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RESEARCH ARTICLE

AN ANALYSIS OF ODD EVEN ROAD RATIONING SCHEME IN DELHI

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ABSTRACT

The most populous democracy, India is also the seventh largest country in the world. New Delhi which is the capital city of India and usually abbreviated as “heart of India” shelters all the state government/MNC, startup centers. Delhi with the increased usage of vehicles, industrialization, and population growth, has turned into a poisonous pollutant punchbowl with innumerable ingredients. The odd-even road rationing scheme is the immediate and foremost measure taken by Delhi government to reduce and control the air pollution in and around Delhi. Thepresent study goal is to analyze the effects of pre, during, and post odd-even road rationing scheme on the ambient air quality in and around Delhi region. The Air Quality Index (AQI) identifies two responsible pollutants which are particulate matters PM 2.5 and PM 10. These are statistically evaluated on data collected from Central Pollution Control Board (CPCB) and Delhi Pollution Control Board (DPCC) websites for the study period (December 1, 2015 to January 30, 2016). The relationship between particulate pollutants (PM 2.5 and PM 10) with meteorological parameters such as temperature, relative humidity, and solar radiation, wind speed is also analyzed. Obtained results found that the different variations in level of pollutants may be due to wind speed, which has an inverse relationship with particulates.

INTRODUCTION

Nowadays, throughout the world, air pollution becomes a significant challenge. In India due to the development of economics, the air pollution has become a serious problem faced by many urban centers because of anthropogenic emission sources, which include vehicular emissions, domestic fuel combustion, industrial, and construction activities, in addition to, natural sources like dust[1, 2]. According to the World Health Organization (WHO) report, six of the top ten most polluted cities in the world are in India, three in Pakistan and one in Iran (Figure 1). This report creates database of 1600 cities in 91 countries for assessing air quality by measuring PM 2.5 and PM 10 concentrations to indicate air pollution levels and raise awareness to protect public health from the adverse impacts of air pollution[3].

The Delhi city had termed as “Gas Chamber”, on the basis of atmospheric particulate matter that are recorded more than ten times higher than prescribed standard[4]. The High Court of Delhi ordered the DPCC, Central and Delhi government to formulate an action plan to fight against air pollution. The Delhi Government has come up with a number of steps to tackle air pollution menace - starting Odd-Even scheme, shutting down Badarpur thermal power plant, increasing numbers of the Delhi Transport Corporation (DTC) buses on the road, increasing the frequency of metro, banning the entry of trucks during day hours, add pollution-cess on diesel trucks and set up pollution sample centers[5].

The odd-even road rationing scheme of Delhi Government to curb air pollution is the first attempt by any Indian government to limit traffic pollution by disallowing cars with odd and even license plates to ply on the roads on alternate days. The main features of this scheme as shown below[6]:

- It has been implemented from January 1 to 15, 2016 as a trial period.
- It has been applied to four-wheeler passenger/private cars.
- The two-wheelers, three- wheelers, cars driven by women (no male member is travelling along), trucks, compressed natural gas (CNG) vehicles, electric & hybrid vehicles, buses, vehicles of very important persons (VIPs), ambulance, fire brigade, hospital & prison vehicles and vehicles carrying by differently abled people were exempted from this project.
- The scheme was bound with an effective time limit i.e., from 8:00 am to 8:00 pm between Monday to Saturday.
- In the case of violation of a rule, a penalty of Rs. 2000 is charged.
- The Delhi government added more buses and increased the frequency of metro trains in and around the city.

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The main objectives of this study are as follows:

- To collect hourly data of pollutants from the selected area of study.
- To find AQI on various combination of pollutants present in the study area during pre-defined period.
- To assess the effects of pre, during and post odd-even road rationing scheme.
- To analyze correlation coefficient between pollutants (PM 2.5, PM 10) and meteorological parameters.

(O_3), Benzene (C_6H_6), PM 2.5 & PM 10. Apart from that, some meteorological parameters such as wind speed, wind direction, temperature, relative humidity, solar radiation and barometric pressure are also monitored continuously for whole day (for 24 hours) and updated at interval of 15 minutes. In this study, the data collected by DPCC and CPCB website from four widely distributed stations of Delhi (marked by * in Figure 2) i.e. Mandir Marg, R. K. Puram, Punjabi Bagh & Anand Vihar. The Civil Lines and IGI airport monitoring stations of DPCC are not working and others stations belonging to CPCB, i.e. Pitampura, Shahdara, Siri Fort, Janakpuri, Nizamuddin, Shahzada Bagh, and BSZ Margto

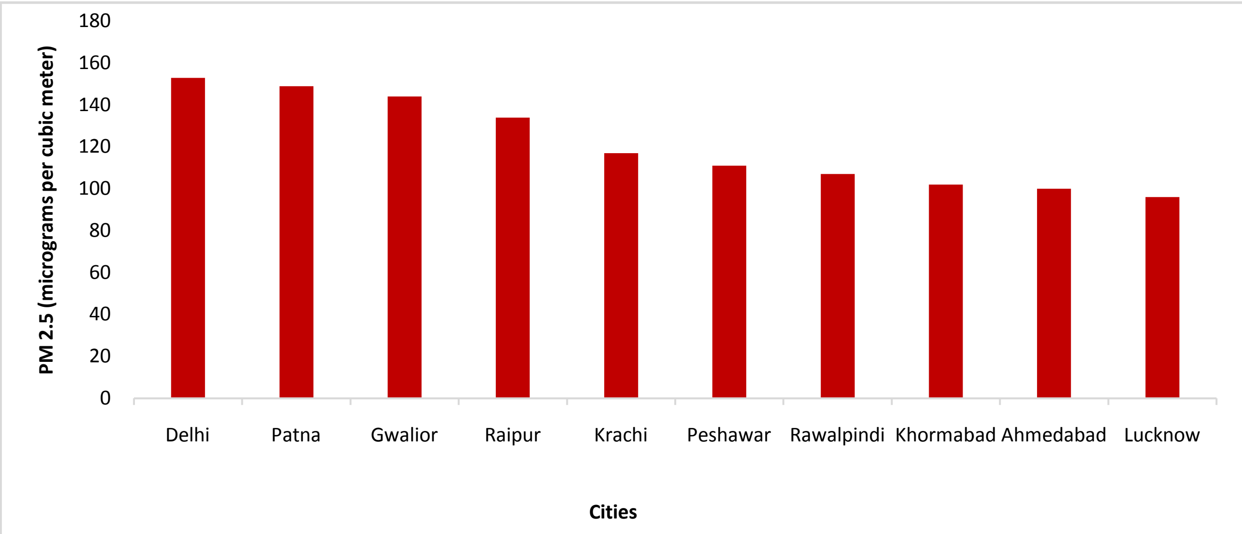

Figure 1 Top 10 most polluted cities in world[3]

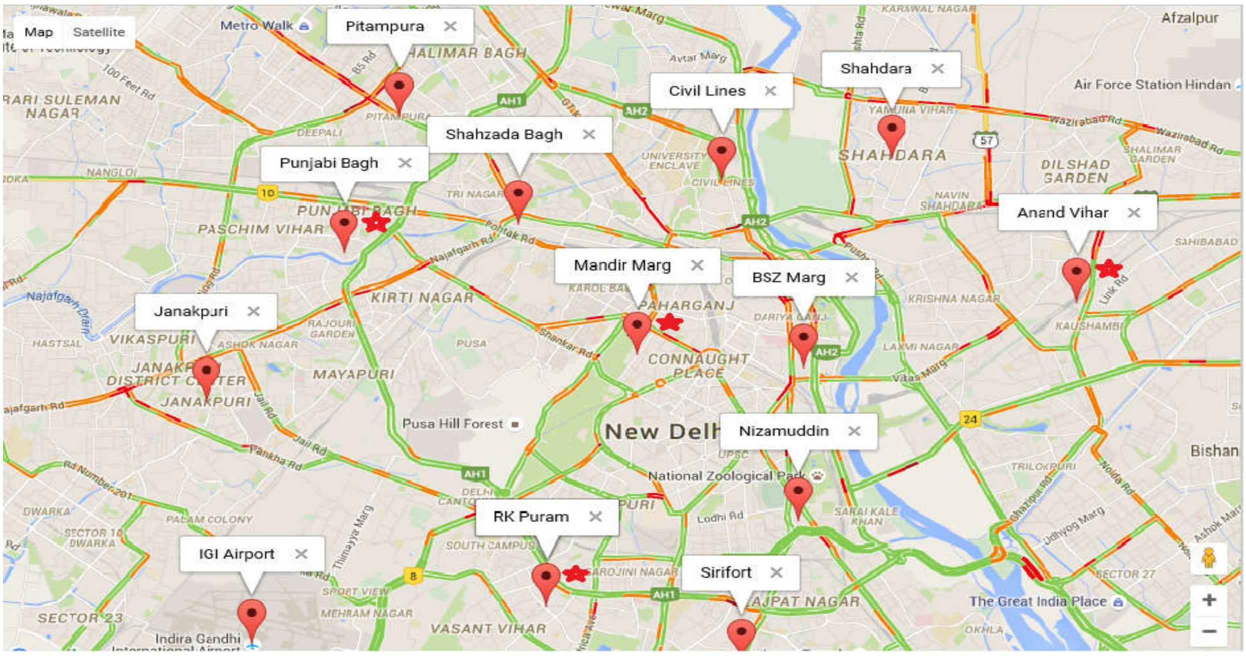

Figure 2 Air monitoring network of Delhi (Google map).

MATERIALS AND METHODS

The DPCC and CPCB run a number of air quality monitoring stations in Delhi to assess the air quality levels. Figure 2 shows the existing air monitoring network in Delhi. These stations, record the pollutants Ammonia (NH_3), Carbon Monoxide (CO), Sulphur Dioxide (SO_2), Nitrogen Dioxide (NO_2), Ozone operate on alternate days. The air quality data was collected for two months (December 1, 2015 to January 30, 2016) from these websites. The data was divided into three different time periods, i.e. December 1 to 30, 2015 as pre odd-even scheme, January 1 to 15, 2016 as during odd-even scheme and January 16 to 30, 2016 as post odd-even scheme. The pollutants used in our assessment are PM 2.5, PM 10, NO_2, SO_2, and NH_3.

The whole methodology is divided in different phases as mentioned in Figure 3:

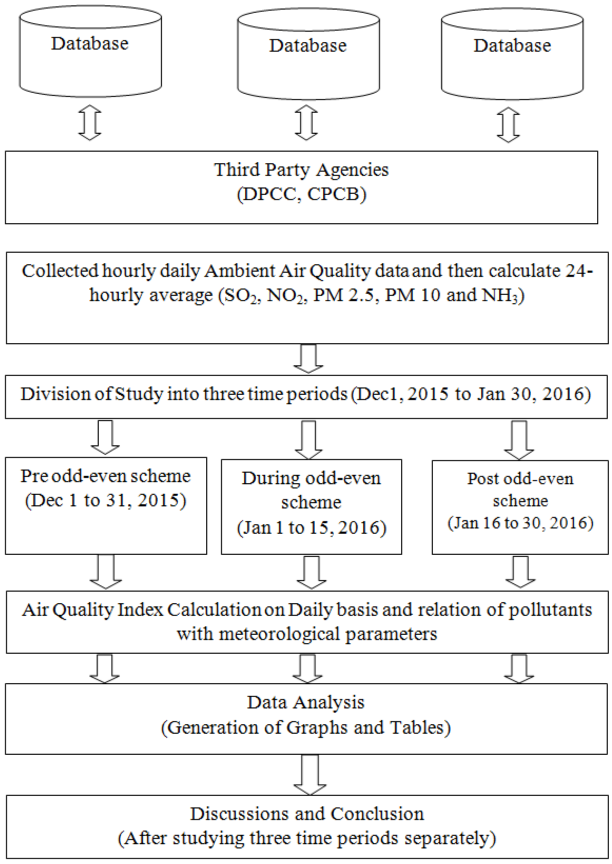

Figure 3 Methodology of study.

1. In first phase, the hourly data from DPCC and CPCB website for four monitoring stations is collected and its daily average concentration values in μg/m^{3}was calculated.
2. In second phase, to analyze the odd-even scheme, the collected data is divided into three different time periods i.e. pre, during, and post odd-even road rationing scheme.
3. In third phase, AQI is calculated on a daily basis which helps in rating the overall quality of air based on the observed values of different pollutants[7]. The two-steps involved in calculated AQI are shown in Figure 4:

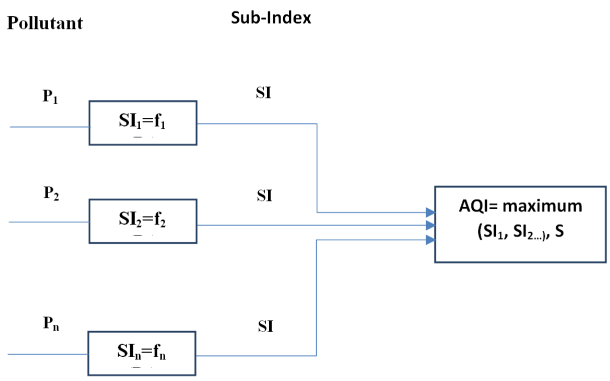

Figure 4 Formulation of Indian Air Quality Index[8].

(a) Formation of sub-indices using 24 hourly average concentration value, but in the case of CO and O_3, 8-hourly average value is taken and breakpoint concentration range shown in the Table 1 with the help of equation (1). It is noted that all the pollutants need not be monitored and an overall AQI is calculated for minimum three pollutant combinations, subject to that one should be either PM 2.5 or PM 10. In addition to this, if 24 hourly average concentration value is not available, then 16 hours' average data is considered because at least on an average 16 hours to be considered.

(b) The largest value of sub-indices is to be used as AQI for that place[8, 9]. The sub-index (SIn) for a given pollutant concentration (Pn), is calculated as[8]:

$$SIn = [\{(I_{HI} - I_{LO}) / (B_{HI} - B_{LO})\} * (Pn - B_{LO})] + I_{LO} \qquad \ldots\ldots (1)$$

B_{HI}= Breakpoint concentration ≥ Pn
B_{LO}= Breakpoint concentration ≤ Pn
I_{HI} = AQI value corresponding to B_{HI}
I_{LO} = AQI value corresponding to B_{LO}; subtract 1 from I_{LO}, if I_{LO} is 50.

(a) In fourth phase, the effects of meteorological factors on the daily average levels of air pollutants is assessed.

(b) In last phase, from the obtained results conclusion is drawn.

RESULTS

The data analyses for pre, during and post odd-even scheme, shows that the air pollutant concentration ranges on the basis of daily average levels are:

- In pre odd-even scheme, PM 10 ranged between (347.05-680.74 μg/m^3); PM 2.5 (182.54-336.92 μg/m^3); SO_2 (15.68-33.92 μg/m^3); NH_3 (37.38-113.95 μg/m^3) and NO_2 (67.54-151.25 μg/m^3).
- During odd-even scheme, the pollutants , PM 10 ranged between (275.34-688.58 μg/m^3); PM 2.5 (156.88-431.02 μg/m^3); SO_2 (12.46-40.91 μg/m^3); NH_3 (51.31-102.38 μg/m^3) and NO_2 (55.56-141.64 μg/m^3)
- In post odd-even scheme, the pollutants, PM 10 ranged between (245.26-562.36 μg/m^3); PM 2.5 (130.46-327.22 μg/m^3); SO_2 (14.08-29.03 μg/m^3); NH_3 (40.60-79.74 μg/m^3) and NO_2 (53.42-120.81 μg/m^3).

The minimum and maximum concentrations of air pollutants in μg/m^{3}are clearly shown in Table 2. From figure 5(a) and 5(b), the PM 2.5 and PM 10 concentrations are regularly showing more than the prescribed standards 60 and 100 μg/m^3 respectively. Table 3 indicates that among these four stations, Anand Vihar is the most polluted place in Delhi. This may be due to:

- Delhi is a marketing hub so all stuff coming from several parts of India through heavy vehicles enters through Anand Vihar. This makes entry and is also exit point of many interstate buses and trucks, for this reason Anand Vihar is called source of transit traffic.
- Delhi's waste dumping ground is situated in Gazipur which is located close to Anand Vihar (2 km away) causing environmental and health problems.
- The industrial area of Patparganj and Sahibabad close to Anand Vihar having small scale industries.

Table 1 Break points for AQI scale in Indian scenario[8]

AQI Category (Range)	Color Code	PM 10 24-hr (μg/m³)	PM 2.5 24-hr (μg/m³)	NO_2 24-hr (μg/m³)	SO_2 24-hr (μg/m³)	NH_3 24-hr (μg/m³)
Good (0-50)		0-50	0-30	0-40	0-40	0-200
Satisfactory (51-100)		51-100	31-60	41-80	41-80	201-400
Moderate (101-200)		101-250	61-90	81-180	81-380	401-800
Poor (201-300)		251-350	91-120	181-280	381-800	801-1200
Very Poor(301-400)		351-430	121-250	281-400	801-1600	1201-1800
Severe (401-500		430+	250+	400+	1600+	1800+

Table 2 Minimum and Maximum concentrations of Pollutants in μg/m³.

Odd-Even Scheme	PM 2.5		PM 10		NO_2		SO_2		NH_3	
	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max
Pre	182.54	336.92	347.05	680.74	67.54	151.2	15.68	33.92	37.38	113.95
During	156.88	431.02	275.34	688.58	55.56	141.6	12.46	40.91	51.31	102.38
Post	130.46	327.22	245.26	562.36	53.42	120.8	14.08	29.03	40.60	79.74

Table 3 Air Quality profile in terms of sub-index values of several stations

Stations	Parameters	Pre odd-even Scheme					During odd-even Scheme					Post odd-even Scheme				
		PM 2.5	PM 10	NO_2	SO_2	NH_3	PM 2.5	PM 10	NO_2	SO_2	NH_3	PM 2.5	PM 10	NO_2	SO_2	NH_3
Anand Vihar	Max	600	1138	323	35	80	607	916	169	50	38	510	814	144	30	25
	Min	353	505	100	15	15	338	295	87	17	18	318	249	74	16	13
Punjabi Bagh	Max	478	816	166	52	15	564	828	217	47	21	475	553	162	36	16
	Min	311	201	81	18	7	333	210	66	11	9	312	186	68	11	8
RK Puram	Max	631	745	123	80	29	552	660	131	84	36	443	556	142	60	21
	Min	339	240	66	26	10	328	216	73	22	13	316	215	74	25	11
Mandir Marg	Max	469	442	151	32	15	538	655	151	42	12	406	463	107	27	9
	Min	230	164	36	10	5	264	187	50	11	4	241	158	72	13	5

Table 4 indicates that the major responsible pollutants which make air quality level of Delhi to very poor and severe are PM 2.5 and PM 10. The analysis based on the average concentration of pollutants suggests that the scheme has not brought traceable improvement in air quality. Not only that there is an increase in the concentration of pollutants PM 2.5, PM 10, NO_2, SO_2, and NH_3 as shown in Figure 6. According to NEERI's report, the particulate matters contributed by the road dust (52.5%), industries (22.1%), area sources include fuel combustion, biomass burning (18.8%) followed by vehicular (6.6%) in Delhi[10].

Therefore, vehicles are in number four in the order of pollution sources. In addition to, among vehicular pollution, heavy vehicles like truck are the leading polluter, two- wheelers second and private four-wheelers are the third source of pollution.The PM 2.5 and PM 10 levels increased by 15.66% and 4.68%, from "pre to during" odd –even scheme and dropped by 7.98% and 7.93% from "during to post" odd-even scheme, based on an average concentration values. Similarly, NO_2, SO_2, and NH_3 concentrations increased by 2.90%, 4.61%, and 17.32%, from "pre to during" odd –even scheme and dropped by 11.13%, 21.99%, and 23.49% from "during to post" odd-even scheme (Figure 6).

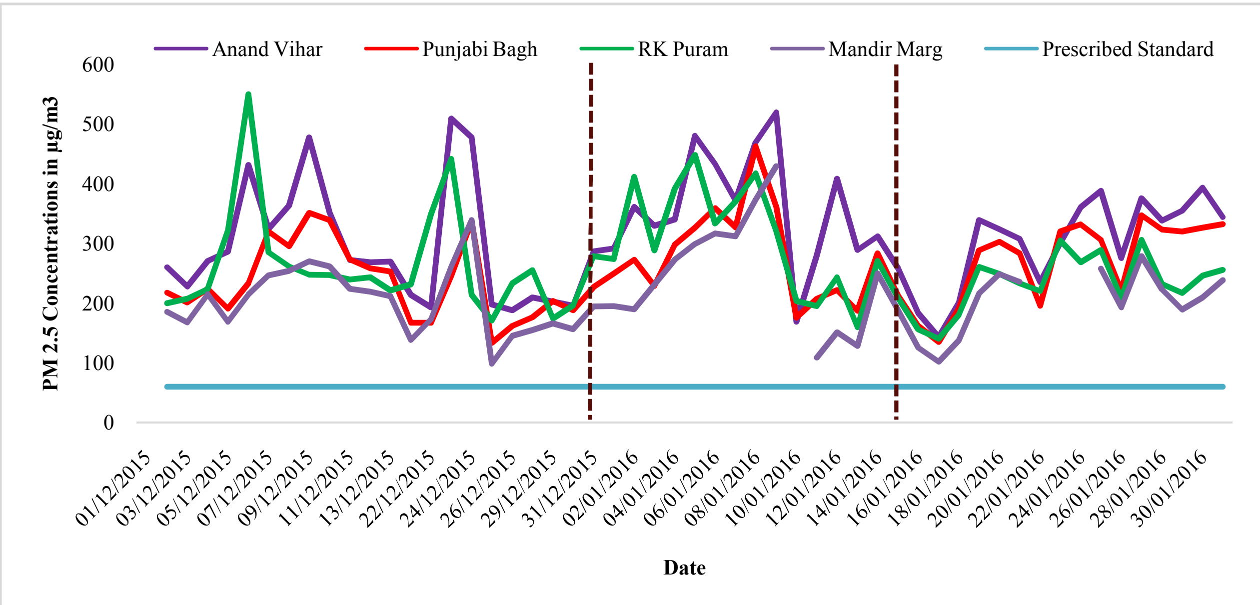

Figure 5(a) Daily Average PM2.5 concentration values of all stations across Delhi

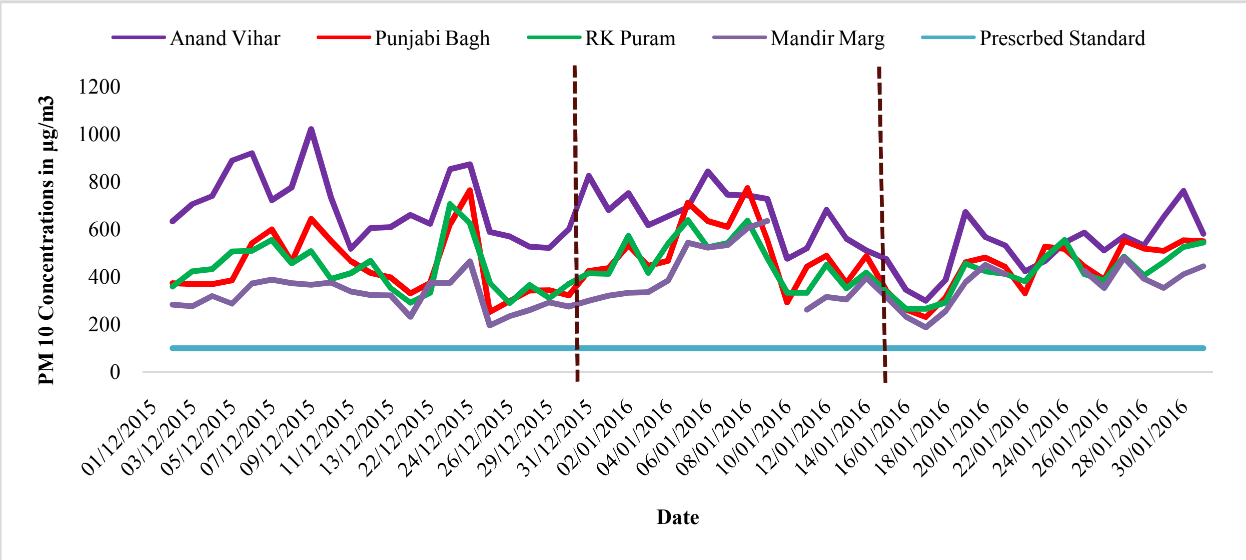

Figure 5(b) Daily Average PM 10 concentration values of all stations across Delhi.

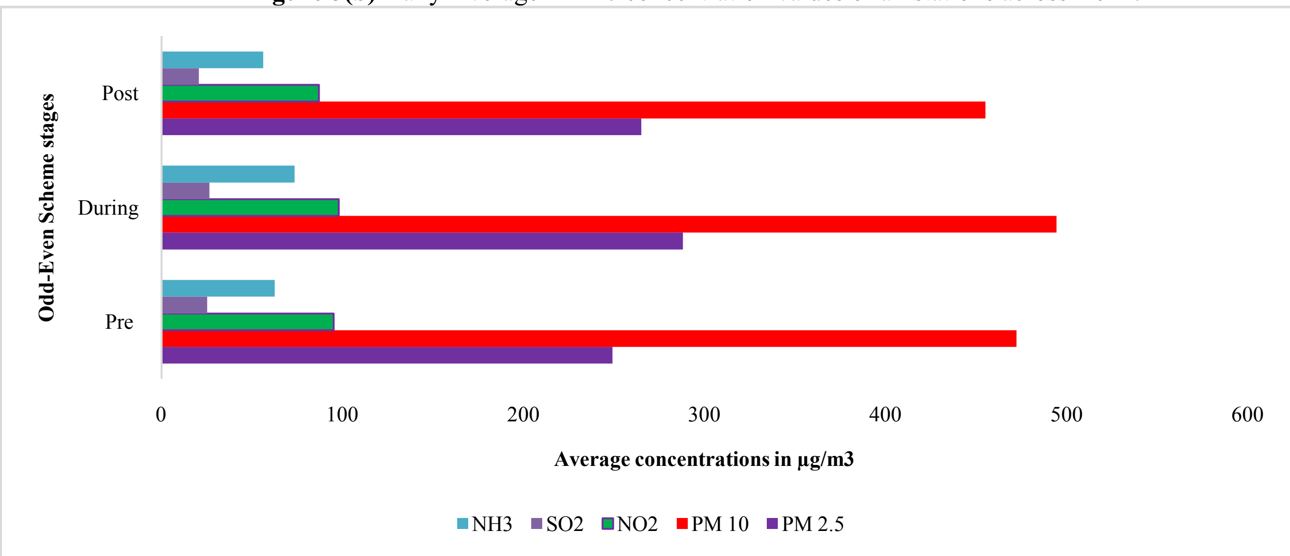

Figure 6 Average concentrations of Pollutants (µg/m^3) in different stages of an odd-even scheme

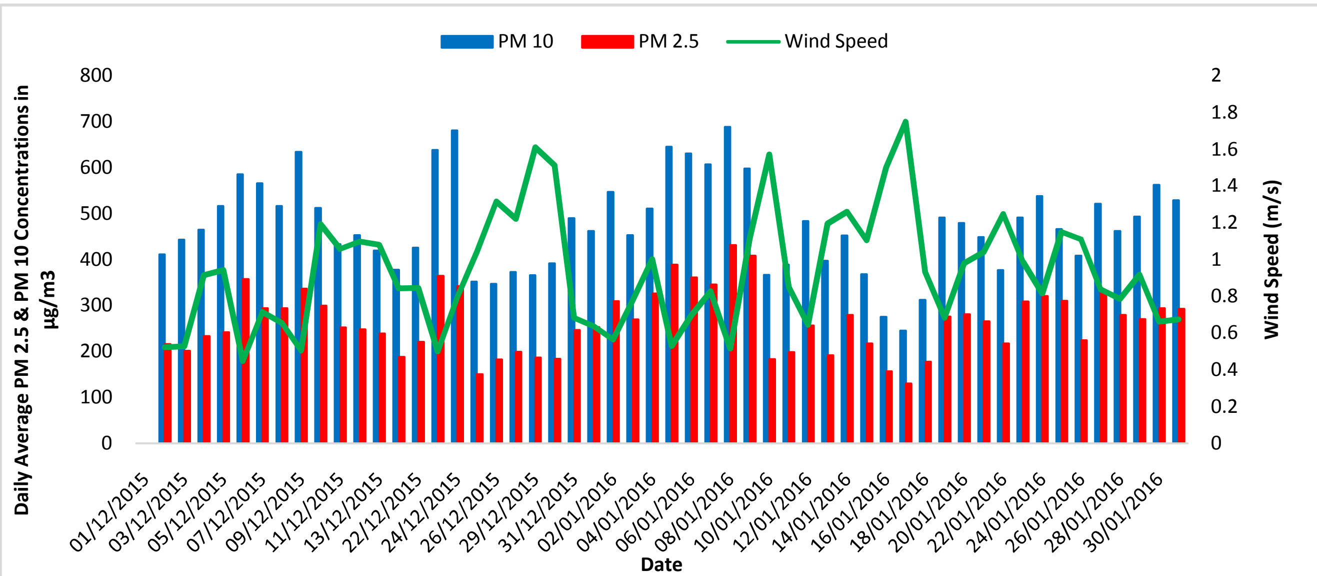

Figure 7 Relationship between Particulate matters with wind speed.

Table 4 Air quality index, responsible pollutant and level of air quality on daily basis

Odd-Even Scheme	Dates	SUB-INDEX					AQI	Responsible Pollutant	Air Quality Level
		PM 2.5	PM 10	NO_2	SO_2	NH_3			
	01/12/2015	374	377	106	27	15	377	PM 10	Very Poor
	02/12/2015	363	416	110	37	13	416	PM 10	Severe
	03/12/2015	387	443	111	27	13	443	PM 10	Severe
	04/12/2015	394	508	106	32	11	508	PM 10	Severe
	05/12/2015	483	594	137	42	15	594	PM 10	Severe
	06/12/2015	434	570	122	38	16	570	PM 10	Severe
	07/12/2015	434	508	153	30	25	508	PM 10	Severe
	08/12/2015	467	655	171	35	28	655	PM 10	Severe
	09/12/2015	438	503	117	26	16	503	PM 10	Severe
	10/12/2015	402	404	111	33	14	404	PM 10	Severe
	11/12/2015	398	429	99	26	14	429	PM 10	Severe
	12/12/2015	392	387	84	20	13	392	PM 2.5	Very Poor
	13/12/2015	352	335	97	28	9	352	PM 2.5	Very Poor
	14/12/2015	378	395	102	20	10	395	PM 10	Very Poor
	22/12/2015	488	660	143	42	19	660	PM 10	Severe
	23/12/2015	471	713	130	34	24	713	PM 10	Severe
	24/12/2015	324	303	111	29	13	324	PM 2.5	Very Poor
	25/12/2015	348	297	101	30	13	348	PM 2.5	Very Poor
Pre	26/12/2015	361	329	107	37	14	361	PM 2.5	Very Poor
	28/12/2015	352	320	96	31	15	352	PM 2.5	Very Poor
	29/12/2015	349	352	97	32	15	352	PM 10	Very Poor
	30/12/2015	398	475	111	34	16	475	PM 10	Severe
	31/12/2015	402	440	121	35	19	440	PM 10	Severe
	01/01/2016	446	547	135	38	20	547	PM 10	Severe
	02/01/2016	415	429	124	37	19	429	PM 10	Severe
	03/01/2016	459	501	107	34	18	501	PM 10	Severe
	04/01/2016	507	669	162	51	19	669	PM 10	Severe
	05/01/2016	485	651	160	49	21	651	PM 10	Severe
	06/01/2016	473	621	139	39	22	621	PM 10	Severe
	07/01/2016	539	723	134	40	26	723	PM 10	Severe
During	08/01/2016	522	610	102	19	23	610	PM 10	Severe
	09/01/2016	349	321	102	27	20	349	PM 2.5	Very Poor
	10/01/2016	360	349	99	36	14	360	PM 2.5	Very Poor
	11/01/2016	405	467	110	34	13	467	PM 10	Severe
	12/01/2016	355	359	120	34	14	359	PM 10	Very Poor
	13/01/2016	422	428	110	24	17	428	PM 10	Severe
	14/01/2016	375	322	88	17	15	375	PM 2.5	Very Poor
	15/01/2016	328	225	69	16	13	328	PM 2.5	Very Poor
	16/01/2016	308	197	67	18	11	308	PM 2.5	Very Poor
	17/01/2016	344	262	85	26	10	344	PM 2.5	Very Poor
	18/01/2016	420	476	100	25	11	476	PM 10	Severe
	19/01/2016	424	462	102	19	12	462	PM 10	Severe
	20/01/2016	412	424	88	22	13	424	PM 10	Severe
	21/01/2016	375	334	92	23	12	375	PM 2.5	Very Poor
	22/01/2016	445	476	115	29	15	476	PM 10	Severe
Post	23/01/2016	454	535	113	28	16	535	PM 10	Severe
	24/01/2016	446	445	98	21	14	446	PM 2.5	Severe
	25/01/2016	381	373	106	23	13	381	PM 2.5	Very Poor
	26/01/2016	459	514	110	26	15	514	PM 10	Severe
	27/01/2016	423	440	119	26	16	440	PM 10	Severe
	28/01/2016	416	480	117	31	16	480	PM 10	Severe
	29/01/2016	434	565	139	34	17	565	PM 10	Severe
	30/01/2016	433	524	141	36	20	524	PM 10	Severe

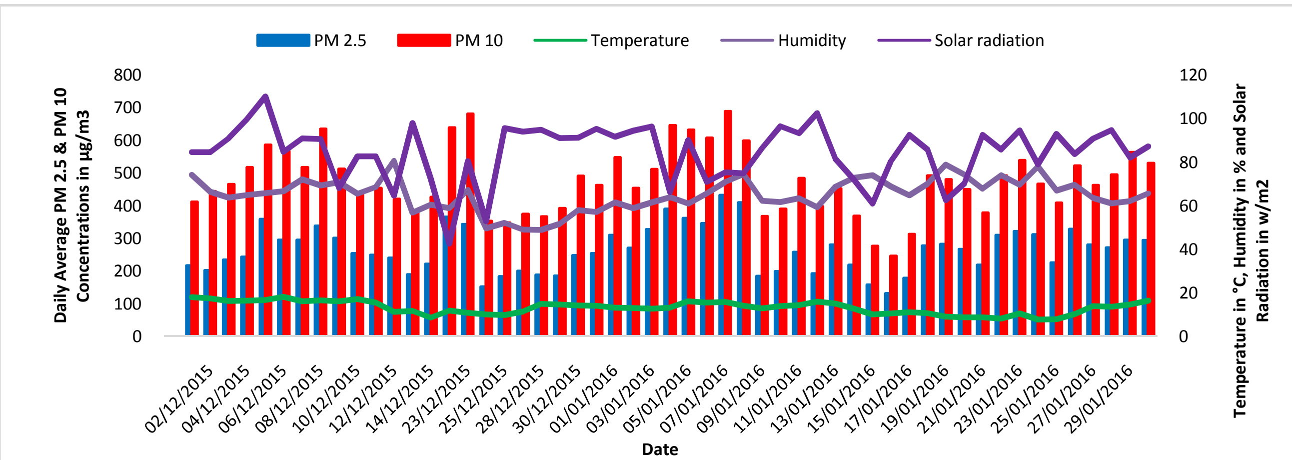

Figure 8 Relationship between Particulate matters with temperature, humidity and solar radiation.

Table 5 Correlation coefficient (r) between pollutants and Meteorological factors

Pollutants	Meteorological Factors			
	Relative Humidity	Temperature	Wind Speed	Solar Radiation
PM 2.5	0.30196	0.18986	-0.58560	-0.14312
PM 10	0.17149	0.32572	-0.68335	-0.10850

Figure 7 shows, different variations in PM 2.5 and PM 10 levels could be attributed to variations in wind speed. Figure 8 shows the relationship between Particulate matters with temperature, humidity and solar radiation. The results showed that PM2.5 and PM 10 are slightly and modestly positive correlated with temperature (r= 0.18 for PM 2.5 and r= 0.33 for PM 10), and modestly and slightly positive correlated with humidity (r= 0.30 for PM 2.5 and r= 0.17 for PM 10), and moderately and moderately strong negative correlated with wind speed (r= -0.59 for PM 2.5 and r= -0.68 for PM 10). However, weak negative correlations were observed between particulates and solar radiation (r= -0.14 for PM 2.5 and r = -0.11 for PM 10) (Table 5).

DISCUSSIONS AND CONCLUSION

The particulates, PM 2.5 and PM 10 are continuously above permissible limits set by CPCB during this study period.

The observed and findings indicate that a moderate negative correlation exists between particulate matters and wind speed, therefore, the smaller the wind speed, the smaller the turbulence, and hence the smaller the dispersion of pollutants near the surface. Moreover, the two particulate pollutants show a slightly positive correlation with temperature and humidity and also weak negative correlation with solar radiation.

The air pollution in Delhi is a transboundary concern[5] and also varies with weather conditions, which cannot be controlled by a single step like odd-even road rationing scheme, it is necessary to examine all sources of various pollutants present in air pollution. The aim of this study is not to justify that vehicles are not the contributor to Delhi air pollution; vehicles are definitely a source of pollution, but insignificant in terms of PM 2.5 and PM 10 and targeting only private cars to reduce air pollution in Delhi is not the correct and effective strategy. Therefore, there is a need to take some radical steps to tackle the pollution levels in a wider framework and increasing public awareness about the health impacts of different pollutants in air. The odd-even scheme expectation has failed by the fact that many residents has gone for two cars in place of one. Thereby, putting more load in atmosphere on free day.

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References

1. Desai. G.P. and Hosamane, D.N., URBAN Air Pollution Trend in India - Present Scenario. *International Journal of Innovative Research in Science, Engineering and Technology, 2003,* 2: 3738-3747.
2. Bhaskar, B. V. and Mehta, V. M., Atmospheric Particulate Pollutants and their relationship with meteorology in Ahmedabad. *Aerosol and Air Quality Research*, 2010, 10: 301-315.
3. World Health Organization Ambient Air Pollution Database (WHOAAD), 2014. Url: http://www.who.int/phe/health_topics/outdoorair/databases/cities/en/.
4. Jha, S., Oddity of Managing Air Pollution in Delhi: Public Policy Myopia. *Journal of Management & Public Policy, 2015,* 1:7-12.
5. Kumar, V. and Sangeeta, Air Pollution in Delhi, Mumbai and other Indian Cities: Urgent Need for an Effective and Long Term Solution. Savitarka: *An E-Magazine on Development Issues, 2015,* 1:1-4.
6. Delhi Pollution Control Board Report (DPCBR), 2015.
7. Sharma, M., Maheswari, M., Sengupta, B., Shukla, B.P., Design of a website for dissemination of an air quality index in India. *Environmental Modelling & software*, 2003, 18, 405-411.
8. National Air Quality Index Report (NAQIR), 2014. URL: www.cpcb.nic.in.
9. Mamta, P. and Bassin, J.K., Analysis of ambient air quality using air quality index – A case study. *International Journal of Advanced Engineering and Technology, 2010,* 1:106:114.
10. National Environmental Engineering Research Institute (NEERI), Nagpur. Air Quality Monitoring, Emission Inventory & Source Apportionment Studies for Delhi.