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Assessment of Air Quality during the 'Odd-Even Scheme' of Vehicles in Delhi

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Abstract

The objective of the study is to analyze the effectiveness of Odd-Even scheme for vehicles, implemented by the Government of Delhi for 15 days, i.e., 1 to 15 January 2016 as a measure to curb increasing pollution of the city. For the study, air quality data of concentration of criteria pollutants at various locations namely RK Puram, ITO, Dwarka, Mandir Marg, Punjabi Bagh and Annand Vihar in Delhi was collected from CPCB website and meteorological data from IMD. The Daily Air Quality Index (AQI) of air pollutants as PM₁₀, PM_{2.5}, SO₂, NO₂, O₃ and NH₃ has been estimated at the selected locations. It was found that PM₁₀ & PM_{2.5} are the major contributors of air pollutants in Delhi. The results of Air Quality Index for almost all locations revealed that the pollution levels were high during the implementation period of odd-even scheme as compared to scenario before and after 1-15 Jan 2016. The reason for high pollution levels, during those 15 days was analyzed to be the meteorological conditions like 'low daily temperatures' and 'low wind speeds'. This article covers the actual scenario of pollution levels recorded by CPCB. Very few studies have been done on this subject and much data is not available in published articles for reference. Detailed study and analysis of AQI before, during and after the odd-even period has been carried out considering the meteorological conditions as well. The odd-even scheme is beneficial attempt to curb the air pollution, but was not as successful as was expected during the selected period due to unfavorable meteorological conditions. The scheme can be implemented in future to reduce increasing pollution levels in the city.

Keywords: Air Quality, Air Quality Index, Delhi, Meteorology, Odd-Even Scheme

1. Introduction

According to the WHO Report¹, Delhi is one of the most polluted cities of the world in respect to air pollution. Poor air quality of any city impacts the health of citizens. One of the main reasons of increasing pollution in Delhi is found to be the increasing number of automobiles on Delhi's roads.

The Delhi Statistical Handbook², a report by the Directorate of Economics and Statistics, Delhi Government, shows that 88.27 lakhs registered vehicles was there in Delhi as on 31 March 2015. Four-wheelers (cars, jeeps and taxis) constitute 32.51% and two-wheelers constitute around 64% of the total vehicles registered with the Transport Department of Delhi. Also, As per Delhi Traffic Police data³, every year since 2009, 4 to 5

lakh registered vehicles have been continuously increasing in Delhi with 5,74,602 in year 2014 and 4,30,603 in the year 2015.

In order to assess the impact of number of vehicles, plying on Delhi roads, the Government of Delhi introduced the odd-even scheme for vehicles in Delhi on trial basis for 15 days, i.e. 1st Jan 2016 to 15th Jan 20164-6.

1.1 The Odd-Even Scheme

According to this scheme, only odd numbered passenger cars were allowed to ply on odd days and even numbered cars on even days between 08.00 and 20.00 hours. The rule did not apply on Saturday and Sundays. The following vehicles were exempted: all taxis, all passenger cars operating on CNG and electric power, cars with only

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women passengers with children of less than 11 years of age of one other woman, all motorized two wheelers and emergency vehicles like PCR vans, fire tenders and ambulances. All schools were kept closed during that period. This system, therefore, was applicable only on private-owned four wheelers, running across Delhi, and also on those coming in Delhi from other states, which was also applicable to vehicles used by ministers and bureaucrats of all ranks.

1.2 Impact of Scheme on Traffic

The Council on Energy, Environment and Water (CEEW) monitored the traffic movement and congestion at five locations of Delhi as Connaught Place, GTB Nagar, IIT Delhi, Mathura Road and Shadipur and found that the daily average number of vehicles were increased by 10% on these five locations during the first two weeks of January as compared to that of the last week of December, despite the implementation of the odd-even policy. CEEW attributed this increase primarily to a 17% increase in two-wheelers,

a 12% increase in three-wheelers, a 22% rise in taxis and a 138% rise in the number of private buses.

1.3 Impact of Scheme on Pollution Levels

To study the success of the odd-even scheme in Delhi, the air quality of those 15 days was assessed by calculating the Air Quality Index at various locations of Delhi and a comparison of AQI of these 15 days has been made against the Delhi's air quality before and after odd-even scheme days.

2. Methodology

2.1 Air Quality Index

Air Quality Index is basically a single number obtained by using a mathematical formula in which each pollutant's (e.g., PM_{2.5}, PM₁₀, NO₂, SO₂ etc.) concentration is transformed to a number, varying between 0 and 500. As the AQI increases, an increase in large percentage of the

Table 1. Air quality index categorization

AQI Category	Color Coding	Levels of Health Concern	Breakpoints for						
			CO (mg/m³)	O ₃ (μg/ m ³)	PM _{2.5} (μg/m³)	PM ₁₀ (μg/m ³)	SO ₂ (μg/m³)	NO ₂ (μg/m³)	NH ₃ (μg/m³)
Good (0-50)	Dark Green	Good	0-1	0-50	0-30	0-50	0-40	0-40	0-200
Satisfactory (51- 100)	Light Green	Moderate	1.1-2.0	51-100	31-60	51-100	41-80	41-80	201-400
Moderately polluted (101-200)	Pink	Unhealthy for sensitive group	2.1-10	101-168	61-90	101-250	81-380	81-180	401-800
Poor (201-300)	Orange	Unhealthy	10 to 17	169-208	91-120	251-350	381-800	181-280	801- 1200
Very Poor (301-400)	Red	Very Unhealthy	17-34	209-748	121-250	351-430	801- 1600	281-400	1201- 1800
Severe (401-500)	Maroon	Hazardous	34+	748+	250+	430+	1600+	400+	1800+

(Report on National Air Quality Index, CPCB, October 2014)

Table 2. Study locations and air quality parameters

Location	СО	PM _{2.5}	PM ₁₀	O ₃	SO ₂	NO ₂	NH ₃
RK Puram							
ITO							
Dwarka							
Mandir Marg							
Punjabi Bagh							
AnandVihar							
	Data availal	ble at CPCB	website	Data not available at CPCB website			

population is experienced, which resulted severe adverse health effects. AQI has been divided into six categories depending on quality of air and its impact on people health. Representation by Color coding has also been done for each category, as given in Table 1. As per report of CPCB^Z, breakpoint concentrations have been calculated for each type of pollutant and are given in Table 1. These breakpoint concentrations are then used to calculate the sub–air quality indices for each pollutant. The maximum of those sub air quality indices is the overall AQI for that location.

2.2 Formulation

The AQI has been calculated by using the formulae as given in Report on National Air Quality Index, by CPCB^{7,8}, October 2014 and given below:

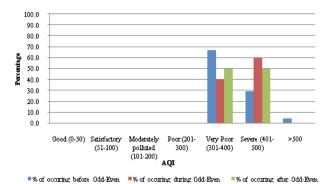


Figure 1. Air quality index before, during and after Odd-Even scheme at RK Puram.

2.2.1 Calculation of Sub-Air Quality Index for i Pollutant at the Selected Location

$$I_{i} = [\{(I_{HI} - I_{LO}) / (B_{HI} - B_{LO})\} \times (I_{P} - B_{LO})] + I_{LO}$$
 (1) where,

 I_i = Sub-air quality index for i pollutant

 $\mathbf{B}_{\mathrm{HI}} = \mathbf{Breakpoint}$ concentration greater or equal to given concentration

 ${\bf B}_{\rm LO}$ = Breakpoint concentration smaller or equal to given concentration

 I_{HI} = AQI value corresponding to B_{HI}

 I_{IO} = AQI value corresponding to B_{IO}

 I_p = Pollutant Concentration

2.2.2 Overall AQI for the Location

$$AQI = \max (I_1, I_2...)$$
 where, (2)

 $I_1 = \text{Sub-air quality index for } 1^{\text{st}} \text{ pollutant, say PM}_{2.5}$

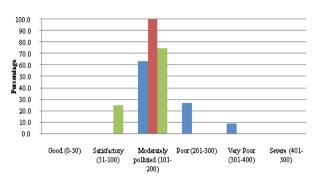
 I_2 = Sub-air quality index for 2^{nd} pollutant, say PM_{10} , Etc...

2.3 Study Locations and Data Collection

Air quality data was collected from CPCB website http://www.cpcb.gov.in/CAAQM/frmUserAvgReportCriteria. aspx. Locations selected for the study are hence those for which air quality data were available on website. The study locations and air quality parameters for which data were available on CPCB website are given in Table 2.

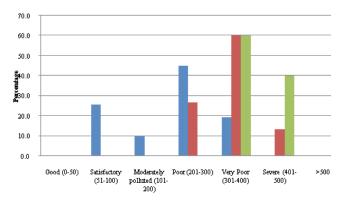
2.4 Data Analysis

The success of odd-even scheme was assessed by comparing the AQI at a particular location during the 15 days of odd-even scheme with that of scenario of air quality during December 2015 and during rest of January 2016. The sub-air quality indices for all pollutants at the study locations are shown in Appendix 1 of the paper. Overall air quality for each location is calculated by using Equation 2, which is shown in Figures 1 to 6.

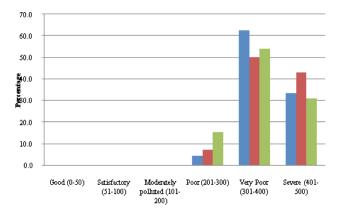


■% of occurring before Odd-Even ■% of occurring during Odd-Even ■% of occurring after Odd-Even

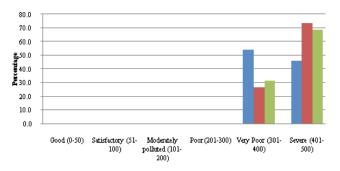
Figure 2. Air quality index before, during and after Odd-Even scheme at ITO.



** of occuring before Odd-Even ** of occuring defet Odd-Even ** of occuring after Odd-Even Figure 3. Air quality before, during and after Odd-Even scheme at Dwarka.



** of occuring before Odd-Even ** of occuring duffing Odd-Even ** of occuring after Odd-Even Figure 4. Air quality before, during and after Odd-Even scheme at Mandir Marg.



** of occuring before Odd-Even ** of occuring addle Even ** of occuring after Odd-Even Figure 5. Air quality index before, during and after Odd-Even scheme at Punjabi Bagh.

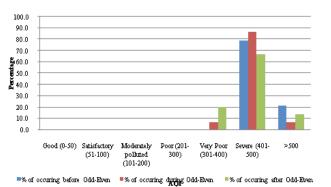


Figure 6. Air quality index before, during and after Odd-Even scheme at Anand Vihar.

3. Results and Discussions

It was observed that among the studied locations, air quality at ITO was best and was "moderately polluted" at maximum number of times during the entire study period. Worst air quality was observed at Punjabi Bagh (54% times 'very poor' during Dec 2015, 73% and 69%

of the times 'severe' during and after odd-even period respectively in Jan 2016).

The pollutants PM25 of concern, at selected locations, are found with average concentration of 208.6µg/ m3, 258.7 µg/m3 and 256.9 µg/m3 before, during and after odd-even respectively. However, PM₁₀ are found to be 484 µg/m3, 507.9 µg/m3, and 449.1 µg/m3 before, during and after odd-even respectively. PM₁₀ concentrations were lying in 'Severe' category of AQI (refer Table 1). Permissible limits of PM₁₀ and PM₂₅ as per National Ambient Air Quality Standards prescribed by Central Pollution Control Board⁹ are 100μg/m³ and 60μg/m³. Overall, it was observed that the air quality Index at all locations was bad during the odd-even period at above mentioned locations as compared to before and after the odd-even period. The average PM₁₀ and PM₂₅ concentrations during the odd-even period were 408% and 331%, which were higher than their permissible limits in spite the fact that during odd-even period, less number of diesel and petrol vehicles (four-wheelers) was plying on the Delhi's roads. Due to which, quality of air deteriorated. The reason for the same was found due to unfavorable meteorological conditions of the city with low wind speed and temperature. On the contrary, the meteorological conditions were better during December 2015 and after 15 January 2016.

The daily meteorological data was obtained from India Meteorological Department (IMD). The daily average temperature during, before and after odd-even period were 16.75, 16.60 and 14.13 degree Celsius respectively and the wind speed, during Odd-Even, was ranged from 2 to 10 km/hr and average speed as 4.7 km/hr. It was observed that only on 6 days wind speed were greater than 5 km/hr. while rest days of the days, it was 2-3 km/hr. Whereas, wind speed before and after Odd-Even ranged between 2 to 13 km/hr. with an has avg. speed of 5.5 km/hr. and 2 to 13 km/hr. with an average speed of 6km/hr. respectively. Favorable wind speeds before and after odd-even period resulted the dispersion of pollutants, which hence leading to reduced pollution levels in the city.

Figures 7-12 are showing daily variation of AQI, temperature and wind speed at four different locations during different periods as before, odd-even, and after in the months of December (12-30) 2015 January (1-15, 16-31) 2016 respectively in Figures 7 to 12.

It has been observed that a few instances, AQI was exceeding 500 at RK Puram, Punjabi Bagh and Anand Vihar, for example on 5th December 2015, the AQI was

calculated to be 519.89. The concentration of PM2.5 on that day was observed to be $550.23\mu g/m^3$, which is nearly 16 times more than permissible limit of PM_{2.5}. In most of Figures, it is noticeable that AQI has reverse trend with wind speeds and ambient air temperature, which justified the reason of high concentrations of pollutants, i.e., severe air quality index during odd-even scheme although the number of vehicles were less compared to before and after of the scheme.

As evident from Figures 7, 10 and 11, the Air Quality is deteriorated during the odd-even period, as compared to before and after implementation of the scheme at RK Puram, Dwarka and Mandir Marg. This can be attributed to the meteorological conditions during the odd-even period, i.e., reduced temperature and wind speeds. Figure 9, showed the reverse pattern of air Quality pattern against Temperature and wind during the period of after the odd-even scheme, which reflects that the air quality further deteriorated as compared to periods of odd-even and before of that. This may be due to the higher flow of traffic from Dwarka, as it connects West Delhi with Gurgaon, which is a commercial hub. At ITO and Anand Vihar, an improvement in Air Quality was observed during and after odd-even as compared to the scenario before odd-even, as evident from Figure 8.

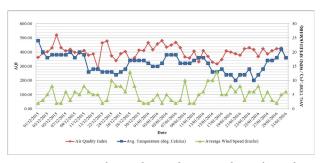


Figure 7. Air quality index and meteorological conditions at RK Puram.

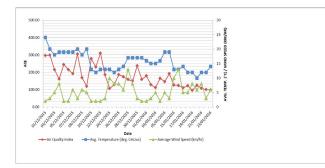


Figure 8. Air quality index and meteorological conditions ITO.

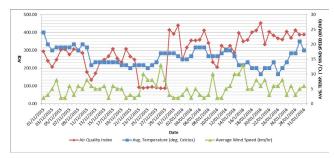


Figure 9. Air quality index and meteorological conditions Dwarka.

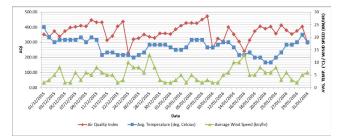


Figure 10. Air quality index and meteorological conditions Mandir Marg.

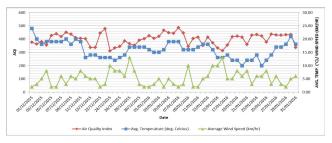


Figure 11. Air quality index and meteorological conditions Punjabi Bagh.

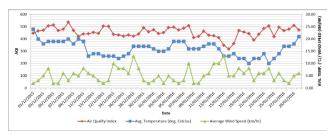


Figure 12. Air quality index and meteorological conditions Anand Vihar.

Comparing the overall pollution levels in Delhi, during the three study periods, as evident from last Figures 7-12, degradation in quality of ambient air occurred during the period when odd-even scheme was implemented in Delhi by the Government of India, as a measure to curb the increasing problem of air pollution. But, the desired

results could not be achieved despite the reduction in daily traffic on roads, which might be due to the meteorological conditions lower temperatures and wind speed that hailed in that period.

In general, the public are not aware of the influence of meteorological conditions on air quality. They could see only air quality index and number of vehicles. However, atmospheric scientists know this reality and assessed it in different ways. According to Figures 7-12, three stations namely RK Puram, Dwarka and Mandir Marg were represented best of reverse pattern of air quality index with ambient air temperature and wind speed.

4. Conclusions

Finally, on the basis of above results and discussions, followings can be concluded:

- Actual objective of scheme was to reduce the air pollution problems and protect the public health in Delhi. Air quality has improved though the meteorological conditions were unfavorable, which could reduce the dispersion of pollutants and was resulted in high values of air quality levels of air pollutants.
- The odd-even scheme of vehicles of Delhi was successful in reducing the traffic on roads of Delhi, as movement of vehicles were easier though the traffic jams were also there at few places. This was experienced by general public and later on they have appreciated also.

The success of the scheme would be correctly identified if it would be re-implemented during summer season, when dispersion of pollutants is better. Also, there are number of other sources also contributing air pollutants in large amount, comparable to vehicular traffic in Delhi. All the possible sources of air pollutants need action and control at source.

This scheme should be implemented periodically throughout the year with appropriate gaps to control the air pollution and protect the public health.

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Appendix1

Graphs showing Sub-Air Quality Indices (Figures A to F)



Figure A. Sub-air quality indices at RK Puram.

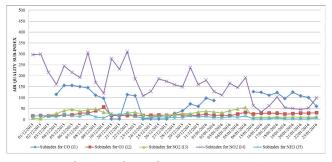


Figure B. Sub-air quality indices at ITO.



Figure C. Sub-air quality indices at Dwarka.



Figure D. Sub-air quality indices at Mandir Marg.

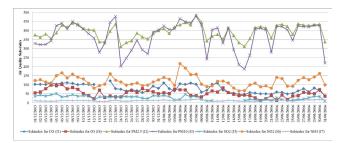


Figure E. Sub-air quality indices at Punjabi Bagh.



Figure F. Sub-air quality indices at Anand Vihar.