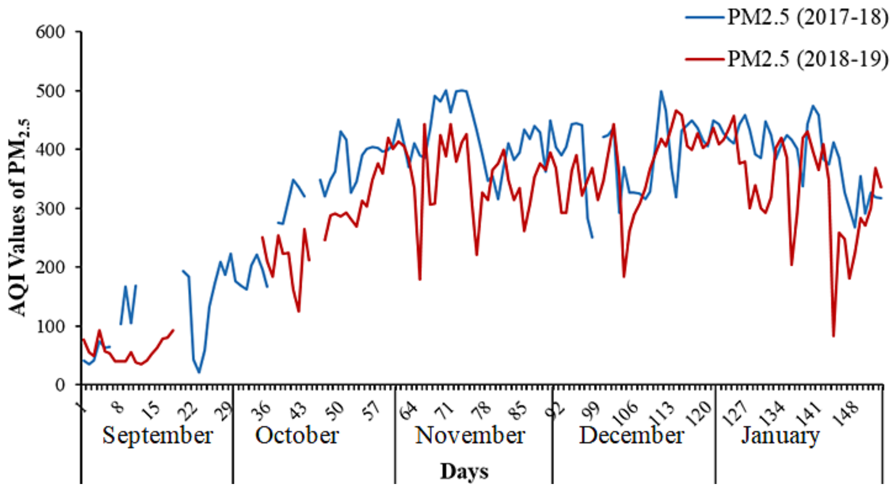

Fig. 4: Daily average plot of $PM_{2.5}$ at DTU site 2017-18 vs 2018-19

AQI of NO_2

The patterns of NO_2 were very much different than $PM_{2.5}$ accordingly (Fig. 5). The average AQI of NO_2 was very high during year 2018-19 as compared to 2017-18 except in the month of December 2018.

During December 2018, the AQI of NO_2 varied between 45 and 70 while during December 2017, owing a huge difference, the maxima of NO_2 AQI reached 100.

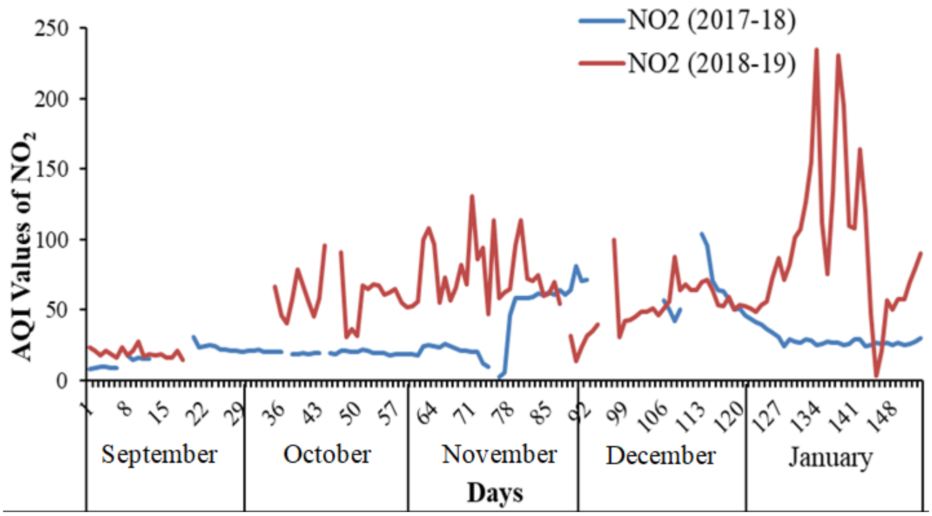

Fig. 5: Daily average plot of NO_2 at DTU site 2017-18 vs 2018-19.

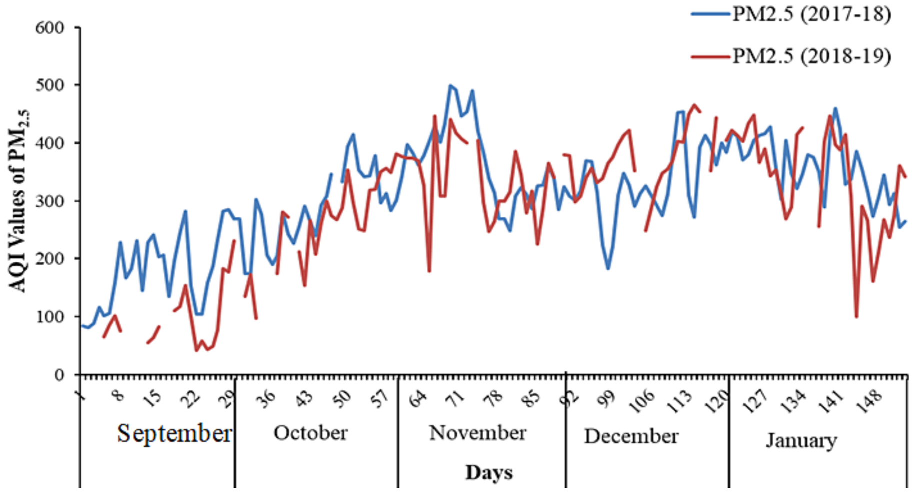

Fig. 6: Daily average plot of $PM_{2.5}$ at ITO site 2017-18 vs 2018-19.

ITO Site

AQI of $PM_{2.5}$

The AQI values at ITO site indicated that $PM_{2.5}$ was very high during all the months except during month of December 2018. In December 2018, the AQI value was not very different from 2017 December. In December 2017, there was a small decrease in the average AQI value of $PM_{2.5}$ which was 341. While in December 2018, the average AQI recorded was 371. Fig. 6 shows that during winter months i.e. December and January for 2017-18 and 2018-19, the AQI values were almost similar because of atmospheric conditions such as temperature inversion etc. which can trap the pollutants near the surface of earth, low wind speed due to which dispersion of pollutants is not possible, and dimming of sun light effect the conversion of various oxides. In general, SO_2 and NO_2 are considered major gases contributing towards $PM_{2.5}$ or finer ranged particles but the SO_2 levels in Delhi region are very low. With respect to NAAQS reason is probably the SO_2 is adsorbed onto calcium carbonate rich dust particles forming calcium sulphate in coarse mode.[30] Due to this reason $PM_{2.5}$ contributed by SO_2 is very low in fine range.[32] Morphological and elemental studies reveal that the dust is composed of spherical (smooth surface), round (rough surface) and irregular shapes of particles indicating the dominance of crystal sources.[31]

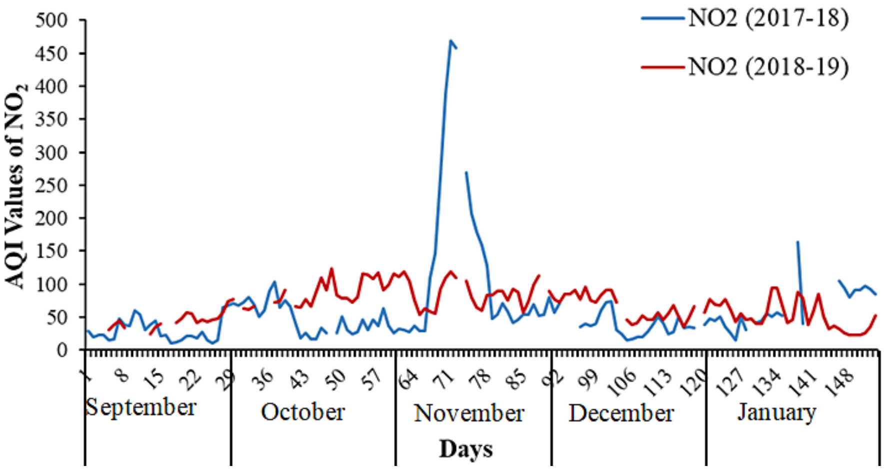

Fig. 7: Daily average plot of NO_2 at ITO site 2017-18 vs 2018-19.

AQI Variation of NO_2

As shown in Fig. 7, the AQI of NO_2 noticed lower during September, October and December 2017 as compared to the respective months in 2018. But in November 2017and January 2018, the AQI values are higher as compared to November 2018 and January 2019. In general the AQI values of NO_2 pollutant are not exceeded more than the moderate category at all sites during all seasons except during episodic periods of pollution such as huge burning of stubbles in agriculture dominant areas, heavy fires in bigger landfills, cracker burning during festive seasons etc.

Table 3: Statistics for daily AQI values of $PM_{2.5}$ and NO_2 at selected sites.

Statistical parameters	$PM_{2.5}$ @ DTU Site 2017-18	2018-19	NO_2 @ DTU Site 2017-18	2018-19	$PM_{2.5}$ @ ITO Site 2017-18	2018-19	NO_2 @ ITO Site 2017-18	2018-19
Mean	343.1	297.6	31.4	64.3	306.3	295.0	61.8	68.1
Median	386.0	321.0	24.7	57.7	312.0	315.7	42.8	67.2
Mode	500.0	305.8	24.0	21.2	488.2	300.0	26.0	83.0
Minimum	21.5	34.5	2.7	3.0	81.5	41.5	10.6	22.5
Maximum	500.0	466.7	103.6	235.0	498.4	465.2	468.3	124.0
No. of Days	140.0	136.0	128.0	133.0	152.0	131.0	138.0	134.0

Table 3 gives the descriptive statistics of AQI of $PM_{2.5}$ and NO_2 at both the study sites. At DTU site the maximum and minimum AQI values for $PM_{2.5}$ was found to be 500, 21.5 while that of NO_2, as 103.6, 2.7 respectively during 2017-18. The maximum and minimum AQI values for $PM_{2.5}$ were found to be 466.7 and 34.5, while for NO_2, as 235.0 and 3.0 respectively during 2018-19.

At ITO site, the values of mean, median and mode for $PM_{2.5}$ and NO_2 during period 2017-18 were 306.3, 312.0 and 488.2. The mean, median and mode of NO_2 AQI were 61.8, 42.8 and 26.0 respectively during same period. $PM_{2.5}$ AQI mean, median and mode values were 295.0, 315.7 and 300.0 respectively during 2018-19 while for NO_2 AQI values of mean, median and mode were 68.1, 67.2 and 83.0 respectively during 2018-19.

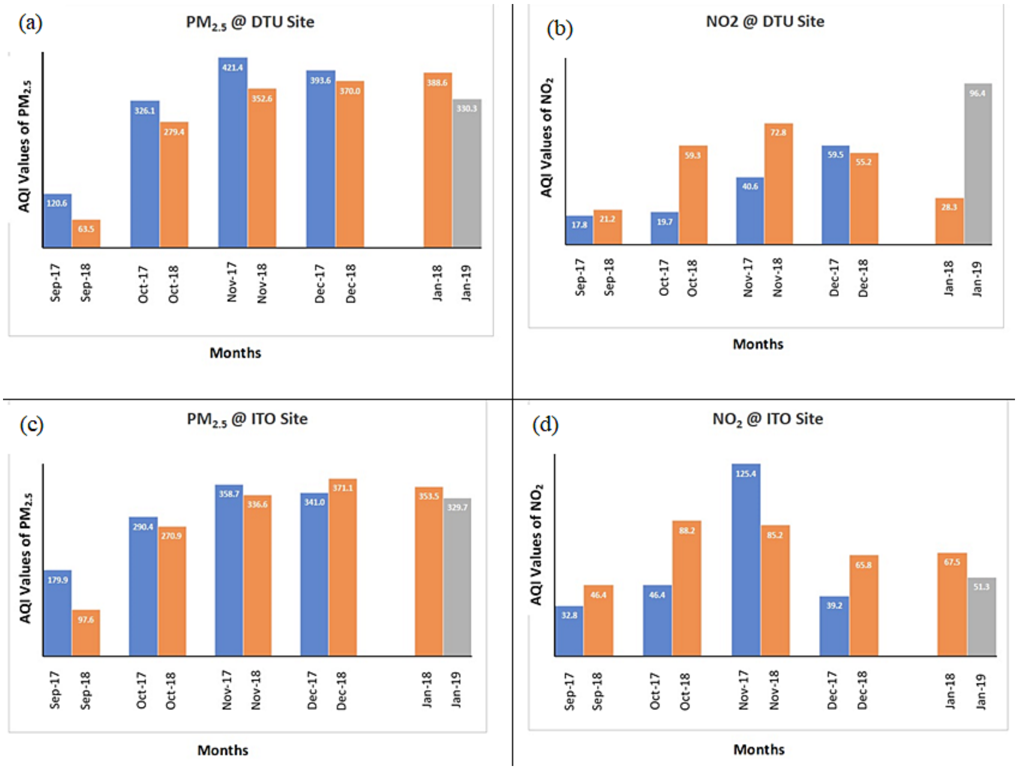

Fig. 8: Monthly AQI Variations of $PM_{2.5}$ and NO_2 at Selected Study Sites.

Monthly Average AQI at ITO and DTU Site

Fig. 8 shows the variation of monthly average AQI values for $PM_{2.5}$ and NO_2 at DTU and ITO sites. The average monthly AQI for $PM_{2.5}$ was found to be minimum during the months of September, 2017 and 2018 which was found to be 120 and 63 respectively for the DTU station. It was found to be in moderate and satisfactory range in accordance with the parameters defined by Indian National Ambient Air Quality Standards (NAAQS). Probably the monsoon rain effect which washes off this was due to the pollutants from the atmosphere easily. Further, it can be observed that $PM_{2.5}$ AQI was found to be maximum in the months of winter season. At DTU, the $PM_{2.5}$ AQI was found to be 421, 393 and 388 during November 2017, December 2017 and January 2018 respectively while it was recorded 369 and 330 during November 2018, December 2018 and January 2019 respectively at DTU site. Accordingly, the air is categorized under very poor and severe range. The elevated AQI values during this winter months might be because of atmospheric conditions, agricultural burning in surroundings of Delhi and major festive seasons (like Diwali, Dussehra, Christmas and New Year) during this period. Similarly, the average monthly AQI for NO_2 was found to be lower (17 and 21) during September 2017 and 2018 respectively at DTU station. While it was found to be higher during the winter season (96) during January 2019. It can also be observed that the average monthly values for NO_2 were found to be 40, 59 and 28 for the months of November-December 2017 and January 2018 respectively and were found to be 72, 55 and

96 for November 2018, December 2018 and January 2019 respectively. Similar patterns were observed for the AQI at ITO as well. The minimum monthly average values for AQI at ITO station were as 179 and 97 for $PM_{2.5}$ and 32 and 46 for NO_2 during the months of September, 2017 and 2018 respectively.

Table 4: $PM_{2.5}$ and NO_2 Variations at Selected Study Sites.

(a)

Months	$PM_{2.5}$ @DTU Site		
	2017-18	2018-19	% Relative difference
Sep	120.5	63.5	-47.3
Oct	326.1	279.4	-14.3
Nov	421.3	352.5	-16.3
Dec	393.5	369.9	-6
Jan	388.5	330.3	-14.9

(b)

Months	NO_2 @DTU Site		
	2017-18	2018-19	% Relative difference
Sep	17.8	21.2	19
Oct	19.7	59.3	200.6
Nov	40.5	72.8	79.5
Dec	59.5	55.2	-7.2
Jan	28.3	96.4	240.5

(c)

Months	$PM_{2.5}$ @ITO Site		
	2017-18	2018-19	% Relative difference
Sep	179.9	97.5	-45.7
Oct	290.3	270.9	-6.7
Nov	358.7	336.5	-6.2
Dec	340.9	371.1	8.8
Jan	353.4	329.6	-6.7

(d)

Months	NO_2 @ITO Site		
	2017-18	2018-19	% Relative differencee
Sep	32.7	46.4	41.4
Oct	46.3	88.2	90.1
Nov	125.4	85.2	-32.1
Dec	39.2	65.8	67.7
Jan	67.5	51.3	-23.9

As given in Table 4, every time there was a decrease in percent relative difference between 6.0 and 47.3 at DTU site and between 8.8 and 45.7 at ITO site. in 2018-19 which might be due conducive atmospheric conditions.

On the other hand, the monthly average relative difference of NO_2 was very different from $PM_{2.5}$ values. The relative difference was noticed between -7.2 to 240.5 at DTU while -32.1 to 90.1 at ITO site. The decrease in AQI was seen during winter months of 2018 as compared to 2017 with few exceptions.

Conclusion

The GRAP task force action plan was very effective during the days when pollution level entered into the severe category. GRAP task force immediately came into action and conducted meetings to mitigate the heavy loadings of pollution in NCR Delhi. In this study we noticed that every time whenever GRAP task force took action, the pollution level decreased significantly and the situation was under control. It was observed that whenever GRAP was implemented, the the AQI values of both $PM_{2.5}$ and NO_2 decreased drastically. This was possible due to stringent steps such as restriction on entry of heavy vehicles, ban on construction activities, introduction of odd-even scheme for vehicles, closure of schools during severe condition, closure of brick kilns and stone crushers; ban on diesel generator sets and burning in landfills and parks etc. taken by the authorities. Therefore, the suggestive outcome of study is to formulate similar task forces in every mega city of India for providing neat and clean air to our citizens. Also, there is need to prepare a fresh inventory of air pollution sources in residential areas.

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Conflict of Interest

The authors do not have any conflict of interest.

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