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AQI Analysis of Delhi City

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Abstract: *Analysis of the Air Quality Indices (AQIs) at two different location ofDelhi City is carried out for year (2016-2018) usingvarious air quality parameters. The 24-hr average concentrations of five criteria pollutants viz. Respirable suspended particulate matter (RSPM/PM2.5), Suspended particulate matter (SPM/PM10), Sulfur dioxide (SO_2), Nitrogen dioxide (NO_2) and Ozone (O_3) were estimated.*
AQIs was calculated and It was observed that AQIs at both the locations were in severe condition in winter season, whereas itwas in moderate to poor condition in the summer and monsoon seasons. During the entire year, AQIs were more than the standard limits. It was also found that NO_2 level in the industrial area was greater than the residential area, whereas SO_2 levels in industrial area was less than that in residential area. At both the locations,SO_2 and NO_2 levels were within the standard limits. Overall the AQIswere found to fall under the category 'Severe' and 'very poor' owing to PM10 and PM2.5, respectively.

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I. Introduction

The Air quality in Delhi, the capital of India from the past few years is in its worst state. Delhi emits about 3000 MT of air pollutants every day from vehicles, thermal power plant (coal-based), industries and domestic activities (CPCB, 2016). Contribution of the vehicle pollutionis maximum (72%), after that thermal power plant and industries (67) (CPCB, 2016). The government of Delhi has tried to control the air pollution due to vehicles implementing rules such as even-odd formula, banning10 year old diesel vehicles, initiation of CNG vehicles and motivating the public for carpooling, etc. Main pollutants in Delhi atmosphere are particulate matter (SPM and RSPM), oxides of nitrogen, sulfur dioxide, carbon monoxide, ozone, benzene, toluene, xylene, etc.

According to World Health Organization (WHO) report in May 2015, New Delhi was found to be the world's most polluted city having an annual average PM2.5 concentration of 153 micrograms, per cubic meter. In November 2016, air quality of Delhi was evenworse (14 times)having a PM concentration up to 1270 μg/m^3 with an average value of 872 μg/ m^3 for PM2.5 and peak value 2060 μg/ m^3 with an average value of 1400 μg/ m^3 for PM10 (WHO REPORT). In 2016, WHO downgraded Delhi to eleventh in the urban air quality database. According to one estimate, air pollution causes the death of about 10,500 people in Delhi every year (18,19,20).

Rao N S et al. 1999 assessed the air and water quality in Kakinada town (Andhra Pradesh) during 1994 and found ambient air quality was within the limit in all the sites. Taking the current status of air pollution as the baseline he also proposes the condition by 2005 by assuming medium scale industries in the future and suggest the methods to improve the condition. Dayal and Nandini, 2000 found that SO_2 and NOx level were within the limit in Bangalore city whereas SPM levelswere higher than CPCB standards at 60% of the locations. He also calculated AQIs and found that Bangalore city air was moderately or light-polluted and at some location it was clean. Mandal, 2000 monitored the concentrations of SPM, NOx, SO_2, and CO over the various parts of Calcutta and found that the pollutant concentration in Hawrah industrial area was higher in comparison to the urbanized area. Chandrashekar et al, 2002 studied the air quality parameters (SPM, NO_2, and SO_2) at different sampling locations of Tuticorin city at weekly intervals for the whole year. Maximum AQIsvaried from 27.9 (fairly clean) to 9.00 (clean). And the concentrations of SO_2 and NO_2 were high during the winter season and SPM concentration were higher in summer for commercial cum residential areas. Senthilnathan and Rajan, 2002 examined the concentrations of PM10 and PM2.5 at different locations of Chennai city in 2000 and found that the average monthly PM10 and PM2.5 concentration were higher than the NAAQS limits. Goyal and Sidhartha, 2003 informed that pollutant concentration in Delhi was reduced after replacing the diesel vehicle with CNG vehicles. PM level came down to 347 from 405μg/m^3, but higher than standards whereas SO_2 and NO_X level also came down but it was within limits. From an analysis of SO_2/ NO_2 and CO/ NO_2, it was found that vehicular pollution contributing to NO_2 whereas industrial pollution contributing to SO_2.

Cheng at al., 2004 proposed a revised EPA air quality Index (RAQI) by introducing a new function to include the effect of the concentration of the rest pollutants other than pollutants with maximum AQI. Further,

this application of RAQI in Taiwan has shown that SPM has a significantly greater impact on PM2.5 and PM10 ratio. Ravindra et al., 2006 also examined the concentration of criteria pollutant and organic pollutants in Delhi before and after the implementation of CNG vehicles and found that PAHs, CO, and SO_2 concentration came down whereas PM10, PM2.5 and xylene concentration shows no changes. NO_2 concentration was increased due to CNG. It was also observed that concentration of PAHs was maximum between 10 AM to 6 PM because of heavy vehicle movement in that period. Pope et al., 1995 observed a 30 to 50% increase in lung cancer rates with exposure to respiratory particles and sulfates. PEFR and respiratory symptoms were strongly associated with PM10 levels marginally with Ozone levels. Pope, 1989 and Dockery et al., 1989 both found that due to an increase in PM concentration in ambient air, hospital admissions for pneumonia, bronchitis, and asthma increased. Long term PM exposure increases the risk of respiratory illness in children.

The major objectives of the present study can be listed as:
1-Estimation and Analysis of Air Quality Index (AQI) and comparative analysis for twolocation.
2- Correlate the Air Quality Index data with meteorological factors.

II. Study Area

Delhi is one of theunion territoriesand also the capital of India. It is surrounded by Haryana on three sides and by Uttar Pradesh to the east. Its area is about 1,484 square kilometers and population is about 25 million.

According to the World Health Organization (WHO) Delhi was the most polluted city in the world in 2014. In 2016 WHO downgraded Delhi to eleventh-worst in the urban air quality database Delhi is geographically located in North India within the latitude 28°24'17" and 28°53'00''N, and longitude 77°45'30'' and 77°21'30''E. The two prominent features of the geography of Delhi are the Yamuna flood plains and the Delhi ridge. Temperatures in Delhi usually range from 2 to 47 °C (35.6 to 116.6 °F), with the lowest and highest temperatures ever recorded being −2.2 and 48.4 °C (28.0 and 119.1 °F), respectively.The hottest day of the year is 22ndMay average of 40°C) whereas the coldest day is 4thJanuary with an average low of 2°C and high 14°C.

For the present study two types of sites were selected:

First is the R K Puram area which is situated in the south west part of Delhi. It is purely a Residential area with no proximity to any industry. The location will termed as L_RES.The other location is the Aanand Vihar situated on the Delhi-UP border. The area includes Aanand Vihar terminal bus stand, railway station and industries near it. It is mostly a industrial area**,** hence it will be termed as L_IND hereafter.

III. Methodology

Selection of Sampling Procedure

Two type of sampling procedures were used. First one is the continuous sampling, whichis carried out by automatic sensors, optical or electrochemical and spectroscopic methods that produce continuous records of concentration values. In the second method, specified time-averaged concentration data can be obtained from continuous records. Time-averaged data can also be obtained by sampling for a short time.

3.2.2 Sampling Time

A period of sampling should be suitable to measure the actual existing ambient air quality. It ispreferable to observe the sampling period reliable with the averaging time for which air quality standards of the given pollutants are specified.

Table: 3.1 Average Sampling Time for Criteria Pollutants

Pollutant	PM10	PM2.5	SO_2	NO_2	CO	O_3
AverageSampling Time	24-hr	24-hr	24-hr	24-hr	8-hr (Maximum)	8-hr (Maximum)

3.3 Air Sampling

The air sampling procedure of four major pollutants PM10, PM2.5, SO_2 and NO_2 is described here

3.3.1 PM2.5 sampling

PM2.5 concentration can be measured by low volume samplers. The size-selective inlet is comprised of two separate size selective inlets: the first is a PM10 inlet to remove all the larger particulates followed by a PM2.5 selective inlet to exclude the particulates greater in diameter than 2.5 μ. The large glass fiber filter used in PM10 instrumentation is replaced by a 47 mm diameter Teflon filter. PM2.5 filters are used mainly for particulate mass determinations and not characterizations as are the larger PM10 filters. The flow rate in a low volume sample is kept about 16.67 liters/minute. This instrument can be used for continuous as well as time average sampling.

Calculation of the volume of air sampled can be done using equation:

$V = (F1 + F2) X T/2$

Where,
V = volume of air sampled in m^3
F1 = measured flow rate before sampling
F2 = measured flow rate after sampling
T = time of sampling
PM2.5 concentration is calculated by:

$PM2.5 = (M_f – M_i) \times 1000/ V_a$

Where,
PM2.5 = Total mass concentration of PM2.5 collected during the sampling period
M_f = Final mass of PTFE filters paper, mg
M_i= Initial mass of PTFE filters paper, mg
V_a= Total air volume sampled, m^3

3.3.2 PM10 sampling

PM10 or fine dust sampler with PM10 impactor assembly is used to find out the concentration of suspended particles of diameter higher than 10μg within the air. For this WINS impactor assembly is removed and only one 47 mm diameter filter paper is used. PM10 samplers are high volume sampler, in which flow rate is kept about 1132liter/minute.

PM10 concentration is calculated by:

$PM10 = (M_f – M_i) \times 1000/ V_a$

Where,

PM10 = Mass concentration of the PM10 collected during the sampling period
M_f , M_i = Final and initial mass of glass fiber filter paper, mg
V_a = total air volume sampled, m^3

3.3.3 SO_2sampling

SO_2 is gravimetrically estimated by adding barium chlorine in slight excess in absorbing solution.H_2O_2 is used as an absorbing solution which gets converted to sulphuric acid during sampling.

$H_2O_2 + SO_2 \rightarrow H_2SO_4$

$H_2SO_4 + BaSO_4 \rightarrow BaSO_4 + 2HCL$

When barium chloride reacts with sulphuric acid, It leads to be formation of barium sulphate which is estimated gravimetrically. With stoichiometric calculation, we estimate sulphate dioxideconcentration in ambient air.

SO_2 concentration can be calculated by

SO_2 = (Mol. Wt. of SO_2 x W x 10_6)/(Mol. Wt of $BaSO_4$ x V_a
Where,

SO_2 = Concentration of SO_2, $\mu g/m^3$
V_a = Total air volume sampled, m^3
W = weight of $BaSO_4$ formed i.e. difference between filter paper before and after filtration

3.3.4 NO_2Sampling

Ambient nitrogen dioxide (NO_2) is collected by bubbling air through a solution of sodium hydroxide. The concentration of nitrite ion (NO_2) produced during sampling is determined calorimetrically by reacting the nitrite ion with phosphoric acid, sulfanilamide, and N-(1-naphthyl)-ethylenediamine di-hydrochloride (NEDA) and measuring the absorbance of the highly colored azo-dye at 540 nm.

The values of NO2 concentration can be taken from the standard curve plotted between concentration and absorbance and then divided by the volume of air sampled.

3.4 Collection of Secondary Data

Under N.A.M.P., four air pollutants Sulphur Dioxide (SO_2), Oxides of Nitrogen as NO_x, Suspended Particulate Matter (SPM) and Repairable Suspended Particulate Matter (RSPM / PM10) have been identified for regular monitoring at all the locations.

In Delhi, at 10 locations (Aanand Vihar, Shadipur, R K Puram, Mandir Marg, IGI Airport, Punjabi Bagh, IHBAS, Dwarka, Civil lines and ITO) real-time Air Quality data is open to the public at various governmental websites. For this work data of last one year (from October 2015 to Sept 2016) is taken for two locations Aanand Vihar and R K Puram. In which Aanand Vihar is an industrial area & R K Puram is a residential area.

3.5 Calculation of AQI

Different methods are used in different countries to measure the quantity of air pollution. Some of the common methods are listed below:

3.5.1 IND-AQI

To calculate IND-AQI, first step is to calculate sub-indices. Chattopadhyay et al., 2010 gave the following equation to calculate sub-indices:

$q = 100 (V/V_s)$

Where,
q = Quality Rating
V = observed values of the parameter and
V_s = standard value recommended for the parameter
If 'n' numbers of parameters are considered, the Geometric Mean of these "n" numbers of Quality Rating is found out and this is considered as Air Quality Index (AQI).

g = anti log {(log a + log b + log c + ……. Log x)/n}
Where,

g = geometric mean
a,b,c,d,x = different values of air quality rating; and
n = number of values of air quality rating,
log = logarithm.

3.5.2 USEPA-AQI
USEPA-AQI can be calculated from the values of concentration of different pollutants using following equation (Upadhyaya and Dashore, 2006; Bishoi et al., 2009; Gufran. 2010*).*

$$\mathbf{I = ((I_{high} - I_{low}) * (C-C_{low}) / (C_{high} - C_{low})) + I_{low}}$$

Where,

I = Air Quality Index
C= Pollutant concentration
$\mathbf{C_{low}}$ = the concentration breakpoint that is ≤ C,
$\mathbf{C_{high}}$ = the concentration breakpoint that is ≥ C,
$\mathbf{I_{low}}$ = the index breakpoint corresponding to $\mathbf{C_{low}}$,
$\mathbf{I_{high}}$ = the index breakpoint corresponding to $\mathbf{C_{high}}$

3.5.3 Average Method
There is one more method to calculate Air Quality Index which represents air quality by using equation below (Chauhan et al., 2010; kumar et al., 2011);

$$\mathbf{AQI = 14}\ [\ \boldsymbol{PM10/sPM10 + PM2.5/sPM2.5 + SO_2/sSO_2 + NO_2/sNO_2}\ ]\boldsymbol{x100}$$

Where,
sPM10, sPM2.5, sSO_2 and s NO_2 represent the ambient air quality standards as prescribed by the CPCB, for PM10, PM2.5, sulphur dioxide and nitrogen dioxides respectively
PM10, PM2.5, SO_2 and NO_2 represent the actual values of the pollutants obtained.

3.6 Formation of an Index
Each sub-index represents a relationship between pollutant concentration and health effects. The functional relationship between sub-index value (Ii) and pollutant concentrations (Xi) is explained here:
Aggregation of sub-indices, Ii is carried out with some mathematical function to obtain the overall index (I), referred to as AQI.

$$\mathbf{I = F(I1, I2,\ldots..,In)}$$

The aggregation function usually is a summation or multiplication operation or simply a maximum operator.
3.6.1 Sub-indices (Step 1)
Sub-index function represents the relationship between pollutant concentration X_i and corresponding sun index Ii. it is an attempt to reflect environmental consequences as the concentration of specific pollutant changes. It may take a form such as linear, non-linear and segmented linear. Typically, the I-X relationship is represented as follows:

$$\mathbf{I = \alpha X + \beta}$$

Where, α = Slope of the line, β = intercept at X=0.
The general equation for the sub-index (Ii) for a given pollutant concentration (Cp); as based on 'linear segmented principle' is calculated as:

$$\mathbf{I_i = [\{(I_{HI} - I_{LO})/(B_{HI} - B_{LO})\} * (C_P - B_{LO})] + I_{LO}}$$

Where,
B_{HI} = Breakpoint concentration greater or equal to given concentration
B_{LO} = Breakpoint concentration smaller or equal to given concentration
I_{HI} = AQI value corresponding to B_{HI}
I_{LO} = AQI value corresponding to B_{LO}
C_P = Pollutant concentration.

3.6.2 Aggregation of sub-indices (Step 2)
Once the sub-indices are formed, they are combined or aggregated in a simple additive form or weighted additive form;

Weighted Additive Form

I = Aggregated Index = $\Sigma W_i I_i$ (For I = 1,2,…..n)
Where,
$\Sigma W_i = 1$
I_i = sub index for pollutant i
n = number of pollutant variables
W_i = weightage of the pollutant

Root-sum-Power Form (non-linear aggregation form)

I = Aggregated Index = $[\Sigma I_i^p]^{(1/p)}$
Where, P is the positive real number >1
Root-Mean-Square Form

I = Aggregated Index = $\{1/k\ (I_1^2 + I_2^2 + \ldots\ldots\ldots + I_k^2\}^{0.5}$

Min or Max Operator (Ott 1978)

I = Min or Max (I_1, I_2, I_3, ……., I_n)

IV. Results and Discussion

First daily basis data of Particulate material PM2.5, PM10, Sulphur Dioxide (SO_2), Nitrogen dioxide (NO_2) and Ozone (O_3) along with meteorological factors temperature, relative humidity, wind speed, vertical wind speed for two locations were taken for the interval of Jan, 2016 to Dec,2018.to September 2016 this was the huge data to plot on a single graph and find out any result, so consideraverage monthly data for the same was computed and represented.

4.1 Calculation of Air Quality Index
AQIs for Aanand Vihar and R K Puram is calculated from oct-2015 to Sept-2016. The sub index for a given pollutant concentration, as based on 'linear segment principle'. AQIs is calculated using USEPA AQI method.

4.2 Air Quality Index for location S-1

For AQI calculation data for PM10, PM2.5, SO_2, NO_2, O_3 was taken from Oct-2015 to Sept-2016 from CPCB website through online monitoring system installed by CPCB.

Every 14 days average data of criteria pollutants for location S1 that was taken from CPCB website and sub-index was calculated for each time zone and for each pollutant, maximum value of this sub index for any particular time zone is represented as AQI for that time.

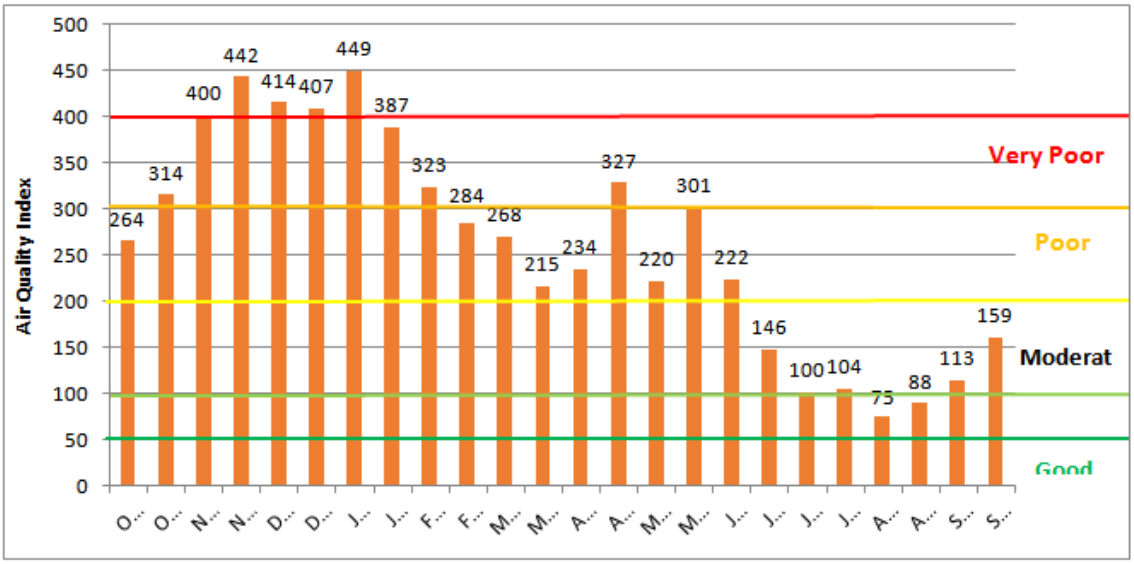


Fig 4.1 Air Quality Index trend analysis for Location S1 (Oct 2015 to Sept 2016)

Figure 4.1 represents the AQI values in graph over the time for location S1. Results from this analysis are as follows:

1. Results show that major pollutants in Delhi are PM10 and PM2.5. In rainy season and in winter (January) major pollutant is PM10 and in other month's major pollutant is PM2.5 for location S1.
2. In most of the case Air Quality Index values are in very poor condition or severe condition.
3. In Delhi not in a single month air pollution data is in Good condition.
4. AQI Value Vs Month graph shows that AQI values are in a trend that means it changes according to season.
5. In winter season AQI is maximum (except Nov II) that means results are severe. So maximum health hazard are in winter season.
6. In rainy season AQI values are minimum which are in satisfactory and in moderate condition.
7. In rainy season particulate particles along with water come on the earth surface and flow with the water that decreases the concentration of PM particles subsequently decreases the AQI.
9. In summer season AQI values lies in poor condition and in mid between winter and rainy season AQI values. That shows AQI depends on ambient temperature.
10. In whole the year maximum AQI value is in NOV II, in which month temperature is not less than DEC II and JAN I. In this time period external factors are more predominant than meteorological factors.

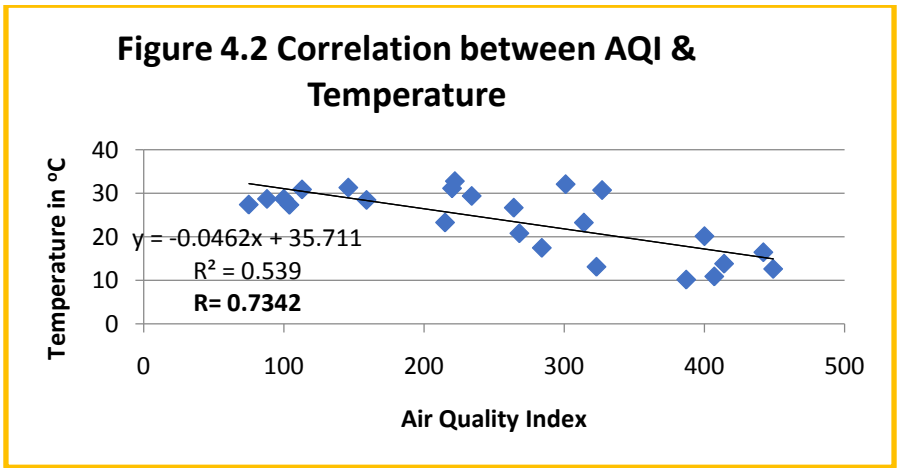
There are two main external factors that represent maximum AQI values-

1. First it is due to burning loads of crackers on Indian festival Diwali and Chatt pooja.

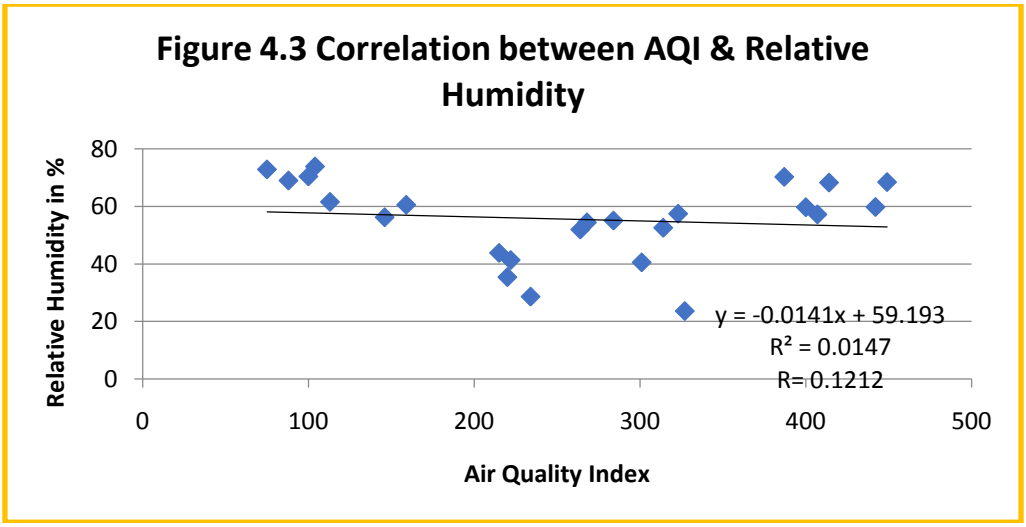
2) The second factor is burning of crops usually in neighboring Punjab and Haryana region. Farmers in neighboring Punjab and Haryana have been setting fire to paddy stubble in their fields after cultivating the crops as a part of slash and burn. Generally burning of crops stubble is considerably impacting the pollution level.

4.3 AQI v/s meteorological factors for Location S1

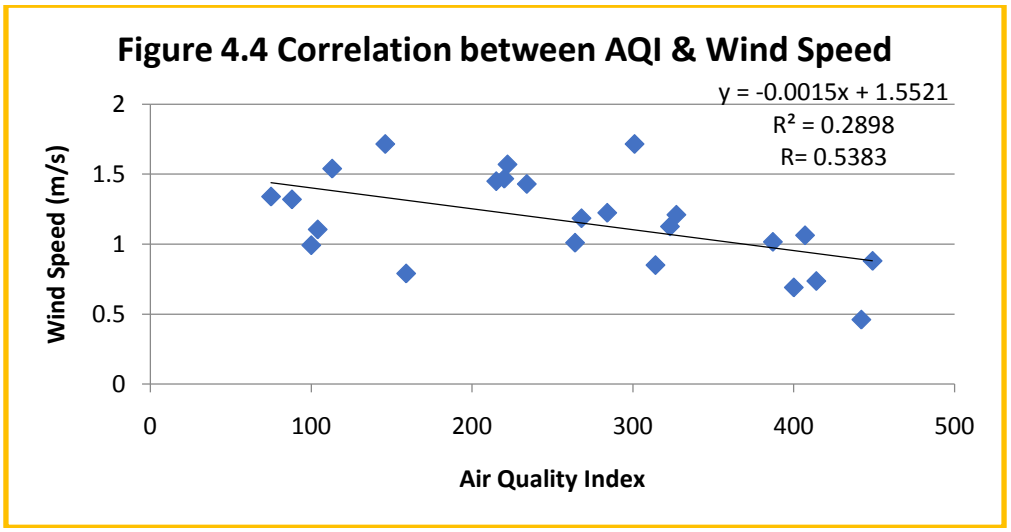
Analysis of dependency of meteorological factors i.e. temperature, relative humidity and wind speed on air quality index value, these factors were analyzed for the same time interval Oct-2015 to Sept-2016 for the location S1.



In Figure 4.2 correlation between calculated AQI values with temperature is shown for location S1. The trend line in this figure indicates that with a decrease in temperature AQI value increases. So maximum pollution in Delhi in the month of winters. Correlation coefficient R-value is 0.7342 which represents that AQI value highly depends on temperature. When temperature decreases, pollutant concentration increases because in winter season inversion occurs when normal atmospheric conditions inverted. Inversion traps a dense layer of cold air under a layer of warm air. The longer the inversion lasts, the higher the levels of pollution trapped under it. In other words, we can say that in winter, Environmental Lapse Rate (ELR) is greater than Adiabatic Lapse Rate (ALR),it means at a particular height (below than inversion layer) ambient air temperature will be less than pollutant temperature. In this case, pollutant is not able to escape out the inversion layer. And in winter inversion layer exist near the earth surface so near the earth surface pollution concentration increases.



In Figure 4.3 correlation between calculated AQI values with relative humidity is shown for location S1. A trend line drawn on this graph is horizontal and obtained correlation coefficient R-value is 0.1212 which shows that there is no significant change in AQI value with change in relative humidity. The relative humidity is responsible for fog in winters.



In Figure 4.4 correlation between calculated AQI values with wind speed is shown for location S1. Trend line slope represent that with increase in wind speed AQI decreases. Because Air pollutant disperse in a large area with wind speed and volume increases that result in decrease in the AQI value near the sampling instrument. Correlation coefficient R value 0.5383 does not represent the significant change.

4.4 Air Quality Index for location S2

For AQI calculation data for PM10, PM2.5, SO_2, NO_2, O_3 was taken from Oct 2015 to Sept 2016 from CPCB website through online monitoring system installed by CPCB.

Every 14 days average data of criteria pollutants for location S2 that was taken from CPCB website and sub-index was calculated for each time zone and for each pollutant, maximum value of these subindicesfor any particular time zone is represented as AQI for that time.

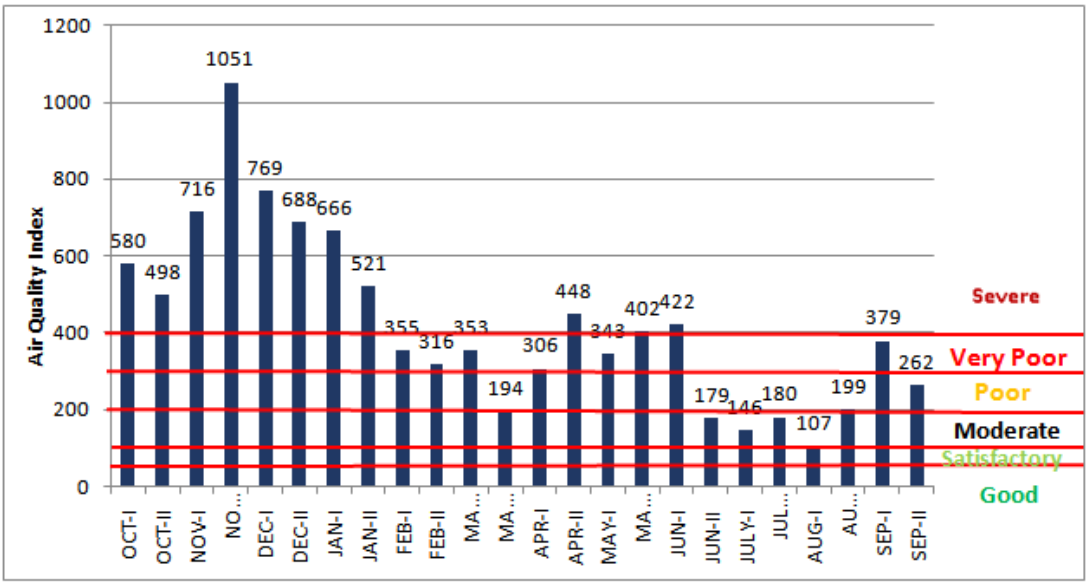


Figure 4.5 represents the AQI values in graph over the time for location S1.

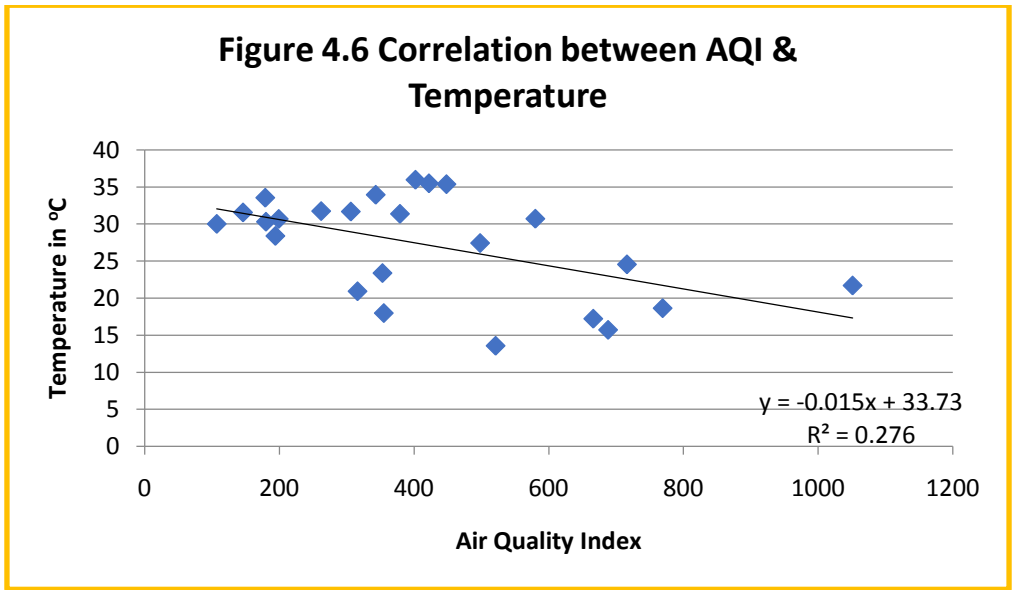
Results from this analysis are as follows:

Results show that industrial site location S2 was with the highest Air Quality Index of 1051 which comes under severe category where it will cause respiratory effects on healthy people and serious health impacts on all people. Similar to R location S1 major pollutants at location S2 are also PM10 and PM2.5, but pollutant concentration is much higher than location S1. In February and March month major pollutant is PM2.5 otherwise in rest of year major pollutant is PM10. From the graph, it is clear that most of the time Air Quality Index value is in the severe zone, which is very hazardous to health (much higher than acceptable limit). Only in the rainy season and summer season, the AQI values are in moderate region.

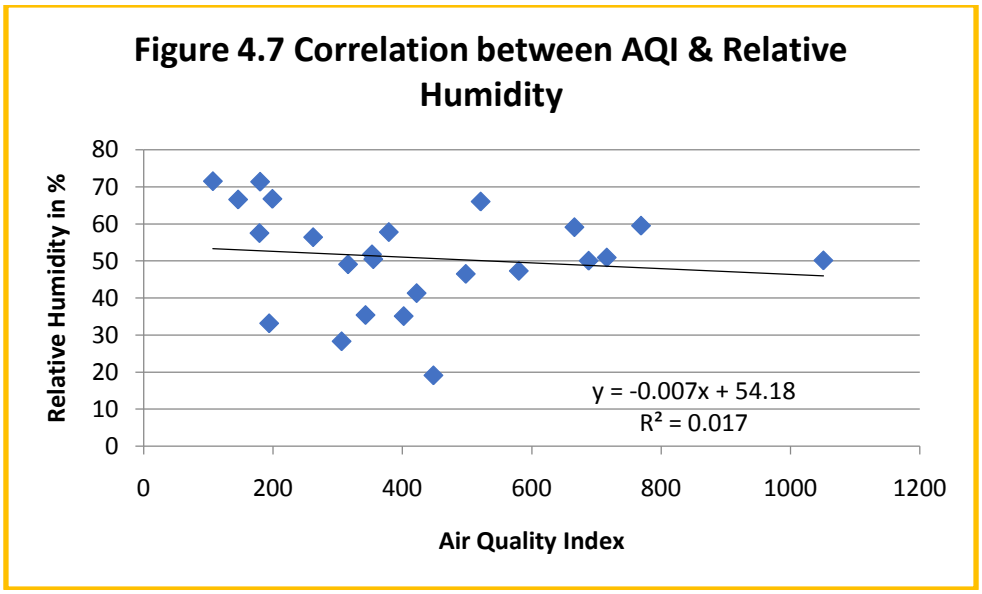
In winter AQI values are maximum due to a low temperature from NOV I to JAN II, and minimum in summer and rainy season from JULY II to AUG II. Same as location S1 in NOV II month the air quality index is maximum in all the year but here this value is very high i.e. 1051.

4.5 AQI Vs meteorological factors for location S2

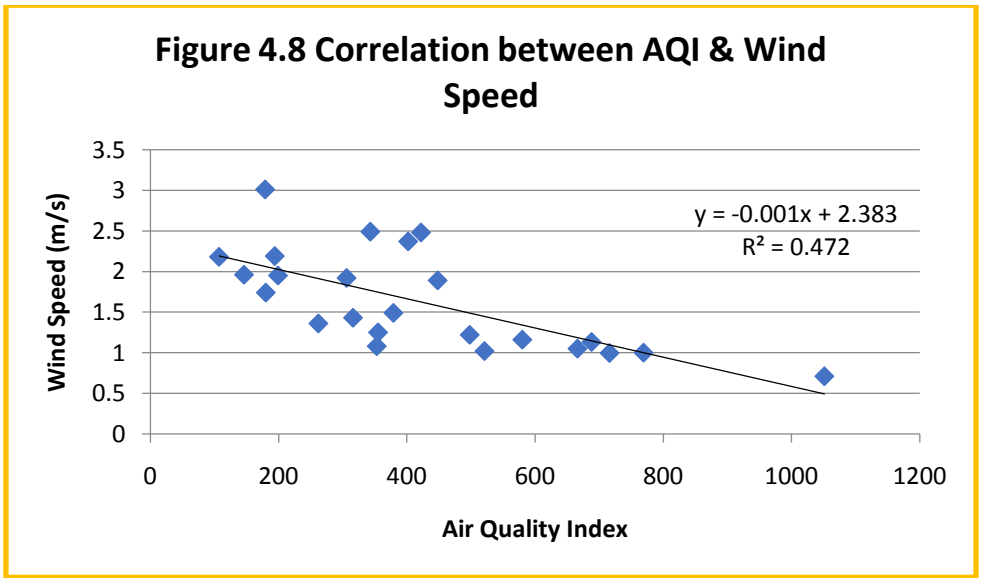
Analysis of dependency of meteorological factors i.e. temperature, relative humidity and wind speed on air quality index value, these factors were analyzed for the same time interval of OCT 2015 to SEPT 2016 for the location S2.



In Figure 4.6 correlation between calculated AQI values with temperature is shown for location S2. Similar to location S1 trend line in this figure also indicates that with a decrease in temperature AQI value increases. Correlation coefficient R-value is 0.5262 which represents that AQI value depends on temperature. In compare to location S1 R-value is low because due to an industrial area external factors are equally predominant for AQI.



In Figure 4.7 correlation between calculated AQI values with relative humidity is shown for location S2. similar to location S1 trend line drawn on this graph is horizontal and obtained correlation coefficient R-value is 0.1327 which shows that there is no significant change in AQI value with change in relative humidity.



In Figure 4.8 correlation between calculated AQI values with wind speed is shown for location S2. similar to location S1 trend line drawn on this graph is horizontal and obtained correlation coefficient R value is 0.6872 which show that there is no significant change in AQI value with change in wind speed.

4.6 Comparison Analysis of AQI, SO_2 and NO_2 for location S1 and S2

Data for Air Quality Index for both the locations are taken from previous tables and are shown in a separate table 4.6

Table 4.6: AQI Values for Location S1 and S2 (Compare)

	OCT I	OCT II	NOV I	NOV II	DEC I	DEC II	JAN I	JAN II	FEB I	FEB II	MAR I	MAR II
Location S1	264	314	400	442	414	407	449	387	323	284	268	215
Location S2	580	498	716	1051	769	688	666	521	355	316	353	194
	APR I	**APR II**	**MAY I**	**MAY II**	**JUN I**	**JUN II**	**JULY I**	**JULY II**	**AUG I**	**AUG II**	**SEP I**	**SEP II**
Location S1	234	327	220	301	222	146	100	104	75	88	113	159
Location S2	306	448	343	402	422	179	146	180	107	199	379	262

From table 4.6 it is clear that Air Quality Index values for Location S2 are 1.5 to 2.25 times higher than Location S1. It means in the same city meteorological data are not so different that affects Air pollution so external factors for the particular locations are more dominant. The main reason for that comparison is that Location S1 is a residential area while Location S2 is an industrial area and the vehicular load is higher in Location S2 also. In location S2 there is ISBT (Bus terminal). But a change in the AQI Values pattern with the month is exactly same for both locations. At both the locations Yearly maximum pollution in NOV II. After that pollution is a maximum in winter and a minimum in summer and rainy season.

Figure 4.9 show the comparison analysis of AQI at both the locations in the graphical view, which show the maximum AQI in November month for location S2 and in January month for location S1.

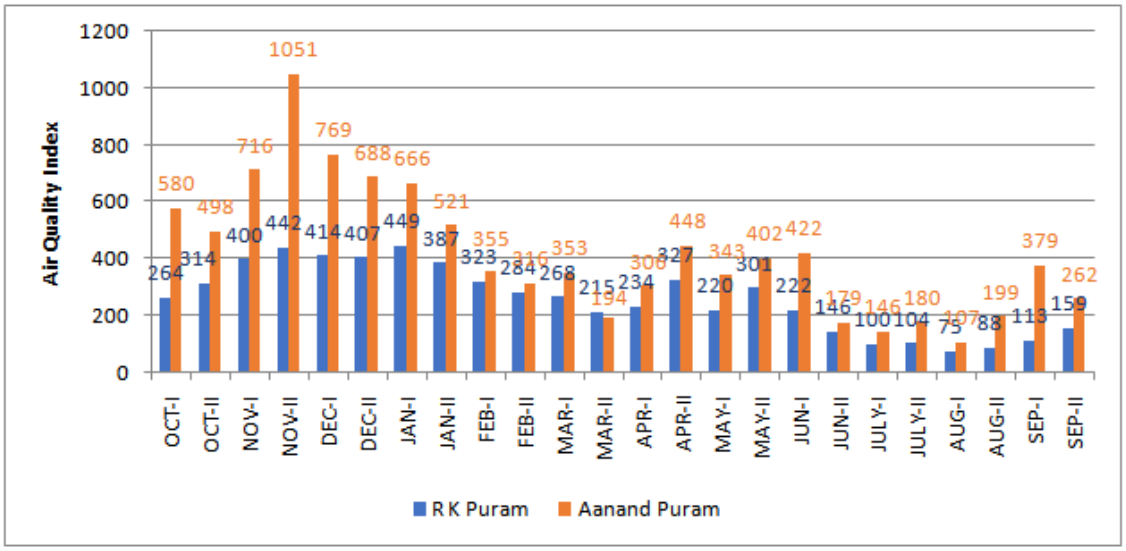


Figure 4.9 show the comparison analysis of AQI at both the locations in the graphical view, which show the maximum AQI in November month for location S2 and in January month for location S1.

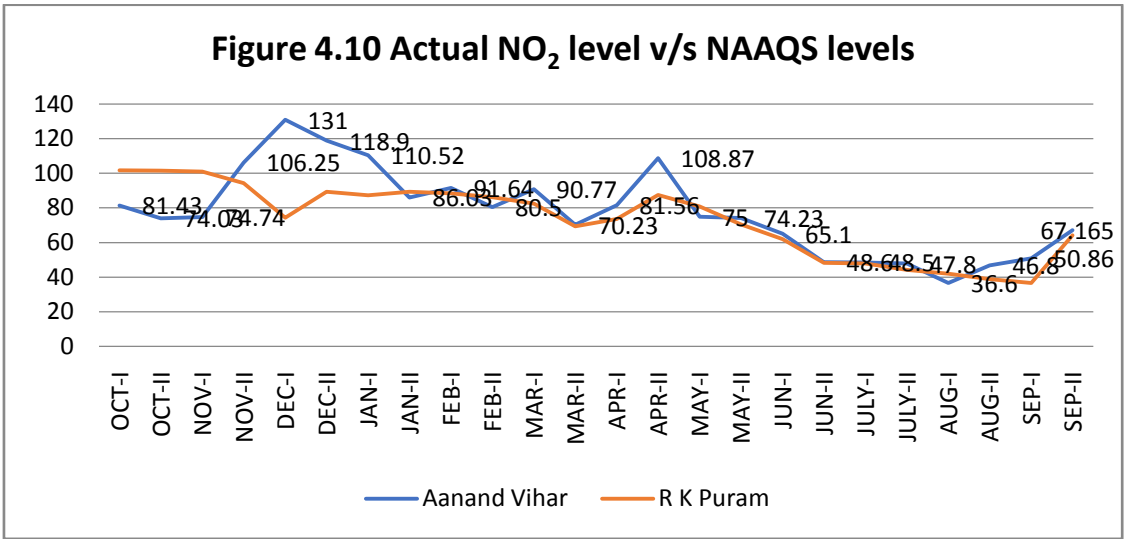


Figure 4.10 shows the NO_2 trend over the year for both the locations. It is clear that maximum time in the Location S2 NO_2 level is higher. As we discuss in theoretical consideration 2.5.2, NO_2 concentration in environment increases due to combustion process and due to Location S2 ISBT, transportation CNG bus and diesel bus are very frequent that is why increment in NO_2 level. According to NAAQS standard permissible level of NO_2 is also shown on the figure separate for residential and industrial area. (Blue line for industrial and red line for the residential area).

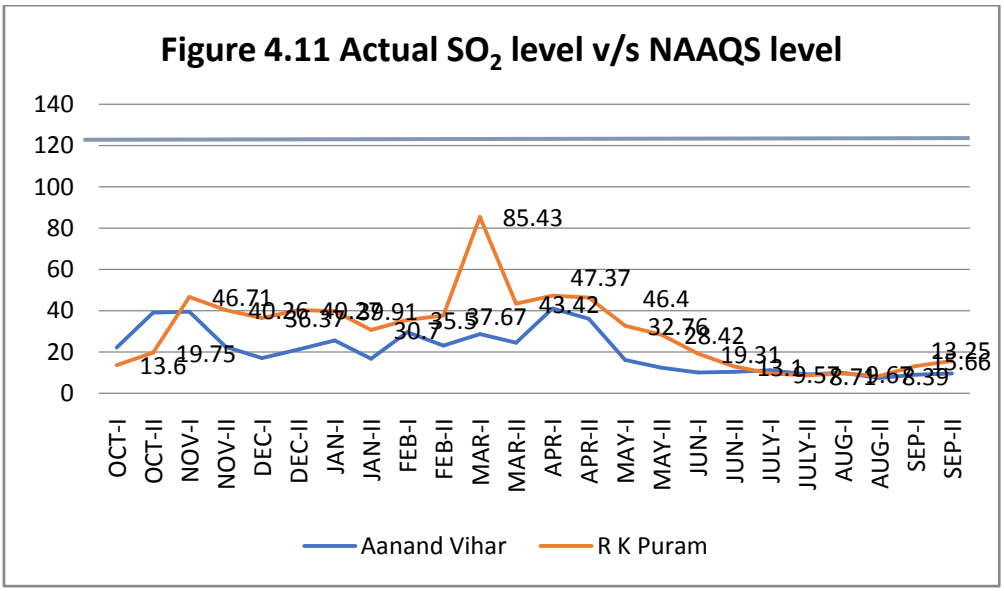


Figure: 4.11 shows the actual SO_2 level over the year for both the locations. In Location S1, SO_2 level is higher than industrial area most of the time. According to NAAQS standard permissible level of SO_2 is also shown on the figure separate for residential and industrial area. (Blue line for industrial and red line for the residential area).

In this chapter trend of the air quality in Delhi city was analyzed for different locations. From both location's AQI data, it was found that air quality follows the same trend at both the locations, its values may differ according to land area use and surrounding conditions, but it represents the same trend of air pollution maximum in winter, after that it decreases to a minimum in summer or monsoon. Future forecasting for air pollution is possible after this study. To find out the source allocation SO2 and NO2 level was also analyzed at both the locations but the results required further analysis of the wind rose diagram to understand the results obtained in this study.

References

[1]. Ishii, S., Marshall, F. M., Bell, J. N. B., & Abdullah, A. M. (2004). Impact of ambient air pollution on locally grown rice cultivars (Oryza sativa L.) in Malaysia. Water, air, and soil pollution, 154(1-4), 187-2011

[2]. Bahauddin, K. M., & Uddin, T. S. (2010, September). Status of particulate matter and its impact on roadside population of Dhaka City, Bangladesh: A review study. In Proceeding of international conference on environmental aspects of Bangladesh (ICEAB10), Japan (pp. 125-128).

[3]. Banerjee, T., & Srivastava, R. K. (2011). Assessment of the ambient air quality at the Integrated Industrial Estate-Pantnagar through the air quality index (AQI) and exceedence factor (EF). Asia-Pacific Journal of Chemical Engineering, 6(1), 64-70.

[4]. Bishoi, B., Prakash, A., & Jain, V. K. (2009). A comparative study of air quality index based on factor analysis and US-EPA methods for an urban environment. Aerosol and Air Quality Research, 9(1), 1-17

[5]. Shooter, D., & Brimblecombe, P. (2009). Air quality indexing. International Journal of Environmental Pollution, 36(1-3), 305-323.

[6]. Chandrasekar, N., Kumaresan, S., & Jayasekhar, T. (2002). A study on air pollution in Tuticorin. INDIAN JOURNAL OF ENVIRONMENTAL PROTECTION, 22(12), 1331-1336.

[7]. Chauhan, A., Pawar, M., Kumar, R., & Joshi, P. C. (2010). Ambient air quality status in Uttarakhand (India): a case study of Haridwar and Dehradun using air quality index. Journal of American Science, 6(9), 565-574

[8]. Chattopadhyay, S., Gupta, S., & Saha, R. N. (2010). Spatial and temporal variation of urban air quality: a GIS approach. Journal of Environmental Protection, 1(03), 264.

[9]. Jain, S., & Khare, M. (2008). Urban air quality in mega cities: a case study of Delhi City using vulnerability analysis. Environmental monitoring and assessment, 136(1-3), 257-265

[10]. Chauhan, A., Pawar, M., Kumar, R., & Joshi, P. C. (2010). Ambient air quality status in Uttarakhand (India): a case study of Haridwar and Dehradun using air quality index. Journal of American Science, 6(9), 565-574.

[11]. Croft, P. J., & Melendez, B. V. (2009). Investigation of the Air Quality Index as related to weather regime. Natl Weather Dig, 33, 132-153

[12]. Dayal, H. V., & Nandini, S. N. (2000). Vehicular emissions and ambient air quality in Bangalore city. Pollution Research, 19(2), 205-209

[13]. Dockery, D. W., Speizer, F. E., Stram, D. O., Ware, J. H., Spengler, J. D., & Ferris Jr, B. G. (1989). Effects of Inhalable Particles on Respiratory Health of Children1-4. Am Rev Respir Dis, 139, 587-594

[14]. Genc, D. D., Yesilyurt, C., & Tuncel, G. (2010). Air pollution forecasting in Ankara, Turkey using air pollution index and its relation to assimilative capacity of the atmosphere. Environmental monitoring and assessment, 166(1-4), 11-27

[15]. Green, M. H. (1966). An air pollution index based on sulfur dioxide and smoke shade. Journal of the Air Pollution Control Association, 16(12), 703-706.

[16]. Beig, G., Ghude, S. D., & Deshpande, A. (2010). Scientific evaluation of air quality standards and defining air quality index for India. Indian Institute of Tropical Meteorology.

[17]. Kumar, A., Garg, A., & Pandel, U. (2011). A study of ambient air quality status in Jaipur city (Rajasthan, India), using air quality index. Nature and Science, 9(6), 38-43.
[18]. "Delhi's Air Has Become a Lethal Hazard and Nobody Seems to Know What to Do About It". Time magazine. 10 February 2014. Archived from the original on 2 March 2014. Retrieved 10 February 2014.
[19]. India's Air Pollution Triggers Comparisons with China". Voice of America. Archived from the original on 21 February 2014. Retrieved 20 February 2014
[20]. A Delhi particular". The Economist. 6 November 2012. Archived from the original on 6 November 2012. Retrieved 6 November 2012.

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