MONITORING OF AMBIENT AIR QUALITY IN COIMBATORE CITY FOR FUTURE OUTLOOK

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Abstract : Air quality considered to be a significant environmental health challenge in Indian cites as well as in most of the metropolitan cities around the world. Contributing factors to air pollution in cities are rapidly growing fleets of vehicles with poor quality exhaust emissions and poor maintenance. This study focuses on monitoring of particulate matter in Coimbatore city. In order to monitor the particulate matter near busy road junctions in Coimbatore city, 6 busy road junctions were selected. In all these stations, ambient air quality monitoring was conducted for a period of 2 years from January 2011 to December 2011. Air quality monitoring was conducted on, two selective days for each month, during January 2011 to December 2011. The concentration of PM_{10}, $PM_{2.5}$, The concentrations of PM_{10}, $PM_{2.5}$, at AAQMS 6 were found to be the highest among all the stations investigated. The concentration of PM_{10} at all stations varied from 98.5 µg/m^3 to 152.5 µg/m^3. The concentration of $PM_{2.5}$ at all stations varied from 16 µg/m^3 to 49.8 µg/m^3.

Keywords: *Ambient air quality, Exhaust emissions, Heterogeneous traffic, Particulate matter, PM10 , PM2.5*

1. INTRODUCTION

The greatest impact of the industrial revolution on people's life is the manufacture of automobiles. Motorization has brought unprecedented mobility and an extremely convenient form of transport for men and goods while creating new opportunities for employment. One of the important sources of air pollution is the vehicular exhaust emission. Study of emissions from automobiles, their transport and transformation at the urban scale are complex tasks. Air pollution is a serious public health problem in most metropolitan areas around the world. Vehicles with poor quality emission and poor maintenance are significant contributors to air pollution in cities. Air Pollutants are fine particles and gaseous contaminants that are let into the atmosphere from various sources. These air pollutants cause physiological responses in organisms and a wide range of health effects in humans. Among the various sources contributing to air pollution, the automobiles have emerged as the largest source for urban air pollution. Because of versatility, flexibility and low initial costs, there has been a boom in the manufacturing and usage of different types of vehicles. This has resulted in deterioration of air quality (**Longhurst et al. 2000**).

Most of the cities suffer from serious outdoor air pollution due to improper maintenance of vehicles (**Ravindra 2003**). The increased demand of vehicles has increased the emission of air pollutants into the atmosphere (**Tecer 2008**). Such activities cannot be stopped as they are directly related to the development of the society. This type of development and urbanization brings with them the unwanted air pollutants, namely Suspended Particulate Matter measured as PM_{10} and $PM_{2.5}$, Sulphur dioxide (SO_2), Oxides of Nitrogen (NO_X), etc. It has been recognized that particulate matter (PM) is one of the most globally, important environmental threats (**Brauer et al. 2015 and Thurston et al. 2016**). In most of the cities the level of $PM_{2.5}$ exceeds the National Ambient Air Quality Standard 40 µg/m^3 (**Venkataraman et al. 2018**).

Automobile exhaust pollution in India

In most of the metropolitan areas of the world, transportation facilities are improving every year in order to meet increased demand. As a result, more and more vehicles are added to the roadways. Vehicular traffic has become a major source of air pollution in urban areas. The rapid growth of motor vehicles ownership and activities in Indian cities are causing serious health, environmental and socio-economic impacts (**Badami 2009**). The rapidly growing vehicle fleet, distance travelled by each vehicle and change in land use pattern are some of the primary causes of vehicular air pollution and consequently the urban air pollution. (**Mayer 1999**).In India, the motor vehicle population has increased from nearly 0.3 million in 1951 to 115 million in 2009, of which two wheelers accounts for approximately 70% of the total vehicles (**CPCB 2010**). Two wheelers combined with cars account for approximately 80% of the total vehicles. Vehicular emission is the major contributor of urban air pollution in most of the cities in India and estimated to account for 70% of CO, 50% of HC, 30% to 40% of NO_X, 30% of SPM and 10 % of SO_2 of the total pollution load. Two third is contributed by two wheelers alone (**Sharma and Maloo 2005**). In India, specifically in Delhi, vehicular emissions contribute 67% of the total air pollution load, which is approximately 3,000 metric tons per day. The results of air analysis must be made known to the public to protect the society from injury and the products from contamination. Hence, determination of pollution level in the atmosphere is important in a toxicological perspective. Average values of PM_{10} and $PM_{2.5}$ concentrations have been found to be 26 µg/m^3 and 18 µg/m^3 under ambient conditions in the city of Hyderabad during the year 2003 (**Latha and Badarinath 2005).** Vehicular emissions are a prime source of polycyclic aromatic hydrocarbons (PAH) and heavy metals. Other traffic related heavy metal pollutants include Fe, Zn, Cu, Cr, Pb, Cd, Ni, Mn and CO (**Omar Ali Al-Khashman, 2007**).

The previous studies in Coimbatore city, on seasonal variation of suspended particulate matter with reference to wind direction show that, the SPM concentration is found to be more in January to March, due to high humidity and low wind velocity (**Tandon et al. 2008**). The elemental composition analysis of ambient air sample of Coimbatore has revealed the presence of heavy metals concentration associated with respirable and non-respirable fractions of suspended particulate matter. The concentration of heavy metals found in the ambient air are in the order : Zinc > Copper > Lead > Nickel > Cadmium (**Mohanraj 2004**). Seasonal variations of PM_{10} and $PM_{2.5}$ have been observed to be maximum during winter and minimum during monsoon.

An attempt has been made in this study to conduct Ambient air quality monitoring to monitor parameters such as PM_{10}, $PM_{2.5}$, SO_2, NO_X, CO, O_3 and NH_3 near all the 6 busy road junctions in Coimbatore city during the period from January 2011 to December 2011.

2. DESCRIPTION OF THE STUDY AREA

The Coimbatore city located at 11.0161°N 76.971°E. It is in the extreme west of Tamil Nadu and near Kerala state. The elevation of Coimbatore city is + 432.50. It is surrounded by mountains on the west and on the north. The location map of the study area is shown in **Figure 1**. The city has a tropical wet and dry climate. The wet season being from October to December, due to the northeast monsoon. The mean maximum and minimum temperature varies between 35°C and 18°C. The average annual rainfall is around 700 mm with the North East and the South West monsoons contributing to 47% and 28% respectively.The soil is predominantly black, which is suitable for cotton cultivation.Coimbatore falls under the Class III Seismic Zone,

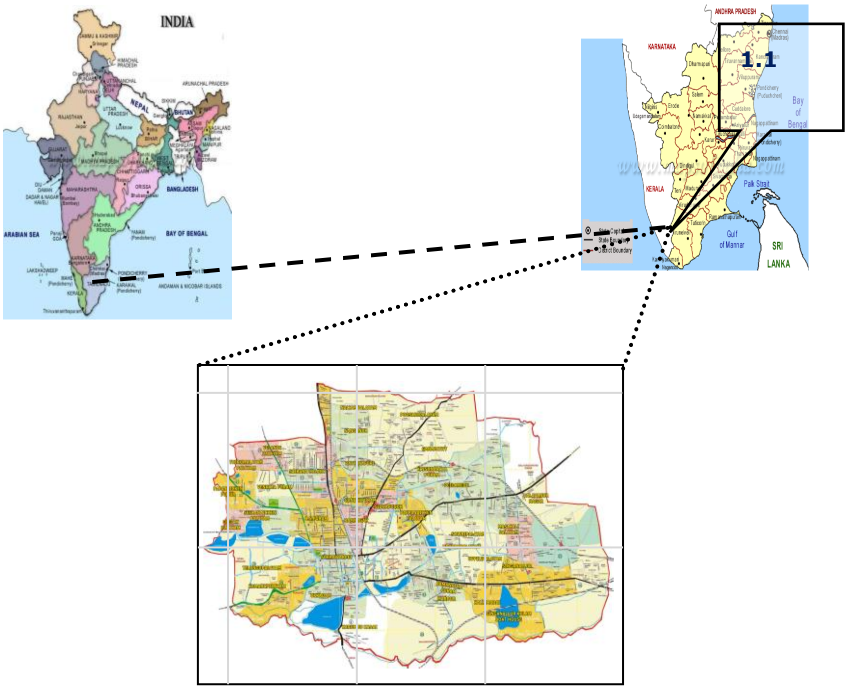

Figure 1 Location map of the study area

Description of Roads and Junctions

There are six major arterial roads in the Coimbatore city; namely, Avinashi Road, Trichy Road, Sathyamangalam Road, Mettupalayam Road, Palakkad Road and Pollachi Road. There are three National Highways passing through the city:

- NH-47 Salem to Kanyakumari
  (via. Coimbatore, Palakkad, Kochi, Kollam, Trivandrum)
- NH-67 Nagapattinam to Gundlupet
  (via. Thanjavur, Tiruchirapalli, Karur, Coimbatore, Udagamandalam)
- NH-209 Dindigul to Bangalore
  (via. Palani, Pollachi, Coimbatore, Sathyamangalam, Chamrajnagar, Kollegal)

Apart from state and National Highways, the city corporation maintains 635.32 kilometres (394.77 miles) long road network. Coimbatore has several major bus stations namely, 1. Gandhipuram Bus Station, 2. Ukkadam Bus station, 3. Singanallur Bus Station, 4. Mettupalayam Bus Staiton and 5. Omni Bus Station. The town buses (intra-city) operate from the town bus stand in Gandhipuram to other bus stands across the city. Inter-city and intra-city buses that connect Coimbatore with other places operate from different bus stands as shown in Table 1.

Table 1 Inter-city and Intra-City Buses that Connect Coimbatore (Courtesy: Road Transport Corporation, Coimbatore)

Sl. No.	Bus stand	Services	Approximately No. of Busses Plying daily
1	Gandhipuram Central Bus stand	Erode, Gobichettipalayam, Sathyamangalam, Tirupur, Salem etc.	992
2	Gandhipuram Town Bus stand	All town services touching Gandhipuram.	4263
3	Singanallur Bus stand	Madurai, Trichy, Thanjavur, Kumbakonam etc.	783
4	Ukkadam Bus stand	Palakkad, Palani, Pollachi, Udumalpet etc.	679
5	Mettupalayam Road Bus stand	Mettupalayam, Ooty, Mysore etc.	757

6	SETC Bus stand	Express buses to Chennai, Bangalore, Hyderabad, Pondicherry etc.	229
7	Omni Bus Stand	Private Omni buses	164

Ambient Air Quality Monitoring Stations

The Ambient Air Quality Monitoring Stations were chosen on the basis of maximum vehicular usage. In order to assess the impact of automobile emissions on the ambient air quality of Coimbatore City, the following Ambient Air Quality Monitoring Stations (AAQMS) were selected:

AAQMS 1: Near Gandipuram bus terminal junction
AAQMS 2: Near Railway station junction
AAQMS 3: Near Ukkadam bus terminal junction
AAQMS 4: Near Hope College Junction – Peelamedu
AAQMS 5: Near Lawley road junction
AAQMS 6: Near Mettupalayam road bus terminal junction

All the 6 Monitoring stations are indicated in Figure 2**.** They are totally urbanized with continuous traffic inflow and highly populated, and represent Coimbatore's traffic intensity. The photographic view of all the six Monitoring stations is shown in the Figures 3 to 8.

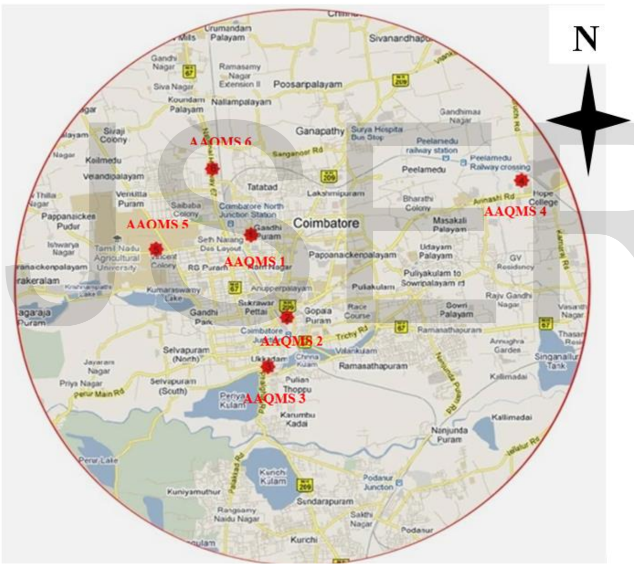

Figure 2 Location of Ambient Air Quality Monitoring Stations

Figure 3 Photographic View of AAQMS 1

Figure 4 Photographic View of AAQMS 2

Figure 5 Photographic View of AAQMS 3

Figure 6 Photographic View of AAQMS 4

Figure 7 Photographic View of AAQMS 5

Figure 8 Photographic View of AAQMS 6

Description of AAQMS 1

It is a junction of 4 major roads. Sakthi road on North, Nanjappa road on the South, Bharathi road on the east and cross cut road on the west. In addition to that, Town bus terminal, State Express Transport Corporation terminal and Omni bus terminal are nearby. More number of vehicles cross this junction. Hence, this location is station. The monitoring equipment was kept in the first floor (terrace) of municipal shopping complex.

Description of AAQMS 2

It is a junction of 2 major roads and a railway junction. Singanalloor road on South (This road is diverged to West for connecting Ukkadam) and Gandhipuram road on North. The railway junction connects various cities of Tamilnadu and other states. This is one of the major road in the south side of the Coimbatore so more number of vehicles cross this junction. Hence this location is station. The monitoring equipment was kept in the first floor (terrace) of a commercial complex.

Description of AAQMS 3

It is a junction of 3 major roads. Pollachi / Palakad road on south, Perur road on West and Railway station road on North. In addition to that, Town bus terminal is nearby. This is one of the major road in south side of the Coimbatore which connects Industrial clusters and many Institutions so more number of vehicles cross this junction. Hence this location is station. The monitoring equipment was kept in the first floor (terrace) of a hotel building.

Description of AAQMS 4

It is a junction of 2 major roads. Avinashi road on East and Gandhipuram road on West. This is one of the major road in East side of the Coimbatore which connects many Institutions and Airport so more number of vehicles cross this junction. Hence this location is station. The monitoring equipment was kept in the first floor (terrace) of a commercial building.

Description of AAQMS 5

It is a junction of 4 major roads. Thadagam road on North, Gandhi park road on South, Cowley brown road on East and Maruthamalai road on West. This is one of the major junction in West side of the Coimbatore which connects many Institutions and Maruthamali temples so more number of vehicles cross the junction. Hence this location is station. The monitoring equipment was kept in the first floor (terrace) of a commercial building.

Description of AAQMS 6

It is a junction of 2 major roads. Gandhipuram road on South and Ooty road on North. This is one of the major road on North side of Coimbatore which connects many small scale industries and tourist places so more number of vehicles cross this road. Hence this location is station. The monitoring equipment was kept in the first floor (terrace) of a commercial complex.

The Figures 9 to 14 show the photographs of the ambient air quality sampling at six sampling stations in Coimbatore.

Figure 9 Ambient Air Quality Monitoring at AAQMS 1

Figure 10 Ambient Air Quality Monitoring at AAQMS 2

Figure 11 Ambient Air Quality Monitoring at AAQMS 3

Figure 12 Ambient Air Quality Monitoring at AAQMS 4

Figure 13 Ambient Air Quality Monitoring at AAQMS 5

Figure 14 Ambient Air Quality Monitoring at AAQMS 6

3. INSTRUMENTS, DATA AND METHODS

Air Quality Monitoring

In all the ambient air quality monitoring stations, the monitoring was conducted on selected two days every month using Ambient Respirable and fine Dust Samplers. The period of monitoring is from 7 A.M to 7 P.M (12 hours monitoring). For CO, the period of sampling is 8 hours. In all these ambient air quality monitoring stations, PM_{10}, $PM_{2.5}$, SO_2, NOX, CO, O_3 and NH_3 were monitored. The air quality monitoring at all the stations were conducted for a period from January 2011 to December 2012.

Methodology for PM_{10} Measurement

The PM_{10} fraction of Suspended Particulate Matter was collected using Ambient Respiarable Dust Sampler. It consists of a suction pump, calibrated air flow meter, filter holder, timer and accessories. Air is drawn through the sample filter at a controlled flow rate by a pump located downstream of the sampler. The equipment was operated continuously for 24 hrs at each sampling site and monitoring was performed for two days for every month.

The filter paper was conditioned at 105° C in oven and numbered before weighing. The filter paper was then fixed in position with the face plate and gasket on Ambient Fine dust sampler. Similarly, a pre-weighed cup was attached to the cyclone at the bottom. The cyclone attachment separates the particles of size above 10 µ and allows them to settle down in the cup. The particles below 10 µ size will settle on to the pre weighed filter paper. Initial and final manometer readings must be noted. After the sampling is done, the filter paper and the cup were removed and labeled. The filter paper was then weighed in a sensitive balance after stabilizing in controlled humidity (40%) and temperature (25° C). The mass concentration is calculated by measuring the weight of collected matter in known volume of air sampled.

Methodology for PM $_{2.5}$ Measurement

Ambient fine dust sampler can be used to determine the concentration of particulate matter of size less than 2.5 µ in atmosphere. PTFE (Poly-tetra-fluoro-ethylene) filters are employed to obtain atmospheric particulate matter samples for mass concentration determination and for subsequent measurement of a wide variety of trace elements. The instruments are continuously operated for 24 hours.

Air is drawn through the sample filter at a controlled flow rate by a pump located downstream of the sample filter. The flow rate is set and size selective inlets are used to remove particles larger than the specified aerodynamic size and the size cut off is based on sample flow rate. A WINS impactor assembly is used to capture particles greater than 2.5 µ. The loaded filters were carefully removed from the holder and stored in clean Petri dishes and kept under controlled humidity and temperature during sampling period to minimize losses due to volatilization and evaporation. The mass concentration is calculated by measuring the weight of collected matter in known volume of air sampled.

4. RESULTS AND DISCUSSION

The pollutant concentrations and CO concentrations recorded at six stations are depicted in Figures 15 to 26.

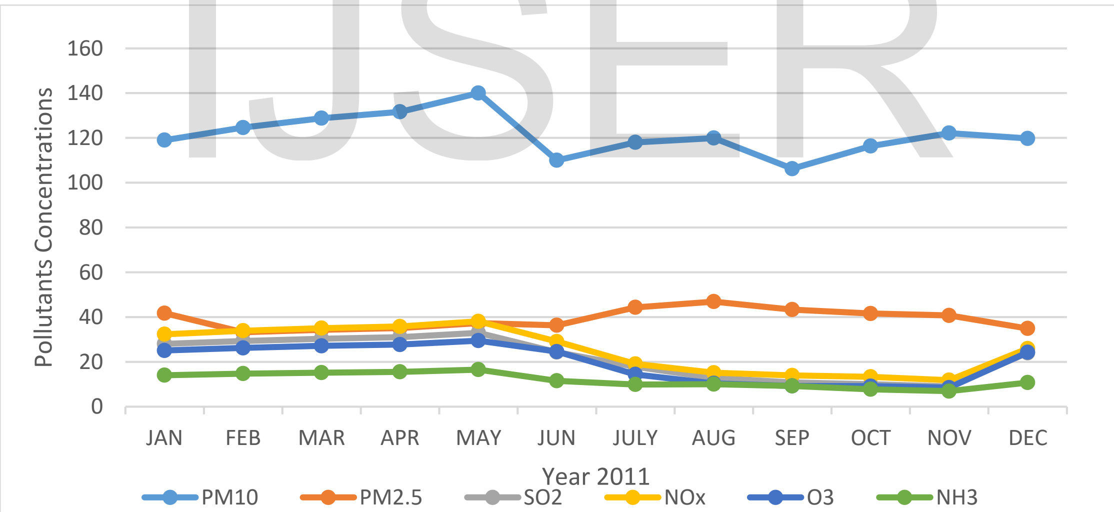

Figure 15 Pollutants Concentrations at AAQMS 1 for the year 2011

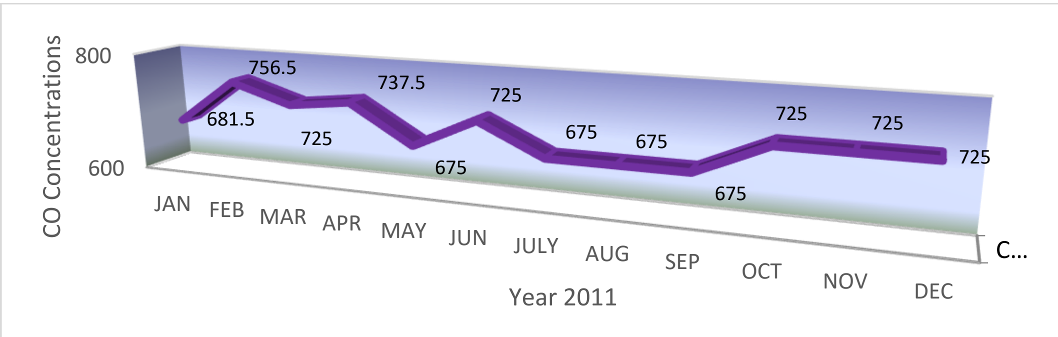

Figure 16 CO Concentrations at AAQMS 1 for the year 2011

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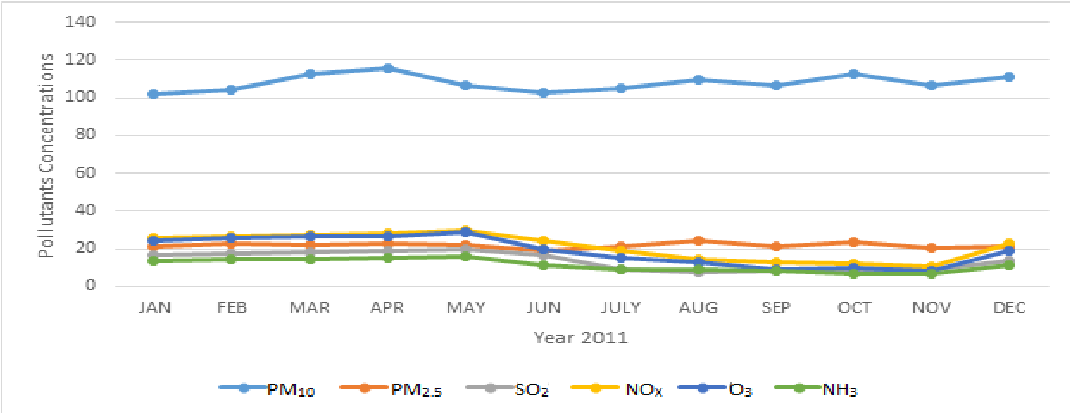

Figure 17 Pollutants Concentrations at AAQMS 2 for the year 2011

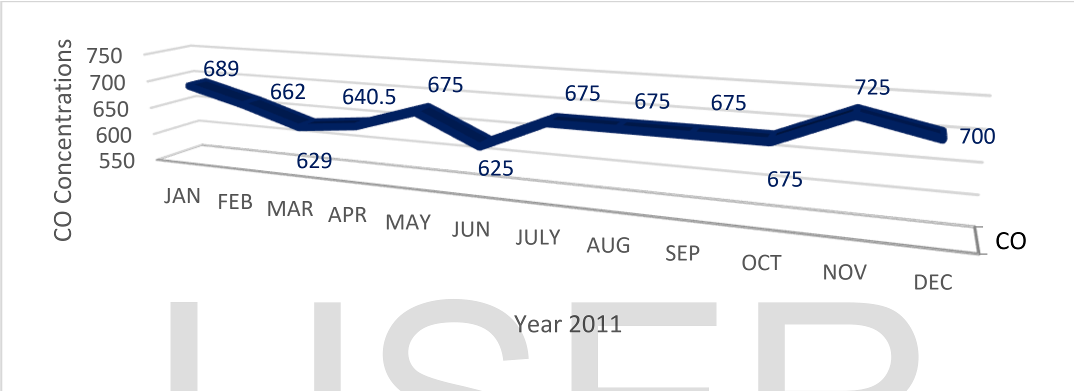

Figure 18 CO Concentrations at AAQMS 2 for the year 2011

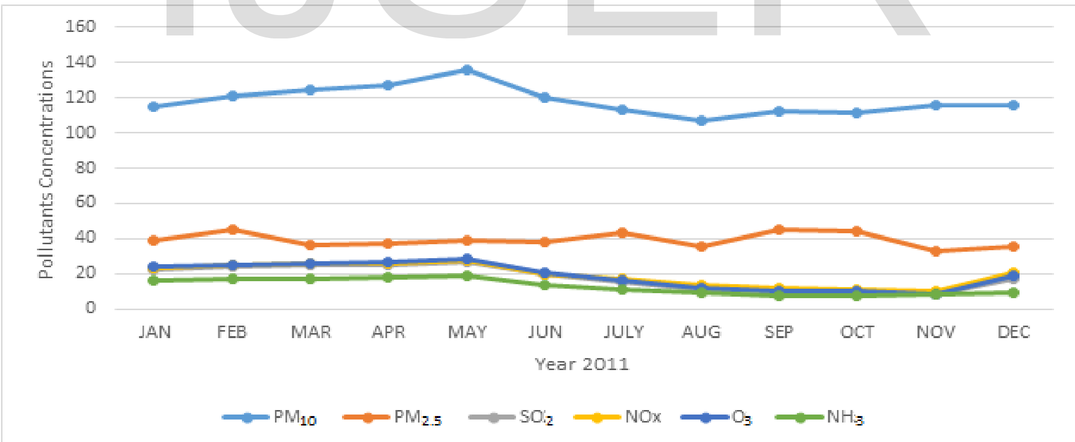

Figure 19 Pollutants Concentrations at AAQMS 3 for the year 2011

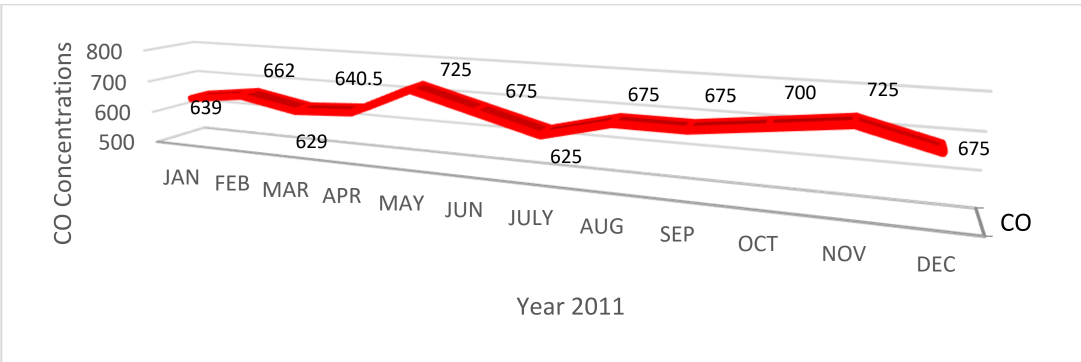

Figure 20 CO Concentrations at AAQMS 3 for the year 2011

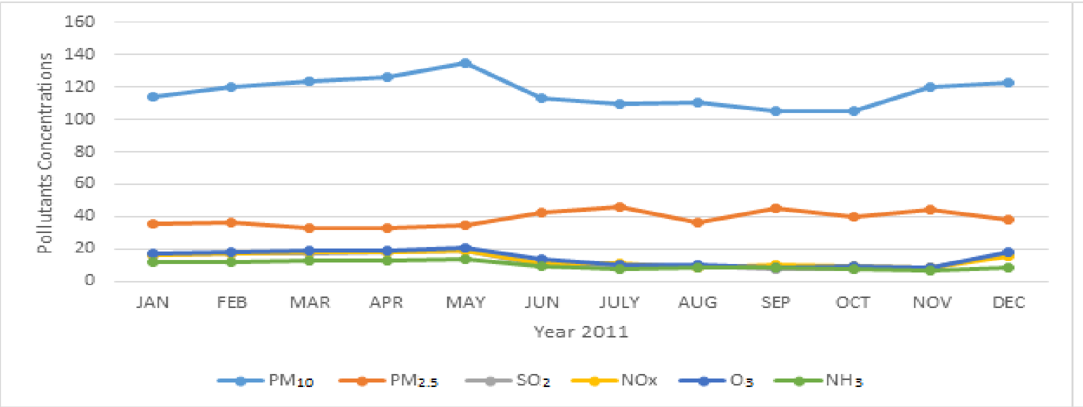

Figure 21 Pollutants Concentrations at AAQMS 4 for the year 2011

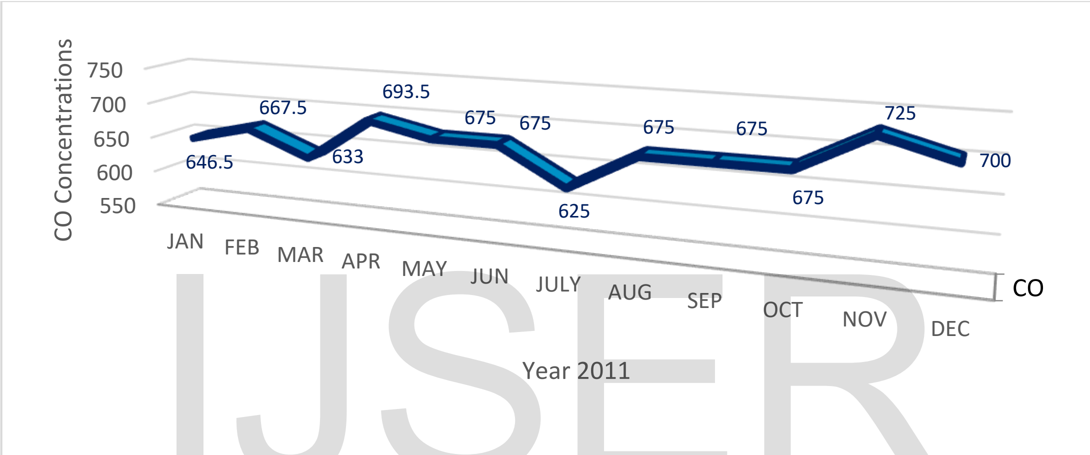

Figure 22 CO Concentrations at AAQMS 4 for the year 2011

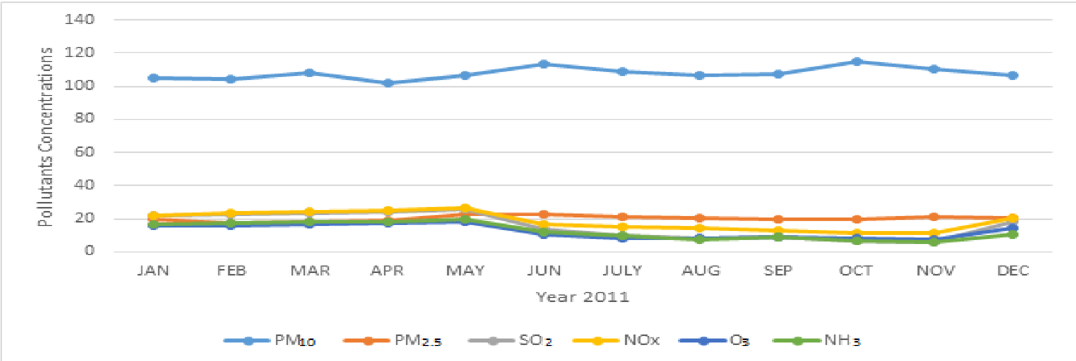

Figure 23 Pollutants Concentrations at AAQMS 5 for the year 2011

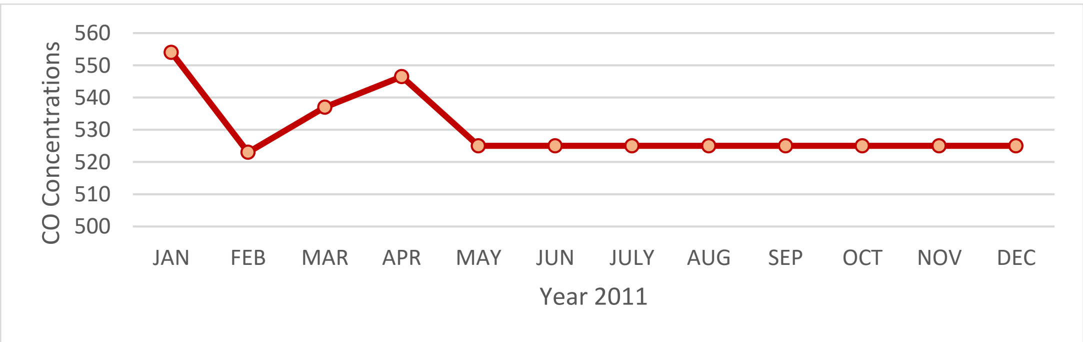

Figure 24 CO Concentrations at AAQMS 5 for the year 2011

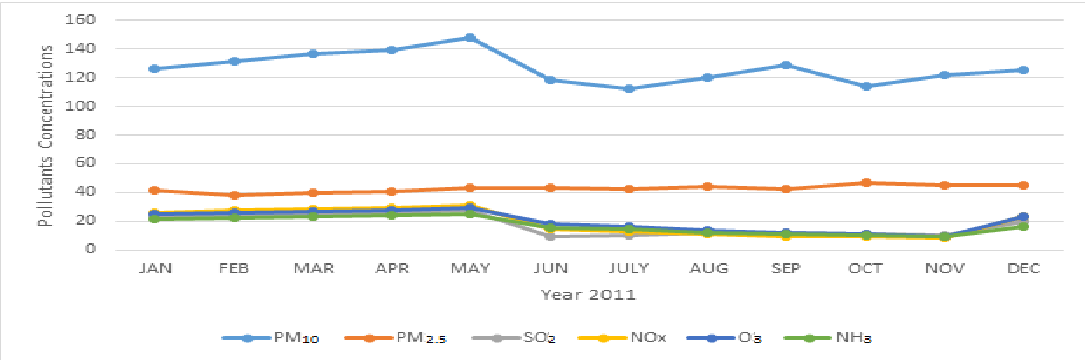

Figure 25 Pollutants Concentrations at AAQMS 6 for the year 2011

Figure 26 CO Concentrations at AAQMS 6 for the year 2011

Mean Concentrations of Air Pollutants during Pre-Monsoon Season in 2011

The pre-monsoon (May and June) mean concentrations of air pollutants were arrived at for the year 2011.

AAQMS 1

The pre-monsoon mean concentrations of air pollutants at AAQMS 1 were 125.0 µg/m3 of PM10, 36.85 µg/m3 of PM2.5, 28.68 µg/m3 of SO2, 33.60 µg/m3 of NOX, 700 µg/m3 of CO, 27.05 µg/m3 of O3 and 14.05 µg/m3 of NH3.

AAQMS 2

The pre-monsoon mean concentrations of air pollutants at AAQMS 2 were 104.90 µg/m3 of PM10, 20.53 µg/m3 of PM2.5, 18.23 µg/m3 of SO2, 26.95 µg/m3 of NOX, 650 µg/m3 of CO, 24.05 µg/m3 of O3 and 13.70 µg/m3 of NH3.

AAQMS 3

The pre-monsoon mean concentrations of air pollutants at AAQMS 3 were 127.95 µg/m3 of PM10, 38.75 µg/m3 of PM2.5, 23.45 µg/m3 of SO2, 23.70 µg/m3 of NOX, 700 µg/m3 of CO, 24.70 µg/m3 of O3 and 16.45 µg/m3 of NH3.

AAQMS 4

The pre-monsoon mean concentrations of air pollutants at AAQMS 4 were 124.0 µg/m3 of PM10, 38.80 µg/m3 of PM2.5, 14.55 µg/m3 of SO2, 15.15 µg/m3 of NOX, 675 µg/m3 of CO, 16.95 µg/m3 of O3 and 11.70 µg/m3 of NH3. Th

AAQMS 5

The pre-monsoon mean concentrations of air pollutants at AAQMS 5 were 110.10 µg/m3 of PM10, 23.05 µg/m3 of PM2.5, 19.65 µg/m3 of SO2, 21.25 µg/m3 of NOX, 525 µg/m3 of CO, 14.00 µg/m3 of O3 and 15.85 µg/m3 of NH3.

AAQMS 6

The pre-monsoon mean concentrations of air pollutants at AAQMS 6 were 133.05 µg/m3 of PM10, 43.05 µg/m3 of PM2.5, 18.50 µg/m3 of SO2, 23.05 µg/m3 of NOX, 725 µg/m3 of CO, 23.70 µg/m3 of O3 and 20.45 µg/m3 of NH3.

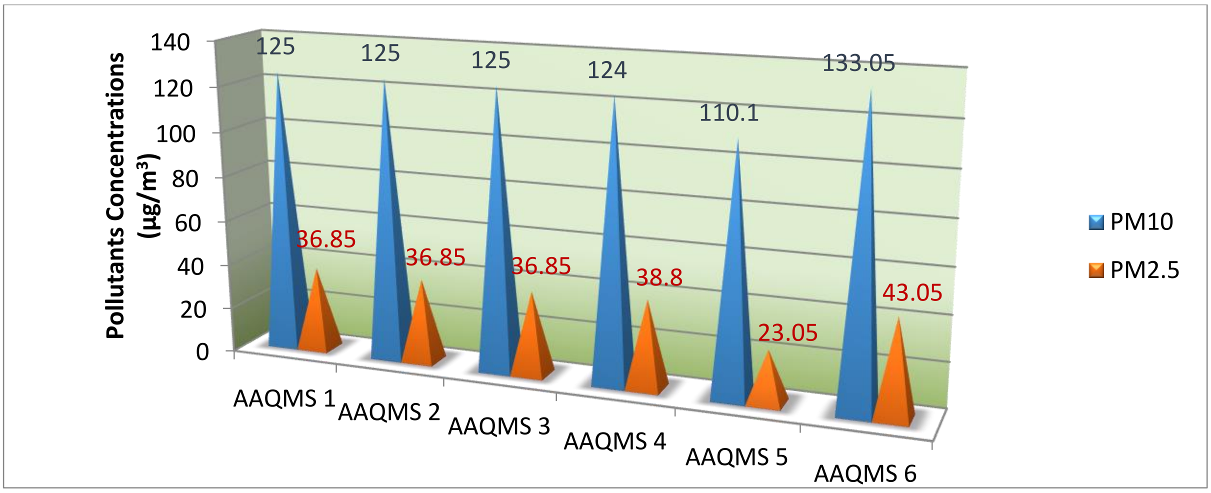

Figure 27 Mean Concentrations of PM_{10} and $PM_{2.5}$ during Pre-monsoon Season

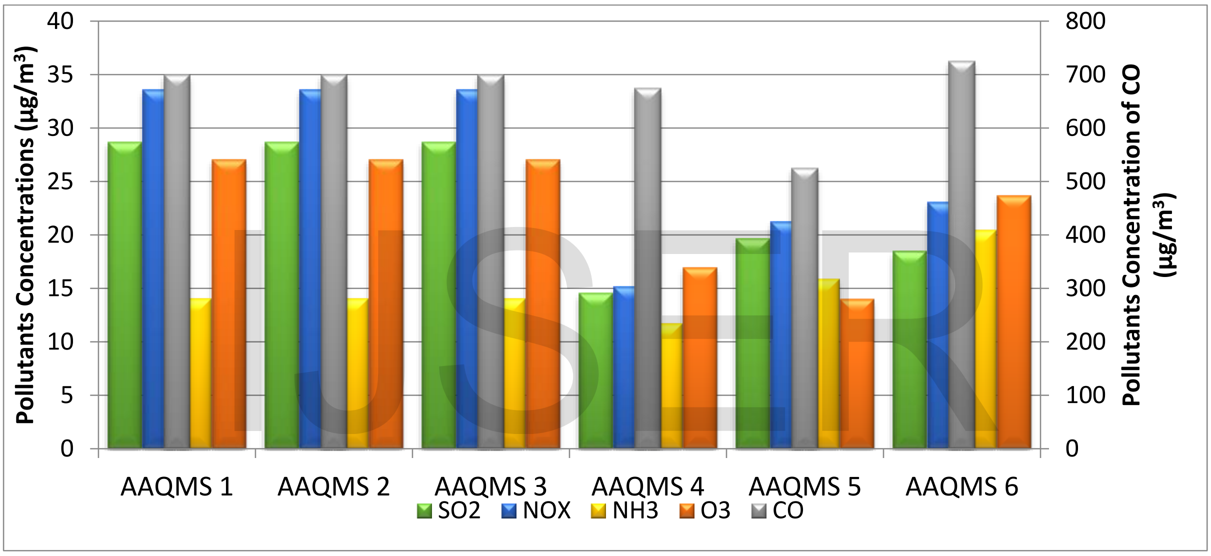

Figure 28 Mean Concentrations of SO_2, NOX, O_3, NH_3 and CO during Pre-monsoon Season

For the year 2011, it was observed that, for PM10 the minimum value has been recorded at AAQMS 3 and the minimum value was 98.5 µg/m^3. The maximum value of PM10 has been recorded at AAQMS 6 and the maximum value was 152.5 µg/m^3.

For the year 2011, it was observed that, for PM2.5 the minimum value has been recorded at AAQMS 3 and the minimum value was 16.0 µg/m^3. The maximum value of PM2.5 has been recorded at AAQMS 6 and the maximum value was 49.8 µg/m^3.

Mean Concentrations of air pollutants during Monsoon Season

The monsoon (July, August and September) mean concentrations of air pollutants were arrived at for the year 2011.

AAQMS 1

The monsoon mean concentrations of air pollutants at AAQMS 1 were 114.73 µg/m3 of PM10, 44.87 µg/m3 of PM2.5, 13.82 µg/m3 of SO2, 16.07 µg/m3 of NOX, 675 µg/m3 of CO, 11.35 µg/m3 of O3 and 9.73 µg/m3 of NH3.

AAQMS 2

The monsoon mean concentrations of air pollutants at AAQMS 2 were 107.22 µg/m3 of PM10, 22.52 µg/m3 of PM2.5, 8.32 µg/m3 of SO2, 15.37 µg/m3 of NOX, 675 µg/m3 of CO, 12.55 µg/m3 of O3 and 8.57 µg/m3 of NH3. Th

AAQMS 3

The monsoon mean concentrations of air pollutants at AAQMS 3 were 110.77 µg/m3 of PM10, 41.43 µg/m3 of PM2.5, 12.32 µg/m3 of SO2, 14.47 µg/m3 of NOX, 658 µg/m3 of CO, 12.78 µg/m3 of O3 and 9.23 µg/m3 of NH3.

AAQMS 4

The monsoon mean concentrations of air pollutants at AAQMS 4 were 108.55 µg/m3 of PM10, 42.40 µg/m3 of PM2.5, 8.62 µg/m3 of SO2, 9.90 µg/m3 of NOX, 658 µg/m3 of CO, 9.62 µg/m3 of O3 and 8.15 µg/m3 of NH3.

AAQMS 5

The monsoon mean concentrations of air pollutants at AAQMS 5 were 107.75 µg/m3 of PM10, 20.42 µg/m3 of PM2.5, 8.98 µg/m3 of SO2, 14.03 µg/m3 of NOX, 525 µg/m3 of CO, 8.05 µg/m3 of O3 and 8.78 µg/m3 of NH3..

AAQMS 6

The monsoon mean concentrations of air pollutants at AAQMS 6 were 120.63 µg/m3 of PM10, 43.32 µg/m3 of PM2.5, 11.58 µg/m3 of SO2, 11.02 µg/m3 of NOX, 692 µg/m3 of CO, 14.15 µg/m3 of O3 and 12.53 µg/m3 of NH3.

Overall Pollutants Concentration and CO concentration for the year 2011 is presented in Table 2 and in Figures 29 and 30.

Table 2 Overall Pollutants Concentrations for the year 2011

MONTHS	Parameters in µg /m ^{3}						
	PM_{10}	$PM_{2.5}$	SO_2	NOX	CO	O_3	NH_3
JAN	113.55	33.05	21.54	24.45	647.30	21.91	15.64
FEB	117.53	32.35	22.56	25.62	670.33	22.89	16.39
MAR	122.35	30.54	23.32	26.48	645.67	23.66	16.93
APR	123.63	31.26	23.83	27.05	665.50	24.22	17.32
MAY	128.58	33.26	25.35	28.78	666.70	25.82	18.41
JUN	113.91	33.99	15.74	19.78	670.83	18.54	12.90
JUL	110.65	36.63	13.05	16.34	629.16	13.64	10.45
AUG	112.41	34.68	10.10	12.95	658.33	11.22	9.48
SEP	111.16	36.32	9.7	11.80	650.00	9.64	8.81
OCT	112.36	36.00	8.92	11.11	662.50	9.60	7.90
NOV	116.05	34.22	8.56	10.12	683.33	8.64	7.45
DEC	117.09	32.52	18.29	21.53	675.00	19.61	11.05

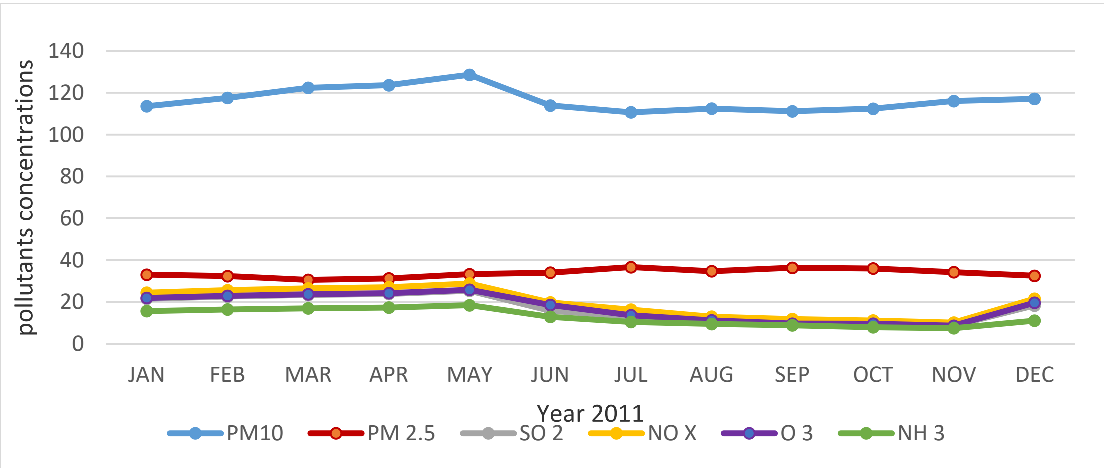

Figure 29 Overall Pollutants Concentrations for the year 2011

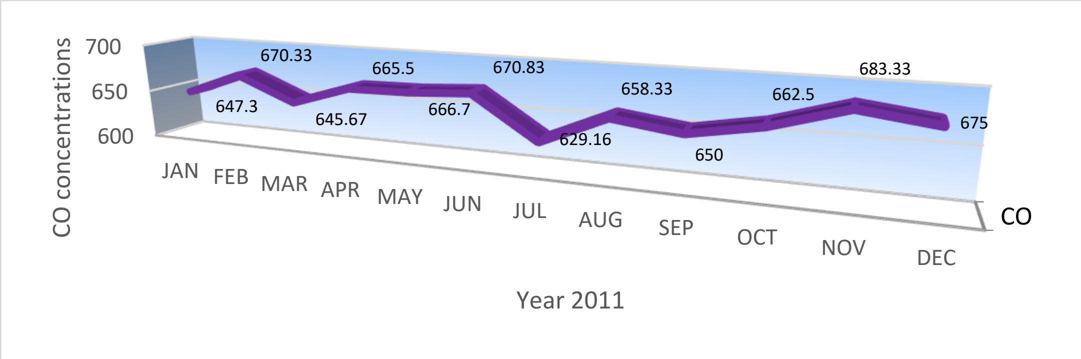

Figure 30 Overall CO Concentrations for the year 2011

5. CONCLUSIONS

The concentrations of PM10, PM2.5, CO and NH3 at AAQMS 6 are found to be the highest among the sites investigated during the pre-monsoon season. Similarly, the concentrations of SO_2, NOX and O_3 at AAQMS 1 found to be the highest among the sites investigated during the pre-monsoon season. The concentrations of PM_{10}, $PM_{2.5}$, O_3 and NH_3 at AAQMS 6 found to be the highest among the sites investigated during the Post monsoon season. Similarly, the concentrations of SO_2, NO_X, and CO at AAQMS 1 site found to be the highest among the sites investigated during the post monsoon period. The maximum value of PM_{10} $PM_{2.5}$ has been recorded at AAQMS 6 and the maximum value was 152.5 µg/m^3 and 49.8 µg/m^3

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