Air Quality Monitoring, Emission Inventory and Source Apportionment Study for Chennai

Project Summary Report

Chemical Engineering Department

I.I.T Madras

TABLE OF CONTENTS

Project Coordinators

Prof. S. Pushpavanam
Principal Investigator
Department of Chemical Engineering, IIT-Madras 600 036

Dr. S. Ramanathan
Co-Investigator
Department of Chemical Engineering, IIT-Madras 600 036

Dr. R. Ravikrishna
Co-Investigator
Department of Chemical Engineering, IIT-Madras 600 036

Dr. Shiva Nagendra
Co-Investigator
Department of Chemical Engineering, IIT-Madras 600 036

Chapter 1: Introduction

1.1 Background of the study

The air quality in Chennai city has been monitored over many years by Tamil Nadu Pollution Control Board (TNPCB) as well as independent academic institutes like IIT Madras. During these studies the levels of the gaseous pollutants NOx, SOx and the levels of particulate matter PM10 have been recorded. During festivals such as Bogi (before Pongal or Makara Sankranthi in mid January) there is a tradition of burning old clothes and tyres and tubes. This gives rise to increase in the pollution levels during this period. During the other major festival of Diwali it is a tradition to burst crackers. This again increases the emissions of toxic gases and here again the pollution level in the atmosphere is expected to be high.during these periods. The state pollution control board has been monitoring levels of various gases in many locations within in the city during these festivals. The stacks in the industrial areas have been monitored for total emission as well, since they fall under the preview of TNPCB.

In addition to these studies there are other reports where monitoring of the pollutants in the Chennai city has been done independently and these are available in the open literature.

With the improving economy and the rapid increase in the population of the urban areas in comparison to the rural areas the stress on the environment has increased drastically. With the improvement in the standard of living almost all households have access to a motorized vehicle either a scooter or a car. This affluence in the population has resulted in increasing pollution load in the big cities. The pollution levels as monitored by the macroscopic parameters PM10 and NOx emissions are definitely showing an increase.

It is hence important to determine the policy to be adopted by the government which can allow the city to develop at a comfortable pace without damaging the environment. This study focuses only on the air pollution and hence the atmosphere or the air quality with a view to identifying the contribution of the various sources to the air quality so that an effective policy can be chalked out for a holistic growth of the country without damaging the environment.

With the drastic increase in the number of motorized vehicles the question to be asked is how crucial is the contribution from vehicles to the air quality. More specifically this will help in determining the auto fuel policy in India by the government. This will in particular help decide whether the vehicles to be manufactured in the future need to go in for stricter environmental norms or whether the pollution levels have to be controlled by some other control policy. Do we need to change the quality of the fuel or do we need to go for a better technology for engines or for the exhaust gas treatment. Hence the contribution of the various sources to the pollution levels has to be determined so that the sensitive sources of pollution can be determined and necessary action can be taken.

To achieve this a detailed analysis of the composition of the particulate matter such as elements, ions, organic carbon and elemental carbon and molecular markers has to be determined. Qualitative as well as quantitative apportionment of pollution by various sources can then be achieved by Factor Analysis and Chemical Mass Balance. These results will be validated from the emission inventory study for the city of Chennai. This will be validated using micro meteorology measurements and dispersion modeling in the locations chosen and comparing the results with the concentrations measured at the monitoring sites.

1.2General Description of Chennai City

1.2.1 Climate: Chennai City experiences a tropical climate. It is in the coastal area with the Bay of Bengal on the eastern side. Thus the weather is typically hot and humid. Although the major seasons viz. summer, winter and monsoon are there, there is only a small variation between them due to the location and proximity to the Indian ocean.

Chennai gets most of the rainfall from the north east monsoon (mid September to mid December) while some rainfall is also there during the south west monsoon (July-August). The hottest time period is typically May-June with a maximum temperature of about 42^o C and the coolest period is January with a minimum temperature of about 20^o C. In addition to this the proximity of the Bay of Bengal results in wide spread showers whenever there is a depression or a tropical storm developing in the Bay of Bengal.

<u>Demographic information :</u>The latitude and longitude of the center of the city are E80^o 14'51" and N13^o 03' 40". The city area is about 70 sq. miles and the metro (overall) area is about 456 sq. miles. The elevation above the sea level is 6 m. The area that falls under Chennai overlaps with three districts (Chennai, Kanchipuram and Thiruvallur). The Chennai Metropolitan Development Authority (CMDA) reports that the population in the city area in 2001 was 43.4 lakhs and is expected to rise to 51 lakhs in 2011. The city population projection for the year 2021 is 58 lakhs. The population in the metro (overall) area in 2001 was 70 lakhs and is expected to rise to 87 lakhs in 2011.The metro population projection for the year 2021 is about 109 lakhs. The floating population in the year 2005 was about 2 lakhs.

1.2.2Source activities The different sources of air pollution in Chennai City are classified under the following categories Transport, Industries, Residential and Others.

1.2.2.1. Transport: All the four major modes of transport (viz. Air, Sea, Road and Rail) are in significant use in Chennai City. However, there is an extensive network of roads which criss-crosses the entire city and this mode i.e., road transport primarily influences the air quality. and hence is studied in more detail for this project. Most of the railways locomotives are electric engine and hence do not directly contribute to the air pollution in the city. Besides the rail network across the city is not very extensive. The MRTS, buses and autos (3 wheelers) are the common public transportation modes. Large number of privately owned 2 wheelers and four wheelers are also used as modes of transportation. Lorrys or trucks are used for transporting goods within the city.

The total length of roads in Chennai city is 2847 km. Out of that, 150 km is maintained by highways while the rest is maintained by the Chennai Corporation. Most of the roads are made of asphalt or unpaved, while 231 km are made of concrete. (refer to www.chennaicoporation.gov.in)

Major imports are conducted through the Chennai port and to some extent through the airport. Railways is also used for transportation of goods to and from other parts of the country.

1.2.2.2 Industries: Chennai can be divided into four areas, North, Central, South and West. The Northern part is primarily an industrial area comprising of petrochemical industries in the Manali area and other general industries in Ambattur. Southern Chennai also has an industrial area (Guindy Industrial Area) and the Western part near Sriperumbudur on Bangalore Highway is developing with new industries.

Manali area is the home to petroleum refinery (Chennai Petrochemical Corporation Limited or CPCL) and allied petrochemical industries. It is in the northern part of the city. Ennore, which is further north, has a thermal power plant. However it is at a sufficient distance from the city so that it may not contribute to the atmospheric pollution.

Ambattur area houses several small scale industries while the western area of Sri perumudur houses different automobile industries as Hyundai, Ford etc. It also houses telecom giants like Samsung and Nokia.

1.2.2.3. Domestic sources Central Chennai is mainly commercial and the West and South Chennai are mainly residential. The residential population relies mainly on LPG for cooking. The lower income classes use wood and kerosene for cooking. However the state government in a proactive step has issued free gas cylinders to each household to reduce the dependency on wood and kerosene.

Most shopping malls, big hospitals have their own diesel generators to overcome any disruption in power supply from the grid.

1.2.2.4. Others: In the miscellaneous category Crematoria, and roadside garbage burning are included as primary contributors to the air pollution. In Chennai, the crematoria have been made electric and the newer installations would use gas. Roadside garbage burning is still an issue. The city has garbage dumps in Kodingayur and Pallikaranai. Some of the solid waste in the dumps is burnt (unauthorized burning) occasionally and contribute to the air pollution.

In addition to this bakeries, restaurants , road side tea shops contribute to air pollution

1.3 Need for the study: Current status of work on air quality

Based on the information available in the CPCB website, the SOX and NOX in the residential area of Chennai city were less than 10 ug/m3 up to the year 2006, and the RSPM was in the range of 60 ug/m3, which is the upper limit specified by CPCB for residential areas.

IIT Madras is executing two projects which have been funded by the Swedish International Development Agency SIDA. This project involves monitoring air quality in the city of Chennai and identifying various sources of pollution which contribute to the air quality.

Indrani Gupta and Rakesh Kumar[1] have monitored the particulate matter (PM) from 1991 to 2003 in three locations in Chennai. Thiruvottiyur an industrial site, General Hospital a commercial site and Taramani a residential site. The monitoring at the residential site was restricted to the time period from 1999 to 2003 only. They have found that the levels of PM10 occasionally exceeded the allowed limit near the commercial site. The TSPM at the industrial site varied between 52 to 417 ug/m3, while the RSPM was in the range of 8 to 171 ug/m3. It is to be noted that, at times, the PM10 values exceeded the TSPM values, which may be due to difference in the monitoring method. The TSPM was measured using a high volume sampler while the PM10 was measured using a Respirable PM sampler. For the commercial site, the TSPM was in the range of 35 to 344 ug/m3, and the PM10 was in the range of 18 to 212 ug/m3. The residential site TSPM level was in the range of 30 to 158 ug/m3 and the PM10 was in the range of 19 to 101 ug/m3.

[1] Indrani Gupta and Rakesh Kumar, "Trends of particulate matter in four cities in India", Atmos. Environ. 40 (2006) 2552-2566.

Pulikesi et al.[2] have monitored the surface ozone concentration, NOX, respirable and total suspended particulate matter (RSPM, TSPM) and meteorological parameters at five sites in the summer of 2005. Kodungaiyur was the industrial site in the north Chennai region which would be affected by the pollution in the Manali petrochemical area. Koyambedu was chosen as the busy commercial zone, while Mandaveli was chosen as sensitive site since the monitoring was done near a hospital. Taramani was the residential site and Vallalar Nagar was the area with high population density and heavy traffic. It was reported that the 24 h average of NOX in industrial areas was about 61 ug/m3, in the residential areas was about 41 ug/m3, and in the sensitive area was about 15 ug/m3. The corresponding values for RSPM were 255, 102 and 51 ug/m3 for the industrial, residential and sensitive sites respectively. TSPM averages were reported as 77, 51 and 38 ug/m3 for the industrial, residential and sensitive sites. In this study, the TSPM and RSPM were measured using one sampler with the RSPM being captured in the filter while the particles with larger diameter being captured in a pouch. Even in this case, some of the TSPM values have exceeded the RSPM values and the reasons are not clear. The PM values in the Chennai city during the period of 2001-2004 in upwind, traffic and commercial sites were monitored and reported by Oanh et al.[3] .

However all these studies have been restricted to stand alone studies and were aimed at detecting the air quality levels prevailing. Specifically they cannot be used beyond determining the air quality levels prevailing. For instance these studies cannot establish the contribution of various sources to the pollution levels. The emission inventory data base for the city of Chennai has not been established in a way which can allow us to predict the growing loads and the pollution levels in the future. Dispersion modeling has not been attempted at the scale of the city to establish concentration contour profiles to determine the hot spots in the city using information from emission inventory and the meteorology. The contribution of the various sources in terms of pollution loads helps us analyse different control options and their combinations to determine which are the most

---

[2] M. Pulikesi, P. Baskaralingam, D. Elango, V.N. Rayudu, V. Ramamurthi, S. Sivanesan, "Air quality monitoring in Chennai, India, in the summer of 2005" J. Hazardous Mat. B136 (2006) 589-596.

[3] N.T. Kim Oanh, N. Upadhyay, Y-H.Zhuang, Z-P. Hao, D.V.S. Murthy, P. Lestari, J.T. Villarin, K. Chengchua, H.X. Co, N.T. Dung, E.S. Lindgren, "Particulate air pollution in six Asian cities. Spatial and temporal distributions, and associated sources" Atmos. Environ., 40 (2006) 3367-3380.

sensitive to be exercised so that the pollution levels can be kept at permissible levels. The present study has been designed to address these concerns.

1.4 Objectives and scope of the current study:

The current study aims to

i) Establish the emission inventory data base and determine the emission levels of various pollutants in particular NOx and PM10 levels at different categories of sites i.e. residential, kerbside and industrial site in addition to a back ground site according to standard protocols.

ii) Two sites would be chosen to belong to each category and the emission load would be determined by carrying out a primary inventory survey in a 2X2 km square area around monitoring sites.

iii) Speciating the PM10 to determine the contents of elements, ions, organic carbon, elemental carbon and molecular markers. Qualitatively and quantitatively estimating the contributions of various sources using factor analysis and chemical mass balance. Validating and confirming the predictions by checking with the emission inventory study conducted.

iv) In addition to this we would also monitor the levels of NOx, SOx and aldehydes in the gaseous phase.

v) Determining the micro-meteorology around each of the monitoring sites. Using a dispersion model to determine the concentration levels in the monitoring area and comparing with the experimentally observed values.

The scope of the work involves

i) Taking into account the population growth and vehicular growth and predicting the pollution loads for the entire city of Chennai in the years 2012 and 2017.

ii) Evaluating different control options and identifying the most sensitive option which would give a drastic reduction in the concentration levels.

iii) Helping the government formulate a policy to allow for feasible growth without compromising on air quality.

1.5 Approach used in the study

The approach used in this study can be best understood by analyzing Figs 1.1 and 1.2. The former depicts the interactions of the different aspects of the study. We first establish the seven receptor sites such that two belong to residential, kerbside and industrial areas and one is a back ground. A 2X2 km area around the monitoring point was chosen to carry out a detailed primary emission inventory study. The different categories of the contributors were identified and a quantitative load of pollution was obtained. These were categorized as point, line or area sources.

The concentrations of the particulate matter PM10, RSPM and other gaseous pollutants were measured using an internationally accepted protocol. The PM10 and PM2.5 levels were measured and speciated to establish contents of elements, ions and carbon levels.

This is used to determine the contribution of various sources to concentration levels at a point using receptor modeling. This in turn is validated with the primary emission inventory study.

The emission inventory data based is used as an input along with the micro-meeorology measured to the dispersion model which is used to predict the concentrations in the areas chosen. This is then verified by the values obtained from the field study.

The approach described above is first validated for the seven sites chosen. After establishing the approach we move on to the next phase which involves As shown in Fig.6.2 we then extend the study to the entire city of Chennai. For this purpose we compute the per capita emission in each class of grid. The entire city is divided into square grids. We use the information from the population, topology to compute the emission loads in all the grids which span the city of Chennai. Information from population growth, vehicular growth and industrial growth is used to predict the levels of pollution anticipated in the years 2012 and 2017.

We then determined various control options and their effect on pollution loads in each grid. This is then used to identify important or most sensitive control options and these are chosen to analyse the concentration profiles using a dispersion modeling approach. This forms the basis for coming up with recommendations to the government so that they can arrive at a policy to sustain industrial growth and also ensure that the air quality is preserved.

1.6 Structure of the report: The report is organized into different chapters as follows. Chapter 2 discusses the details of the monitoring carried out in the seven sites. It discusses the choice of the seven sites as well as the results of the analysis carried out for all the seven sites and all the three seasons. Correlations between the different variables are established. Chapter 3 discusses the emission inventory details that were obtained from the primary emission inventory study as well as from the secondary sources of information. The summary of the emission loads in each of the seven sites as well as for the city of Chennai are detailed there.

Chapter 4 contains the details of the receptor modeling studies based on two approaches Factor Analysis as well as Chemical Mass Balance approach. The former helps us identify sources qualitatively while the latter helps us identify sources quantitatively.

Chapter 5 contains the results of the dispersion modeling using a standard software package. The predictions of the package in the 2X2 km region around the receptors are shown in the form of contour plots for all the seven sites.

Chapter 6 discusses the methodology adopted for estimating the pollution loads across the entire Chennai. Different control options are analysed and their impact on the emission loads on a per capita basis is determined. This is then used to estimate the pollution loads in each grid and the options which are most effective are identified. Chapter 7 contains the results of the select control options and we determine the concentration profiles when these options are exercised using a dispersion model. The report finally closes with the important recommendations.

To keep the report focused in this study we have added Appendices to contain all auxiliary information like QA/QC (quality assurance /quality control processes).

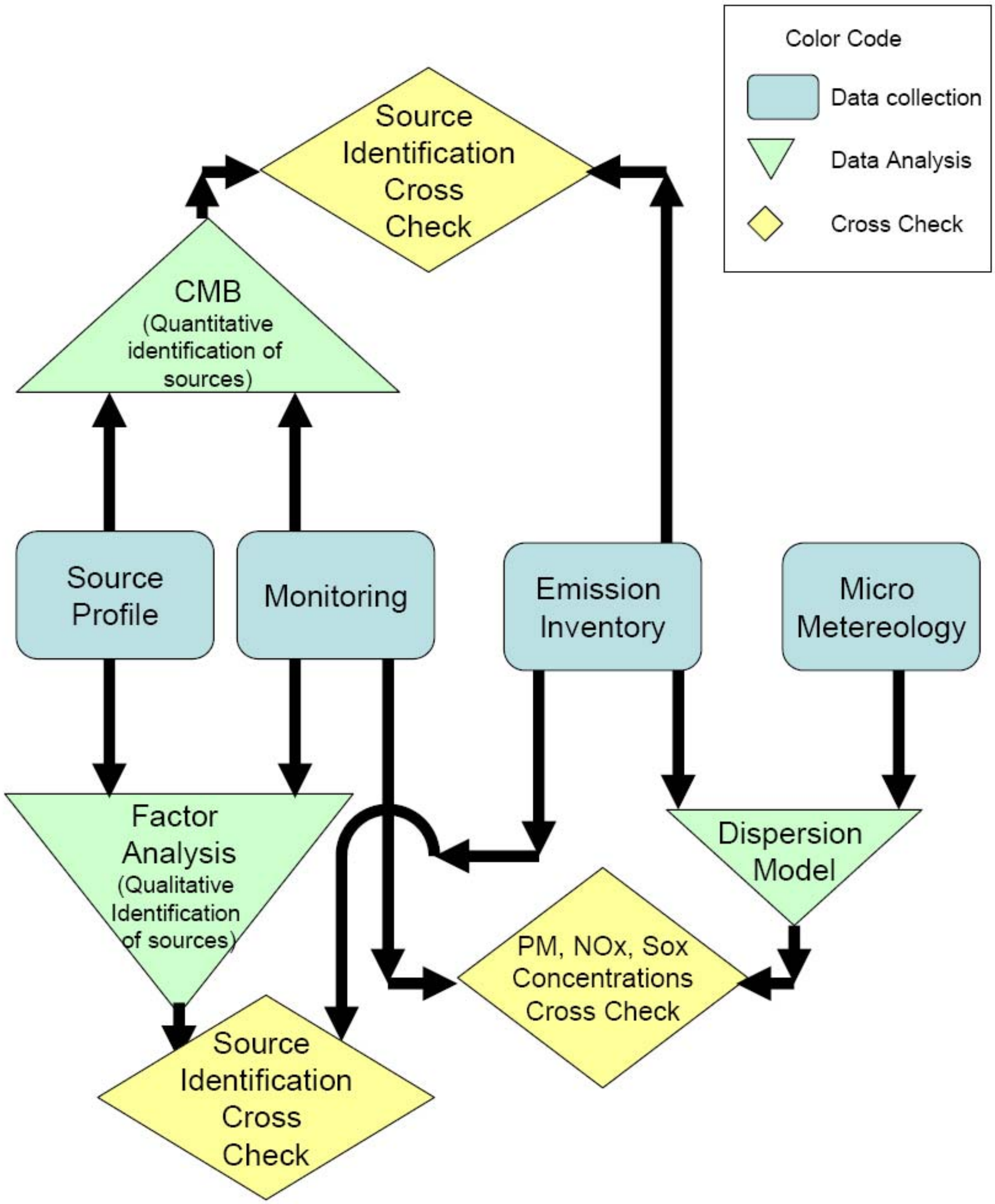


Figure 1.1 Linkages between the different parts of the study in the report

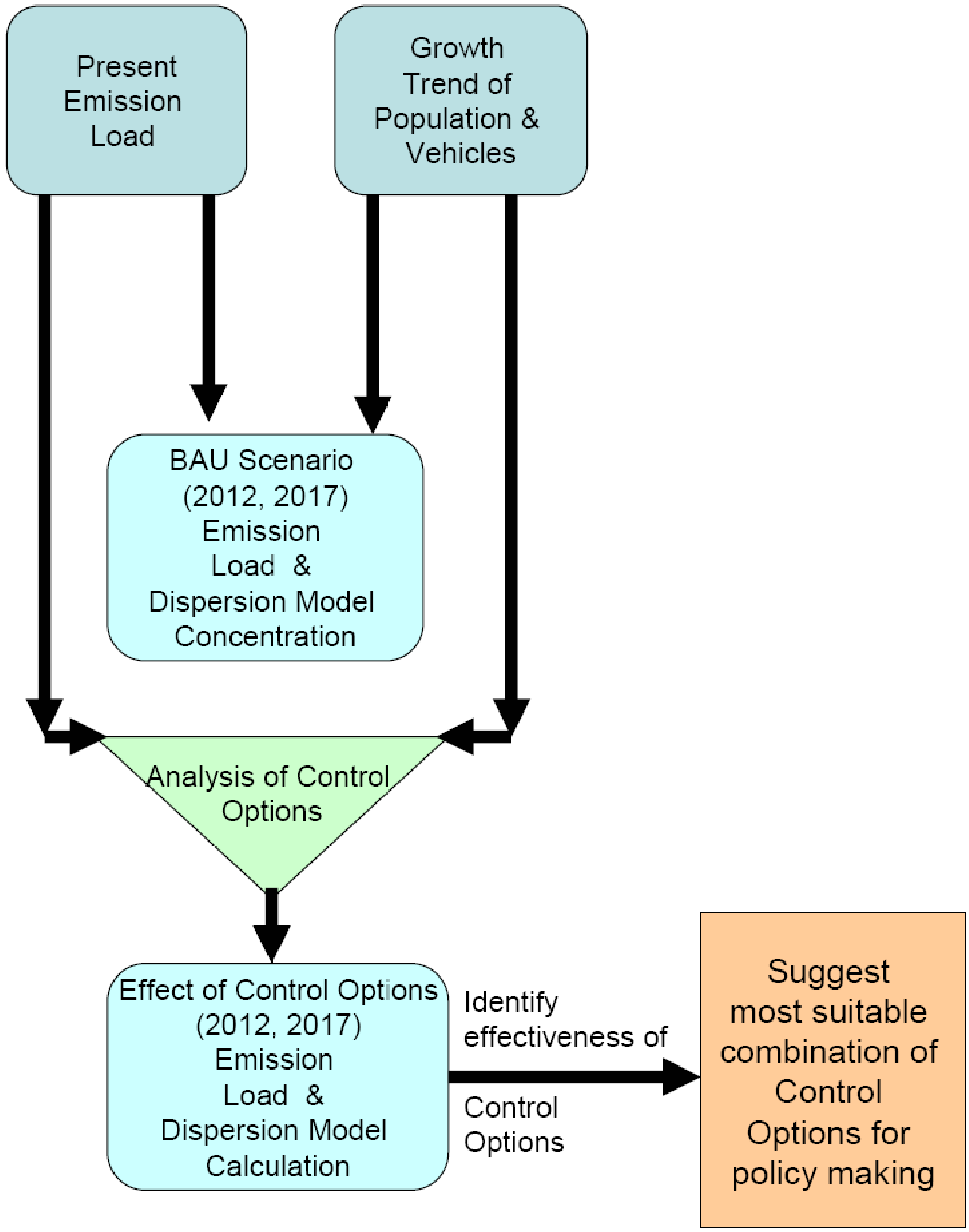


Figure 1.2 Methodology for predicting future scenarios adopted in this study

Chapter 2.

Air Quality Status

2.1 Introduction

There have a few ambient air quality monitoring studies conducted in Chennai, as was indicated in Chapter 1. Under the objectives of the current project, several air quality parameters were monitored at seven locations - two residential, two industrial, two traffic and one background locations. The details of the selected monitoring locations, their air quality measurement and analysis are presented in the following sections.

2.2 Methodology

Figure 2.1 shows the details of the selected air quality monitoring (seven) stations in Chennai city. The summary of land use pattern at each site is provided in Table 2.1. The monitoring of ambient air quality parameter specified by CPCB at these sites was carried out during summer, winter and monsoon seasons of the year 2006 and 2007. Samples were collected at the selected sites for a period of about 30 days in each season. Sampling instruments such as respirable dust sampler, speciation samplers and weather stations were kept at 3-6 meter from the ground level. Table 2.2 shows the schedule of monitoring at selected sites for all the three seasons. Chennai does not follow the seasonal patterns observed at several other locations in the country. There is intermittent rain during south-west monsoon (June-August) (>100 mm), but the heaviest rain occurs due to the north-east monsoon between the months of October and December (>300 mm). This is followed by a very short winter period. The average temperature variation (both high and low) is well below 10°C. For this reason, the monitoring intervals in Chennai city have been designated as periods rather than as actual seasons. In this report any reference to 'season' implies a 'period' without any direct correlation with a season since the seasons in Chennai are hot, hotter and hottest.

Table 2.1. Sampling Sites at Chennai

S. No.	Sampling Location	Description of the site	Land use type
1.	IIT Madras (IITM)	Background area	Forest area, residential, minor roads
2.	Mylapore	Residential	Residential, minor roads, minor commercial
3.	Triplicane	Residential	Residential, minor roads, commercial
4.	Adyar	Kerbside Site	Commercial, major roads, residential
5.	Saidapet	Kerbside Site	Commercial, major roads, residential
6.	R K Nagar	Industrial	Industries, roads, commercial.
7.	Ambattur	Industrial	Industries, roads, commercial.

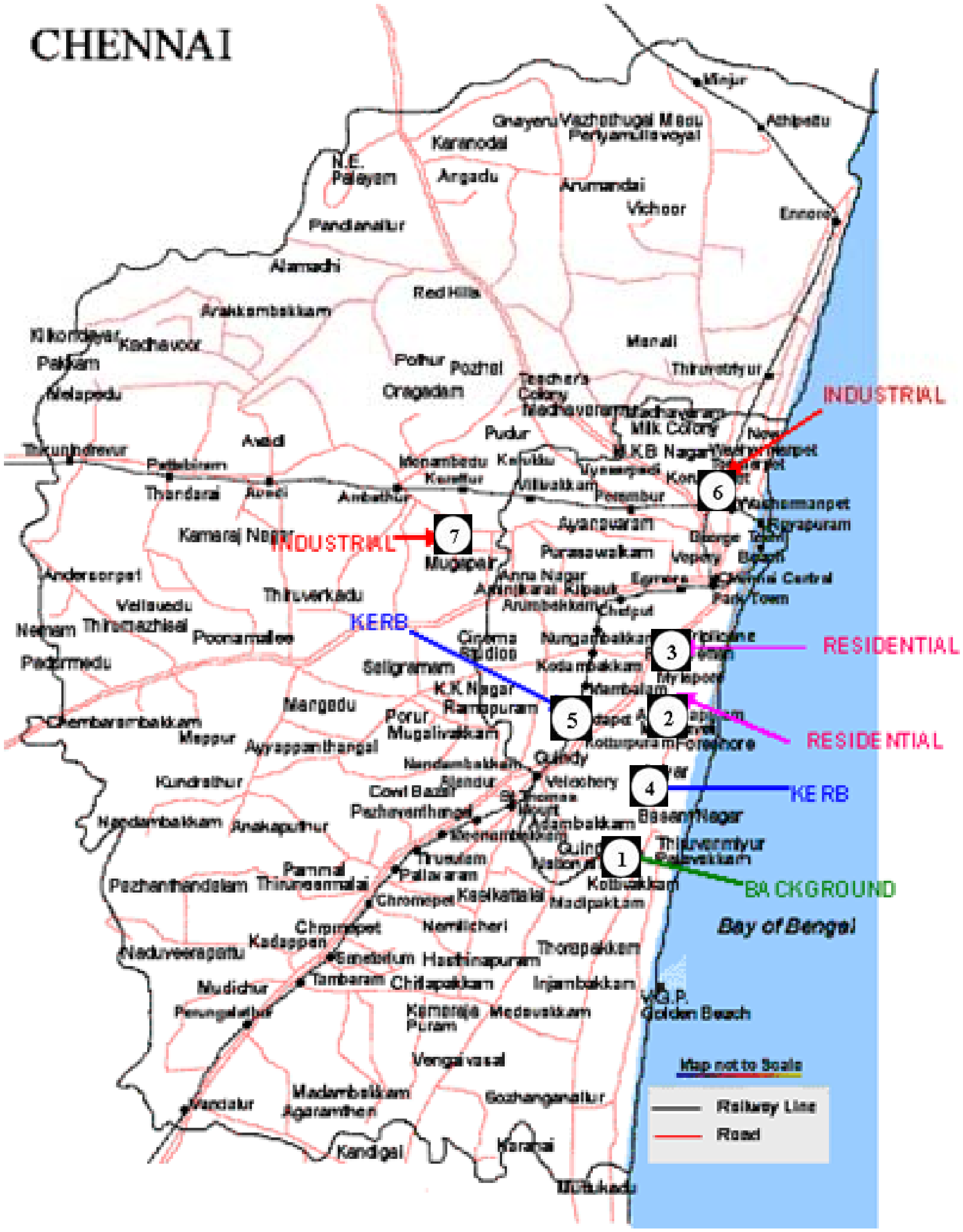


Figure 2.1. Chennai city map showing sampling sites.

Table 2.2. Season wise monitoring period for the seven sites in Chennai.

SITE	First Period	Second Period	Third Period
IITM (Background)	1/2/07 – 28/2/07	4/7/07 – 30/7/07	29/11/07 – 31/12/07
SAIDAPET (Kerbside)	6/3/07 – 13/4/07	12/8/07 – 4/10/07	5/10/07 – 4/11/07
ADYAR (Kerbside)	6/3/07 – 13/4/07	5/7/07 - 9/8/07	1/3/08 – 30/3/08
MYLAPORE (Residential)	21/4/07 – 22/5/07	23/5/07-16/6/07	5/10/07 – 4/11/07
TRIPLICANE (Residential)	9/7/07 – 8/8/07	12/8/07 – 20/9/07	26/11/07 – 2/1/08
RK NAGAR (Industrial)	7/3/07 – 11/4/07	23/8/07 – 4/10/07	5/10/07 – 3/11/07
AMBATTUR (Industrial)	28/5/07 – 16/6/07	13/11/07 – 13/12/07	14/12/07 – 20/1/08

2.3 Monitoring Parameters

Table 2.3 gives the list of pollutants monitored in this project, instruments used and frequency of sampling.

Particular	SPM	RSPM	PM_{10}	$PM_{2.5}$	NO_X	SO_2	CO
Sampling Instrument	High Volume Sampler	RDS Sampler	Multichannel (4 channel) Speciation Sampler	FRM Partisol (PM2.5) sampler Or Equivalent	Impingers attached to HVS	Impingers attached to HVS	Automatic analyzer
Sampling Principle	Filtration of aerodyna-mic sizes	Filtration of aerodyna-mic sizes	Filtration of aerodynamic sizes with a size cut by impaction	Filtration of aerodynamic sizes with a size cut by impaction followed by cyclone separation	Chemical absorption in suitable media	Chemical absorption in suitable media	Suction by Pump As per instrument specification
Flow rate	0.8-1.2 m3/min	0.8-1.2 m3/min	16.7 LPM	16.7 LPM	1.0 LPM	1.0 LPM	0.2 – 0.5 LPM
Sampling Period	8 hr, 24 Hourly Reporting	8 hr, 24 Hourly Reporting	20 days 24 hourly And 10 days 8 Hourly filter change	24 hourly	4 Hourly change of absorbing media, 24 Hourly Reporting	4 Hourly change of absorbing media, 24 Hourly Reporting	Real time analysis and 8/24 hourly reporting
Sampling frequency	30 Days continuous in each season, for three seasons	30 Days continuous in each season, for three seasons	30 Days continuous in each season, for three seasons	One week continuous. First 2 days with Quartz, next 3 days with Teflon and next 2 days again with quartz filter	30 Days continuous in each season, for three seasons	30 Days continuous in each season, for three seasons	One week continuous during 30 days of monitoring in each season
Analytical instrument	Electronic Balance	Electronic Balance	Electronic Balance	Electronic Micro Balance	Spectrophoto-meter	Spectrophoto-meter	Automatic Analyser
Analytical method	Gravimetric	Gravimetric	Gravimetric	Gravimetric	Colorimetric Improved West & Gaeke Method	Colorimetric Jacobs & Hochheiser Modified method	Electro chemical
Minimum Reportable value	5 µg/m^3	5 µg/m^3	5 µg/m^3	5 µg/m^3	9 µg/m^3	4 µg/m^3	0.1 ppm

Particular	OC/EC	Ions	VOC (Benzene and 1,3 Butadiene,)	Aldehyde	NMHC	HC	PAHs (Included in organic Markers)
Sampling Instrument	PM10 Sampler Particulate collected on Quartz filter	PM10 Sampler Particulate collected on Teflon filter	Low volume sampling pump connected to Adsorption Tube	Impingers attached to HVS / RDS	Low volume sampling pump connected to Tedlar bags	Low volume sampling pump connected to Tedlar bags	PM 10 Sampler
Sampling Principle	Filtration of aerodynamic sizes with a size cut by impaction	Filtration of aerodynamic sizes with a size cut by impaction	Active pressurized sampling / Adsorption	Chemical Absorption Or Active pressurized sampling	Suction by Pump	Auto suction by pump	Filtration of aerodynamic sizes
Flow rate	16.7 LPM	16.7 LPM	0.2 - 0.5 LPM	0.5 LPM	As per instrument specification	As per instrument specification	16.7 LPM
Sampling Period	24 hourly Or 8 / 24 Hourly	24 hourly Or 8 / 24 Hourly	8 Hourly sampling and 24 Hourly Reporting	8 Hourly sampling and 24 Hourly Reporting	8 Hourly sampling and 24 Hourly Reporting	8 Hourly sampling and 24 Hourly Reporting	Weekly composite of left over Quartz filter after OC/EC analysis
Sampling frequency	30 Days continuous in each season, for three seasons	30 Days continuous in each season, for three seasons	Twice during 30 days of monitoring in each season	Twice in 30 days of monitoring in each season	Once in every week during 30 days of monitoring in each season	Once in every week during 30 days of monitoring in each season	04 weekly composite samples per season
Analytical instrument	OC/EC Analyzer	Ion Chromatograph	GC-ATD-FID / MS Or GC-FID / MS	Spectrophotometer	GC - FID with Methaniser	GC - FID with Methaniser	GC-MS
Analytical method	TOR/TOT Method NIOSH 5040	Ion Chromatography	USEPA method TO-1/ TO-2 / TO-4 / TO-10 / TO-14	Colorimetric (MBTH method)	FID Analysis	FID Analysis	GC-MS
Minimum Reportable value	0.2 µg/ 0.5 cm^2 punch		0.1 ppb	1.0 µg/m^3	0.05 ppm	0.05 ppm	1 ng/m^3

2.4 Monitoring Results

In the following subsections the results of the air quality data monitored at all the seven locations during summer, winter and monsoon period are discussed.

2.4.1 Season 1

2.4.1.1 IIT Madras - Background

Figures 2.1.1.1 shows the 24-hr average values for TSPM and RSPM measured at IIT Madras site. The data analysis indicated that the TSPM and RSPM were generally below 100 µg/m³ except for 4 days where the values were above 100 µg/m³. The highest TSPM and RSPM value were found to be 199.63µg/m³ and 159.86µg/m³ respectively on 14th February 2007.

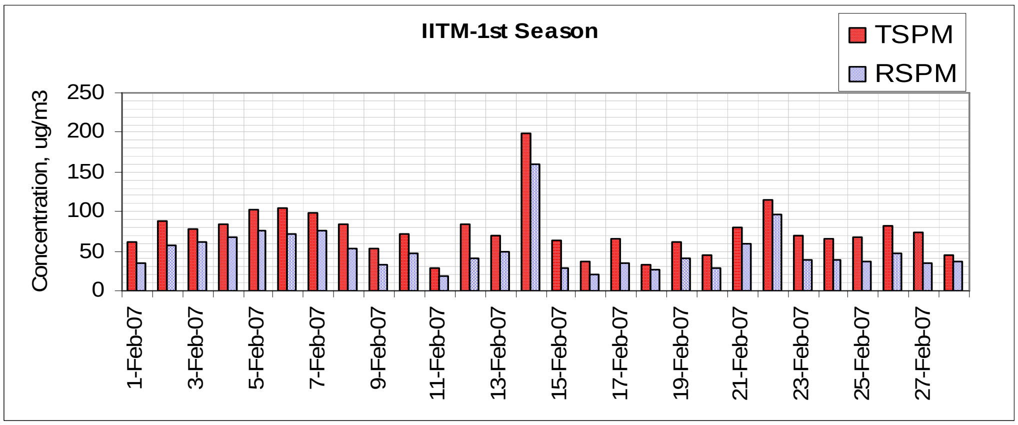


Figure 2.1.1.1--Time series of TSPM and RSPM at IITM

Figure 2.1.1.2 shows the variation of OC, EC and the EC/OC ratio associated with PM_{10} concentrations at IIT Madras site. The EC/OC ratio for PM_{10} varies between 0.16 and 0.56 with a mean value of 0.34. Within the IIT campus, the number of vehicles is very small. There is a considerable area of unpaved land and a large section is also forested.

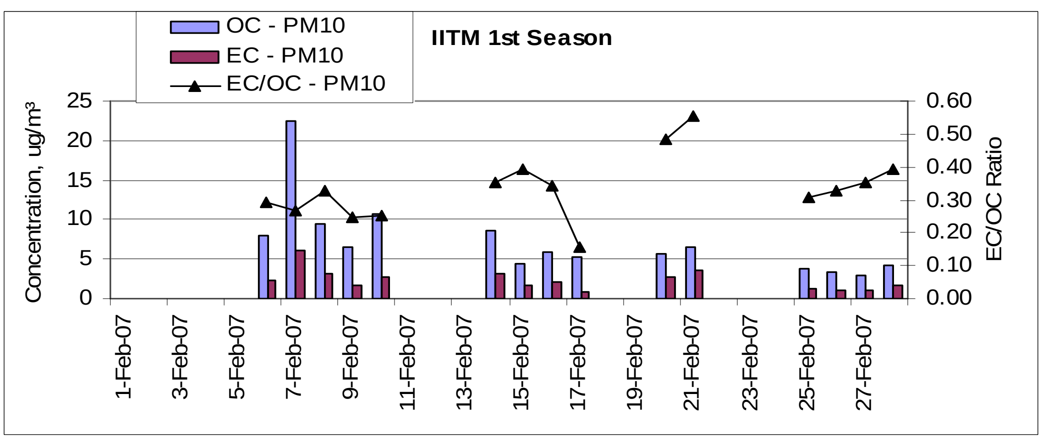


Figure. 2.1.1.2-- Measurements of OC/EC for IITM

Figure 2.1.1.3 shows the NOx and SO_2 distribution at IIT Madras. NOx values were found to vary between 1.45 and 14.8µg/m³ with the mean value of 8.1µg/m³. SO_2 values range from 0.07 to 2.04 µg/m³ with the mean value of 0.72 µg/m³. The minimum detection limit of NO_X and SO_2 for the methods were 0.38 µg/m³ and 6.1 µg/m³ respectively.

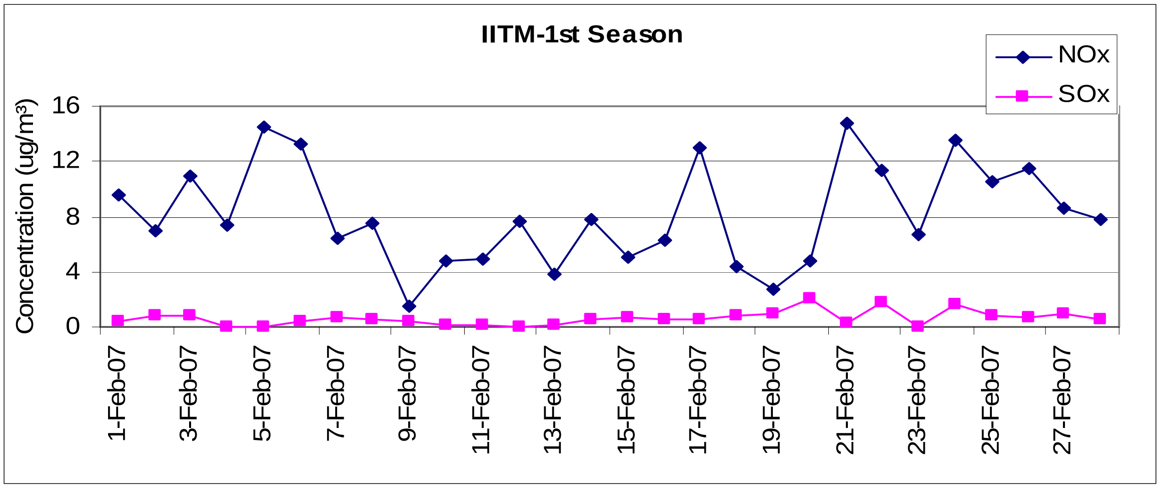


Figure 2.1.1.3-- Time series measurements for SO_2 and NOx

Figure 2.1.1.4 shows the levels of anions associated with PM_{10}. The anions shown were the ones that were found to be significant in the samples consistently. Other anions that were analyzed for were fluoride, phosphate and bromide. The concentration of Sulphate (4.9 ± 2.0 µg/m³) was higher than those of nitrate (1.9 ± 2.4 µg/m³) and chloride (2.3 ± 1.3 µg/m³).

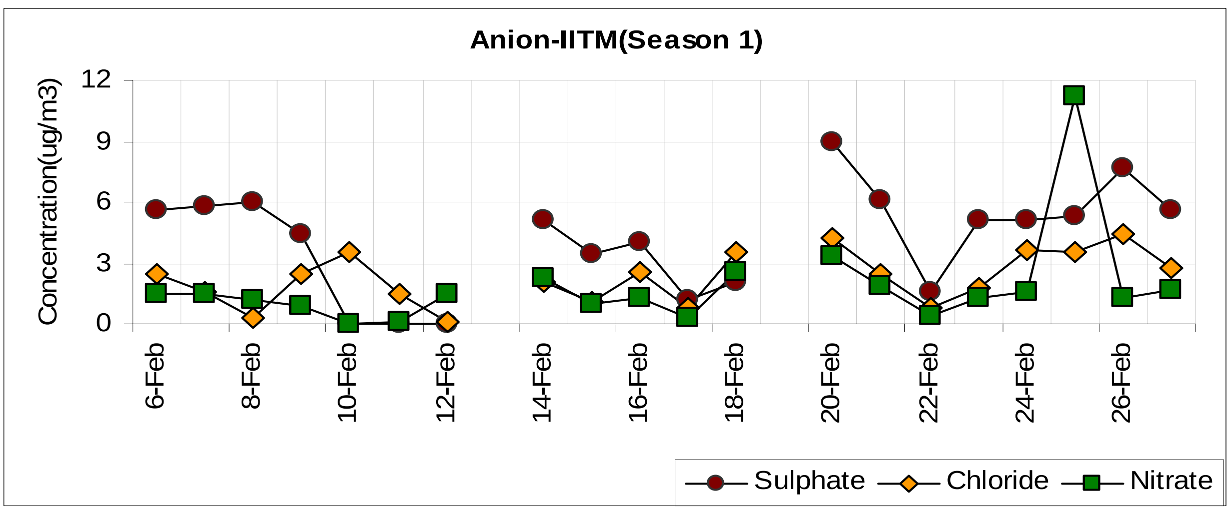


Figure 2.1.1.4-- Time series of anions on PM_{10}

Figure 2.1.1.5 shows the levels of Cations associated with PM_{10}. The Cations shown were the ones detected consistently. The concentrations of sodium (2.4 ± 1.3 µg/m³) and ammonium (2.1 ± 1.6 µg/m³) ions were higher than that of potassium ion (1.6 ± 0.8 µg/m³).

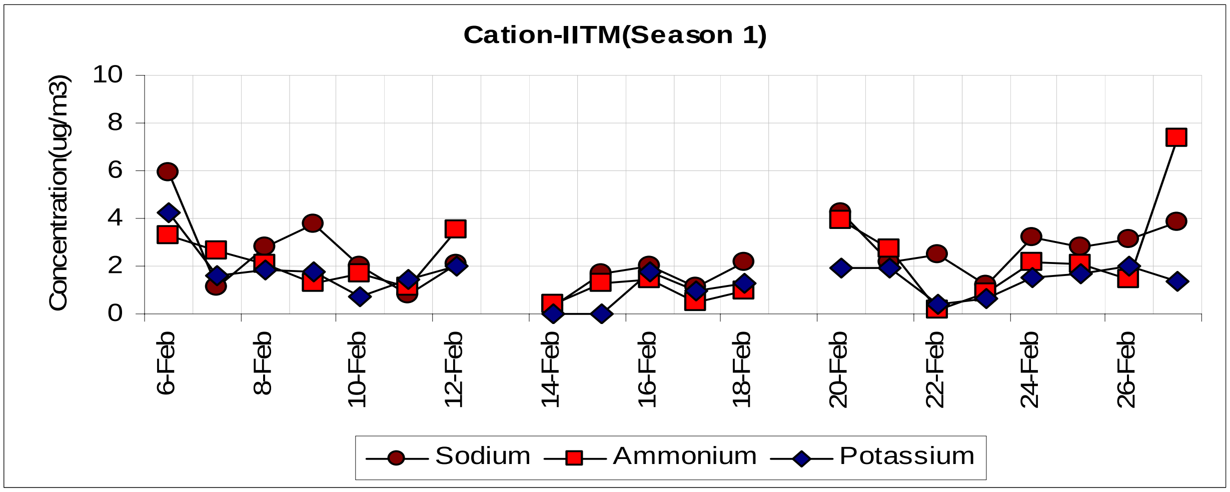


Figure 2.1.1.5-- Time series of Cations on PM_{10}

Figure 2.1.1.6 shows the measurement of the diurnal variation of CO levels averaged over the period of monitoring. The mean levels are shown to vary between 2700 and 4300 µg/m³. These values were below NAAQS 1-hr average standard (4000 µg/m³), but the 8-hr averages were above the 8-hr averaging NAAQS standard of 2000 µg/m³.

..

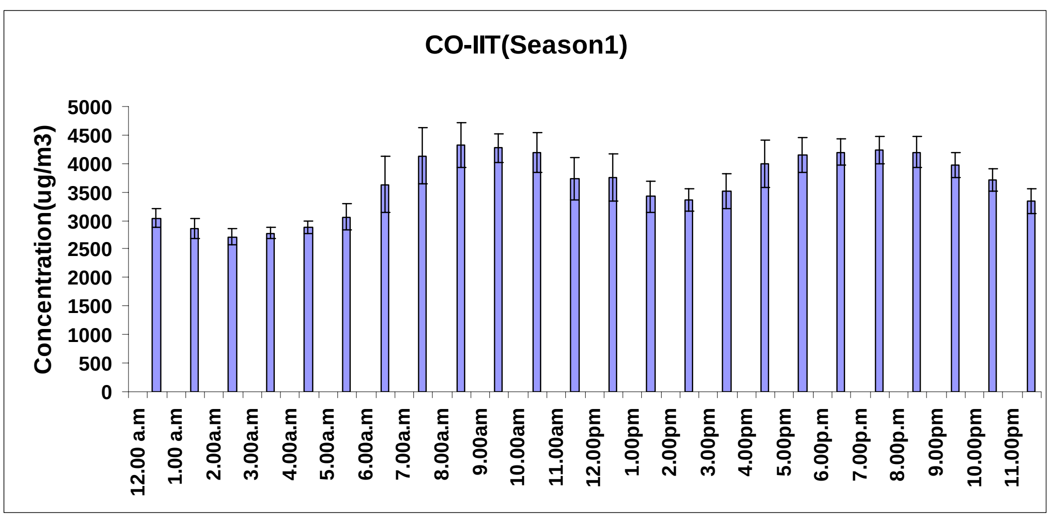


Figure 2.1.1.6. CO – diurnal variation for IITM.

Figure 2.1.1.7 shows the distribution of the various speciation analysis associated with the PM_{10}. It should be noted that Si was not analyzed with the technique used for elements analysis (acid digestion + ICP-OES). The fraction, which is shown as unknown in figure includes Si and other species such as the H,O and N fraction of organic matter, oxygen in the elemental oxides and other constituents not analyzed in the sample. Of the measured components OC (14.31%) was the highest fraction followed by Sulphate ion (9.66%) and Ca (9.04%). Ca, Na and K is likely to come from road dust and from construction or demolition activities.

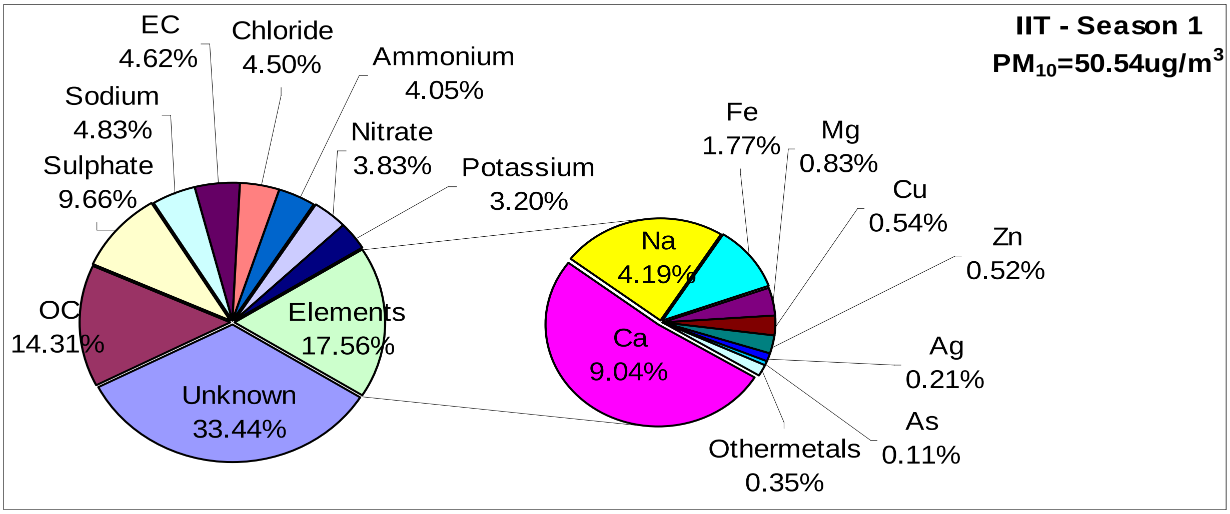


Figure 2.1.1.7-- Distribution of species on PM_{10} at IITM – Season 1

2.4.4.2 Mylapore (Residential)

Figures 2.1.2.1 shows the 24-hr average values for TSPM and RSPM at Mylopore site. During the monitoring period, the RSPM values were higher than the NAAQS (100µg/m³ for residential area) for 4 days, with highest values on 8th (309.67 µg/m³) and 15th May (312.59 µg/m³). The TSPM values were higher than the NAAQS (200µg/m³ for residential area) for 7 days. Particularly on 8th, 12th and 15th May TSPM values were 372.41, 305.18 and 337.57µg/m³ respectively.

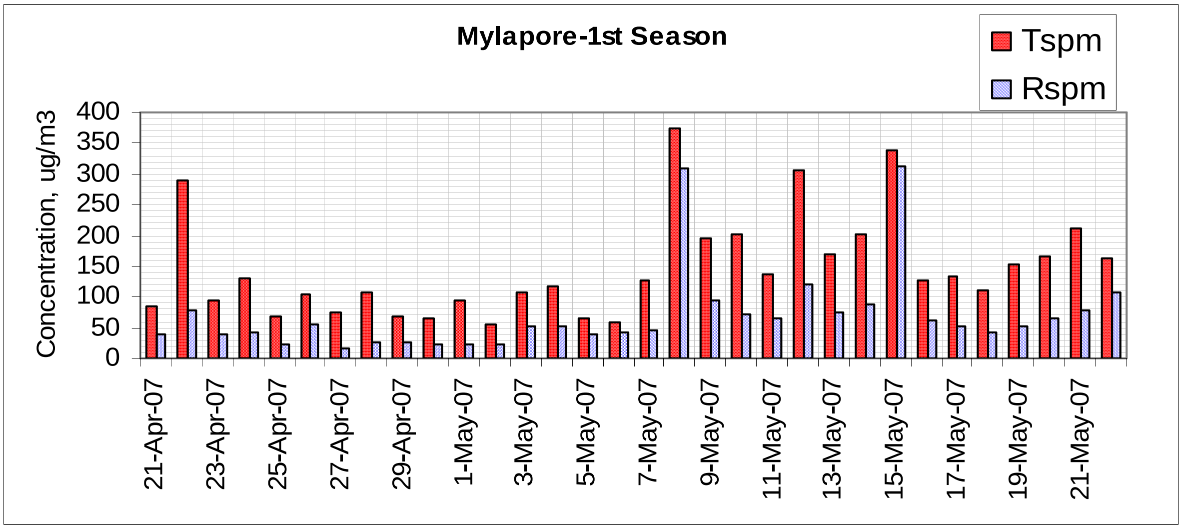


Figure 2.1.2.1--Time series of TSPM and RSPM at Mylapore

Figure2.1.2.2 shows the variation of OC, EC and the EC/OC ratio associated with PM_{10}. The EC/OC ratio for PM_{10} varies between 0.12 and 0.37 with a mean value of 0.26.

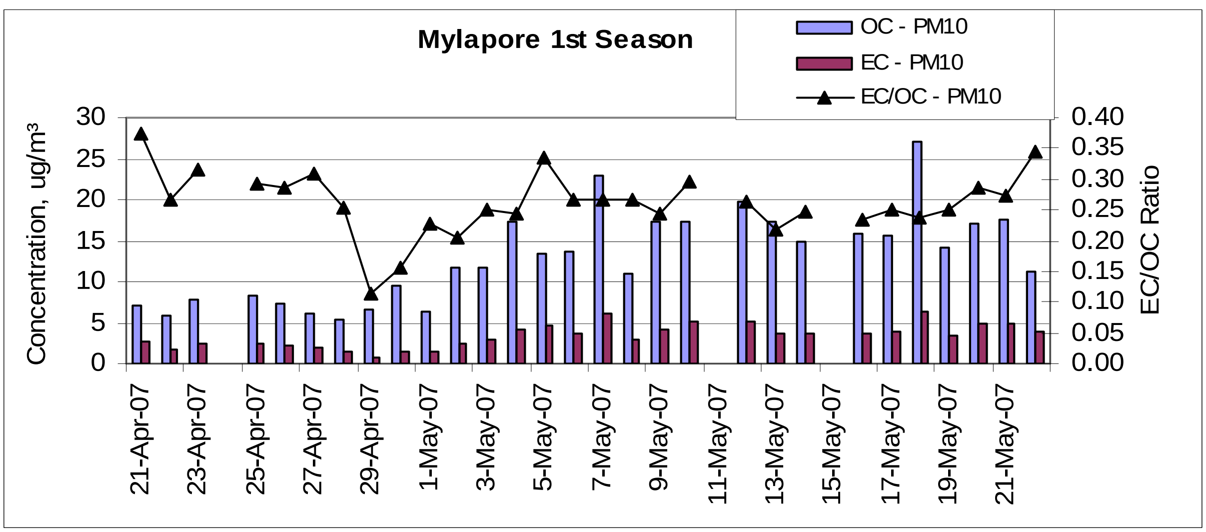


Figure2.1.2.2-- Measurements of OC/EC for Mylapore

Figure 2.1.2.3 shows the NOx and SO_2 distribution at Mylapore. NOx values were found to vary between 5.19and 27.84µg/m³ with the mean value of 14.52µg/m³. SO_2 values range from 0.29 to 6.64 µg/m³ with the mean value of 3.02 µg/m³.

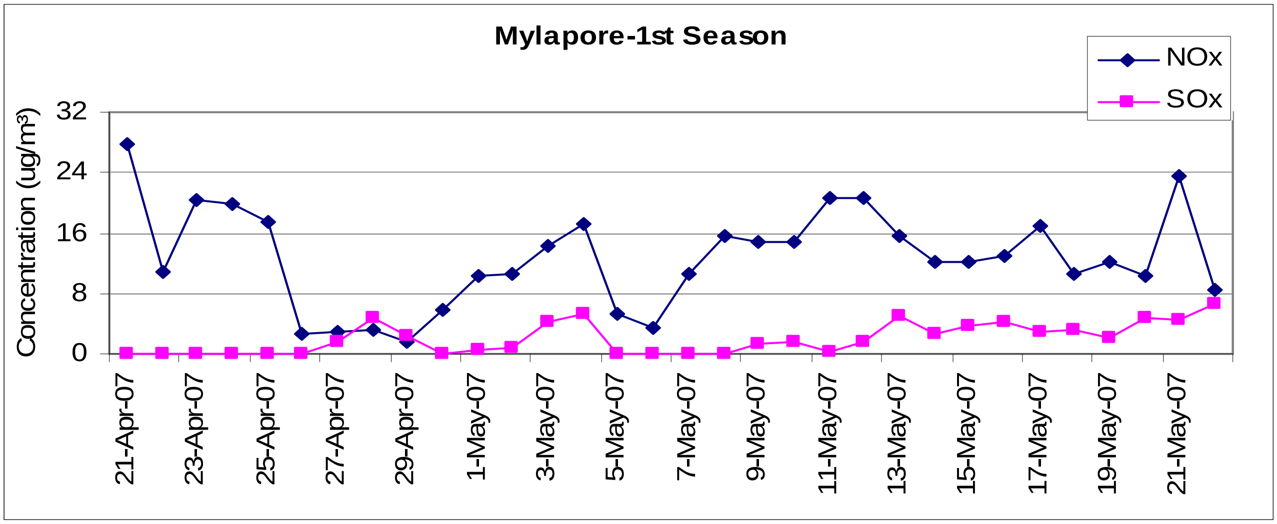


Figure2.1.2.3-- Time series measurements for SO_2 and NOx

Figure 2.1.2.4 shows the levels of anions associated with PM_{10}. The anions shown were the ones that were found to be significant in the samples consistently. Other anions that were analyzed for were fluoride, phosphate and bromide. The concentration of Sulphate (4.8 ± 2.5 µg/m³) was higher than those of nitrate (2.4 ± 1.2 µg/m³) and chloride (3.3 ± 1.7 µg/m³).

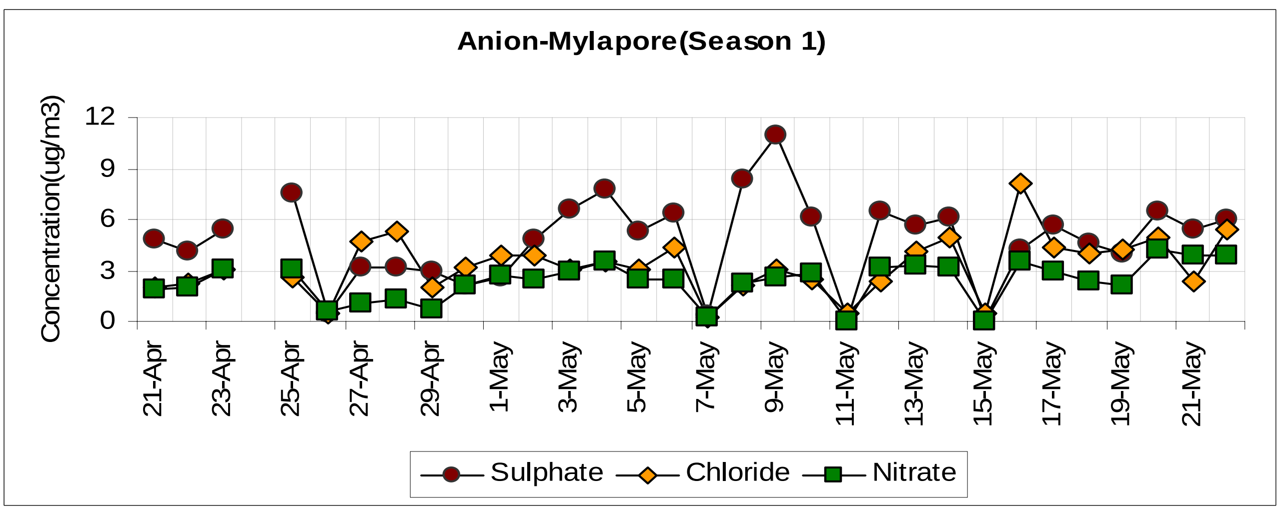


Figure 2.1.2.4-- Time series of anions on PM10

Figure 2.1.2.5 shows the levels of Cations associated with PM_{10}. The Cations shown were the ones detected consistently and are of interest in the region. The concentrations of sodium (2.4 ± 1.1 µg/m³) and ammonium (1.7 ± 2.0 µg/m³) ions were higher than that of potassium ion (0.9 ± 0.6 µg/m³).

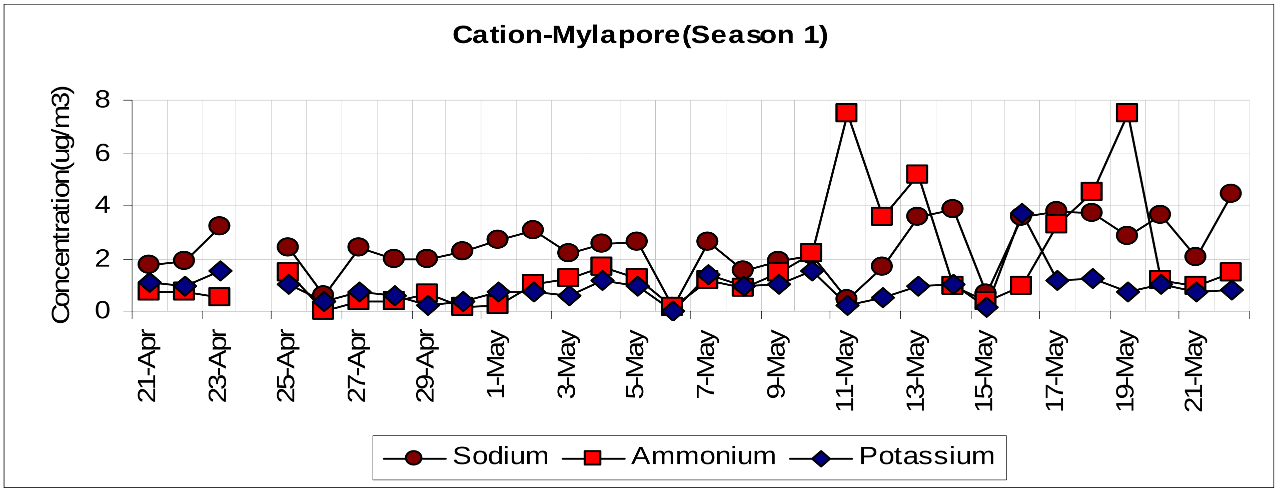


Figure 2.1.2.5-- Time series of Cations on PM10

Figure 2.1.2.6 shows the measurement of the diurnal variation of CO levels averaged over the period of monitoring. The levels are shown to vary between 3900 µg/m³ and 8700 µg/m³. These values are exceeding NAAQS 1-hr average standard (4000 µg/m³).

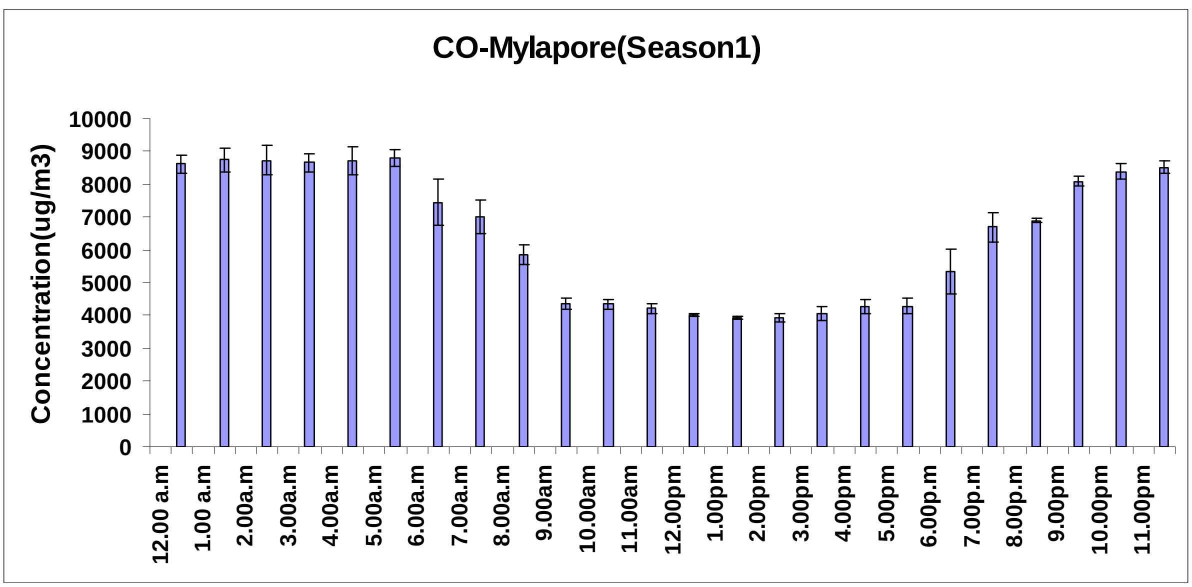


Figure 2.1.2.6-- CO – diurnal variation for Mylapore.

Figure 2.1.2.7 shows the distribution of the various speciation analysis associated with the PM_{10}. Of the measured components, OC (18.5%) was the highest fraction followed by Sulphate ion (6.79%) and Fe (5.61%). The fraction, which is shown as unknown in figure includes Si and other species such as the H,O and N fraction of organic matter, oxygen in the elemental oxides and other constituents not analyzed in the sample..

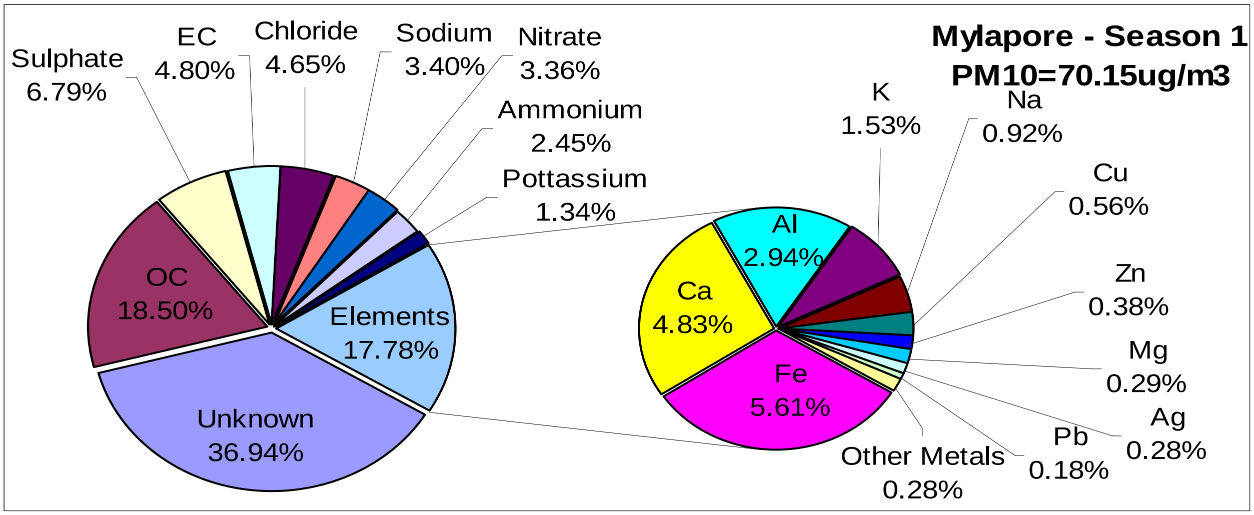


Figure 2.1.2.7-- Distribution of species on PM_{10} at Mylapore

2.4.1.3 Triplicane (Residential)

Figures 2.1.3.1 shows the 24-hr average values for TSPM and RSPM concentrations at the Triplicane site. During the monitoring period, the RSPM values were higher than NAAQS (100µg/m³ for Residential area) for 3 days in particular, on 11th (833.1µg/m³) and 12th (929.9 µg/m³) July, 2007 the RSPM concentrations were highest. Further, the TSPM values were higher than the NAAQS (200µg/m³ for Residential area) for 4 days. Particularly, on 11th and 12th July TSPM values were highest i.e. 986.45and 971.7µg/m³, respectively. These high spikes seem to be an aberration due to an abnormal event in the sampling location such as road sweeping or construction activity and may not reflect an average ambient air quality. On 13th July sampling was not done.

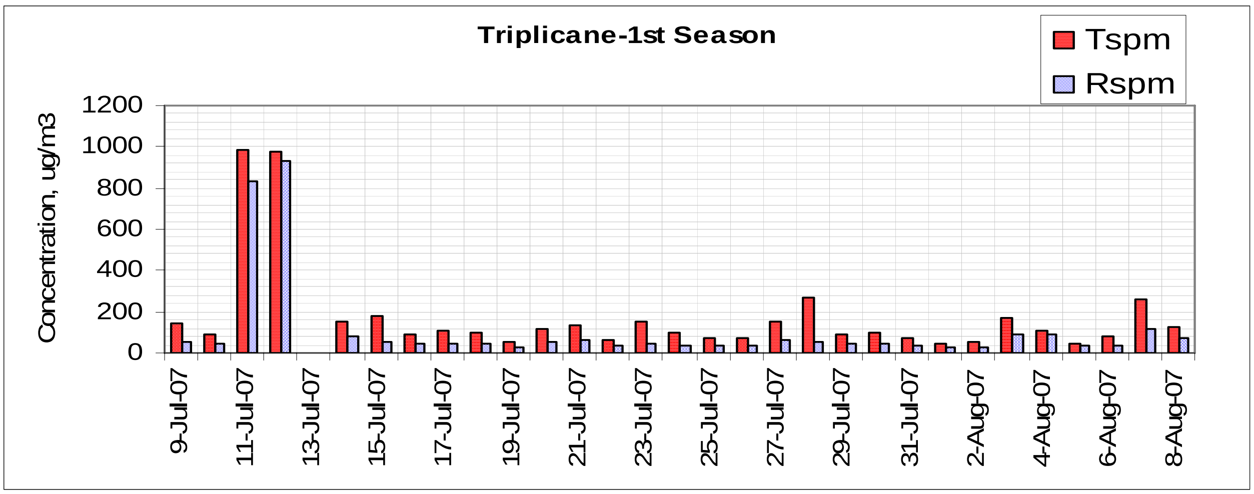


Figure 2.1.3.1-- Particulate matters at Triplicane

Figure 2.1.3.2 shows the variation of OC, EC and the EC/OC ratio associated with PM_{10}. The EC/OC ratio for PM_{10} varies between 0.22 and 0.63 with a mean value of 0.31.

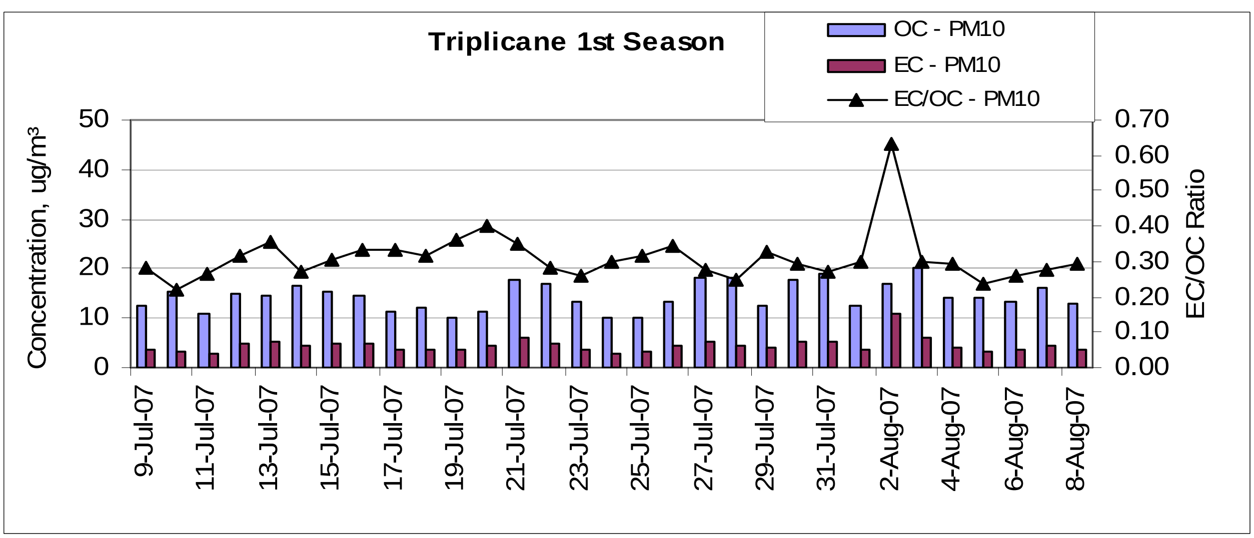


Figure2.1.3.2-- Measurements of OC/EC for Triplicane

Figure 2.1.3.3 shows the NOx and SO_2 distribution at Triplicane. NOx values were found to vary between 7.35 and 33.76µg/m³ with the mean value of 17.36 µg/m³. SO_2 values range from 1.27 to 4.7 µg/m³ with the mean value of 3.16 µg/m³.These values are well below the NAAQS values specified for residential area (80 µg/m³)

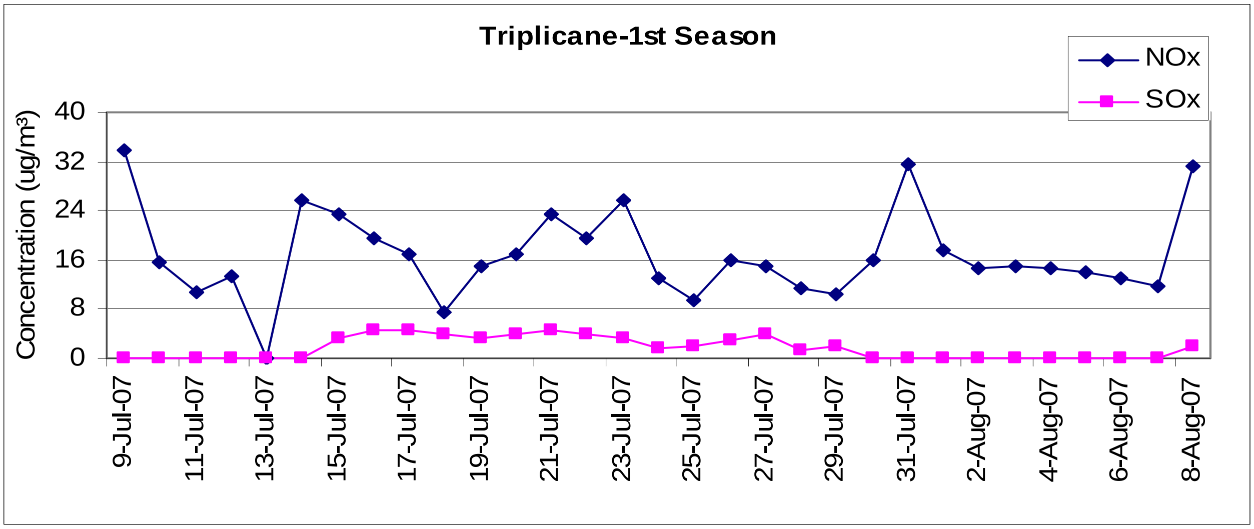


Figure2.1.3.3-- Time series measurements for SO_2 and NOx

Figure 2.1.3.4 shows the levels of anions present in the PM_{10} samples at the study area. The sample analysis indicated that the concentration of Sulphate (5.76 ± 3.69 µg/m³) was higher than nitrate (2.74 ± 1.58µg/m³) and chloride (3.82 ± 2.95 µg/m³) ions.

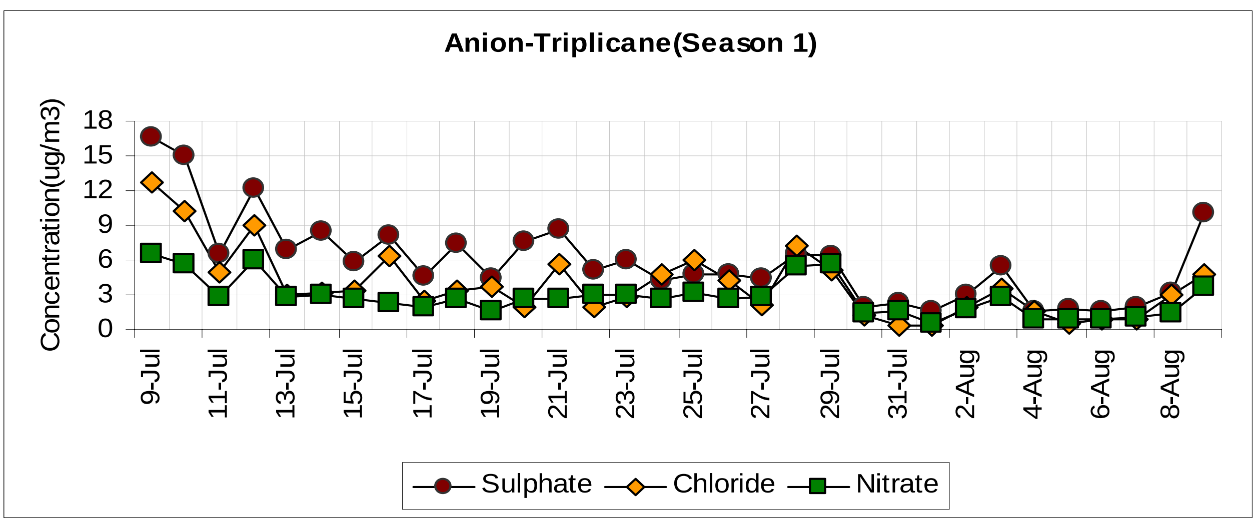


Figure 2.1.3.4-- Time series of anions on PM10

Figure 2.1.3.5 shows the levels of cations present in PM_{10} samples measured at Triplicane site. In this site, the concentrations of sodium (2.38 ± 1.33 µg/m³) and ammonium (0.67 ± 0.43 µg/m³) ions were higher than that of potassium ion (0.48± 0.41 µg/m³).

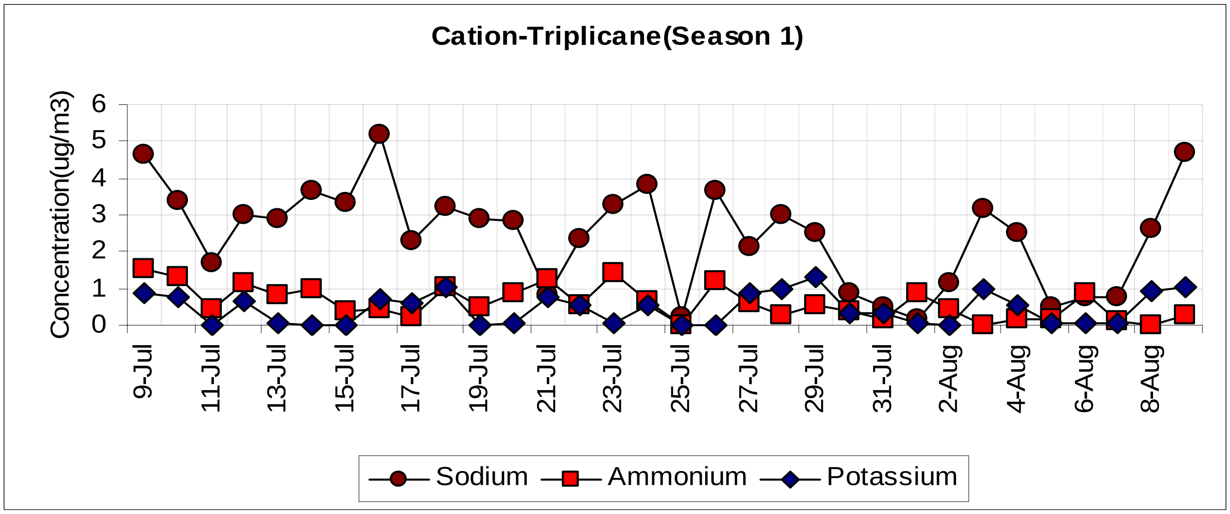


Figure 2.1.3.5-- Time series of Cations on PM10

Figure 2.1.3.6 shows the measurement of the diurnal variation of hourly average CO concentrations at Triplicane site. The data analysis indicated that the mean CO values were range between 4800 and 6500 µg/m³. These values are exceeding NAAQS 1-hr average standard (4000 µg/m³).

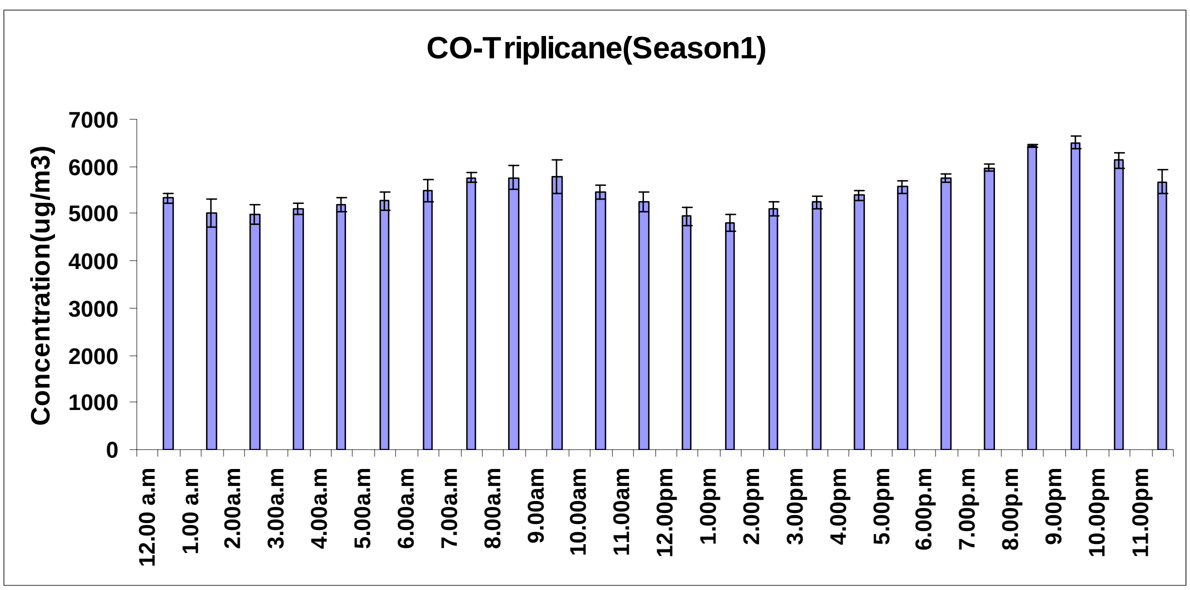


Figure 2.1.3.6-- CO – diurnal variation for Triplicane.

Figure 2.1.3.7 shows the distribution of the various speciation analysis associated with the PM_{10}. The fraction, which is shown as unknown in figure includes Si and other species such as the H,O and N fraction of organic matter, oxygen in the elemental oxides and other constituents not analyzed in the sample. Among the measured components, OC (13.51%) was the highest fraction followed by Sulphate ion (5.39%) and EC (4.18%). Pb is shown to be high (~4%) among the elements detected in Triplicane. This is due to a spike in the value of lead on a few days where the Pb concentration was greater than 10 µg/m³. If these values were neglected, the percentage contribution is around 2%. One possible source in a residential area is from lead based paints.

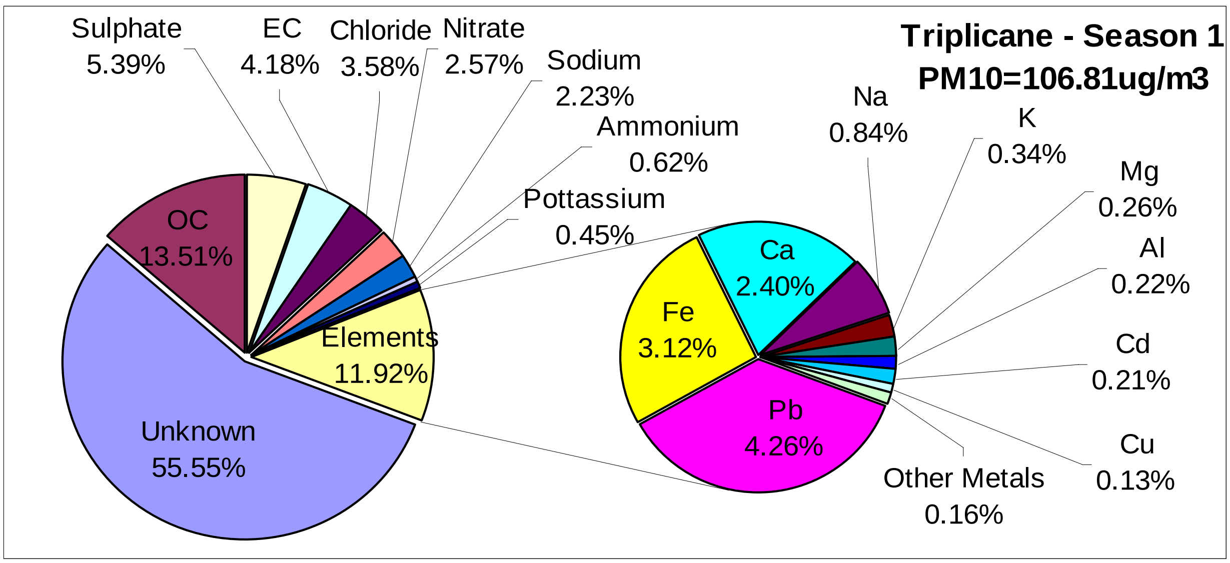


Figure 2.1.3.7-- Distribution of species on PM_{10} at Triplicane

2.4.1.4 Adyar (Kerbside)

Figures 2.1.4.1 shows the 24-hr average values for TSPM and RSPM at Adyar site. During the monitoring period the RSPM values were higher than NAAQS (100µg/m³ for Kerb site) for 8 days. Highest RSPM concentrations of 238.27and 275.66µg/m³ were observed on 24th and 28th March, respectively. The TSPM values were also exceeded the NAAQS (200µg/m³ for Kerb site) for 14 days. Particularly on 22nd and 24th March the TSPM values were 553.3 and 638.09µg/m³, respectively. On 31st Mar and 9th Apr sampling was not done.

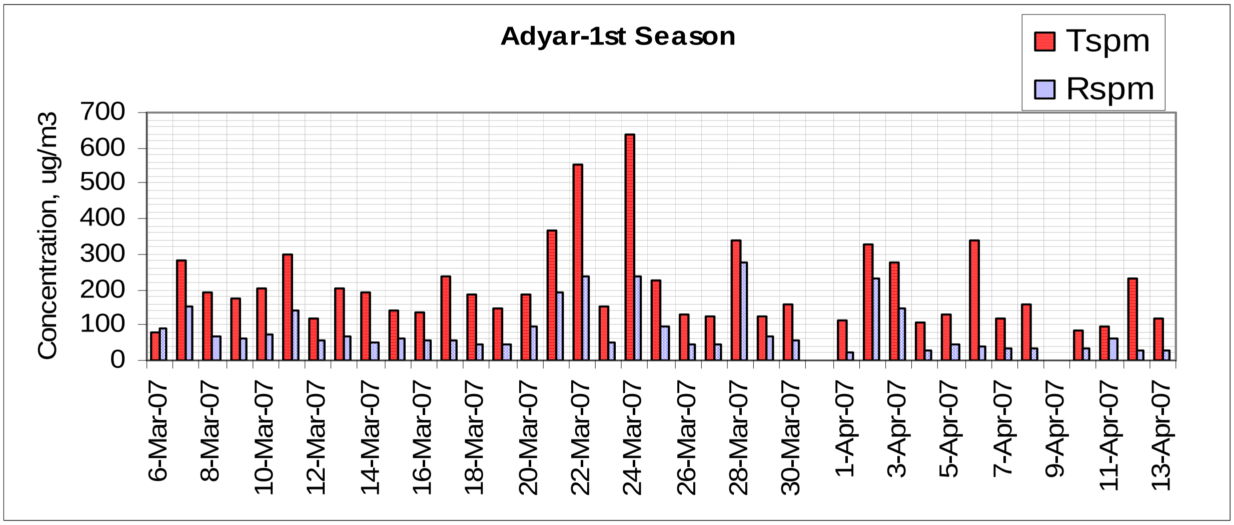


Figure 2.1.4.1--Time series of TSPM and RSPM at Adyar

Figure 2.1.4.2 shows the variation of OC, EC and the EC/OC ratio associated with PM_{10} at Adyar site. The EC/OC ratio for PM_{10} varies between 0.31 and 0.77 with a mean value of 0.48.

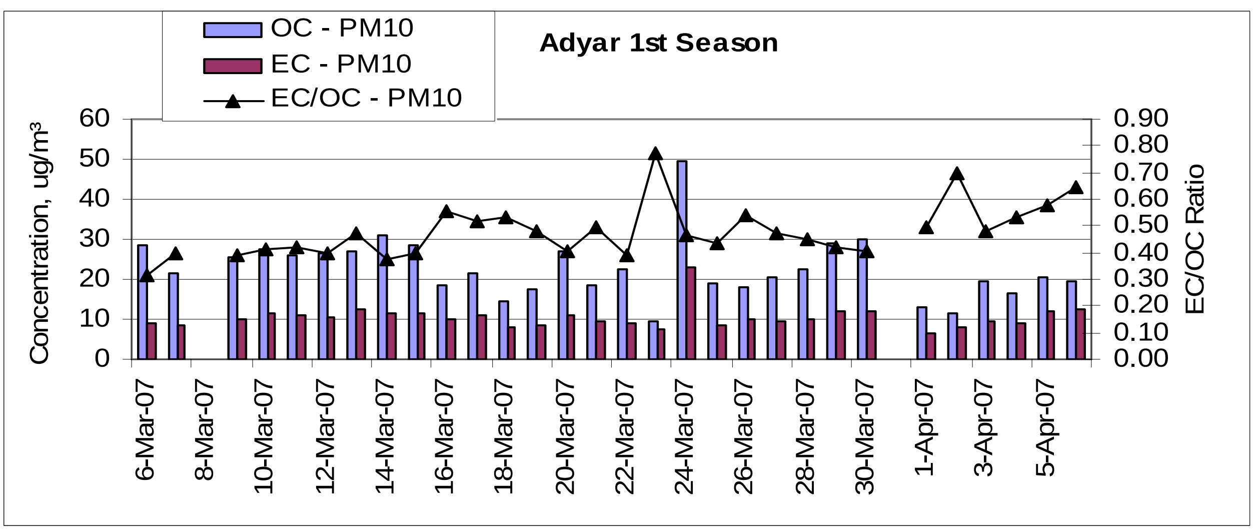


Figure2.1.4.2-- Measurements of OC/EC for Adyar

Figure 2.1.4.3 shows the NOx and SO_2 distribution at Adyar. NOx values were found to vary between 12.93and 40.01µg/m³ with the mean value of 25.42µg/m³. SO_2 values range from 0.17 to 3.76µg/m³ with the mean value of 1.32µg/m³.

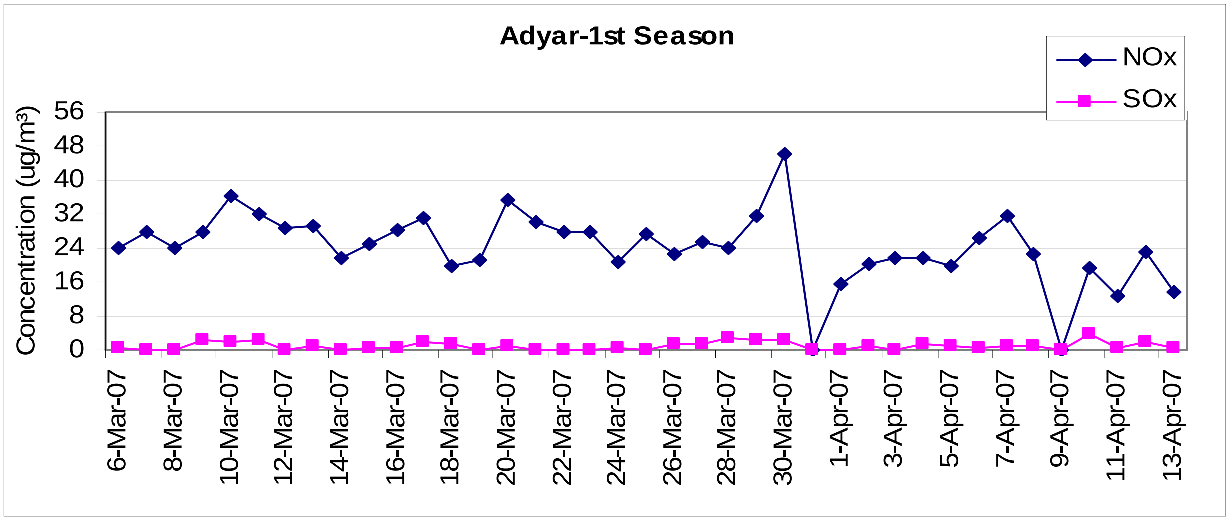


Figure2.1.4.3-- Time series measurements for SO_2 and NOx

Figure 2.1.4.4 shows the levels of anions associated with PM_{10}. From the analysis it is observed that the concentration of Sulphate (7.4 ± 3.3 µg/m³) was higher than those of nitrate (2.8± 1.7 µg/m³) and chloride (3.4± 1.2 µg/m³).

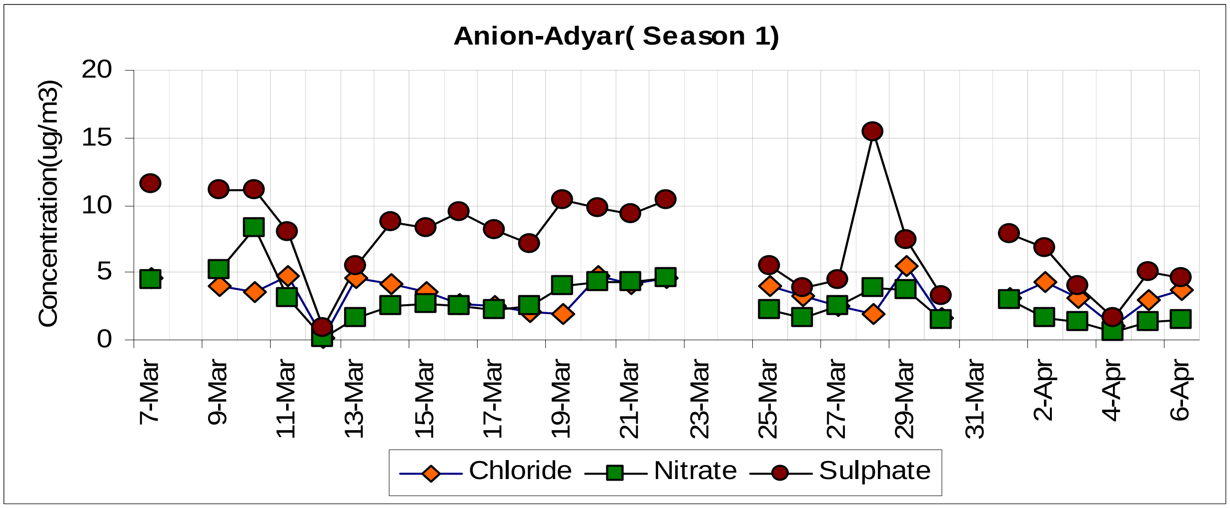


Figure 2.1.4.4-- Time series of anions on PM10

Figure 2.1.4.5 shows the levels of cations associated with PM_{10} at Adyar site. The concentrations of sodium (2.1 ± 1.0 µg/m³) and ammonium (2.6 ± 3.4 µg/m³) ions were higher than that of potassium ion (1.3 ± 0.7 µg/m³).

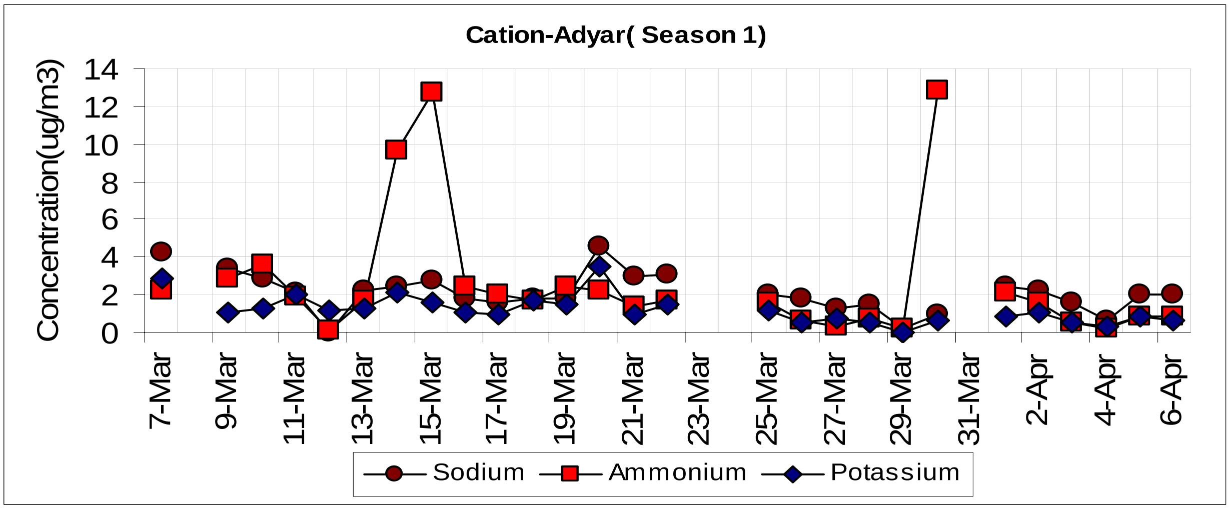


Figure 2.1.4.5--Time series of Cations on PM10

Figure 2.1.4.6 shows the measurement of the diurnal variation of CO levels averaged over the period of monitoring. The mean levels are shown to vary between 4900µg/m³ and 6400 µg/m³. These values are exceeding the NAAQS standards 1-hr standard of 4000 µg/m³.

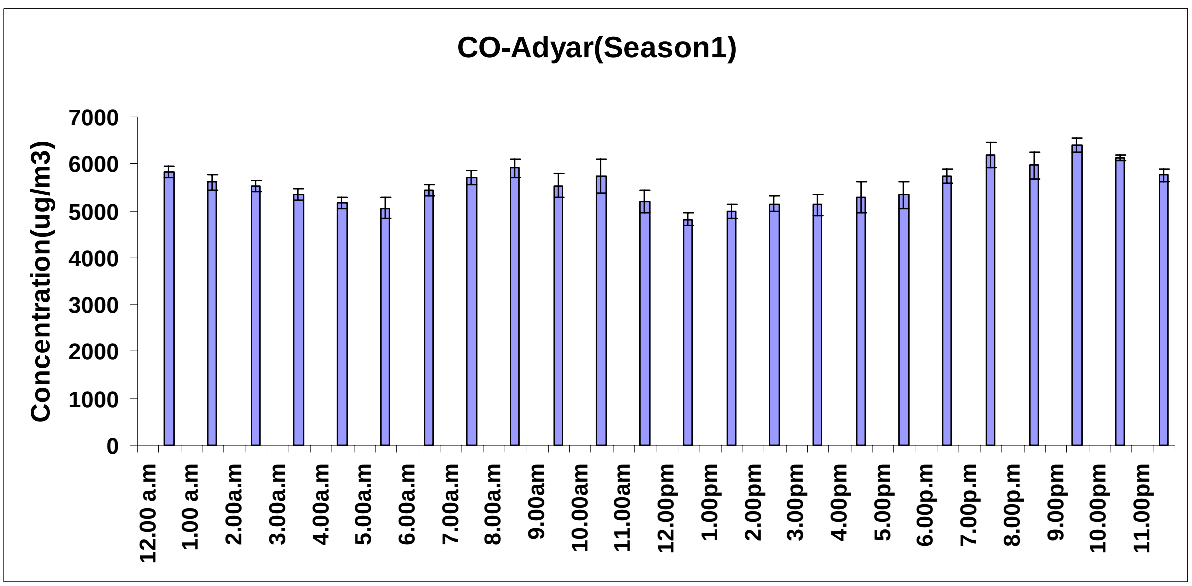


Figure 2.1.4.6-- CO – diurnal variation for Adyar.

Figure 2.1.4.7 shows the distribution of the various speciation analysis associated with the PM_{10}. The fraction, which is shown as unknown in figure includes Si and other species such as the H,O and N fraction of organic matter, oxygen in the elemental oxides and other constituents not analyzed in the sample.. Of the measured components, OC (26.95%) was the highest fraction followed by EC (12.33%) and Sulphate ion (8.76%).

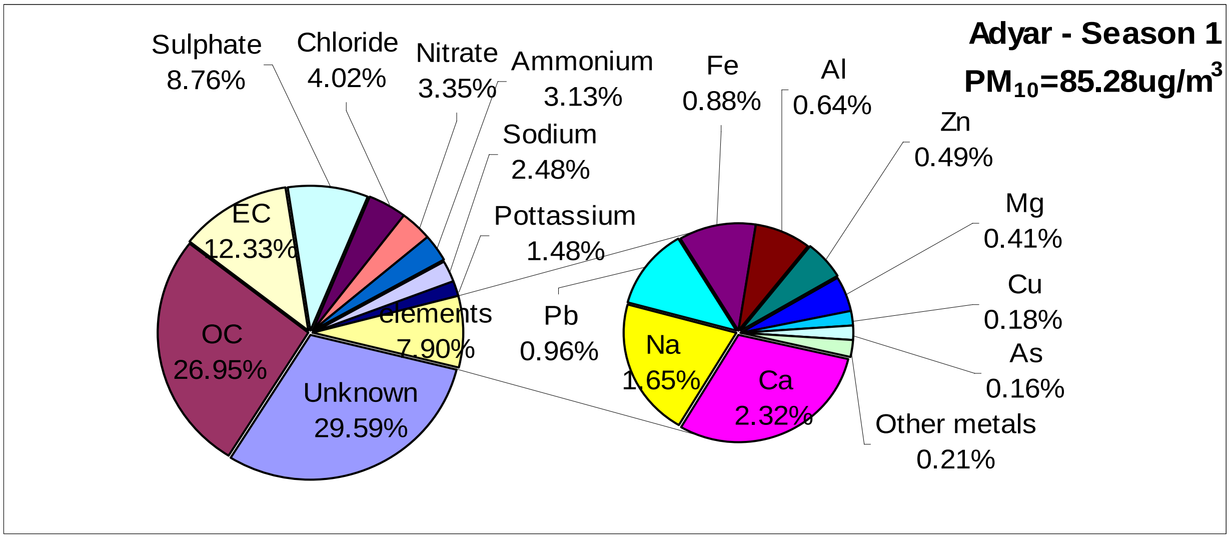


Figure 2.1.4.7-- Distribution of species on PM_{10} at Adyar

2.4.1.5 Saidapet (Kerbside)

Figures 2.1.5.1 shows the 24-hr average values for TSPM and RSPM at Saidapet. The RSPM values were higher than NAAQS (100µg/m³ for Kerb site) for 10 days, especially on 19th, 22nd March and 4th April the RSPM values were 262.47, 360.62 and 640.04µg/m³ respectively. The TSPM values were also exceeding the NAAQS (200µg/m³ for Kerb site) during the monitoring period. Particularly on 19th, 22nd and 28th March TSPM values were 412.09, 501.8 and 428.62µg/m³ respectively. From 20th, 31st March and 9th April sampling was not done.

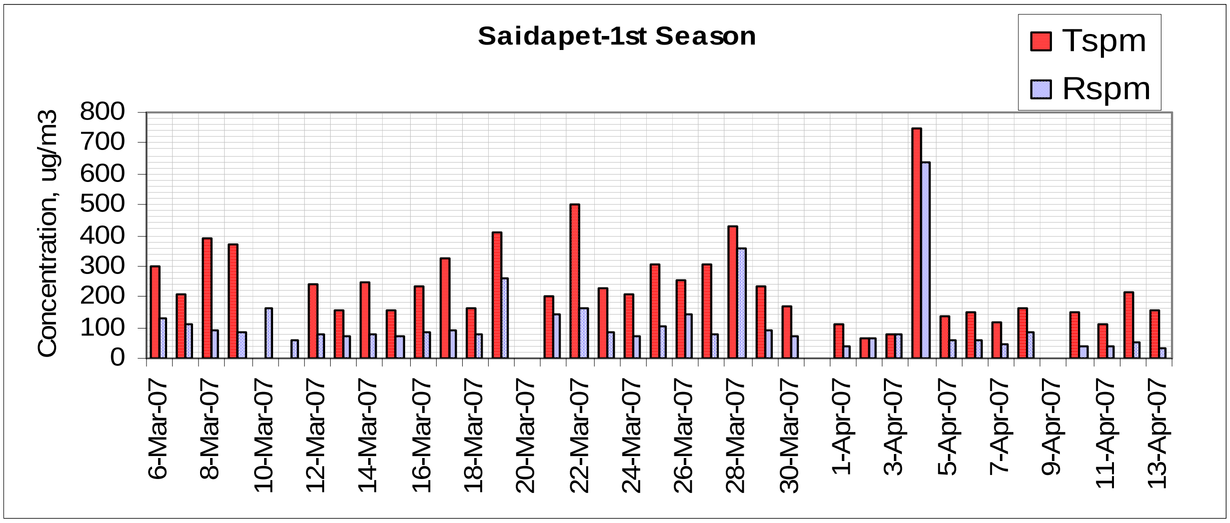


Figure 2.1.5.1--Time series of TSPM and RSPM at Saidapet

Figure 2.1.5.2 shows the variation of OC, EC and the EC/OC ratio associated with PM_{10}. The EC/OC ratio for PM_{10} varies between 0.31 and 0.73 with a mean value of 0.44. The values of OC+EC exceed the values of a 24-hr average $PM_{2.5}$ standard of 65 µg/m^3 for several days. This is perhaps due to the high traffic at this kerbside. The value of the EC/OC ratio is also high indicative of impact due to high traffic.

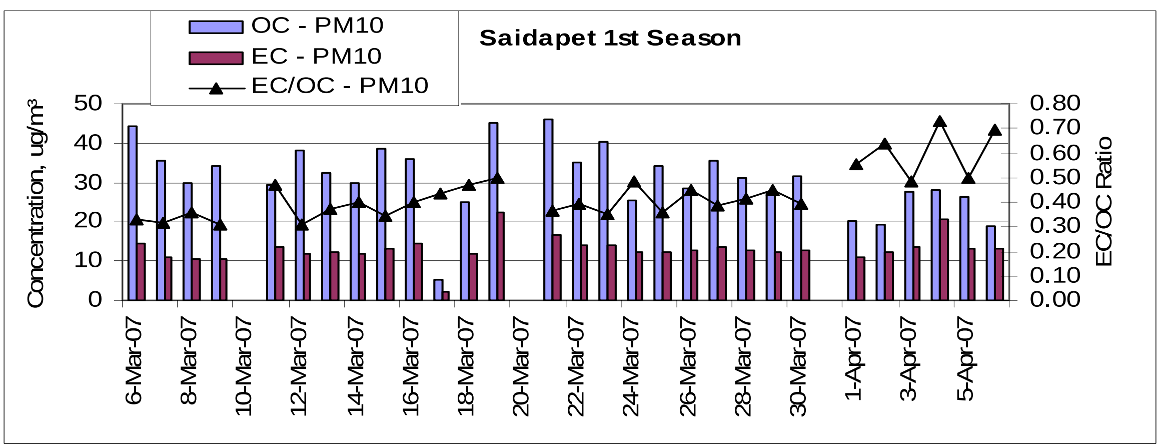


Figure2.1.5.2-- Measurements of OC/EC for Saidapet

Figure 2.1.5.3 shows the NOx and SO_2 distribution at Saidapet. NOx values were found to vary between 19.79and 49.82µg/m³ with the mean value of 33µg/m³. The SO_2 values range from 0.03 to 5.52µg/m³ with the mean value of 1.29 µg/m³. At this site both NOx and SO_2 concentrations were well below the NAAQS (80 µg/m³).

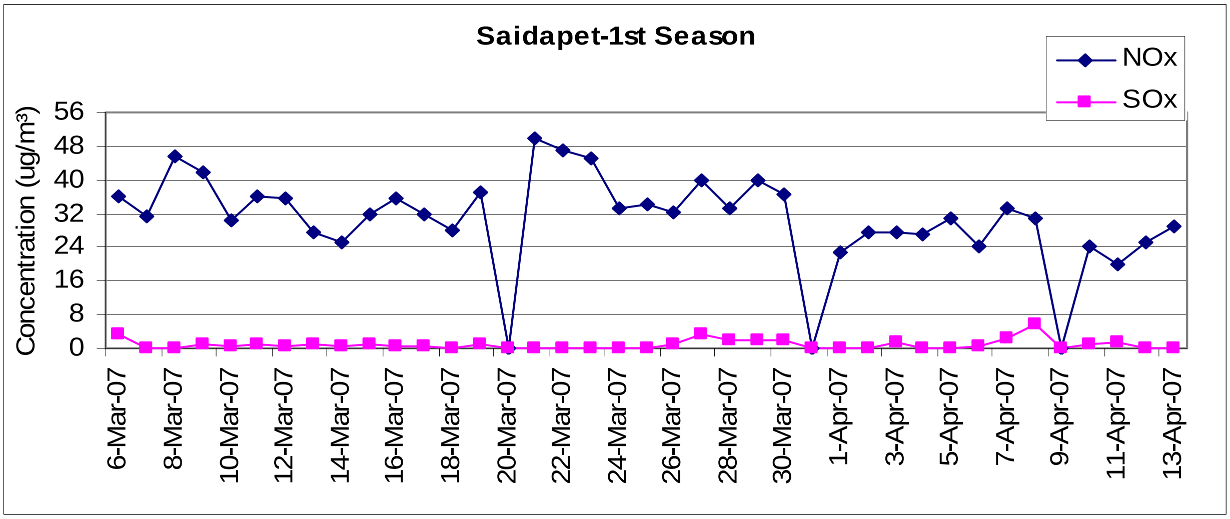


Figure2.1.5.3-- Time series measurements for SO_2 and NOx

Figure 2.1.5.4 shows the levels of anions associated with PM_{10} at Saidapet. The concentration of Sulphate (6.4 ± 3.0 µg/m³) was higher than those of nitrate (2.5 ± 1.4 µg/m³) and chloride (3.1 ± 1.6µg/m³) at this site.

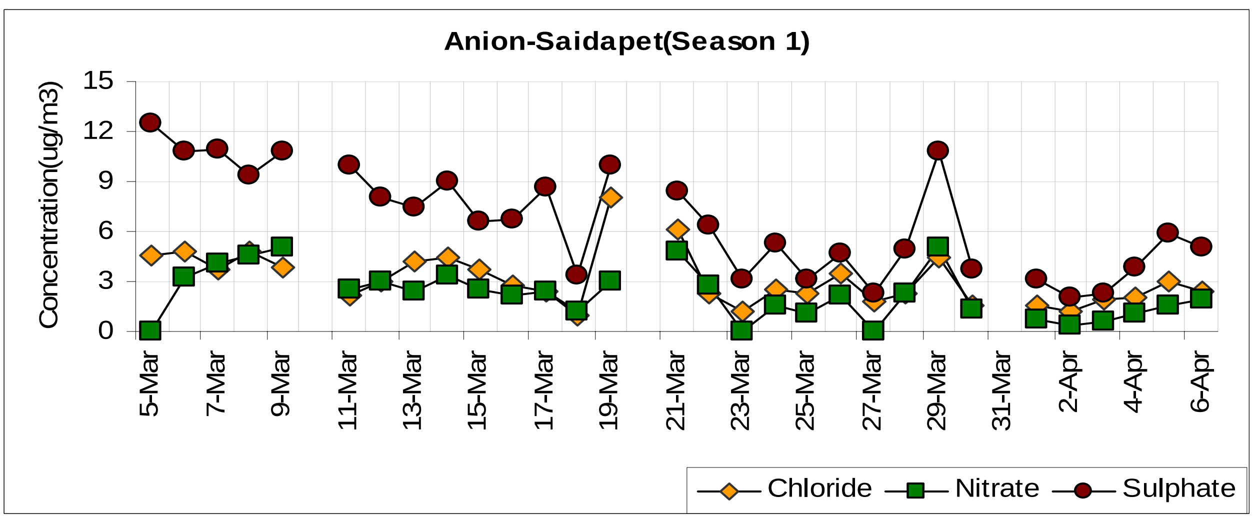


Figure 2.1.5.4-- Time series of anions on PM10

Figure 2.1.5.5 shows the levels of cations associated with PM_{10} at Saidapet. The concentration of ammonium (2.5 ± 2.9 μg/m³) was higher than those of sodium (2.0 ± 1.7 μg/m³) and potassium (1.8 ± 2.4 μg/m³) at this site.

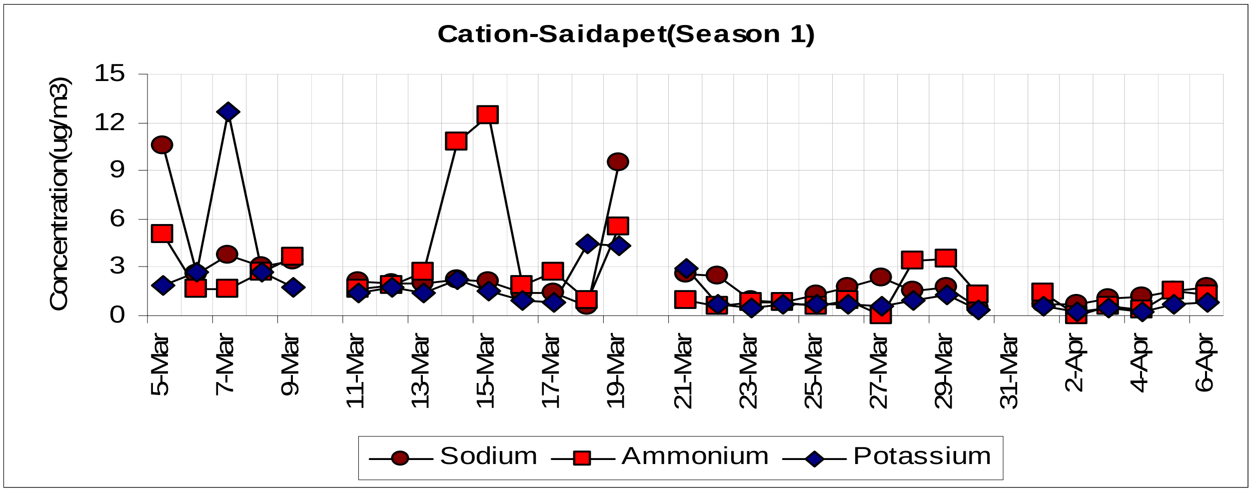


Figure 2.1.5.5-- Time series of cations on PM10

Figure 2.1.5.6 shows the measurement of the diurnal variation of CO concentrations at the monitoring station. The mean levels are shown to vary between 4800 μg/m³ and 7000 μg/m³. At this site CO concentration is exceeding the 1-hr average NAAQS standard of (4000 μg/m³).

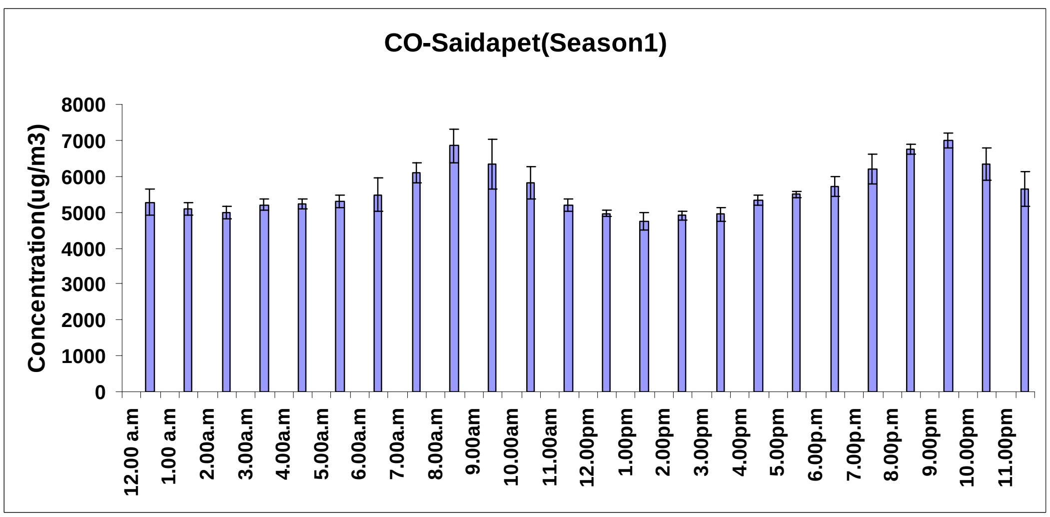


Figure 2.1.5.6-- CO – diurnal variation for Saidapet

Figure 2.1.5.7 shows the distribution of the various speciation analysis associated with the PM_{10}. The fraction, which is shown as unknown in figure includes Si and other species such as the H,O and N fraction of organic matter, oxygen in the elemental oxides and other constituents not analyzed in the sample.. The analysis showed highest OC (27.92%) fraction followed by EC (11.73%) and Sulphate ion (5.79%).

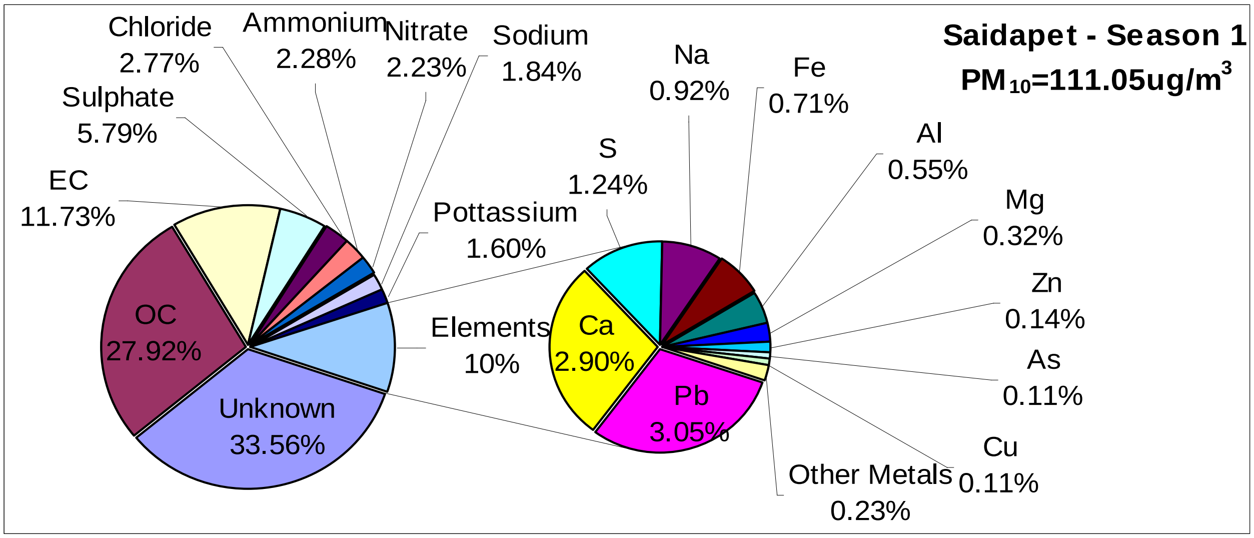


Figure 2.1.5.7-- Distribution of species on PM_{10} at Saidapet

2.4.1.6 R.K.Nagar (Industrial)

Figures 2.1.6.1 shows the 24-hr average values for TSPM and RSPM at RK Nagar. The data analysis showed that the RSPM values were higher than NAAQS (150µg/m³ for Industrial area) for 6 days during the monitoring period. Particularly on 12th, 14th and 29th March the RSPM values were 216.94, 206.93and 223.68µg/m³ respectively. The TSPM values were well within the NAAQS limit (500µg/m³ for Industrial area) except on 8th March 2007. On that day TSPM value was 554.14µg/m³. On 31st Mar sampling was not done.

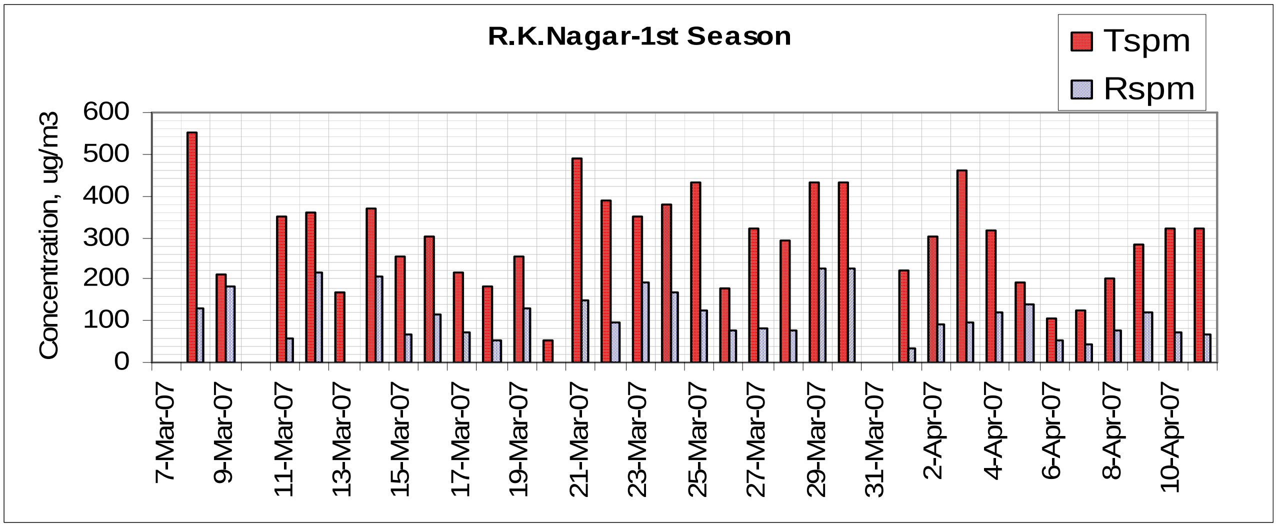


Figure 2.1.6.1--Time series of TSPM and RSPM at R.K.Nagar

Figure 2.1.6.2 shows the variation of OC, EC and the EC/OC ratio associated with PM_{10}. The EC/OC ratio for PM_{10} varies between 0.15 and 0.45 with a mean value of 0.31. The values for OC are high on two days, which are indicative of a spiked event.

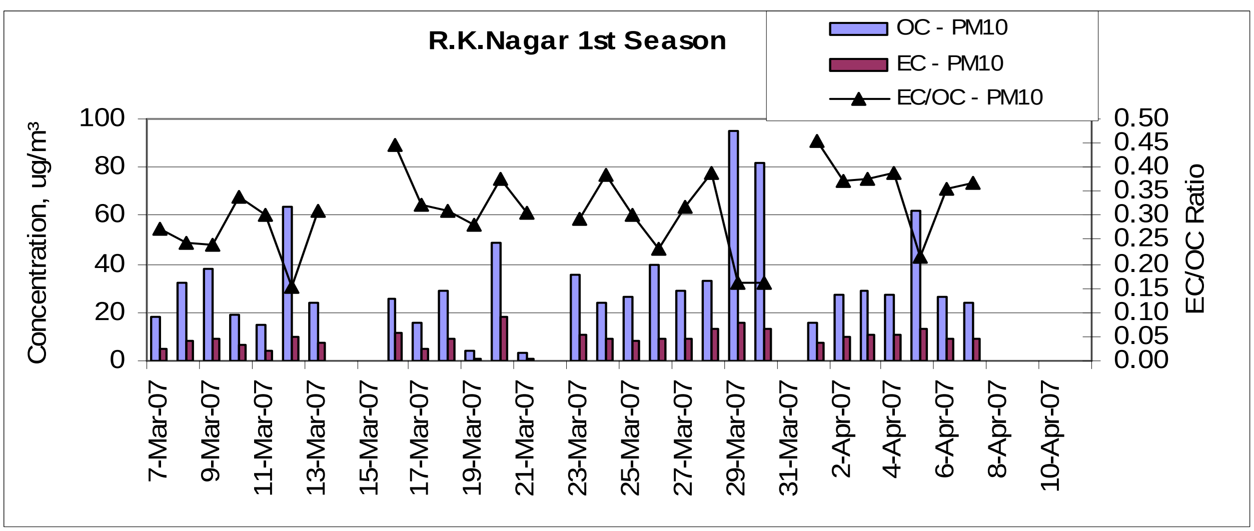


Figure2.1.6.2-- Measurements of OC/EC for R.K.Nagar

Figure 2.1.6.3 shows the variation of NOx and SO_2 concentration at R.K.Nagar. NOx values were found to vary between 11.95 and 36.98µg/m³ with the mean value of 20.4µg/m³. SO_2 values range from 0.1to 2.77µg/m³ with the mean value of 1.02 µg/m³. The NOx and SO_2 concentration at R.K.Nagar were well below the NAAQS limit of 120 µg/m³.

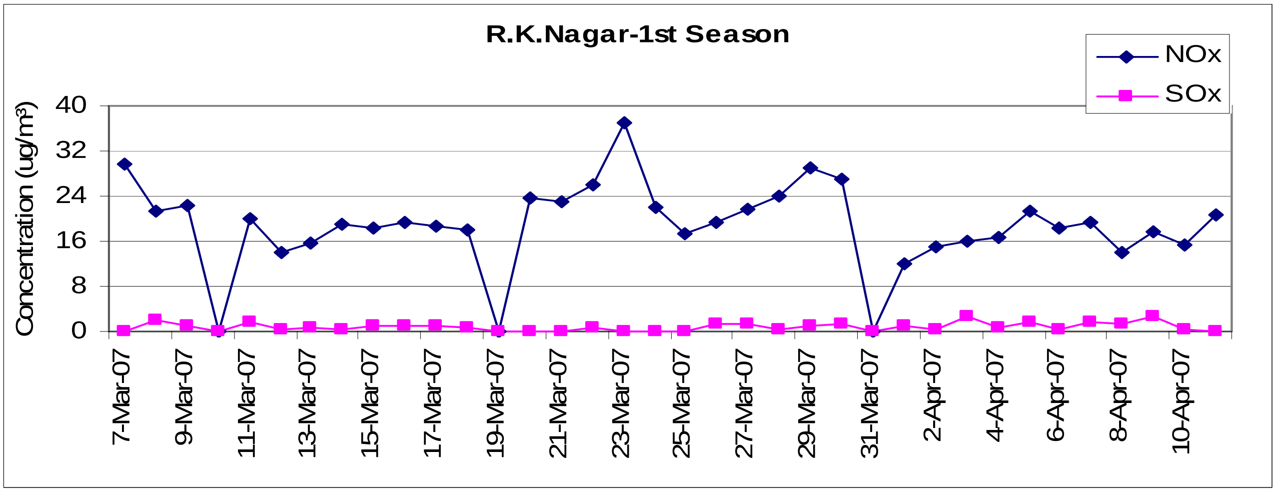


Figure 2.1.6.3-- Time series measurements for SO_2 and NOx

Figure 2.1.6.4 shows the levels of anions associated with PM_{10}. The concentration of Sulphate (9.8 ± 5.7 µg/m³) was higher than those of nitrate (3.7 ± 1.9 µg/m³) and chloride (5.4 ± 2.9 µg/m³). The other anions concentrations were well below the detection limit.

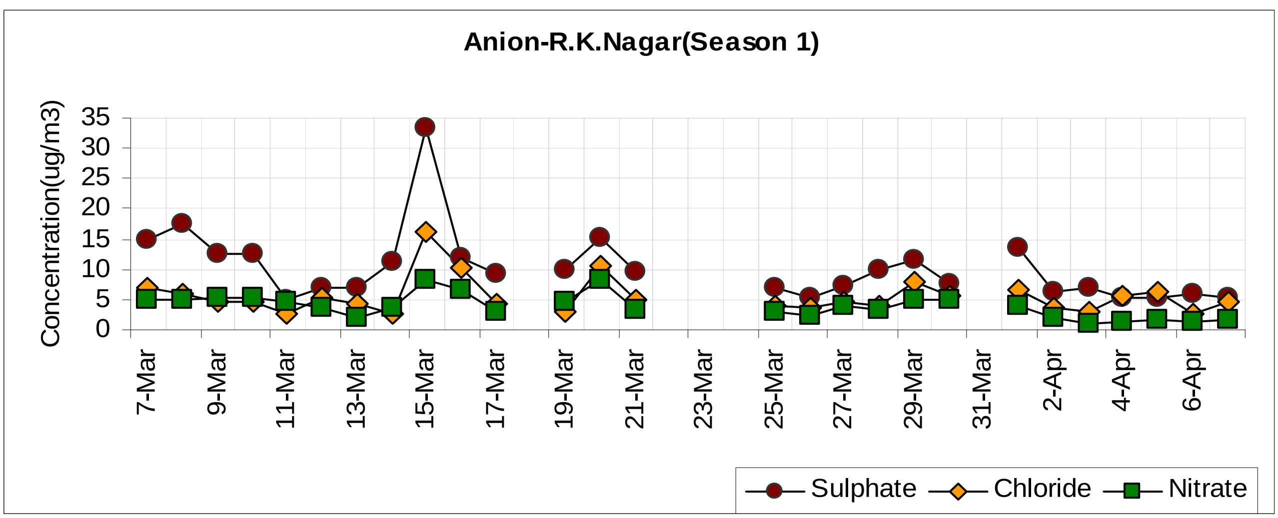


Figure 2.1.6.4-- Time series of anions on PM10

Figure 2.1.6.5 shows the levels of Cations associated with PM_{10}. The concentrations of sodium (2.9 ± 2.4 µg/m³) and ammonium (2.3 ± 4.5 µg/m³) ions were higher than that of potassium ion (1.7 ± 1.6 µg/m³). The other Cations concentrations at the site were well below the detection limit.

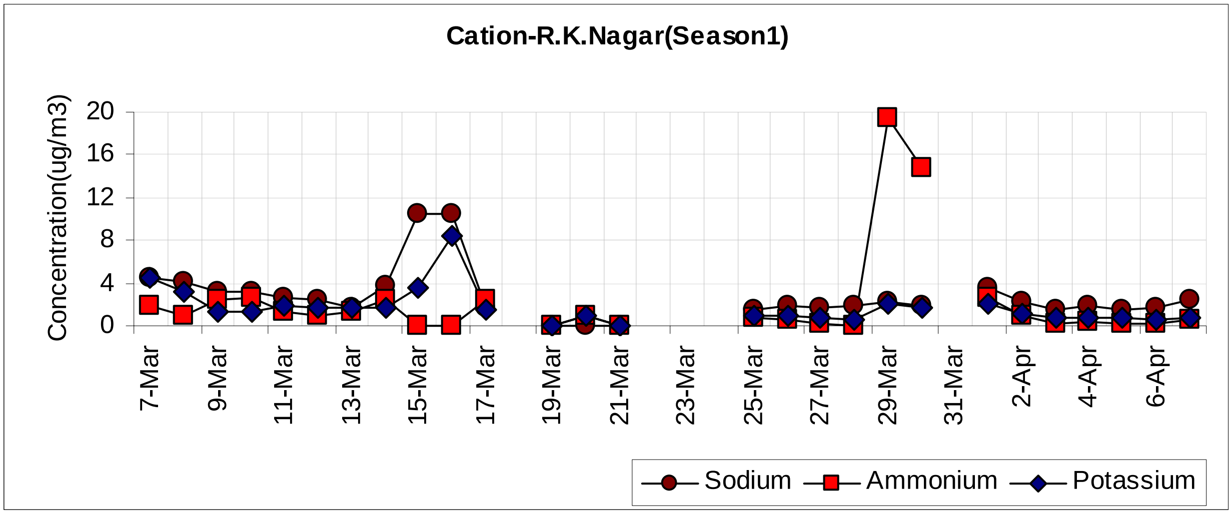


Figure 2.1.6.5-- Time series of Cations on PM10

Figure 2.1.6.6 shows the diurnal variation of CO concentration at the RK Nagar. The mean CO levels at the site were varying between 4000 µg/m^3 and 6000 µg/m^3. At this site CO concentrations are above the 1-hr standard NAAQS value of 4000 µg/m^3. .

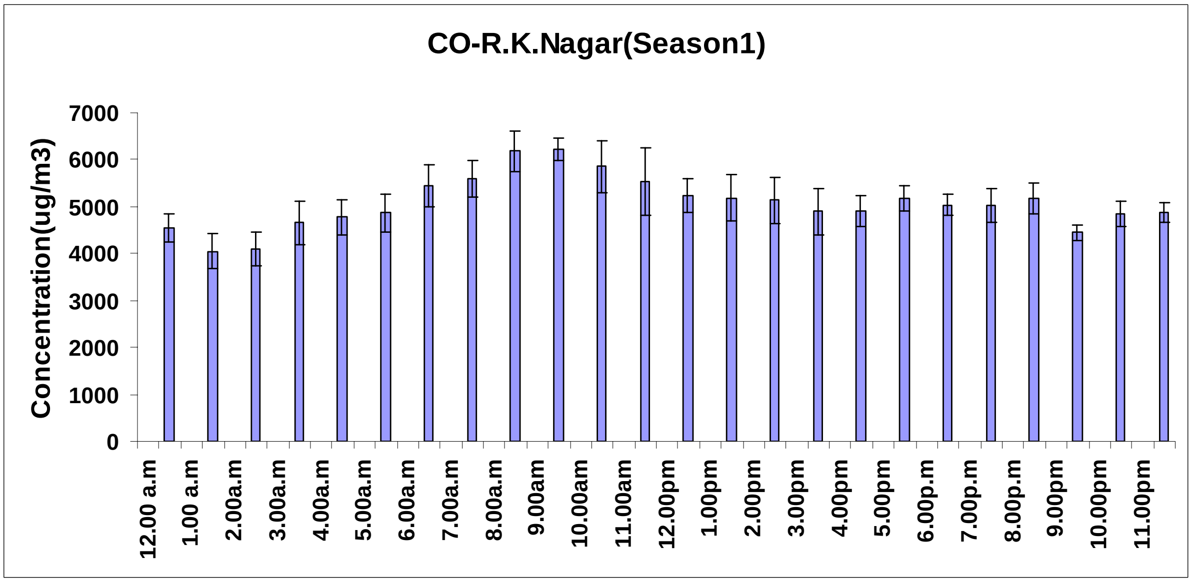


Figure 2.1.6.6 CO – diurnal variation for R.K.Nagar.

Figure 2.1.6.7 shows the distribution of the various speciation associated with the PM_{10}. The fraction, which is shown as unknown in figure includes Si and other species such as the H,O and N fraction of organic matter, oxygen in the elemental oxides and other constituents not analyzed in the sample. Among the measured species the OC (28.69%) was the highest fraction followed by Sulphate ion (8.64%) and EC (7.98%).

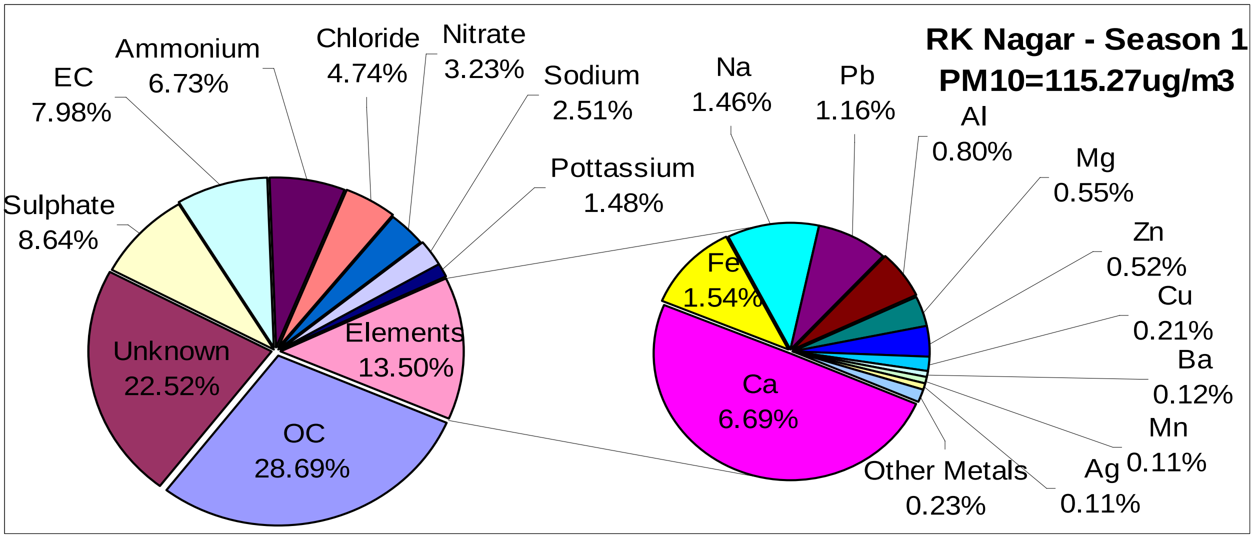


Figure 2.1.6.7-- Distribution of species on PM_{10} at R.K.Nagar

2.4.1.7 Ambattur (Industrial)

Figures 2.1.7.1 shows the 24-hr average values for TSPM and RSPM concentration at the monitoring site. The RSPM values at the site were higher than NAAQS (150µg/m³ for Industrial area) for 5 days. Particularly on 28th May, 1st June and 5th June the RSPM values were 260.05, 333.5and 245.79µg/m³ respectively. The TSPM values were also higher than the NAAQS limit of 500µg/m³ for 2 days. Particularly on 28th May and 6th June TSPM values were 971.54 and 517.56µg/m³ respectively.

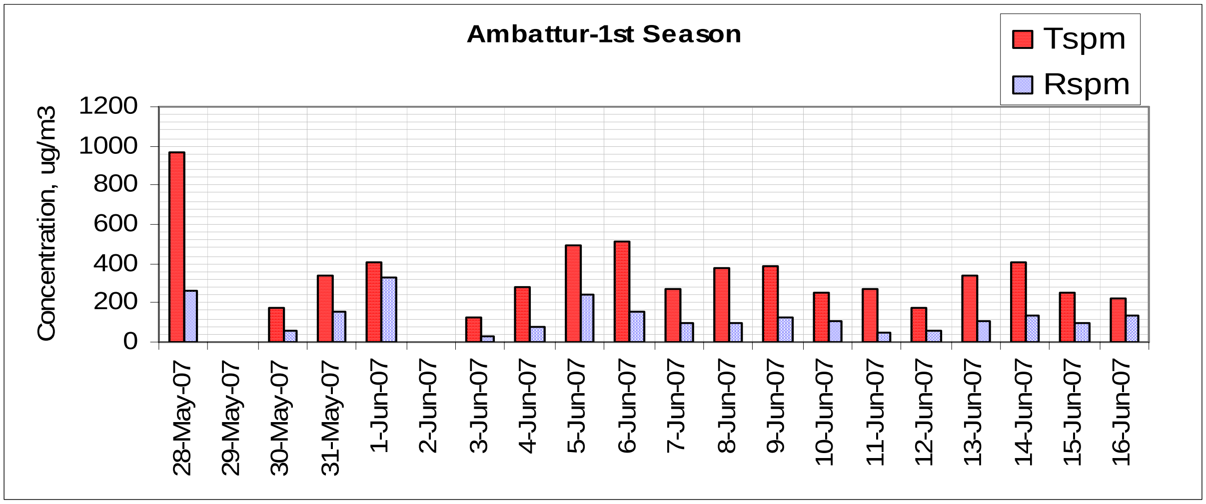


Figure 2.1.7.1--Time series of TSPM and RSPM at Ambattur

Figure 2.1.7.2 shows the variation of OC, EC and the EC/OC ratio associated with PM_{10}. The EC/OC ratio for PM_{10} varies between 0.23 and 0.49 with a mean value of 0.31. The EC/OC ratio for $PM_{2.5}$ varies between 0.49 and 0.51 with a mean value of 0.50.

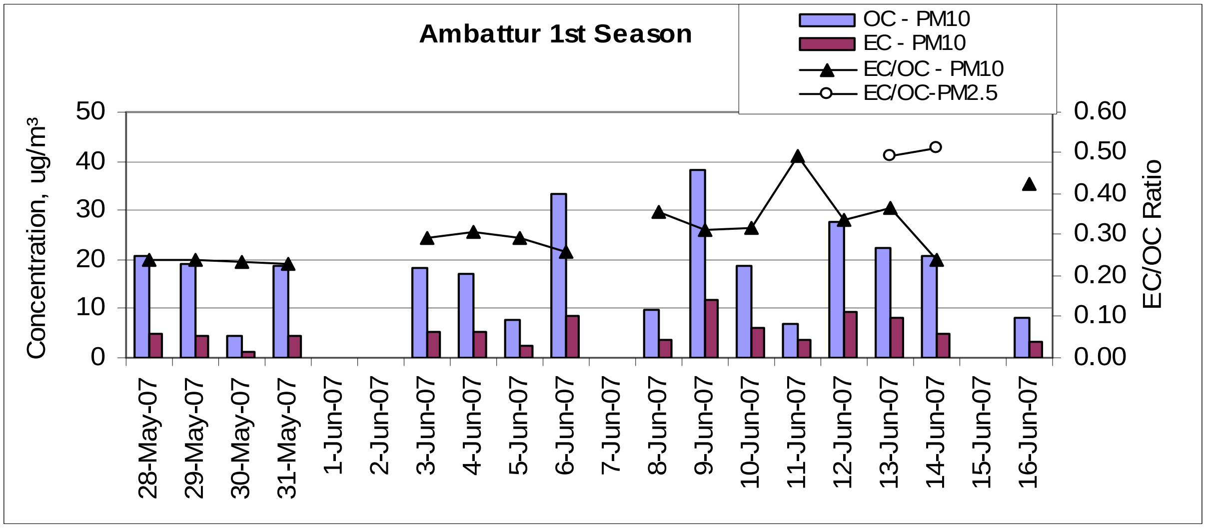


Figure2.1.7.2-- Measurements of OC/EC for Ambattur

Figure 2.1.7.3 shows the NOx and SO_2 distribution at Ambattur site. The NOx values were found to vary between 6.22and 46.54µg/m³ with the mean value of 17.1µg/m³. SO_2 values range from 0.25 to 6.34µg/m³ with the mean value of 4.16µg/m³. At this site both the NOx and SO_2 concentrations were well below the NAAQS limit of 120 µg/m³ for industrial areas.

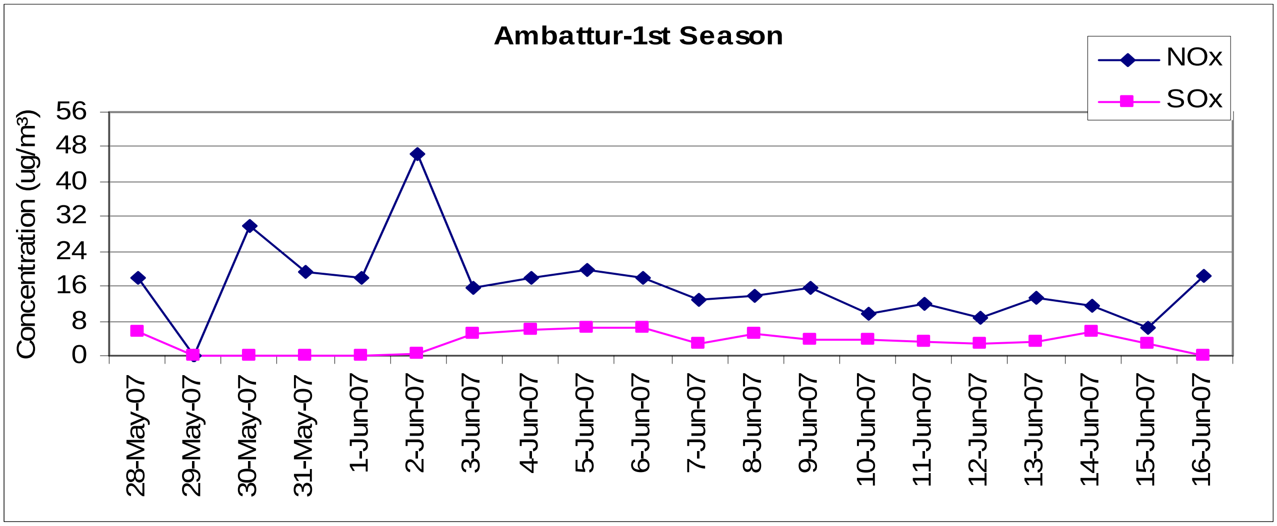


Figure2.1.7.3-- Time series measurements for SO_2 and NOx

Figure 2.1.7.4 show the levels of anions associated with PM_{10}. The mean concentration of sulphate (8.59± 4.85 ug/m³) was higher than those of nitrate (4.2 ± 2.48 ug/m³) and chloride (3.88 ± 2.03 ug/m³). For the $PM_{2.5}$ fraction, the sulphate concentration found was 3.35ug/m³. The ratio of sulphate in the $PM_{2.5}/PM_{10}$ fractions was 0.29 indicating that a majority of the sulphate in this site were associated with the $PM_{2.5}$ phase. Similar ratios for chloride and nitrate were found to be 0.07 and 0.05 respectively.

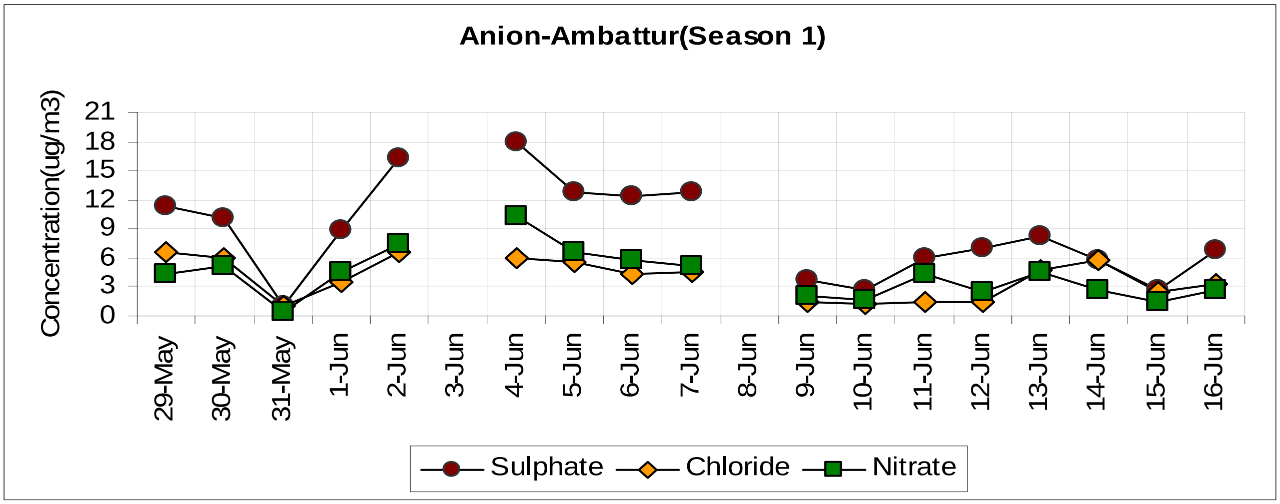


Figure 2.1.7.4-- Anions in PM-10 at Ambattur

Figure 2.1.7.5 shows the levels of Cations associated with PM_{10}. The concentrations of sodium (2.38± 1.55 ug/m³) and ammonium (2.89 ± 1.58 ug/m³) ions were higher than that of potassium ion (1.29 ± 0.91 ug/m³). The ratio of the ion concentrations on $PM_{2.5}$ to that in PM_{10} were 0.15, 0.24 and 0.39 for sodium, ammonium and potassium respectively.

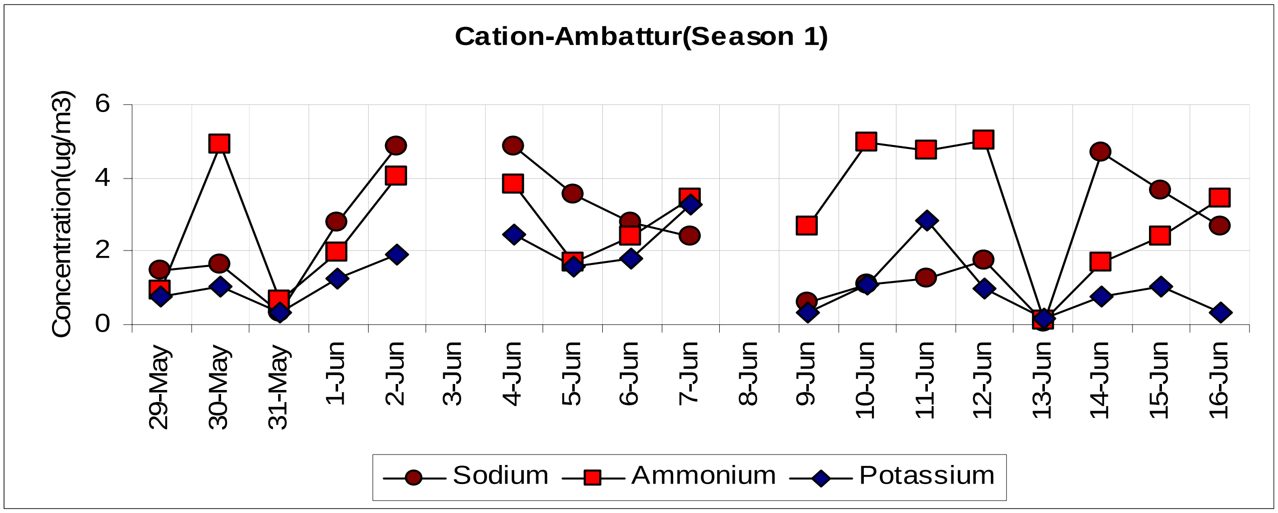


Figure 2.1.7.5--Cations in PM-10 at Ambattur

Figure 2.1.7.6 shows the diurnal variation of CO concentrations at Ambattur site. The mean levels are shown to vary between 1500 and 2100 µg/m³. At this site CO concentrations were below the 1 hr NAAQS standard of 4000 µg/m³ .

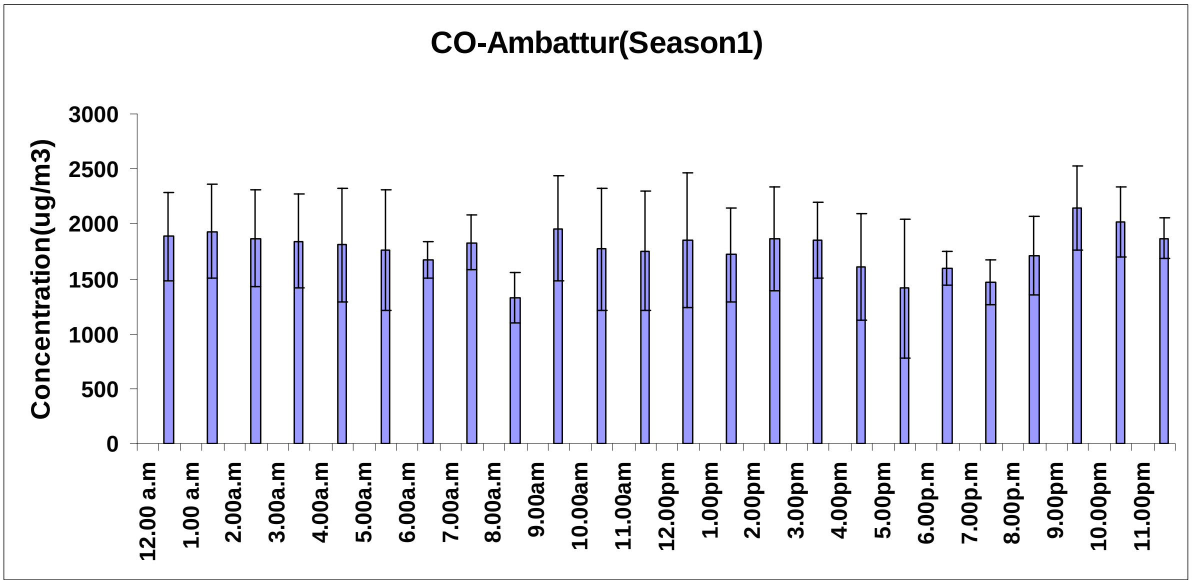


Figure 2.1.7.6-- CO – diurnal variation for Ambattur.

Figure 2.1.7.7 shows the distribution of the various speciation associated with the PM_{10}. The fraction, which is shown as unknown in figure includes Si and other species such as the H,O and N fraction of organic matter, oxygen in the elemental oxides and other constituents not analyzed in the sample. Of the measured components, OC (14.24%) was the highest fraction followed by Sulphate ion (6.69%) and EC (4.24%).

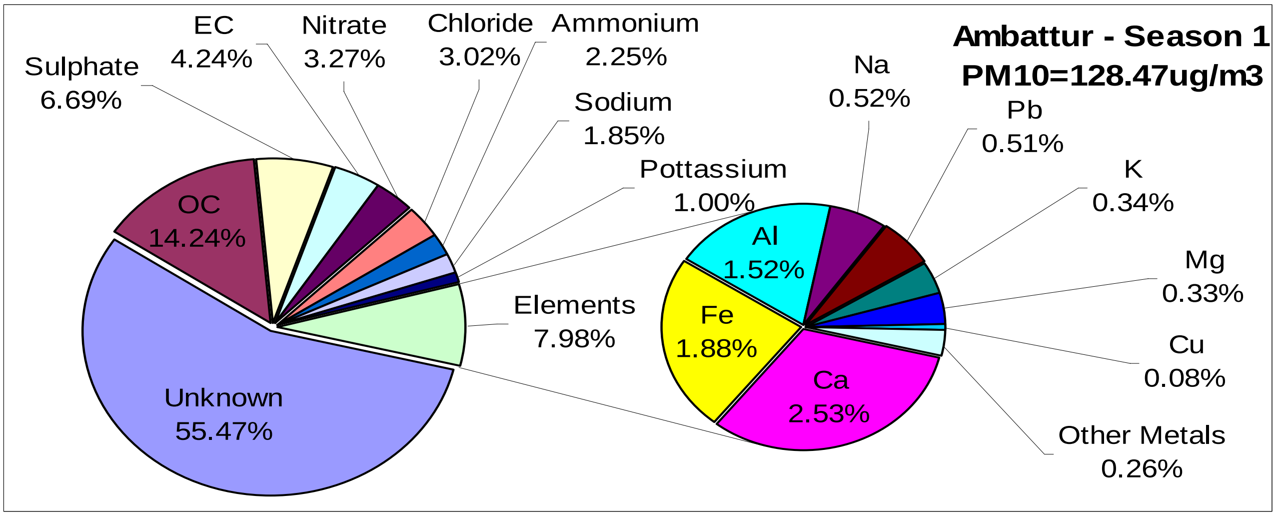


Figure 2.1.7.7-- Distribution of species on PM_{10} at Ambattur

2.4.2 Season 2

2.4.2.1 IIT Madras

Figures 2.2.1.1 shows the 24-hr average values for TSPM, RSPM, PM_{10}, $PM_{2.5}$ and the $PM_{2.5}/PM_{10}$ ratio. The RSPM values were higher than NAAQS limit (75 µg/m³ for sensitive area) for 6 days. Particularly on 11th July RSPM value was 1111.76µg/m³. The TSPM values were higher than the NAAQS limit (100µg/m³ for sensitive area) for most of the days. Particularly on 4th, 11th and 16th July TSPM values were 284.95, 1199.76 and 346.55µg/m³ respectively. The PM_{10} values were also slightly higher than the NAAQS for most of the days. Especially on 13th and 30th July the PM10 values were 551.2 and 466.34µg/m³ respectively. The $PM_{2.5}$ values were found to vary between 4.73 and 411.3µg/m³. The $PM_{2.5}/PM_{10}$ ratio was found to vary between 0.10 and 0.94. There is large variation of the ratio. The reason for this large variation is not clear at this stage.

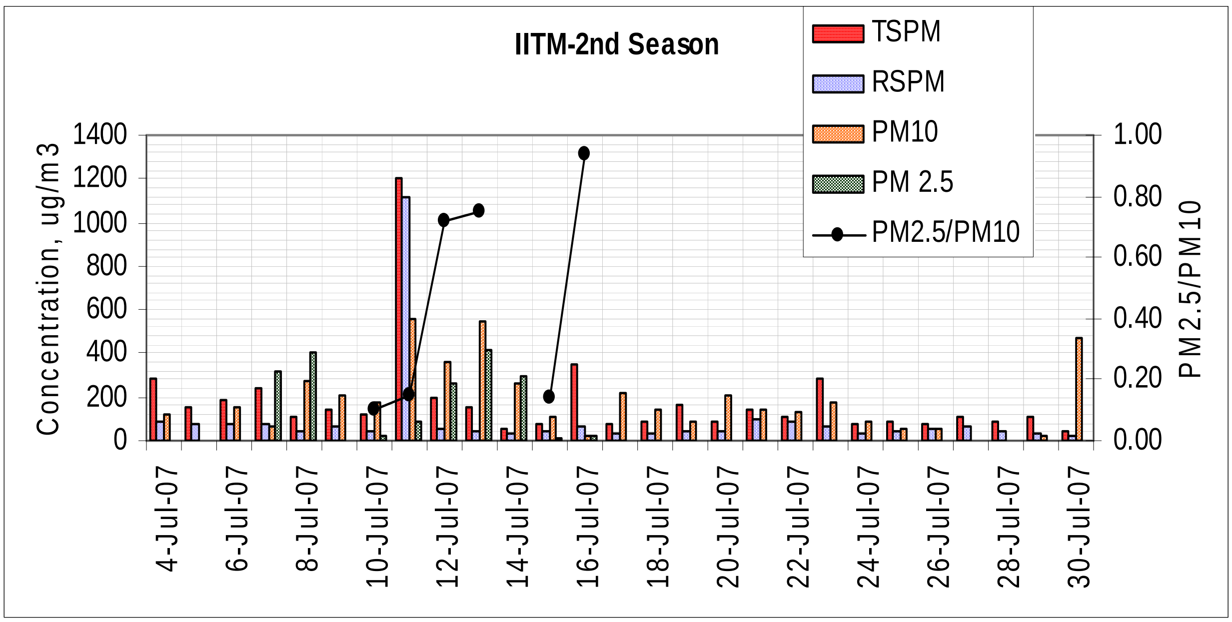


Figure 2.2.1.1-- Particulate matter at IIT Madras

Figure2.2.1.2 shows the variation of OC, EC and the EC/OC ratio associated with PM_{10}. The EC/OC ratio for PM_{10} varies between 0.16 and 0.52 with a mean value of 0.28. The EC/OC ratio for $PM_{2.5}$ varies between 0.32 and 0.49 with a mean value of 0.39.

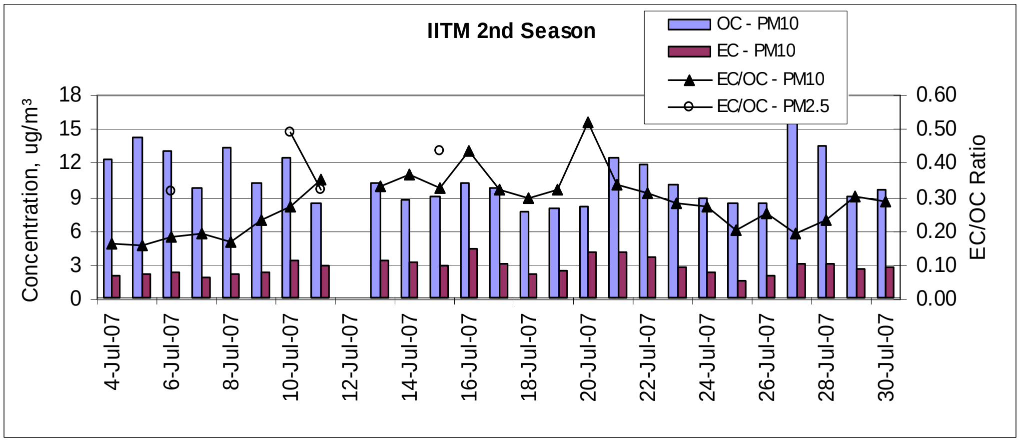


Figure2.2.1.2-- Measurements of OC/EC/TC for IITM

Figure 2.2.1.3 shows the NOx and SO_2 distribution at IIT Madras. NOx values were found to vary between 5.05 and 26.56µg/m³ with the mean value of 13.84µg/m³. SO_2 values range from 1.13 to 9.22µg/m³ with the mean value of 4.61µg/m³. At this site both the NOx and SO_2 concentrations were well below the NAAQS limit of 30 µg/m³.

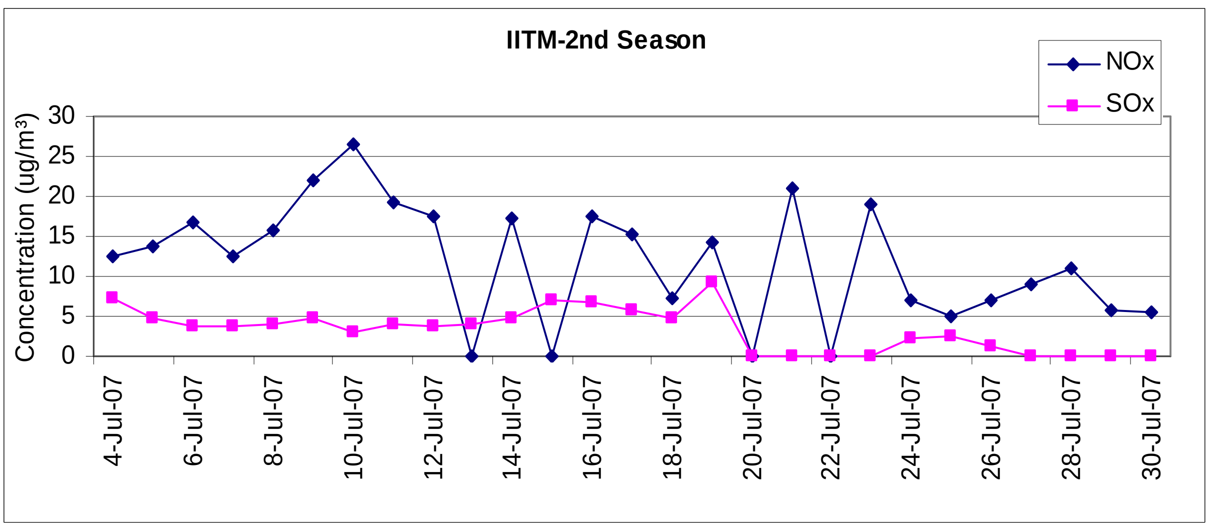


Figure2.2.1.3-- Time series measurements for SO_2 and NOx

Figure 2.2.1.4 shows the levels of anions associated with PM_{10}. The concentration of Sulphate (5.21± 3.16 ug/m³) was higher than those of nitrate (2.09± 1.04 ug/m³) and chloride (2.14 ± 1.71 ug/m³). For the $PM_{2.5}$ fraction, the sulphate concentration found was 3.66ug/m³. The ratio of sulphate in the $PM_{2.5}/PM_{10}$ fractions was 0.79 indicating that the majority of the sulphate in this site were associated with the $PM_{2.5}$ phase. Similar ratios for chloride and nitrate were found to be 0.21 and 0.12 respectively.

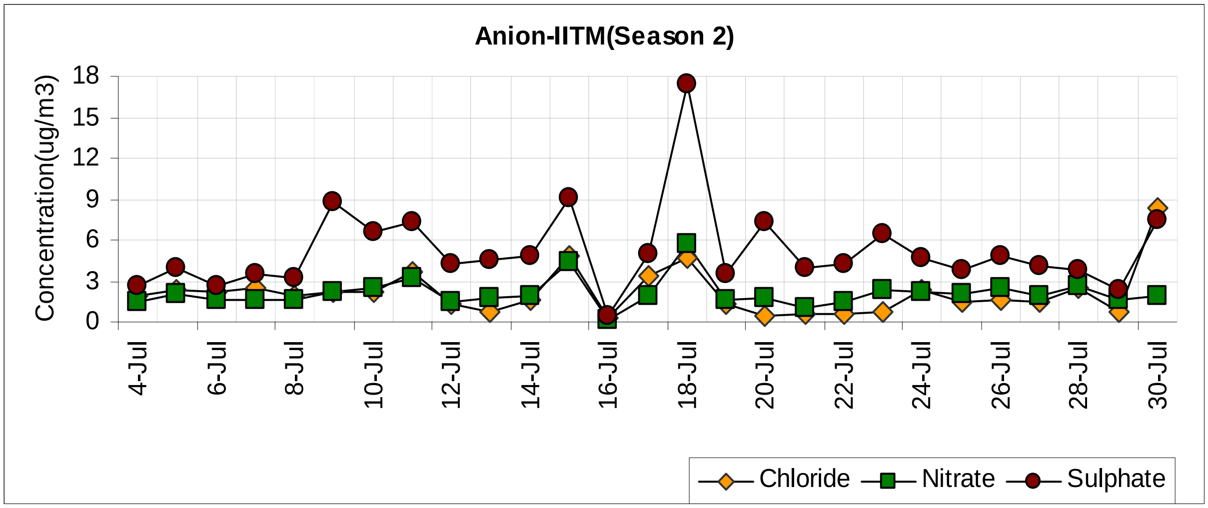


Figure 2.2.1.4-- Time series of anions on PM_{10}

Figure 2.2.1.5 shows the levels of Cations associated with PM_{10}. The concentrations of sodium (1.54± 0.57 ug/m³) and ammonium (0.66 ± 0.31 ug/m³) ions were higher than that of potassium ion (0.55 ± 0.38 ug/m³). The ratio of the ion concentrations on $PM_{2.5}$ to that in PM_{10} were 0.26 and 1.78 for sodium and ammonium respectively. This indicated that the predominant portion of the ammonium ion is associated with PM_{10} fraction.

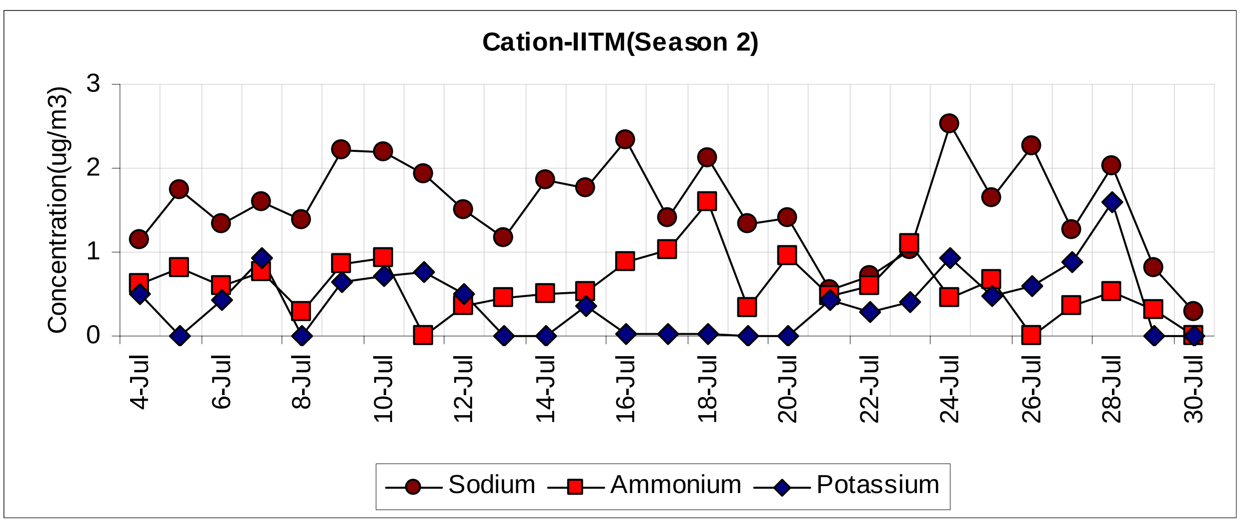


Figure 2.2.1.5--Cations in PM_{10} at IIT Madras

Figure 2.2.1.6 shows the diurnal variation of CO levels at IIT madras. The mean levels at this were vary between 2700 and 4400 µg/m³. At this site CO concentration exceeds the 1-hr NAAQS standard of 4000 µg/m³ for a few hours during the morning and evening, when traffic is expected to be higher.

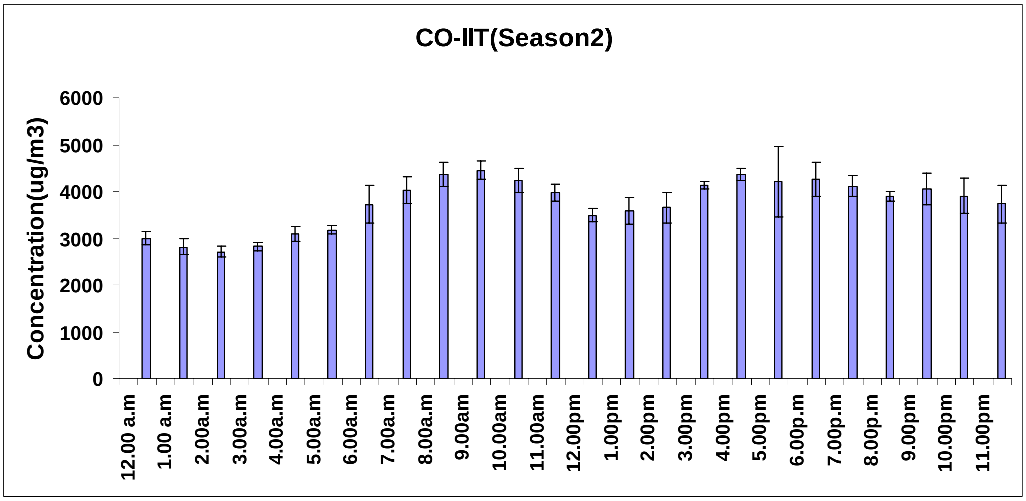


Figure 2.2.1.6-- CO – diurnal variation for IITM.

Figure 2.2.1.7 shows the distribution of the various speciation associated with the PM_{10}. The fraction, which is shown as unknown in figure includes Si and other species such as the H,O and N fraction of organic matter, oxygen in the elemental oxides and other constituents not analyzed in the sample. Of the measured components Fe (11.78%) was the highest fraction followed by OC (11.25%) and Sulphate (5.54%).

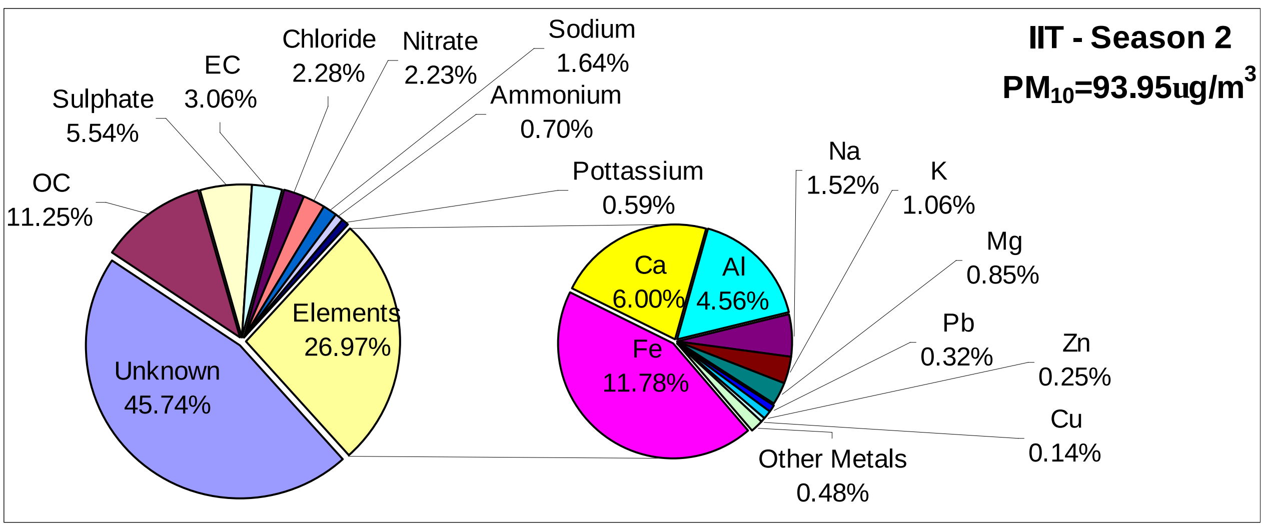


Figure 2.2.1.7-- Distribution of species on PM_{10} at IITM

2.4.2.2 Mylapore

Figures 2.2.2.1 shows the 24-hr average values for TSPM and RSPM. The RSPM values were higher than NAAQS (100 µg/m³ for residential area) for 4 days. Particularly on 9th and 12th June RSPM values were 385.72 and 339.04µg/m³ respectively. The TSPM values were higher than the NAAQS (200µg/m³ for residential area) for 6 days. Particularly on 31st May, 9th and 12th June TSPM values were 467.58, 544.27 and 402.57µg/m³ respectively. This is again a spike events, perhaps due to local cleaning activities.

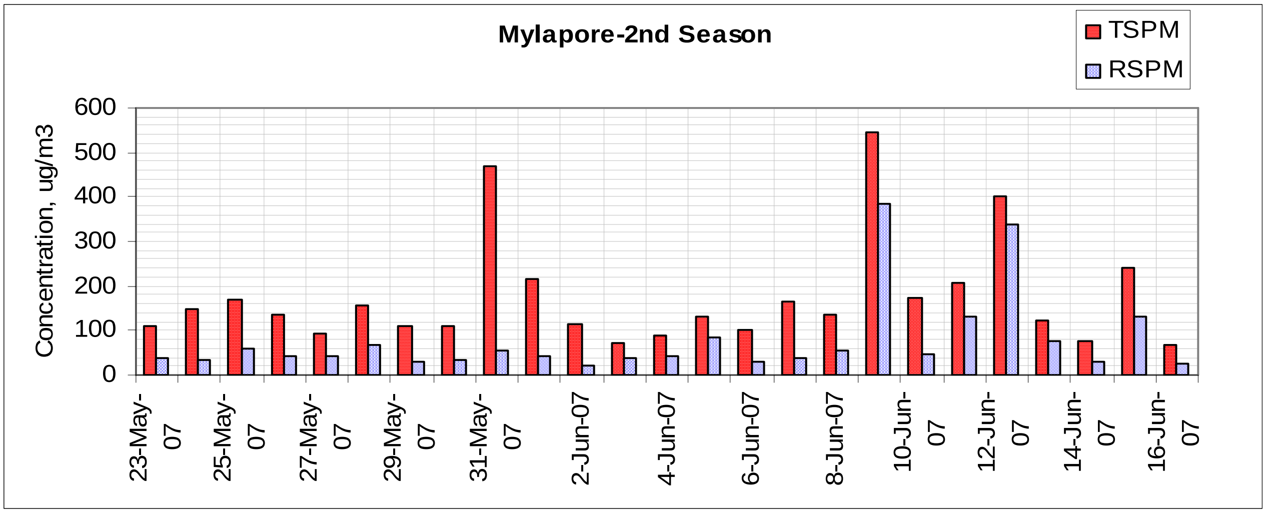


Figure 2.2.2.1-- Particulate matter at Mylapore

Figure2.2.2.2 shows the variation of OC, EC and the EC/OC ratio associated with PM_{10}. The EC/OC ratio for PM_{10} varies between 0.24 and 0.38 with a mean value of 0.31.

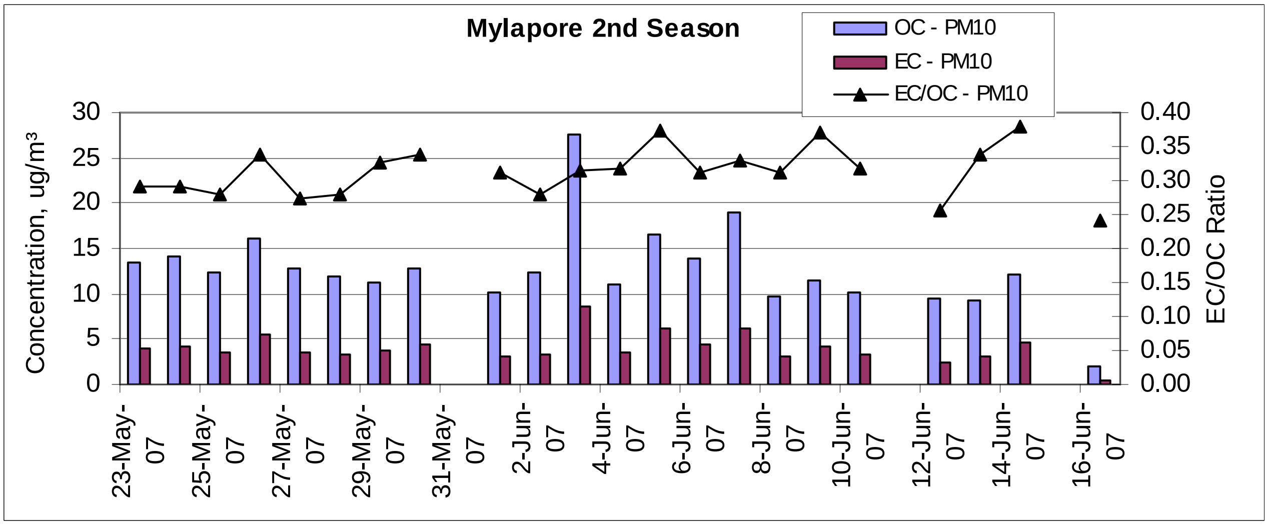


Figure 2.2.2.2-- Measurements of OC/EC/TC for Mylapore

Figure 2.2.2.3 shows the NOx and SO_2 distribution at Mylapore. NOx values were found to vary between 5.11and 32.37µg/m³ with the mean value of 12.34µg/m³. SO_2 values range from 0.72 to 9.24µg/m³ with the mean value of 5.04µg/m³. At this site both the NOx and SO_2 concentrations were well below the NAAQS limit of 80 µg/m³.

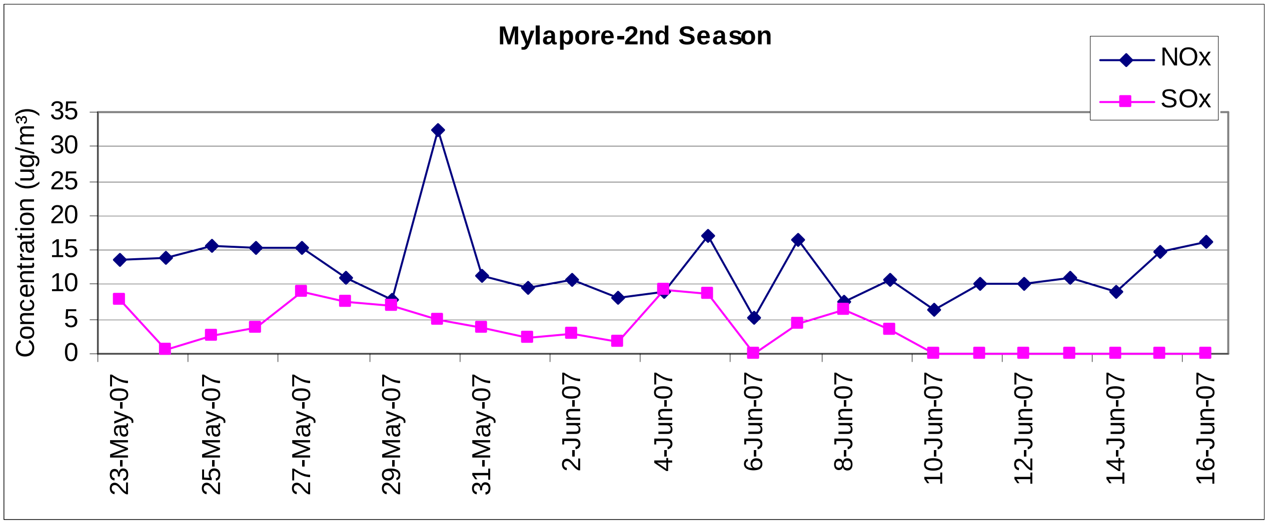


Figure2.2.2.3-- Time series measurements for SO_2 and NOx

Figure 2.2.2.4 shows the levels of anions associated with PM_{10}. The concentration of Sulphate (9.98± 5.31 ug/m³) was higher than those of nitrate (5.41± 2.89 ug/m³) and chloride (5.83± 4.16 ug/m³). For the $PM_{2.5}$ fraction, the Sulphate, Chloride and Nitrate concentration values were 4.51,0.31 and 0.47ug/m³ respectively.

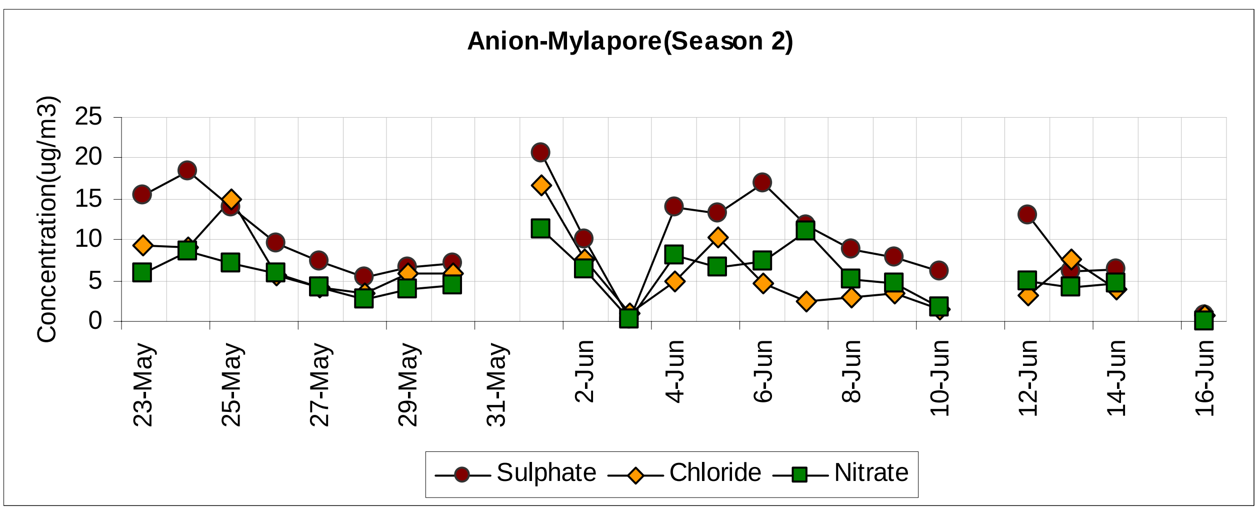


Figure 2.2.2.4-- Time series of anions on PM10

Figure 2.2.2.5 shows the levels of Cations associated with PM_{10}. The concentrations of sodium (1.28± 0.55 ug/m³) and ammonium (0.63 ± 0.84 ug/m³) ions were higher than that of potassium ion (0.61 ± 0.17 ug/m³). For the $PM_{2.5}$ fraction, the Sodium and Ammonium concentration values were 0.24 and1.74ug/m³ respectively. For the $PM_{2.5}$ fraction, the Potassium concentration value was below detention limit (BDL).

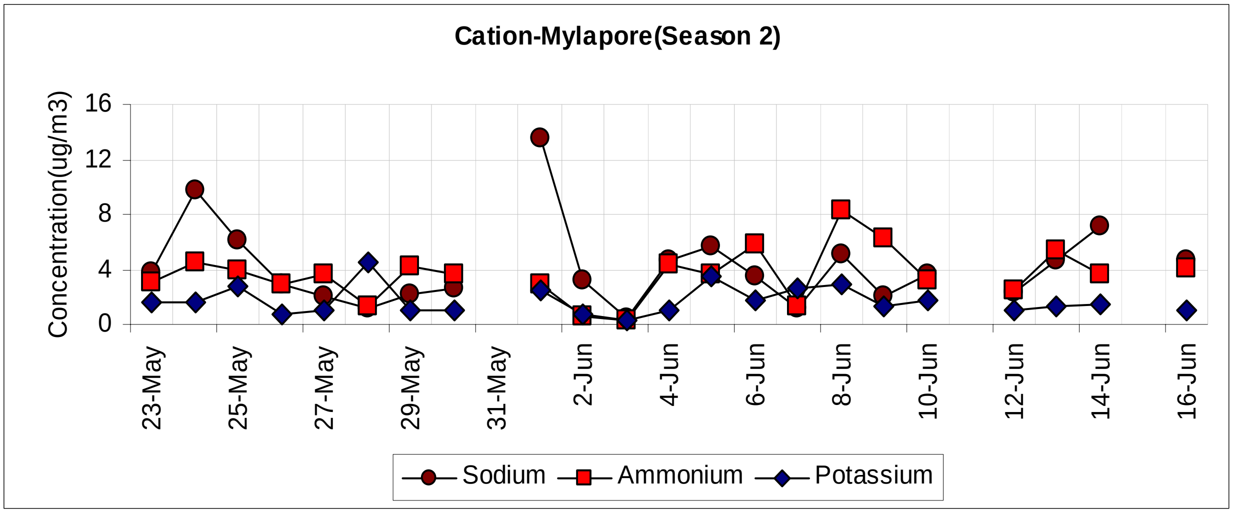


Figure 2.2.2.5--Cations in PM_{10} at Mylapore

Figure 2.2.2.6 shows the diurnal variation of CO levels at Mylapore monitoring station. The mean levels are shown to vary between 3850 and 9300 µg/m³. At this site CO concentration is exceeding the NAAQS 1-hr average standard of 4000 µg/m³.

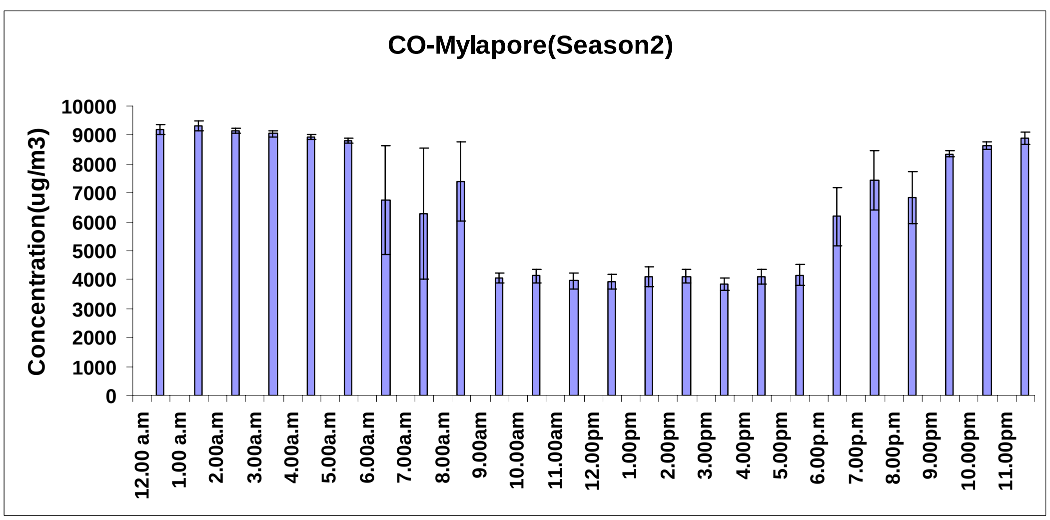


Figure 2.2.2.6-- CO – diurnal variation for Mylapore.

Figure 2.2.2.7 shows the distribution of the various speciation analysis associated with the PM_{10}. The fraction, which is shown as unknown in figure includes Si and other species such as the H,O and N fraction of organic matter, oxygen in the elemental oxides and other constituents not analyzed in the sample. Of the measured components OC (16.53%) was the highest fraction followed by Sulphate ion (12.98%) and Chloride (7.59%).

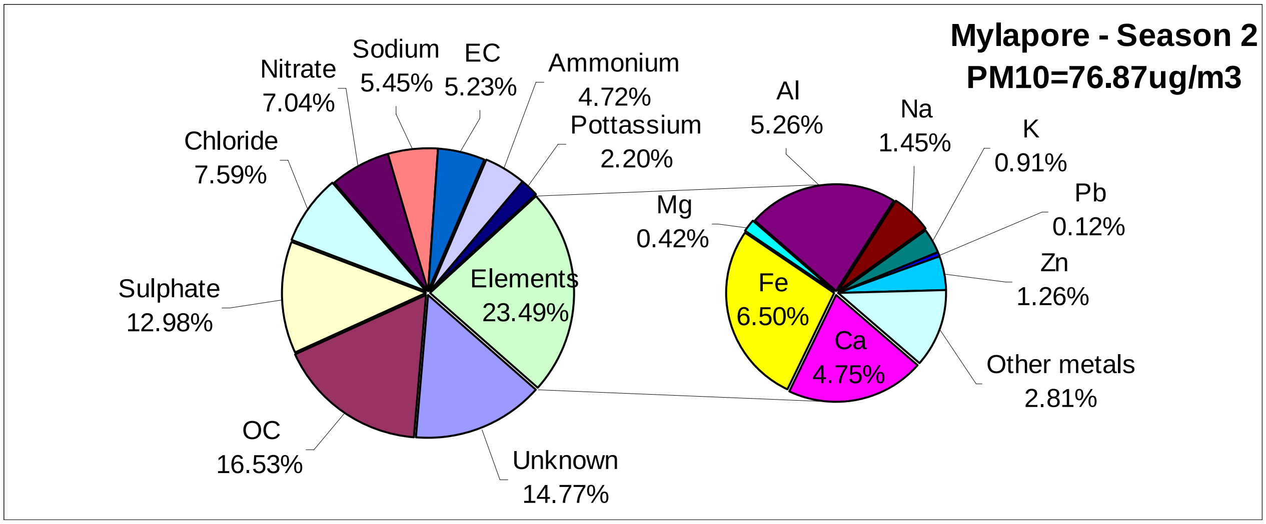


Figure 2.2.2.7-- Distribution of species on PM_{10} at Mylapore

2.4.2.3. Triplicane

Figures 2.2.3.1 shows the 24-hr average values for TSPM, RSPM, PM_{10}, $PM_{2.5}$ and the $PM_{2.5}/PM_{10}$ ratio at Triplicane site. The RSPM values were higher than NAAQS (100µg/m³ for Residential area) for 5 days. Particularly on 20th Aug and 19th Sep RSPM values were 443.86 and 432.42µg/m³ respectively. The TSPM values were higher than the NAAQS (200µg/m³ for Residential area) for 7 days. Particularly on 20th Aug, 15th Sep and 19th Sep TSPM values were 473.59, 1221.06 and 603.27µg/m³ respectively. The PM_{10} values were slightly higher than the NAAQS for 8 days. Particularly on 27th Aug and 1st Sep PM_{10} values were 415.78 and 278.8µg/m³ respectively. The $PM_{2.5}$ values were found to vary between 13.36 and 31.77µg/m³. The $PM_{2.5}/PM_{10}$ ratio was found to vary between 0.29 and 0.59. On 29th Aug and 5th Sep sampling was not done.

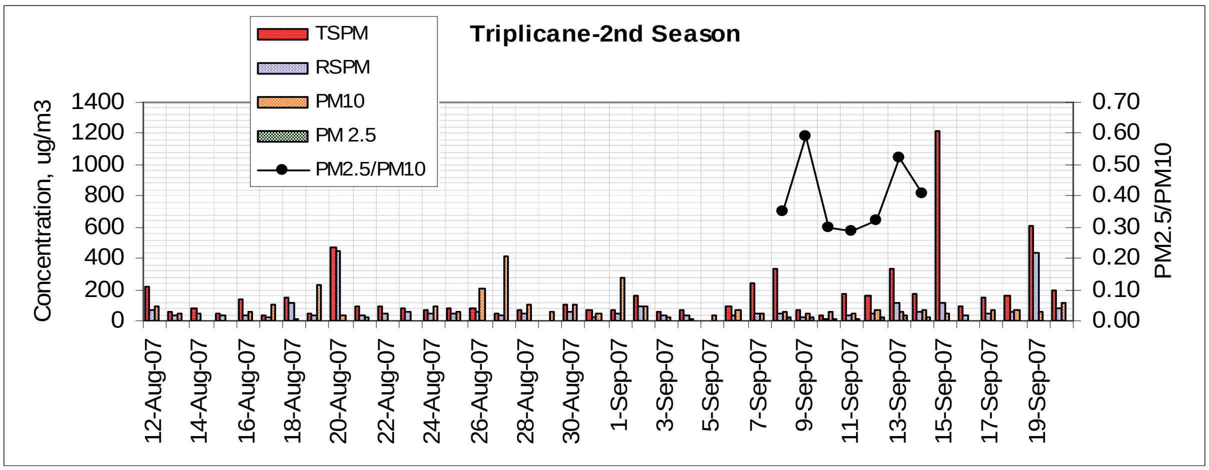


Figure 2.2.3.1-- Particulate matter at Triplicane

Figure2.2.3.2 shows the variation of OC, EC and the EC/OC ratio associated with PM_{10}. The EC/OC ratio for PM_{10} varies between 0.19 and 0.39 with a mean value of 0.27. The EC/OC ratio for $PM_{2.5}$ is marginally higher and varies between 0.31 and 0.35 with a mean value of 0.33.

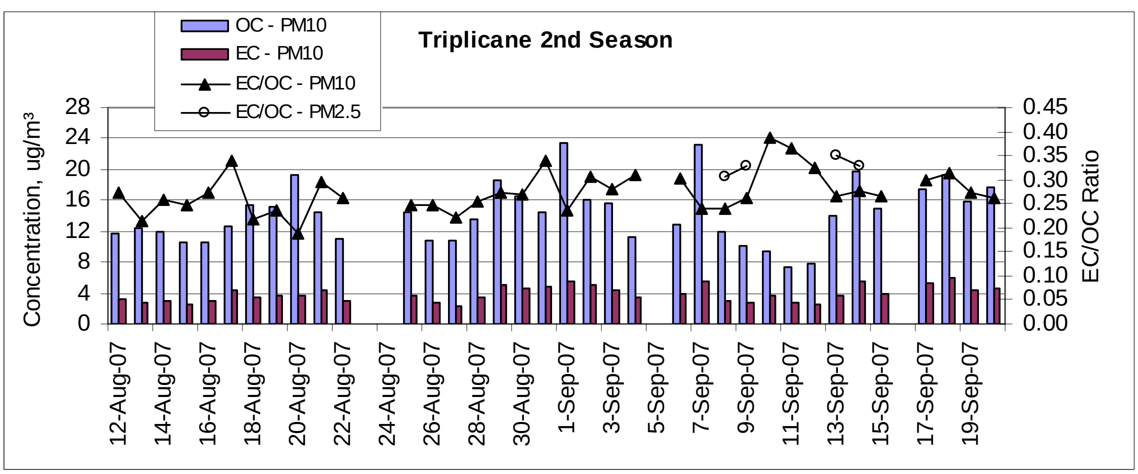


Figure2.2.3.2-- Measurements of OC/EC for Triplicane

Figure 2.2.3.3 shows the NOx and SO_2 distribution at Triplicane. NOx values were found to vary between 14.02 and 60.36µg/m³ with the mean value of 28.82µg/m³. SO_2 values range from 0.32 to 12.48µg/m³ with the mean value of 3.42µg/m³. At this site both the NOx and SO_2 concentrations were well below the NAAQS limit of 80 µg/m³(residential area).

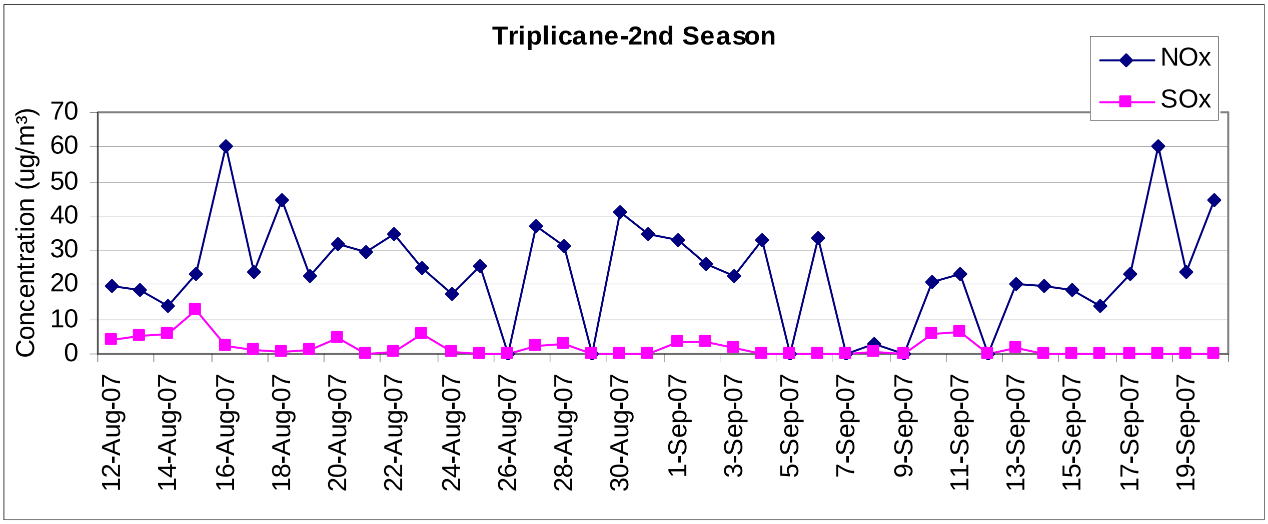


Figure2.2.3.3-- Time series measurements for SO_2 and NOx

Figure 2.2.3.4 shows the levels of anions associated with PM_{10}. The concentration of Sulphate (4.26± 1.87 µg/m³) was higher than those of nitrate (1.77± 0.95 µg/m³) and chloride (2.58 ± 1.65 µg/m³). For the $PM_{2.5}$ fraction, the sulphate concentration found was 3.0µg/m³ and the corresponding ratio of sulphate in the $PM_{2.5}/PM_{10}$ fractions was 0.62 indicating that a majority of the sulphate in this site were associated with the $PM_{2.5}$ phase. Similar ratios for chloride and nitrate were found to be 0.13 and 0.27 respectively.

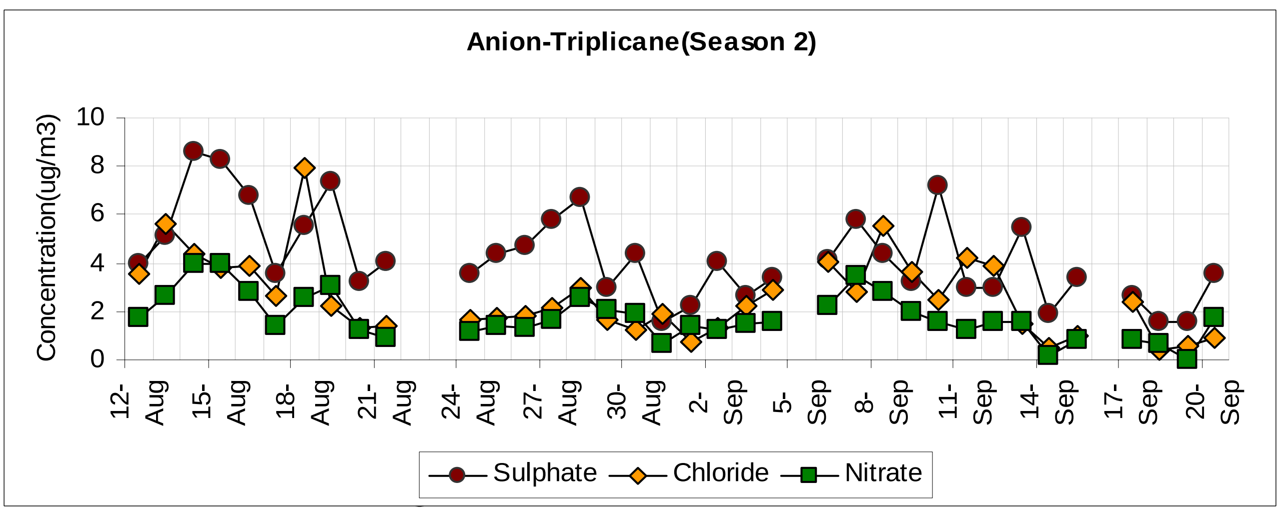


Figure 2.2.3.4--Cations in PM_{10} at Triplicane

Figure 2.2.3.5 shows the levels of Cations associated with PM_{10}. The concentrations of sodium (1.92± 1.13 µg/m³) and ammonium (0.69 ± 0.36 µg/m³) ions were higher than that of potassium ion (0.53 ± 0.19 µg/m³). For the $PM_{2.5}$ fraction, the ammonium concentration found was 0.22µg/m³ and the corresponding ratio of ammonium in the $PM_{2.5}/PM_{10}$ fractions was 0.2 indicating that a majority of the ammonium in this site was associated with the $PM_{2.5}$ phase. Similar ratio for sodium was found to be 0.19.

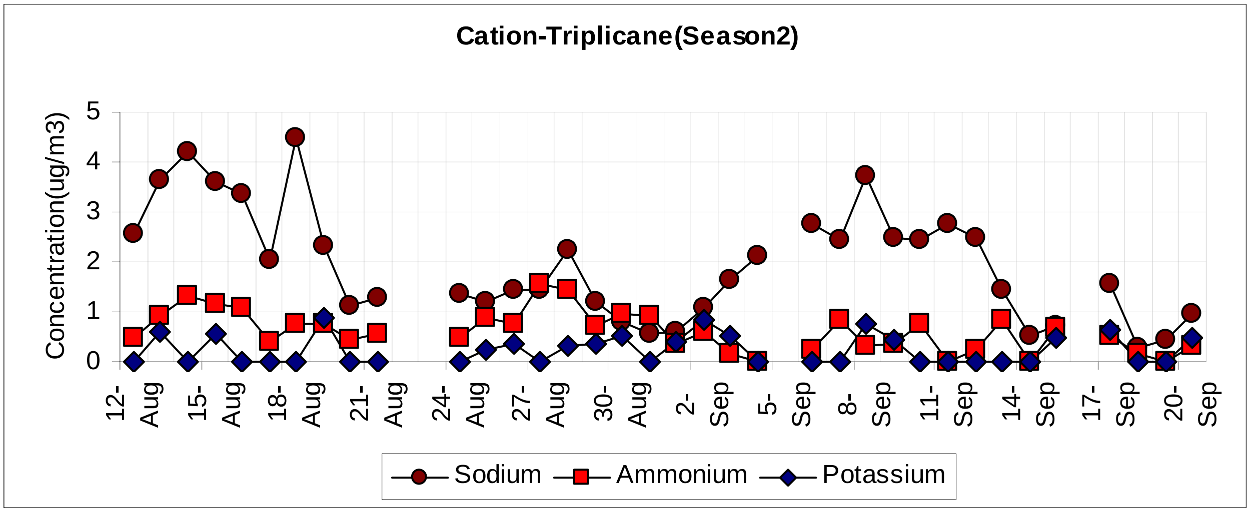


Figure 2.2.3.5--Cations in PM_{10} at Triplicane

Figure 2.2.3.6 shows the diurnal variation of CO concentrations at the monitoring station. The mean levels are shown to vary between 2500 and 4900 µg/m³. At this site CO concentration is exceeding the NAAQS 1-hr average standard of 4000 µg/m³ for a few hours in the mid-morning indicative of high traffic.

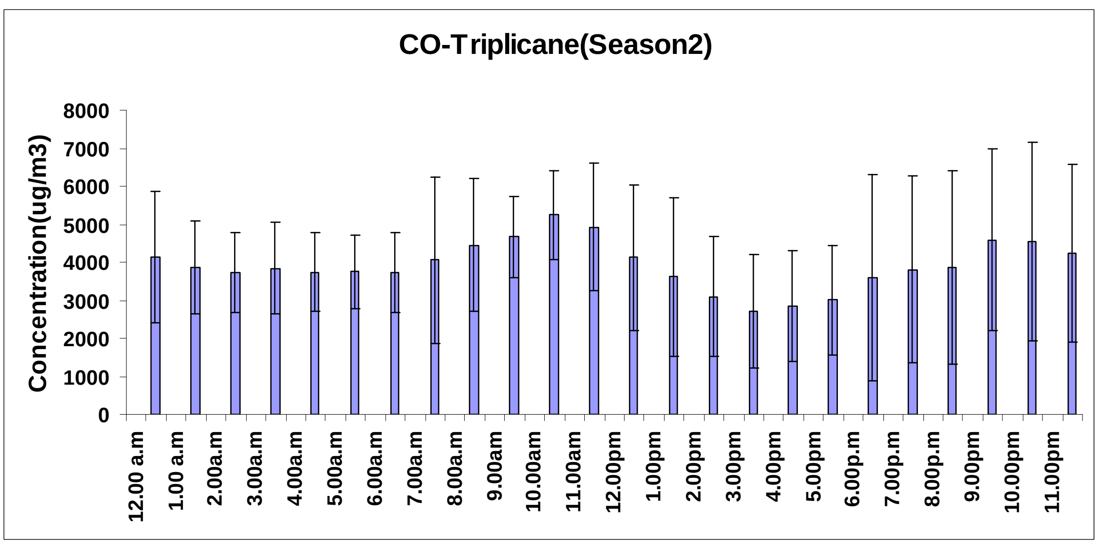


Figure 2.2.3.6-- CO – diurnal variation for Triplicane.

Figure 2.2.3.7 shows the distribution of the various speciation associated with the PM_{10}. The fraction, which is shown as unknown in figure includes Si and other species such as the H,O and N fraction of organic matter, oxygen in the elemental oxides and other constituents not analyzed in the sample. Of the measured components OC (16.56%) was the highest fraction followed by Ca (8.19%) and Sulphate (4.96%).

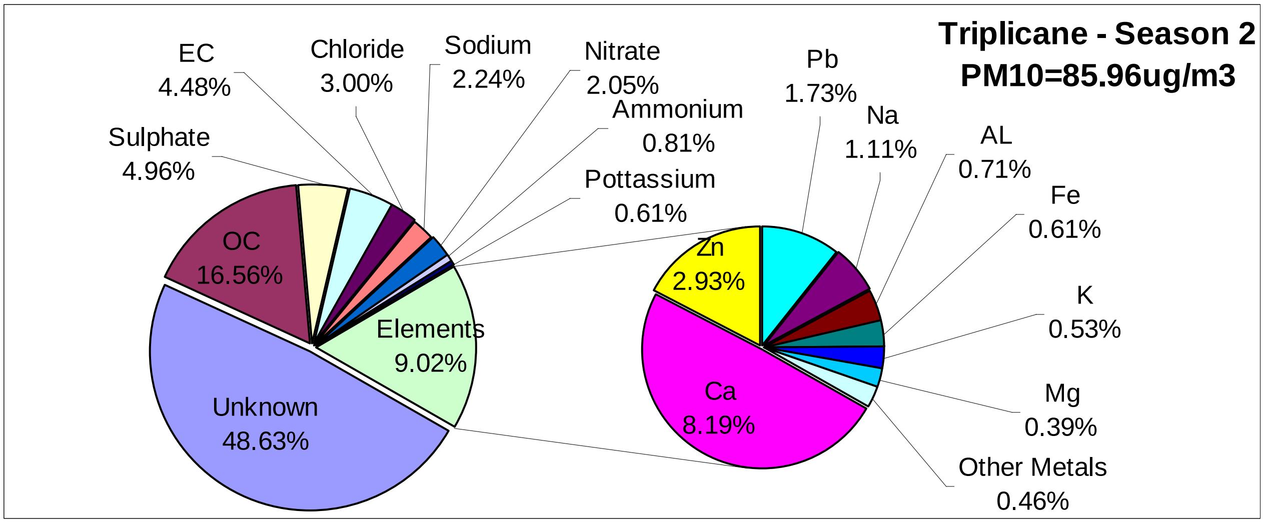


Figure 2.2.3.7-- Distribution of species on PM_{10} at Triplicane

2.4.2.4 Adyar

Figures 2.2.4.1 shows the 24-hr average values for TSPM, RSPM, PM_{10}, $PM_{2.5}$ and the $PM_{2.5}/PM_{10}$ ratio. The RSPM values were higher than NAAQS (100µg/m³ for Kerb site) for 6 days. Especially on 5th and 27th July RSPM values were 307.29and 203.16µg/m³ respectively. The TSPM values were higher than the NAAQS (200µg/m³ for Kerb site) for 11 days. Particularly on 11th, 21st and 27th July TSPM values were 351.18, 431.86 and 577.52µg/m³ respectively. The PM_{10} values were higher than the NAAQS for most of the days. Particularly on 16th July, 3rd Aug the PM_{10} values were 1172.4 and 951.3µg/m³ respectively. The $PM_{2.5}$ values were found to vary between 30.08 and 66.3µg/m³. The $PM_{2.5}/PM_{10}$ ratio was found to vary between 0.11 and 0.91, except for one day when the ratio is greater than 1, which is perhaps due to the very small values of the PM and associated errors. On 9th July and 1st Aug sampling was not done.

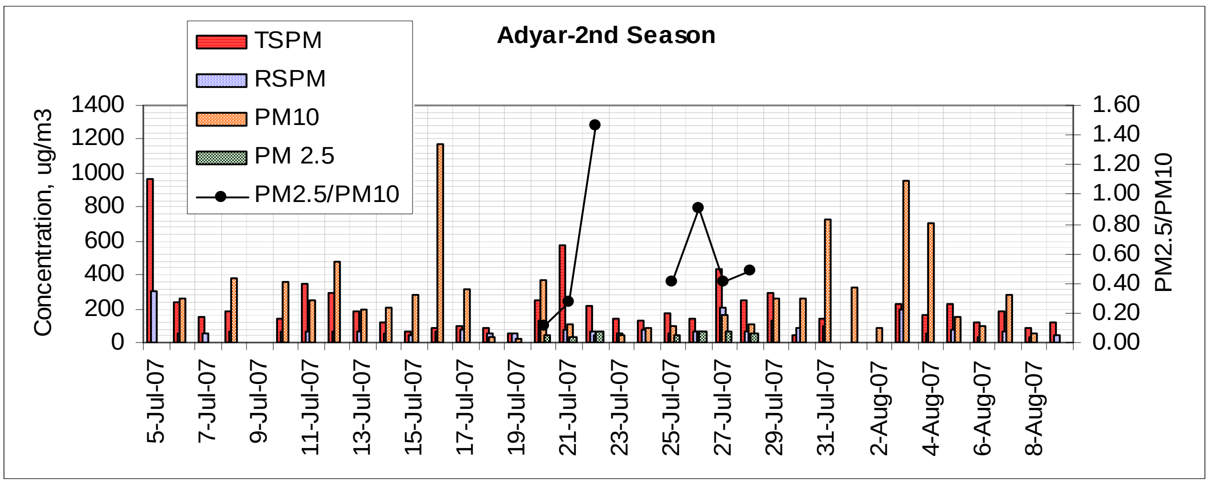


Figure 2.2.4.1-- Particulate matter at Adyar

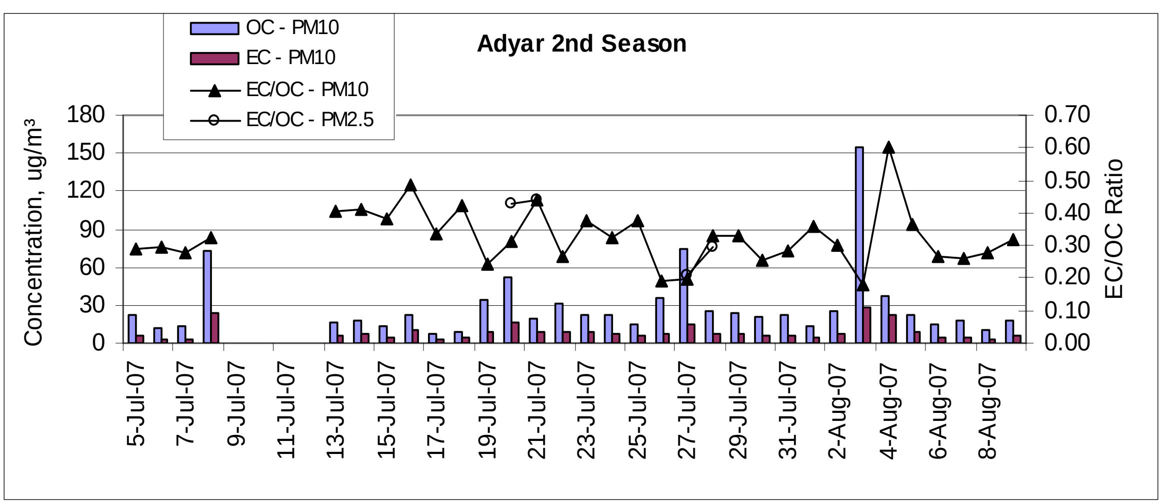


Figure 2.2.4.2-- Measurements of OC/EC for Adyar

Figure2.2.4.2 shows the variation of OC, EC and the EC/OC ratio associated with PM_{10}. The EC/OC ratio for PM_{10} varies between 0.18 and 0.6 with a mean value of 0.33. The EC/OC ratio for $PM_{2.5}$ varies between 0.21 and 0.44 with a mean value of 0.34.
Figure 2.2.4.3 shows the NOx and SO_2 distribution at Adyar. The NOx values were found to vary between 8.43and 42.95µg/m³ with the mean value of 24.73µg/m³. SO_2 values range from 1.56 to 9.88µg/m³ with the mean value of 3.8µg/m³. At this site both the NOx and SO_2 concentrations were well below the NAAQS limit of 80 µg/m³(residential area)

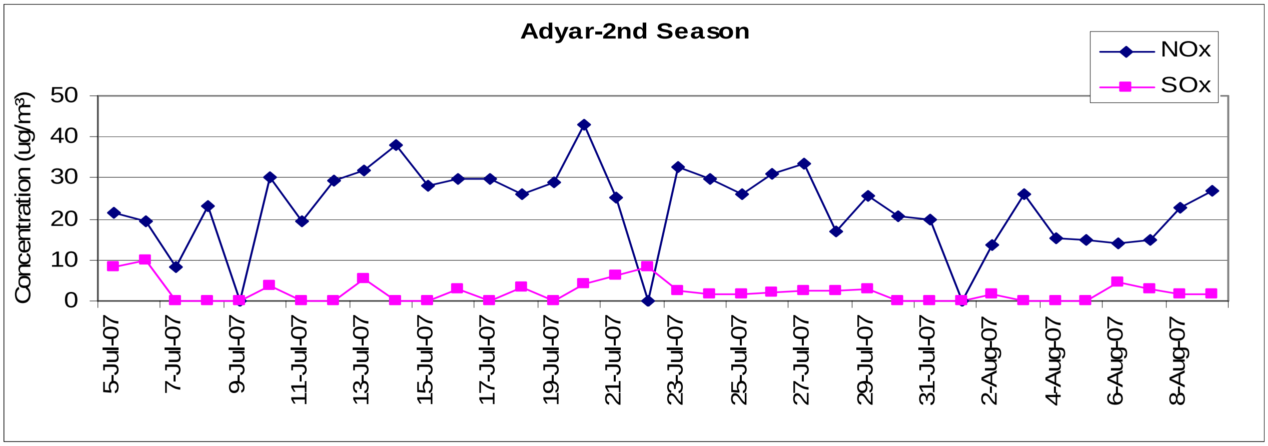


Figure 2.2.4.3-- Time series measurements for SO_2 and NOx

Figure 2.2.4.4 shows the levels of anions associated with PM_{10}. The concentration of Sulphate (5.25± 3.14 ug/m³) was higher than those of nitrate (2.43± 1.12 ug/m³) and chloride (2.55 ± 1.72 ug/m³). For the $PM_{2.5}$ fraction, the sulphate concentration found was 3.49ug/m³ and the corresponding ratio of sulphate in the $PM_{2.5}/PM_{10}$ fractions was 0.73 indicating that a majority of the sulphate in this site were associated with the $PM_{2.5}$ phase. Similar ratios for chloride and nitrate were found to be 0.07 and 0.12 respectively.

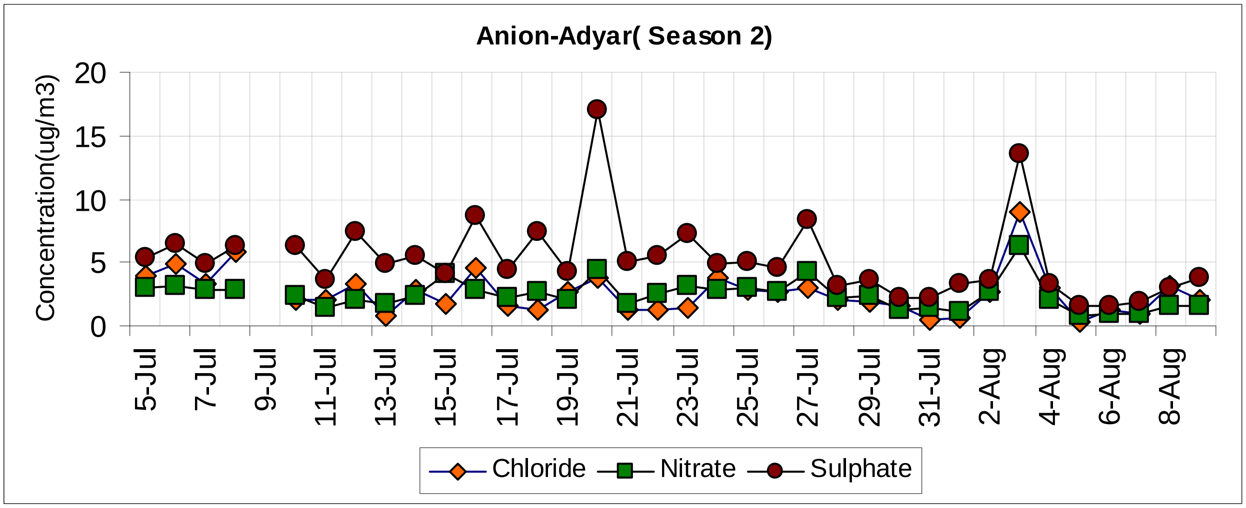


Figure 2.2.4.4-- Time series of anions on PM_{10}

Figure 2.2.4.5 shows the levels of Cations associated with PM_{10}. The concentrations of sodium (1.85± 0.97 ug/m³) and ammonium (0.97 ± 0.93 ug/m³) ions were higher than that of potassium ion (0.57 ± 0.29 ug/m³). For the $PM_{2.5}$ fraction, the Ammonium, sodium and Potassium concentrations were found to be 0.62, 0.32 and 0.39 ug/m³ respectively.

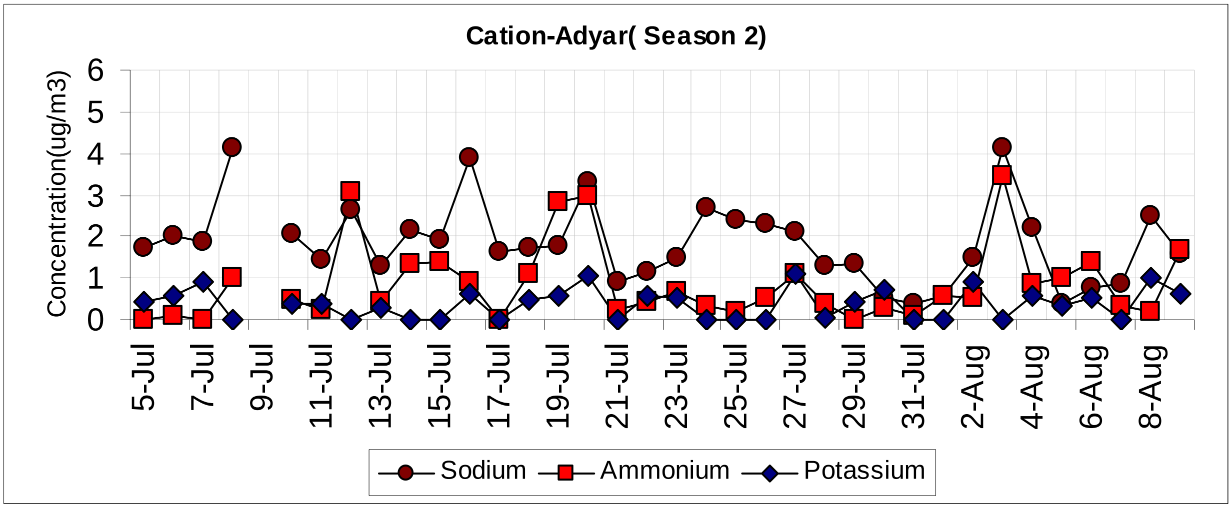


Figure 2.2.4.5--Cations in PM_{10} at Adyar

Figure 2.2.4.6 shows the diurnal variation of CO concentrations at the monitoring station. The mean levels are shown to vary between 2300 and 3350 µg/m³. At this site CO concentration were below the 1-hr NAAQS average (4000 µg/m³).

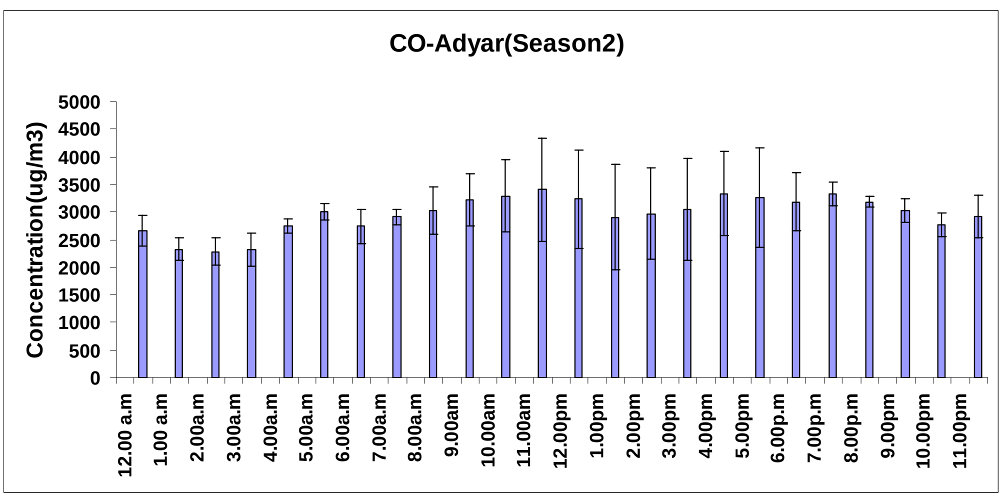


Figure 2.2.4.6-- CO – diurnal variation for Adyar.

Figure 2.2.4.7 shows the distribution of the various speciation associated with the PM_{10}. The fraction, which is shown as unknown in figure includes Si and other species such as the H,O and N fraction of organic matter, oxygen in the elemental oxides and other constituents not analyzed in the sample. Of the measured components OC (35.39%) was the highest fraction followed by EC (10.5%) and Ca (6.56%).

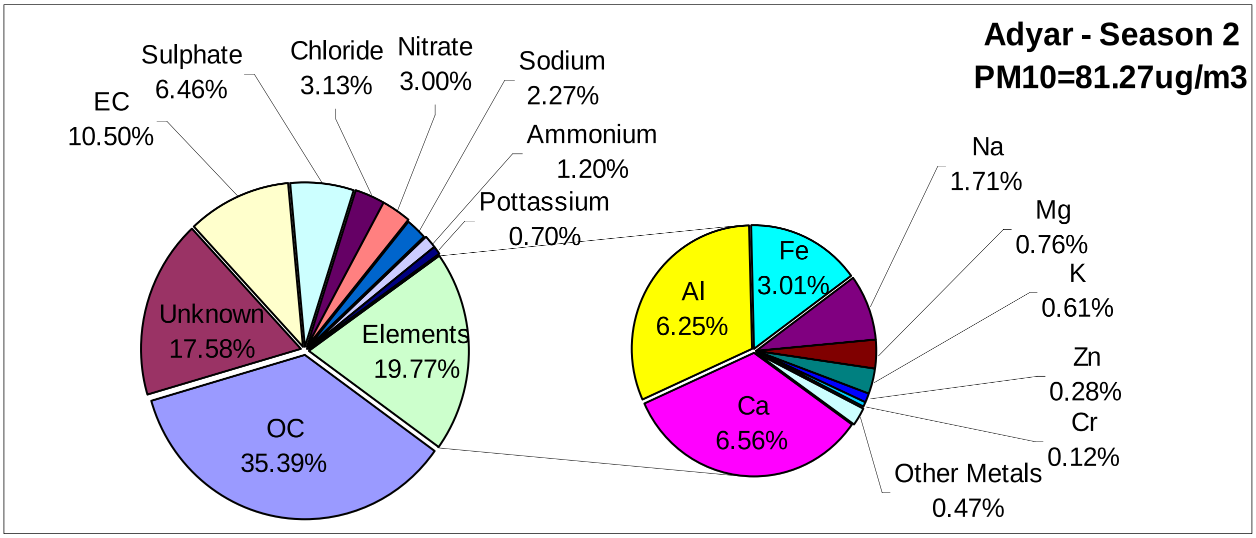


Figure 2.2.4.7-- Distribution of species on PM_{10} at Adyar

2.4.2.5 Saidapet

Figures 2.2.5.1 shows the 24-hr average values for TSPM, RSPM and PM_{10} at Saidapet study area. The RSPM values were higher than NAAQS (100 µg/m³ for residential site) for 5 days. Especially on 25th Sep and 2nd Oct RSPM values were 172.89 and 161.53µg/m³ respectively. The TSPM values were also higher than the NAAQS (200 µg/m³ for residential site) for 6 days. Particularly on 25th, 27th Sep and 4th Oct TSPM values were 342.89, 269.41 and 281.85µg/m³ respectively. The PM_{10} values were slightly higher than the NAAQS for most of the days. On 13th, 16th and 17th Aug PM_{10} values were 352.65, 622.21 and 550.21µg/m³ respectively. There is gap between 6th Sep and 24th Sep in sampling. And also on 12th, 13th, 17th, 29th Aug, 30th Sep and 1st Oct sampling was not done.

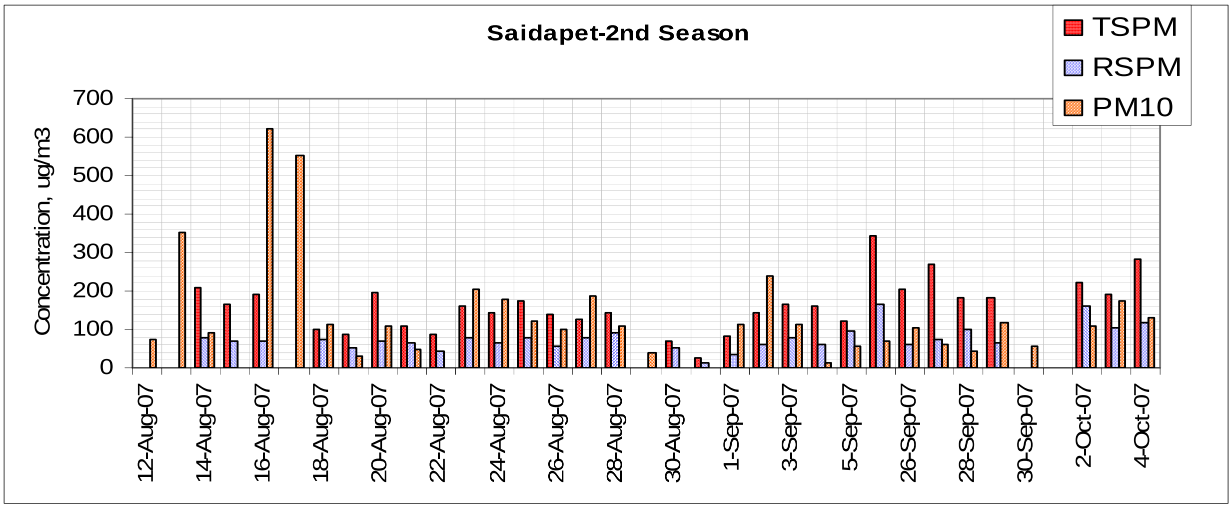


Figure 2.2.5.1-- Particulate matter at Saidapet

Figure2.2.5.2 shows the variation of OC, EC and the EC/OC ratio associated with PM_{10}. The EC/OC ratio for PM_{10} varies between 0.18 and 0.50 with a mean value of 0.37.

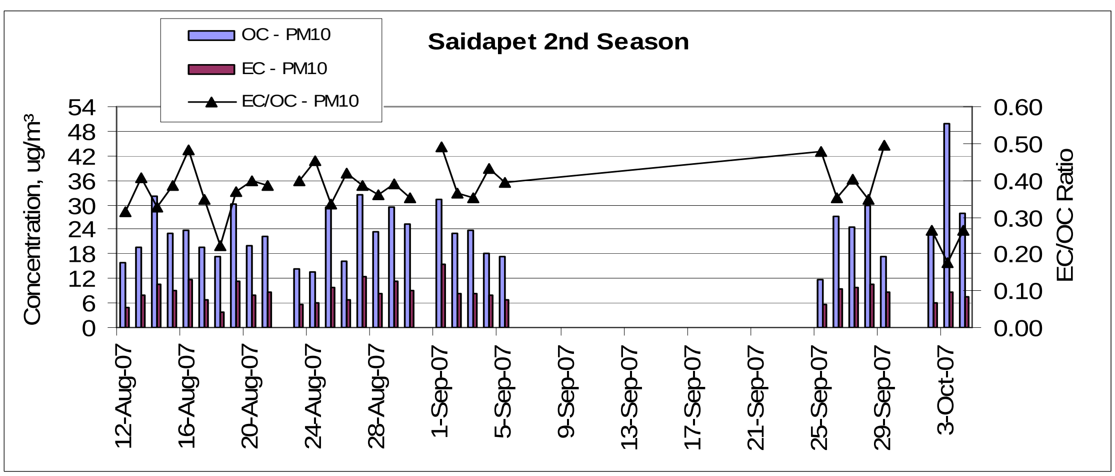


Figure2.2.5.2-- Measurements of OC/EC for Saidapet

Figure 2.2.5.3 shows the NOx and SO_2 distribution at Saidapet. NOx values were found to vary between 28.05and 70.87µg/m³ with the mean value of 43.16µg/m³. SO_2 values range from 0.4to 4.89µg/m³ with the mean value of 2.45µg/m³. At this site both the NOx and SO_2 concentrations were well below the NAAQS limit of 80 µg/m³(residential area)

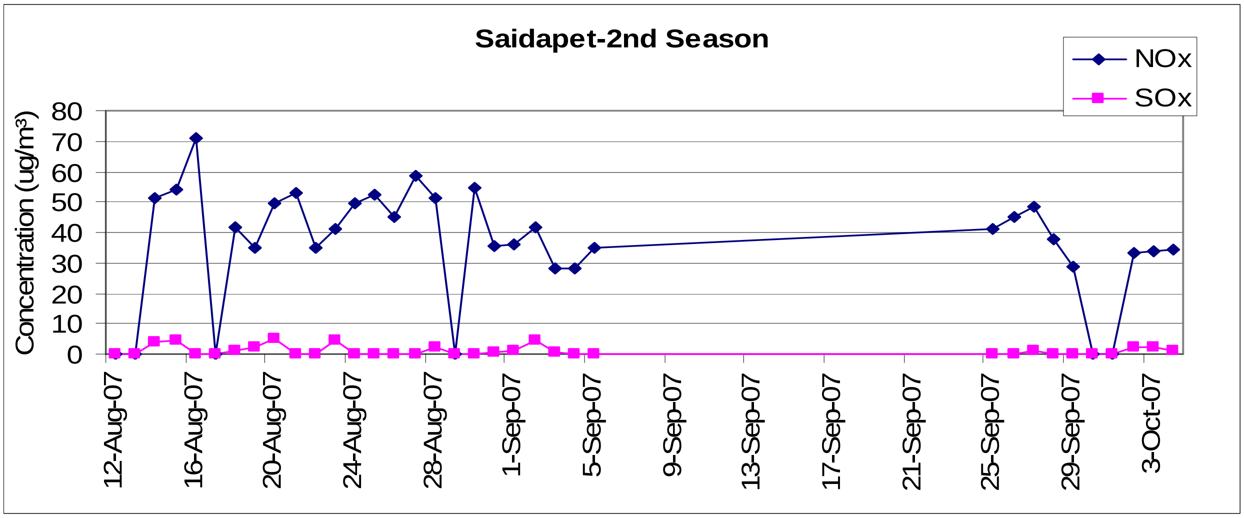


Figure 2.2.5.3-- Time series measurements for SO_2 and NOx

Figure 2.2.5.4 shows the levels of anions associated with PM_{10}. At this site, the concentration of Sulphate (4.5± 2.34ug/m³) was higher than those of nitrate (1.92± 1.08 ug/m³) and chloride (1.25± 1.32 ug/m³).

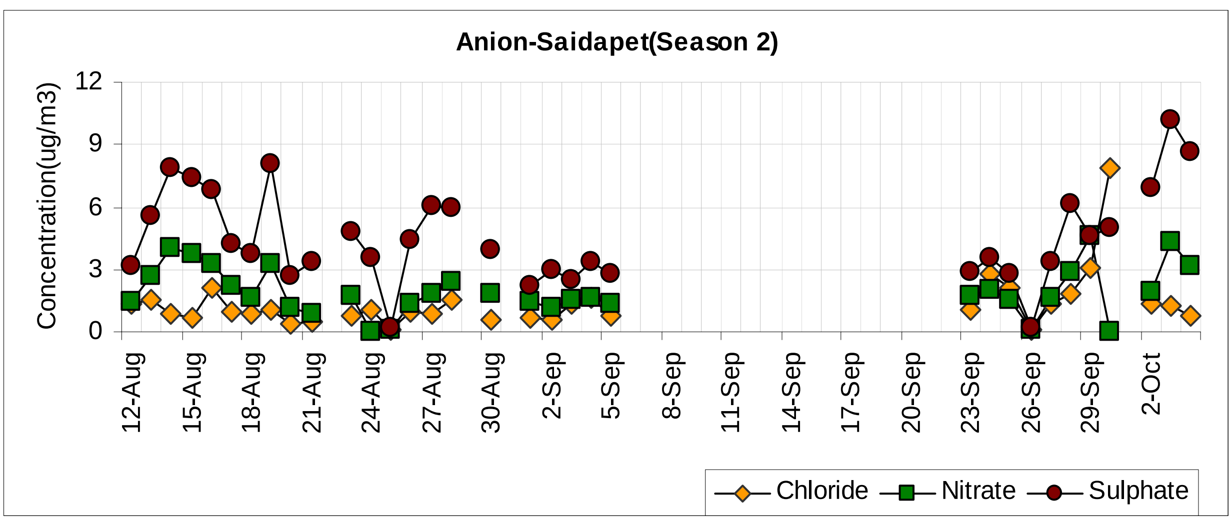


Figure 2.2.5.4-- Time series of anions on PM_{10}

Figure 2.2.5.5 shows the levels of Cations associated with PM_{10}. The concentration of Sodium (1.29± 1.02ug/m³) was higher than those of ammonium (0.72± 0.5ug/m³) and potassium (0.77± 0.66 ug/m³).

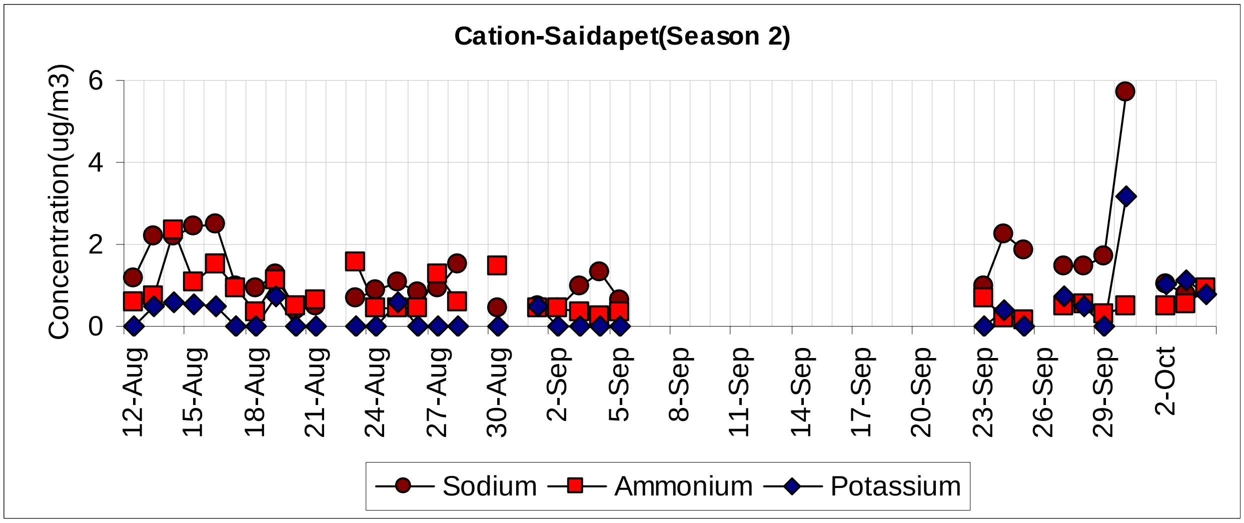


Figure 2.2.5.5--Cations in PM_{10} at Saidapet

Figure 2.2.5.6 6 shows the diurnal variation of CO concentrations at the monitoring station. The mean levels are shown to vary between 4700 and 6500 µg/m³. At this site CO concentration is exceeding the NAAQS 1-hr average standard (4000 µg/m³).

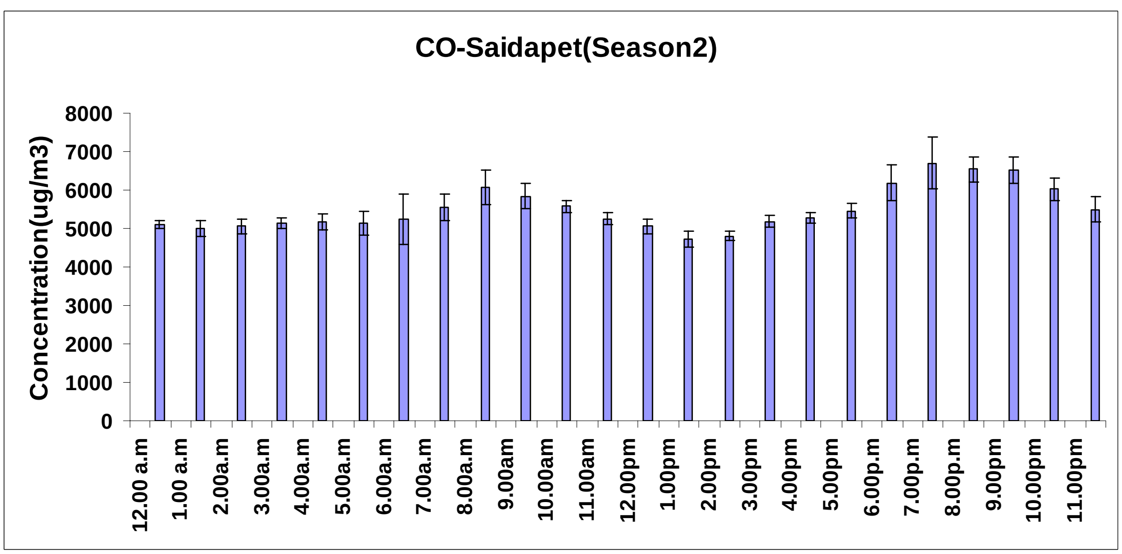


Figure 2.2.5.6-- CO – diurnal variation for Saidapet

Figure 2.2.5.7 shows the distribution of the various speciation associated with the PM_{10}. The fraction, which is shown as unknown in figure includes Si and other species such as the H,O and N fraction of organic matter, oxygen in the elemental oxides and other constituents not analyzed in the sample. Of the measured components OC (16.39%) was the highest fraction followed by EC (5.94%) and Al (3.24%).

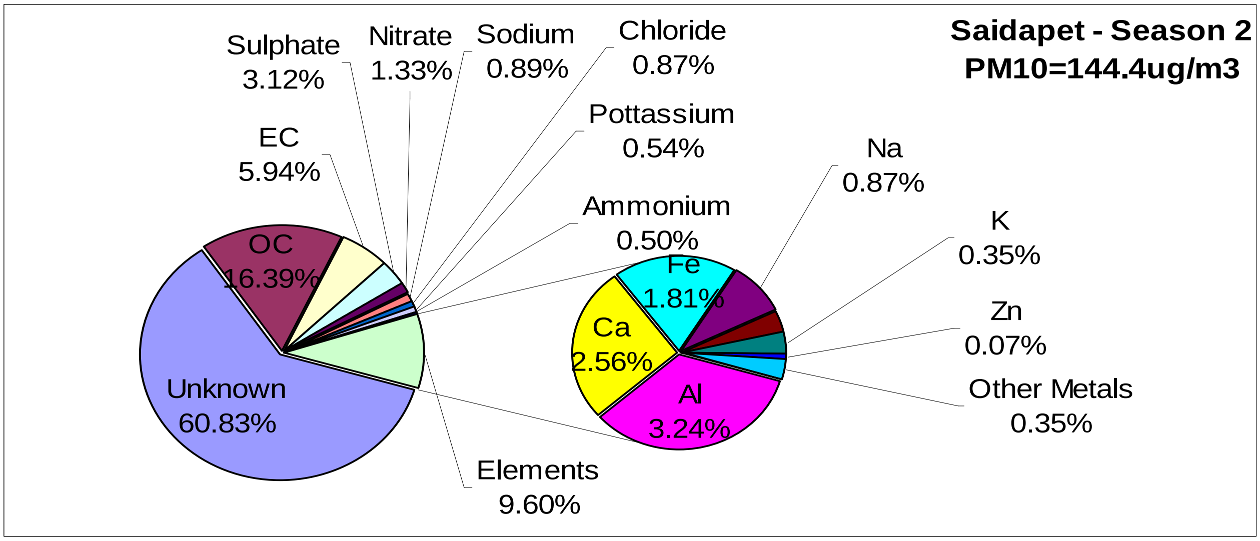


Figure 2.2.5.7-- Distribution of species on PM_{10} at Saidapet

2.4.2.6 R K Nagar

Figures 2.2.6.1 shows the 24-hr average values for TSPM, RSPM, PM_{10}, $PM_{2.5}$ and the $PM_{2.5}/PM_{10}$ ratio. The RSPM values were higher than NAAQS (150µg/m³ for Industrial area) for 2 days. Particularly on 5th Sep and 3rd Oct RSPM values were 226.92 and 186.31µg/m³ respectively. The TSPM values were higher than the NAAQS (500µg/m³ for Industrial area) for 2 days. Particularly on 7th Sep and 3rd Oct TSPM values were 523.29and 524.11µg/m³ respectively. The PM_{10} values were slightly higher than the NAAQS for 5 days. For example on 23rd, 24th and 29th Aug PM_{10} values were 735.57, 207.48 and 323.79µg/m³ respectively. The $PM_{2.5}$ values were found to vary between 35.33 and 217.62µg/m³. The $PM_{2.5}/PM_{10}$ ratio was found to vary between 0.2 and 0.41. On 29th and 30th Aug, 22nd and 30th Sep and 1stOct sampling was not done.

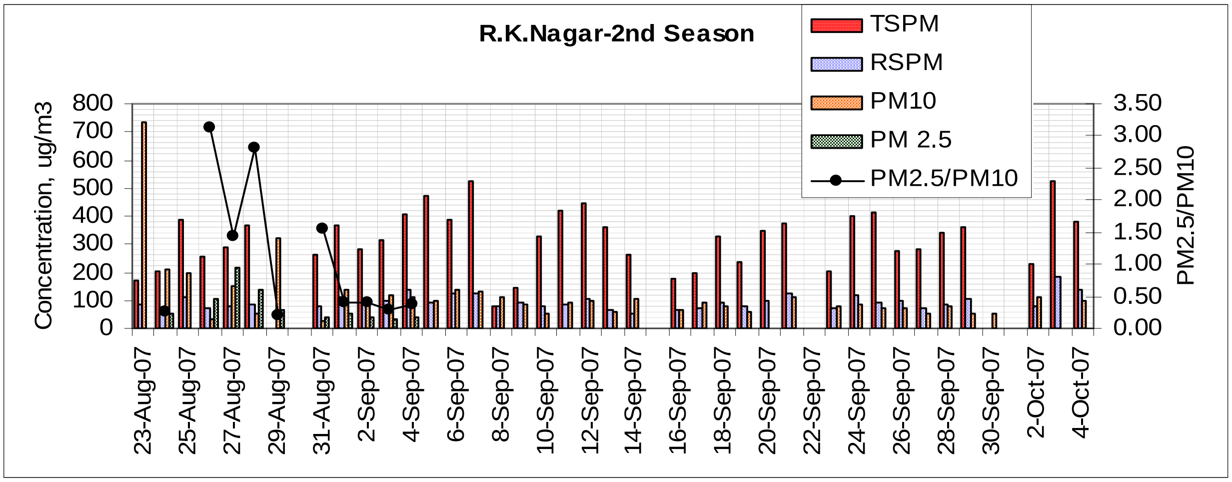


Figure 2.2.6.1-- Particulate matter at R.K.Nagar

Figure2.2.6.2 shows the variation of OC, EC and the EC/OC ratio associated with PM_{10}. The EC/OC ratio for PM_{10} varies between 0.19 and 0.46 with a mean value of 0.30. The EC/OC ratio for $PM_{2.5}$ varies between 0.24 and 0.54 with a mean value of 0.35.

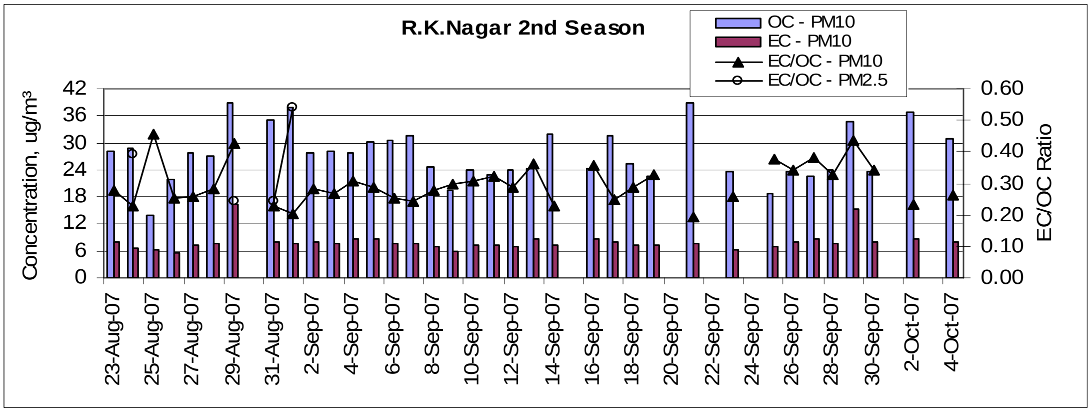


Figure2.2.6.2-- Measurements of OC/EC/TC for R.K.Nagar

Figure 2.2.6.3 shows the NOx and SO_2 distribution at R.K.Nagar. NOx values were found to vary between 19.1and 62.66µg/m³ with the mean value of 35.75µg/m³. SO_2 values range from 0.35to 12.79µg/m³ with the mean value of 3.28µg/m³. At this site both the NOx and SO_2 concentrations were well below the NAAQS limit of 120 µg/m³ (industrial area).

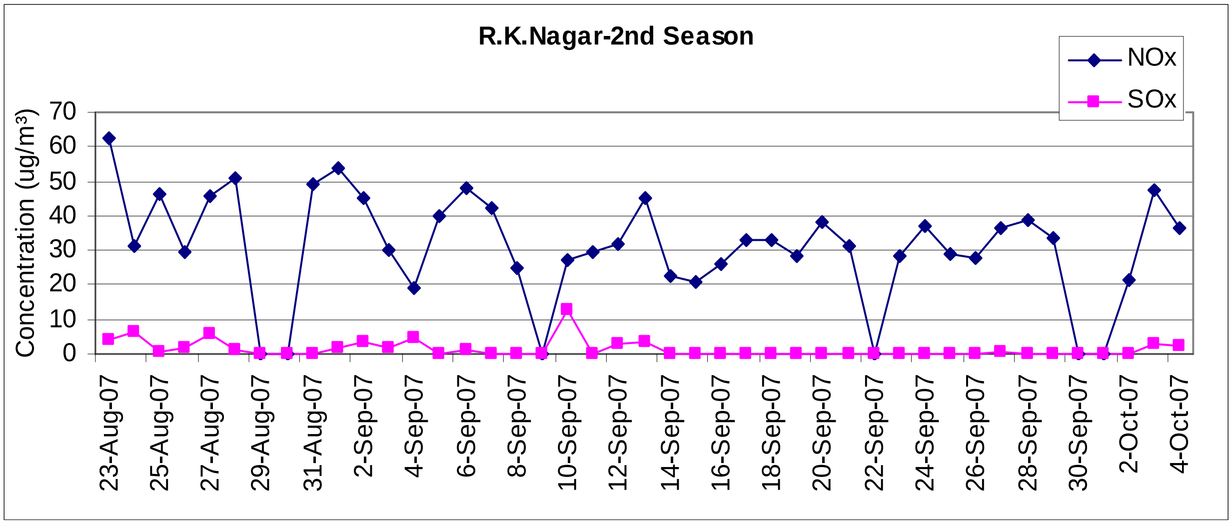


Figure2.2.6.3-- Time series measurements for SO_2 and NOx

Figure 2.2.6.4 shows the levels of anions associated with PM_{10}. The concentration of Sulphate (4.52± 1.99 ug/m³) was higher than those of nitrate (1.76± 0.82 ug/m³) and chloride (1.93 ± 0.95 ug/m³). For the $PM_{2.5}$ fraction, the sulphate concentration found was 5.11ug/m³ and the corresponding ratio of sulphate in the $PM_{2.5}/PM_{10}$ fractions was 0.76 indicating that a majority of the sulphate in this site were associated with the $PM_{2.5}$ phase. Similar ratios for chloride and nitrate were found to be 0.3 and 0.42 respectively.

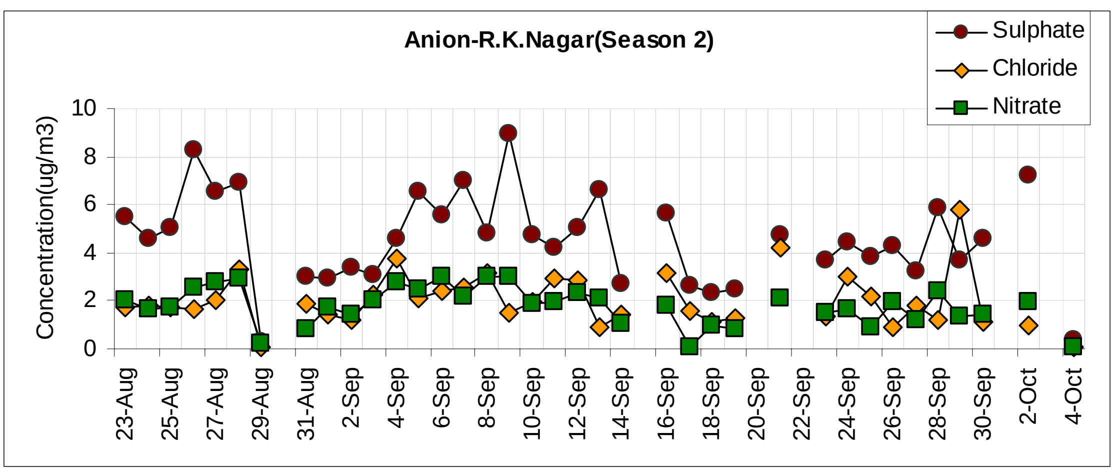


Figure 2.2.6.4-- Time series of anions on PM10

Figure 2.2.6.5 shows the levels of Cations associated with PM_{10}. The concentrations of sodium (1.28± 0.55 ug/m³) and ammonium (0.63 ± 0.84 ug/m³) ions were higher than that of potassium ion (0.61 ± 0.17 ug/m³). For the $PM_{2.5}$ fraction, the Ammonium concentration was found 1.02ug/m³ and the corresponding ratio of Ammonium in the $PM_{2.5}/PM_{10}$ fractions was 2.73 indicating that a majority of the Ammonium in this site was associated with the $PM_{2.5}$ phase. Similar ratios for Sodium and Potassium were found to be 0.48 and 0.84 respectively.

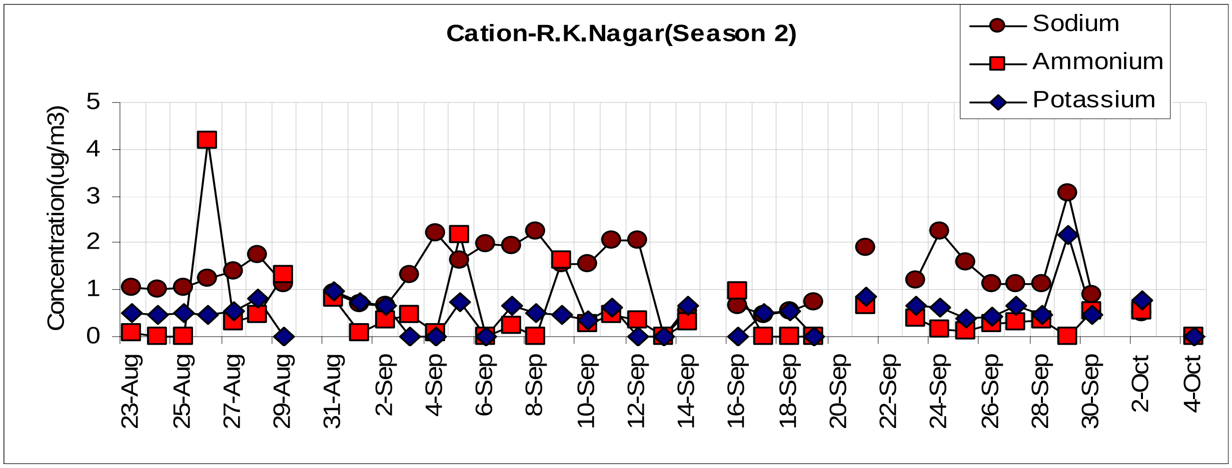


Figure 2.2.6.5--Cations in PM_{10} at R.K.Nagar

Figure 2.2.6.6 shows the diurnal variation of CO concentrations at the monitoring station. The mean levels are shown to vary between 6500 and 8400 µg/m³. At this site CO concentration is above the NAAQS 1-hr average (4000 µg/m³).

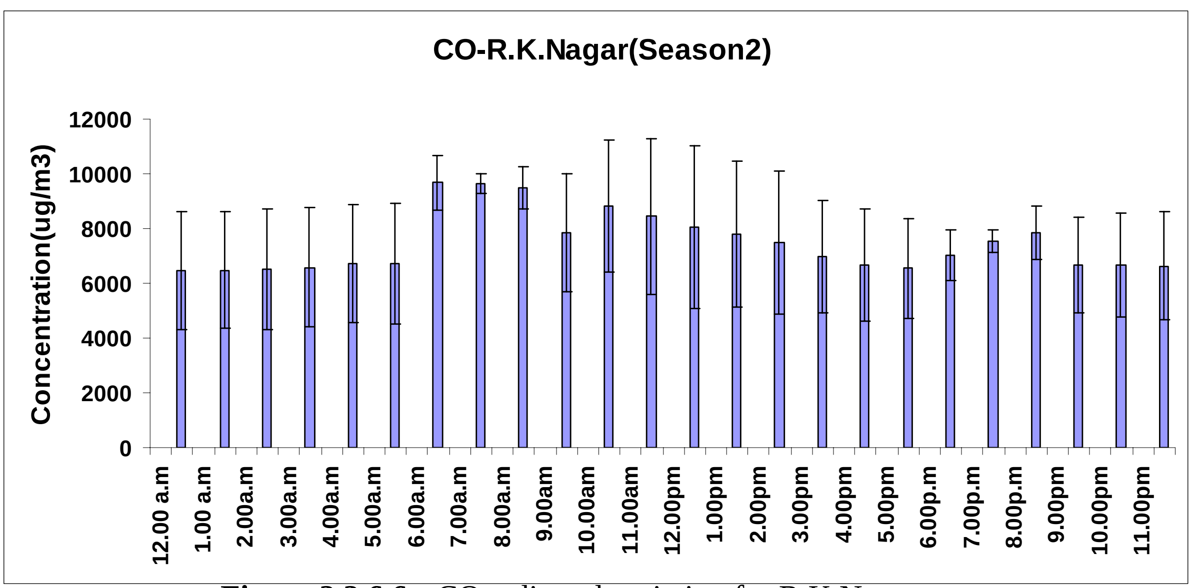


Figure 2.2.6.6-- CO – diurnal variation for R.K.Nagar.

Figure 2.2.6.7 shows the distribution of the various speciation associated with the PM_{10}. The fraction, which is shown as unknown in figure includes Si and other species such as the H,O and N fraction of organic matter, oxygen in the elemental oxides and other constituents not analyzed in the sample. Of the measured components OC (23.5%) was the highest fraction followed by EC (6.86%) and Ca (6.26%).

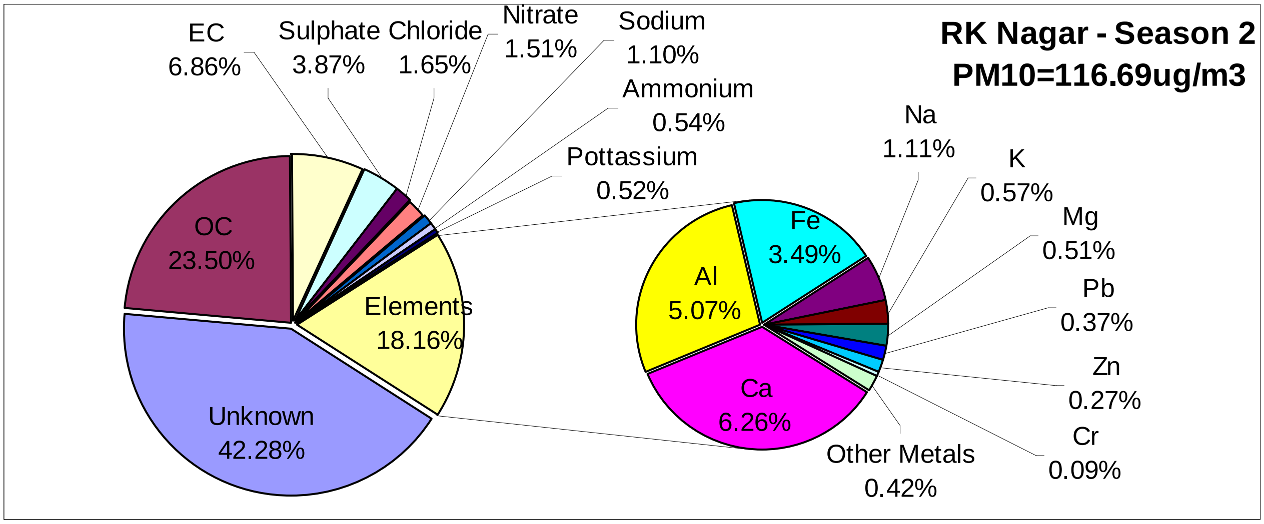


Figure 2.2.6.7-- Distribution of species on PM_{10} at R.K.Nagar

2.4.2.7 Ambattur

Figures 2.2.7.1 shows the 24-hr average values for TSPM, RSPM and $PM_{10.}$ The RSPM values were higher than NAAQS (150µg/m³ for Industrial area) for 11 days. Particularly on 13th, 15th and 16th Nov RSPM values were 349.82, 384.3and 208.99µg/m³ respectively. The TSPM values were higher than the NAAQS (500 µg/m³ for Industrial area) for 5 days. Particularly on 13th and 15th Nov TSPM values were 673.43 and 715.71µg/m³. The PM_{10} values were slightly higher than the NAAQS for 11 days. Particularly on 15th and 29th Nov PM_{10} values were 469.21 and 295.99µg/m³ respectively. On 19th and 20th Nov sampling was not done.

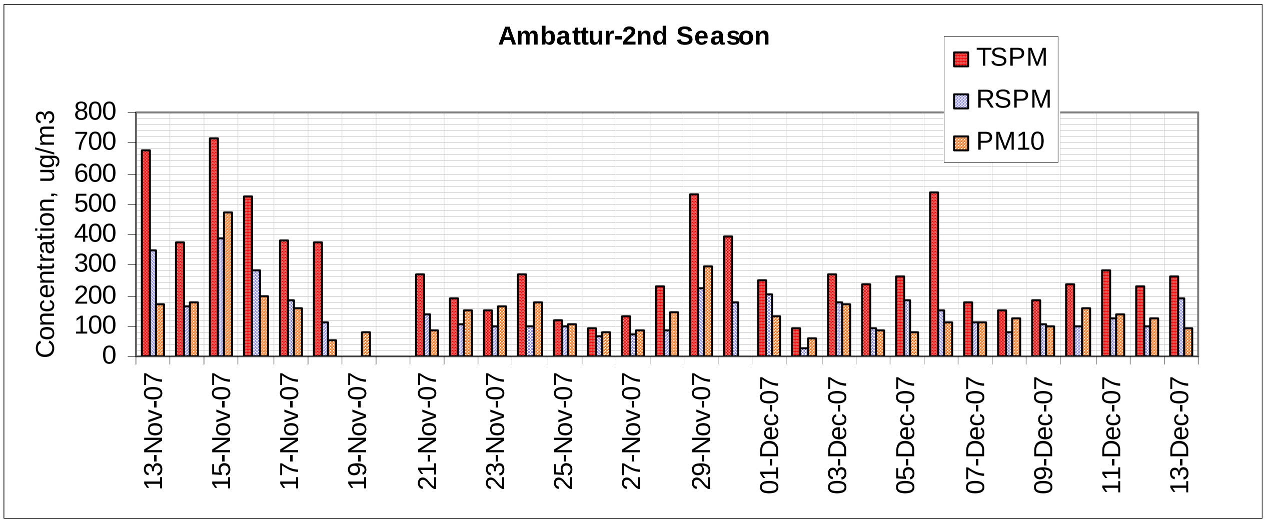


Figure 2.2.7.1-- Particulate matter at Ambattur

Figure2.2.7.2 shows the variation of OC, EC and the EC/OC ratio associated with PM_{10}. The EC/OC ratio for PM_{10} varies between 0.08 and 0.72 with a mean value of 0.28.

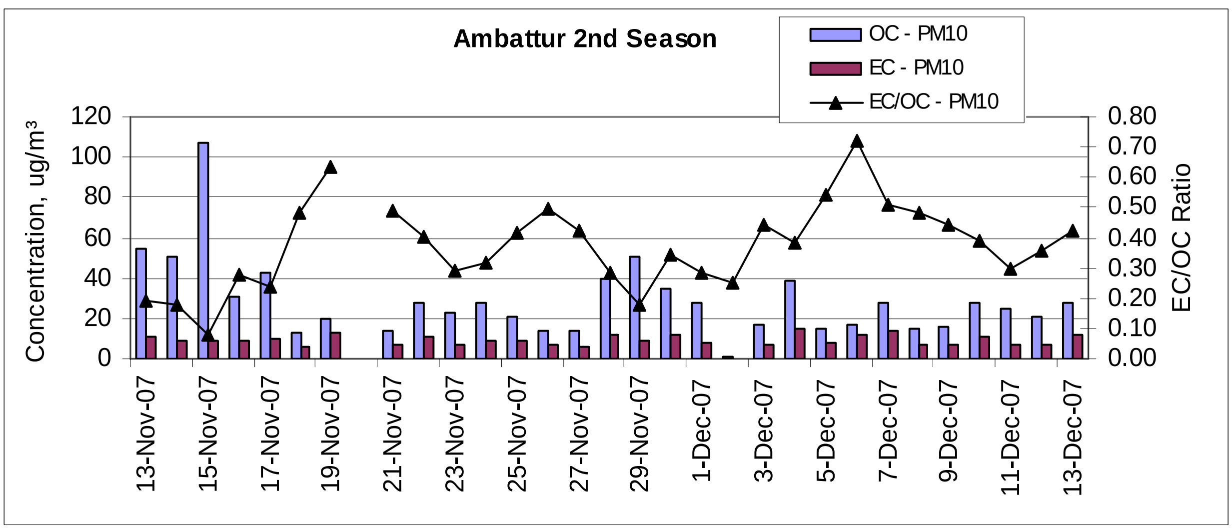


Figure 2.2.7.2-- Measurements of OC/EC for Ambattur

Figure 2.2.7.3 shows the NOx and SO_2 distribution at Ambattur site. NOx values were found to vary between 21.72and 59.76µg/m³ with the mean value of 41.83µg/m³. SO_2 values range from 1.98 to 17.91µg/m³ with the mean value of 5.87µg/m³. At this site both the NOx and SO_2 concentrations were well below the NAAQS limit of 120 µg/m³ (industrial area).

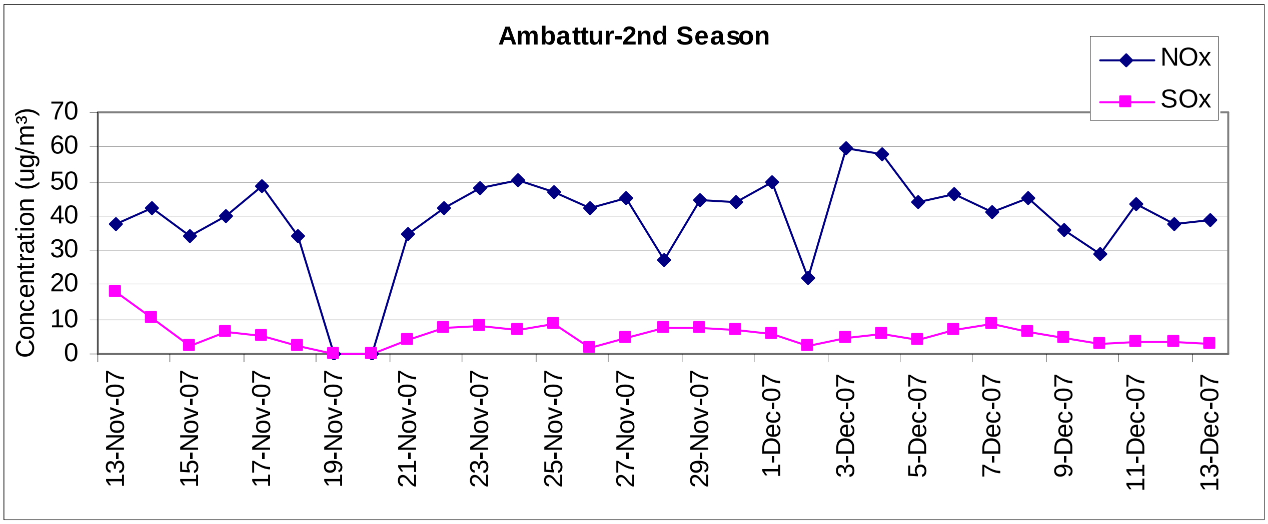


Figure2.2.7.3-- Time series measurements for SO_2 and NOx

Figure 2.2.7.4 shows the levels of anions associated with PM_{10}. The concentration of Sulphate (10.67± 5.51 ug/m³) was higher than those of nitrate (2.64± 1.48 ug/m³) and chloride (3.12± 1.58 ug/m³). For the $PM_{2.5}$ fraction, the Sulphate, Chloride and Nitrate concentration values were 7.64, 0.92 and 1.04ug/m³ respectively.

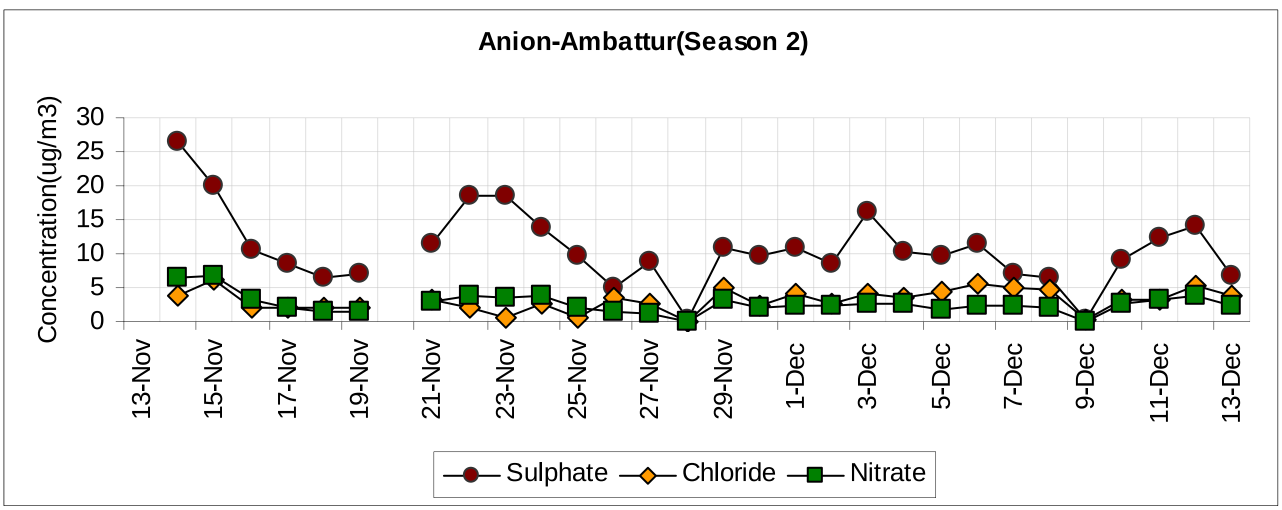


Figure 2.2.7.4-- Time series of anions on PM_{10}

Figure 2.2.7.5 shows the levels of Cations associated with PM_{10}. The concentrations of sodium (1.46± 0.59 ug/m³) and ammonium (2.1 ± 1.44 ug/m³) ions were higher than that of potassium ion (1.37 ± 0.61 ug/m³). For the $PM_{2.5}$ fraction, the Ammonium, Sodium and potassium concentrations were 2.98, 0.58 and1.21ug/m³ respectively.

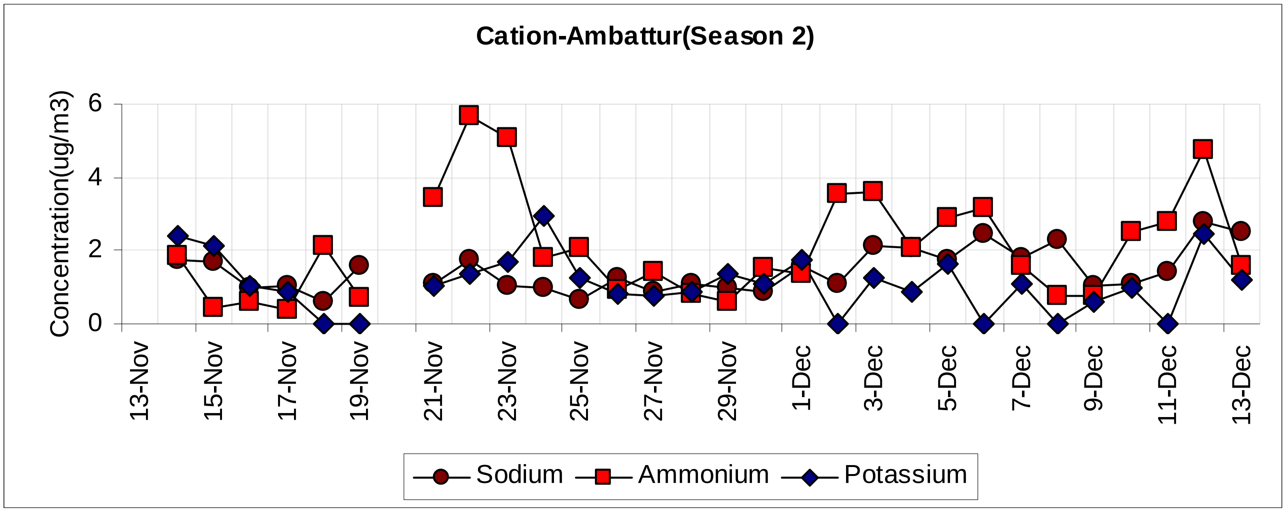


Figure 2.2.7.5--Cations in PM_{10} at Ambattur

Figure 2.2.7.6 shows the diurnal variation of CO concentrations at the monitoring station. The mean levels are shown to vary between 4000 and 5600 µg/m³. At this site CO concentration is above the NAAQS 1-hr average (4000 µg/m³).

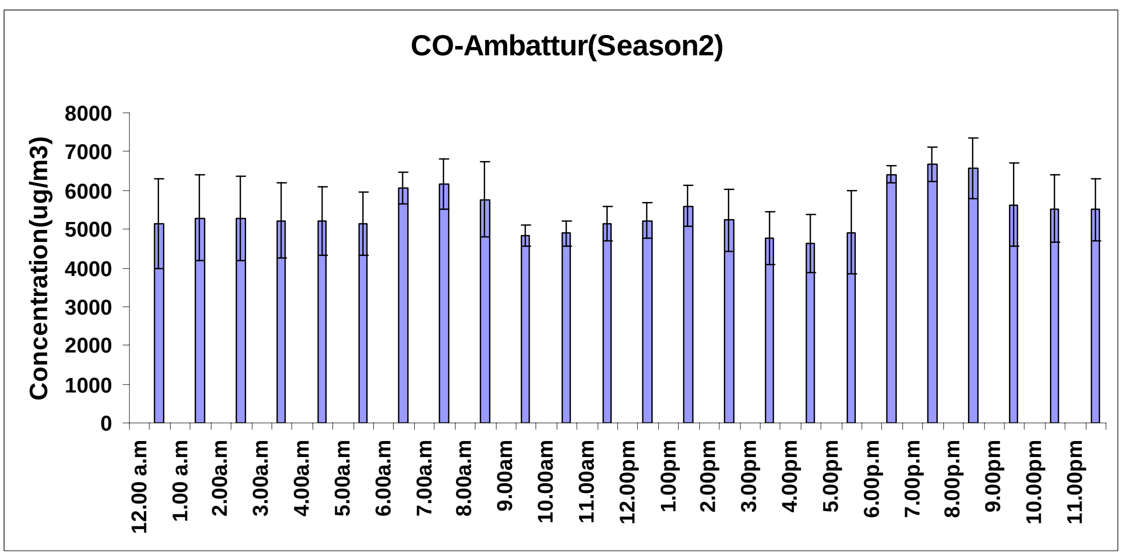


Figure 2.2.7.6-- CO – diurnal variation for Ambattur.

Figure 2.2.7.7 shows the distribution of the various speciation associated with the PM_{10}. The fraction, which is shown as unknown in figure includes Si and other species such as the H,O and N fraction of organic matter, oxygen in the elemental oxides and other constituents not analyzed in the sample. Of the measured components Ca (25.77%) was the highest fraction followed by OC (20.31%) and Sulphate (7.57%).

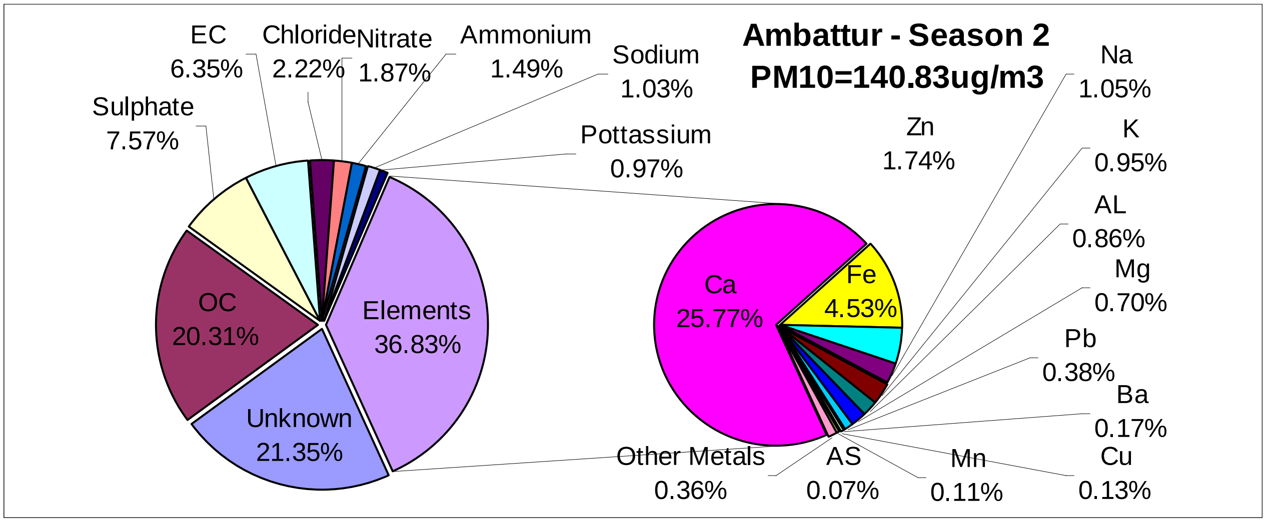


Figure 2.2.7.7-- Distribution of species on PM_{10} at Ambattur

2.4.3 Season 3
2.4.3.1 IIT Madras

Figures 2.3.1.1 shows the 24-hr average values for TSPM, RSPM, PM_{10}, $PM_{2.5}$ and the $PM_{2.5}/PM_{10}$ ratio. The RSPM values were higher than NAAQS (75µg/m³ for sensitive area) for 7 days. Particularly on 24th Dec RSPM value was 172.44µg/m³. The TSPM values were also higher than the NAAQS (100µg/m³ for sensitive area) for 7 days. Particularly on 17th Dec TSPM value was 410.6µg/m³. The PM_{10} values were slightly higher than the NAAQS for 4 days. The $PM_{2.5}$ values were found to vary between 16.87 and 71.53µg/m³. The $PM_{2.5}/PM_{10}$ ratio was found to vary between 0.40 and 0.56. On 18th, 19th and 30th Dec sampling was not done.

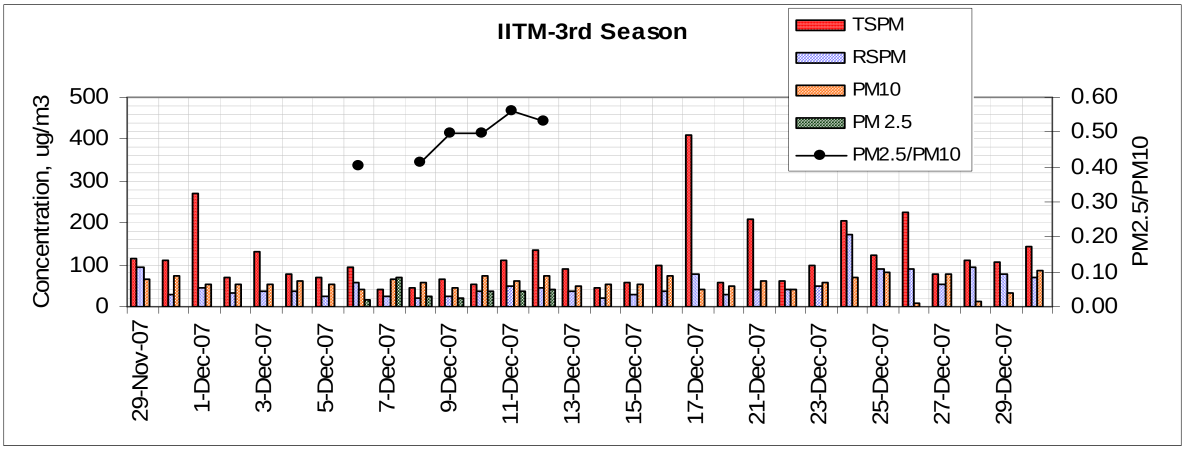


Figure 2.3.1.1-- Particulate matters at IIT Madras

Figure 2.3.1.2 shows the variation of OC, EC and the EC/OC ratio associated with PM_{10} and $PM_{2.5}$. The EC/OC ratio for PM_{10} varies between 0.23 and 0.65 with a mean value of 0.39. The EC/OC ratio for $PM_{2.5}$ varies between 0.37 and 0.6 with a mean value of 0.49. On 18th, 19th and 30th Dec sampling was not done.

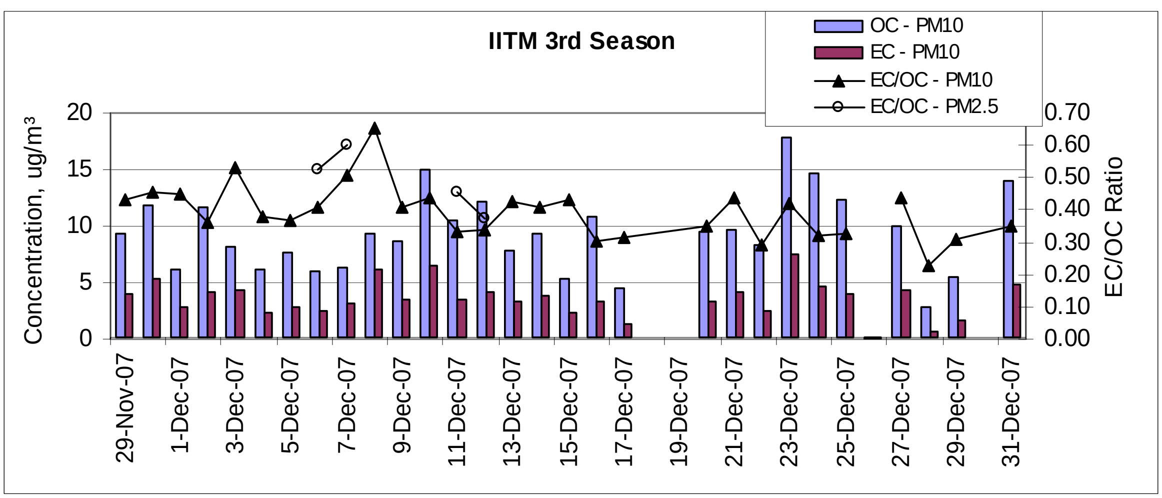


Figure 2.3.1.2-- Measurements of OC/EC for IIT Madras

Figure 2.3.1.3 shows the NOx and SO_2 distribution at IIT Madras. NOx values were found to vary between 9.26 and 40.87µg/m³ with the mean value of 26.87µg/m³. SO_2 values range from 0.36 to 9.53µg/m³ with the mean value of 3.16µg/m³. At this site both the NOx and SO_2 concentrations were well below the NAAQS limit of 30 µg/m³ (sensitive aera). On 18th, 19th and 30th Dec sampling was not done.

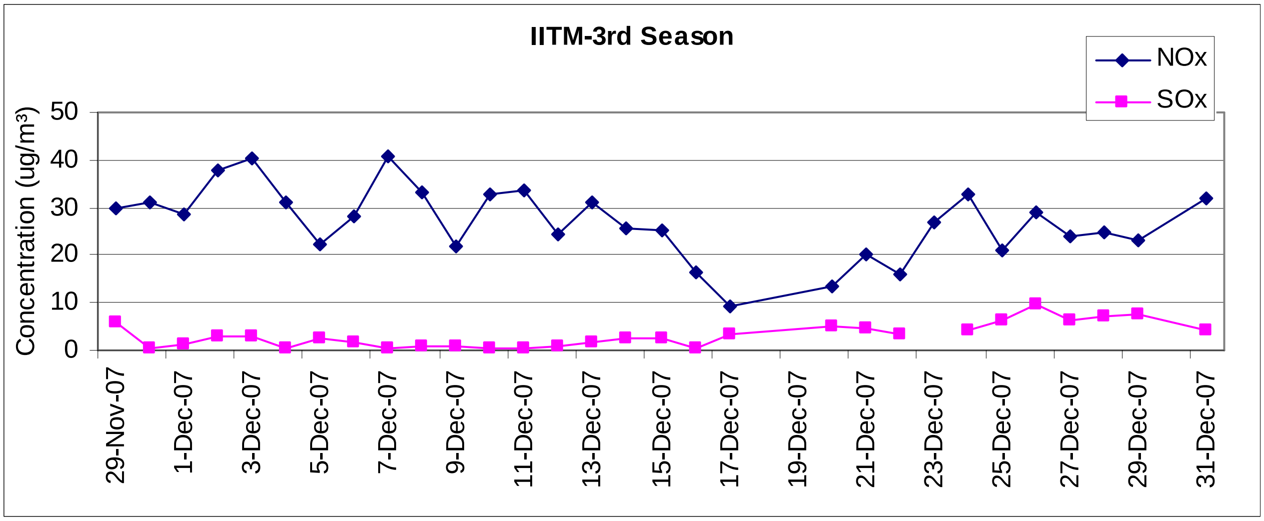


Figure 2.3.1.3-- Time series measurements for SO_2 and NOx

Figure 2.3.1.4 shows the levels of anions associated with PM_{10}. The concentration of sulphate (7.25± 3.83 µg/m³) was higher than those of nitrate (2.46± 2.72 µg/m³) and chloride (2.44 ± 2.05 µg/m³). For the $PM_{2.5}$ fraction, the sulphate concentration found was 4.29µg/m³ and the corresponding ratio of sulphate in the $PM_{2.5}/PM_{10}$ fractions was 0.77 indicating that majority of the sulphate in this site were associated with the $PM_{2.5}$ phase. Similar ratios for chloride and nitrate were found to be 1.39 and 0.36 respectively.

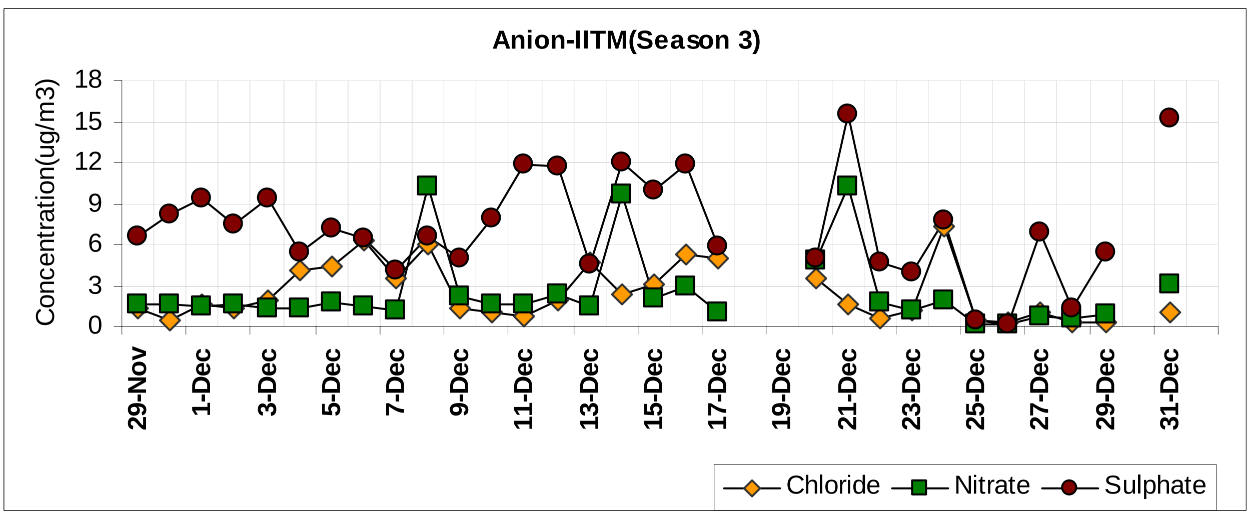


Figure 2.3.1.4-- Time series of anions on PM10

Figure 2.3.1.5 shows the levels of Cations associated with PM_{10}. The concentrations of sodium (2.29± 1.65 µg/m³) and ammonium (2.38 ± 1.74 µg/m³) ions were higher than that of potassium ion (0.69 ± 0.52 µg/m³). The ratio of the ion concentrations on $PM_{2.5}$ to that in PM_{10} were 0.22 and 1.61 for sodium and ammonium respectively.

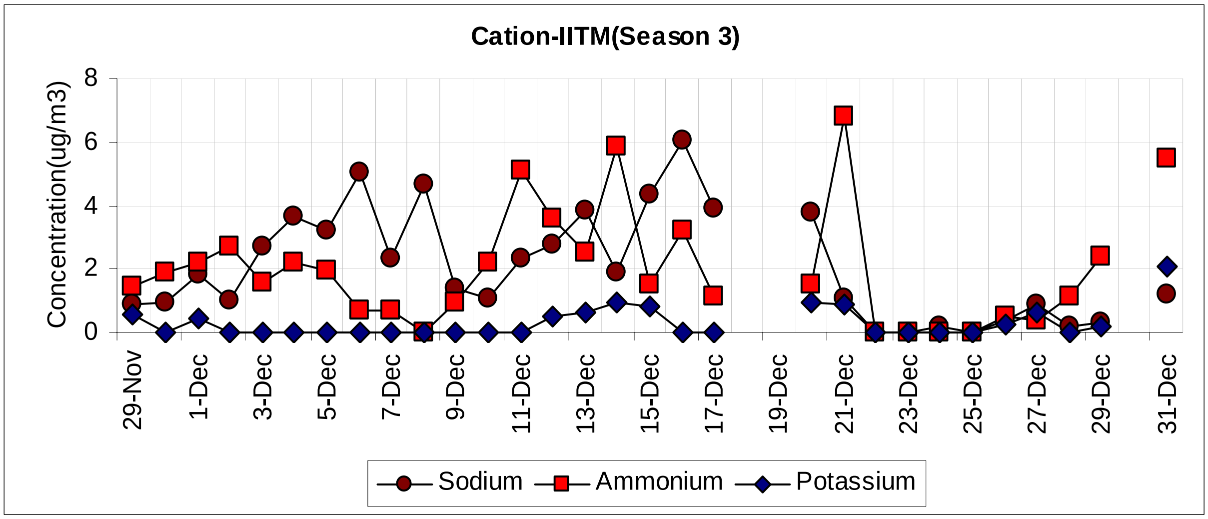


Figure 2.3.1.5--Cations in PM-10 at IIT Madras

Figure 2.3.1.6 shows the diurnal variation of CO levels at IIT Madras site. The mean levels are shown to vary between 3400 and 4380 µg/m³. At this site CO concentration is around the NAAQS 1-hr average of 4000 µg/m³.

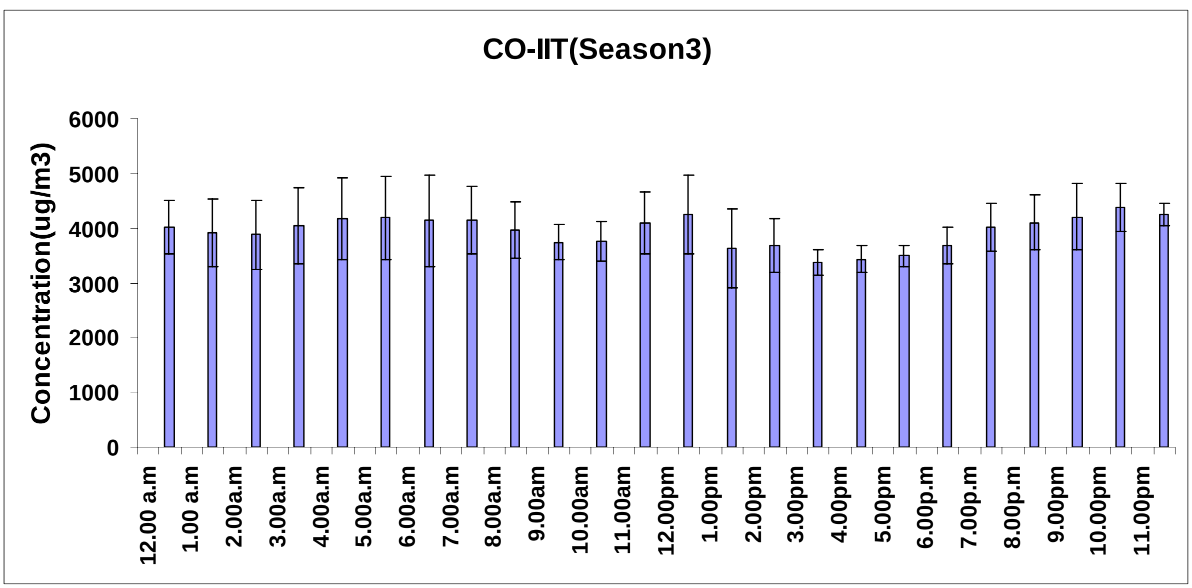


Figure 2.3.1.6-- CO – diurnal variation for IITM.

Figure 2.3.1.7 shows the distribution of the various speciation analysis associated with the PM_{10}. The fraction, which is shown as unknown in figure includes Si and other species such as the H,O and N fraction of organic matter, oxygen in the elemental oxides and other constituents not analyzed in the sample. Of the measured components OC (16.8%) was the highest fraction followed by Sulphate (13.02%) and Ca (12.62%).

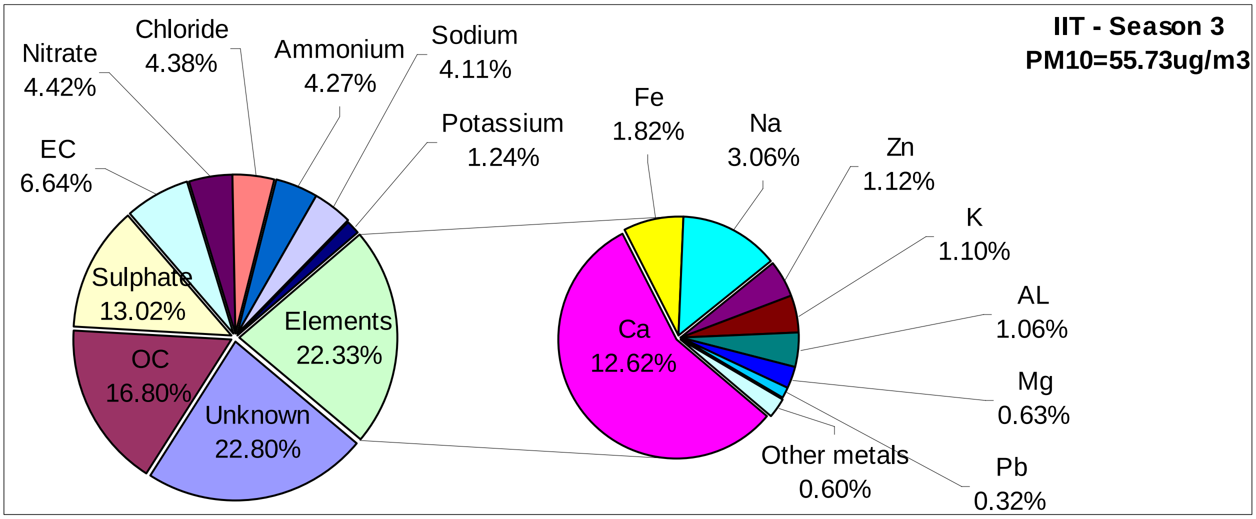


Figure 2.3.1.7-- Distribution of species on PM_{10} at IIT Madras

2.4.3.2 Mylapore

Figures 2.3.2.1 shows the 24-hr average values for TSPM, RSPM, PM_{10}, $PM_{2.5}$ and the $PM_{2.5}/PM_{10}$ ratio. The RSPM values were higher than NAAQS limit of 100µg/m³ (for residential area) for 8 days. Particularly on 26th Oct 2nd and 4th Nov RSPM values were 224.25, 205.49 and 579.41µg/m³ respectively. The TSPM values were higher than the NAAQS (200µg/m³ for residential area) for 5 days. Particularly on 26th, 29th Oct and 4th Nov TSPM values were 337.88, 346.01 and 641.59µg/m³ respectively. The PM_{10} values were also slightly higher than the NAAQS for 6 days. Particularly on 8th and 14th Oct PM10 values were 167.95 and 148.67µg/m³. The $PM_{2.5}$ values were found to vary between 19.39 and 60.97µg/m³. The $PM_{2.5}/PM_{10}$ ratio was found to vary between 0.15 and 0.49. On 20th, 21st and 28th Oct sampling was not done.

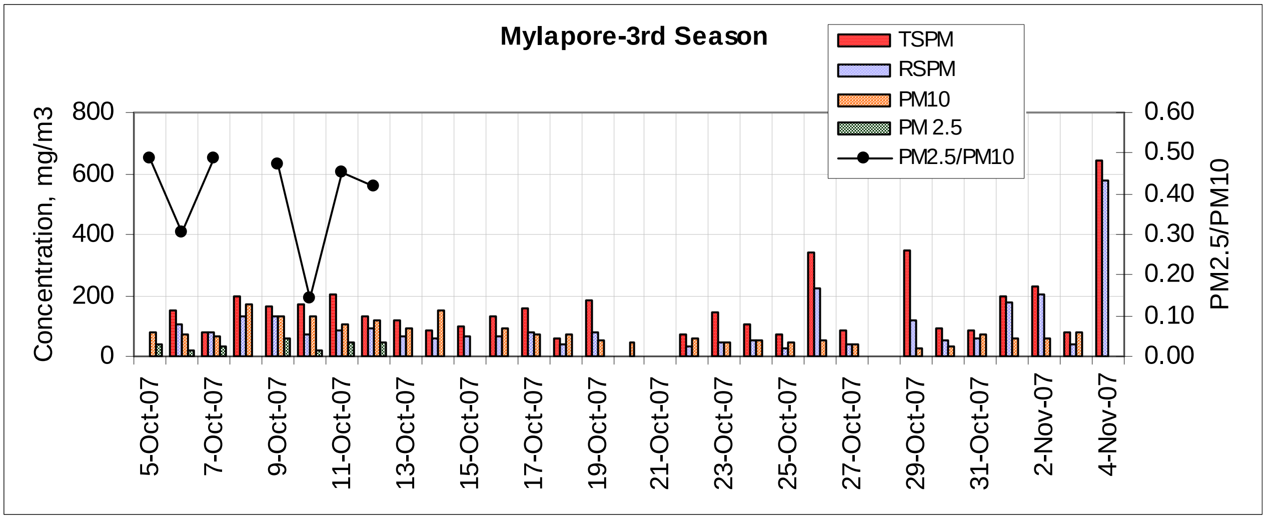


Figure 2.3.2.1-- Particulate Matter at Mylapore

Figure 2.3.2.2 shows the variation of OC, EC and the EC/OC ratio associated with PM_{10} and $PM_{2.5}$. The EC/OC ratio for PM_{10} varies between 0.21 and 0.61 with a mean value of 0.39. The EC/OC ratio for $PM_{2.5}$ varies between 0.42 and 0.69 with a mean value of 0.53.

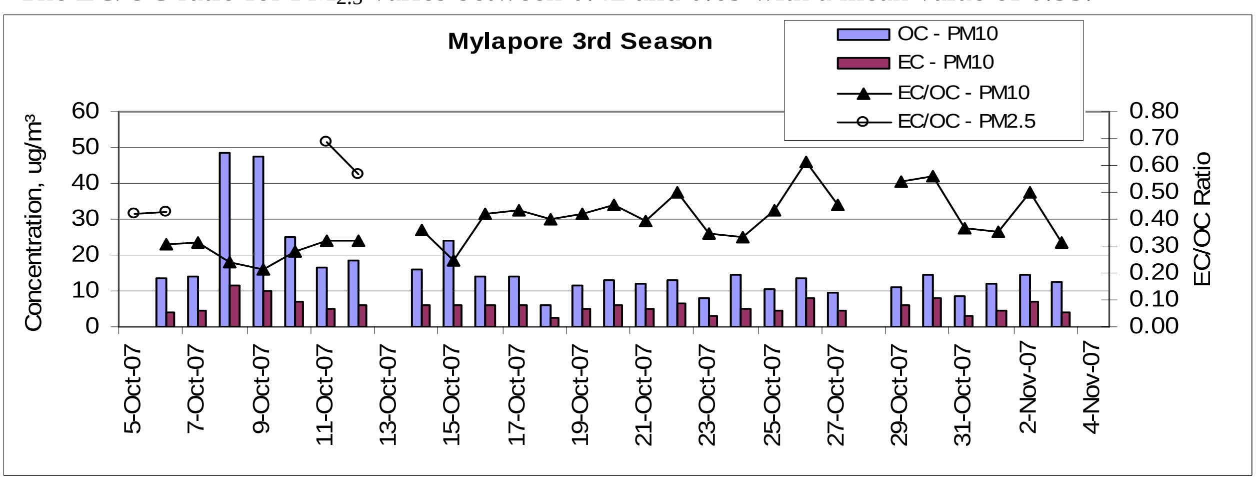


Figure 2.3.2.2-- Measurements of OC/EC for Mylapore

Figure 2.3.2.3 shows the NOx and SO_2 distribution at Mylapore. NOx values were found to vary between 12.3and 42.13µg/m³ with the mean value of 28.35µg/m³. SO_2 values range from 0.48 to 8.07µg/m³ with the mean value of 3.26µg/m³. At this site both the NOx and SO_2 concentrations were well below the NAAQS limit of 80 µg/m³(residential area)

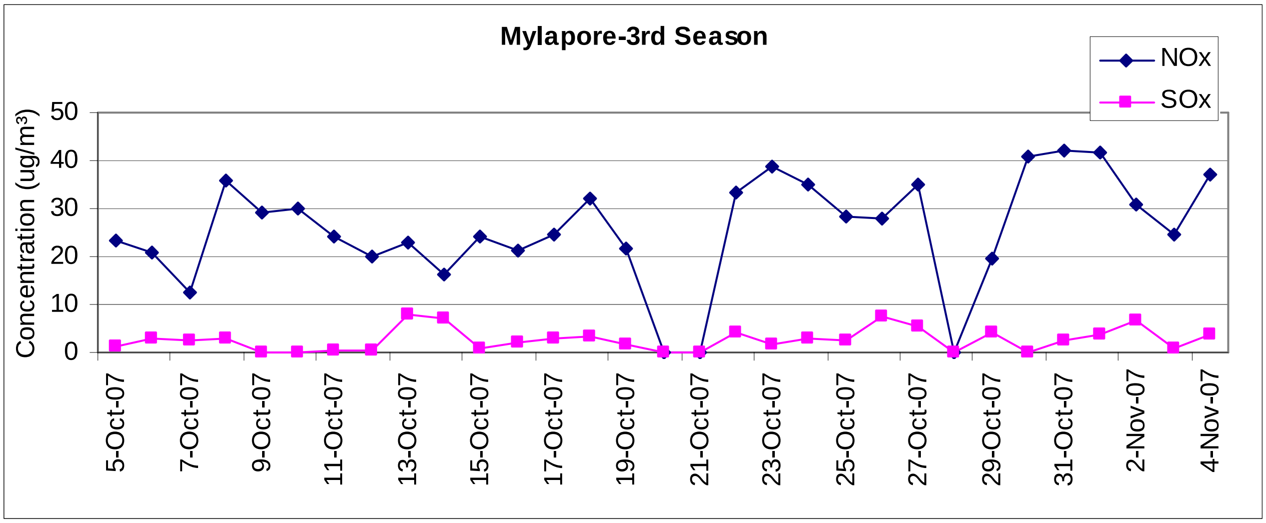


Figure 2.3.2.3-- Time series measurements for SO_2 and NOx

Figure 2.3.2.4 shows the levels of anions associated with PM_{10}. The concentration of Sulphate (9.71± 5.34 µg/m³) was higher than those of nitrate (1.78± 1.27 µg/m³) and chloride (1.55 ± 1.28 µg/m³). For the $PM_{2.5}$ fraction, the Sulphate concentration found was 17.25 µg/m³ and the corresponding ratio of Sulphate in the $PM_{2.5}/PM_{10}$ fractions was 0.83 indicating that majority of the Sulphate in this site were associated with the $PM_{2.5}$ phase. Similar ratios for chloride and nitrate were found to be 0.38 and 0.04 respectively.

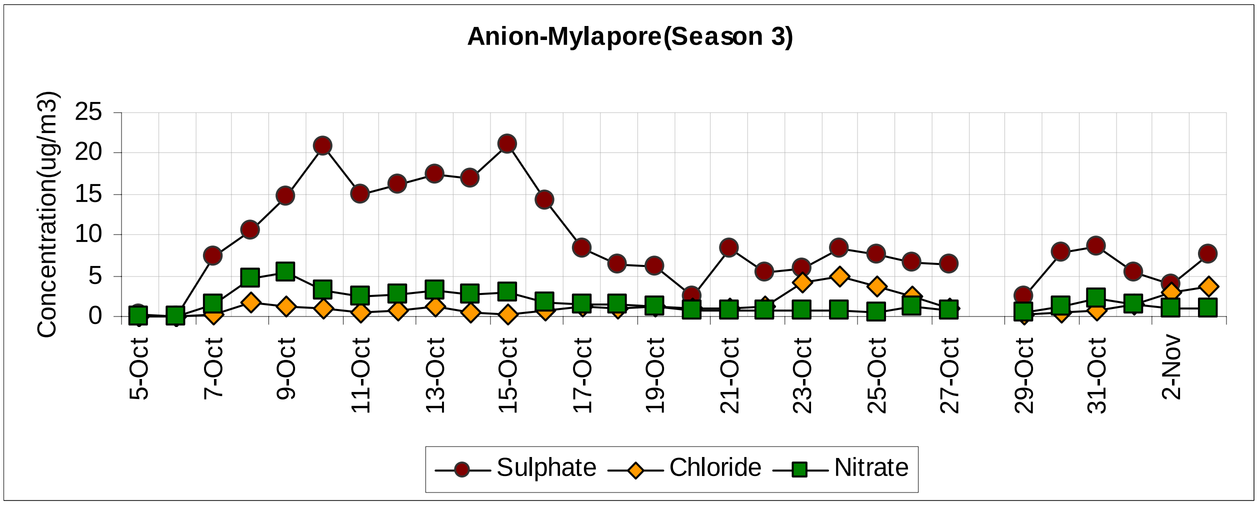


Figure 2.3.2.4-- Time series of anions on PM10

Figure 2.3.2.5 shows the levels of Cations associated with PM_{10}. The concentrations of ammonium (1.61± 1.14 µg/m³) and sodium (1.32 ± 0.83 µg/m³) ions were higher than that of potassium ion (0.67 ± 0.25 µg/m³). The ratio of the ion concentrations on $PM_{2.5}$ to that in PM_{10} were 1.4, 0.29 and 0.51 for ammonium, sodium and potassium respectively.

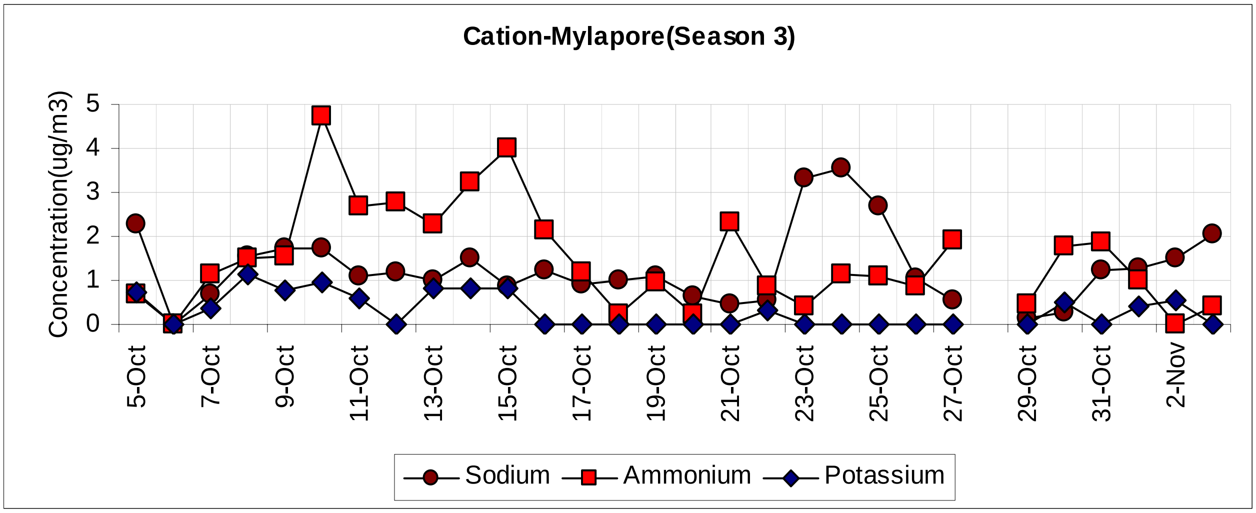


Figure 2.3.2.5--Cations in PM-10 at Mylapore

Figure 2.3.2.6 shows the diurnal variation of CO levels at the Mylapore site. The mean levels are shown to vary between 7200 and 9800 µg/m³. At this site CO concentration is exceeding the NAAQS 1-hr average of 4000 µg/m³.

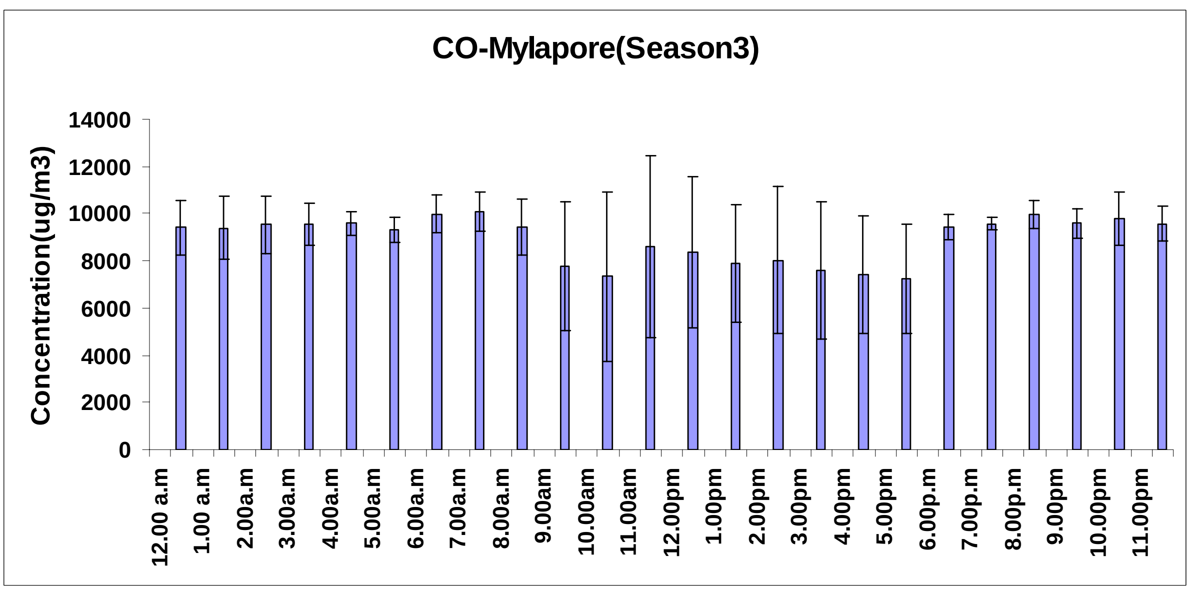


Figure 2.3.2.6-- CO – diurnal variation for Mylapore.

Figure 2.3.2.7 shows the distribution of the various speciation analysis associated with the PM_{10}. The fraction, which is shown as unknown in figure includes Si and other species such as the H,O and N fraction of organic matter, oxygen in the elemental oxides and other constituents not analyzed in the sample. Of the measured components Ca (25.17%) was the highest fraction followed by OC (20.91%) and sulphate (12.56%).

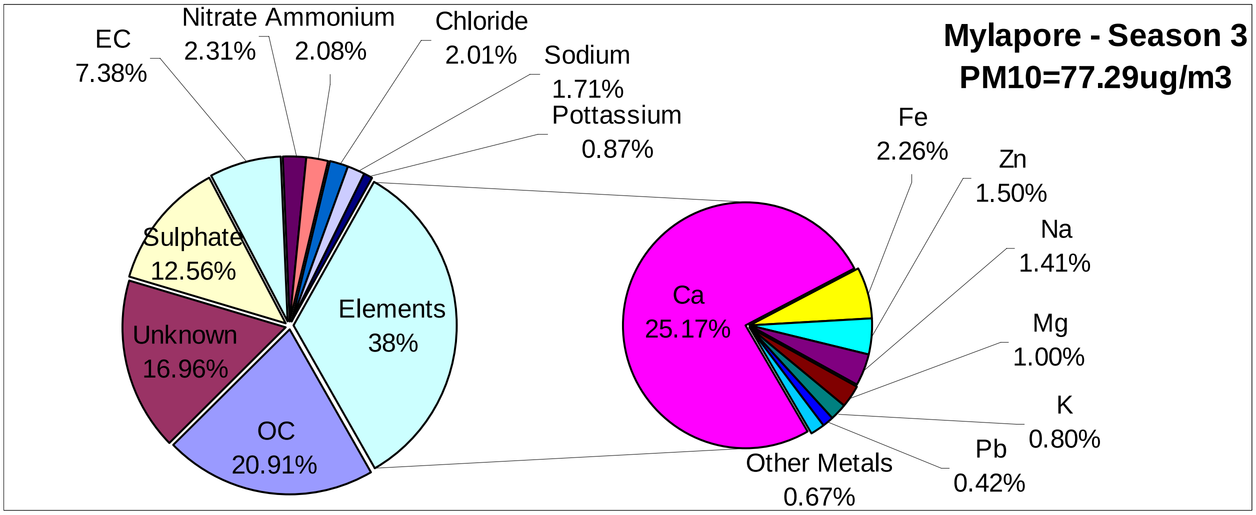


Figure 2.3.2.7-- Distribution of species on PM_{10} at Mylapore

2.4.3.3 Triplicane

Figures 2.3.3.1 shows the 24-hr average values for TSPM, RSPM, PM_{10}, $PM_{2.5}$ and the $PM_{2.5}/PM_{10}$ ratio. The RSPM values were higher than NAAQS (100µg/m³ for Residential area) for 4 days. Particularly on 27th Nov RSPM value was 479µg/m³. The TSPM values were also higher than the NAAQS (200µg/m³ for Residential area) for 2 days. Particularly on 27th Nov and 17th Dec TSPM values were 594.54 and 285.64µg/m³. The PM_{10} values were slightly higher than the NAAQS for 9 days. Particularly on 24th and 27th Dec PM_{10} values were 166.52 and 158.67µg/m³ respectively. The $PM_{2.5}$ values were found to vary between 49.13and 109.84µg/m³. The $PM_{2.5}/PM_{10}$ ratio was found to vary between 0.56 and 0.73. On 18th and 19th Dec and sampling was not done.

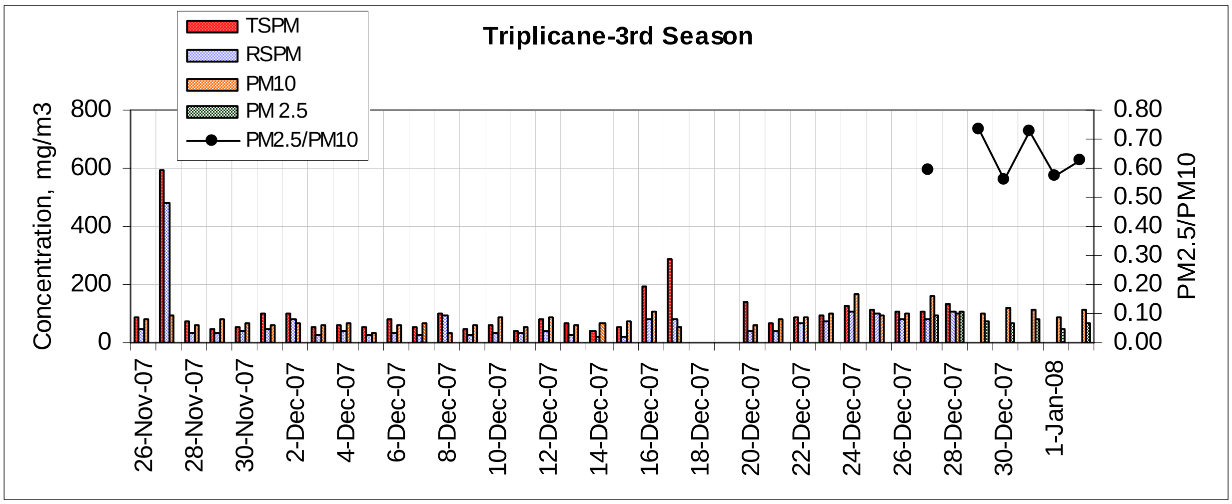


Figure 2.3.3.1-- Particulate matters at Triplicane

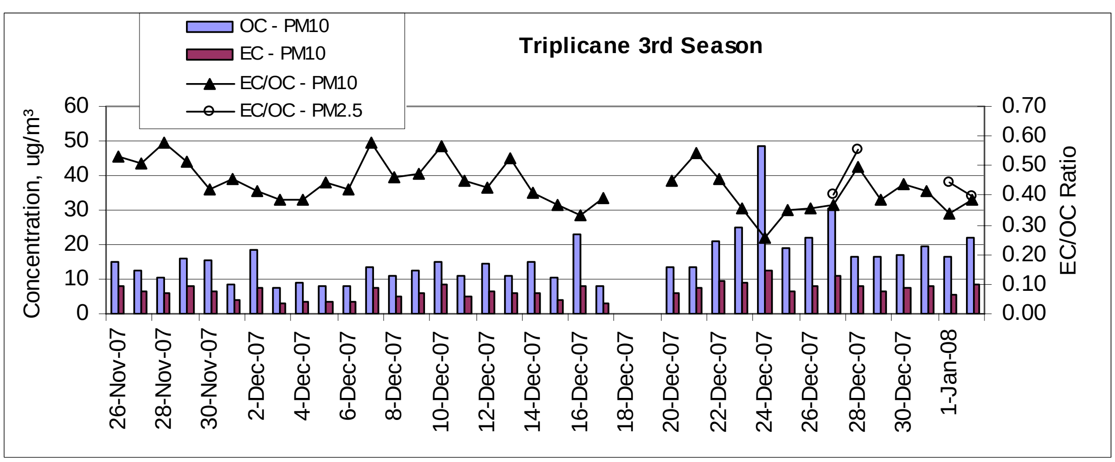


Figure 2.3.3.2-- Measurements of OC/EC for Triplicane

Figure 2.3.3.2 shows the variation of OC, EC and the EC/OC ratio associated with PM_{10} and $PM_{2.5}$. The EC/OC ratio for PM_{10} varies between 0.26 and 0.58 with a mean value of 0.43. The EC/OC ratio for $PM_{2.5}$ varies between 0.4 and 0.55 with a mean value of 0.45.

Figure 2.3.3.3 shows the NOx and SO_2 distribution at Triplicane. NOx values were found to vary between 12.94 and 58.46µg/m³ with the mean value of 31.58µg/m³. SO_2 values range from 0.28 to 36.36µg/m³ with the mean value of 4.19µg/m³. At this site both the NOx and SO_2 concentrations were well below the NAAQS limit of 80 µg/m³(residential area)

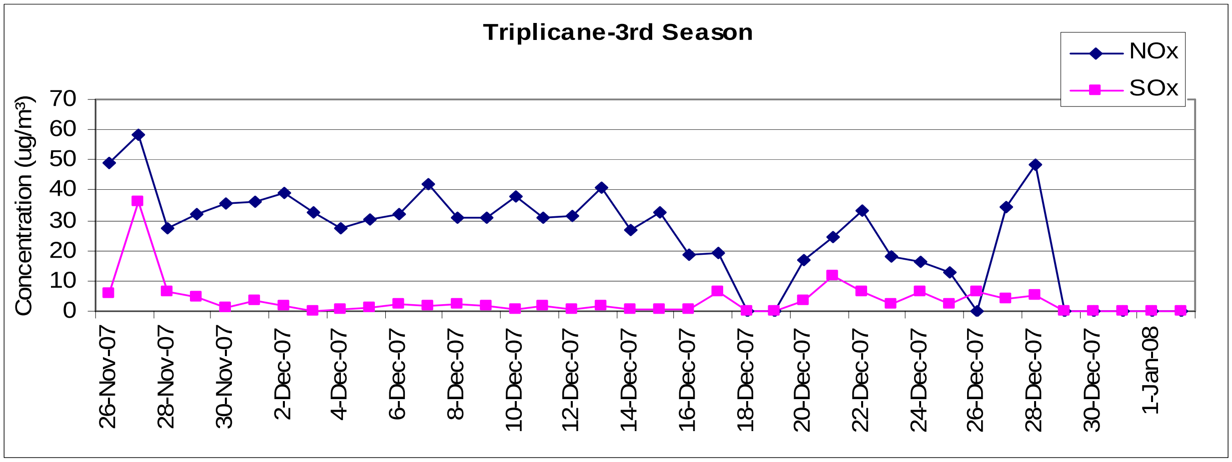


Figure 2.3.3.3-- Time series measurements for SO_2 and NOx

Figure 2.3.3.4 shows the levels of anions associated with PM_{10}. The concentration of Sulphate (9.25±5.09 µg/m³) was higher than those of nitrate (2.4±1.48 µg/m³) and chloride (5.33±5.92 µg/m³). For the $PM_{2.5}$ fraction, the Sulphate concentration found was 20.73 µg/m³ and the corresponding ratio of Sulphate in the $PM_{2.5}/PM_{10}$ fractions was 1.33, indicating that majority of the Sulphate in this site were associated with the $PM_{2.5}$ phase. Similar ratios for chloride and nitrate were found to be 0.29 and 0.2 respectively.

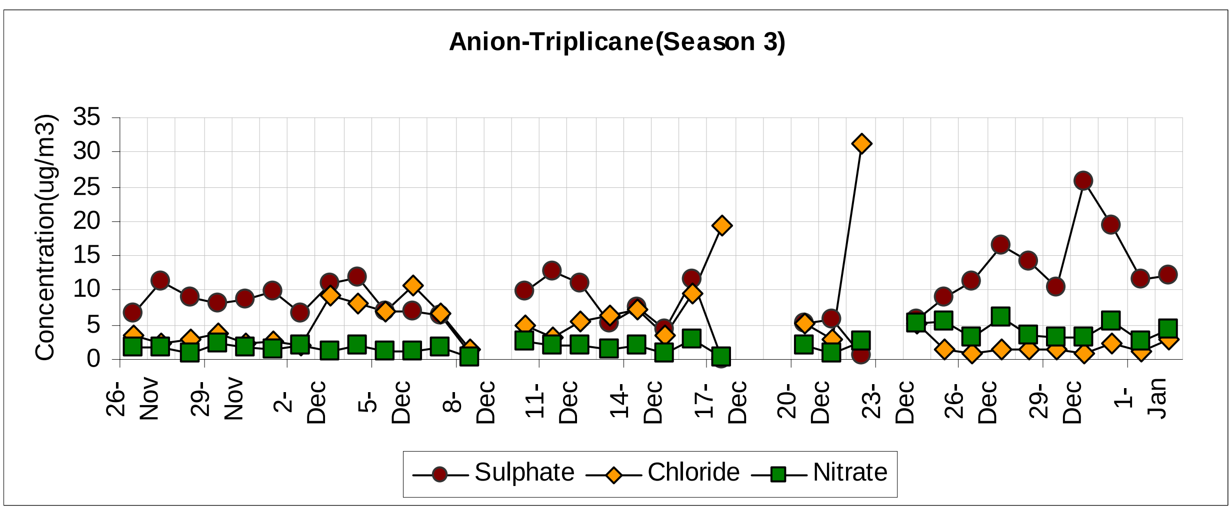


Figure 2.3.3.4-- Time series of anions on PM10

Figure 2.3.3.5 shows the levels of Cations associated with PM_{10}. The concentrations of sodium (3.37±2.1 µg/m³) and ammonium (3.17±2.09µg/m³) ions were higher than that of potassium ion (2.9±4.99 µg/m³). The ratio of the ion concentrations on $PM_{2.5}$ to that in PM_{10} were 3.36, 0.23 and 0.88 for ammonium, sodium and potassium respectively.

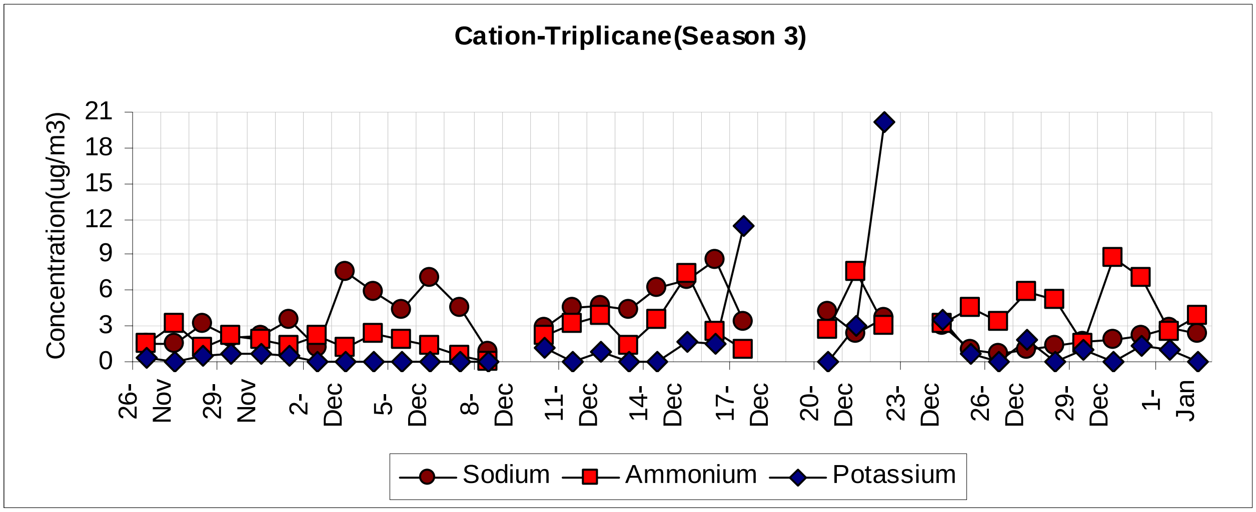


Figure 2.3.3.5--Cations in PM-10 at Triplicane

Figure 2.3.3.6 shows the diurnal variation of CO concentrations at the monitoring station. The mean levels are shown to vary between 6500 and 7470 µg/m³. At this site CO concentration is exceeding the NAAQS 1-hr average 4000 µg/m³.

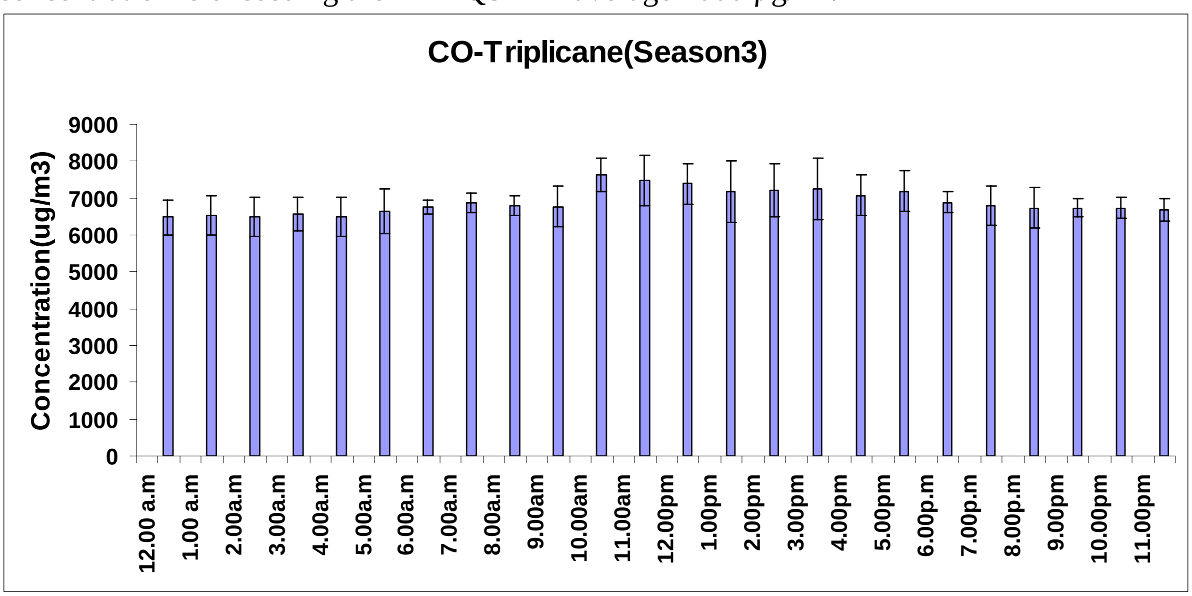


Figure 2.3.3.6-- CO – diurnal variation for Triplicane.

Figure 2.3.3.7 shows the distribution of the various speciation associated with the PM_{10}. The fraction, which is shown as unknown in figure includes Si and other species such as the H,O and N fraction of organic matter, oxygen in the elemental oxides and other constituents not analyzed in the sample. Of the measured components OC (19.52%) was the highest fraction followed by Sulphate (11.28%) and EC (8.11%).

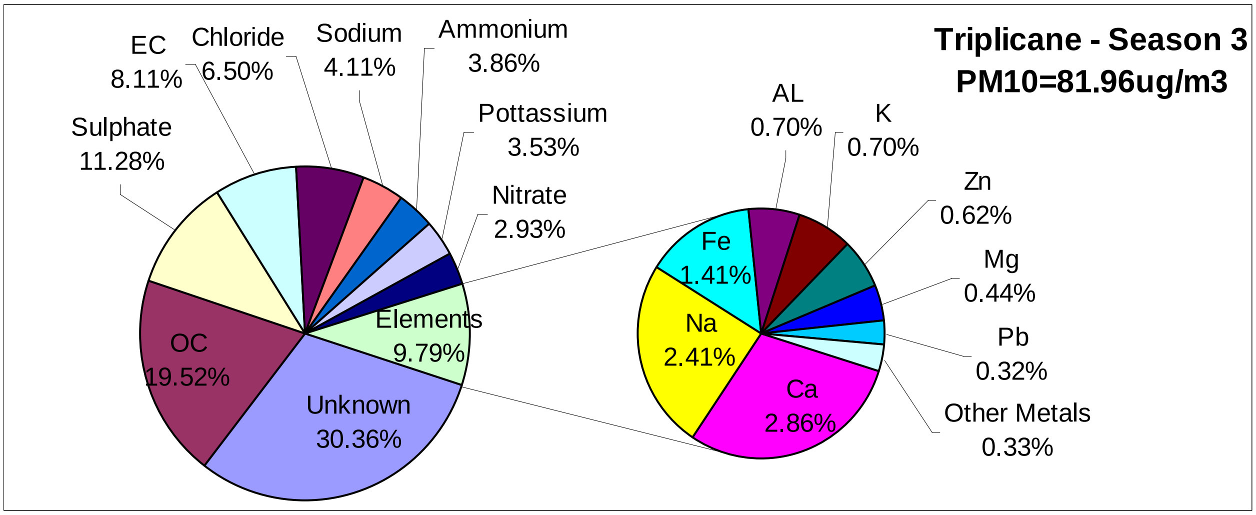


Figure 2.3.3.7-- Distribution of species on PM_{10} at Triplicane

2.4.3.4 Adyar

Figures 2.3.4.1 shows the 24-hr average values for TSPM, RSPM, PM_{10}, $PM_{2.5}$ and the $PM_{2.5}/PM_{10}$ ratio. The RSPM values were higher than NAAQS (100µg/m³ for residential area) for 13 days as seen in the figure above. Especially on 4th and 21st Mar RSPM values were 440.9and 646.92µg/m³ respectively. The TSPM values were higher than the NAAQS (200µg/m³ for residential area) for most of the days. Particularly on 11th and 21st Mar TSPM values were 859.2 and 1586.78µg/m³ respectively. The PM_{10} values were within the NAAQS limit except on 8th Mar. On that day PM_{10} value was 157.83µg/m³. The $PM_{2.5}$ values were found to vary between 40.93and 109.95µg/m³. The $PM_{2.5}/PM_{10}$ ratio was found to vary between 0.46 and 0.72. On 22nd Mar sampling was not done.

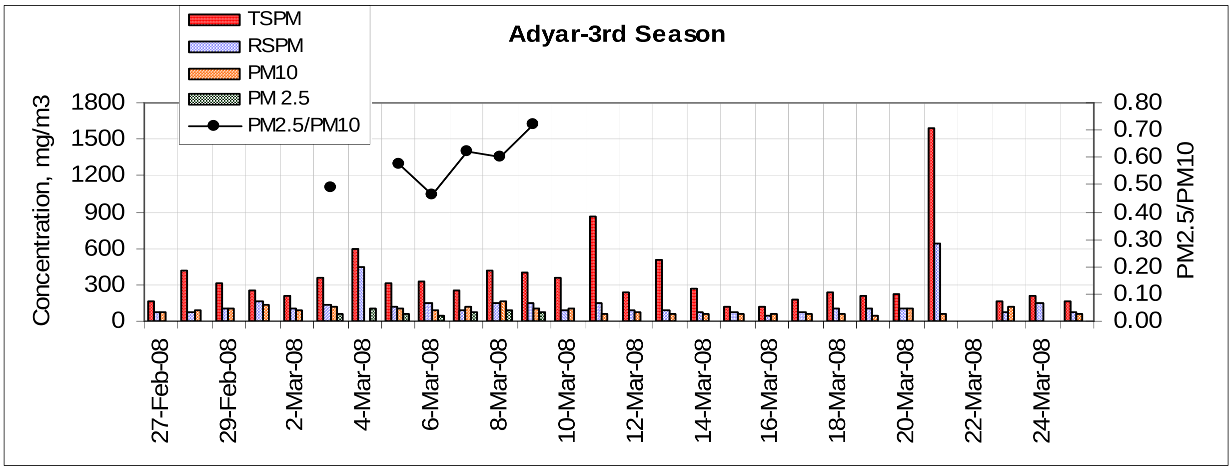


Figure 2.3.4.1-- Particulate matter at Adyar

Figure 2.3.4.2 shows the NOx and SO_2 distribution at Adyar. NOx values were found to vary between 24.37and 60.77µg/m³ with the mean value of 45.33µg/m³. SO_2 values range from 0.79 to 24.29µg/m³ with the mean value of 5.60µg/m³. At this site both the NOx and SO_2 concentrations were well below the NAAQS limit of 80 µg/m³(residential area)

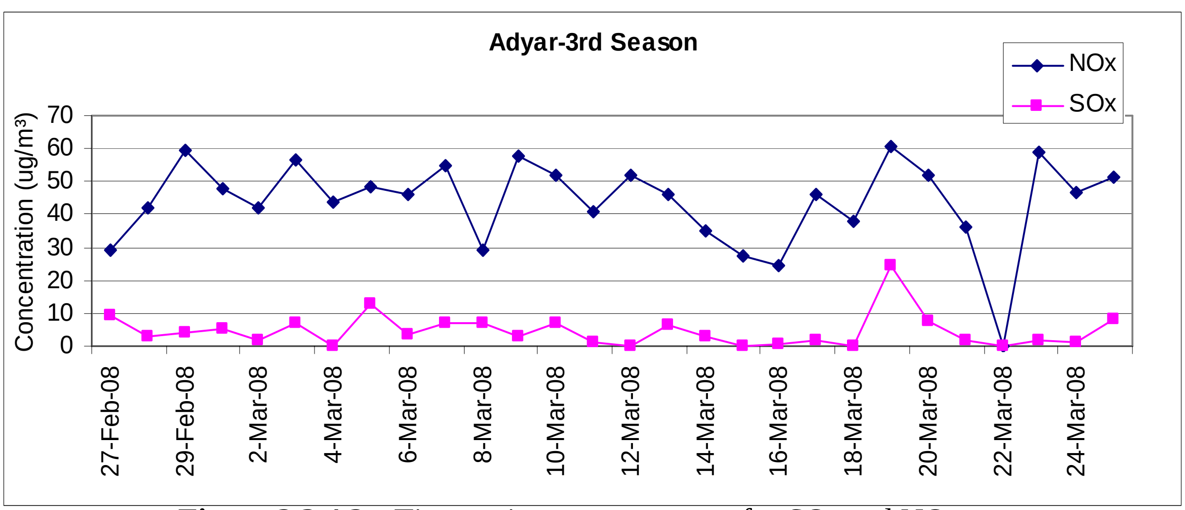


Figure 2.3.4.2-- Time series measurements for SO_2 and NOx

Figure 2.3.4.3 shows the levels of anions associated with PM_{10}. The concentration of sulphate (6.63± 3.48 µg/m³) was higher than those of nitrate (1.28± 0.59 µg/m³) and chloride (0.76 ± 0.34 µg/m³). For the $PM_{2.5}$ fraction, the sulphate concentration found was 7.88µg/m³ and the corresponding ratio of sulphate in the $PM_{2.5}/PM_{10}$ fractions was 0.94. Similar ratios for chloride and nitrate were found to be 0.36and 0.21 respectively.

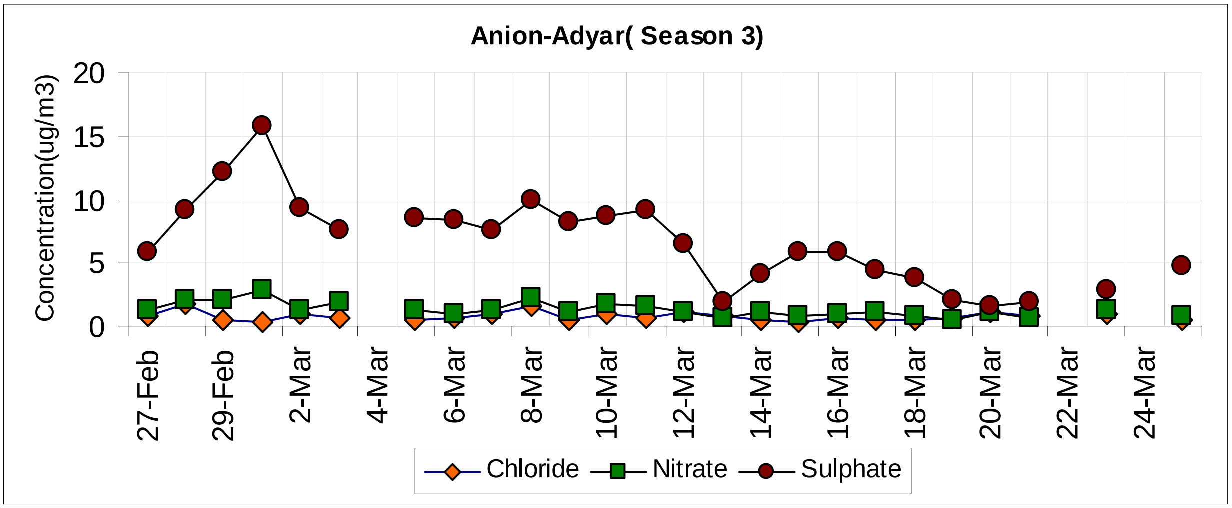


Figure 2.3.4.3-- Time series of anions on PM10

Figure 2.3.4.4 shows the levels of Cations associated with PM_{10}. The concentrations of ammonium (2.03± 0.95 µg/m³) and sodium (0.66± 0.29 µg/m³) ions were higher than that of potassium ion (0.63± 0.19 µg/m³). The ratio of the ion concentrations on $PM_{2.5}$ to that in PM_{10} were 0.46 and 1.17 for sodium and ammonium respectively.

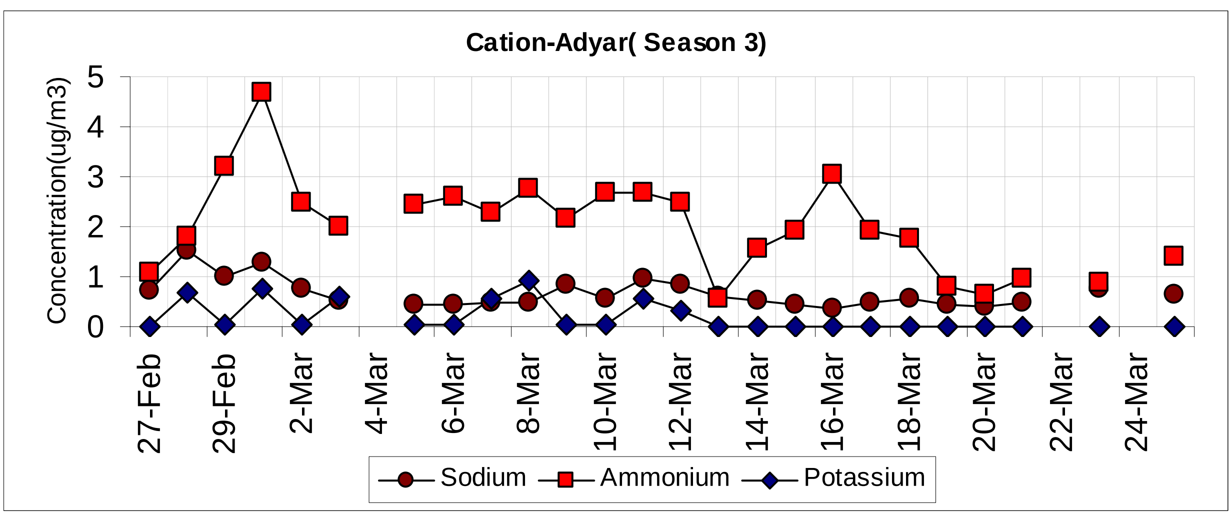


Figure 2.3.4.4--Cations in PM-10 at Adyar

Figure 2.3.4.5 shows the diurnal variation of CO concentrations at the monitoring station. The mean levels are shown to vary between 4900 and 6400 µg/m³. At this site CO concentration is exceeding the NAAQS 1-hr average (4000 µg/m³).

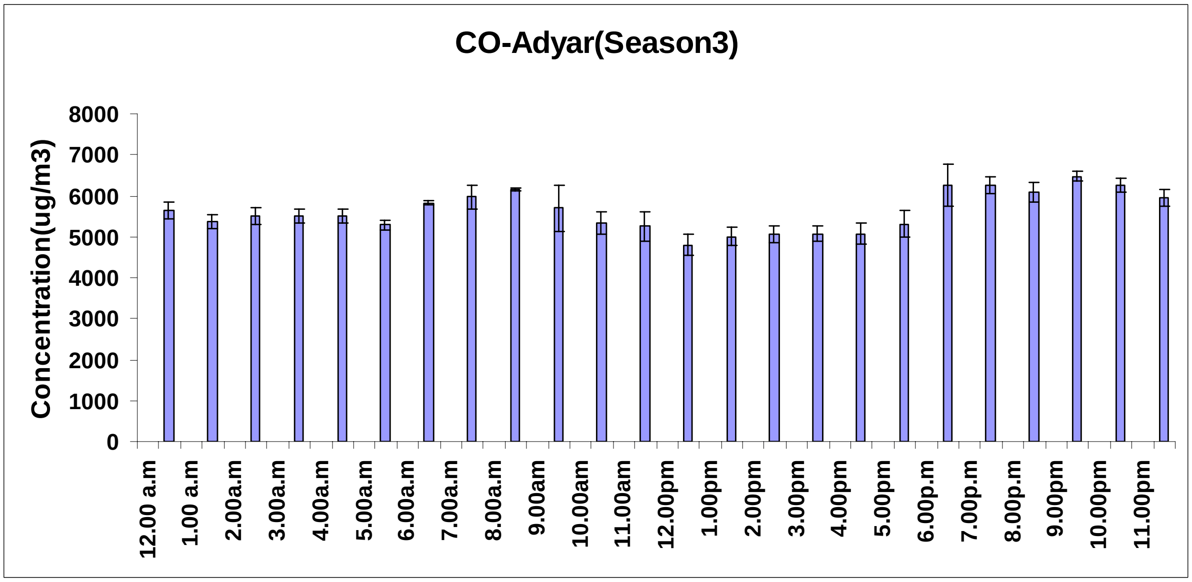


Figure 2.3.4.5-- CO – diurnal variation for Adyar.

Figure 2.3.4.6 shows the distribution of the various speciation associated with the PM_{10}. The fraction, which is shown as unknown in figure includes Si and other species such as the H,O and N fraction of organic matter, oxygen in the elemental oxides and other constituents not analyzed in the sample. Of the measured components Fe (2.33%) was the highest fraction followed by Nitrate (1.47%) and Mg (1.28%).

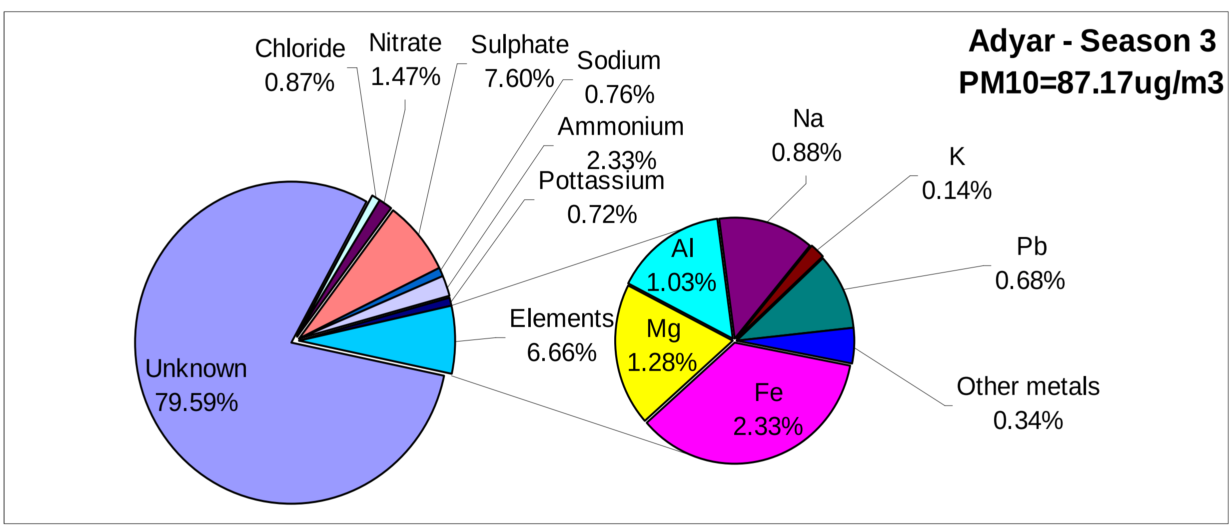


Figure 2.3.4.6-- Distribution of species on PM_{10} at Adyar

2.4.3.5 Saidapet

Figures 2.3.5.1 shows the 24-hr average values for TSPM, RSPM, PM_{10}, $PM_{2.5}$ and the $PM_{2.5}/PM_{10}$ ratio. The RSPM values were higher than NAAQS (100µg/m³ for residential site) for 12 days. Especially on 25th Oct, 26th Oct and 4th Nov RSPM values were 483.23, 313.79 and 315.18µg/m³ respectively. The TSPM values were also higher than the NAAQS (200µg/m³) for most of the days. Particularly on 25th Oct, 26th Oct and 4th Nov TSPM values were 661.54, 344.84 and 350.06µg/m³ respectively. The PM_{10} values were slightly higher than the NAAQS for most of the days. On 17th Oct PM_{10} value was 261.39µg/m³. The $PM_{2.5}$ values were found to vary between 28.85and 94.21µg/m³. The $PM_{2.5}/PM_{10}$ ratio was found to vary between 0.21 and 0.55. From 20th to 23rd Oct and 28th Oct sampling was not done.

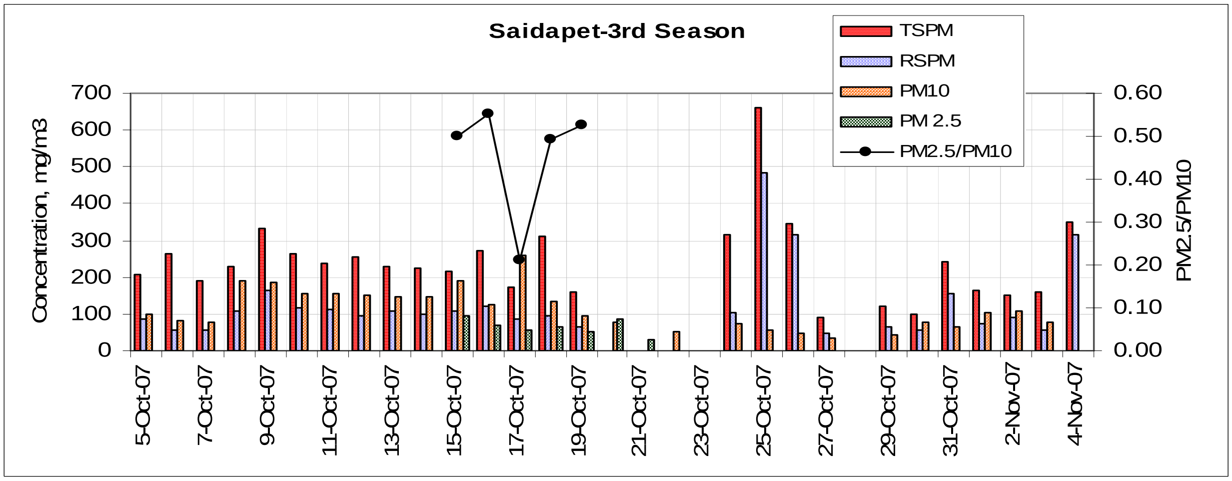


Figure 2.3.5.1-- Particulate matter at Saidapet

Figure 2.3.5.2 shows the variation of OC, EC and the EC/OC ratio associated with PM_{10}. The EC/OC ratio for PM_{10} varies between 0.21 and 0.75 with a mean value of 0.45. The EC/OC ratio for $PM_{2.5}$ varies between 0.24 and 0.81 with a mean of 0.56, which is marginally higher than that the corresponding values for PM_{10}.

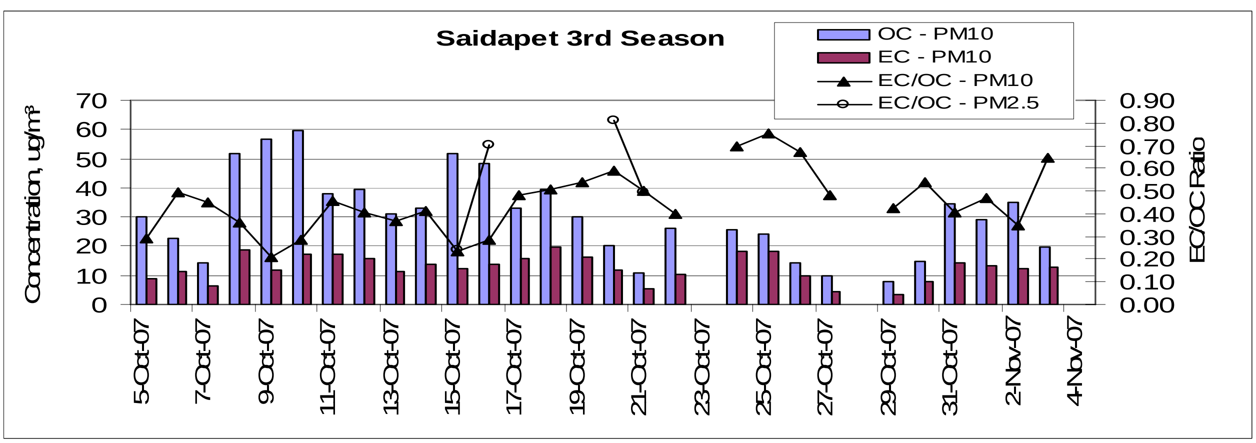


Figure 2.3.5.2-- Measurements of OC/EC for Saidapet

Figure 2.3.5.3 shows the NOx and SO_2 distribution at Saidapet. NOx values were found to vary between 30.79and 72.7µg/m³ with the mean value of 49.0µg/m³. SO_2 values range from 0.31 to 6.85µg/m³ with the mean value of 2.86µg/m³. At this site both the NOx and SO_2 concentrations were well below the NAAQS limit of 80 µg/m³ (residential area)

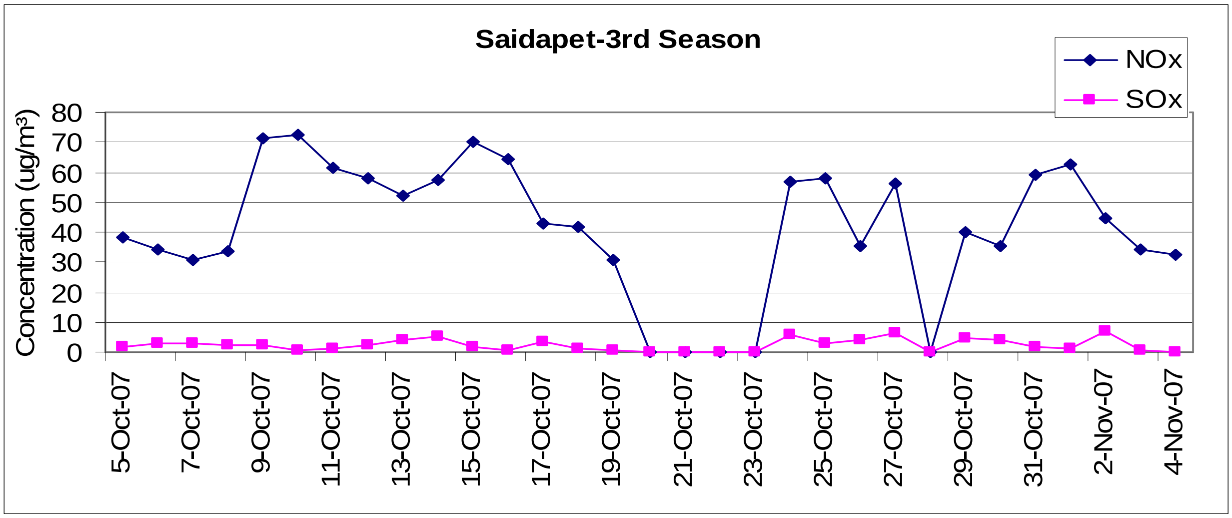


Figure 2.3.5.3-- Time series measurements for SO_2 and NOx

Figure 2.3.5.4 shows the levels of anions associated with PM_{10}. The concentration of sulphate (9.02± 5.89 µg/m³) was higher than those of nitrate (2.40± 1.89µg/m³) and chloride (0.93± 0.49 µg/m³). For the $PM_{2.5}$ fraction, the Sulphate concentration found was 7.92µg/m³ and the corresponding ratio of sulphate in the $PM_{2.5}/PM_{10}$ fractions was 0.82 indicating that majority of the sulphate in this site were associated with the $PM_{2.5}$ phase. Similar ratios for chloride and nitrate were found to be 0.46 and 0.09 respectively.

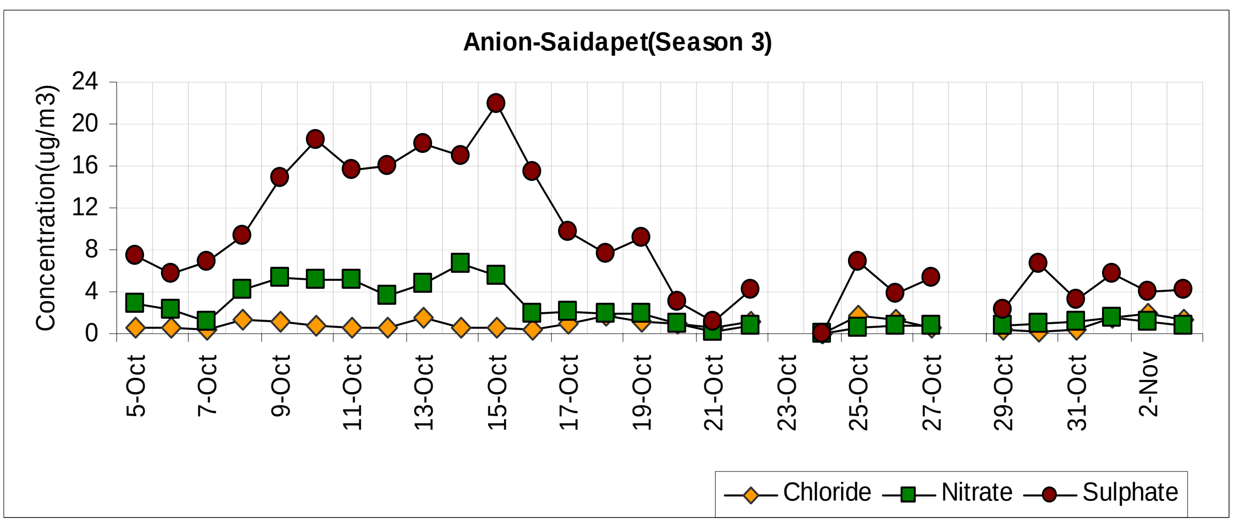


Figure 2.3.5.4-- Time series of anions on PM_{10}

Figure 2.3.5.5 shows the levels of Cations associated with PM_{10}. The concentrations of ammonium (1.68± 1.36 µg/m³) and sodium (0.8 ± 0.38 µg/m³) ions were higher than that of potassium ion (0.62 ± 0.31 µg/m³). The ratio of the ion concentrations on $PM_{2.5}$ to that in PM_{10} were 0.5, 0.89 and 1.12 for sodium, ammonium and potassium respectively.

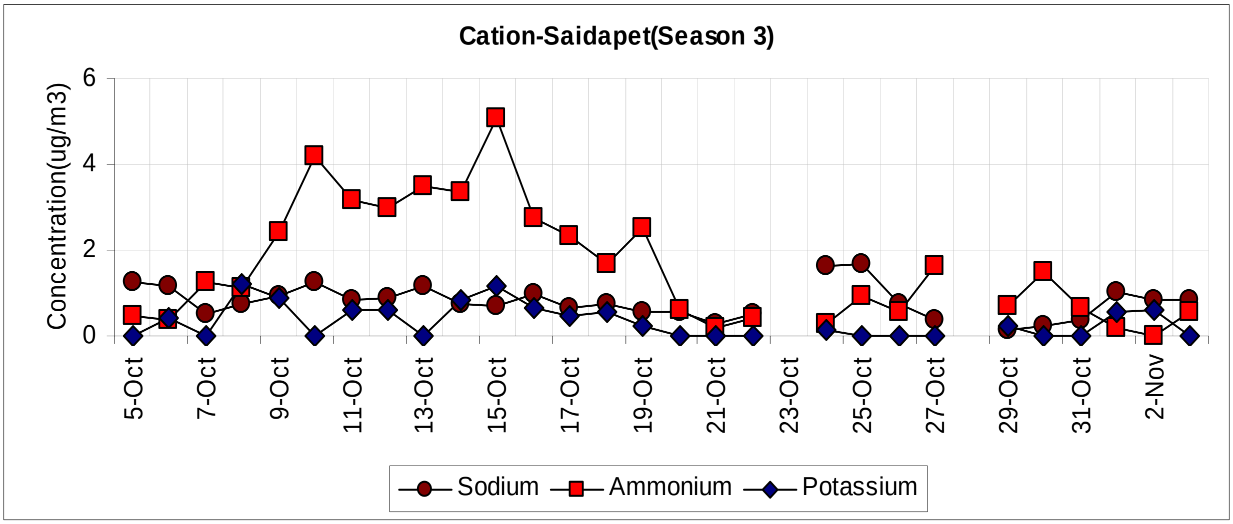


Figure 2.3.5.5--Cations in PM-10 at Saidapet

Figure 2.3.5.6 shows the diurnal variation of CO concentrations at the monitoring station. The mean levels are shown to vary between 5000 and 8200 µg/m³. At this site CO concentration is exceeding the NAAQS 1-hr average standard (4000 µg/m³).

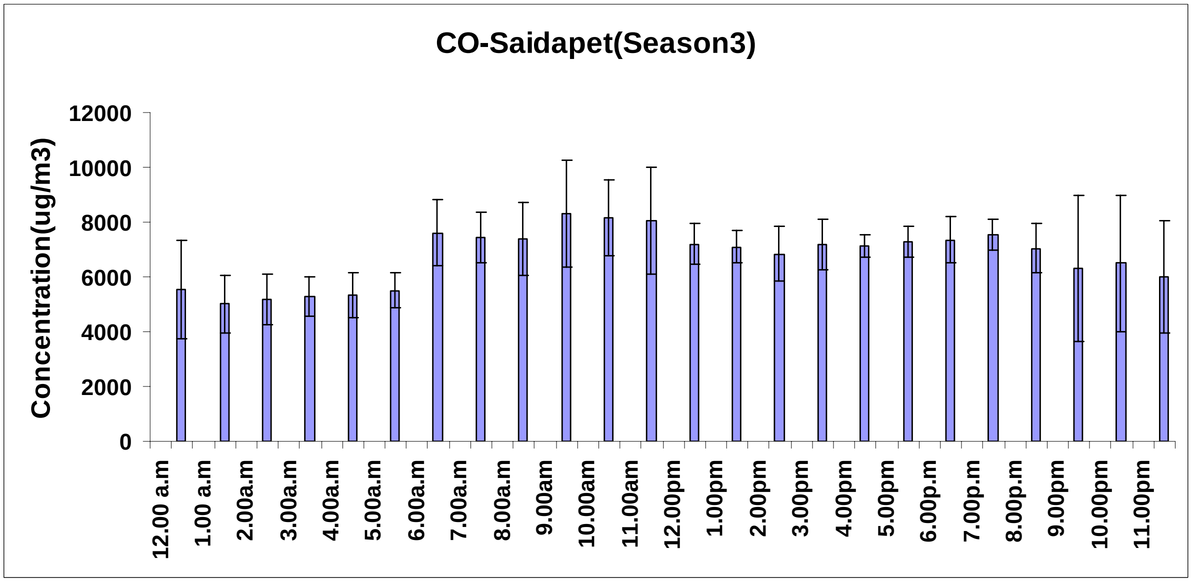


Figure 2.3.5.6-- CO – diurnal variation for Saidapet

Figure 2.3.5.7 shows the distribution of the various speciation associated with the PM_{10}. The fraction, which is shown as unknown in figure includes Si and other species such as the H,O and N fraction of organic matter, oxygen in the elemental oxides and other constituents not analyzed in the sample. Of the measured components OC (27.33%) was the highest fraction followed by EC (11.32%) and Sulphate (8.12%).

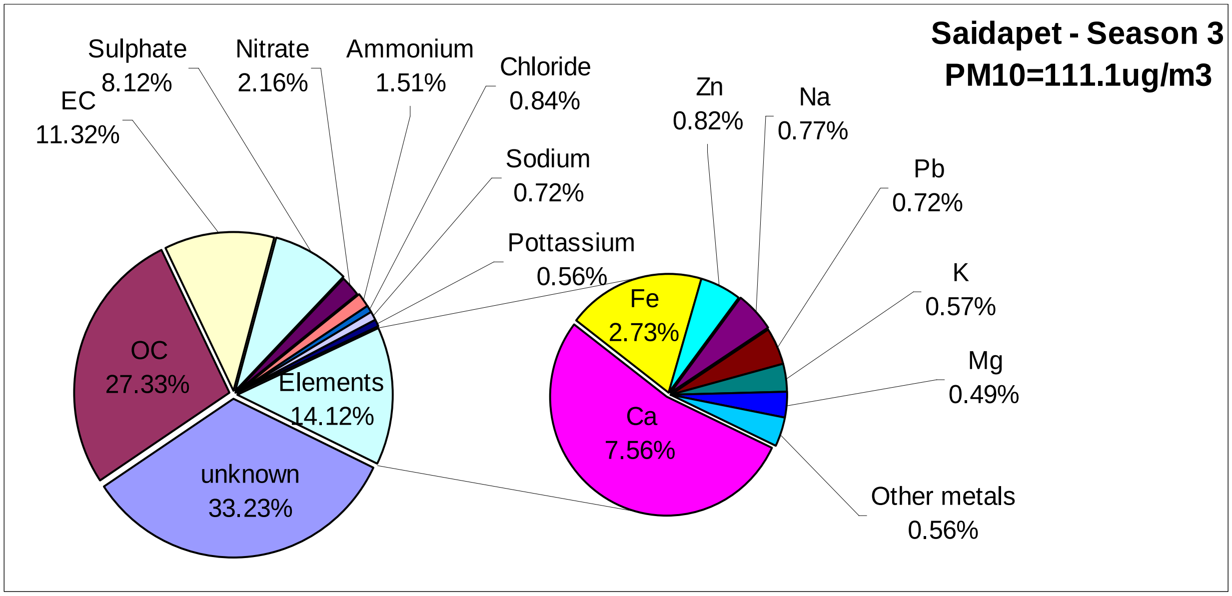


Figure 2.3.5.7-- Distribution of species on PM_{10} at Saidapet

2.4.3.6. R. K. Nagar

Figures 2.3.6.1 shows the 24-hr average values for TSPM, RSPM and PM_{10},. At this site, the RSPM values were higher than NAAQS (150µg/m³ for Industrial area) for 5 days, particularly on 8th October and 2nd November RSPM values were 211.54 and 468.24µg/m³ respectively. The TSPM values were higher than the NAAQS (500µg/m³ for Industrial area) for 2 days (6th October and 2nd November TSPM values were 565.88 and 571.63µg/m³ respectively). The PM_{10} values were slightly higher than the NAAQS for 2 days i.e. on 15th and 31st October the PM_{10} values were 217.41 and 245.98µg/m³ respectively. On 21st, 22nd, 28th and 29th Oct sampling was not done.

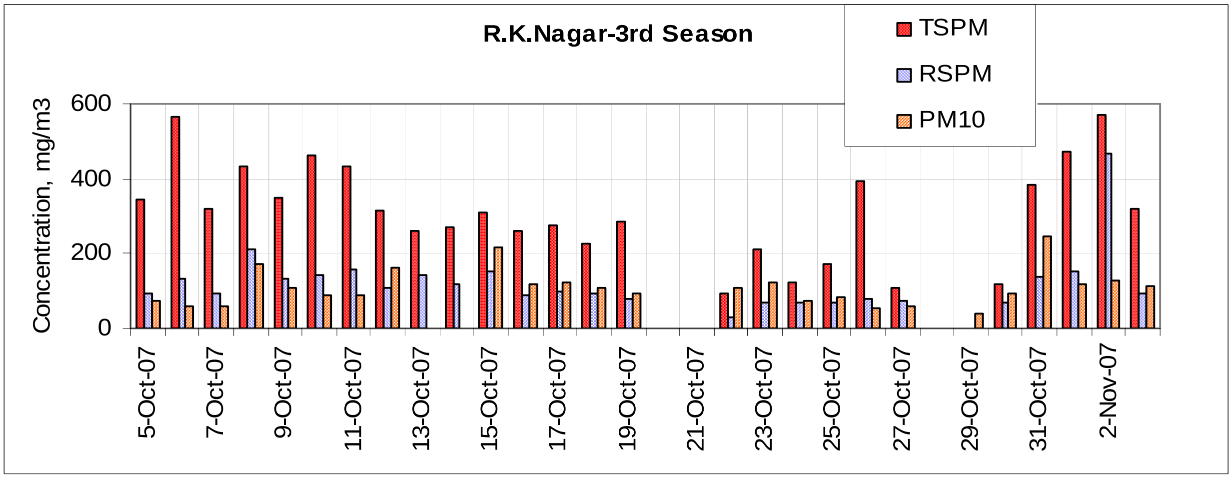


Figure 2.3.6.1-- Particulate matters at R.K.Nagar

Figure 2.3.6.2 shows the variation of OC, EC and the EC/OC ratio associated with PM_{10} and $PM_{2.5}$. The EC/OC ratio for PM_{10} varies between 0.19 and 0.64 with a mean value of 0.43.

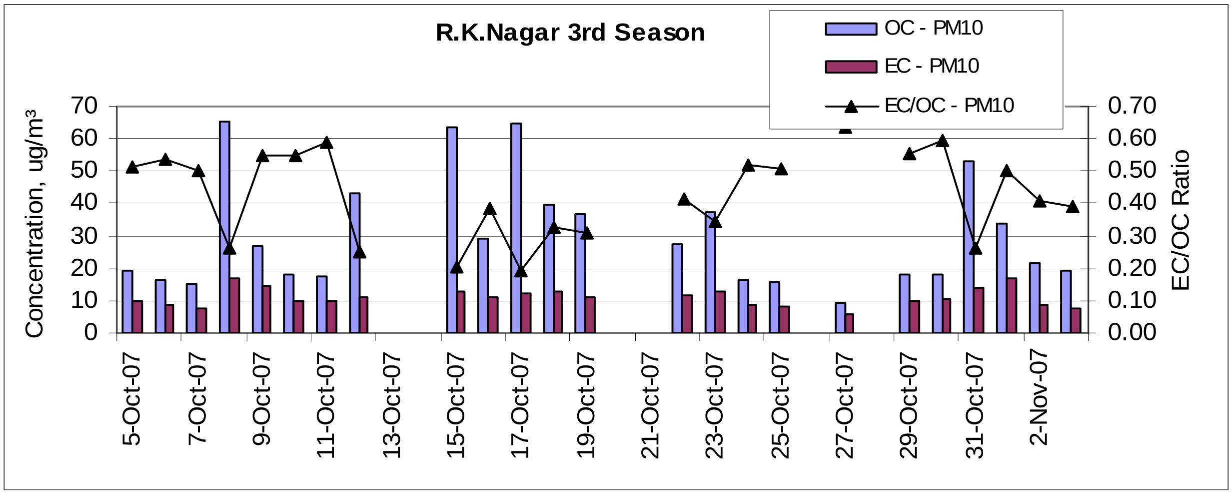


Figure 2.3.6.2-- Measurements of OC/EC for R.K.Nagar

Figure 2.3.6.3 shows the NOx and SO_2 distribution at R.K.Nagar. NOx values were found to vary between 20.51and 70.67µg/m³ with the mean value of 38.64µg/m³. SO_2 values range from 0.66to 22.05µg/m³ with the mean value of 4.88µg/m³. At this site both the NOx and SO_2 concentrations were well below the NAAQS limit of 120 µg/m³ (industrial area).

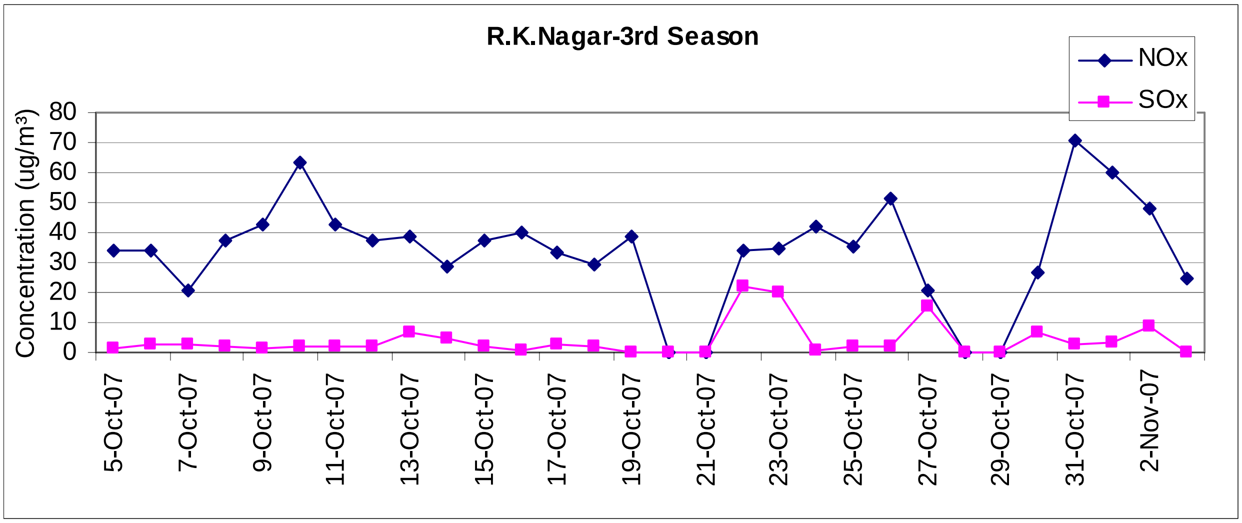


Figure 2.3.6.3-- Time series measurements for SO_2 and NOx

Figure 2.3.6.4 shows the levels of anions associated with PM_{10}. The concentration of Sulphate (9.11± 5.01 µg/m³) was higher than those of nitrate (1.78± 1.34µg/m³) and chloride (1.91± 0.98 µg/m³). For the $PM_{2.5}$ fraction, the Sulphate concentration found was 16.45µg/m³ and the corresponding values of Chloride and nitrate were 0.24 and 0.34µg/m³ respectively.

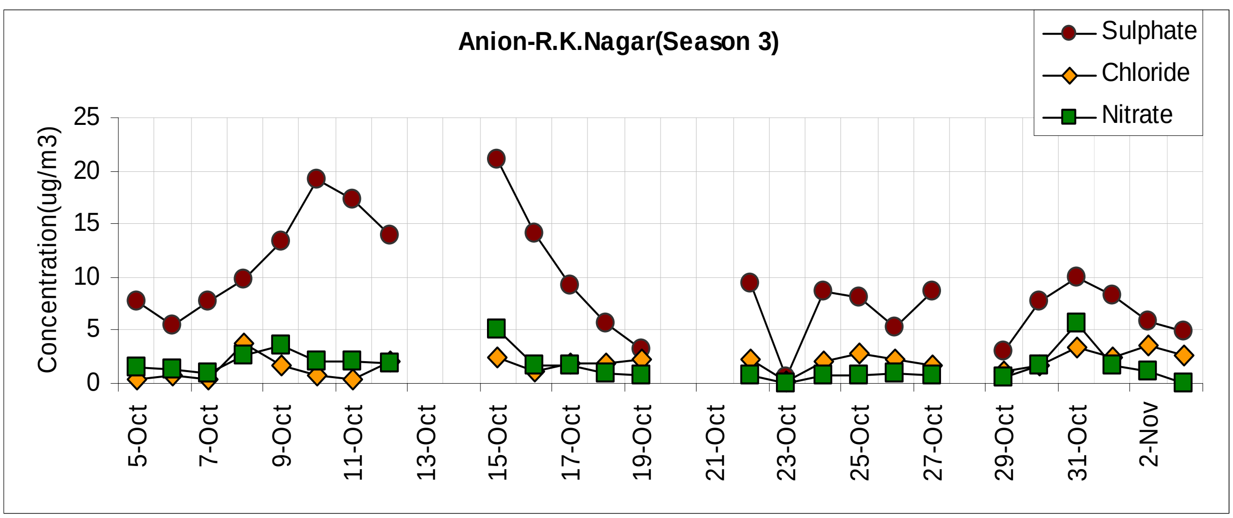


Figure 2.3.6.4-- Time series of anions on PM10

Figure 2.3.6.5 shows the levels of Cations associated with PM_{10}. The concentrations of sodium (1.11± 0.7 µg/m³) and ammonium (1.5 ± 1.78 µg/m³) ions were higher than that of potassium ion (0.72 ± 0.33 µg/m³). For the $PM_{2.5}$ fraction, the ammonium concentration found was 6.58µg/m³ and the corresponding value of sodium was 0.31 µg/m³.

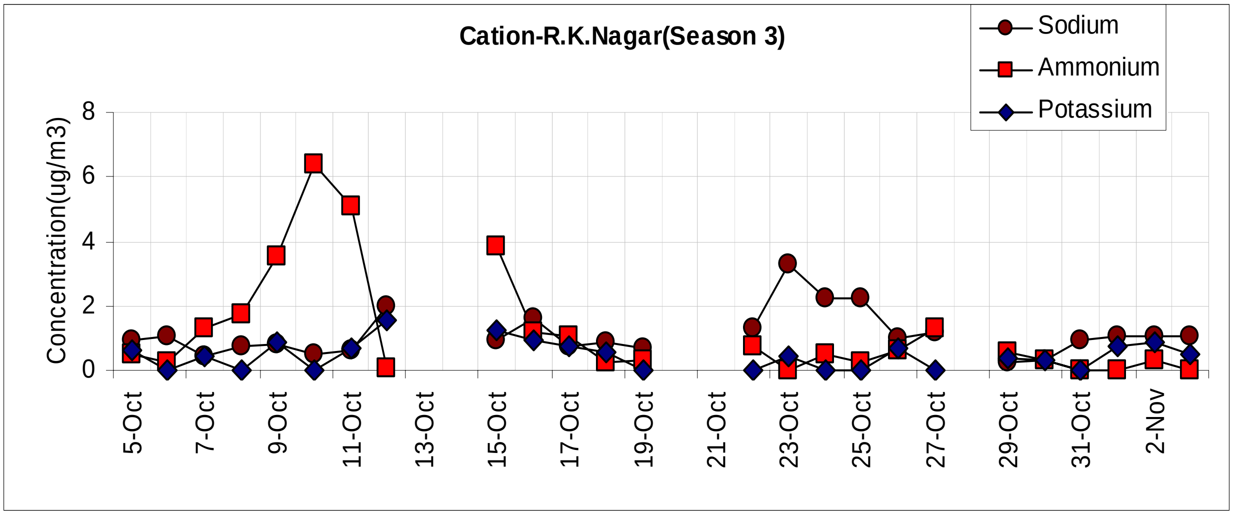


Figure 2.3.6.5--Cations in PM-10 at R.K.Nagar

Figure 2.3.6.6 shows the diurnal variation of CO concentrations at the monitoring station. The mean levels are shown to vary between 3800 and 5300 µg/m³. At this site CO concentration is well below the NAAQS 1-hr average standard (4000 µg/m³).

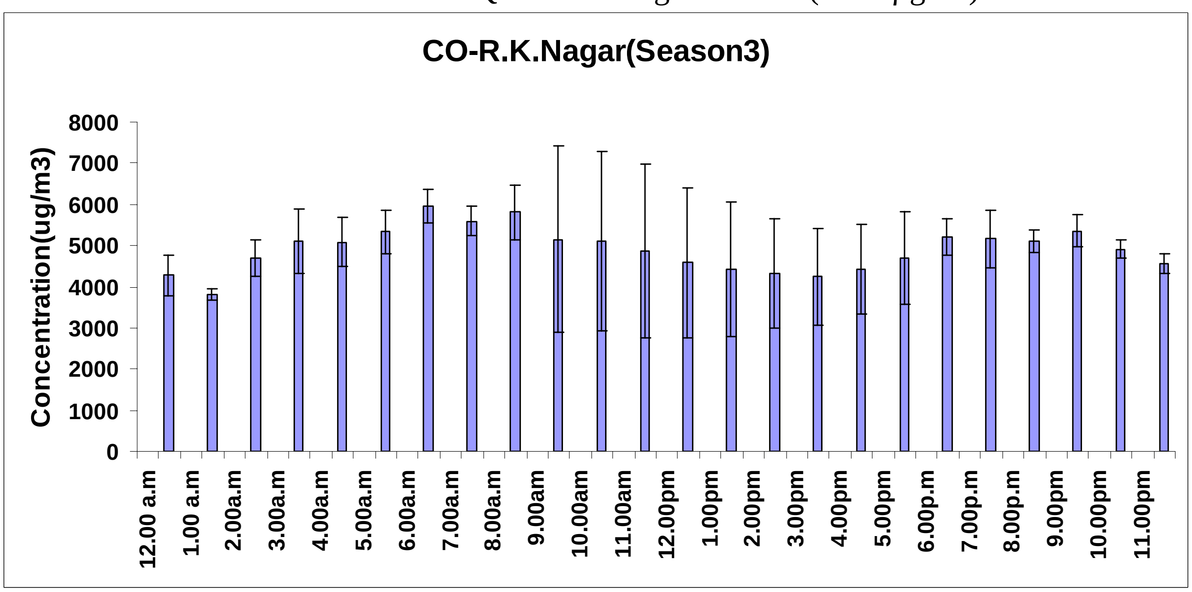


Figure 2.3.6.6-- CO – diurnal variation for R.K.Nagar.

Figure 2.3.6.7 shows the distribution of the various speciation associated with the PM_{10}. The fraction, which is shown as unknown in figure includes Si and other species such as the H,O and N fraction of organic matter, oxygen in the elemental oxides and other constituents not analyzed in the sample. Of the measured components OC (28%) was the highest fraction followed by EC (10.21%) and sulphate (8.43%).

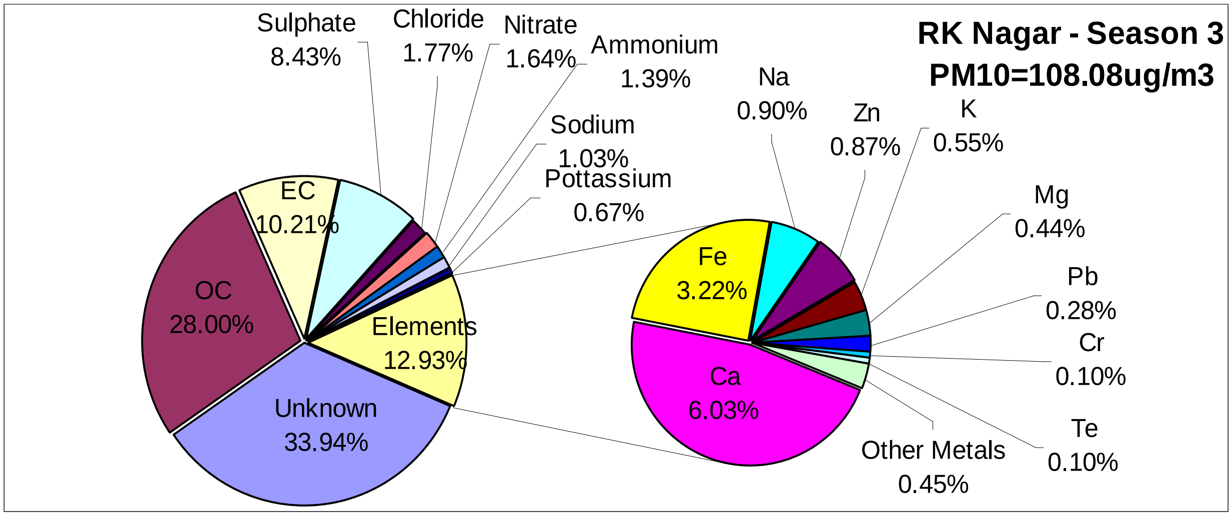


Figure 2.3.6.7-- Distribution of species on PM_{10} at R.K.Nagar

2.4.3.7. Ambattur

Figures 2.3.7.1 shows the 24-hr average values for TSPM, RSPM, PM_{10}, $PM_{2.5}$ and the $PM_{2.5}/PM_{10}$ ratio. The RSPM values were higher than NAAQS (150µg/m³ for Industrial area) for most of the days. Particularly on 25th, 31st Dec and 10th Jan RSPM values were 367.77, 316.25and 391.9µg/m³ respectively. The TSPM values were also higher than the NAAQS (500µg/m³ for Industrial area) for 3 days. Particularly on 25th, 29th and 31st Dec TSPM values were 667.7, 589.08 and 571.55µg/m³ respectively. The PM_{10} values were slightly higher than the NAAQS for 11 days. Particularly on 25th, 28th and 29th Dec PM_{10} values were 364.55, 297.3and 289.44µg/m³ respectively. The $PM_{2.5}$ values were found to vary between 47.95and 86.97µg/m³. The $PM_{2.5}/PM_{10}$ ratio was found to vary between 0.34 and 0.72. On 18th, 19th Dec and 15th Jan sampling was not done.

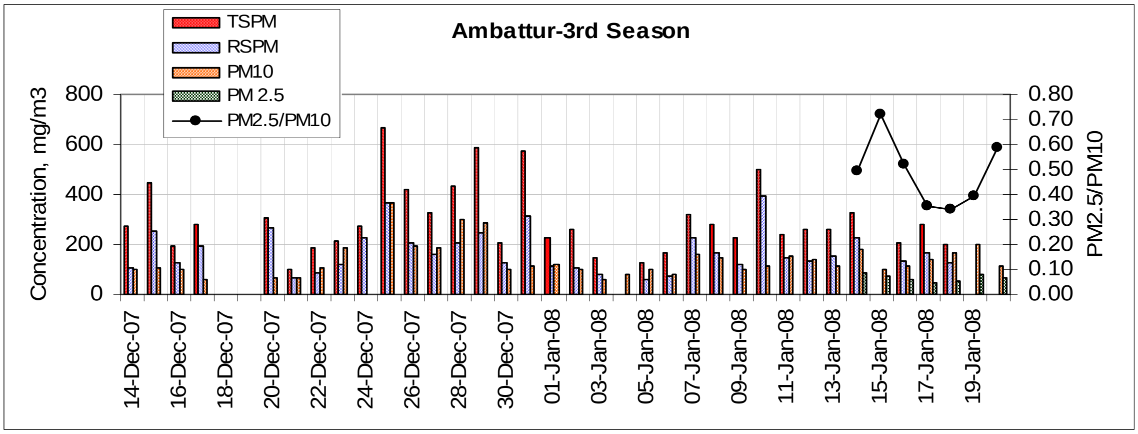


Figure 2.3.7.1-- Particulate Matter at Ambattur

Figure 2.3.7.2 shows the variation of OC, EC and the EC/OC ratio associated with PM_{10} and $PM_{2.5}$. The EC/OC ratio for PM_{10} varies between 0.09 and 0.43 with a mean value of 0.26. The EC/OC ratio for $PM_{2.5}$ varies between 0.26 and 0.4 with a mean value of 0.34.

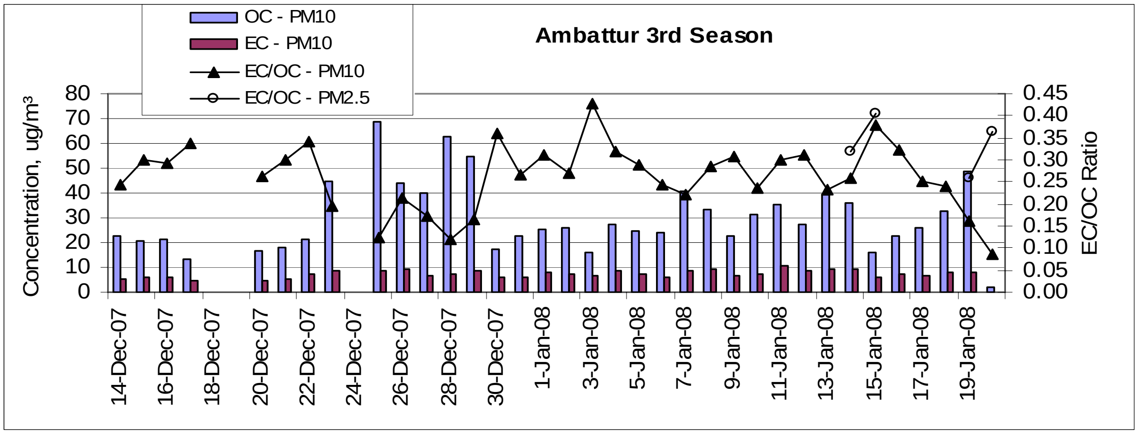


Figure 2.3.7.2-- Measurements of OC/EC for Ambattur

Figure 2.3.7.3 shows the NOx and SO_2 distribution at Ambattur site. NOx values were found to vary between 24.64and 69.1µg/m³ with the mean value of 45.35µg/m³. SO_2 values range from 2.02 to 13.75µg/m³ with the mean value of 6.08µg/m³. At this site both the NOx and SO_2 concentrations were well below the NAAQS limit of 120 µg/m³ (industrial area).

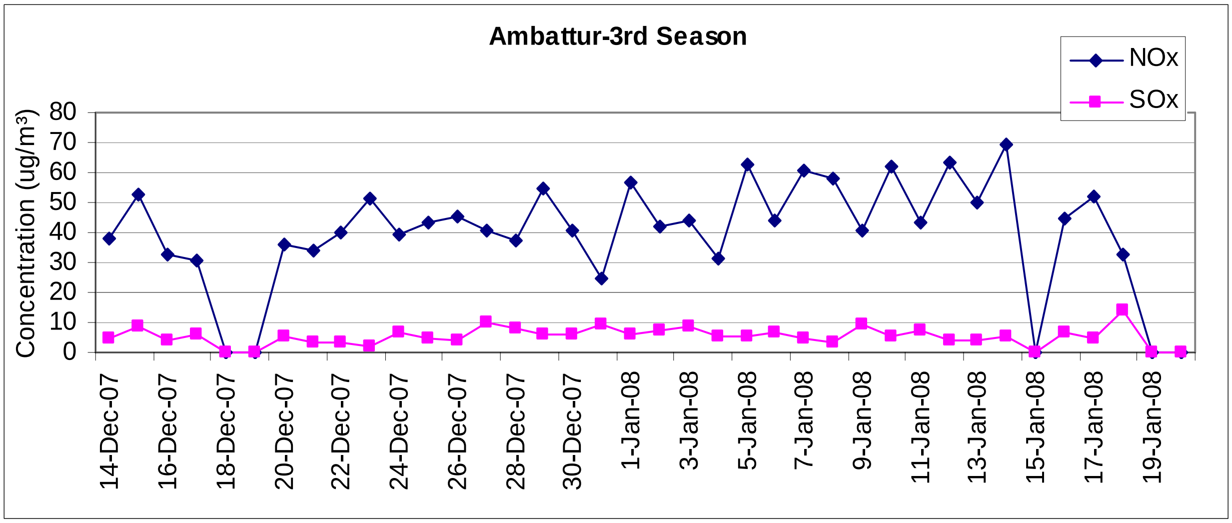


Figure 2.3.7.3-- Time series measurements for SO_2 and NOx

Figure 2.3.7.4 shows the levels of anions associated with PM_{10}. The concentration of Sulphate (13.09±5.11µg/m³) was higher than those of nitrate (5.02±2.96 µg/m³) and chloride (2.83±1.05 µg/m³). For the $PM_{2.5}$ fraction, the Sulphate concentration found was 8.69µg/m³ and the corresponding ratio of Sulphate in the $PM_{2.5}/PM_{10}$ fractions was 0.82 indicating that majority of the Sulphate in this site were associated with the $PM_{2.5}$ phase. Similar ratios for chloride and nitrate were found to be 0.39 and 0.26 respectively.

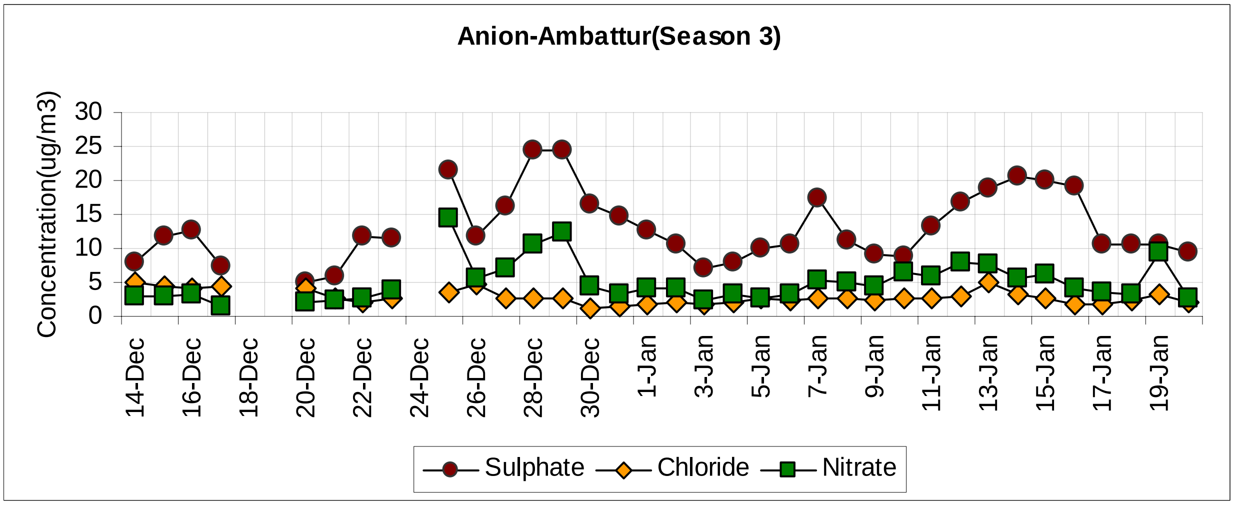


Figure 2.3.7.4-- Time series of anions on PM10

Figure 2.3.7.5 shows the levels of Cations associated with PM_{10}. The concentrations of ammonium (3.31±1.68 µg/m³) and sodium (1.5±0.68µg/m³) ions were higher than that of potassium ion (1.43±0.33 µg/m³). The ratio of the ion concentrations on $PM_{2.5}$ to that in PM_{10} were 2.05, 0.45 and 0.86 for ammonium, sodium and potassium respectively.

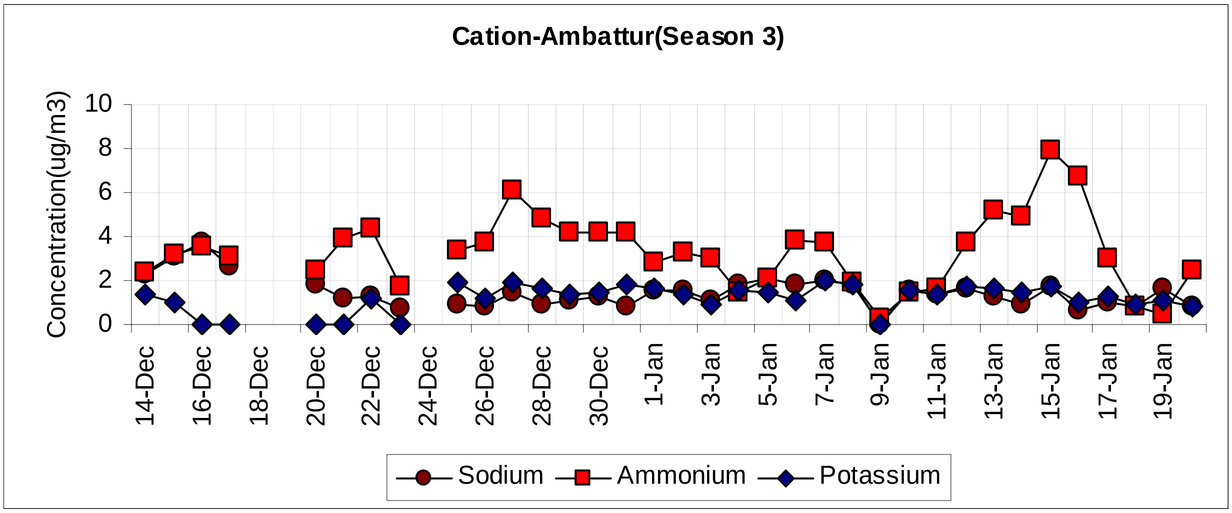


Figure 2.3.7.5--Cations in PM-10 at Ambattur

Figure 2.3.7.6 shows the diurnal variation of CO concentrations at the monitoring station. The mean levels are shown to vary between 1100 and 1900 µg/m³. At this site CO concentration is below the NAAQS 1-hr average standard (4000 µg/m³).

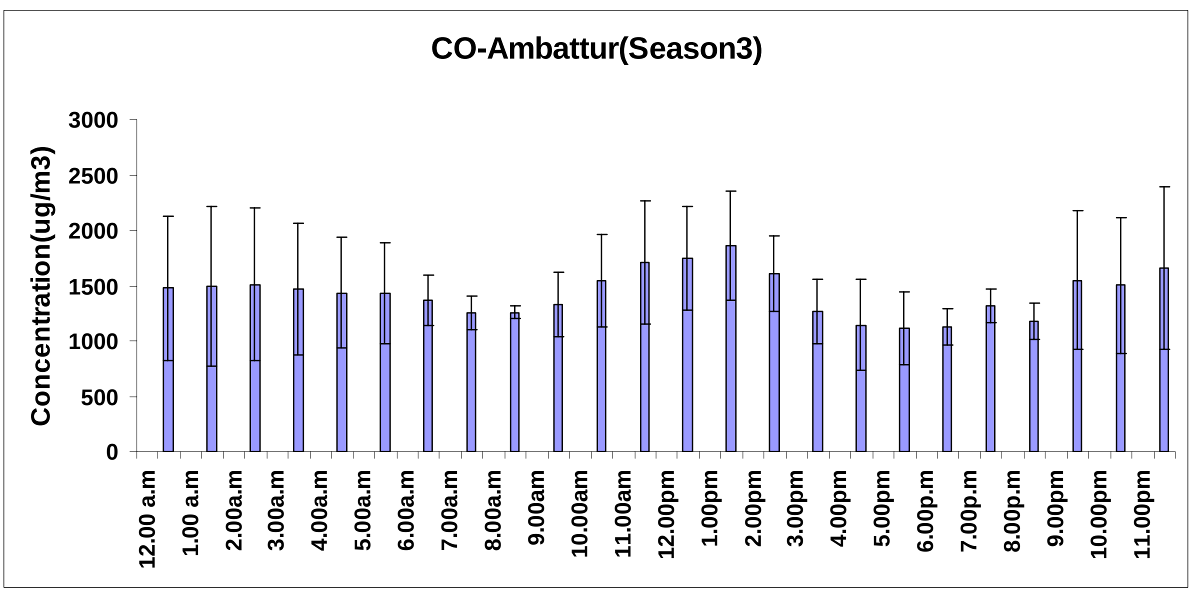


Figure 2.3.7.6-- CO – diurnal variation for Ambattur.

Figure 2.3.7.7 shows the distribution of the various speciation associated with the PM_{10}. The fraction, which is shown as unknown in figure includes Si and other species such as the H,O and N fraction of organic matter, oxygen in the elemental oxides and other constituents not analyzed in the sample. Of the measured components OC (21.69%) was the highest fraction followed by Sulphate (9.49%) and EC (5.22%).

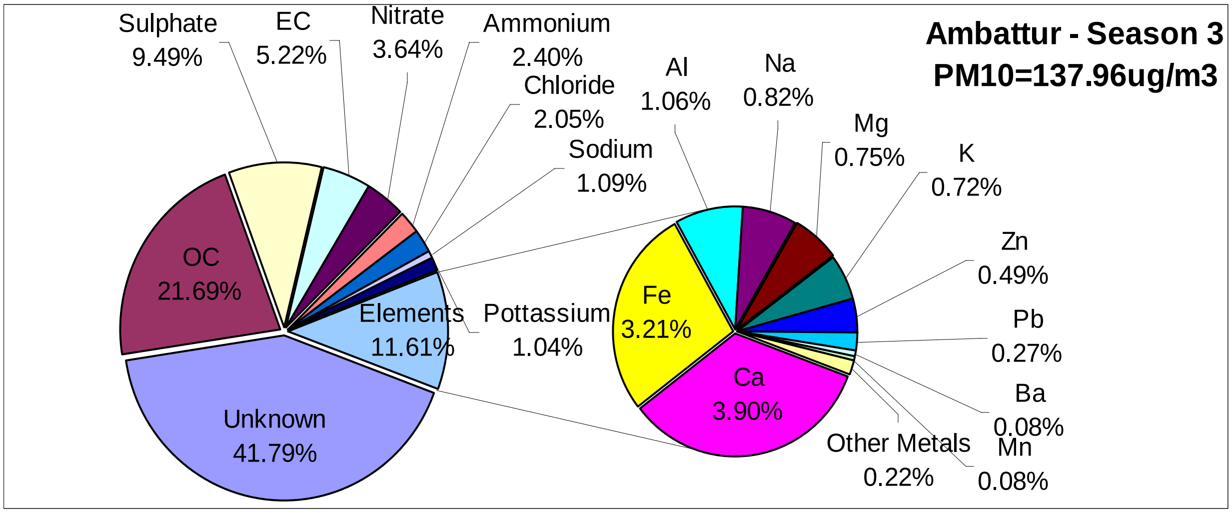


Figure 2.3.7.7-- Distribution of species on PM_{10} at Ambattur

2.4.4.1 Summary of 1st Season Results

Figure 2.4.1.1 shows that the average SPM and RSPM concentrations at background site were less than NAAQS of 100 and 75 µg/m³, respectively, specified for sensitive area. While at residential site the mean RSPM concentration was above the NAAQS (100 µg/m³) and mean SPM concentration was with in NAAQS (200 µg/m³). At industrial area the mean RSPM and SPM values were well below the NAAQS (150 and 500 µg/m³, respectively)

Figure 2.4.1.1 also shows that SO_2 values are uniformly low across all sites. This was the observation in the other seasons as well. The NO_x values are higher in Saidapet, RK Nagar and Ambattur in comparison to the residential and the background sites and may be attributed to the higher levels of combustion related activities (vehicles/industries) in that area.

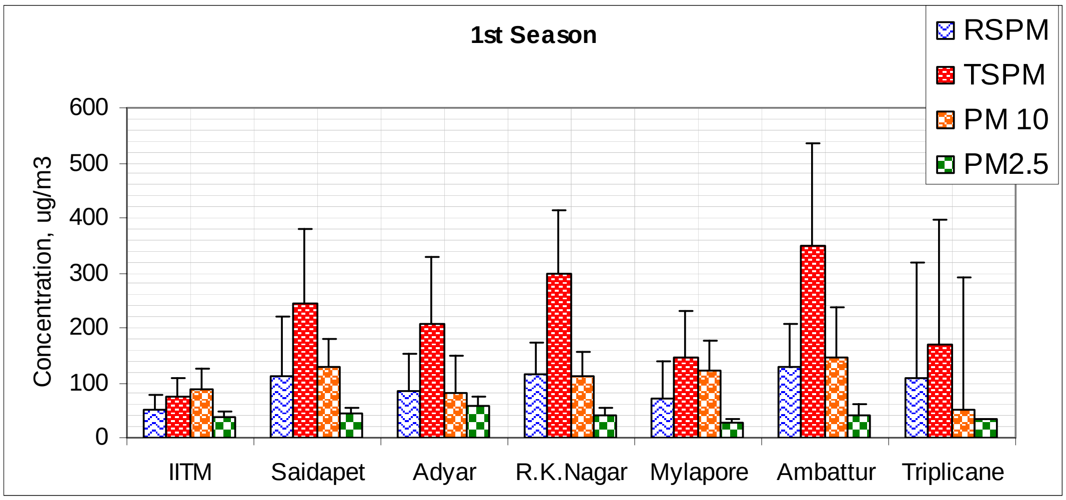


Figure 2.4.1.1-- Comparison of PM values at six sites.

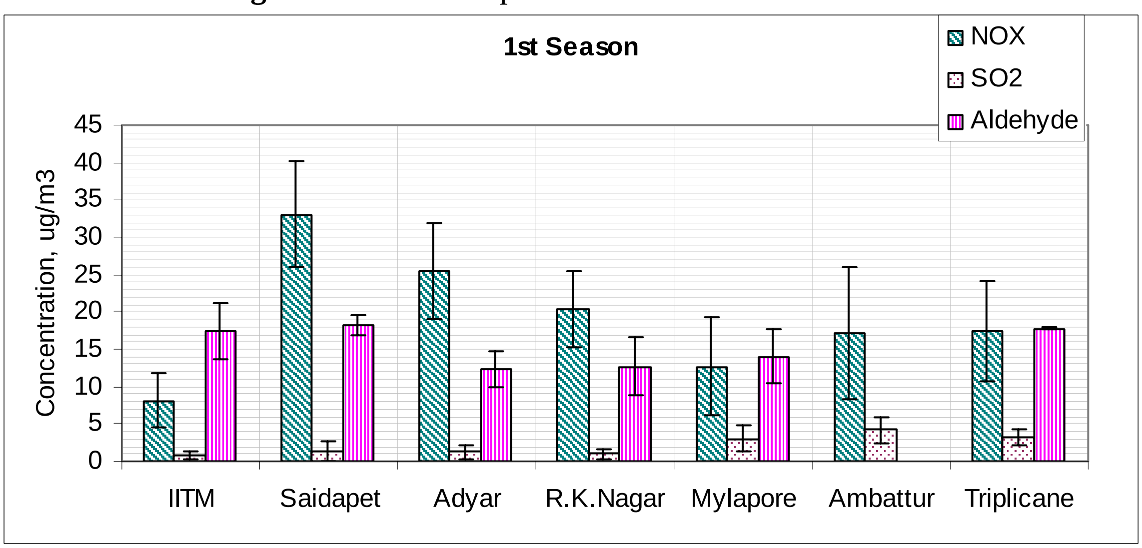


Figure 2.4.1.2--Comparison SO_2, NOx and aldehyde

Figure 2.4.1.3 shows the comparison of mean EC/OC ratio at different sites. There is no significant difference of OC/EC values at different sites. From the variation, it can be inferred that Adyar (Kerbside) and RK Nagar (industrial site) have a slightly higher EC proportion in the PM_{10} fraction

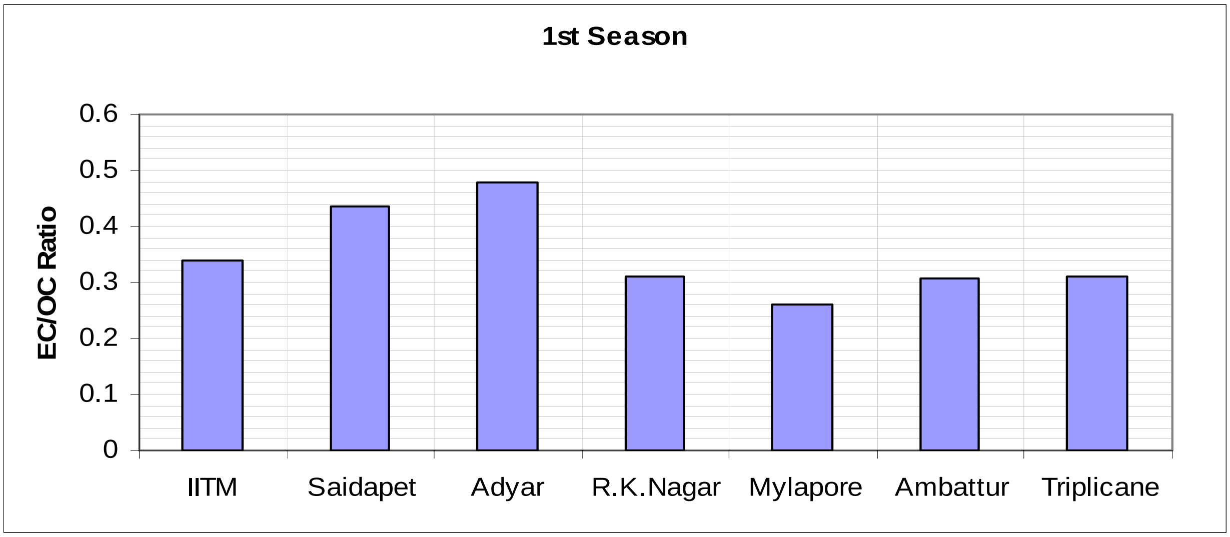


Figure 2.4.1.3--Comparison of EC/OC ratio

Figure 2.4.1.4 shows the Sulphate ion values are higher in RK Nagar, Ambattur and Adyar in comparison to the residential and the background sites. The higher sulphates corresponding to low SO_2 values might be due to conversion of gas phase SO_2 to condensed phase on the particulate matter.

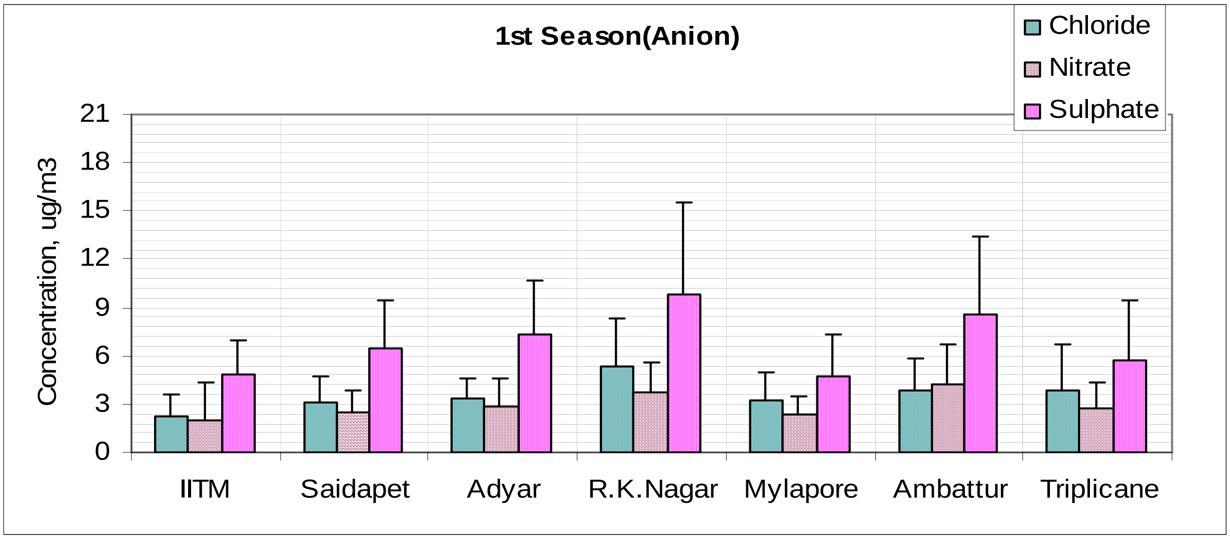


Figure 2.4.1.4-- Comparison of Anions

Figure 2.4.1.5 shows the Ammonium ion values are higher in RK Nagar in comparison to the residential and the background sites.

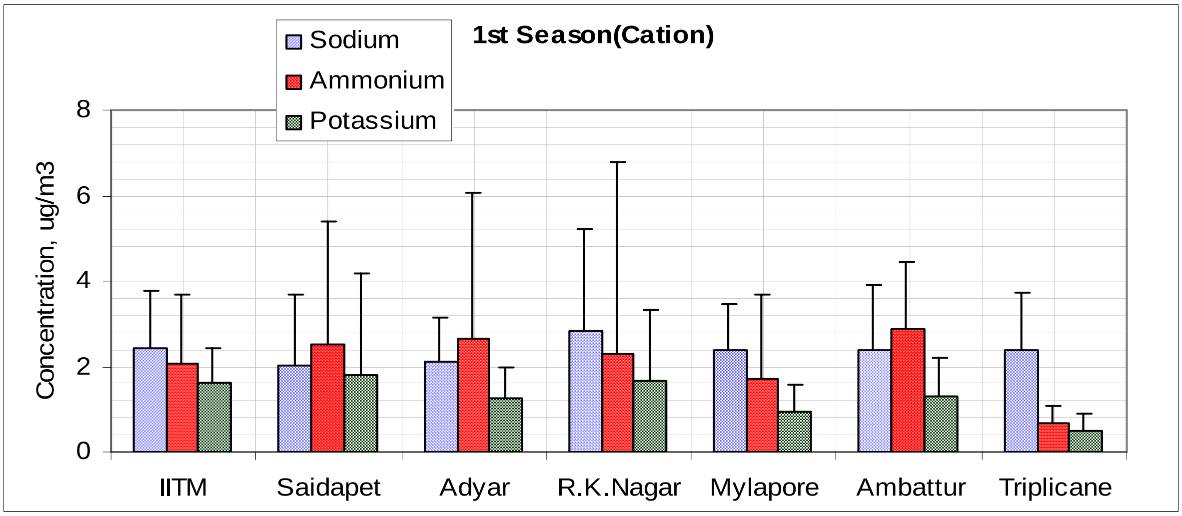


Figure 2.4.1.5-- Comparison of Cations

Figure 2.4.1.6 shows the breakup of the speciated fractions in the PM_{10}. The unknown fraction includes Si and other components of organic matter (such as O, N and H) that was not explicitly measured. The other major component in most of the samples is OC (organic carbon) followed by the elemental carbon faction (EC). Among the ions, sulphate dominates. The origin of sulphate aerosols might be direct (sea spray as salts) or indirect (conversion of atmospheric SO_2 in the presence of high humidity on particulate matter or as suspended water droplets). There is also a high fraction of elemental calcium in certain locations. This is due to elevated levels during a few days of sampling, perhaps due to increased construction activities during specific days. Table—2.4.1.1.(a) and (b) summarizes the season 1 air quality data.

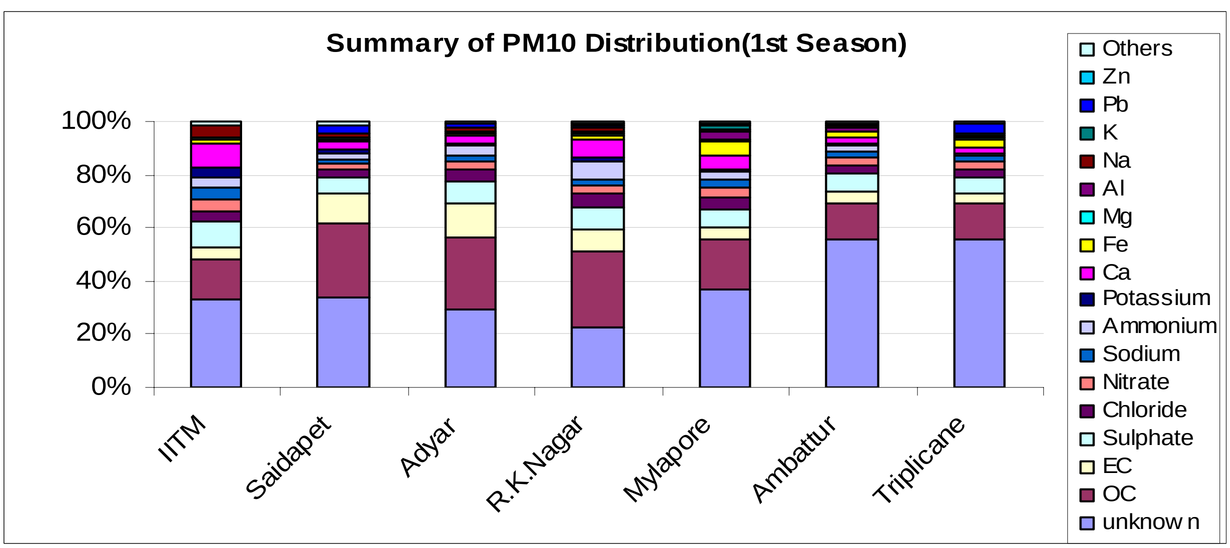


Figure 2.4.1.6 Summary of PM_{10} speciation

1st Season Summary Data

Table—2.4.4.1.a Summary of site wise average pollutant concentration for season 1

Site	SPM	RSPM	PM_{10}	$PM_{2.5}$	NO_X	SO_2	OC	EC	TC	EC/OC Ratio
IIT Madras (Background)	75.5	50.5	87.6	38.5	8.1	0.7	7.23	2.33	9.57	0.34
Mylapore (Residential)	146.9	70.2	121.9	28.1	12.7	3.0	12.98	3.37	16.34	0.26
Triplicane (Residential)	170.9	106.8	51.5	33.8	17.4	3.2	14.43	4.46	18.67	0.31
Adyar (Kerbside)	207.5	85.3	81.0	56.1	25.4	1.3	22.74	10.41	33.15	0.48
Saidapet (Kerbside)	242.5	111.1	127.6	44.1	33.0	1.3	31.00	13.03	44.08	0.44
R.K.Nagar (Industrial)	297.6	115.3	112.6	41.4	20.4	1.0	32.60	9.06	41.66	0.31
Ambattur (Industrial)	348.2	128.5	146.9	40.2	17.1	4.2	18.29	5.45	23.71	0.31

Table—2.4.4.1b—Ions value for all the sites

Site	Chloride (µg/m³)	Nitrate (µg/m³)	Sulphate (µg/m³)	Sodium (µg/m³)	Ammonium (µg/m³)	Potassium (µg/m³)
IIT Madras (Background)	2.27	1.93	4.88	2.44	2.05	1.62
Mylapore (Residential)	3.26	2.35	4.76	2.38	1.72	0.94
Triplicane (Residential)	3.82	2.74	5.76	2.38	0.67	0.48
Adyar (Kerbside)	3.39	2.83	7.39	2.10	2.64	1.25
Saidapet (Kerbside)	3.07	2.47	6.43	2.04	2.53	1.78
R.K.Nagar (Industrial)	5.38	3.67	9.82	2.85	2.28	1.68
Ambattur (Industrial)	3.88	4.20	8.59	2.38	2.89	1.29

2.4.4.2 – Summary of 2nd Season Results

Figure 2.4.2.1 shows that the average SPM and RSPM concentrations at background site were exceeding the NAAQS of 100 and 75 µg/m³, respectively, specified for sensitive area. While at residential sites the mean RSPM concentrations were above the NAAQS (100 µg/m³) and mean SPM concentration was with in NAAQS (200 µg/m³). However, at kerb sites SPM concentration was exceeding the NAAQS. At industrial area the mean RSPM and SPM values were well below the NAAQS (150 and 500 µg/m³, respectively)

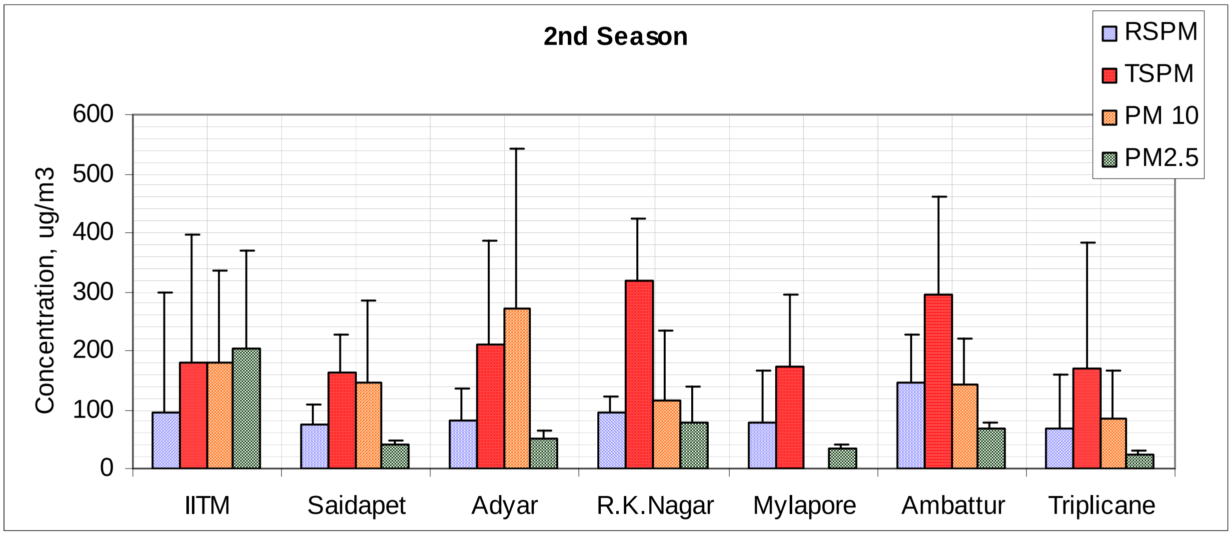


Figure 2.4.2.1-- Comparison of PM values at six sites.

Figure 2.4.2.2 shows that SO_2 values are uniformly low across all sites. This was the observation in the other seasons as well. The NO_x values are higher in Saidapet, RK Nagar and Ambattur in comparison to the residential and the background sites and may be attributed to the higher levels of combustion related activities (vehicles/industries) in that area.

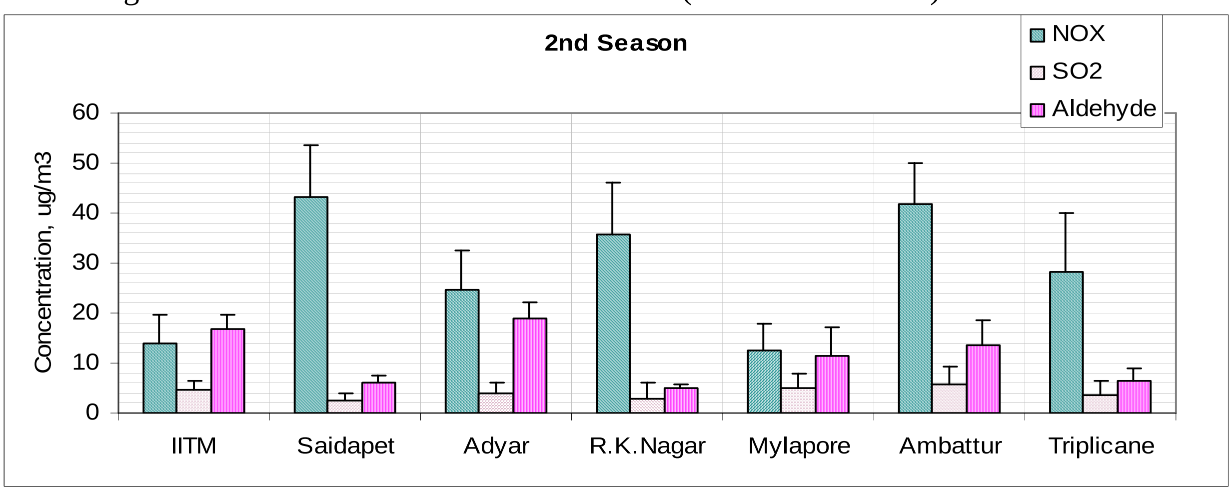


Figure 2.4.2.2--Comparison SO_2, NOx and Aldehyde

Figure 2.4.2.3 shows the comparison of mean EC/OC ratio at different sites. There is no significant difference between the values at different sites. From the variation, it can be inferred that Saidapet (Kerbside) and Ambattur (industrial site) have a slightly higher EC proportion in the PM_{10} fraction. A higher EC fraction is generally indicative of vehicular emissions.

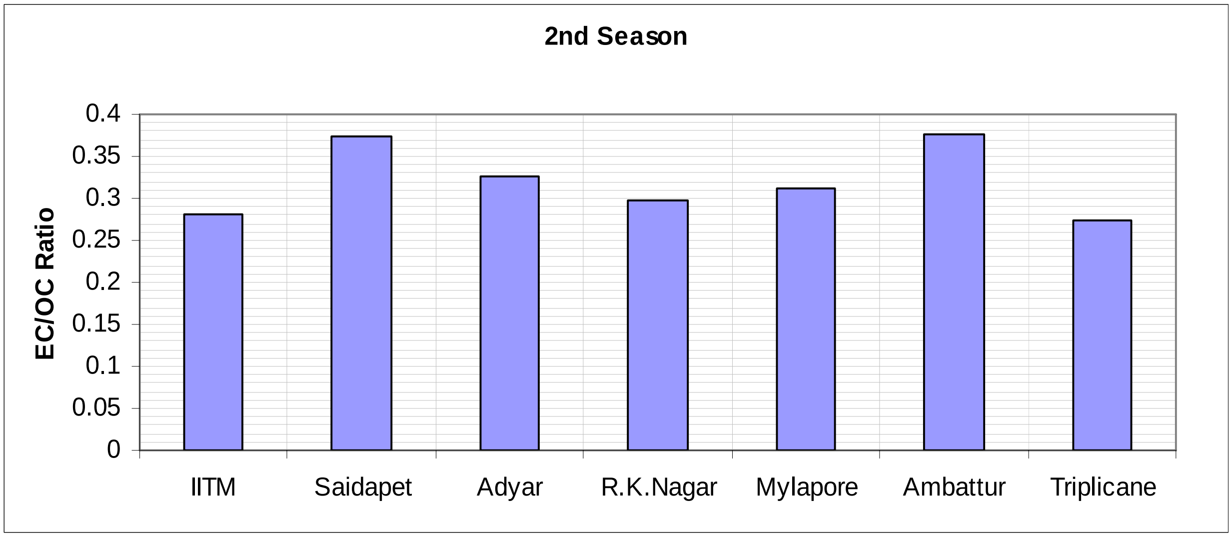


Figure 2.4.2.3--Comparison of EC/OC ratio

Figure 2.4.2.4 shows the Sulphate ion values are higher in RK Nagar and Ambattur site in comparison to the residential and the background sites.

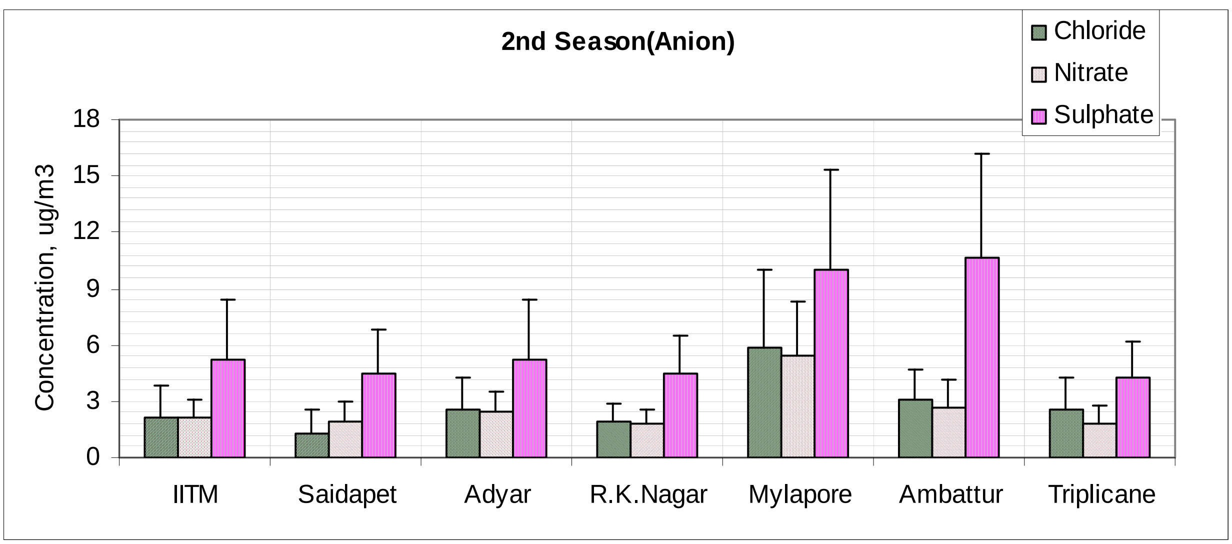


Figure 2.4.2.4-- Comparison of Anions

Figure 2.4.2.5 shows the sodium and ammonium values are high in Mylapore site (residential) in comparison to the Industrial and the background sites.

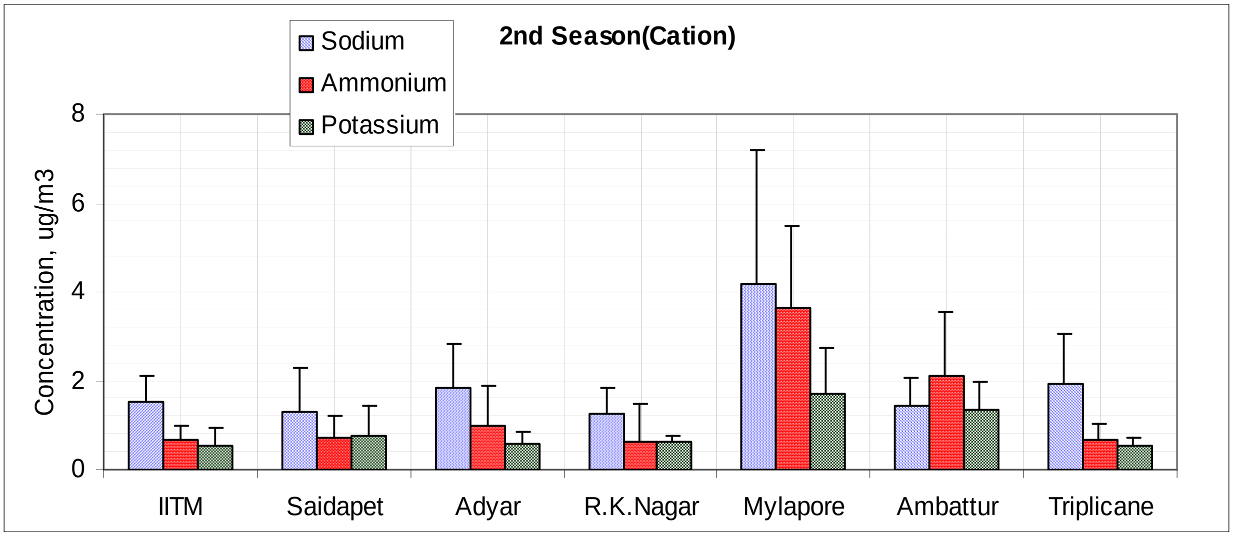


Figure 2.4.2.5-- Comparison of Cations

Figure 2.4.2.6 shows the breakup of the speciated fractions in the PM_{10}. The fraction labeled as unknown includes Si and other components of organic matter (such as O, N and H) that were not explicitly measured. The other major component in most of the samples is OC (organic carbon) followed by the elemental carbon faction (EC). Among the ions, sulphate dominates. The origin of sulphate aerosols might be direct (sea spray as salts) or indirect (conversion of atmospheric SO_2 in the presence of high humidity on particulate matter or as suspended water droplets). There is also a high fraction of elemental calcium in certain locations. This is due to elevated levels during a few days of sampling, perhaps due to increased construction activities during specific days. Table—2.4.2.2 (a) and (b) summarizes the season 2 air quality data.

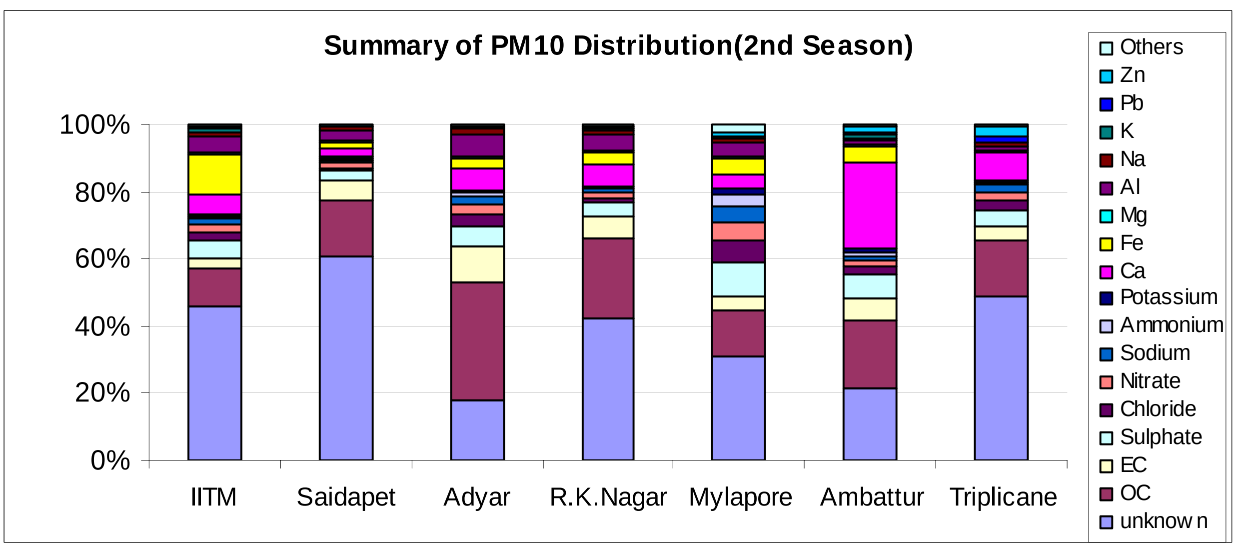


Figure 2.4.2.6 Summary of PM_{10} speciation

<u>**2nd Season Summary Data**</u>

Table—2.4.4.2 a Summary of site wise average pollutant concentration for season 2

Site	SPM	RSPM	PM_{10}	$PM_{2.5}$	NO_X	SO_2	OC	EC	TC	EC/OC Ratio
IIT Madras (Background**)**	178.17	93.95	179.30	202.75	13.84	4.61	10.57	2.88	13.45	0.28
Mylapore (Residential)	174.47	76.87	73.2	34.10	12.34	5.04	12.71	4.02	16.73	0.31
Triplicane (Residential)	168.28	69.42	85.96	22.52	28.06	3.42	14.23	3.85	18.08	0.27
Adyar (Kerbside)	211.12	81.27	270.79	50.91	24.73	3.80	28.76	8.54	37.11	0.33
Saidapet (Kerbside)	161.53	76.23	144.40	41.57	43.16	2.45	23.66	8.57	32.35	0.37
R.K.Nagar (Industrial)	319.00	94.58	116.69	79.10	35.75	2.93	27.43	8.00	35.43	0.30
Ambattur (Industrial)	295.31	146.74	140.83	66.77	41.83	5.87	28.60	8.94	37.50	0.38

Table—2.4.4.2 b Ions value for all the sites

Site	**Chloride (µg/m³)**	**Nitrate (µg/m³)**	**Sulphate (µg/m³)**	**Sodium** (µg/m³)	**Ammonium** (µg/m³)	**Potassium** (µg/m³)
IIT Madras (Background**)**	2.14	2.09	5.21	1.54	0.66	0.55
Mylapore (Residential)	5.83	5.41	9.98	4.19	3.63	1.69
Triplicane (Residential)	2.58	1.77	4.26	1.92	0.69	0.53
Adyar (Kerbside)	2.55	2.43	5.25	1.85	0.97	0.57
Saidapet (Kerbside)	1.25	1.92	4.50	1.29	0.72	0.77
R.K.Nagar (Industrial)	1.93	1.76	4.52	1.28	0.63	0.61
Ambattur (Industrial)	3.12	2.64	10.67	1.46	2.10	1.37

2.4.4.3. Summary of 3rd season results

Figure 2.4.2.1 shows that the average SPM concentrations at background site were exceeding the NAAQS of 100 µg/m³. While the average RSPM concentration were with in the NAAQS limit (75 µg/m³). At residential sites the mean RSPM concentrations were above the NAAQS (100 µg/m³) at Mylapore and mean SPM concentrations were with in NAAQS (200 µg/m³).

However, at kerb sites SPM concentration was exceeding the NAAQS. At industrial area the mean RSPM concentrations were exceeding at Ambattur (150 µg/m³,) and mean SPM values were well below the NAAQS (500 µg/m³)

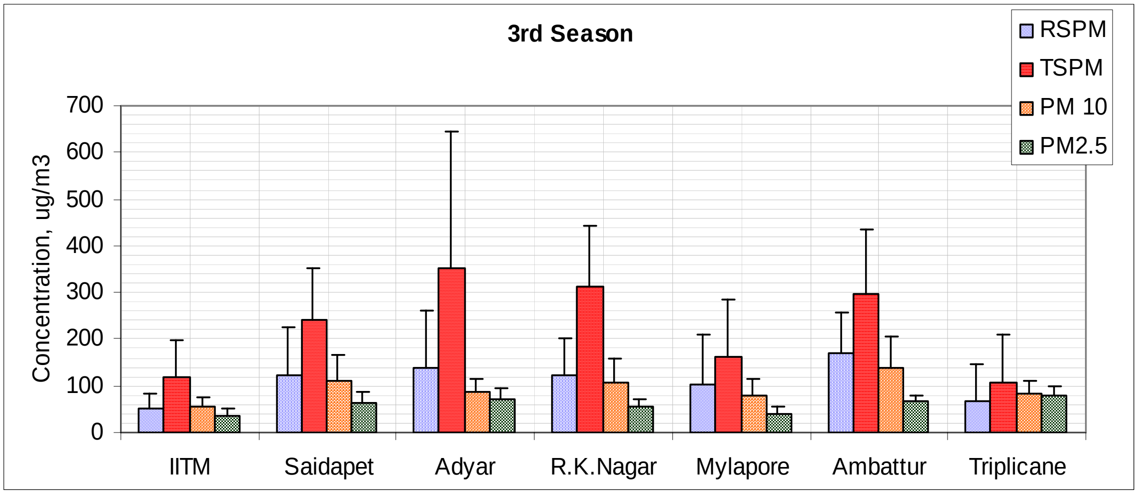


Figure 2.4.3.1-- Comparison of PM values at six sites.

Figure 2.4.3.2 shows that SO_2 values are uniformly low across all sites. This was the observation in the other seasons as well. The NO_x values are higher in Saidapet, Adyar and Ambattur in comparison to the residential and the background sites and may be attributed to the higher levels of combustion related activities (vehicles/industries) in that area.

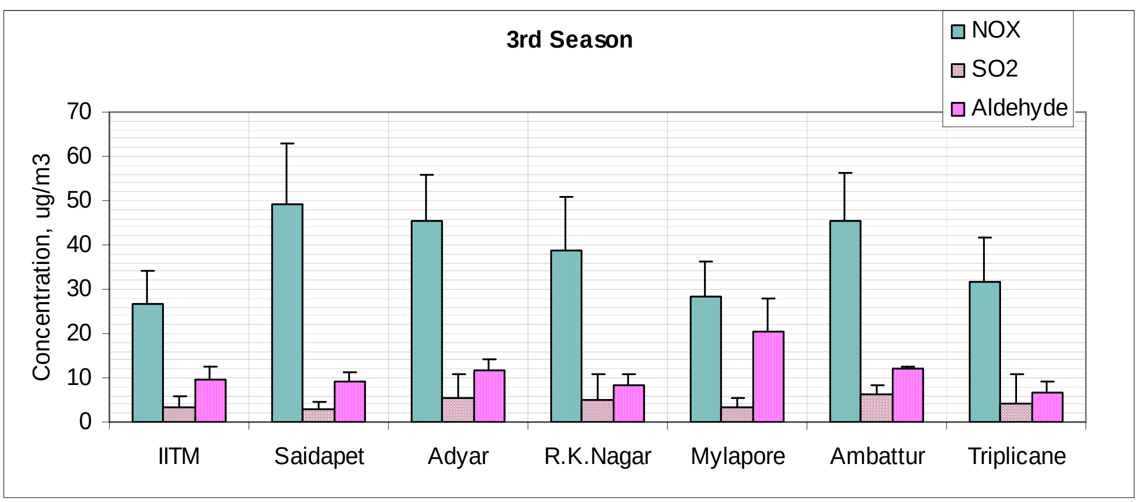


Figure 2.4.3.2--Comparison SO_2, NOx and Aldehyde

Figure 2.4.3.3 shows the comparison of mean EC/OC ratio at different sites. There is no significant difference between the values at different sites. From the variation, it can be inferred that Saidapet (Kerbside), Triplicane (Residential Site) and R.K.Nagar (Industrial Site) have a slightly higher EC proportion in the PM_{10} fraction. A higher EC fraction is generally indicative of vehicular emissions.

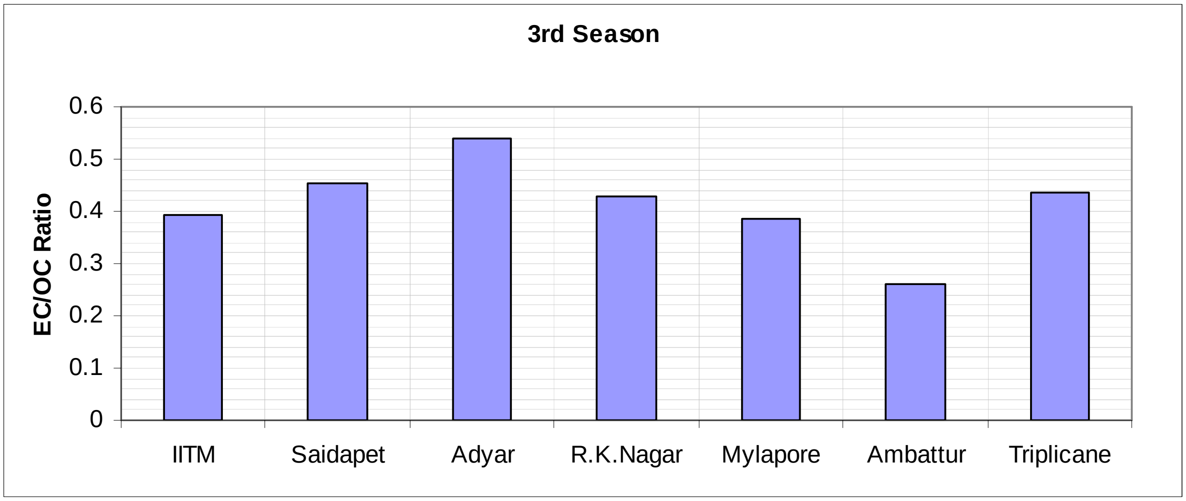


Figure 2.4.3.3--Comparison of EC/OC ratio

Figure 2.4.3.4 shows the Sulphate values are high in all the sites compare to the other anions.

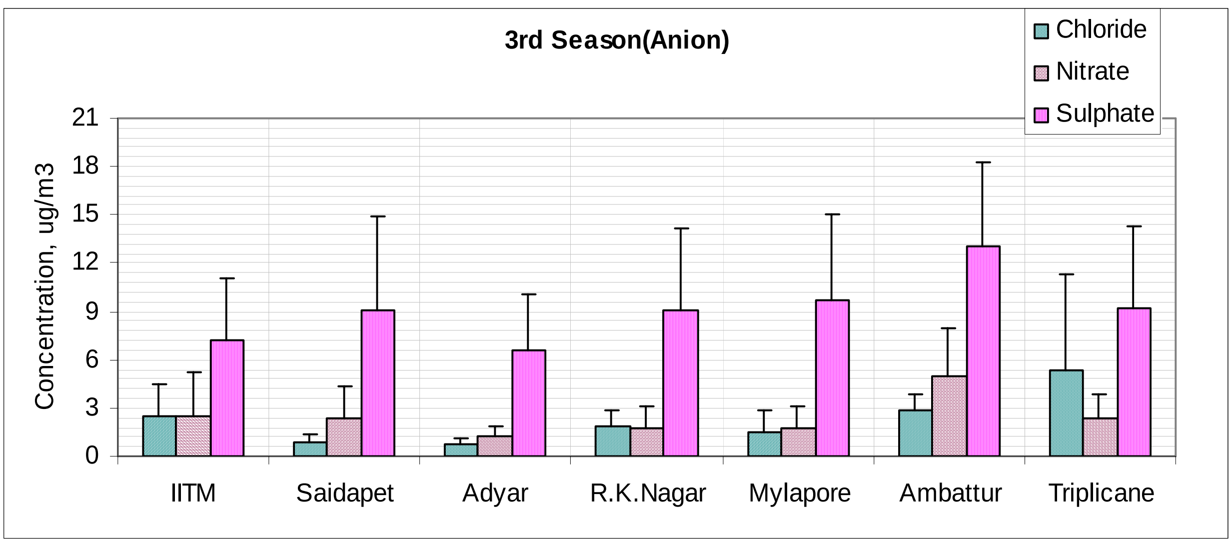


Figure 2.4.3.4-- Comparison of Anions

Figure 2.4.3.5 shows all the Cation values are high in Triplicane (Residential Site) compare to the Industrial and the background sites.

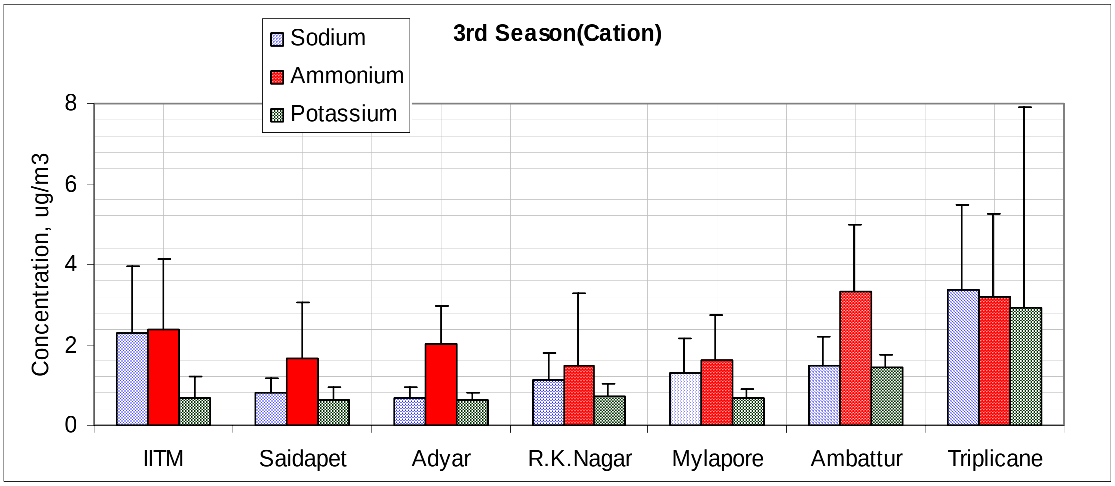


Figure 2.4.3.5-- Comparison of Cations

Figure 2.4.3.6 shows the breakup of the speciated fractions in the PM_{10}. The fraction labeled as unknown includes Si and other components of organic matter (such as O, N and H) that were not explicitly measured. The other major component in most of the samples is OC (organic carbon) followed by the elemental carbon faction (EC). Among the ions, sulphate dominates. The origin of sulphate aerosols might be direct (sea spray as salts) or indirect (conversion of atmospheric SO_2 in the presence of high humidity on particulate matter or as suspended water droplets). There is also a high fraction of elemental calcium in certain locations. This is due to elevated levels during a few days of sampling, perhaps due to increased construction activities during specific days. Table—2.4.4.3.(a) and (b) summarizes the season 1 air quality data.

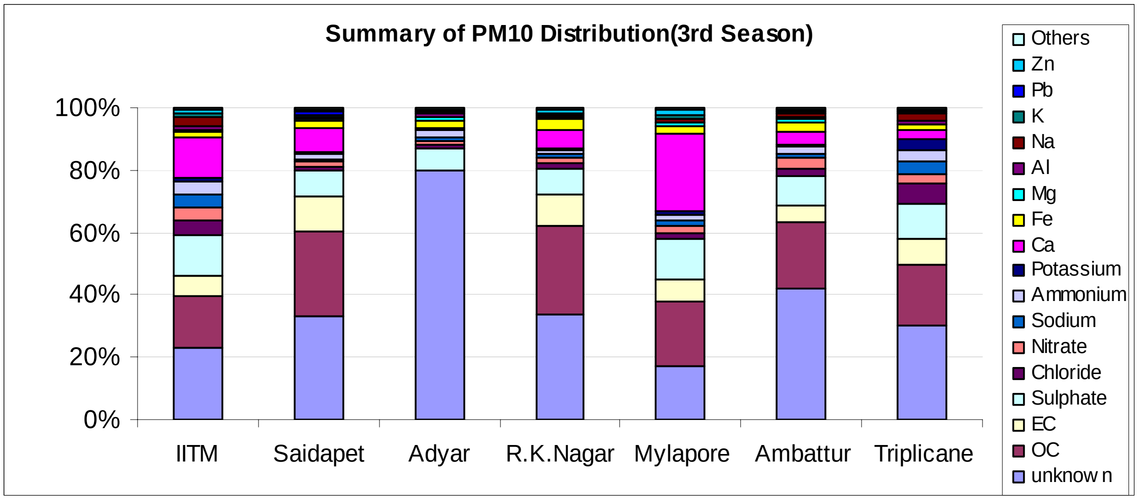


Figure 2.4.3.6 Summary of PM_{10} speciation

3rd Season Summary Data

Table—2.4.4.3.a Summary of site wise average pollutant concentration for season 3

Site	SPM	RSPM	PM_{10}	$PM_{2.5}$	NO_X	SO_2	OC	EC	TC	EC/OC Ratio
IIT Madras **(**Background**)**	117.06	52.22	55.73	35.01	26.87	3.16	9.36	3.70	13.06	0.39
Mylapore (Residential)	163.82	103.66	77.29	38.62	28.35	3.26	16.16	5.70	21.86	0.39
Triplicane (Residential)	106.10	66.52	81.96	77.70	31.58	4.19	16.00	6.65	22.65	0.43
Adyar (Kerbside)	350.15	137.08	87.17	72.98	45.33	5.60	25.83	12.41	38.24	0.54
Saidapet (Kerbside)	240.98	124.48	111.10	64.39	49.00	2.86	30.37	12.58	42.96	0.45
R.K.Nagar (Industrial)	310.79	121.79	108.08	56.80	38.64	4.88	30.26	11.04	41.30	0.43
Ambattur (Industrial)	297.27	171.82	137.96	67.37	45.35	6.08	29.92	7.20	37.12	0.26

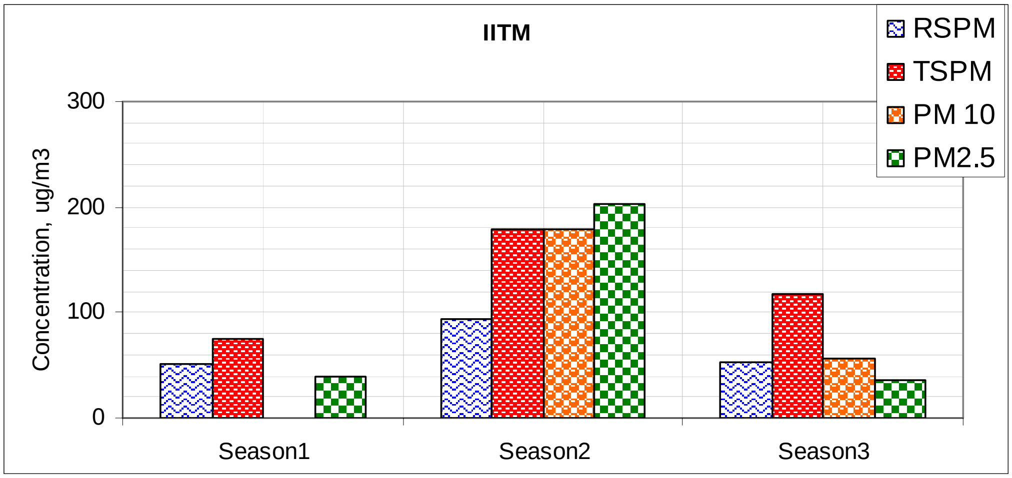
Table-- 2.4.4.3.b Ions value for the entire site

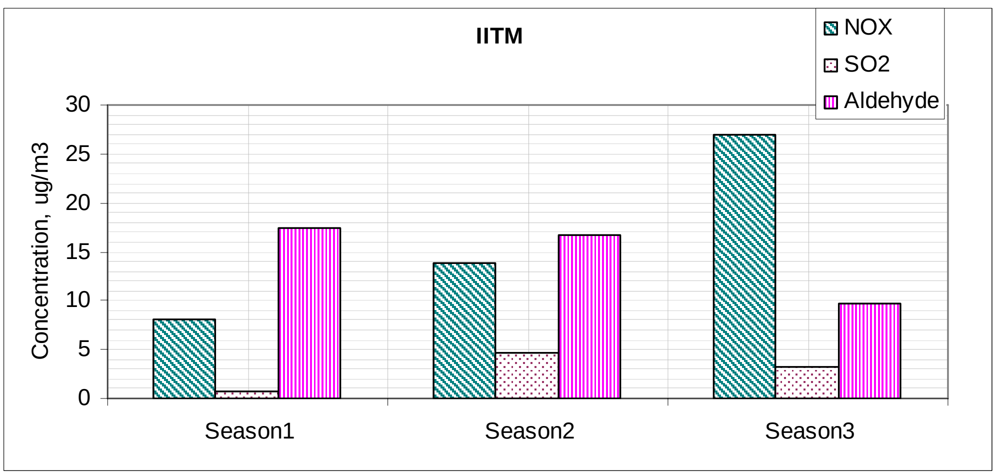
Site	**Chloride ($\mu g/m^3$)**	**Nitrate ($\mu g/m^3$)**	**Sulphate ($\mu g/m^3$)**	**Sodium** ($\mu g/m^3$)	**Ammonium** ($\mu g/m^3$)	**Potassium** ($\mu g/m^3$)
IIT Madras **(**Background**)**	2.44	2.46	7.25	2.29	2.38	0.69
Mylapore (Residential)	1.55	1.78	9.71	1.32	1.61	0.67
Triplicane (Residential)	5.33	2.40	9.25	3.37	3.17	2.90
Adyar (Kerbside)	0.76	1.28	6.63	0.66	2.03	0.63
Saidapet (Kerbside)	0.93	2.40	9.02	0.80	1.68	0.62
R.K.Nagar (Industrial)	1.91	1.78	9.11	1.11	1.50	0.72
Ambattur (Industrial)	2.83	5.02	13.09	1.50	3.31	1.43

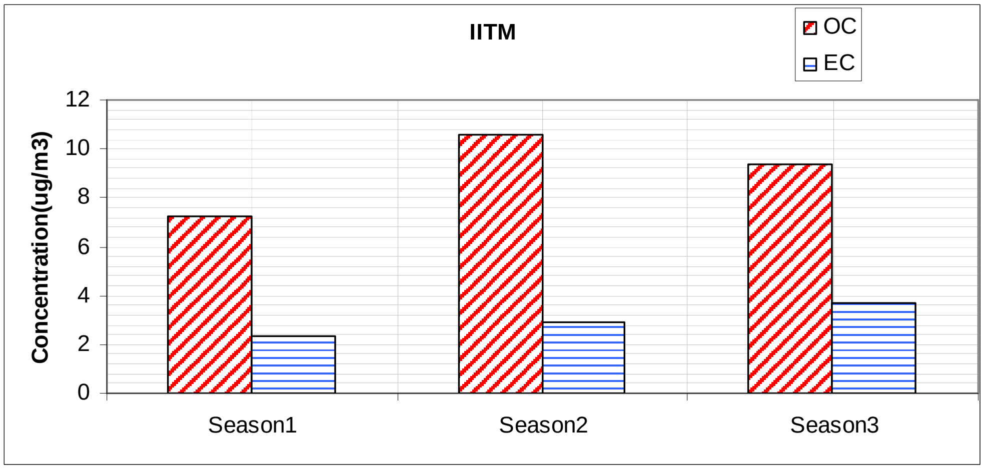
Site-wise Seasonal Comparison of Data Summary

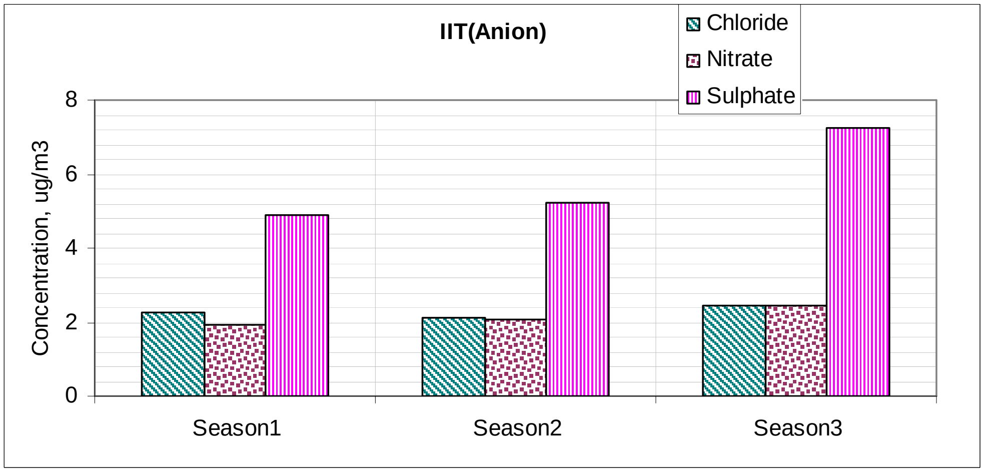
a) IITM :

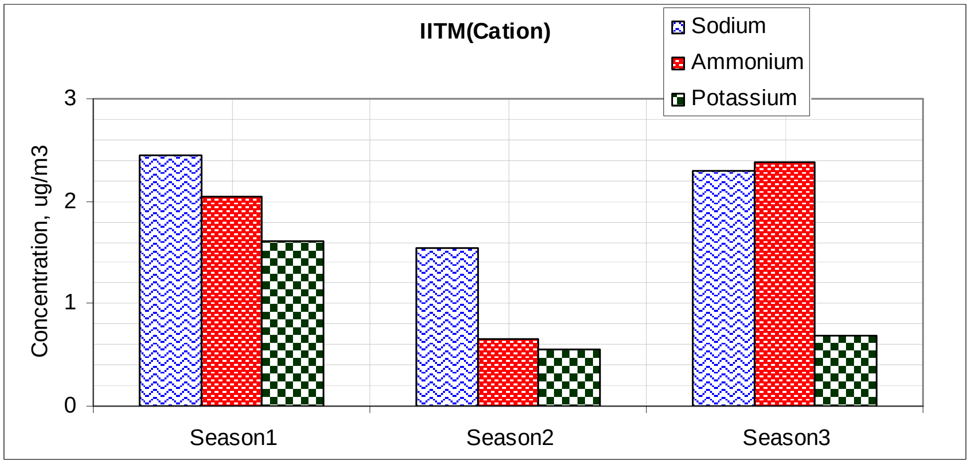
For the IITM site, the PM concentrations are higher in season 2 (which is warmer). The PM values for season 1 and 3, which are in relatively cooler temperatures, are lower. NO_x, SO_X and aldehydes are marginally higher is season 3 (which is the coldest part of the year). Rest of the parameters do not show any significant trend.

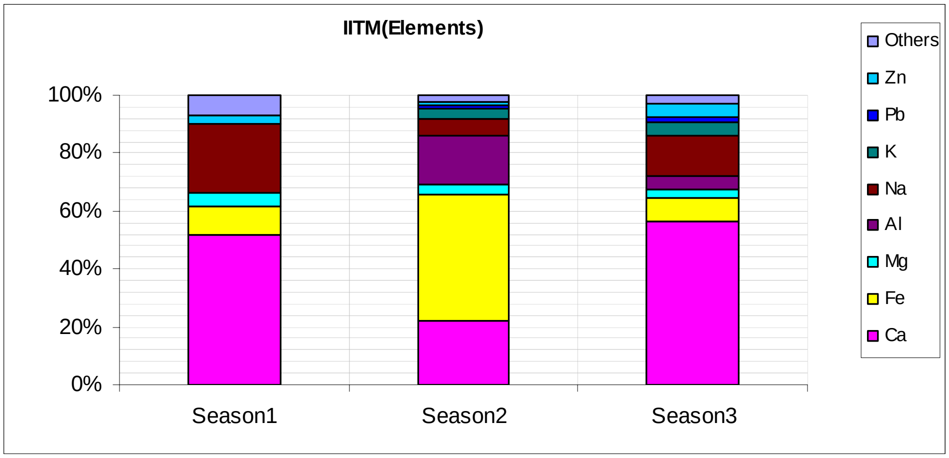





IITM
OC
EC
Concentration(ug/m3)
0
2
4
6
8
10
12
Season1
Season2
Season3

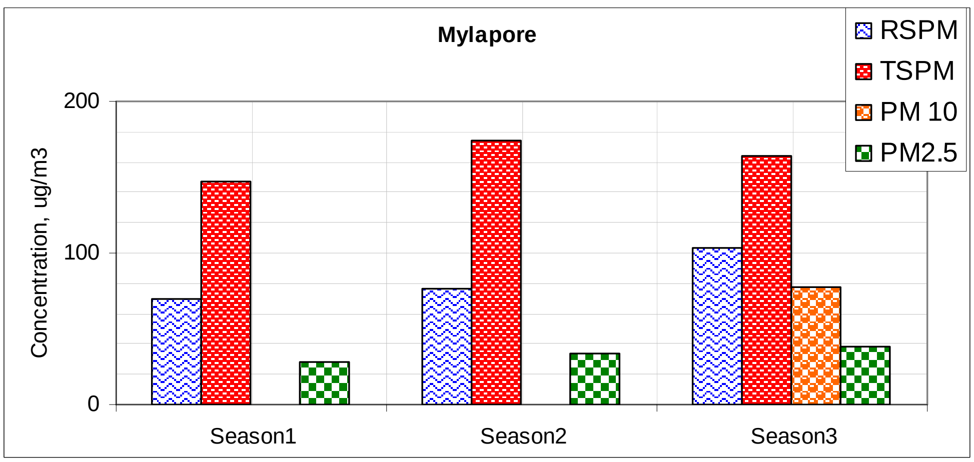

IIT(Anion)
Chloride
Nitrate
Sulphate
Concentration, ug/m3
0
2
4
6
8
Season1
Season2
Season3

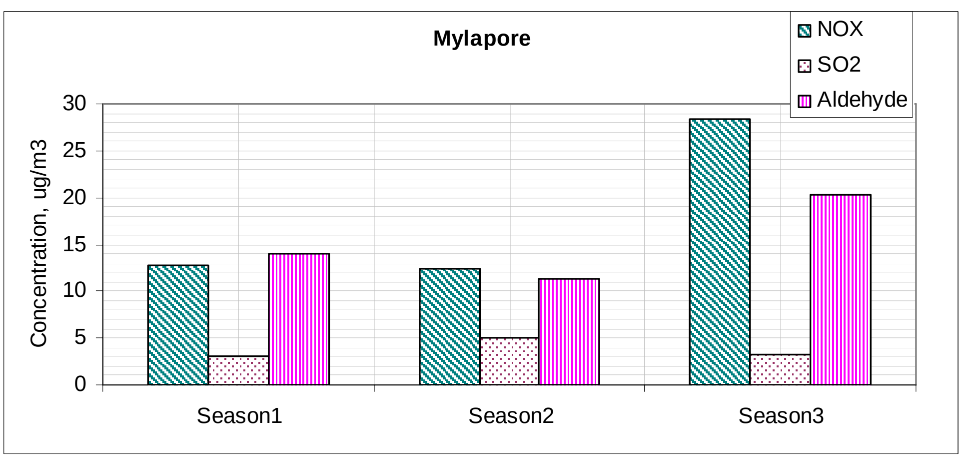

IITM(Cation)
Sodium
Ammonium
Potassium
Concentration, ug/m3
0
1
2
3
Season1
Season2
Season3

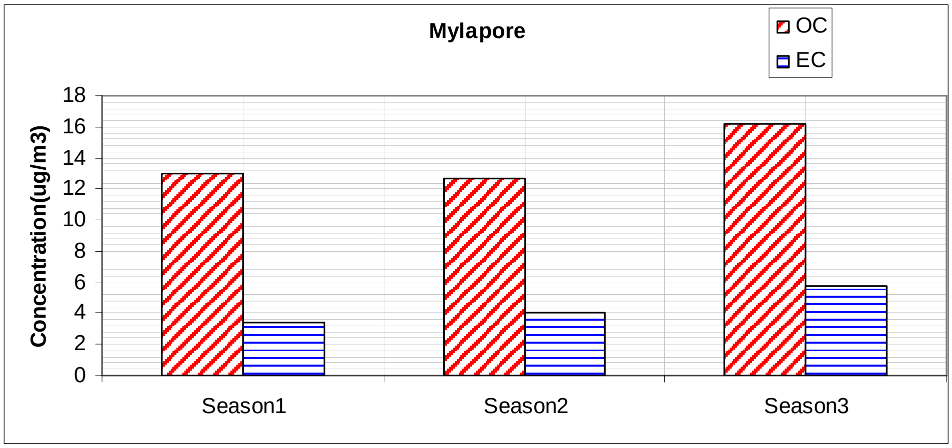


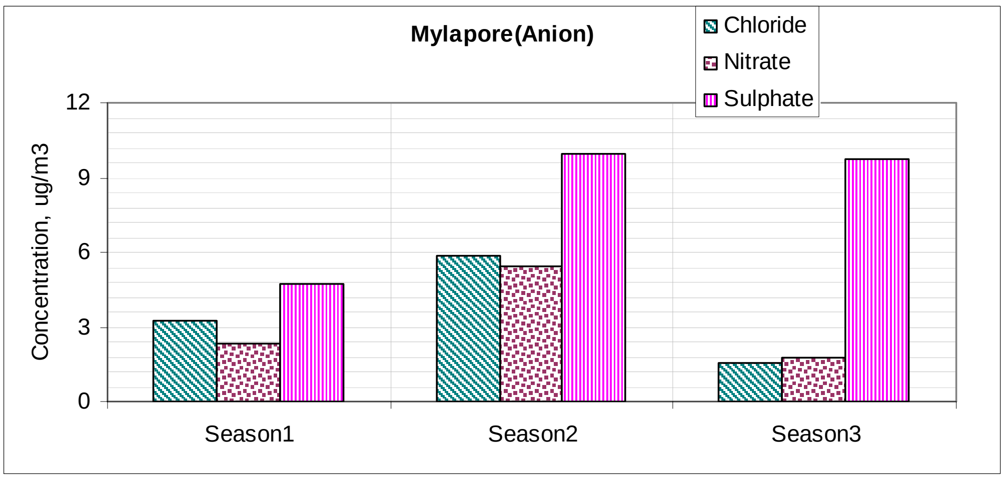
b: Mylapore

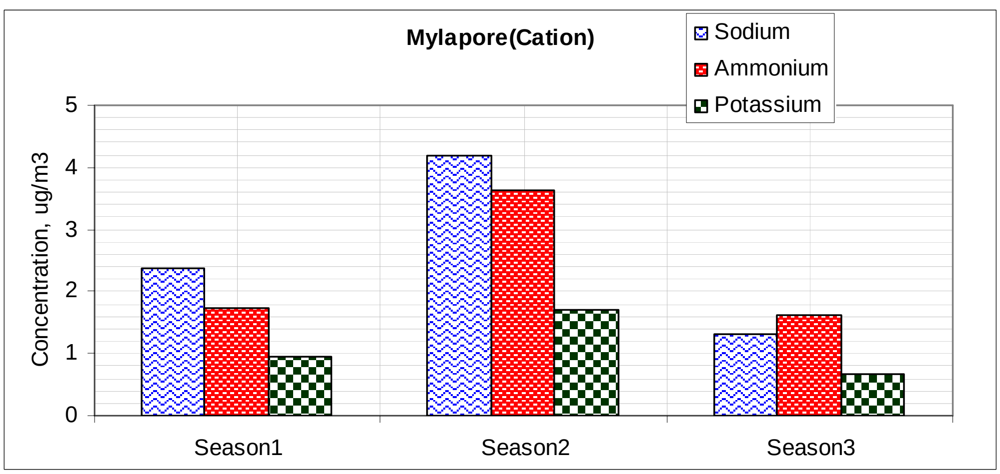
Season 1 (Apr-May) and 2 (May – June) are warmer at this site as compared season 3 (Nov-Dec). No significant differences in PM trends are observed. NO_x, SO_X, aldehydes, OC and EC are marginally higher in the season 3 (colder season). The concentration of sulphates is high both in season 2 and 3, while other ions are generally higher in season 2.

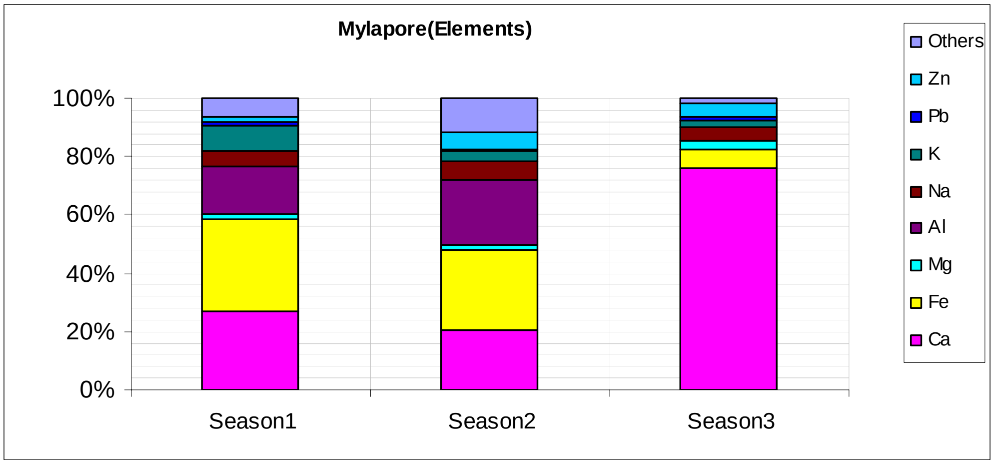





Mylapore
OC
EC
Concentration(ug/m3)
18
16
14
12
10
8
6
4
2
0
Season1
Season2
Season3

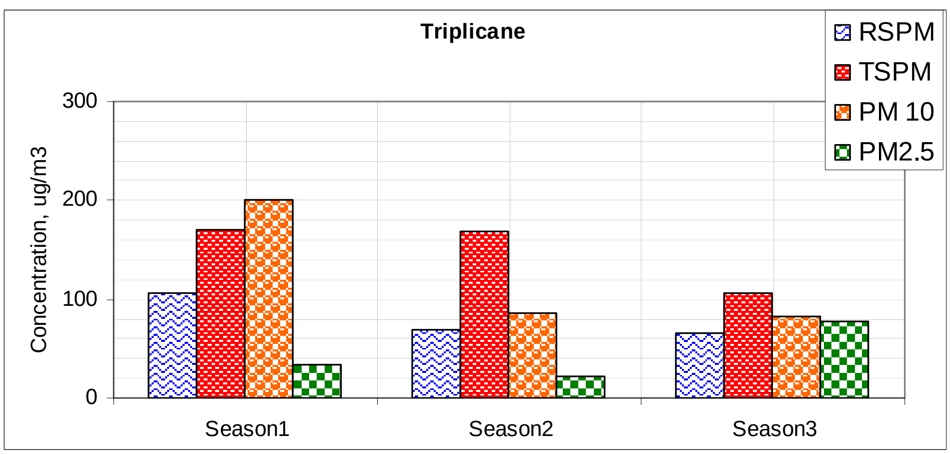

Mylapore(Anion)
Chloride
Nitrate
Sulphate
Concentration, ug/m3
12
9
6
3
0
Season1
Season2
Season3

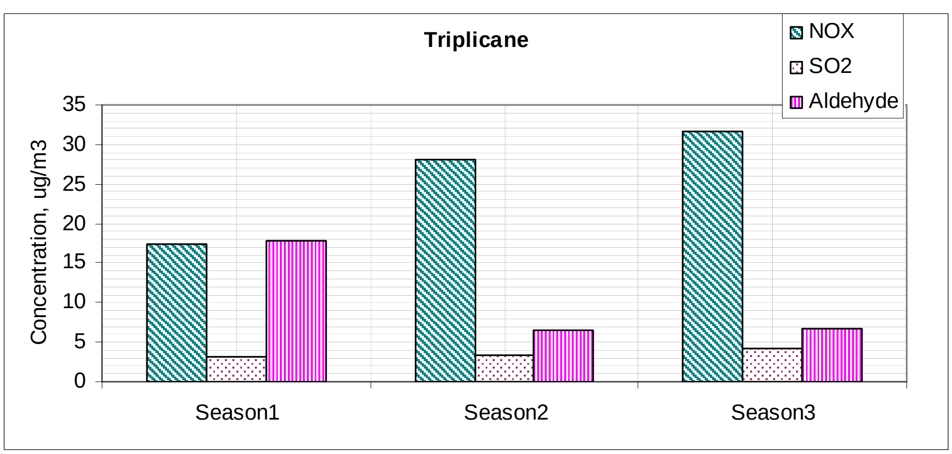

Mylapore(Cation)
Sodium
Ammonium
Potassium
Concentration, ug/m3
5
4
3
2
1
0
Season1
Season2
Season3

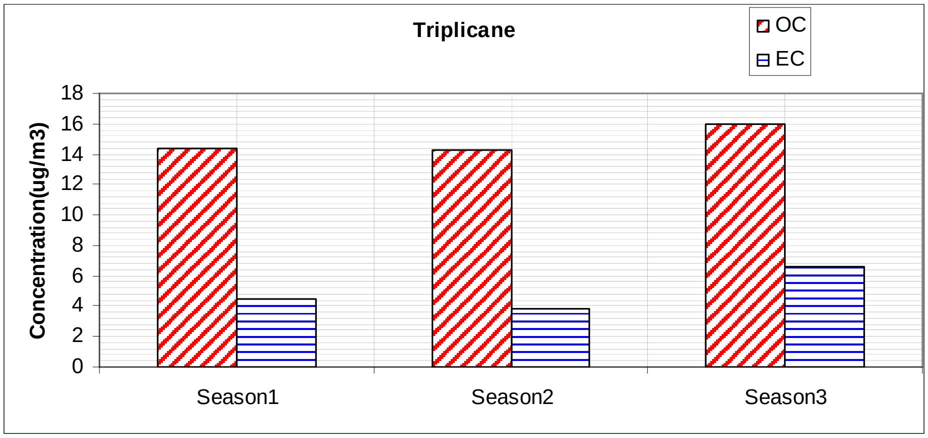


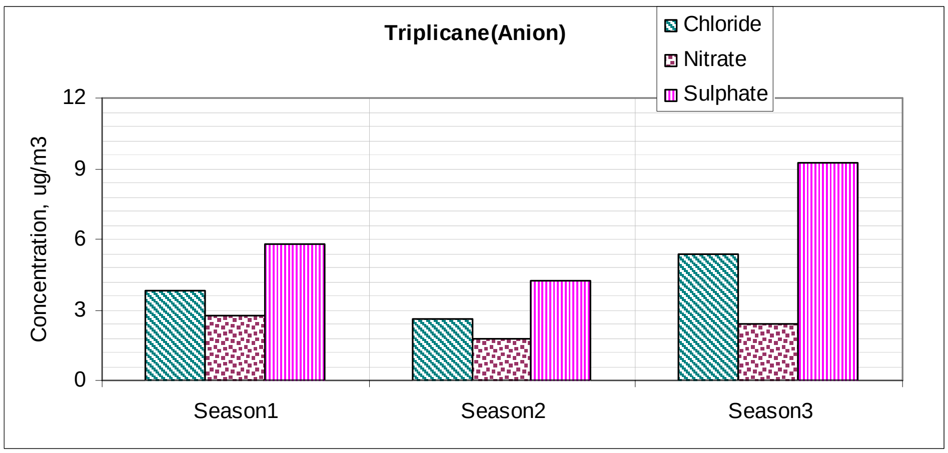
c) Triplicane

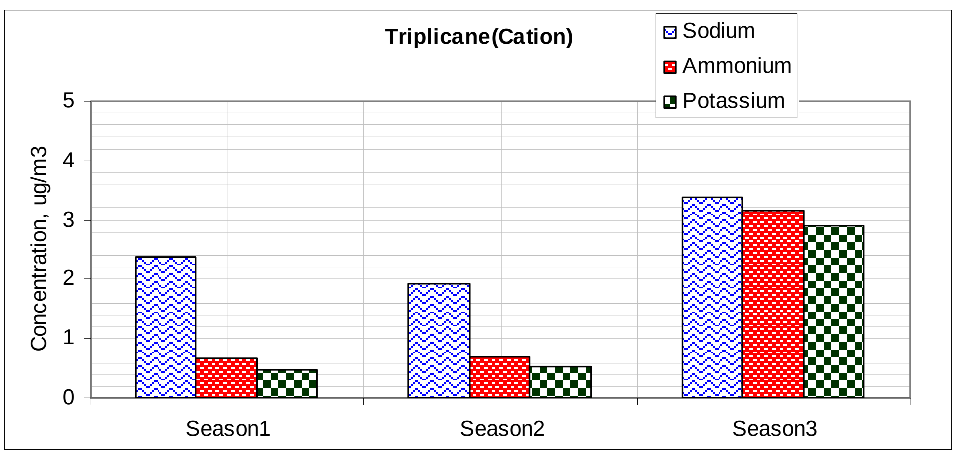
Season 1 (July-Aug) and season 2 (Aug-Sept) are warmer than season 3 (Nov-Jan). The PM values are lower in season 3 as compared to the warmer seasons. The NO_x value is higher in season 3 than in the warmer seasons. The sulphate ion and the cation concentrations are higher in the colder season.

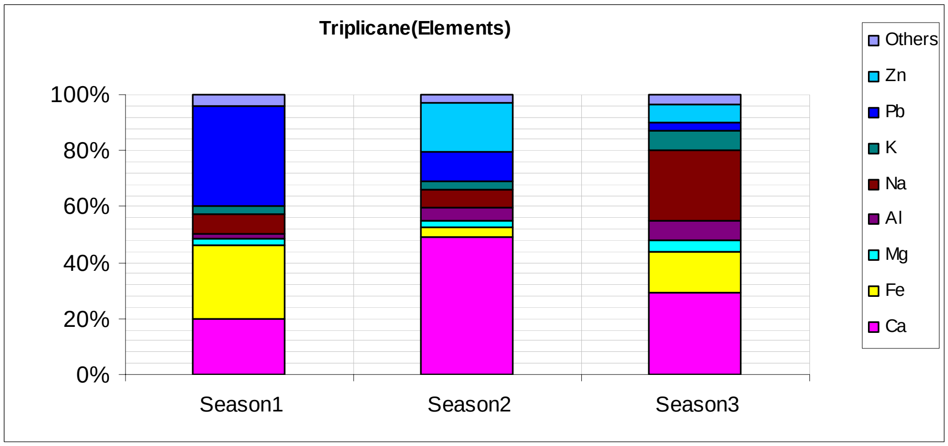





Triplicane
OC
EC
Concentration(ug/m3)
18
16
14
12
10
8
6
4
2
0
Season1
Season2
Season3

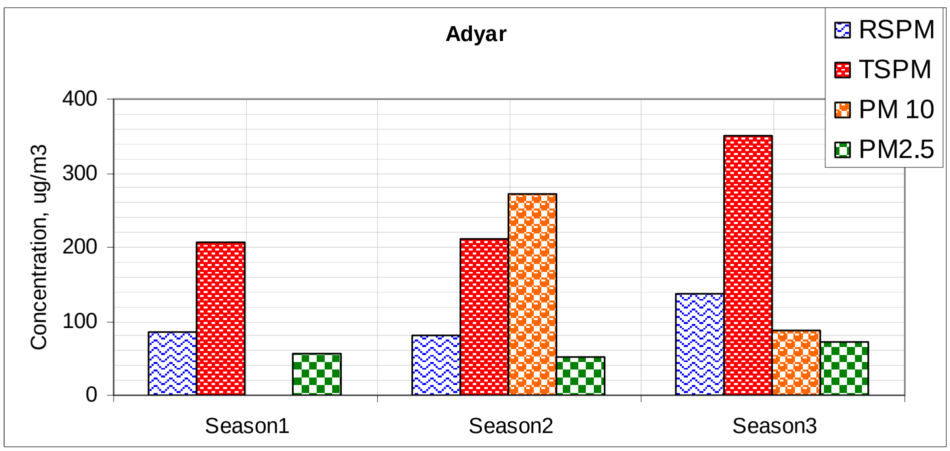

Triplicane(Anion)
Chloride
Nitrate
Sulphate
Concentration, ug/m3
12
9
6
3
0
Season1
Season2
Season3

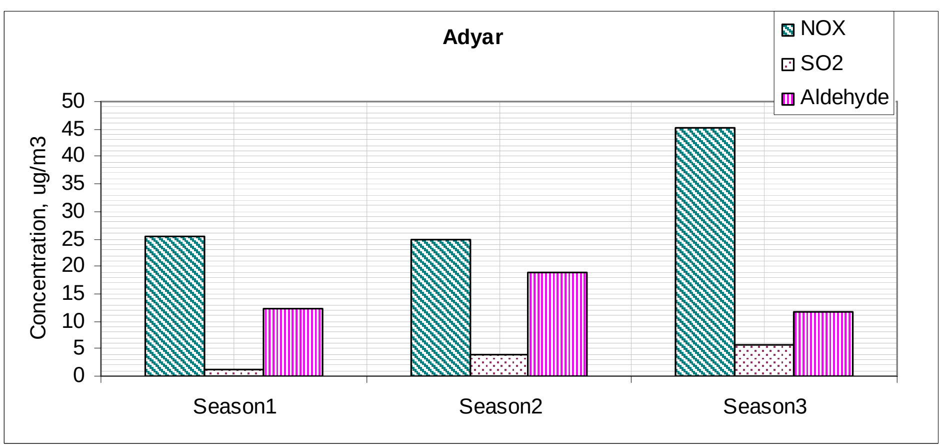

Triplicane(Cation)
Sodium
Ammonium
Potassium
Concentration, ug/m3
5
4
3
2
1
0
Season1
Season2
Season3

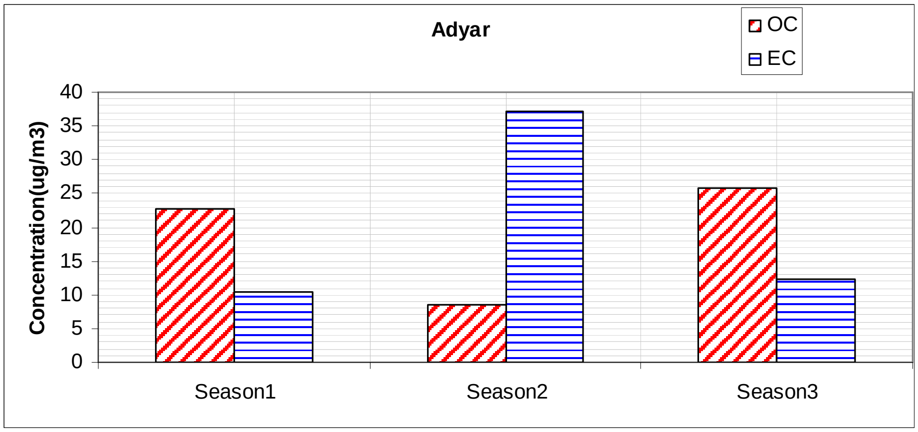


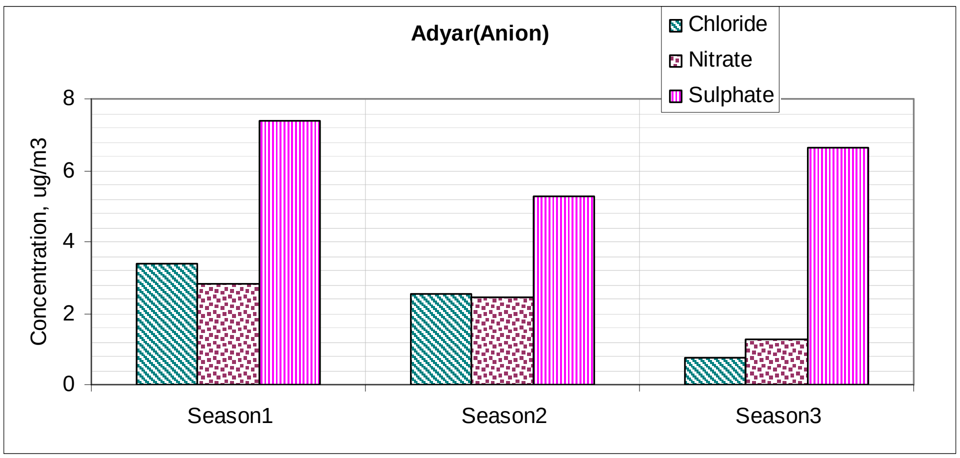
d) Adyar:

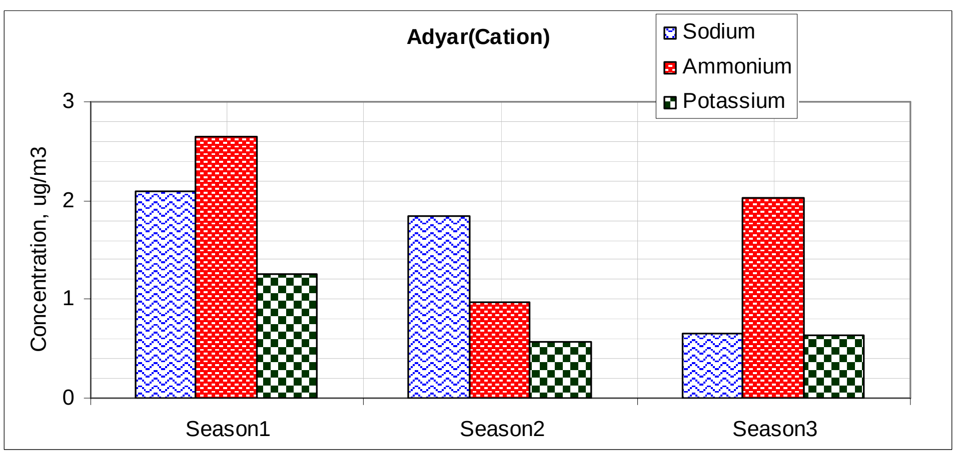
All seasons measurements at this site were within the months (March – April) in a span of one year. The temperatures are relatively similar in all the periods of measurement. However there are some differences. Season 3 was approximately one year after season 1 and 2. The PM values are marginally higher in season 3. The NO_x values are higher as well.

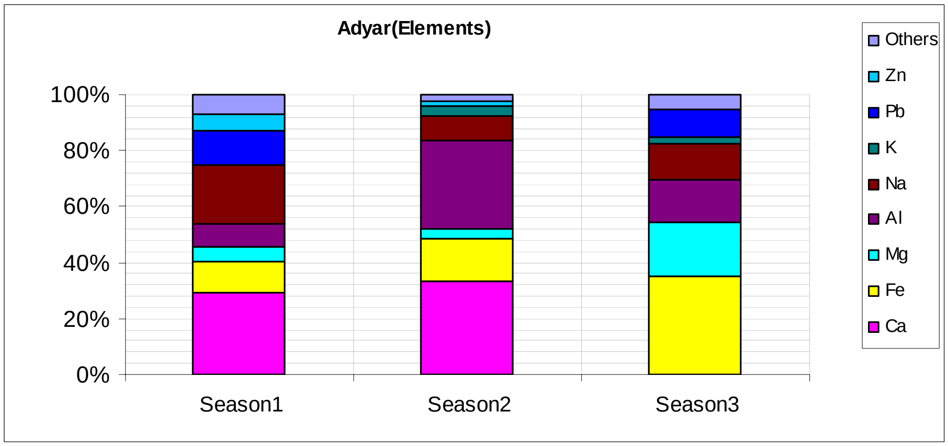





Adyar
OC
EC
Concentration(ug/m3)
40
35
30
25
20
15
10
5
0
Season1
Season2
Season3

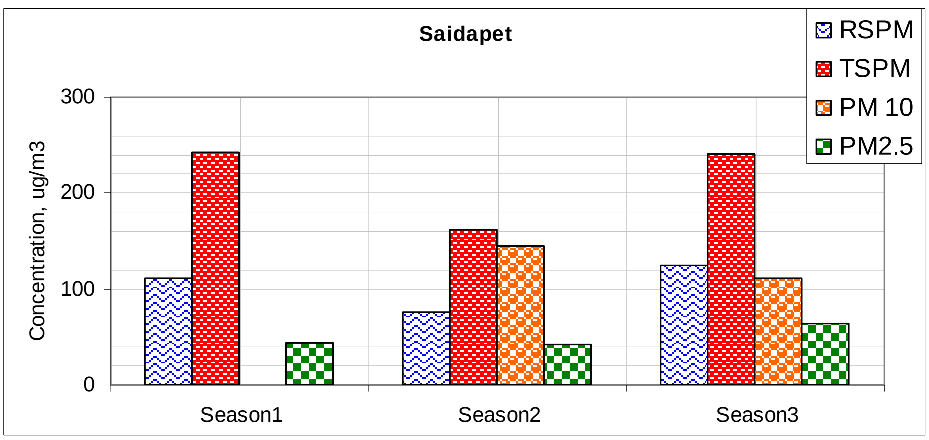

Adyar(Anion)
Chloride
Nitrate
Sulphate
Concentration, ug/m3
8
6
4
2
0
Season1
Season2
Season3

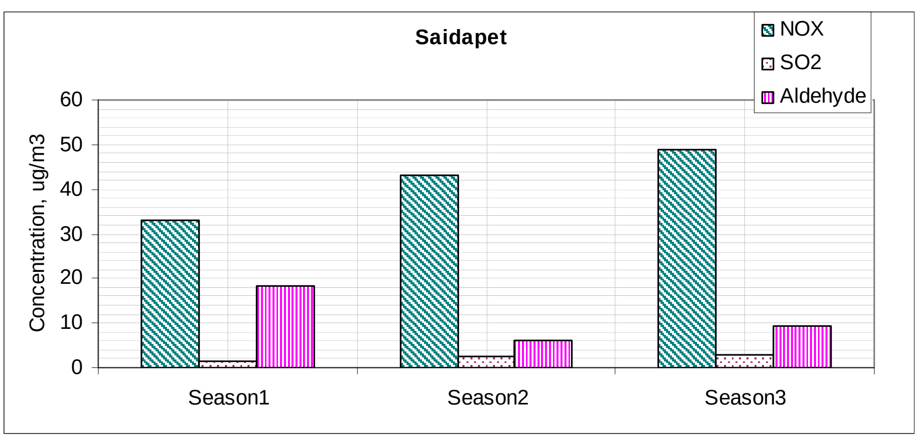

Adyar(Cation)
Sodium
Ammonium
Potassium
Concentration, ug/m3
3
2
1
0
Season1
Season2
Season3

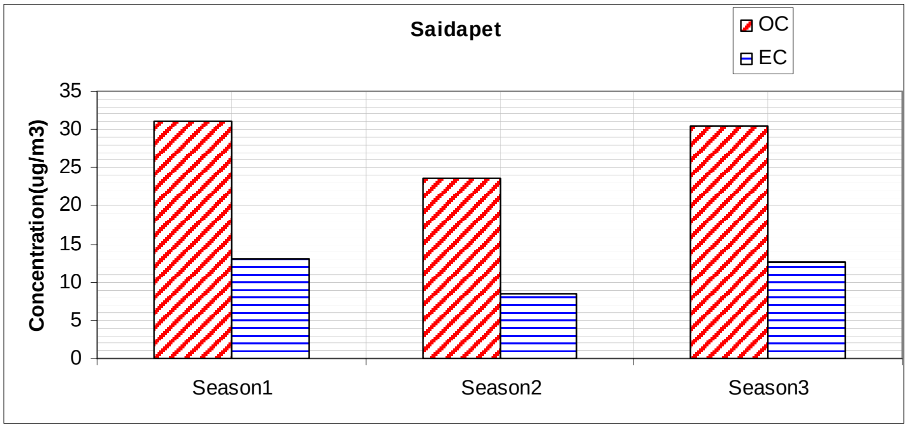


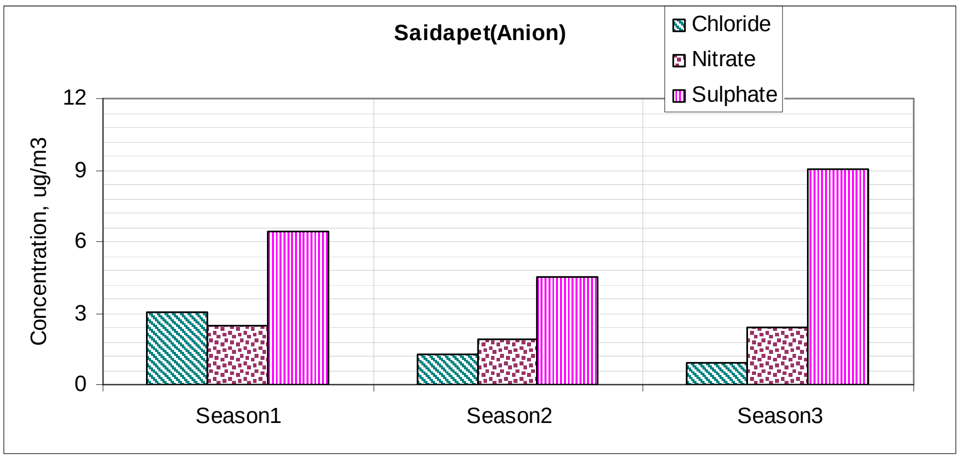
e) Saidapet:

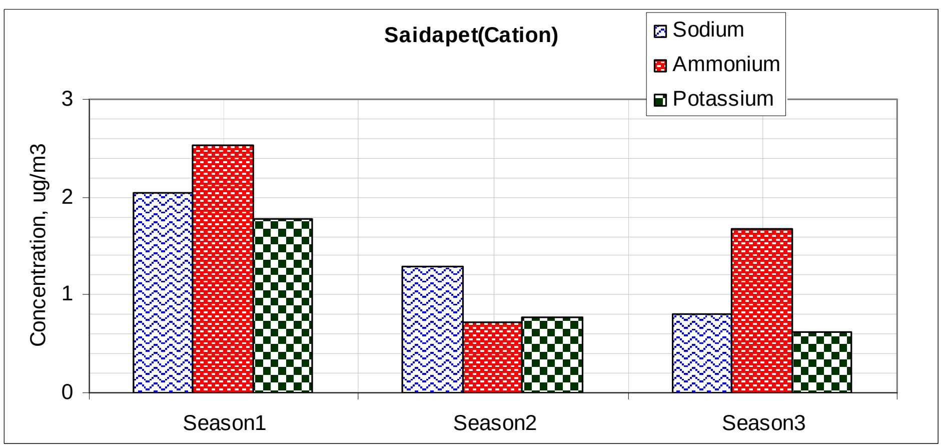
Season 1 (Mar-Apr) and season 2 (Aug – Oct) were similar and warmer than season 3 (Oct-Nov). Cations are higher in season 1, while anions increase in season 3. NO_x is also higher in season 3.

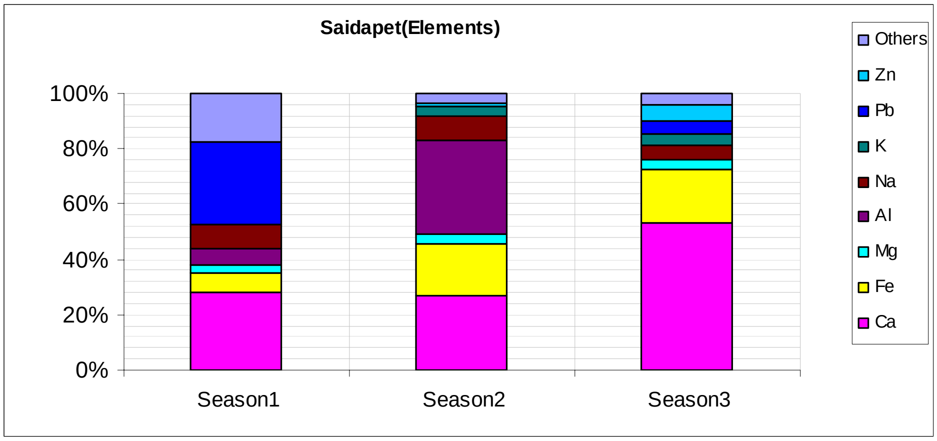





Saidapet
OC
EC
Concentration(ug/m3)
35
30
25
20
15
10
5
0
Season1
Season2
Season3

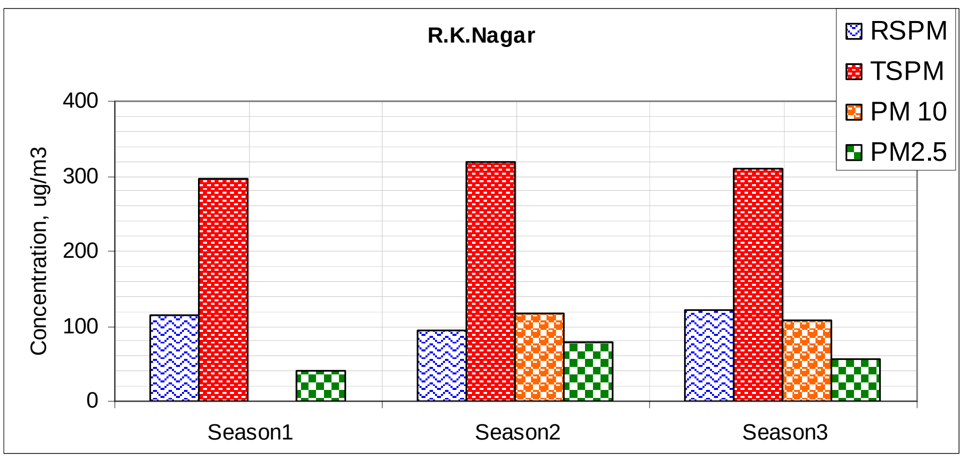

Saidapet(Anion)
Chloride
Nitrate
Sulphate
Concentration, ug/m3
12
9
6
3
0
Season1
Season2
Season3

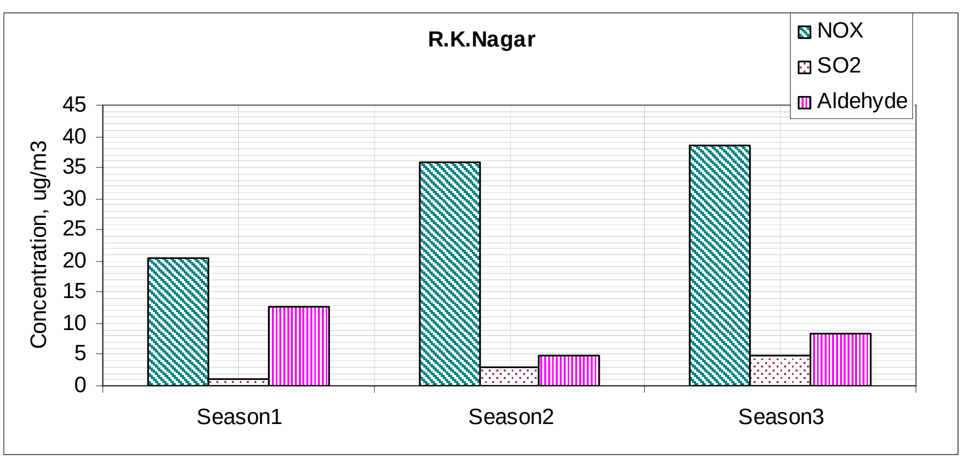

Saidapet(Cation)
Sodium
Ammonium
Potassium
Concentration, ug/m3
3
2
1
0
Season1
Season2
Season3

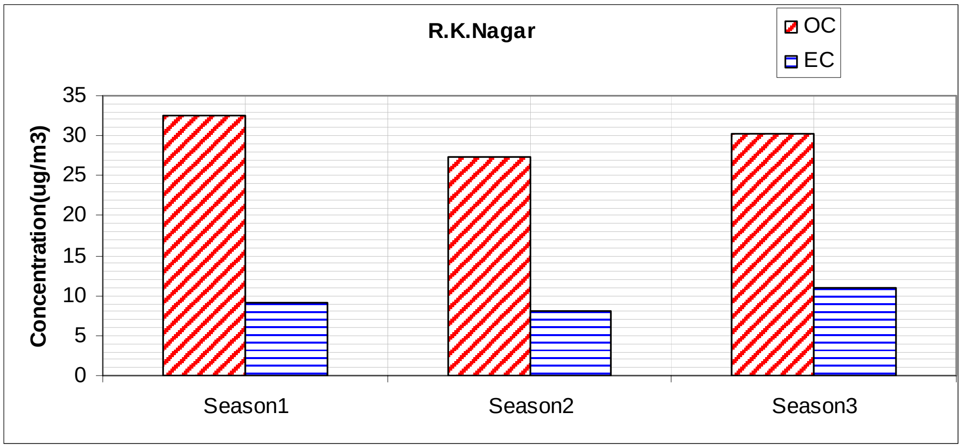


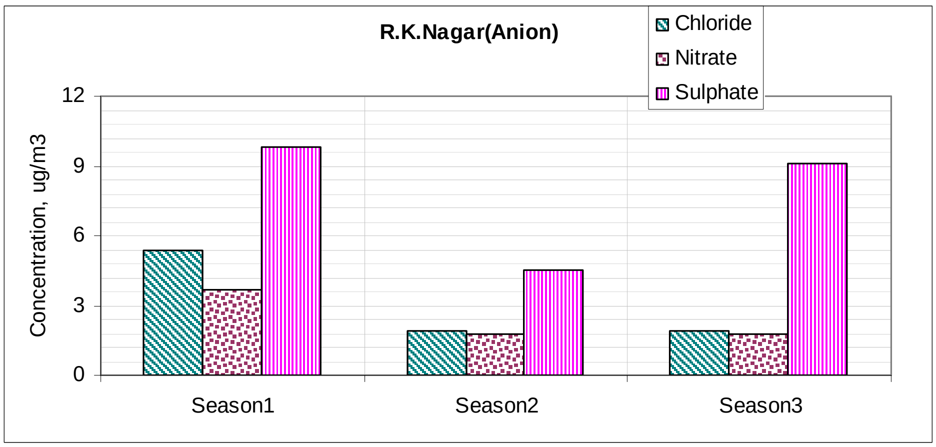
f) RK Nagar:

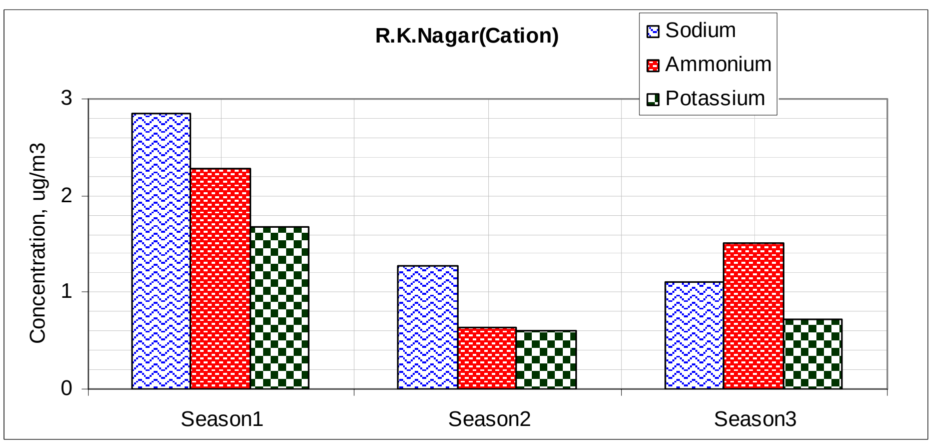
Season 1 (Mar-Apr) and season 2 (Aug-Sept) are relatively warmer than season 3 (Oct-Nov). NO_x is higher in season 3. The sulphate ion and the cations are higher in season 1.

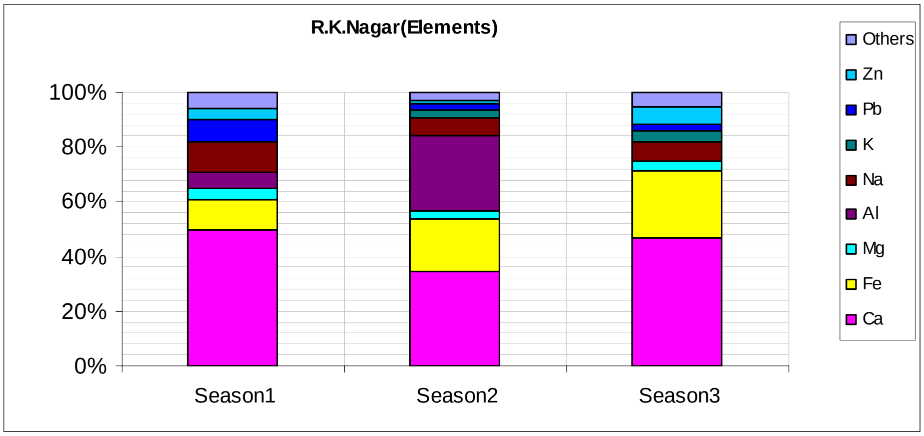





R.K.Nagar
OC
EC
Concentration(ug/m3)
35
30
25
20
15
10
5
0
Season1
Season2
Season3

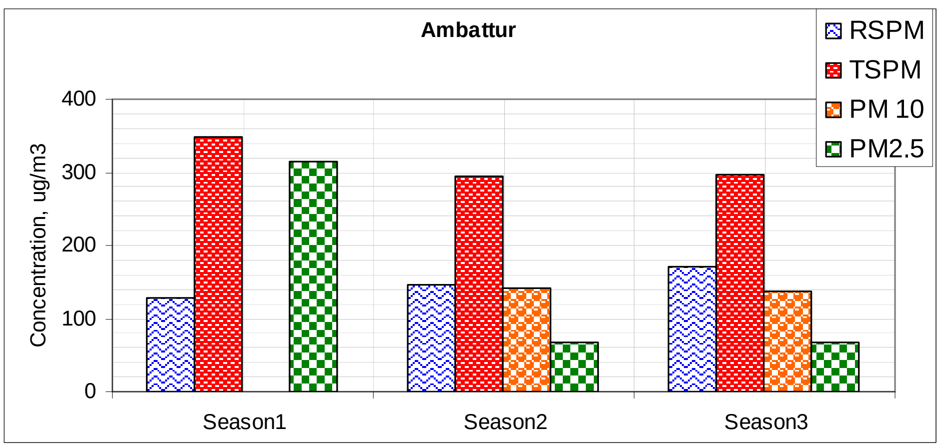

R.K.Nagar(Anion)
Chloride
Nitrate
Sulphate
Concentration, ug/m3
12
9
6
3
0
Season1
Season2
Season3

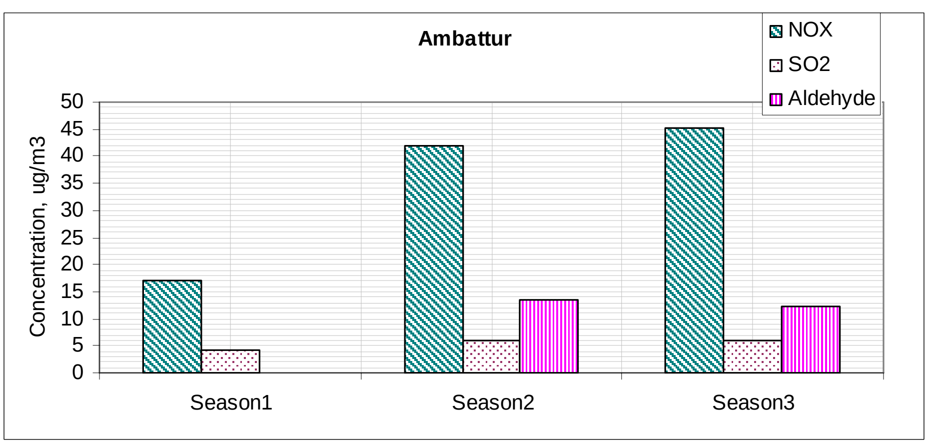

R.K.Nagar(Cation)
Sodium
Ammonium
Potassium
Concentration, ug/m3
3
2
1
0
Season1
Season2
Season3

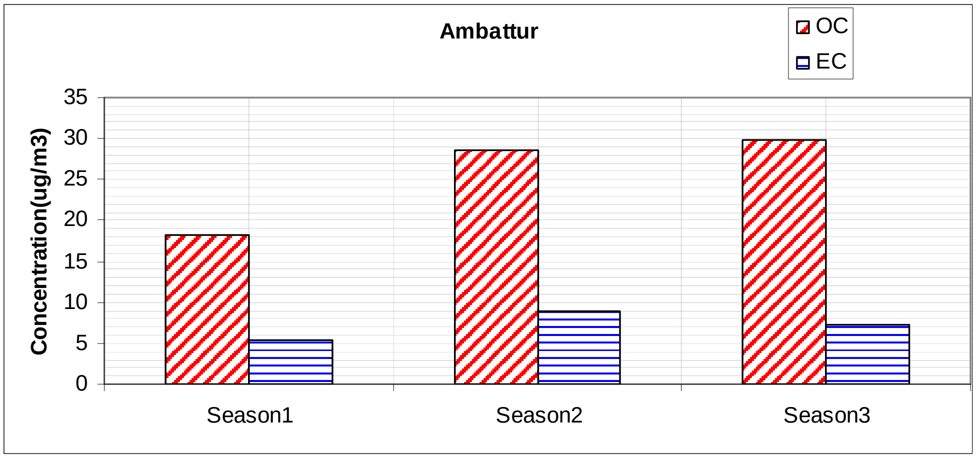


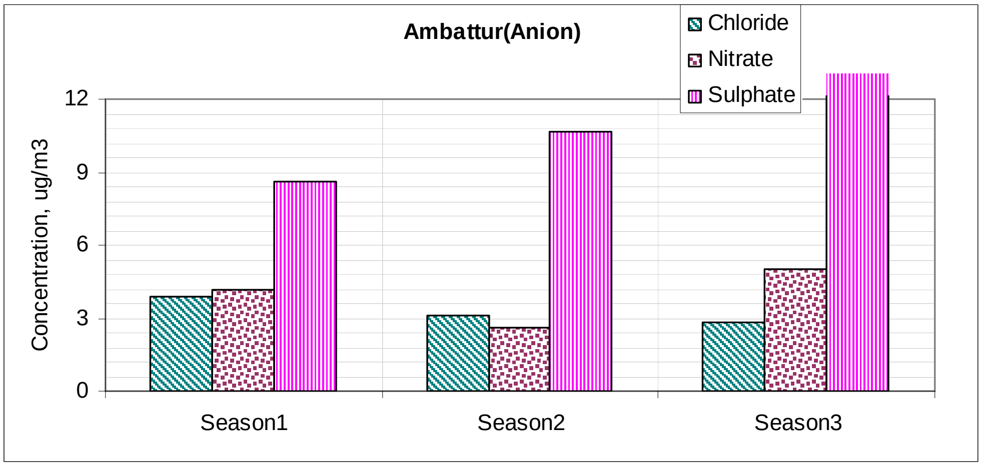
g) Ambattur:

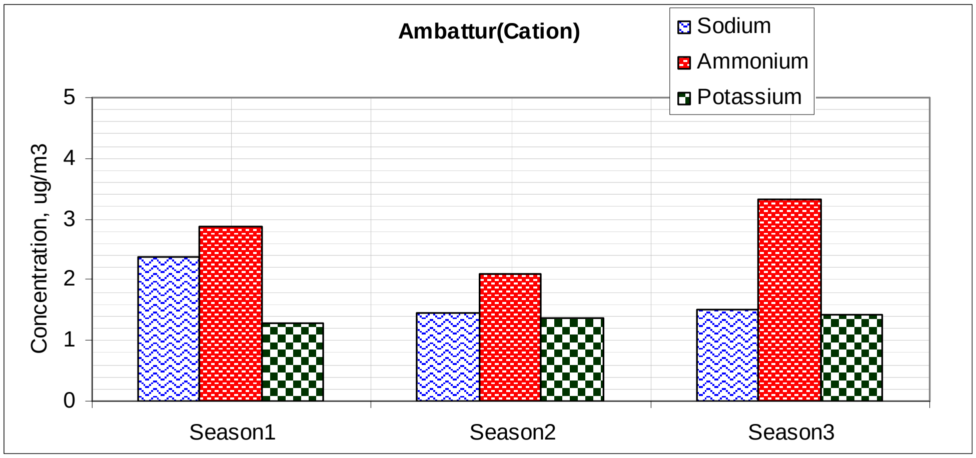
Season 1 (May-June) is warmer than season 2 (Nov-Dec) and season 3 (Dec – Jan). The NOx and aldehyde concentrations are higher in the colder seasons. The OC and EC are higher as well in season 2 and 3. The sulphate ion is also higher in season 3.

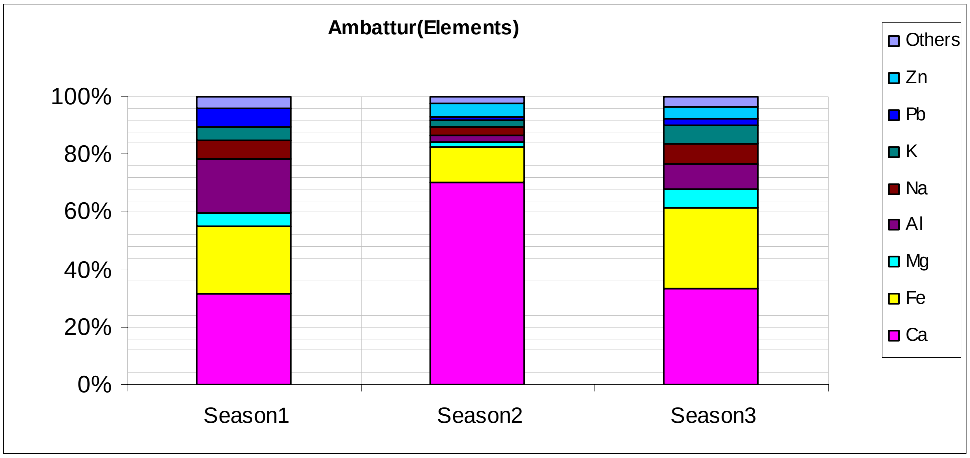





Ambattur
OC
EC
Concentration(ug/m3)
35
30
25
20
15
10
5
0
Season1
Season2
Season3


Ambattur(Anion)
Chloride
Nitrate
Sulphate
Concentration, ug/m3
12
9
6
3
0
Season1
Season2
Season3


Ambattur(Cation)
Sodium
Ammonium
Potassium
Concentration, ug/m3
5
4
3
2
1
0
Season1
Season2
Season3


Ambattur(Elements)
100%
80%
60%
40%
20%
0%
Season1
Season2
Season3
Others
Zn
Pb
K
Na
Al
Mg
Fe
Ca

2.5. Correlations

Correlations between different classes of particulate matter are shown in the following subsections.

The following tables give the correlation between some of the important parameters for different sites and seasons.

IITM Site

Season 1	TSPM	RSPM	PM10	NO2	SO2	NH4	SO4	NO3	OC	EC	TC
TSPM	1.000	0.960		0.330	0.010	-0.104	0.048	-0.022	0.321	0.348	0.333
RSPM		1.000		0.285	0.034	-0.216	0.002	-0.037	0.392	0.448	0.412
PM10											
NO2				1.000	0.152	0.085	0.000	0.094	-0.209	-0.131	-0.195
SO2					1.000	0.180	0.098	0.126	-0.145	-0.011	-0.118
NH4						1.000	0.515	0.127	-0.105	-0.007	-0.086
SO4							1.000	0.224	0.068	0.303	0.122
NO3								1.000	-0.185	-0.150	-0.180
OC									1.000	0.898	0.995
EC										1.000	0.936
TC											1.000

Season 2	TSPM	RSPM	PM10	NO2	SO2	NH4	SO4	NO3	OC	EC	TC
TSPM	1.000	0.954	0.429	0.309	0.050	0.100	-0.008	0.052	-0.119	0.056	-0.094
RSPM		1.000	0.476	0.233	-0.064	-0.012	0.103	0.177	-0.140	0.043	-0.117
PM10			1.000	0.306	-0.122	-0.037	0.216	0.043	-0.187	0.116	-0.134
NO2				1.000	0.231	0.118	-0.053	-0.217	0.249	0.485	0.359
SO2					1.000	-0.049	-0.060	-0.095	-0.011	0.296	0.085
NH4						1.000	0.666	0.481	-0.301	0.020	-0.276
SO4							1.000	0.861	-0.389	-0.105	-0.394
NO3								1.000	-0.312	-0.306	-0.382
OC									1.000	0.078	0.954
EC										1.000	0.374
TC											1.000

Season 3	TSPM	RSPM	PM10	NO2	SO2	NH4	SO4	NO3	OC	EC	TC
TSPM	1.000	0.480	-0.176	-0.291	0.247	0.022	0.063	-0.140	-0.136	-0.224	-0.168
RSPM		1.000	-0.079	-0.026	0.575	-0.186	-0.238	-0.340	0.141	-0.099	0.070
PM10			1.000	0.176	-0.428	0.386	0.524	0.117	0.681	0.605	0.676
NO2				1.000	-0.239	-0.010	0.075	-0.092	0.191	0.387	0.258
SO2					1.000	-0.163	-0.394	-0.157	-0.139	-0.280	-0.188
NH4						1.000	0.818	0.741	0.446	0.298	0.409
SO4							1.000	0.501	0.241	0.213	0.239
NO3								1.000	0.080	0.264	0.140
OC									1.000	0.872	0.988
EC										1.000	0.937
TC											1.000

At IITM site, NH_4 ion is correlated with SO_4 and NO_3 ions, indicating the presence of ammonium sulphate (formed from SO_2 and NH_3).

Mylapore

Season 1	TSPM	RSPM	PM10	NO2	SO2	NH4	SO4	NO3	OC	EC	TC
TSPM	1.000	0.853		0.302	0.096	0.095	0.161	0.033	0.245	0.279	0.255
RSPM		1.000		0.169	0.174	-0.037	0.073	-0.120	0.154	0.198	0.165
PM10											
NO2				1.000	-0.061	0.331	0.312	0.322	0.263	0.326	0.279
SO2					1.000	-0.199	0.216	0.457	0.113	0.191	0.130
NH4						1.000	-0.040	-0.029	0.523	0.447	0.513
SO4							1.000	0.745	0.245	0.291	0.257
NO3								1.000	0.309	0.352	0.321
OC									1.000	0.937	0.997
EC										1.000	0.960
TC											1.000

Season 2	TSPM	RSPM	PM10	NO2	SO2	NH4	SO4	NO3	OC	EC	TC
TSPM	1.000	0.791		-0.103	-0.290	0.158	0.159	0.110	-0.141	-0.110	-0.134
RSPM		1.000		-0.094	-0.092	0.178	0.010	-0.070	-0.138	-0.105	-0.131
PM10											
NO2				1.000	0.021	-0.125	-0.057	0.053	0.021	0.055	0.029
SO2					1.000	0.201	-0.129	-0.178	-0.304	-0.251	-0.293
NH4						1.000	0.133	0.061	-0.461	-0.360	-0.438
SO4							1.000	0.870	-0.012	-0.049	-0.022
NO3								1.000	0.095	0.102	0.097
OC									1.000	0.966	0.998
EC										1.000	0.981
TC											1.000

Season 3	TSPM	RSPM	PM10	NO2	SO2	NH4	SO4	NO3	OC	EC	TC
TSPM	1.000	0.925	-0.047	0.116	0.170	-0.115	-0.197	-0.001	0.159	0.410	0.207
RSPM		1.000	0.076	0.202	0.198	-0.083	-0.162	0.166	0.283	0.477	0.324
PM10			1.000	-0.224	-0.044	0.622	0.788	0.873	0.738	0.482	0.713
NO2				1.000	0.041	-0.177	-0.325	-0.097	0.012	0.030	0.015
SO2					1.000	0.016	-0.114	-0.022	-0.115	0.287	-0.040
NH4						1.000	0.889	0.509	0.312	0.214	0.303
SO4							1.000	0.718	0.483	0.248	0.455
NO3								1.000	0.881	0.611	0.858
OC									1.000	0.812	0.995
EC										1.000	0.867
TC											1.000

Triplicane

Season 1	TSPM	RSPM	PM10	NO2	SO2	NH4	SO4	NO3	OC	EC	TC
TSPM	1.000	0.980	0.119	-0.197	-0.261	0.066	0.294	0.330	-0.056	-0.122	-0.066
RSPM		1.000	0.161	-0.207	0.137	0.085	0.277	0.284	-0.104	-0.110	-0.107
PM10			1.000	0.128	0.402	0.071	0.131	-0.089	0.091	-0.040	0.034
NO2				1.000	0.172	0.147	0.228	0.023	0.206	0.048	0.224
SO2					1.000	0.259	0.463	-0.470	0.161	0.473	0.220
NH4						1.000	0.686	0.518	-0.146	-0.090	-0.148
SO4							1.000	0.832	-0.055	-0.120	-0.059
NO3								1.000	0.021	-0.095	0.005
OC									1.000	0.588	0.989
EC										1.000	0.619
TC											1.000

Season 2	TSPM	RSPM	PM10	NO2	SO2	NH4	SO4	NO3	OC	EC	TC
TSPM	1.000	0.539	-0.210	-0.157	-0.123	-0.120	-0.237	-0.282	0.191	0.102	0.177
RSPM		1.000	-0.140	0.026	0.019	-0.120	-0.258	-0.314	0.300	0.087	0.263
PM10			1.000	0.082	-0.088	0.350	0.227	0.069	0.036	-0.117	0.004
NO2				1.000	-0.123	0.022	-0.104	-0.078	0.216	0.237	0.228
SO2					1.000	0.329	0.343	0.357	-0.232	-0.224	-0.239
NH4						1.000	0.701	0.450	-0.248	-0.373	-0.283
SO4							1.000	0.814	-0.355	-0.517	-0.399
NO3								1.000	-0.195	-0.416	-0.248
OC									1.000	0.854	0.994
EC										1.000	0.906
TC											1.000

Season 3	TSPM	RSPM	PM10	NO2	SO2	NH4	SO4	NO3	OC	EC	TC
TSPM	1.000	0.930	0.213	0.268	0.854	-0.012	0.044	0.001	0.044	0.021	0.040
RSPM		1.000	0.290	0.392	0.902	0.092	0.152	0.118	0.143	0.156	0.149
PM10			1.000	-0.109	0.219	0.503	0.508	0.847	0.855	0.791	0.860
NO2				1.000	0.420	-0.118	0.234	-0.214	-0.288	-0.002	-0.230
SO2					1.000	0.135	0.055	-0.026	0.048	0.146	0.071
NH4						1.000	0.511	0.425	0.259	0.296	0.274
SO4							1.000	0.543	0.160	0.198	0.173
NO3								1.000	0.762	0.703	0.767
OC									1.000	0.868	0.994
EC										1.000	0.919
TC											1.000

Adyar

Season 1	TSPM	RSPM	PM10	NO2	SO2	NH4	SO4	NO3	OC	EC	TC
TSPM	1.000	0.807		0.085	-0.044	-0.154	0.384	0.289	0.357	0.488	0.404
RSPM		1.000		0.063	0.145	-0.181	0.479	0.265	0.216	0.217	0.223
PM10											
NO2				1.000	0.296	0.340	0.034	0.272	0.281	0.139	0.249
SO2					1.000	-0.207	0.229	0.297	-0.043	-0.122	-0.068
NH4						1.000	0.072	0.056	0.514	0.307	0.487
SO4							1.000	0.789	0.101	-0.130	0.049
NO3								1.000	0.212	-0.092	0.148
OC									1.000	0.859	0.990
EC										1.000	0.924
TC											1.000

Season 2	TSPM	RSPM	PM10	NO2	SO2	NH4	SO4	NO3	EC	OC	TC
TSPM	1.000	0.759	-0.067	-0.066	0.512	-0.042	0.119	0.123	0.119	0.103	0.140
RSPM		1.000	0.323	0.133	0.282	0.348	0.359	0.468	0.471	0.318	0.463
PM10			1.000	0.084	0.003	0.295	0.345	0.268	0.439	0.548	0.445
NO2				1.000	-0.130	0.389	0.614	0.417	0.179	0.152	0.197
SO2					1.000	-0.147	0.111	0.043	-0.124	-0.107	-0.101
NH4						1.000	0.602	0.462	0.623	0.528	0.618
SO4							1.000	0.794	0.605	0.552	0.620
NO3								1.000	0.686	0.547	0.680
OC									1.000	0.862	0.996
EC										1.000	0.881
TC											1.000

Season 3	TSPM	RSPM	PM10	NO2	SO2	NH4	SO4	NO3	EC	OC	TC
TSPM	1.000	0.849	-0.111	-0.118	-0.216	-0.134	-0.111	-0.048	0.117	0.292	0.141
RSPM		1.000	-0.021	-0.107	-0.169	-0.098	-0.116	-0.069	0.178	0.411	0.211
PM10			1.000	0.257	-0.064	0.410	0.561	0.722	0.550	0.187	0.536
NO2				1.000	0.318	-0.060	0.048	0.085	0.074	-0.099	0.059
SO2					1.000	-0.269	-0.200	-0.214	0.070	0.144	0.080
NH4						1.000	0.901	0.683	0.263	0.153	0.263
SO4							1.000	0.841	0.293	0.094	0.285
NO3								1.000	0.265	-0.009	0.247
OC									1.000	0.543	0.996
EC										1.000	0.617
TC											1.000

Saidapet

Season 1	TSPM	RSPM	PM10	NO2	SO2	NH4	SO4	NO3	OC	EC	TC
TSPM	1.000	0.827		0.374	-0.161	-0.065	0.194	0.226	0.172	0.346	0.239
RSPM		1.000		0.075	-0.152	-0.093	-0.067	-0.068	0.132	0.555	0.270
PM10											
NO2				1.000	0.269	-0.139	0.326	0.676	0.565	0.141	0.483
SO2					1.000	-0.047	-0.021	0.268	0.389	0.057	0.322
NH4						1.000	0.336	0.272	0.148	-0.016	0.108
SO4							1.000	0.883	0.272	-0.063	0.199
NO3								1.000	0.437	-0.037	0.329
OC									1.000	0.624	0.972
EC										1.000	0.789
TC											1.000

Season 2	TSPM	RSPM	PM10	NO2	SO2	NH4	SO4	NO3	OC	EC	TC
TSPM	1.000	0.827		0.374	-0.161	-0.065	0.194	0.226	0.172	0.346	0.239
RSPM		1.000	-0.107	-0.118	0.095	-0.187	0.248	0.153	-0.055	-0.439	-0.164
PM10			1.000	0.575	0.459	0.361	0.178	0.234	-0.051	0.029	-0.038
NO2				1.000	0.582	0.515	0.066	-0.012	0.006	0.250	0.067
SO2					1.000	0.475	0.066	0.075	-0.241	-0.135	-0.276
NH4						1.000	0.536	0.528	0.270	0.296	0.290
SO4							1.000	0.868	0.468	0.103	0.410
NO3								1.000	0.460	0.213	0.434
OC									1.000	0.636	0.982
EC										1.000	0.762
TC											1.000

Season 3	TSPM	RSPM	PM10	NO2	SO2	NH4	SO4	NO3	OC	EC	TC
TSPM	1.000	0.878	-0.037	0.220	-0.129	-0.057	0.126	0.053	0.209	0.492	0.297
RSPM		1.000	-0.167	0.090	0.005	-0.104	-0.045	-0.116	0.025	0.270	0.089
PM10			1.000	0.307	-0.241	0.652	0.697	0.703	0.741	0.487	0.734
NO2				1.000	-0.143	0.534	0.634	0.516	0.580	0.260	0.544
SO2					1.000	-0.171	-0.235	-0.130	-0.465	-0.410	-0.488
NH4						1.000	0.942	0.784	0.643	0.286	0.597
SO4							1.000	0.883	0.731	0.414	0.699
NO3								1.000	0.718	0.394	0.683
OC									1.000	0.648	0.981
EC										1.000	0.783
TC											1.000

RK Nagar

Season 1	TSPM	RSPM	PM10	NO2	SO2	NH4	SO4	NO3	OC	EC	TC
TSPM	1.000	0.503		0.248	0.297	0.060	0.057	0.038	0.112	-0.172	0.071
RSPM		1.000		0.488	0.015	0.009	-0.007	0.248	0.638	0.299	0.607
PM10											
NO2				1.000	-0.019	0.064	0.186	0.450	0.320	0.206	0.314
SO2					1.000	-0.060	-0.151	-0.240	-0.002	-0.224	-0.033
NH4						1.000	0.611	0.572	0.125	0.221	0.143
SO4							1.000	0.768	-0.039	0.021	-0.030
NO3								1.000	0.158	0.166	0.165
OC									1.000	0.756	0.995
EC										1.000	0.820
TC											1.000

Season 2	TSPM	RSPM	PM10	NO2	SO2	NH4	SO4	NO3	OC	EC	TC
TSPM	1.000	0.661	-0.198	0.225	-0.198	-0.175	-0.033	0.040	0.100	0.200	0.136
RSPM		1.000	0.063	0.242	-0.155	-0.246	-0.144	0.099	0.222	0.157	0.232
PM10			1.000	0.478	0.087	-0.133	-0.021	0.016	0.164	0.156	0.180
NO2				1.000	-0.298	-0.101	0.139	0.110	0.130	0.016	0.119
SO2					1.000	-0.196	0.123	0.120	-0.022	-0.042	-0.026
NH4						1.000	0.405	0.219	-0.136	-0.121	-0.147
SO4							1.000	0.818	-0.317	-0.467	-0.397
NO3								1.000	-0.238	-0.422	-0.319
OC									1.000	0.506	0.967
EC										1.000	0.708
TC											1.000

Season 3	TSPM	RSPM	PM10	NO2	SO2	NH4	SO4	NO3	OC	EC	TC
TSPM	1.000	0.681	0.141	0.511	-0.405	0.314	0.128	0.258	0.105	0.220	0.126
RSPM		1.000	0.279	0.315	-0.103	0.116	0.089	0.166	0.104	0.107	0.109
PM10			1.000	0.382	-0.075	0.280	0.382	0.828	0.800	0.589	0.797
NO2				1.000	-0.267	0.506	0.284	0.478	0.212	0.447	0.255
SO2					1.000	-0.216	-0.389	-0.311	-0.141	-0.110	-0.142
NH4						1.000	0.869	0.632	0.085	0.203	0.103
SO4							1.000	0.590	0.204	0.139	0.201
NO3								1.000	0.586	0.528	0.598
OC									1.000	0.722	0.995

Ambattur

Season 1	TSPM	RSPM	PM10	NO2	SO2	NH4	SO4	NO3	OC	EC	TC
TSPM	1.000	0.700		0.148	0.498	-0.593	0.268	0.138	0.215	0.045	0.179
RSPM		1.000		0.242	0.525	-0.581	0.167	0.075	0.076	-0.094	0.041
PM10											
NO2				1.000	-0.317	0.122	0.546	0.497	-0.364	-0.489	-0.393
SO2					1.000	-0.424	0.169	0.228	-0.187	-0.454	-0.245
NH4						1.000	0.115	0.140	-0.243	-0.102	-0.215
SO4							1.000	0.947	-0.154	-0.185	-0.161
NO3								1.000	-0.215	-0.203	-0.213
OC									1.000	0.938	0.997
EC										1.000	0.961
TC											1.000

Season 2	TSPM	RSPM	PM10	NO2	SO2	NH4	SO4	NO3	OC	EC	TC
TSPM	1.000	0.880	0.674	-0.030	0.319	-0.320	0.338	0.494	0.718	0.283	0.713
RSPM		1.000	0.702	0.047	0.318	-0.357	0.359	0.516	0.748	0.240	0.734
PM10			1.000	-0.004	0.108	-0.231	0.492	0.680	0.879	0.095	0.841
NO2				1.000	0.180	0.033	0.293	0.091	-0.028	0.305	0.011
SO2					1.000	0.000	0.285	0.170	0.255	0.374	0.291
NH4						1.000	0.450	0.206	-0.366	-0.204	-0.376
SO4							1.000	0.900	0.417	-0.047	0.384
NO3								1.000	0.640	0.000	0.603
OC									1.000	0.352	0.991
EC										1.000	0.471
TC											1.000

Season 3	TSPM	RSPM	PM10	NO2	SO2	NH4	SO4	NO3	OC	EC	TC
TSPM	1.000	0.883	0.670	0.053	0.058	0.126	0.505	0.668	0.613	0.199	0.591
RSPM		1.000	0.454	0.090	0.025	0.022	0.312	0.478	0.427	0.104	0.408
PM10			1.000	0.188	-0.014	0.078	0.686	0.871	0.905	0.443	0.881
NO2				1.000	-0.322	0.014	0.275	0.268	0.224	0.499	0.262
SO2					1.000	-0.105	0.002	-0.066	-0.086	-0.156	-0.096
NH4						1.000	0.625	0.184	-0.001	-0.047	-0.006
SO4							1.000	0.742	0.593	0.401	0.591
NO3								1.000	0.842	0.472	0.827
OC									1.000	0.672	0.996
EC										1.000	0.737
TC											1.000

The only consistent correlation is between SO_4 and NH_4 ions; and between SO_4 and NO_3 ions.

2.5.1. Correlations between Particulate matter classifications

Figure 2.5.1.1 to 2.5.1.20 shows the correlations between different size particulate matter concentrations (RSPM, TSPM, PM10 and PM2.5) at seven sites for during all the three seasons. The correlations between RSPM and TSPM were positive and varied between 0.44

and 0.96. The mean correlation for all sites for RSPM and TSPM was 0.711. There were no discernable patterns of the correlation with respect to site category or season. None of the other plots showed any significant correlation – positive or negative. The correlation coefficient values for the correlations between the other factors were below 0.4 except for Ambattur for PM_{10}-TSPM and PM_{10}/RSPM, where the correlation is above 0.7.

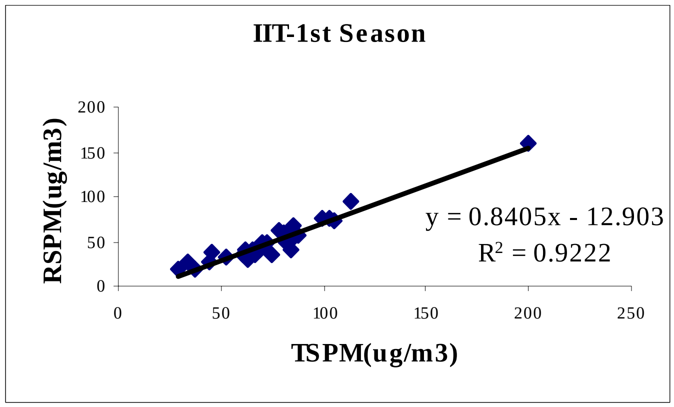


Figure 2.5.1.1. Correlation of PM parameters at IITM – season 1

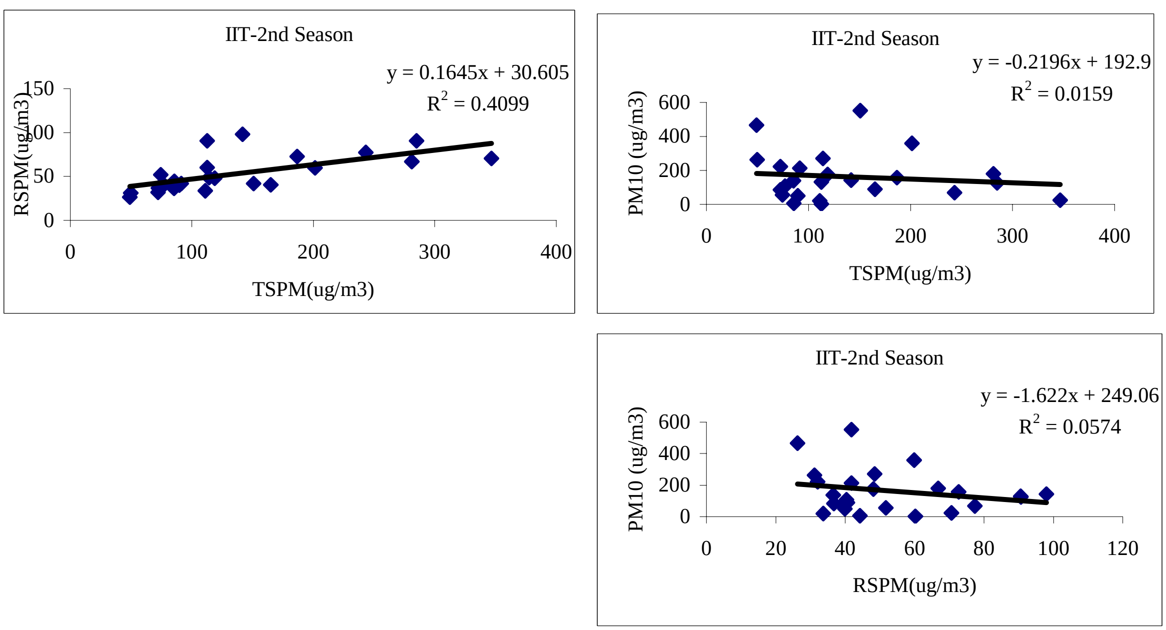


Figure 2.5.1.2. Correlation of PM parameters at IITM – season 2

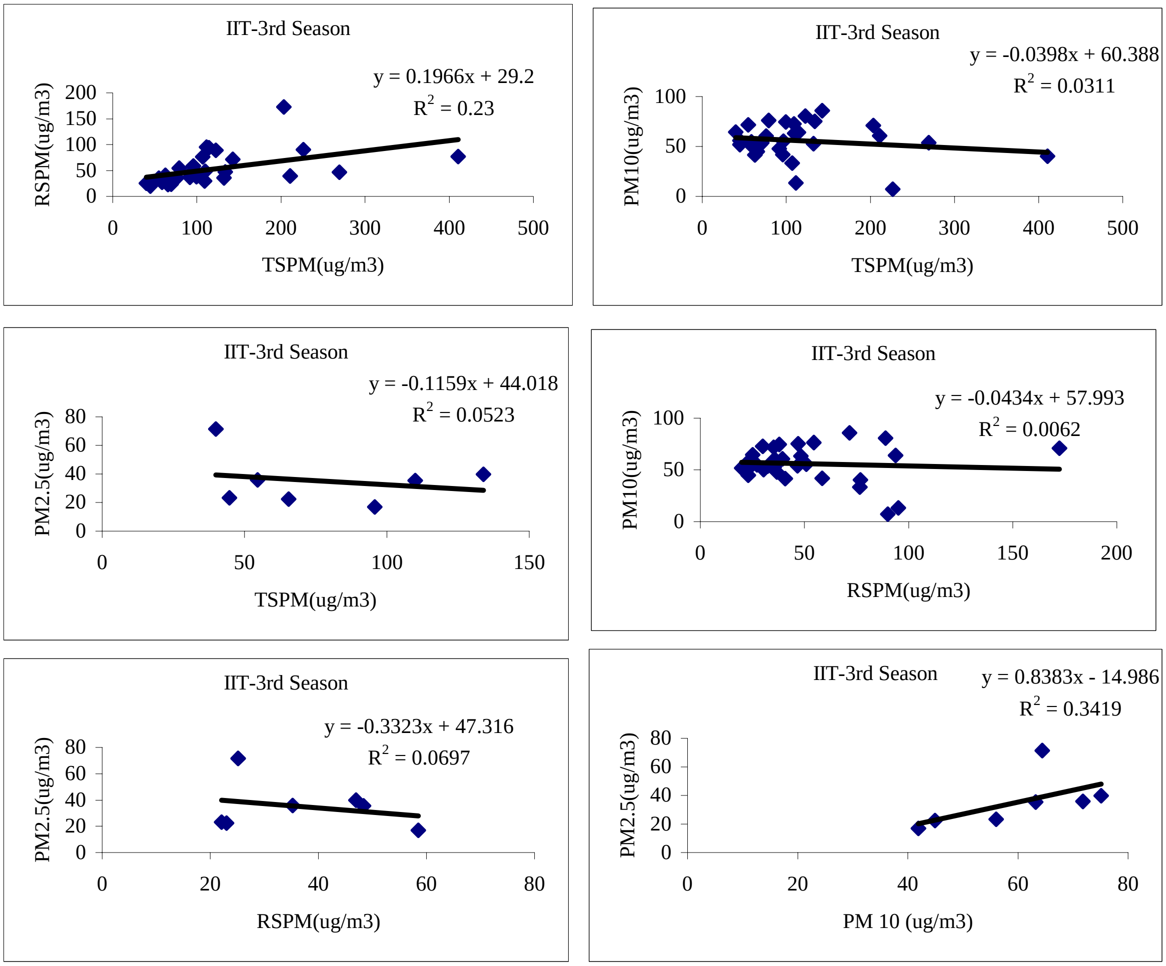


Figure 2.5.1.3. Correlation of PM parameters at IITM – season 3

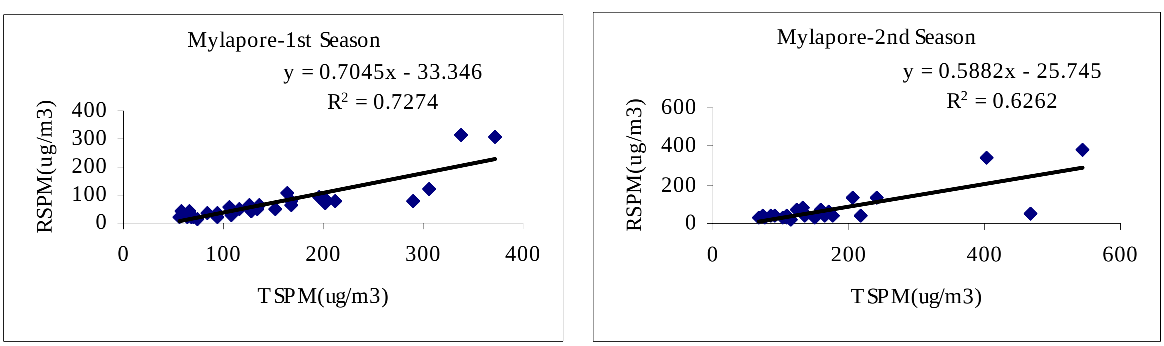


Figure 2.5.1.4. Correlation of PM parameters at Mylapore (residential) – Season 1,2

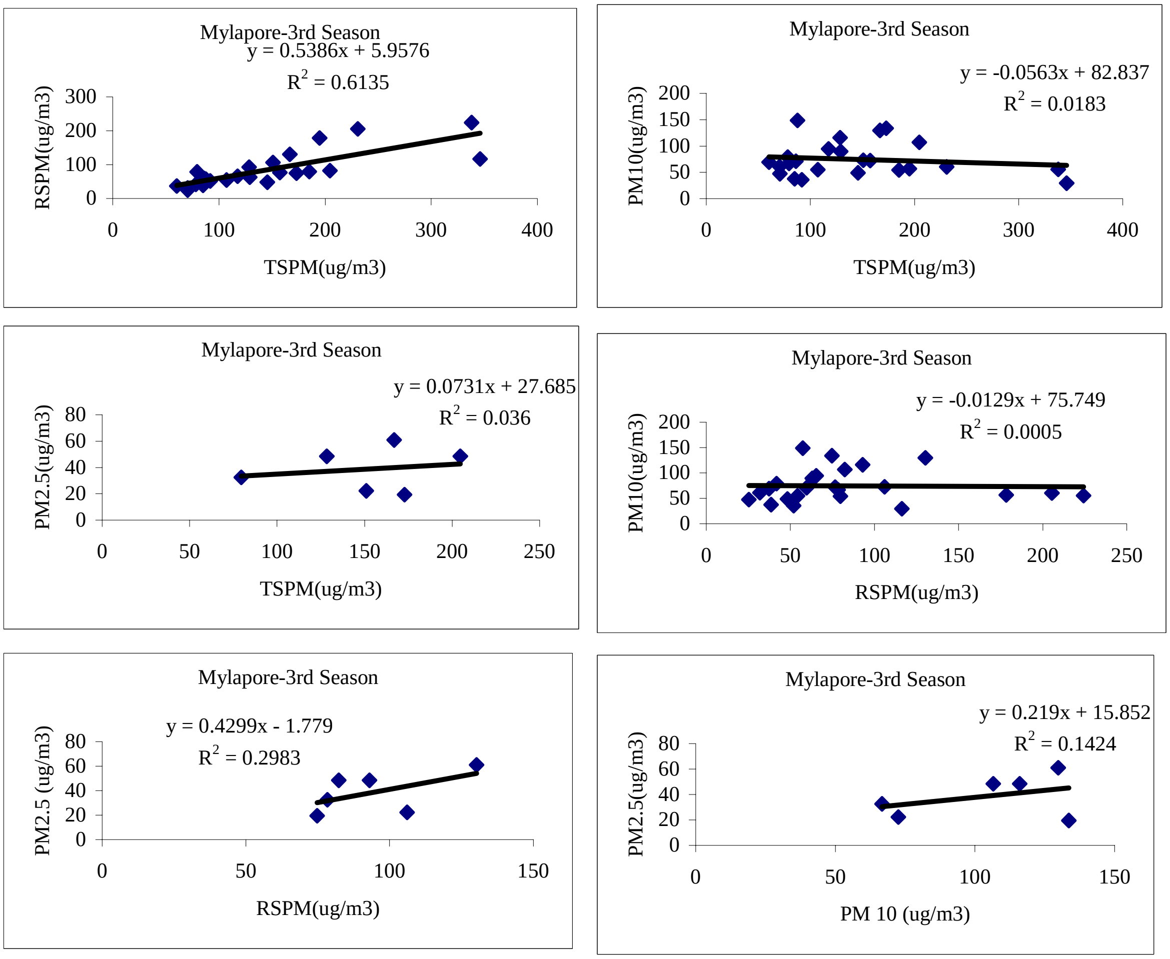


Figure 2.5.1.5. Correlation of PM parameters at Mylapore (residential) – Season 3

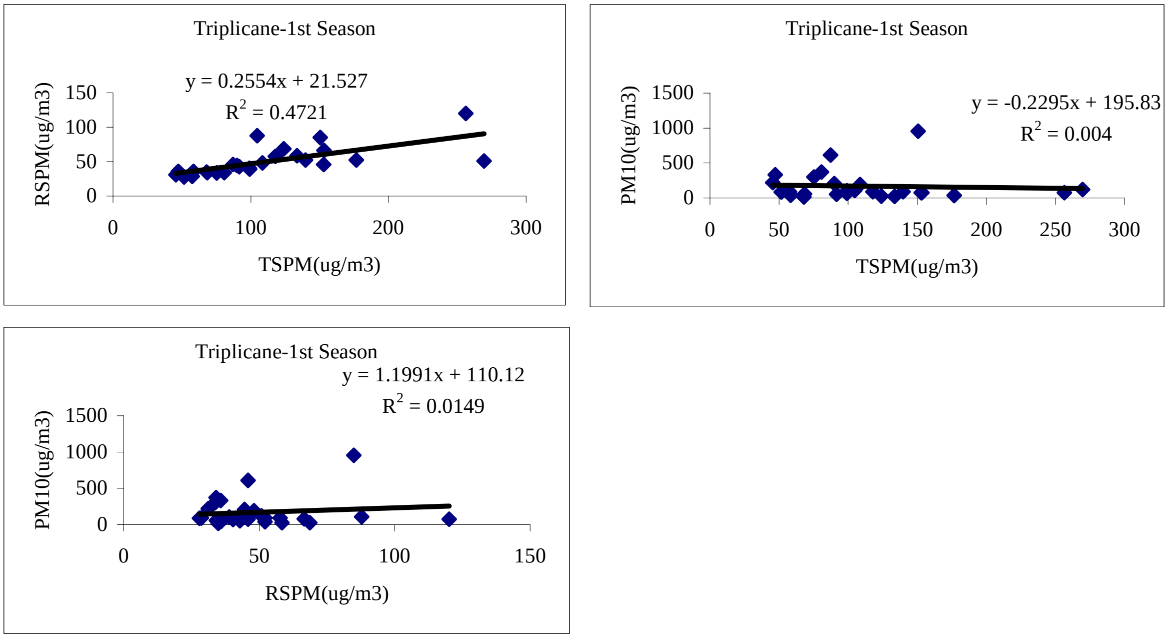


Figure 2.5.1.6. Correlation of PM parameters at Triplicane (residential) – Season 1

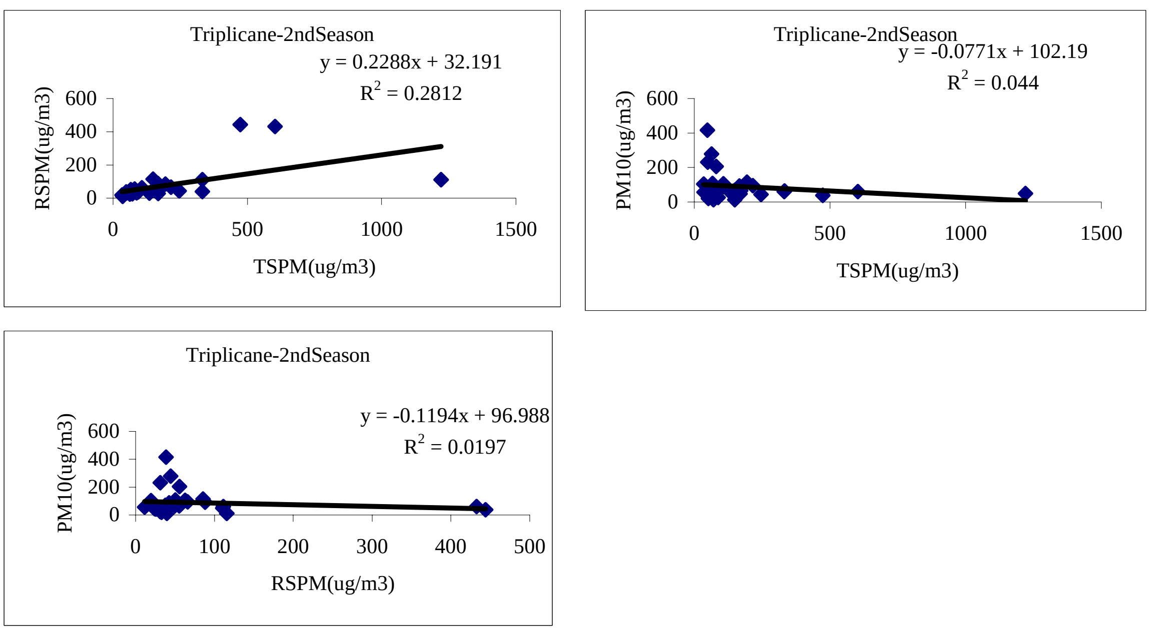


Figure 2.5.1.7. Correlation of PM parameters at Triplicane (residential) – Season 2

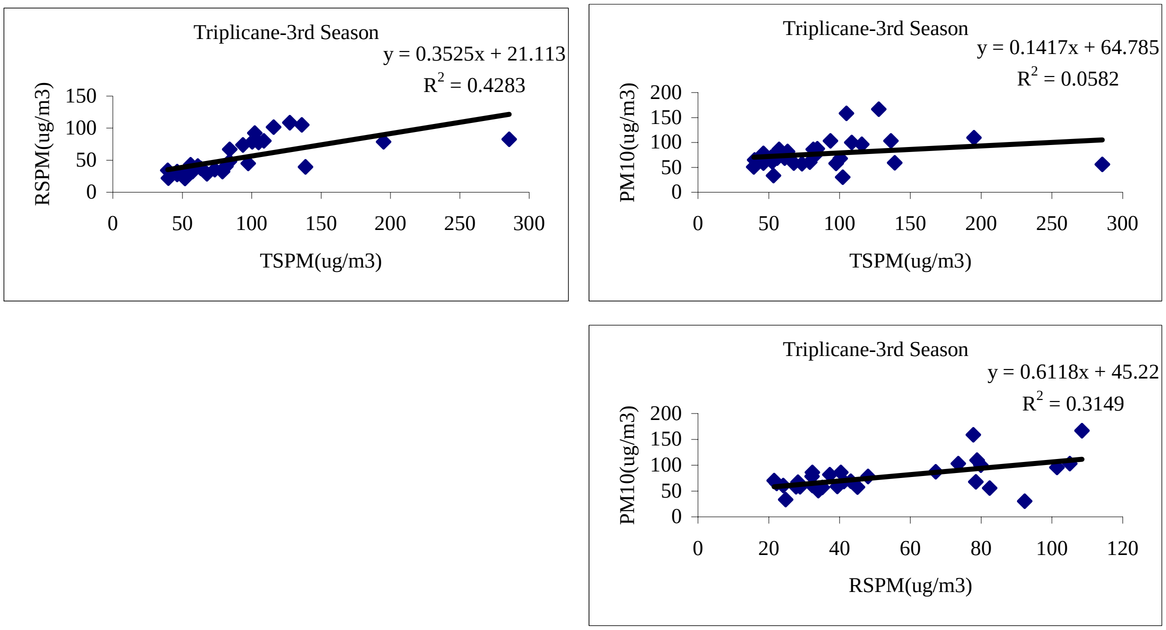


Figure 2.5.1.8. Correlation of PM parameters at Triplicane (residential) – Season 3

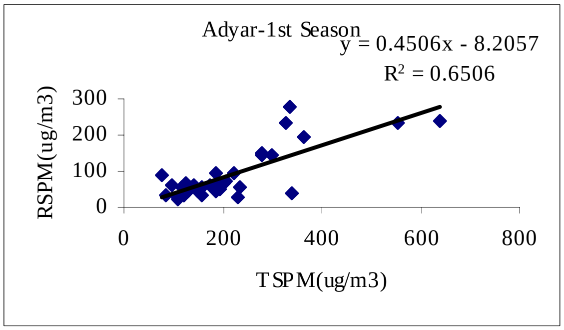


Figure 2.5.1.9 Correlation of PM parameters at Adyar (kerbside) – Season 1

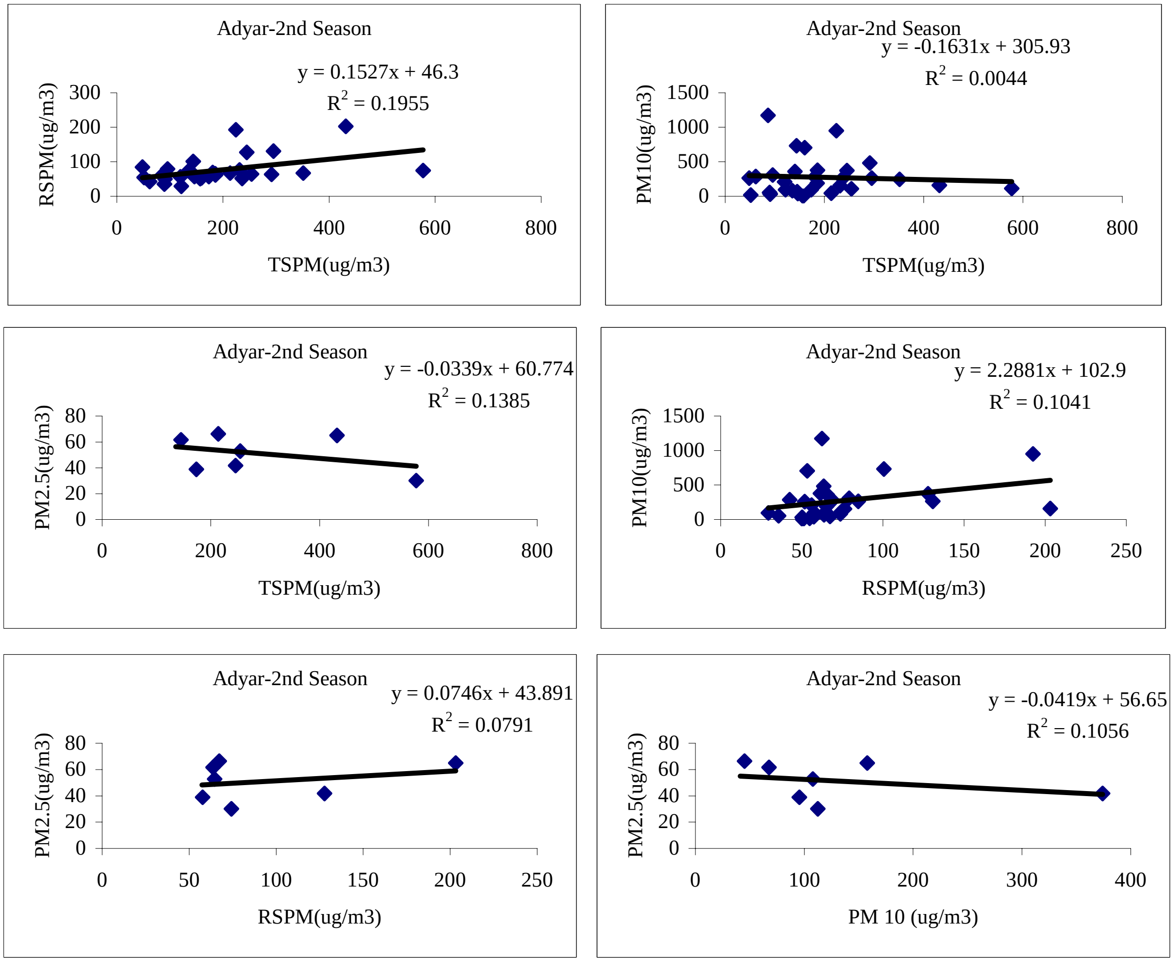


Figure 2.5.1.10 Correlation of PM parameters at Adyar (kerbside) – Season 2

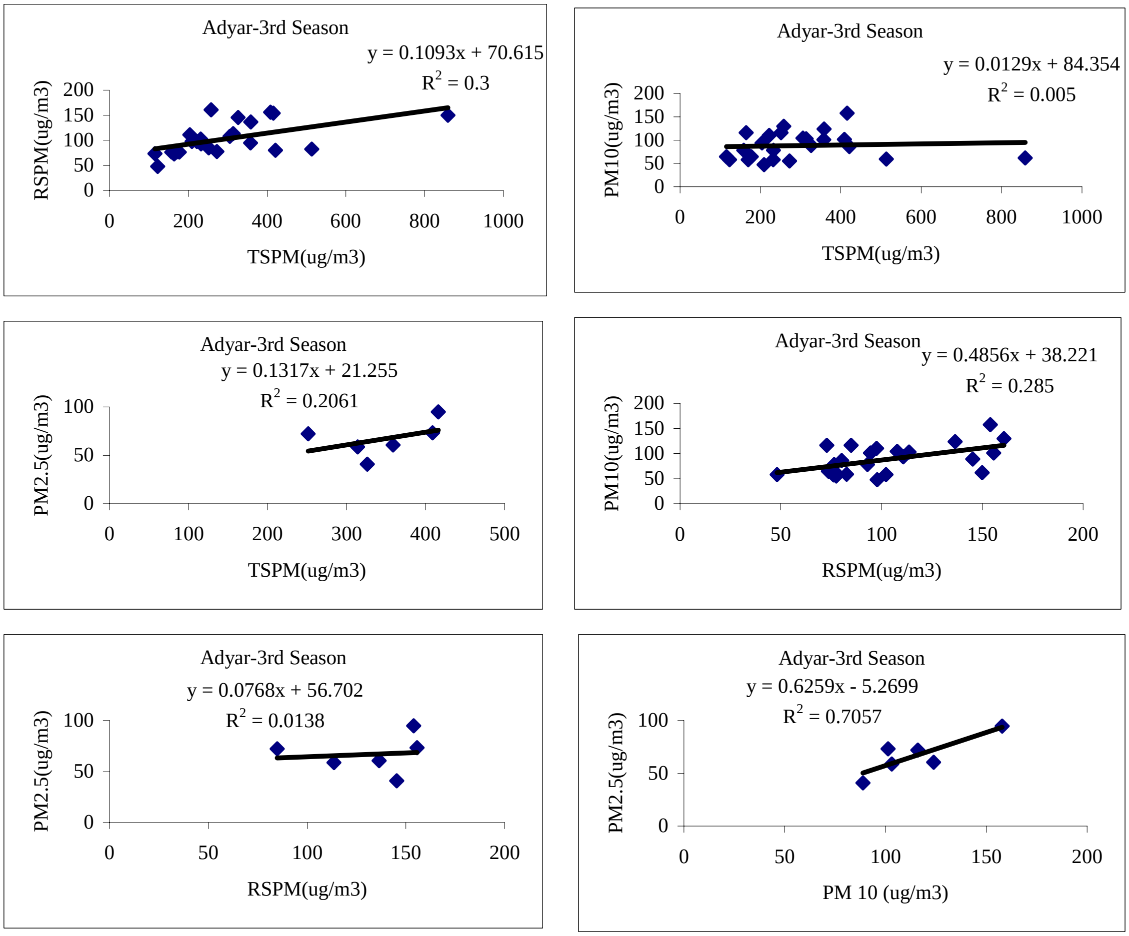


Figure 2.5.1.11 Correlation of PM parameters at Adyar (kerbside) – Season 3

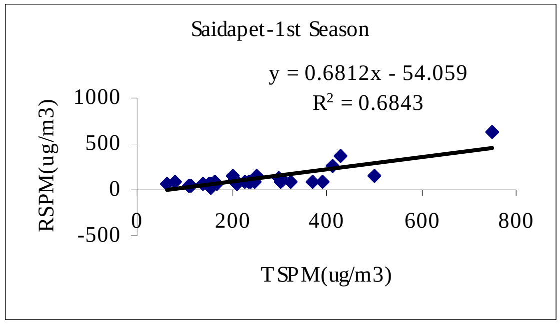


Figure 2.5.1.12 Correlation of PM parameters at Saidapet (kerbside) – Season 1

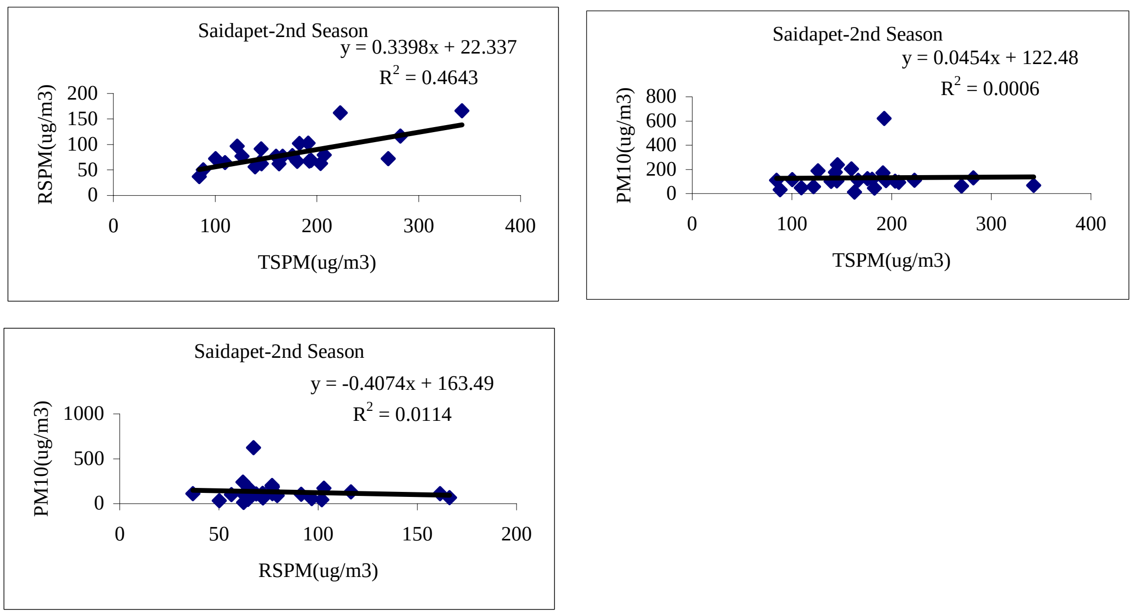


Figure 2.5.1.13 Correlation of PM parameters at Saidapet (kerbside) – Season 2

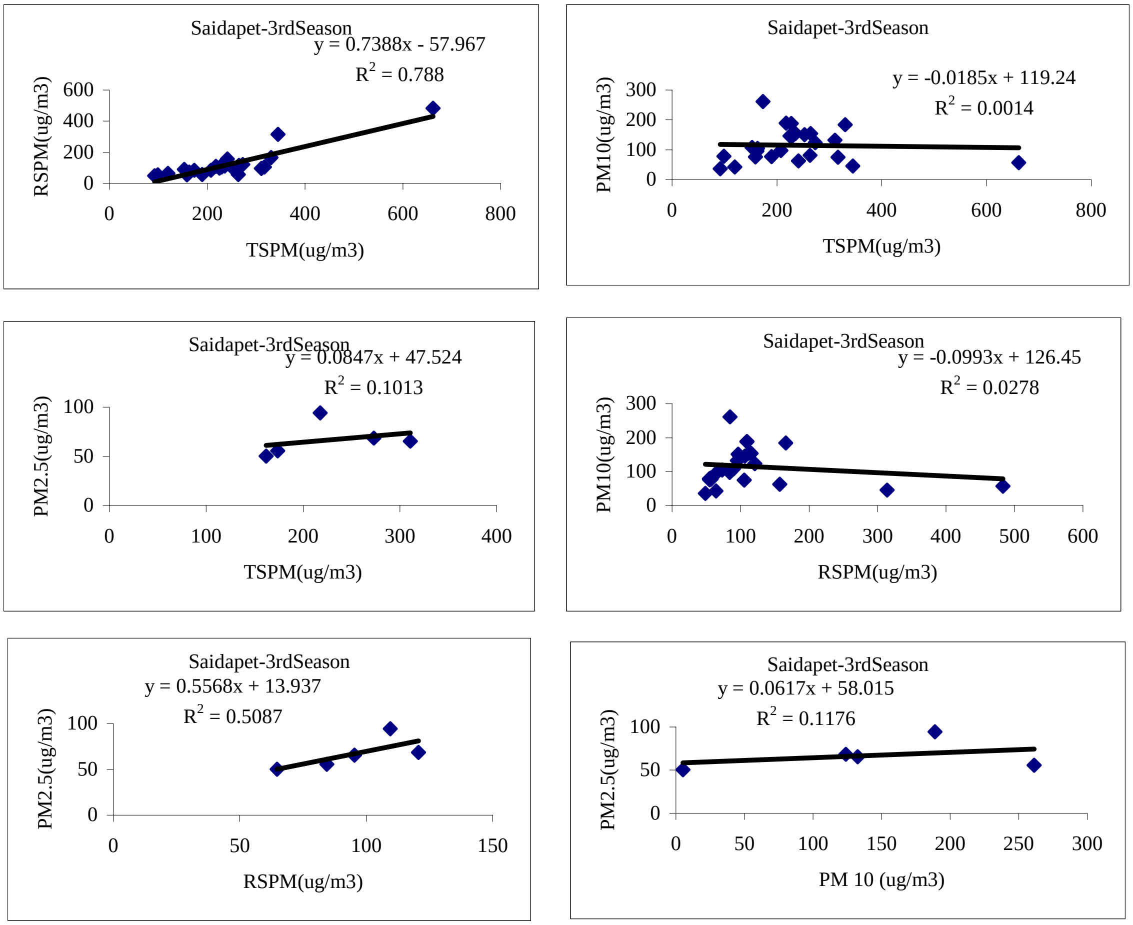


Figure 2.5.1.14 Correlation of PM parameters at Saidapet (kerbside) – Season 3

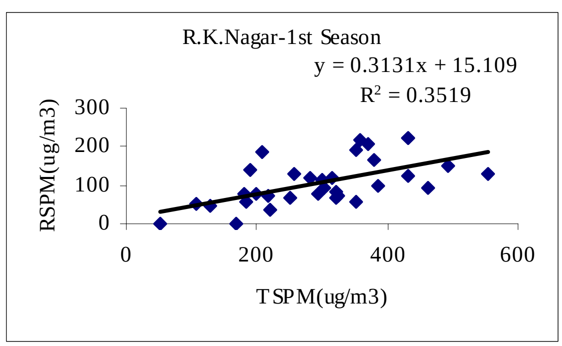


Figure 2.5.1.15 Correlation of PM parameters at R K Nagar (Industrial) – Season 1

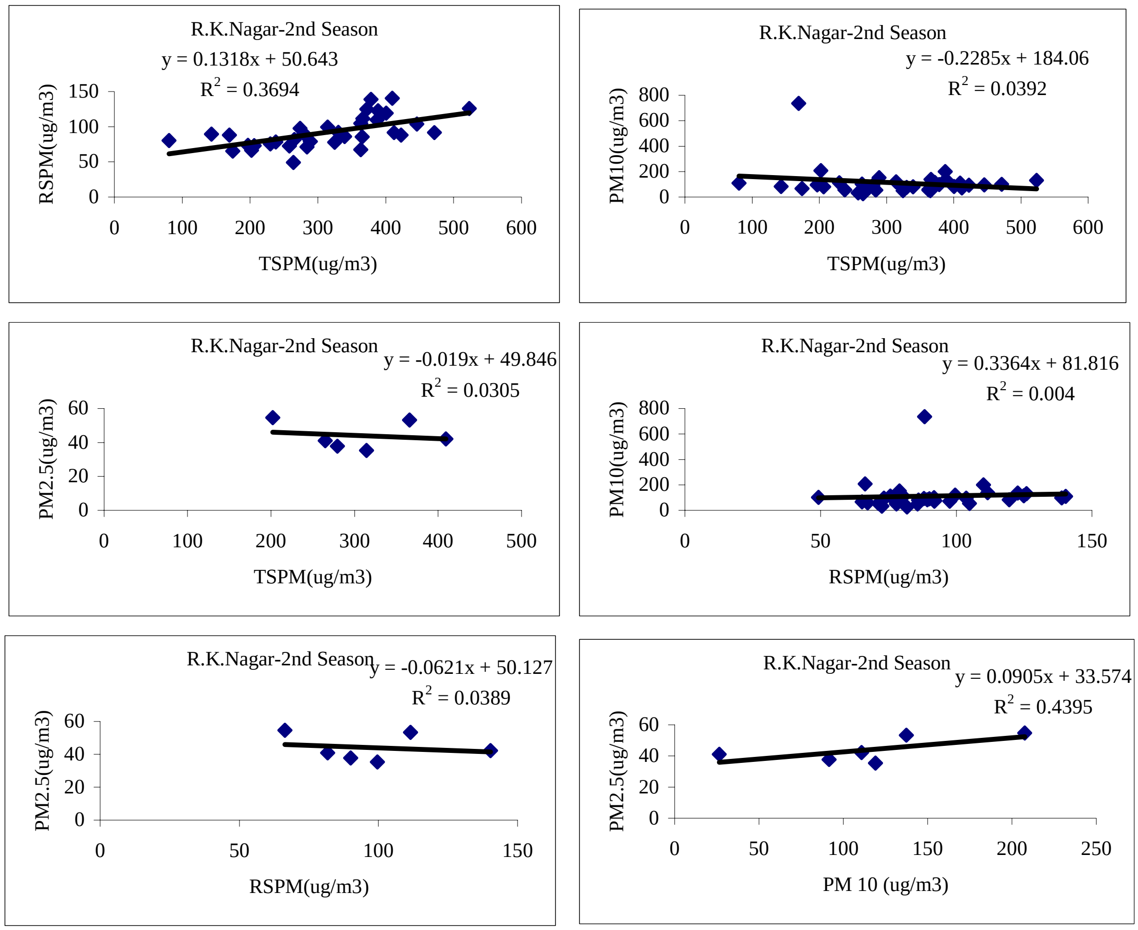


Figure 2.5.1.16 Correlation of PM parameters at R K Nagar (Industrial) – Season 2

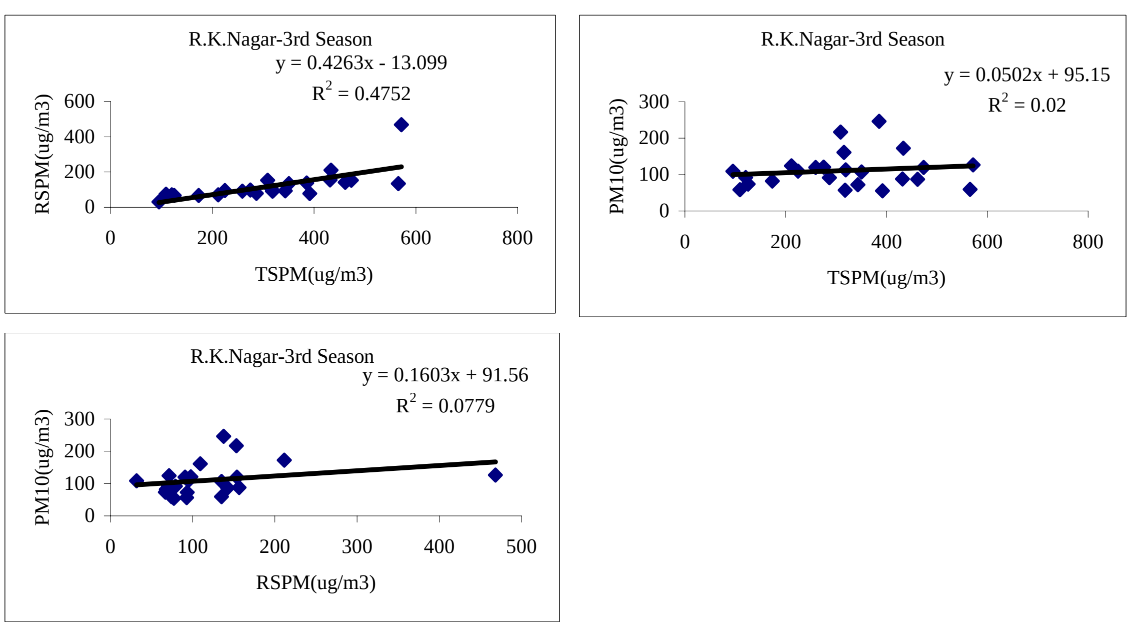


Figure 2.5.1.17 Correlation of PM parameters at R K Nagar (Industrial) – Season 3

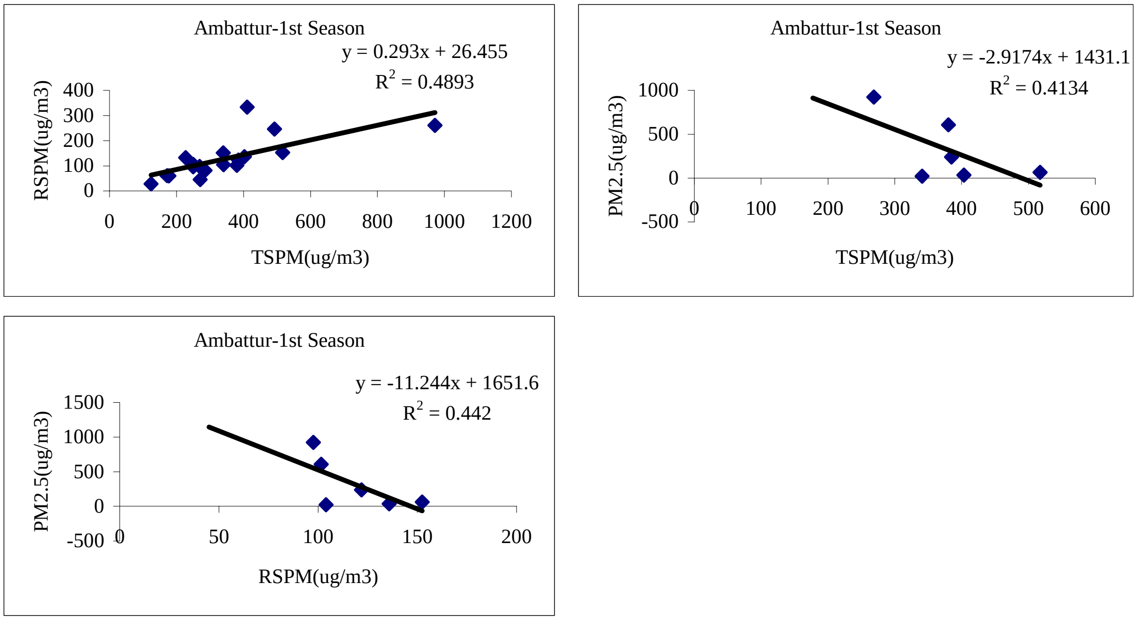


Figure 2.5.1.18 Correlation of PM parameters at Ambattur (Industrial) – Season 1

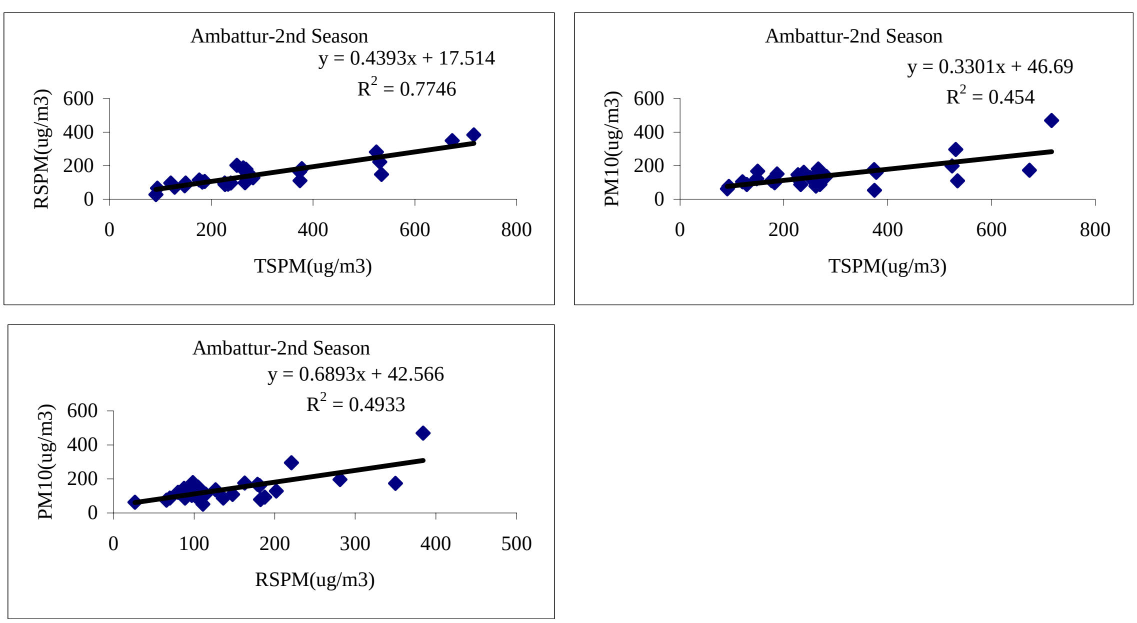


Figure 2.5.1.19 Correlation of PM parameters at Ambattur (Industrial) – Season 2

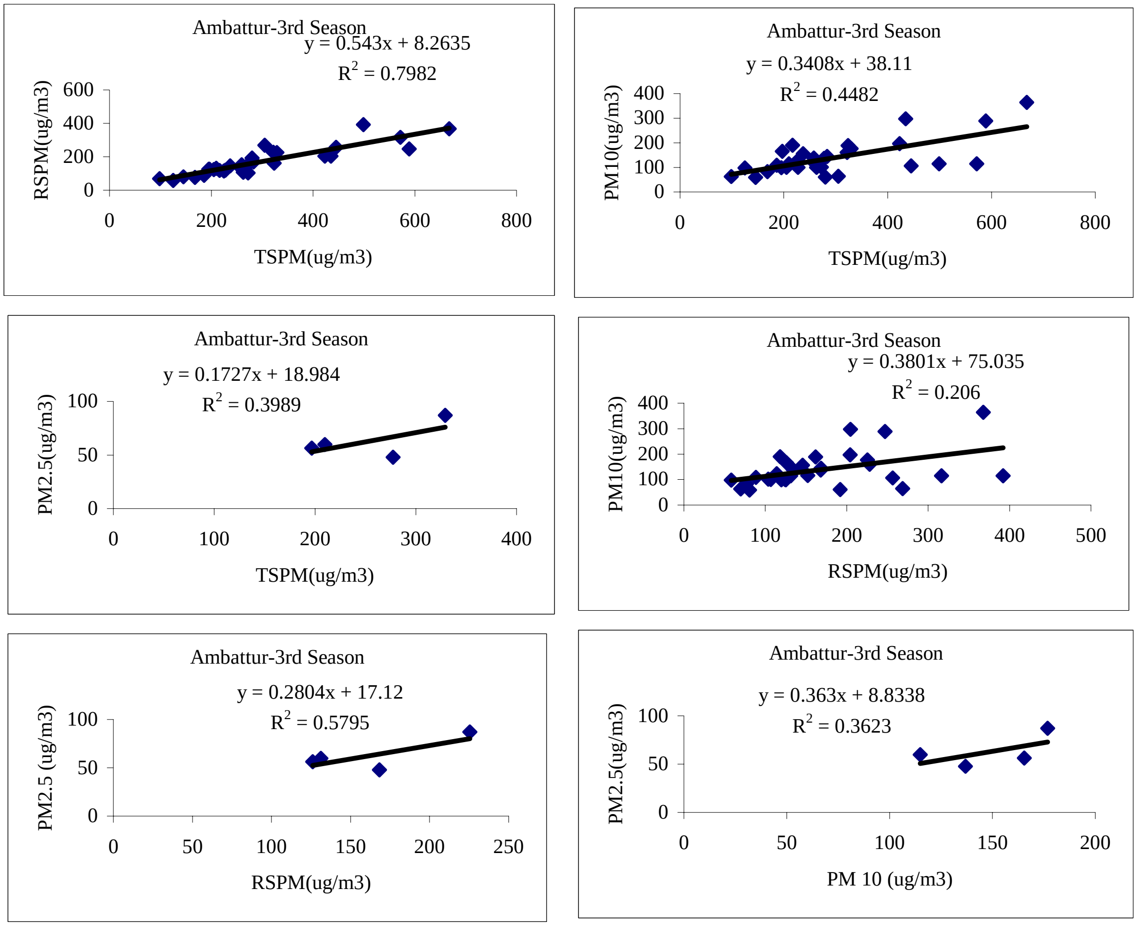
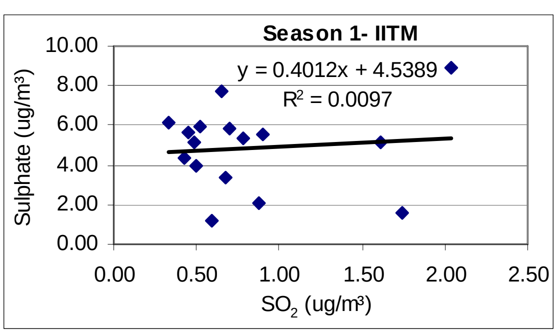
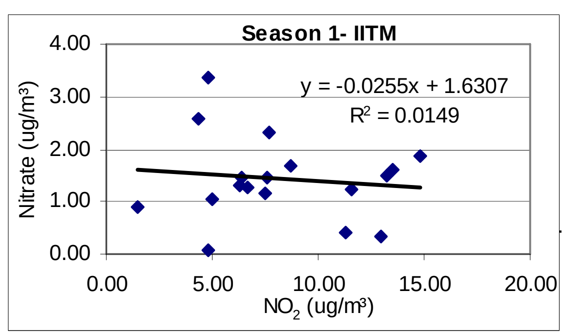


Figure 2.5.1.20 Correlation of PM parameters at Ambattur (Industrial) – Season 3

2.5.2 Correlation between SO_X-SO_4^- / NO_x-NO_3

Figure 2.5.2.1 to 2.5.2.21 show the correlation between the vapor phase SO_2 and the aerosol phase sulphate ion and between the vapor phase NO_2 and the aerosol phase nitrate ion. Review of the correlation plots show that the correlation (r) between SO_2 and sulphate ion are below 0.4 and therefore not significant. A high and consistent correlation would suggest that equilibration between the sulphur in the gas phase and that in the aerosol phase is the only source of sulphate ion. The lack of a significant correlation thus would suggest that the sulphate in the ion may also be coming from a different source. Since the gas phase SO_2 concentrations are very low and the sulphate concentrations are very high, the hypothesis is that there is a conversion of the SO_2 (vapor) → SO_3^{2-} → SO_4^{2-} through a series of absorption and reaction processes. This process may be happening, but since there are no systematic measurements of ozone or other species that





contribute to the conversion of sulphite to sulphate ions in the aerosol phase, one cannot confirm.

Figure 2.5.2.1 Correlation between SO_X-SO_4^- and NO_2-NO_3^- at IITM Season1

Review of the NO_2 and nitrate ion concentration also indicates very low correlation between the two species in most cases. The r values were found to be below 0.4 in most cases except a few where ‘r’ was between 0.0.45 – 0.68. These were found in the kerb and industrial monitoring locations in some monitoring periods. While this does point to an absorptive process, a different source for nitrate ion in addition to the absorption from gas phase NO_x is also contributing.

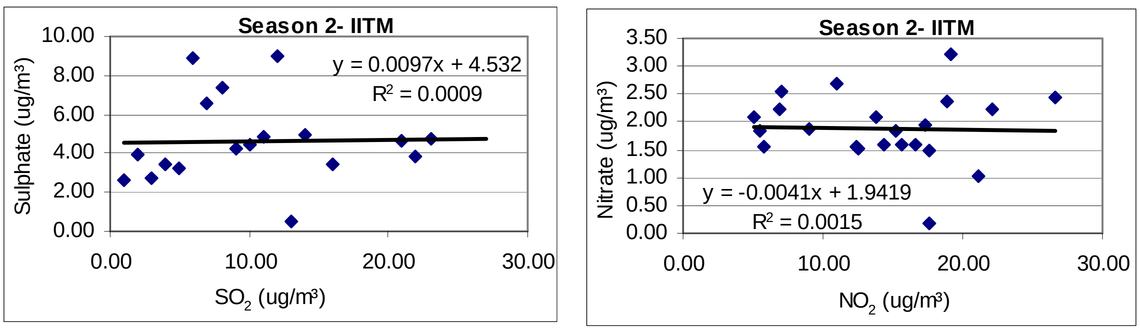


Figure 2.5.2.2 Correlation between SO_X-SO_4^- and NO_2-NO_3^- at IITM Season 2

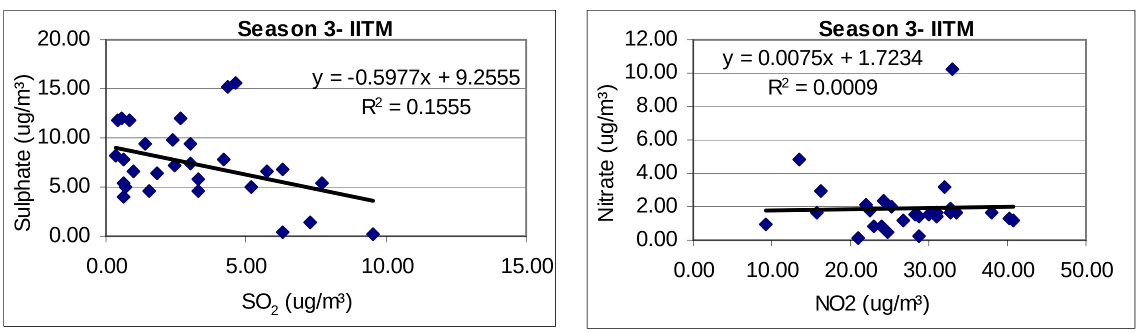


Figure 2.5.2.3 Correlation between SO_X-SO_4^- and NO_2-NO_3^- at IITM Season 3

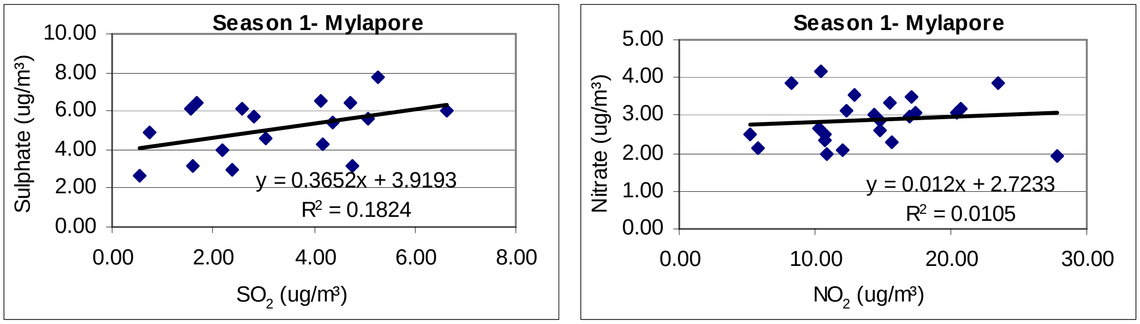


Figure 2.5.2.4 Correlation between SO_X-SO_4^- and NO_2-NO_3^- at Mylapore Season1

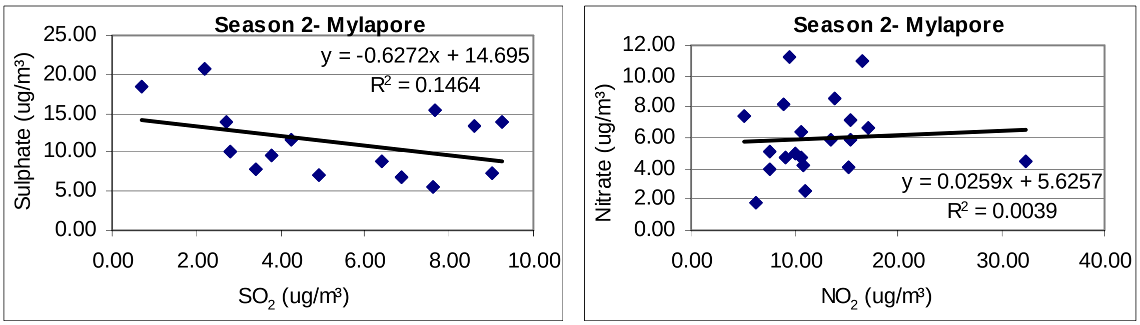


Figure 2.5.2.5 Correlation between SO_X-SO_4^- and NO_2-NO_3^- at Mylapore Season 2

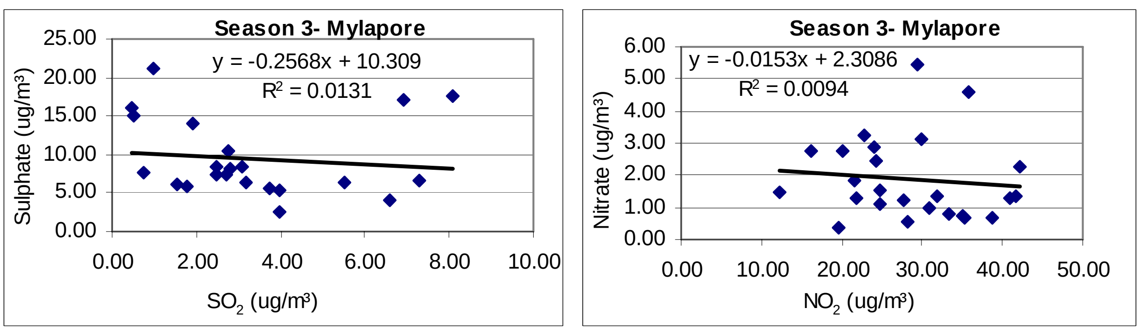


Figure 2.5.2.6 Correlation between SO_X-SO_4^- and NO_2-NO_3^- at Mylapore Season 3

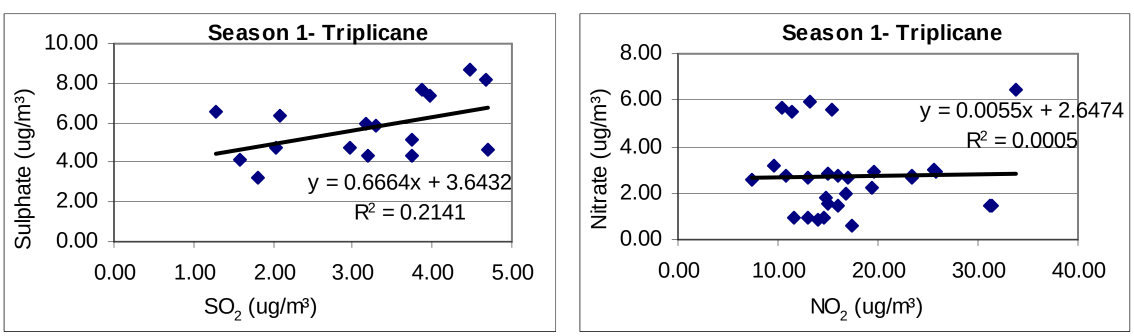


Figure 2.5.2.7 Correlation between SO_X-SO_4^- and NO_2-NO_3^- at Triplicane Season1

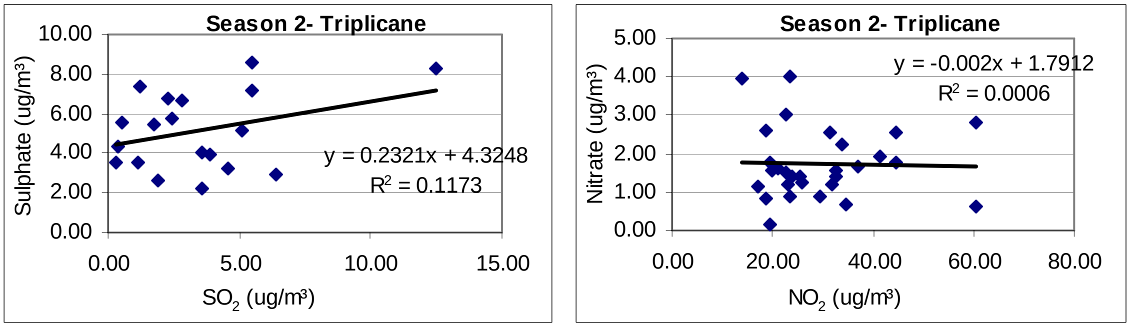


Figure 2.5.2.8 Correlation between SO_X-SO_4^- and NO_2-NO_3^- at Triplicane Season 2

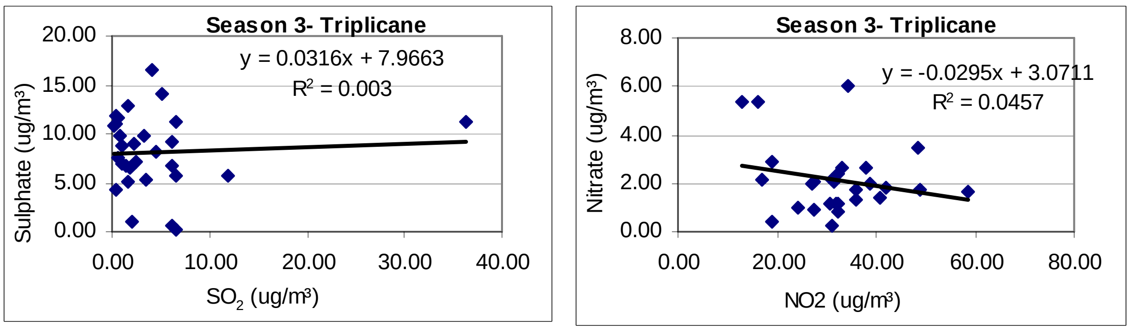


Figure 2.5.2.9 Correlation between SO_X-SO_4^- and NO_2-NO_3^- at Triplicane Season 3

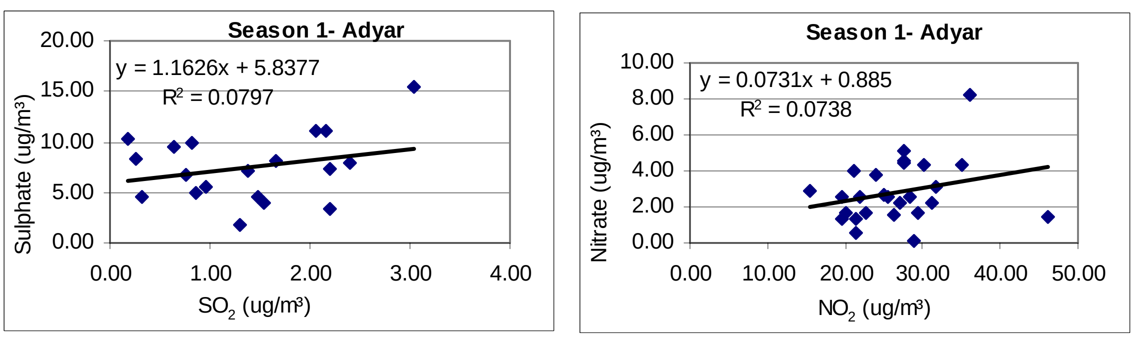


Figure 2.5.2.10 Correlation between SO_X-SO_4^- and NO_2-NO_3^- at Adyar Season1

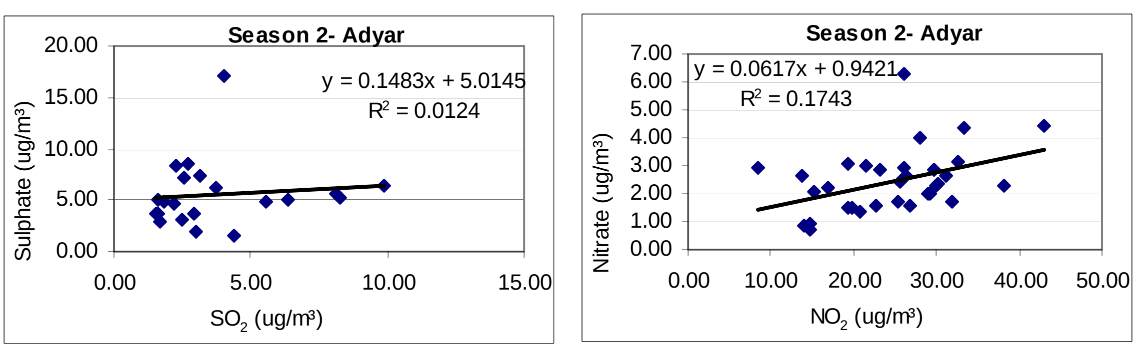


Figure 2.5.2.11 Correlation between SO_X-SO_4^- and NO_2-NO_3^- at Adyar Season 2

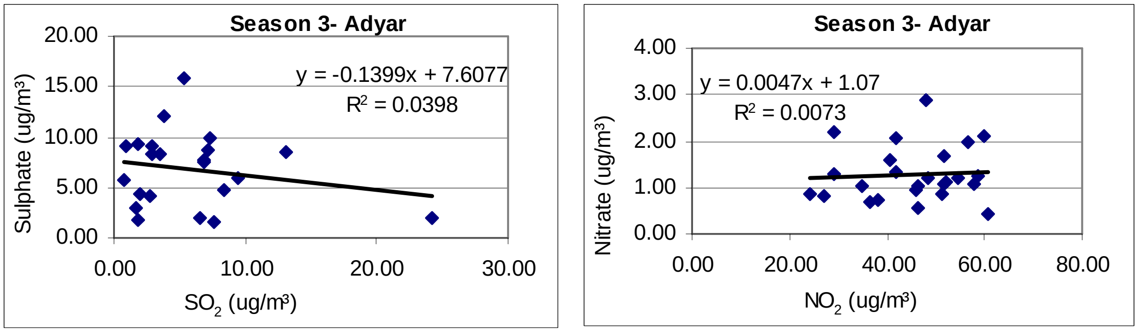


Figure 2.5.2.12 Correlation between SO_X-SO_4^- and NO_2-NO_3^- at Adyar Season 3

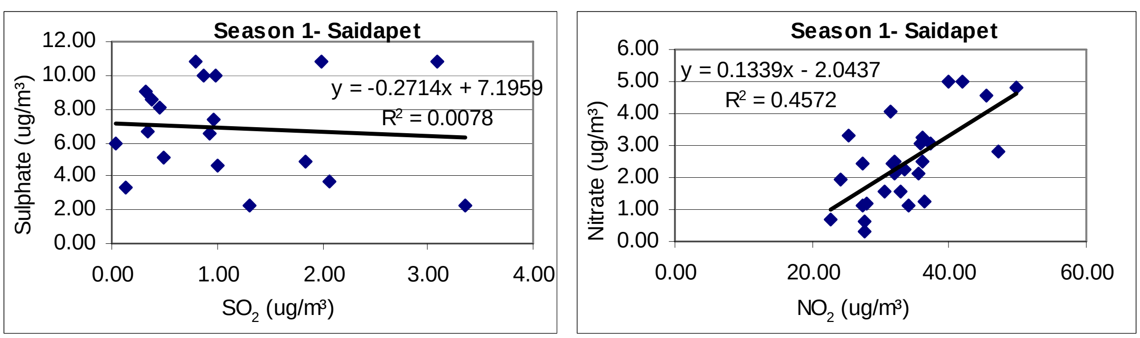


Figure 2.5.2.13 Correlation between SO_X-SO_4^- and NO_2-NO_3^- at Saidapet Season1

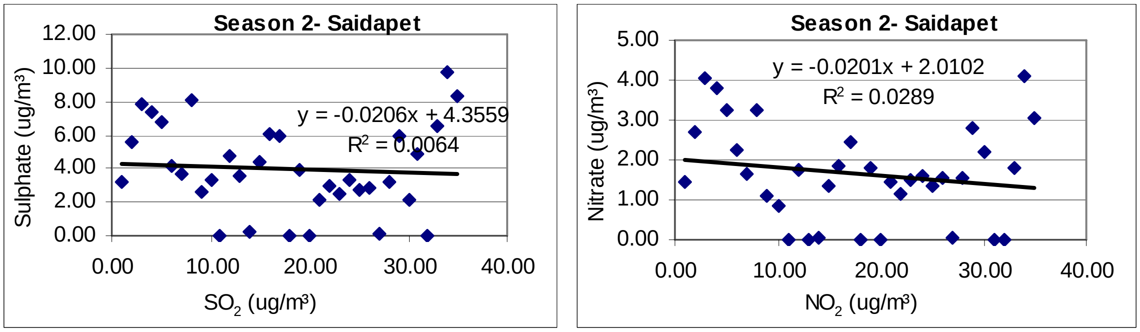


Figure 2.5.2.14 Correlation between SO_X-SO_4^- and NO_2-NO_3^- at Saidapet Season 2

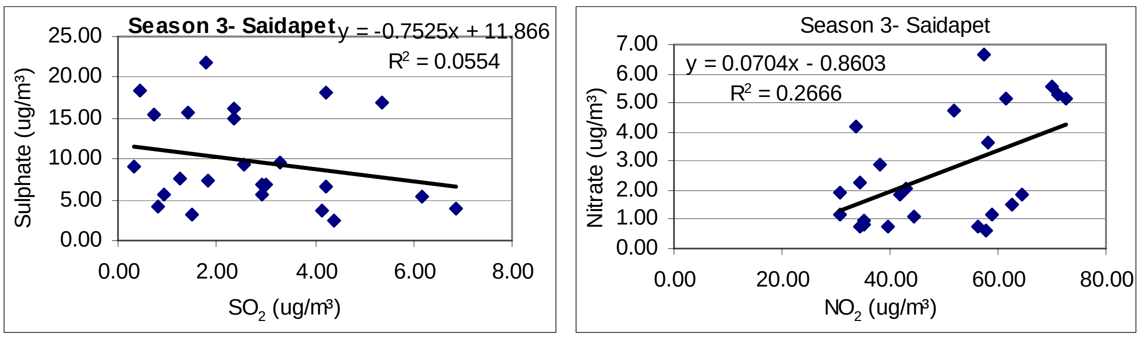


Figure 2.5.2.15 Correlation between SO_X-SO_4^- and NO_2-NO_3^- at Saidapet Season 3

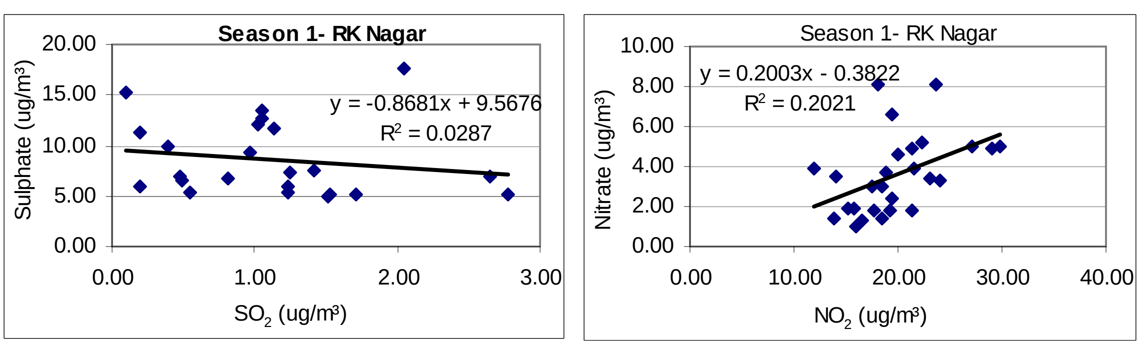


Figure 2.5.2.16 Correlation between SO_X-SO_4^- and NO_2-NO_3^- at R.K.Nagar Season1

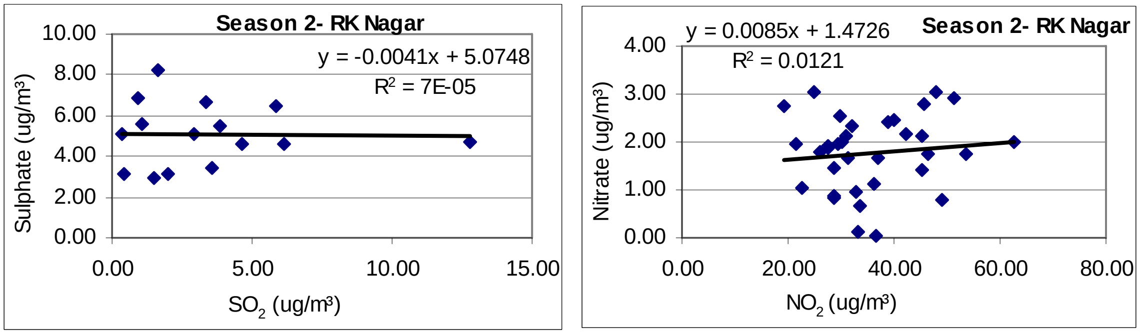


Figure 2.5.2.17 Correlation between SO_X-SO_4^- and NO_2-NO_3^- at R.K.Nagar Season 2

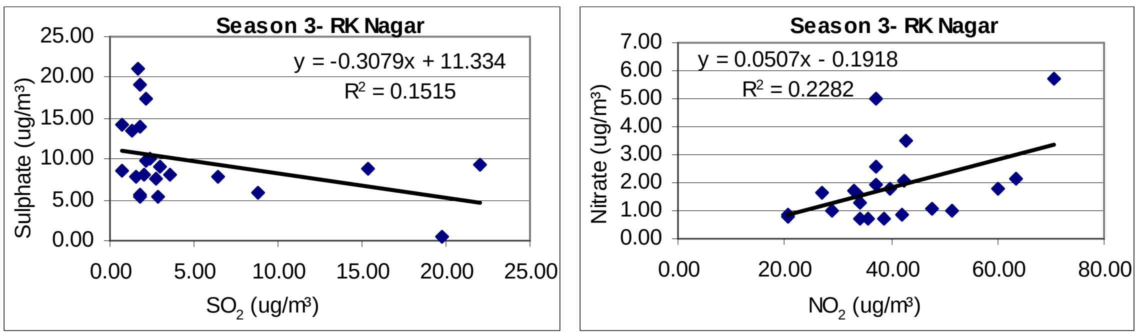


Figure 2.5.2.18 Correlation between SO_X-SO_4^- and NO_2-NO_3^- at R.K.Nagar Season 3

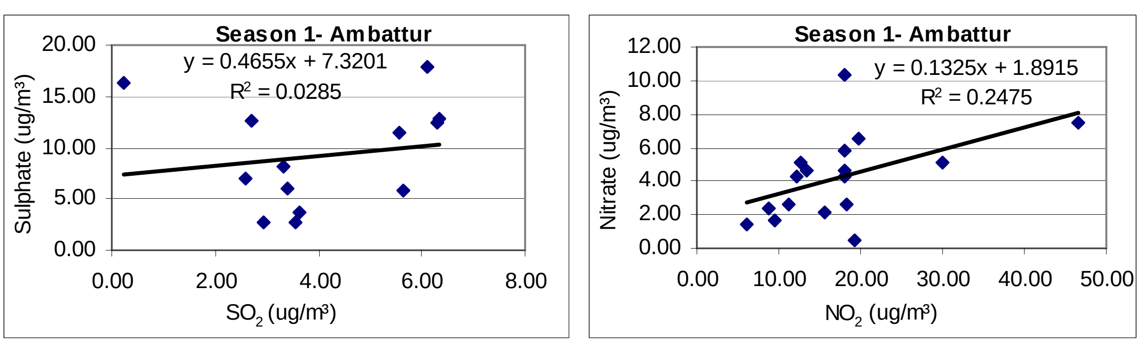
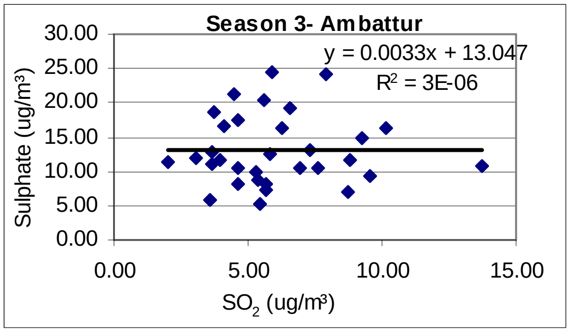
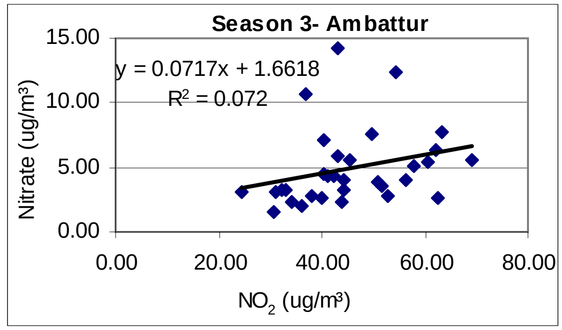
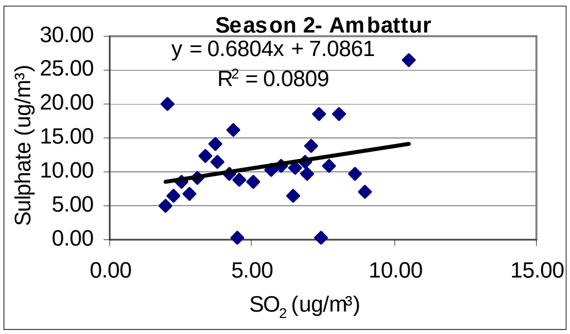


Figure 2.5.2.19 Correlation between SO_X-SO_4^- and NO_2-NO_3^- at Ambattur Season1
Figure 2.5.2.20 Correlation between SO_X-SO_4^- and NO_2-NO_3^- at Ambattur Season 2







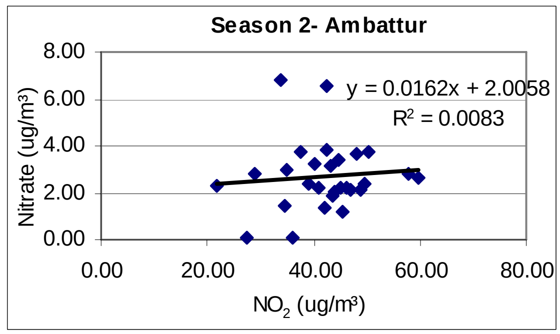
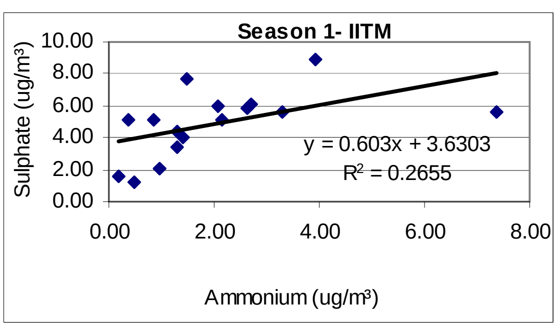


Figure 2.5.2.21 Correlation between SO_X-SO_4^- and NO_2-NO_3^- at Ambattur Season 3

2.5.3 Correlation between SO_4^-, NO_3^- / $NH4^+$

Figure 2.5.3.1 to 2.5.3.21 show the correlation of sulphate and nitrate ions with ammonium ions respectively. A strong correlation suggests that the sulphate and nitrate ions are associated with ammonium in the aerosol phase. Review of the correlation coefficients (r) shows that there is a positive correlation between sulphate and ammonium ions and these values are between 0.073 and 0.942 (with a mean of 0.528). Similarly a positive correlation exists between the nitrate and ammonium ions with the r values ranging between 0.056 and 0.784 (mean of 0.398). This indicates that in most cases, there is a significant correlation suggesting the presence of ammonium nitrate and ammonium sulphate in the atmospheric aerosols.



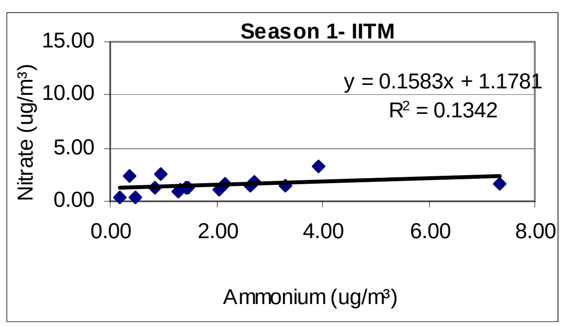


Figure 2.5.3.1 Correlation between SO_4^-, NO_3^- / $NH4^+$ at IITM Season1

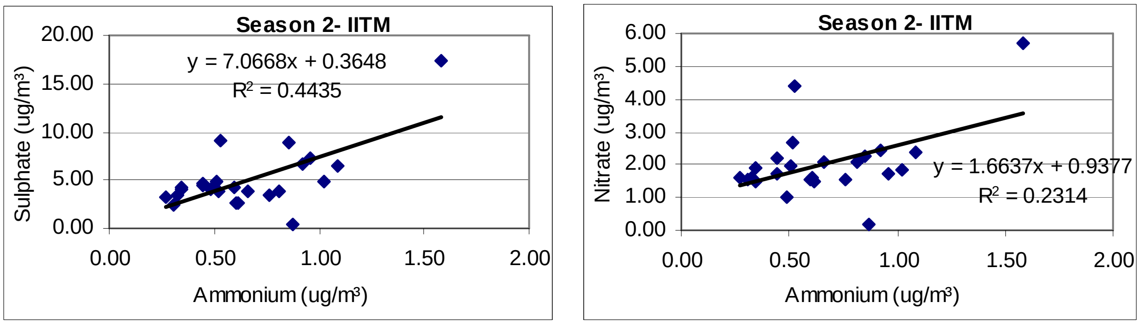


Figure 2.5.3.2 Correlation between SO_4^-, NO_3^- / $NH4^+$ at IITM Season2

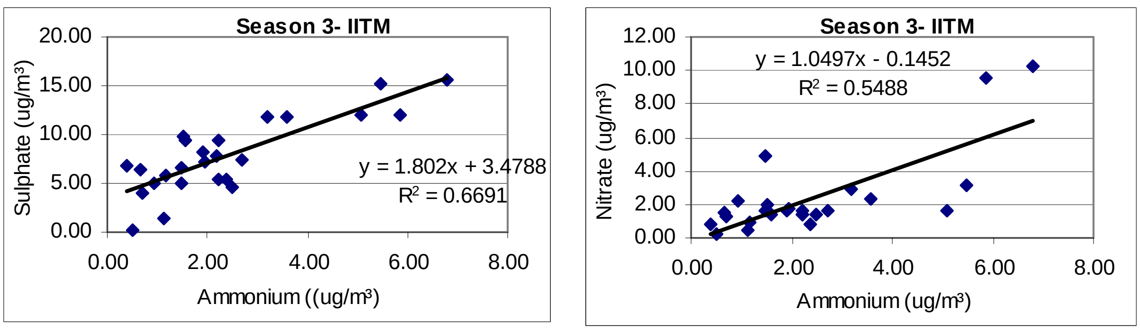


Figure 2.5.3.3 Correlation between SO_4^-, NO_3^- / $NH4^+$ at IITM Season3

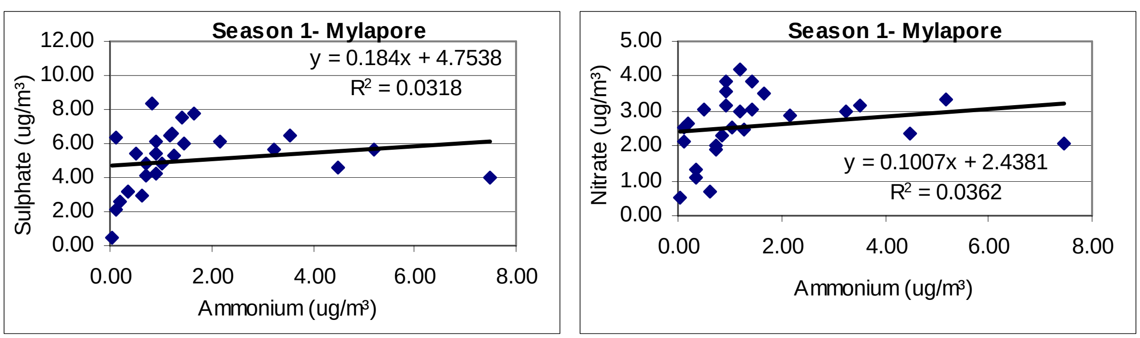


Figure 2.5.3.4 Correlation between SO_4^-, NO_3^- / $NH4^+$ at Mylapore Season1

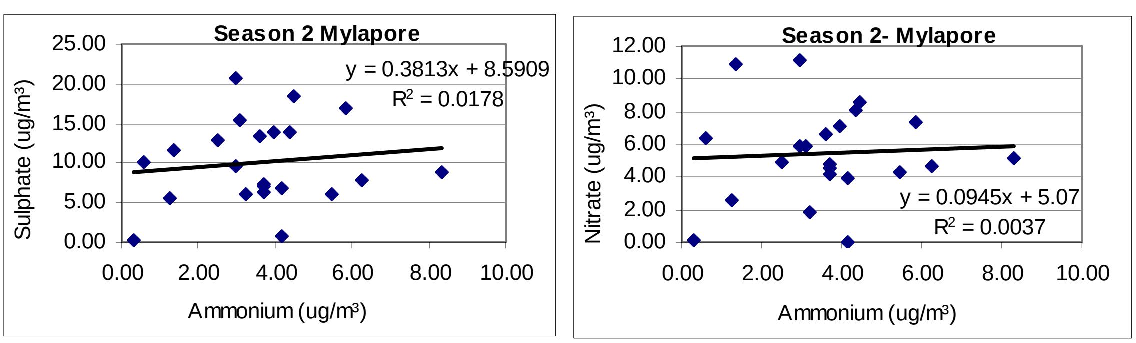


Figure 2.5.3.5 Correlation between SO_4^-, NO_3^- / $NH4^+$ at Mylapore Season2

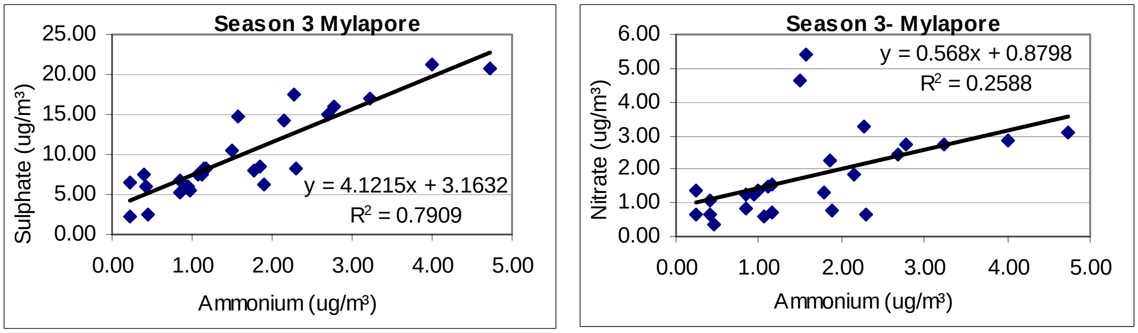


Figure 2.5.3.6 Correlation between SO_4^-, NO_3^- / $NH4^+$ at Mylapore Season3

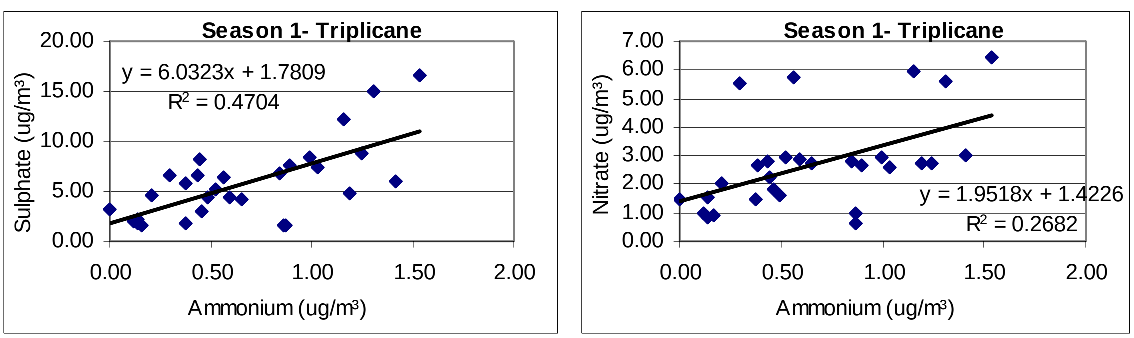


Figure 2.5.3.7 Correlation between SO_4^-, NO_3^- / $NH4^+$ at Triplicane Season1

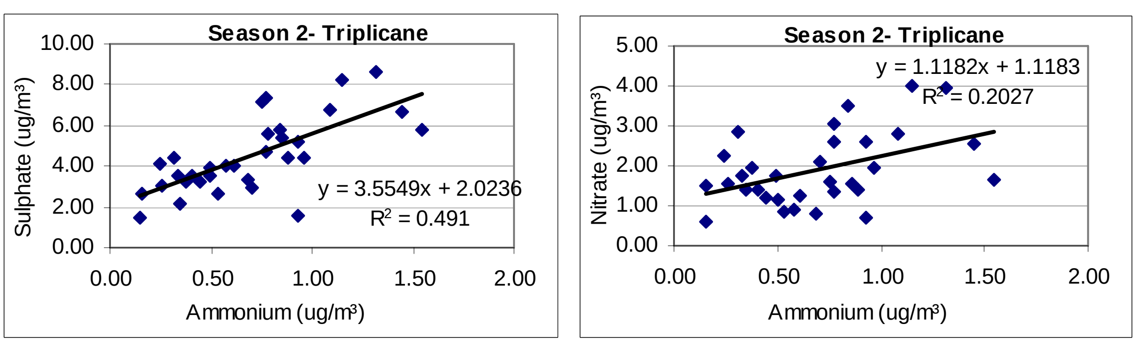


Figure 2.5.3.8 Correlation between SO_4^-, NO_3^- / $NH4^+$ at Triplicane Season 2

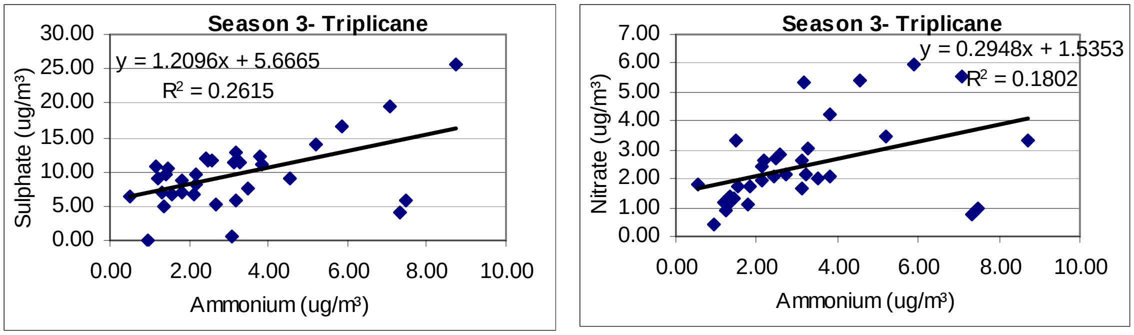


Figure 2.5.3.9 Correlation between SO_4^-, NO_3^- / $NH4^+$ at Triplicane Season 3

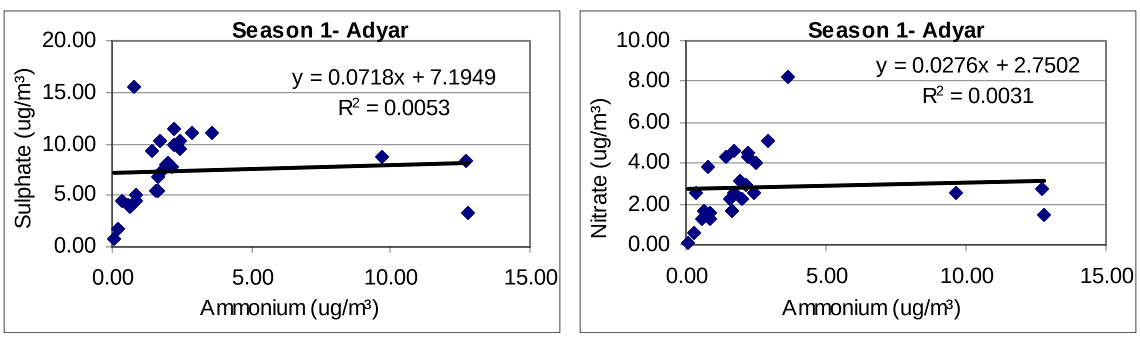


Figure 2.5.3.10 Correlation between SO_4^-, NO_3^- / $NH4^+$ at Adyar Season1

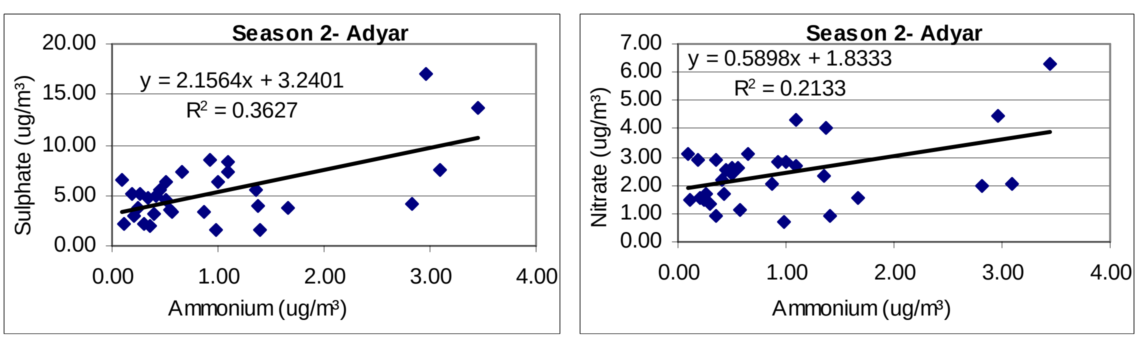


Figure 2.5.3.11 Correlation between SO_4^-, NO_3^- / $NH4^+$ at Adyar Season2

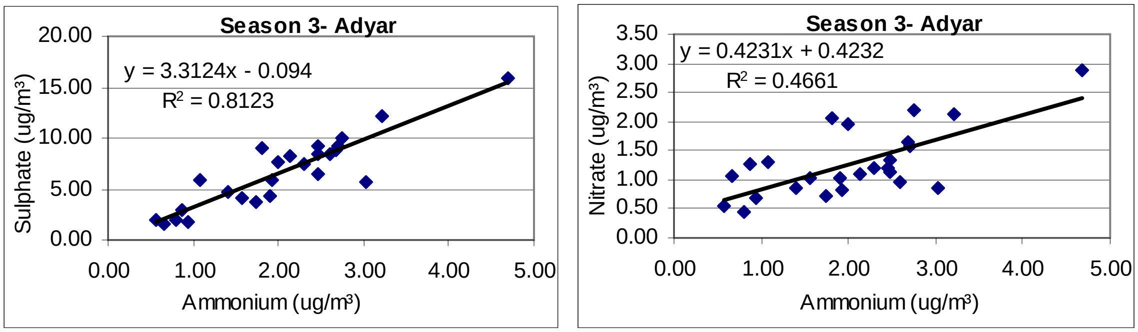


Figure 2.5.3.12 Correlation between SO_4^-, NO_3^- / $NH4^+$ at Adyar Season3

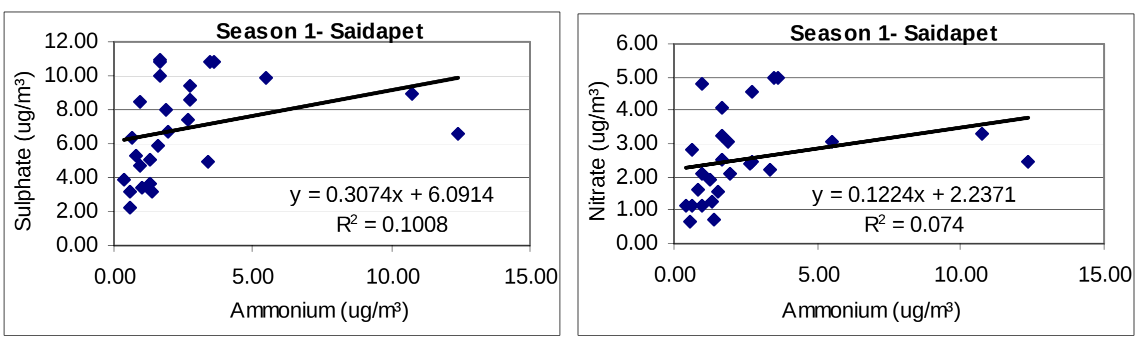


Figure 2.5.3.13 Correlation between SO_4^-, NO_3^- / $NH4^+$ at Saidapet Season1

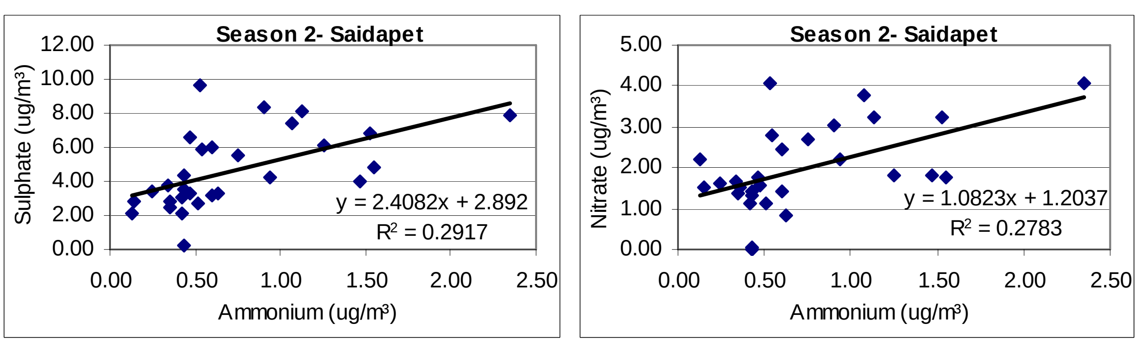


Figure 2.5.3.14 Correlation between SO_4^-, NO_3^- / $NH4^+$ at Saidapet Season 2

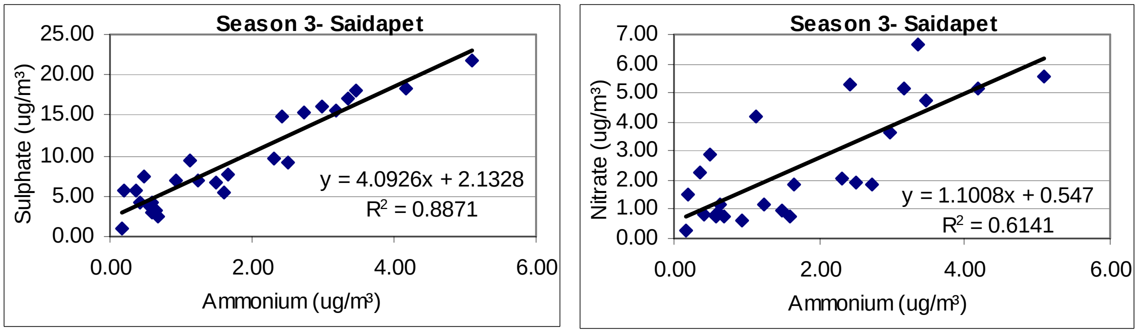


Figure 2.5.3.15 Correlation between SO_4^-, NO_3^- / $NH4^+$ at Saidapet Season 3

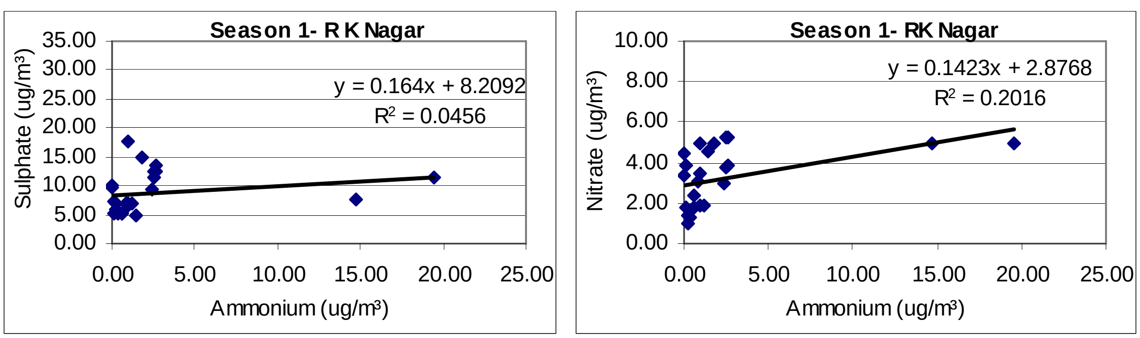


Figure 2.5.3.16 Correlation between SO_4^-, NO_3^- / $NH4^+$ at R.K.Nagar Season1

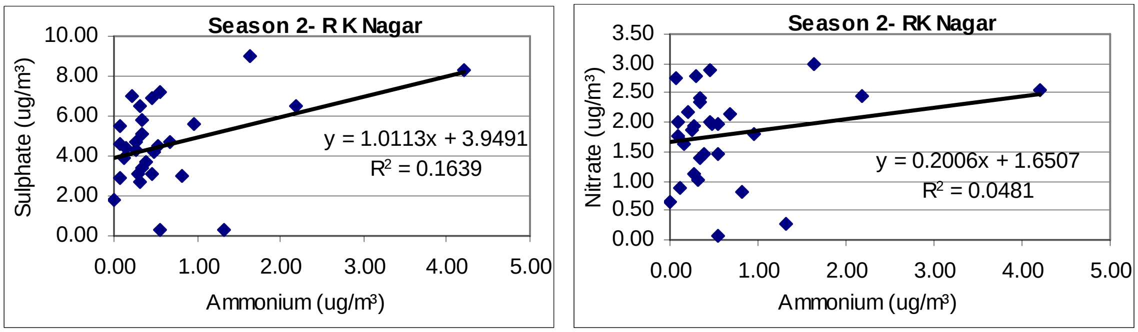


Figure 2.5.3.17 Correlation between SO_4^-, NO_3^- / $NH4^+$ at R.K.Nagar Season 2

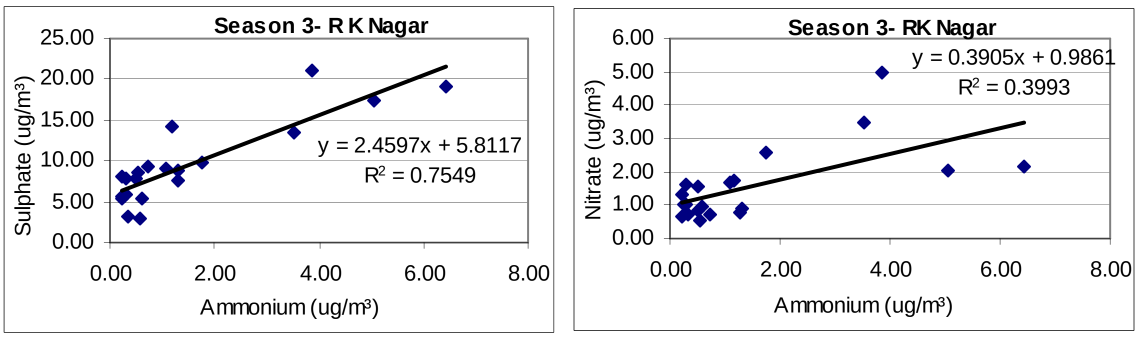


Figure 2.5.3.18 Correlation between SO_4^-, NO_3^- / $NH4^+$ at R.K.Nagar Season 3

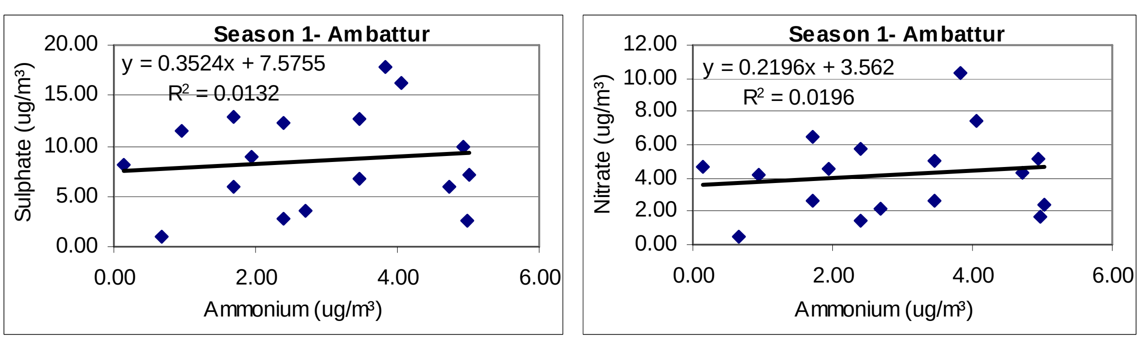


Figure 2.5.3.19 Correlation between SO_4^-, NO_3^- / $NH4^+$ at Ambattur Season1

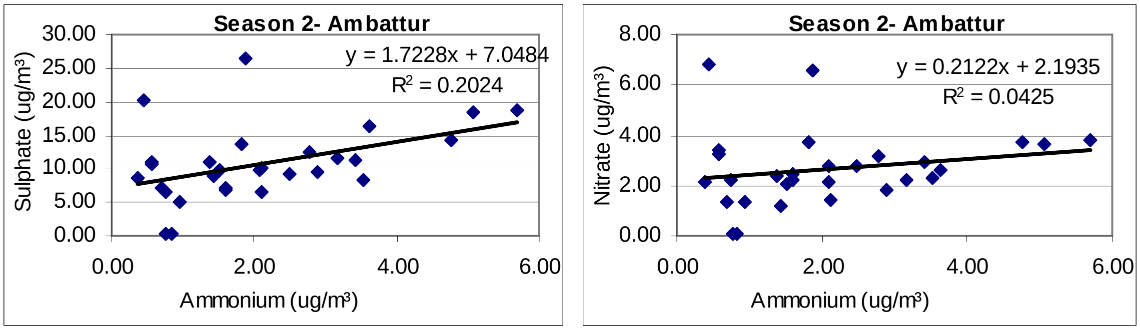


Figure 2.5.3.20 Correlation between SO_4^-, NO_3^- / $NH4^+$ at Ambattur Season2

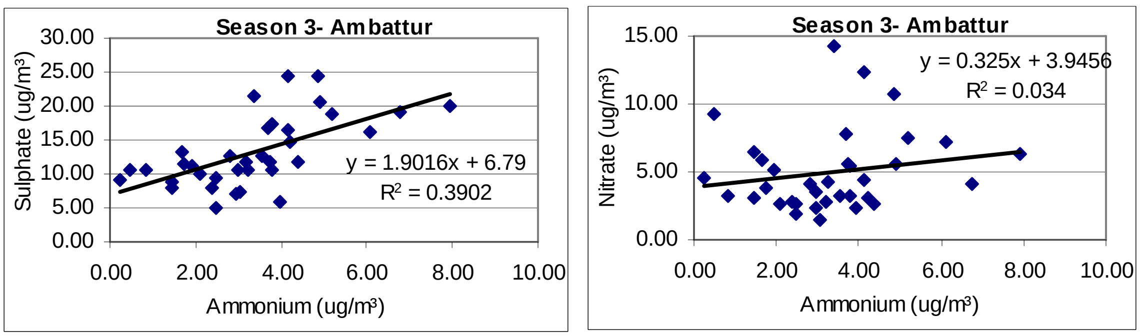


Figure 2.5.3.21 Correlation between SO_4^-, NO_3^- / $NH4^+$ at Ambattur Season3

2.5.4 Correlation between NO_x, OC, PM_{10} / EC

Figure 2.5.4.1 to 2.5.2.20 plots show the correlation between NO_X, OC and PM_{10} vs EC. The average correlation coefficient (r) calculated for NO_x – EC was 0.229 (± 0.179) with a maximum of 0.522, observed at a kerbside site (Adyar). The mean correlation coefficient calculated for OC-EC was 0.701 (± 0.26). There was good correlation with respect to the OC-EC in all sites and all periods of monitoring. This implied that the sources of OC/EC are correlated. The most likely source for both these species is automobiles. The correlation coefficient between PM_{10} and EC was 0.363 ± 0.232, which is ‘mild’. This implies that there is some correlation between the PM_{10} and the EC, possibly coming from the same source. Since EC is very specific to vehicles, this implies a partial correlation of the PM_{10} to vehicles as well.

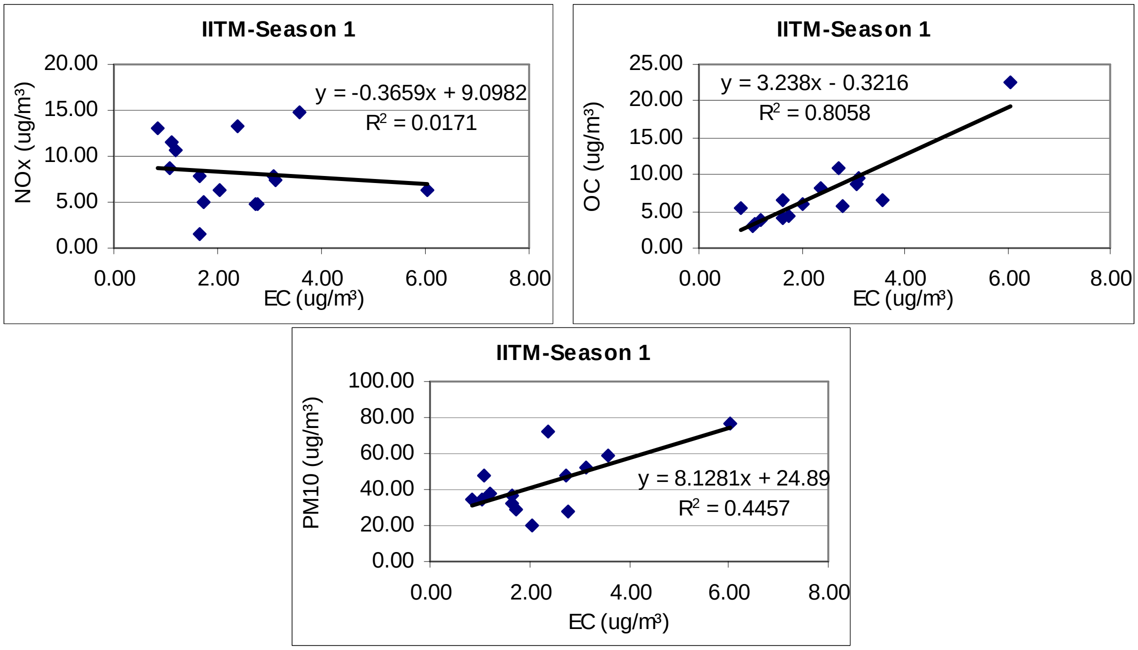


Figure 2.5.4.1 Correlation between NOx, OC, PM_{10} /EC at IITM Season1

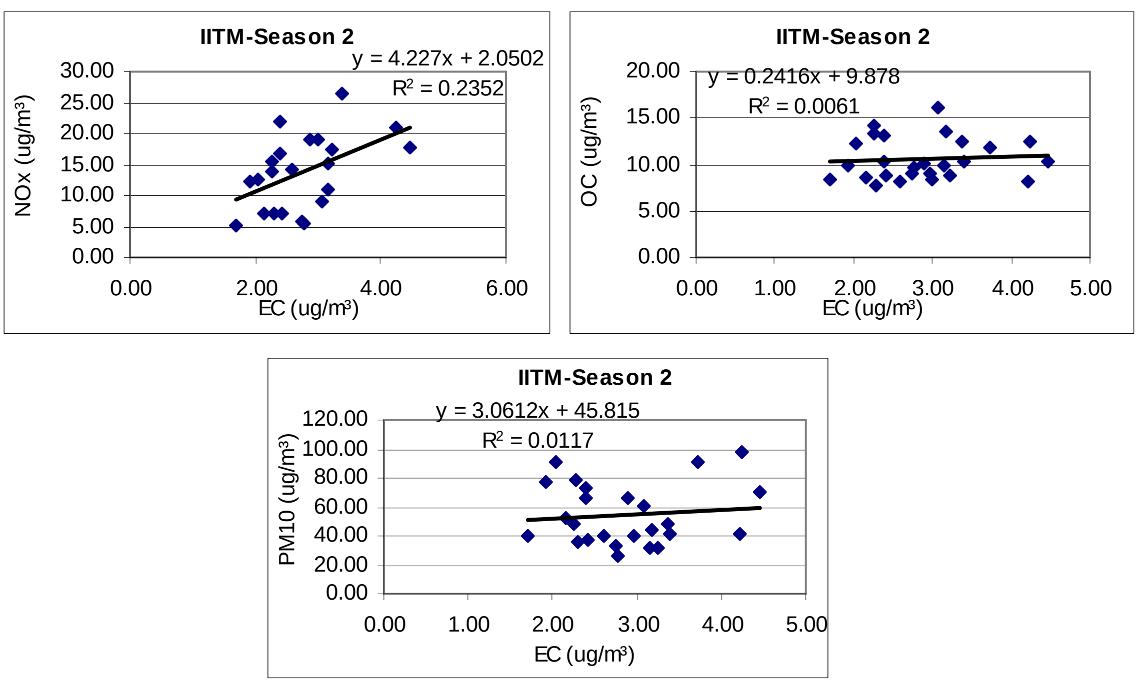


Figure 2.5.4.2 Correlation between NOx, OC, PM_{10} /EC at IITM Season2

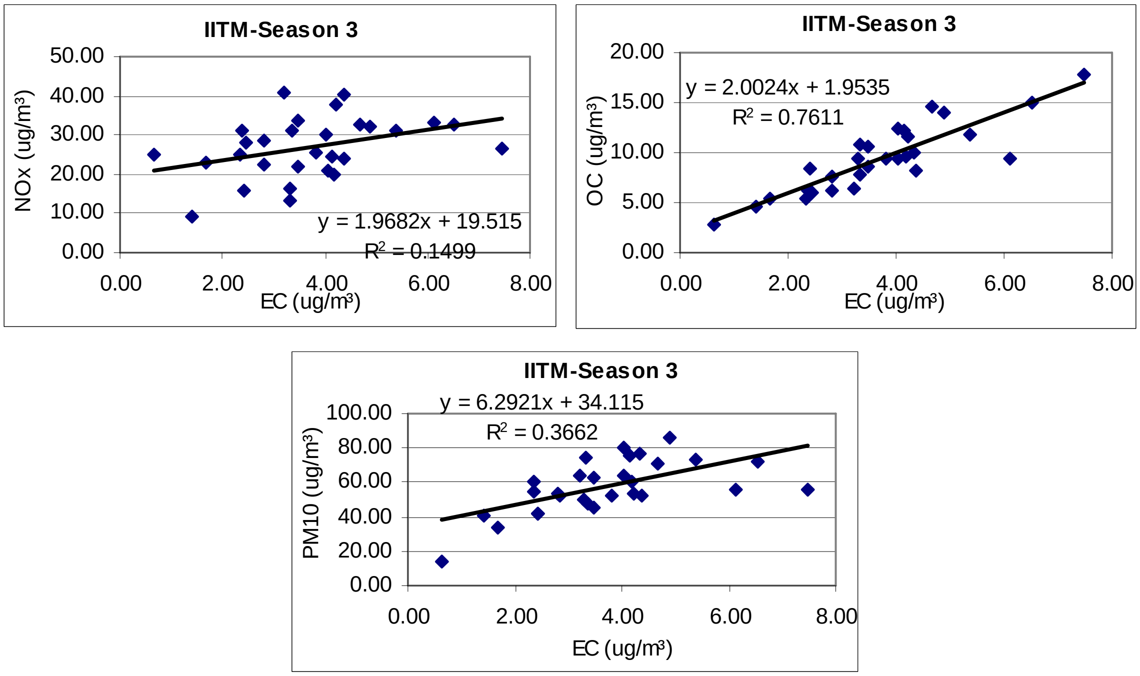


Figure 2.5.4.3 Correlation between NOx, OC, PM_{10} /EC at IITM Season3

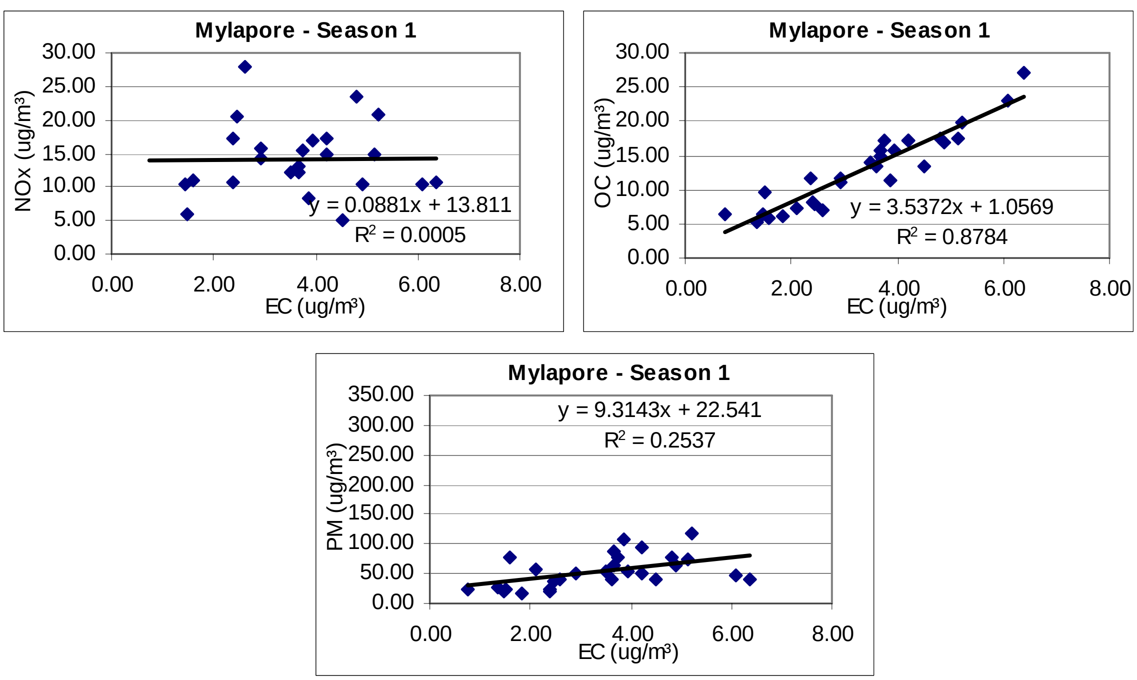


Figure 2.5.4.4 Correlation between NOx, OC, PM_{10} /EC at Mylapore Season1

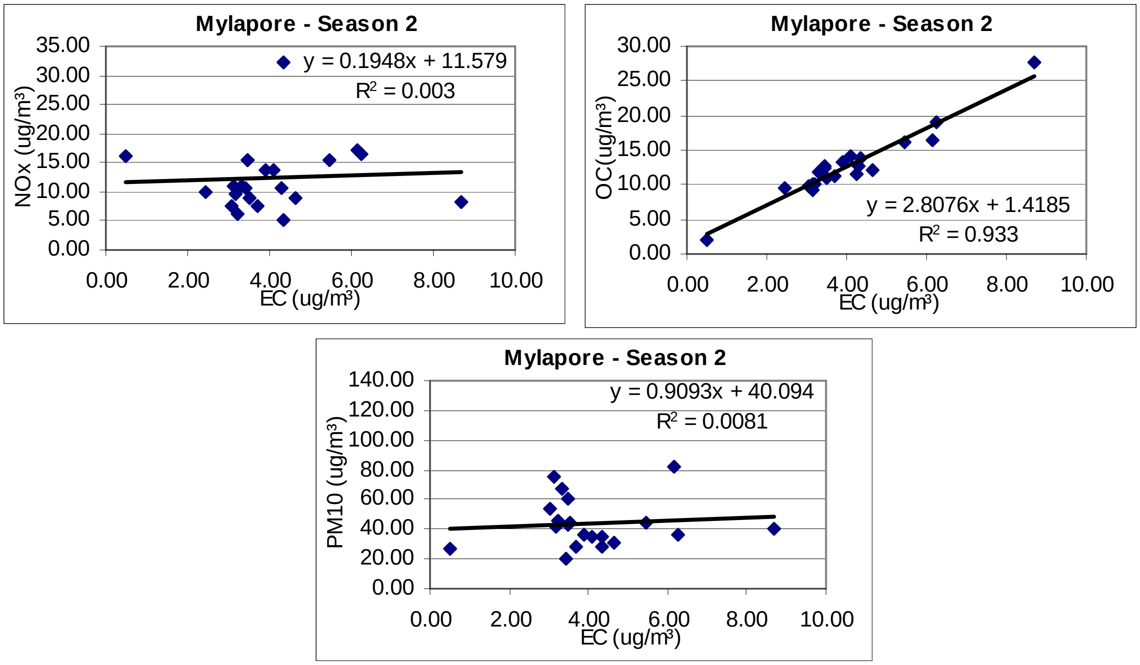


Figure 2.5.4.5 Correlation between NOx, OC, PM_{10} /EC at Mylapore Season2

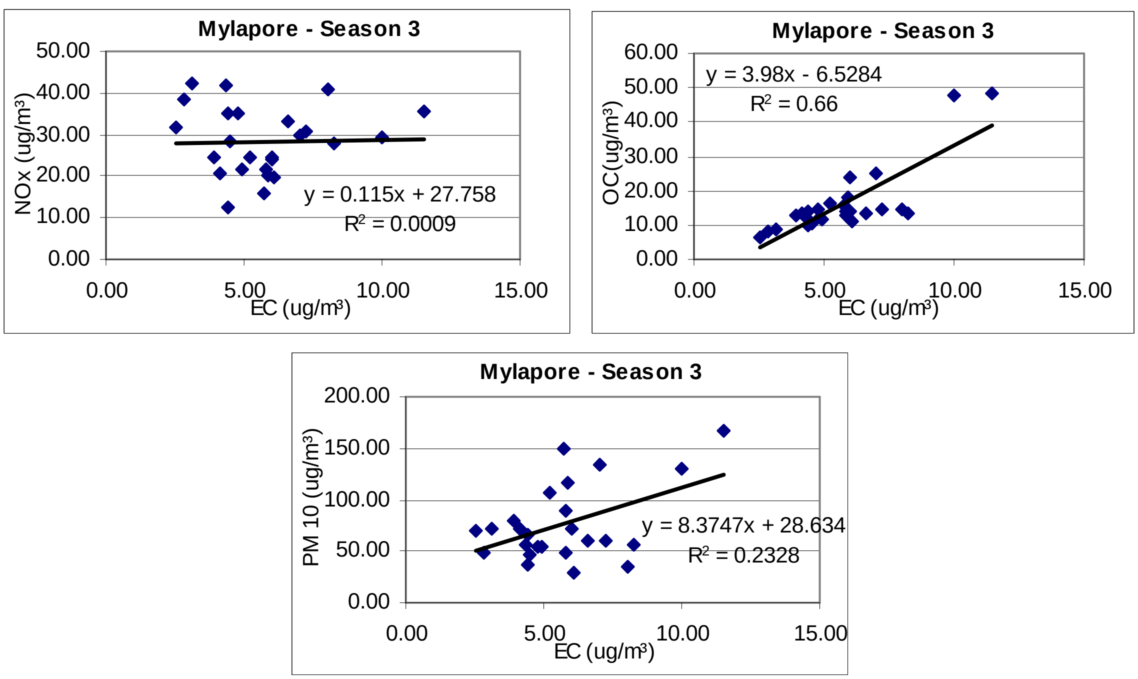


Figure 2.5.4.6 Correlation between NOx, OC, PM_{10} /EC at Mylapore Season3

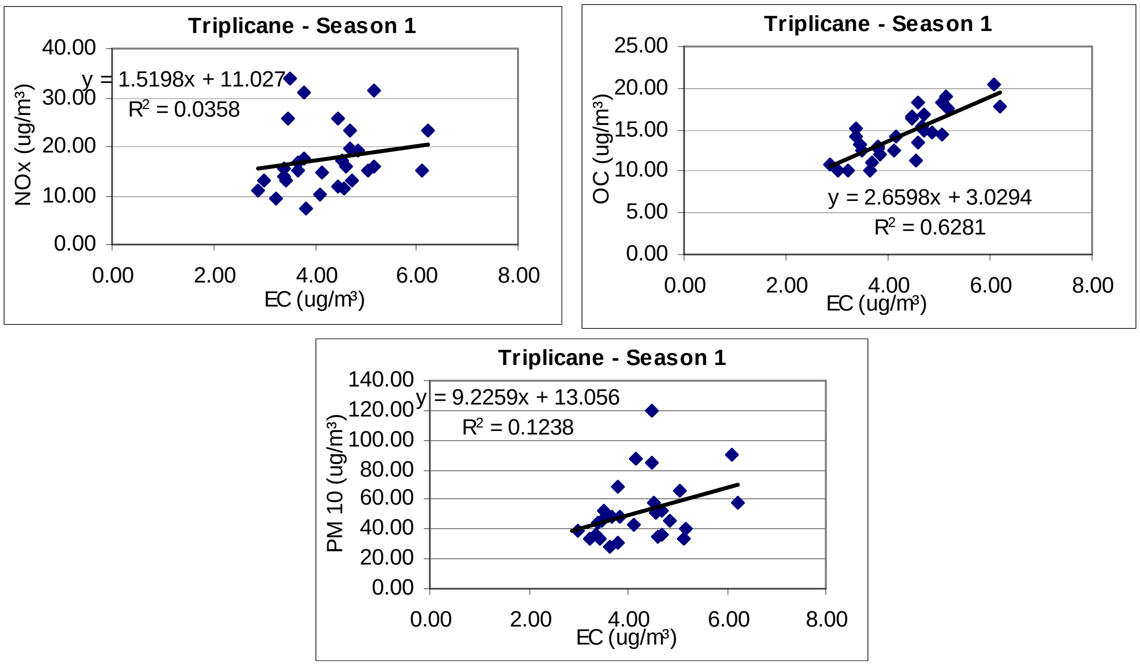


Figure 2.5.4.7 Correlation between NOx, OC, PM_{10} /EC at Triplicane Season1

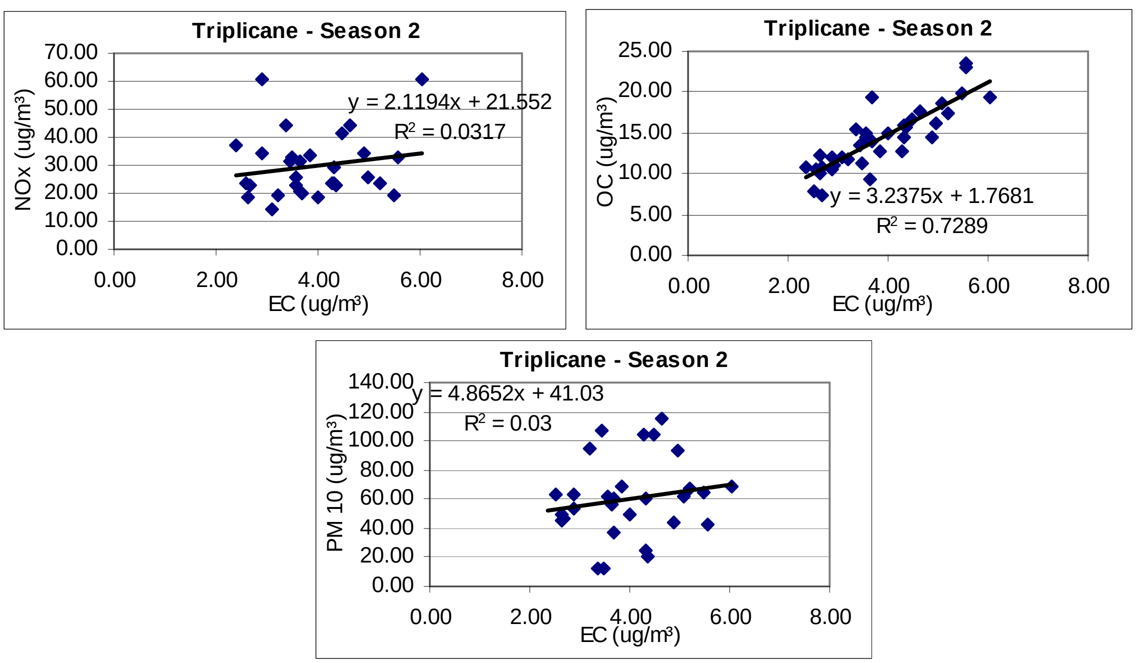


Figure 2.5.4.8 Correlation between NOx, OC, PM_{10} /EC at Triplicane Season2

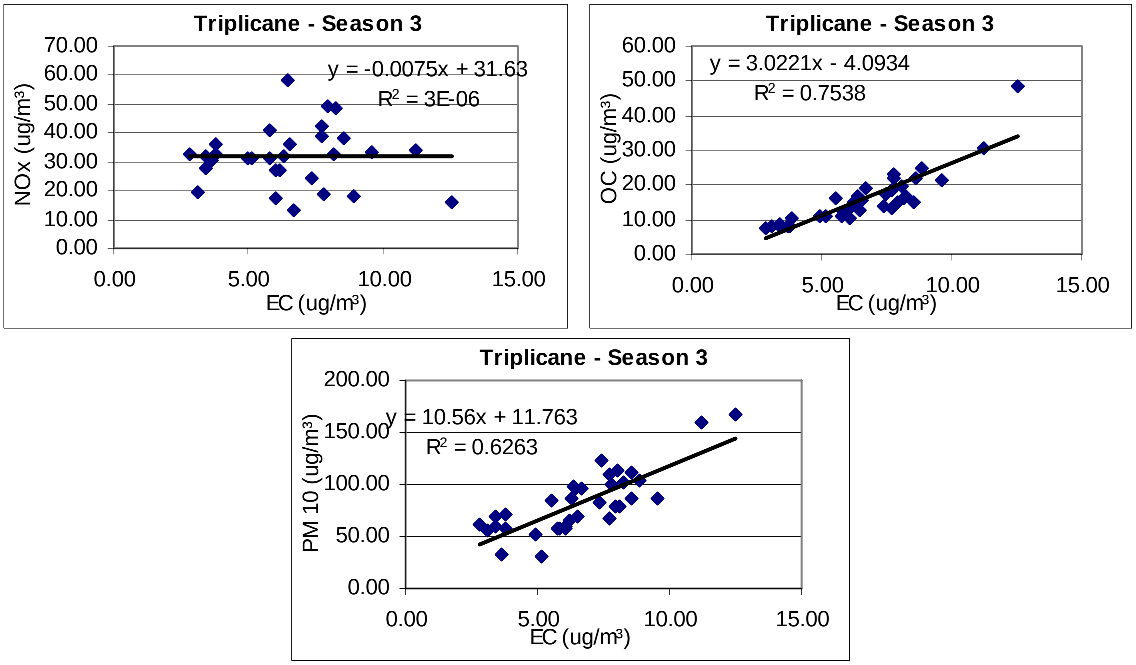


Figure 2.5.4.9 Correlation between NOx, OC, PM_{10} /EC at Triplicane Season3

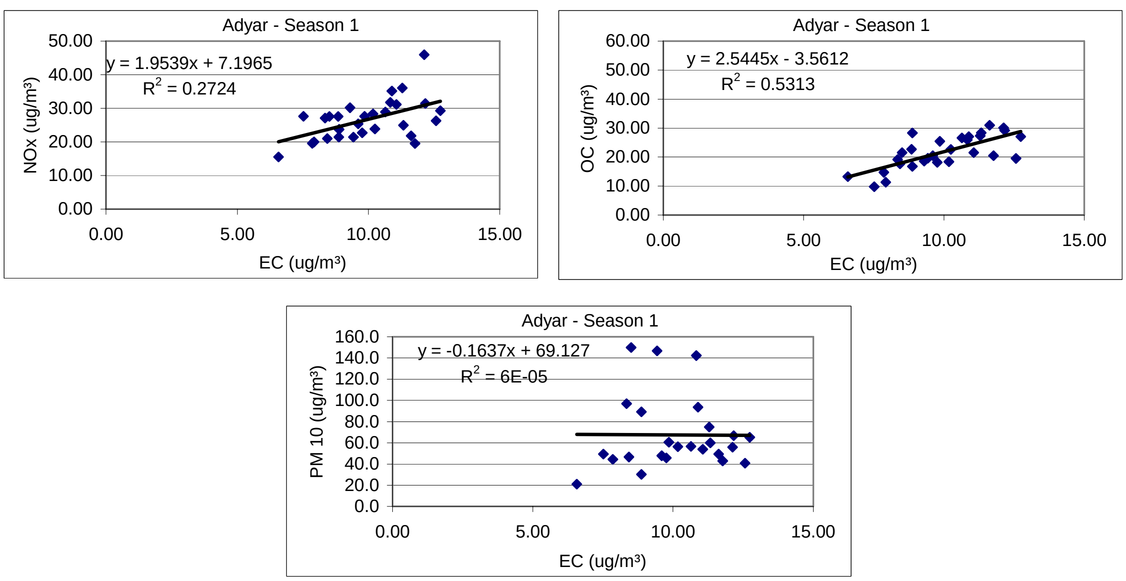


Figure 2.5.4.10 Correlation between NOx, OC, PM_{10} /EC at Adyar Season1

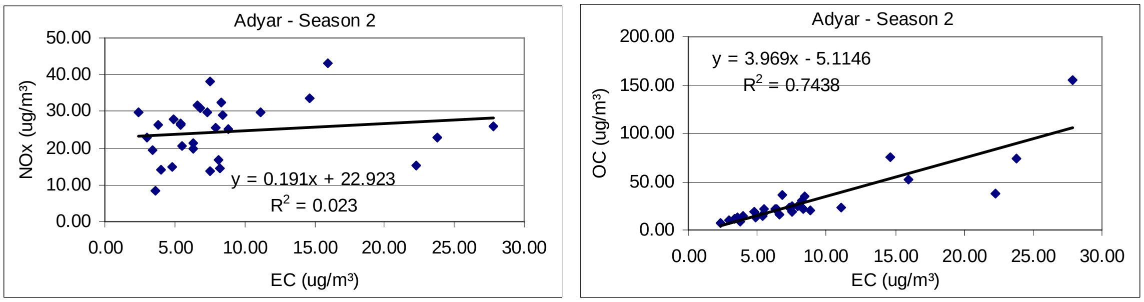


Figure 2.5.4.11 Correlation between NOx, OC, PM_{10} /EC at Adyar Season2

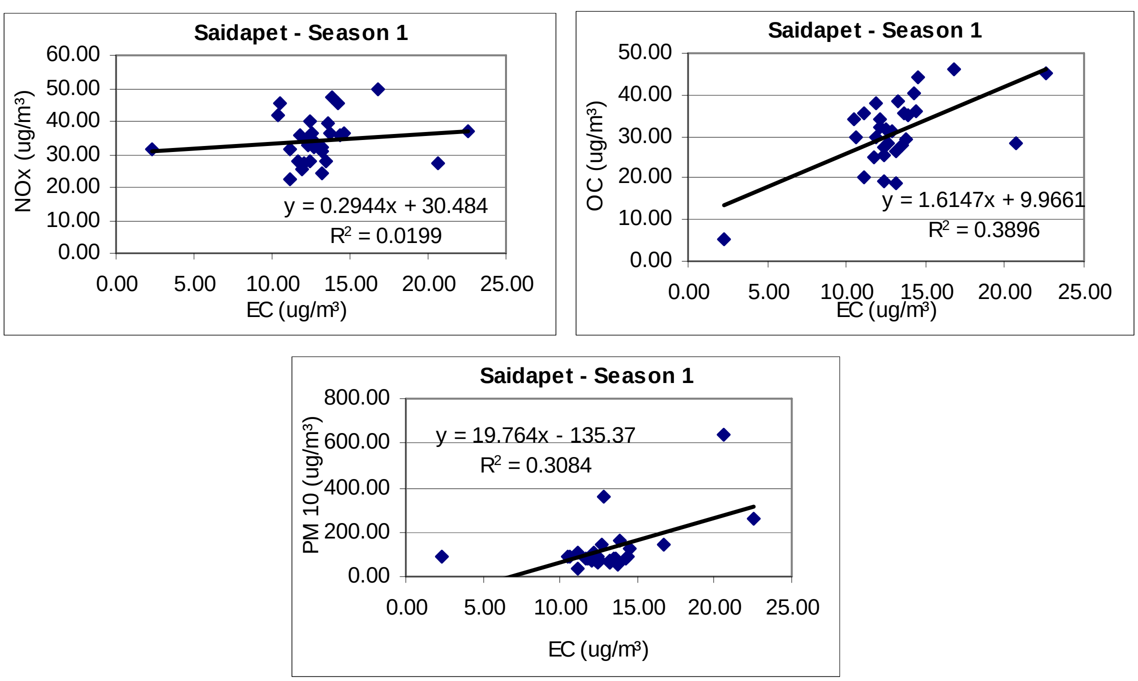


Figure 2.5.4.12 Correlation between NOx, OC, PM_{10} /EC at Saidapet Season1

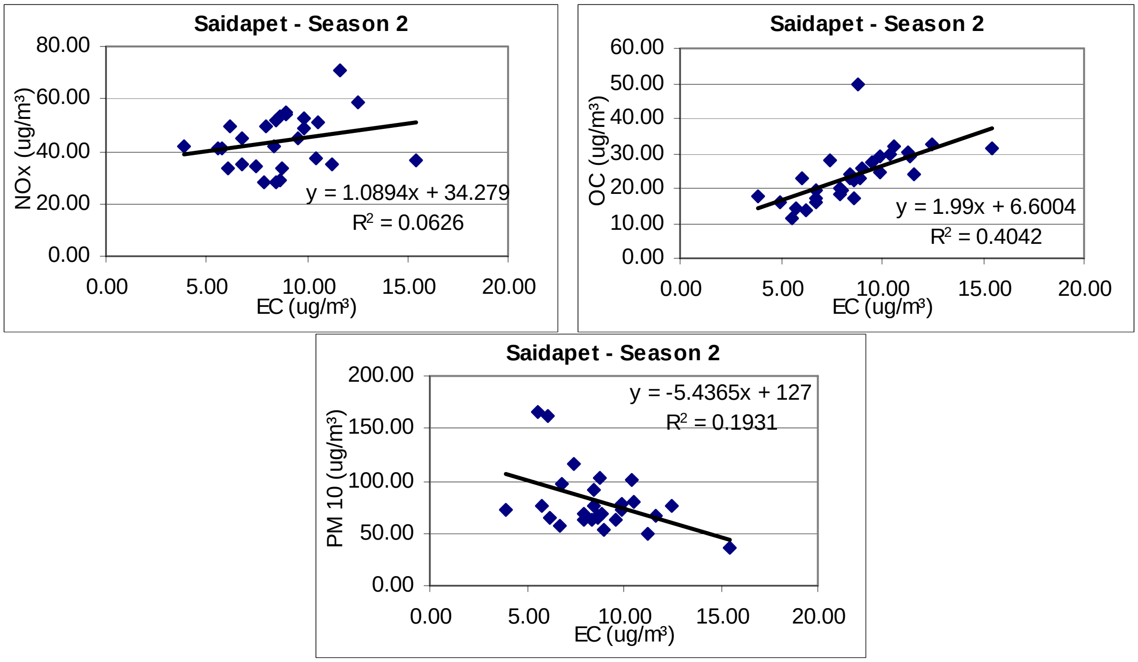


Figure 2.5.4.13 Correlation between NOx, OC, PM_{10} /EC at Saidapet Season2

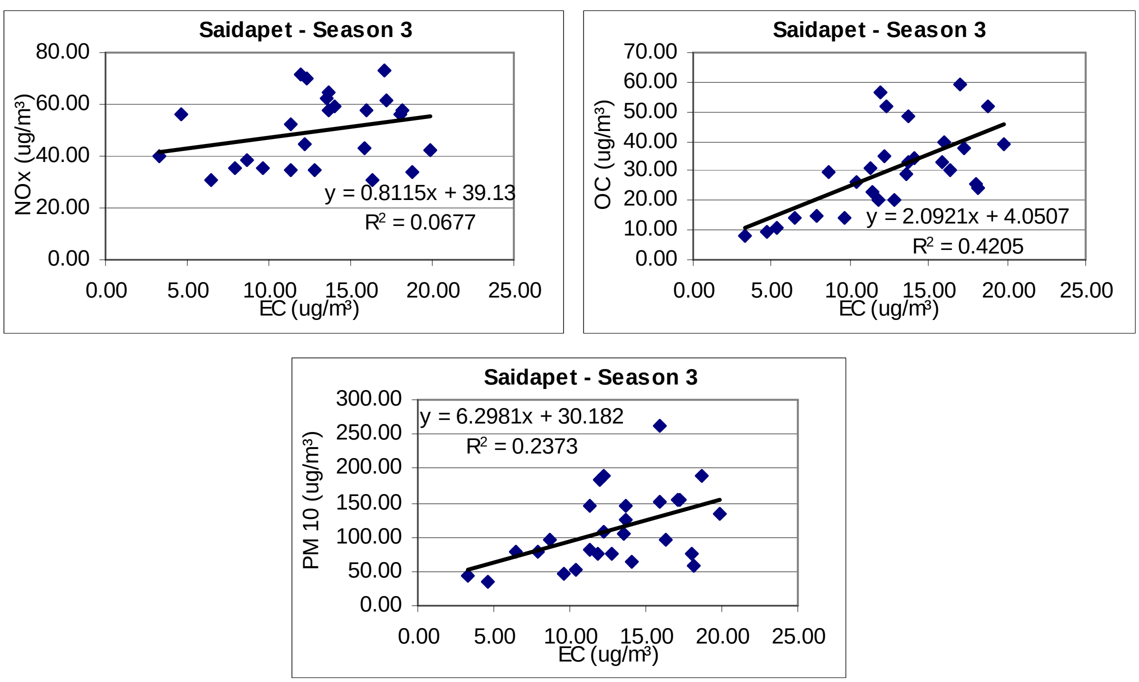


Figure 2.5.4.14 Correlation between NOx, OC, PM_{10} /EC at Saidapet Season3

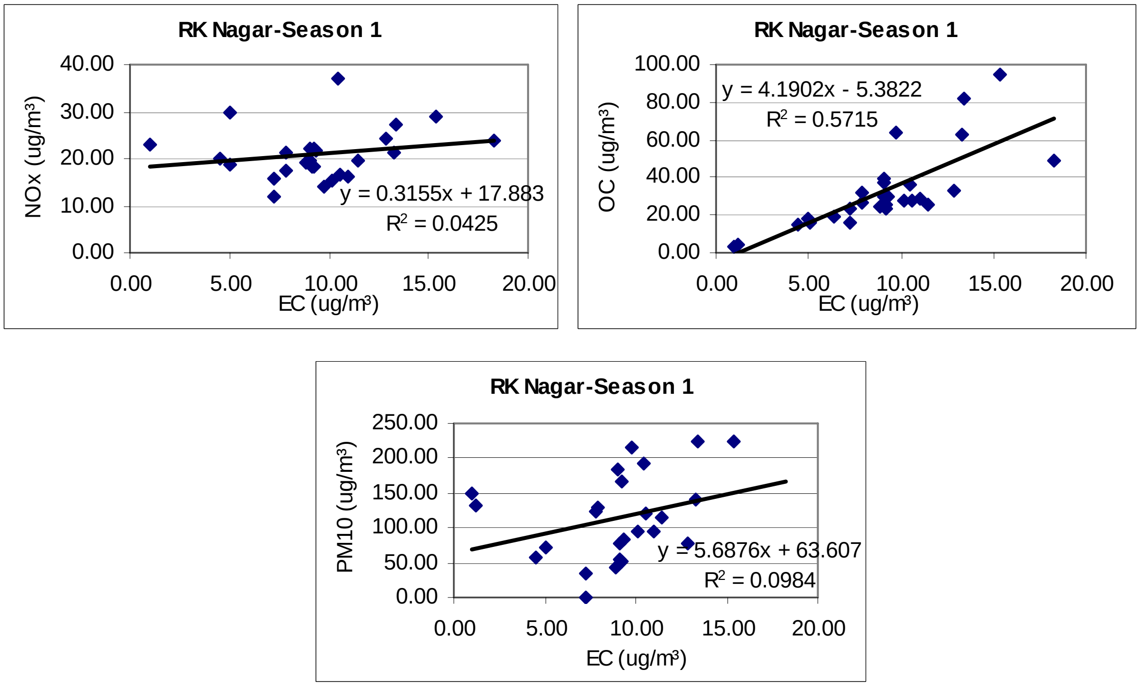


Figure 2.5.4.15 Correlation between NOx, OC, PM_{10} /EC at R.K.Nagar Season1

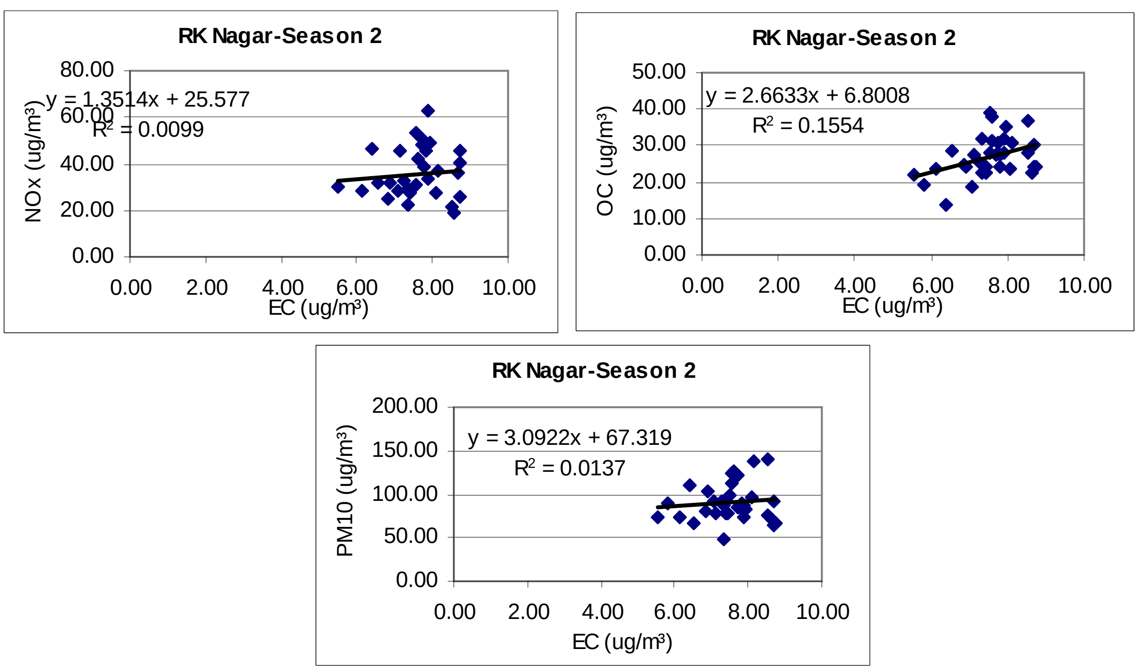


Figure 2.5.4.16 Correlation between NOx, OC, PM_{10} /EC at R.K.Nagar Season2

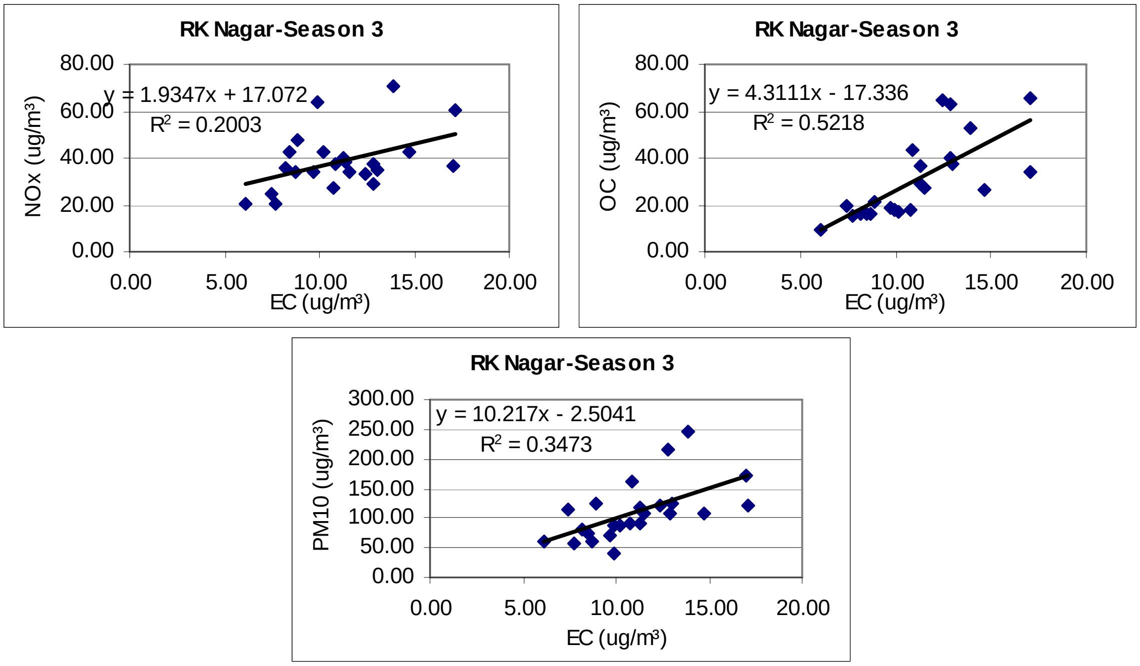


Figure 2.5.4.17 Correlation between NOx, OC, PM_{10} /EC at R.K.Nagar Season3

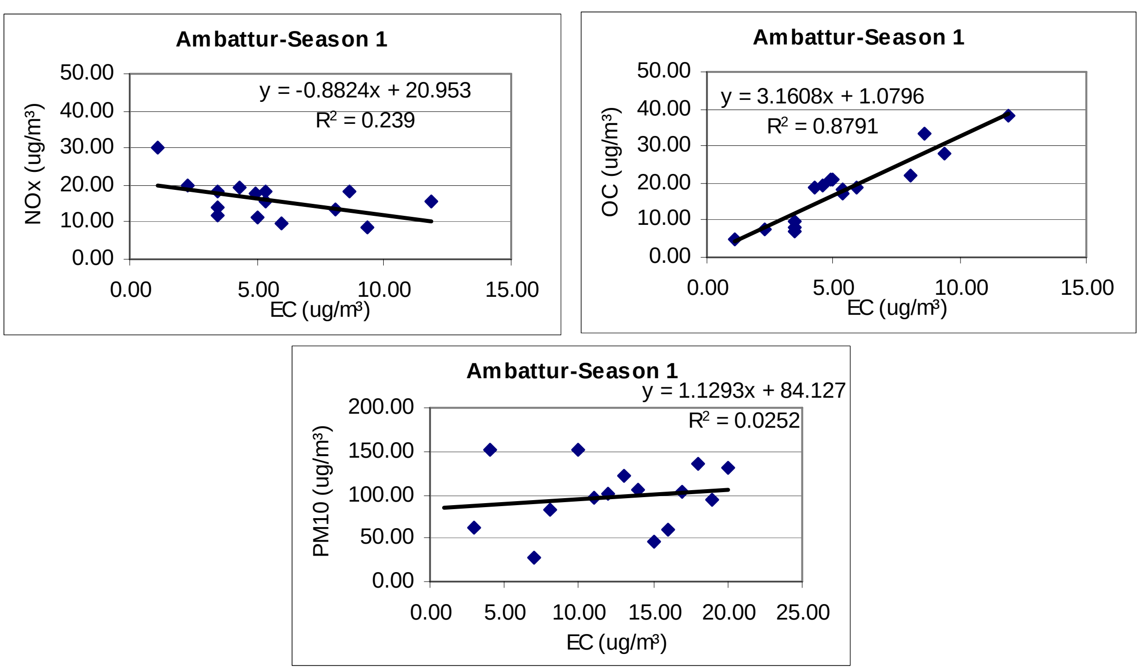


Figure 2.5.4.18 Correlation between NOx, OC, PM_{10} /EC at Ambattur Season1

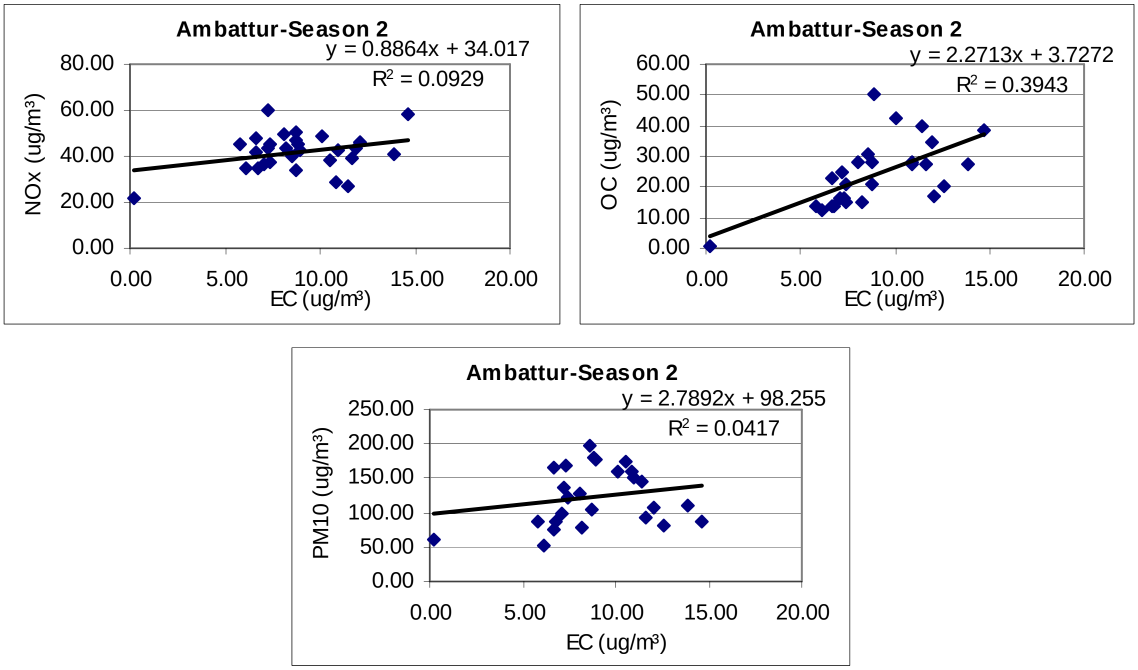


Figure 2.5.4.19 Correlation between NOx, OC, PM_{10} /EC at Ambattur Season2

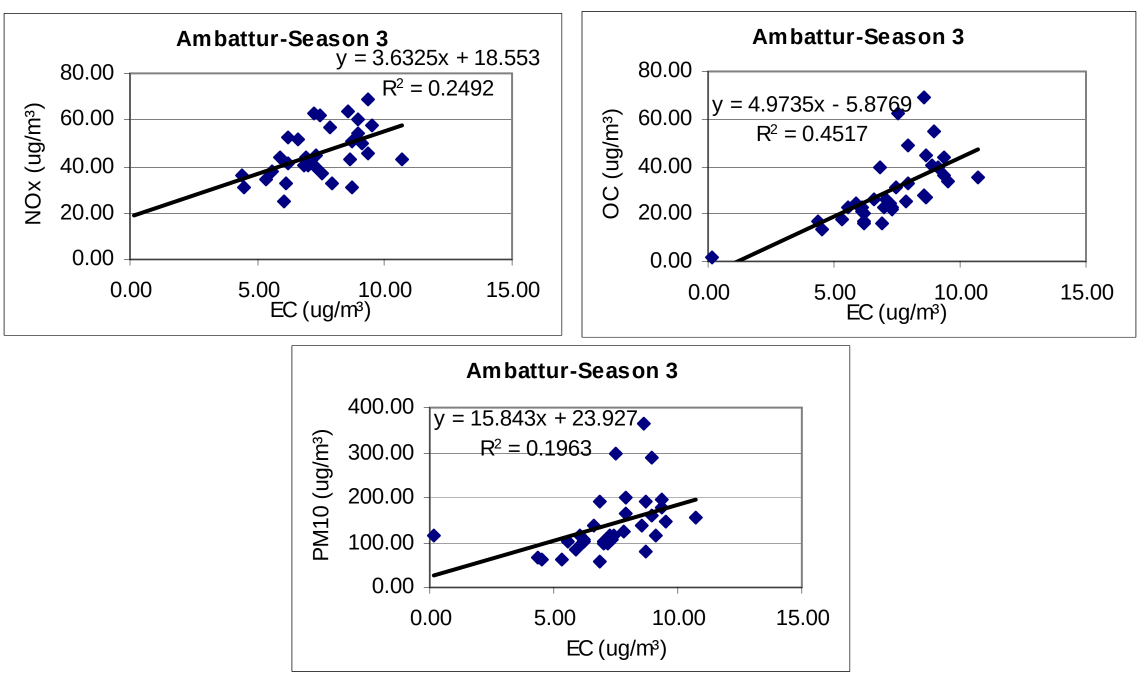


Figure 2.5.4.20 Correlation between NOx, OC, PM_{10} /EC at Ambattur Season3

2.5.5 Correlation Matrix for OC-EC-TC

Table 2.5.1 shows high correlation between the OC-EC fractions of TC indicating that they are derived from similar sources. Since the primary source of EC is from automobiles, it may be inferred that the OC fraction is also associated with vehicles.

. Table 2.5.1- Correlation Coefficient of OC-EC-TC

	IITM					
	Season 1	**Season 2**	**Season 3**			
OC-EC	0.898	0.078	0.872			
OC-TC	0.995	0.954	0.988			
EC-TC	0.936	0.374	0.937			
	Mylapore			**Triplicane**		
	Season 1	**Season 2**	**Season 3**	**Season 1**	**Season 2**	**Season 3**
OC-EC	0.937	0.966	0.812	0.588	0.854	0.868
OC-TC	0.997	0.998	0.995	0.989	0.993	0.994
EC-TC	0.960	0.981	0.867	0.619	0.906	0.919
	Adyar			**Saidapet**		
	Season 1	**Season 2**	**Season 3**	**Season 1**	**Season 2**	**Season 3**
OC-EC	0.859	0.862		0.624	0.636	0.648
OC-TC	0.990	0.996		0.972	0.982	0.981
EC-TC	0.924	0.881		0.789	0.762	0.783
	RK Nagar			**Ambattur**		
	Season 1	**Season 2**	**Season 3**	**Season 1**	**Season 2**	**Season 3**
OC-EC	0.756	0.506	0.722	0.938	0.352	0.672
OC-TC	0.995	0.967	0.995	0.997	0.991	0.996
EC-TC	0.820	0.708	0.790	0.961	0.471	0.737

CONTENT

Chapter 3 – Emission Inventory

3.0 Methodology

General Methodology First develop the code of each source type(again using about 10 digit numbers) including: nature of source-point, line or area, type of source, location of source with respect to city, 2x2 grid number,season etc and provide the list in annexture. (such codes shall be useful for subsequent modeling) . If possible plot them indifferent colors for Point, Line or area source categories)

Area Source

3.1 Area Sources

3.1.1 Bakery

Description

Assumptions

Emission Estimations [Describe methodology with respect to primary /secondary data. Emission factors with sources]

Data constraints/Assumptions [Describe levels of understanding with respect to data quality, computations, projections etc.]

Define the units of "activity levels" for this source and methodology used for primary data collection

3.1.2 Crematoria

(Same as above)

3.1.3 Open Eat outs

(Same as above) .]

3.1.4 Hotel & Restaurants

(Same as above)

3.1.5 Domestic Sector [Household cooking]

(Same as above)

3.1.6 Open Burning [Refuse burning, biomass burning, tyre burning]

(Same as above)

3.1.7 Paved & Unpaved Road Dust

(Same as above)

3.1.8 Construction / Demolition/ Alteration [Buildings, roads, flyovers]

(Same as above)

3.1.9 Locomotive (if any)

(Same as above)

3.1.10 Aircraft

(Same as above)

3.1.11 Marine Vessels (if any)

(Same as above)

3.1.12 Give other sources as per city specific inventory

3.1.13 Percentage Distribution of area sources [discuss all the sources and their contribution together and without each other]

3.2 Point Sources [mainly industries categories them under SSI, MSI, LSI]

3.2.1 Approach/Methodology for different categories of Industries (with data sources)

3.2.2 Methodology Adopted for upgrading inventory for the city level

3.2.3 Total Emission Estimation for(0.5X0.5)

3.2.3 Uncertainteties or limitations of estimations

3.2.4 Percentage Distribution of Pollutants from Industrial Sources

3.2.5 Data Constraints / Assumptions

Give industry category wise information as per local inventory

3.3 Line Source: Define the category of road used for inventry and provide details in scaled maps for each 2x2 grid

3.3.1 Primary Data Collection Elements and Methodology

3.3.2 Vehicles Count

3.3.3 Vehicle Kilometers Traveled (VKT) Estimation

3.3.4 Emission Factors

3.3.5 Vehicle Emission Inventory

3.4 Emission Inventory Summary [of all sources together e.g. area, line and point sources]

3.4.1 Future Growth Scenario [Short methodology for management plan wrt 5 and 10 years business as usual scenario]

3.4.2 Projections for whole city for line, area, and point sources

3.5 Emission Inventory QA/QC

Chapter 3

EMISSION INVENTRY

3.1. Introduction

The expansion of industries, growth of cities and concentrated human activities are leading to alarming increase in air pollution levels in almost all metro cities of the world. Vehicular, industrial and domestic sources are major anthropogenic categories causing emission of air pollutants into the environment. Due to multiplicity and complexity of air polluting sources, an itemized listing of emission estimation for sources and rates of emission of pollutants from each source in a given area are very essential to control air pollution emissions and to prepare control strategies. The urban air pollution emission inventory studies describe the pollutant sources and their contribution to city specific air pollution problems.

In general, an emissions inventory is a database that lists, by source, the amount of air pollutants discharged into the atmosphere from the community for a given time period. Such an inventory is used to establish and put forth emission standards. Present and future year inventories are critical components of air quality planning and modeling. The ultimate goal of the planning process is to identify and achieve emission patterns that do not result in violations of ambient air quality standards. Figure 3.1 shows the air pollution sources considered in urban emission inventory.

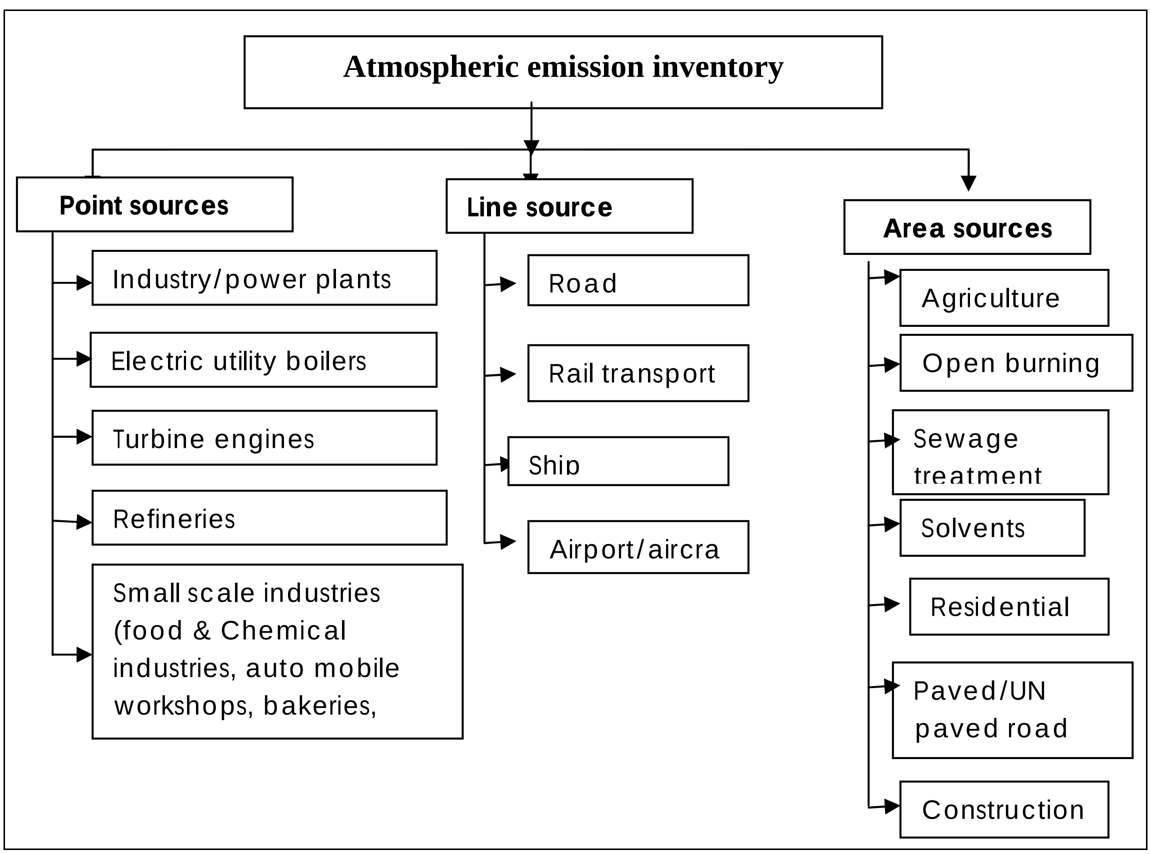


Figure 3.1. Air pollution sources in the urban environment

For listing the sources of air pollution, sources are classified as

1. Point sources (industries, mining, fuel terminal, etc.)
2. Area sources (biomass burning, road construction, electric generators, fuels, filling stations, dry cleaning, etc.)
3. Line sources (on-road an off-road mobile source) and
4. Natural sources (wind-blown dust, sea spray, etc.)

***Point sources*:** Air pollution sources identified on an individual facility basis or as a single source are called point sources. The emission characteristics of individual facilities vary widely and each facility is examined individually. Point sources include industrial and non-industrial stationary equipment or processes that can be identified by name and location and are considered significant sources of air pollution emissions. Point sources are subcategorized into combustion emission, process emission (industry-specific), fugitive emission (uncontrolled material handling, conveyers), storage tank emission, and the emissions from miscellaneous solvent usage.

***Area sources*:** Stationary air pollution sources not identified individually are called area sources. Area sources also include the diverse, un-permitted small sources which individually do not emit significant amounts of pollutants but which together make an appreciable contribution to the emission inventory.

Area source can be sub-categorized into:

1. Stationary source fuel combustion emissions (industrial, commercial, residential fuels, biomass or waste-derived fuels) and evaporative emission
2. Fugitive source for VOC emission (organic solvent utilization, fuel and organic material storage and distribution, waste treatment and disposal, pesticide usage)
3. Fugitive source for particulate matter emission (paved and unpaved roads, agricultural tilling and harvest activities, construction activities, wind erosion) and
4. Fugitive source for ammonic emission (livestock, fertilizer usage, domestic ammonia)

***Line sources*:** Non-stationary or mobile sources are called as line sources or mobile sources. On-road mobile sources include emission from vehicle exhaust of different categories, evaporative emission and crankcase emissions. Off-road mobile sources include aircraft, trains, boats, construction, and agricultural equipment.

***Natural sources*:** Natural sources include sea spray, lightning, volcanoes, windblown dust and transpiration from vegetation.

3.2 Methodology

Generally two basic approaches are followed in quantifying source emissions into the ambient environment. In first case, bottom–up approach quantifies the emissions using quality data on a particular source type. ie., the individual base elements of the system are first specified in great detail. These elements are then linked together to form larger subsystems, which then in turn are linked, sometimes in many levels, until a complete top-level system is formed. This strategy often resembles a "seed" model, whereby the beginnings are small but eventually grow in complexity and completeness. Usually this approach is used for inventory of point sources, however, it can be used to find out the area sources when resources are available to collect local activity data through a rigorous survey, requires more resources to collect site- specific information on emission sources, activity levels and emission factors, results are more accurate estimates because data are collected directly from individual sources.

In second, top-down approach, calculates the emissions using aggregated statistical data and demographical data available for a national or regional scale. This method is used when local data are not available and the end use of the data does not justify the cost of collecting detailed site-specific data. Emission factors or national or regional-level emission estimates are used in a state or country based on a surrogate parameter such as pollution or employment in a specific sector. One potential problem with this approach is that an emission estimates will lose some accuracy due to the uncertainty associated and the representativeness of the estimates once extrapolated to the local level.

A properly compiled emission inventory is the fundamental building block of any air quality management system in a country. The bottom up approach is most preferable because of its simplicity and accurate method of quantifying the emissions. The basic steps followed in emission inventory by bottom up approach are

1. Identification of area boundary
2. Listing of the types of sources in the specified area
3. Determination of the type of pollutant emitting from various sources.
4. Selection of appropriate emission factor for each air pollutant from the sources.
5. Estimation of emission intensity or emission concentration of different air pollutants using empirical equations or through experiments and equipments.
6. Determination of total emission concentration of the different air pollutants from the urban area.

Emission factors: Emission factors (EFs) are important elements of inventory development. An EF is a representative value that attempts to relate the quantity of a pollutant released to the atmosphere with an activity associated with the release of that pollutant. These factors are usually expressed as the weight of pollutant divided by a unit weight, volume, distance, or duration of the activity emitting the pollutant (e.g., kilograms of particulate emitted per mega gram of coal burned). Such factors facilitate estimation of emissions from various sources of air pollution. In most cases, these factors are simply averages of all available data of acceptable quality, and are generally assumed to be representative of long-term averages for all facilities in the source category (i.e., a population average).

The general equation for emission estimation is

$$E = A \times EF \times (1 - ER/100) \qquad (3.1)$$

Where, E = emissions, A = activity rate, EF = emission factor, and ER = overall emission reduction efficiency (%). ER is further defined as the product of the control device destruction or removal efficiency and the capture efficiency of the control system. When estimating emissions for a long period of time (e.g., 1 year), both the device and the capture efficiency terms should account for upset periods as well as routine operations. EF have been determined for a wide range of industrial, commercial and domestic activities and tabulated values may be used to estimate emissions; however, these emission factors need to be used with care, as adjustments in emission factors may be needed to take into account difference in operating conditions, fuel and feed materials.

The primary emission inventory has been carried out at seven selected locations in Chennai each having a grid size of 2×2 km (4 km^2) area. Figure 2.1 in Chapter 2 shows the details of the selected air quality monitoring (seven) stations in Chennai city. The summary of land use pattern at each site is presented in Table 2.1 of chapter 2.

Source code used in emission inventory (10 digit number:1010101010)
First tow digit indicates the nature of the source: i.e. 10–point source; 20–line source and 30-area source. Next two digits indicate type of source (01-99). The fifth and sixth digits indicate source category: RS-residential; IN-industrial; DO-domestic and OS-other sources. The seventh and eighth digits indicate the reference 2x2 km grid number (01-99) and the last two digits indicate the season (WS-winter season, SS-summer season, MS-monsoon season, and PS-post monsoon season). The detailed list of emission inventory code is provided in Annexure 3A.

Figure 3.1(a) and (b) shows the details of the study area and land use pattern at the IIT Madras 2 km x 2 km grid. The land use pattern shows that a large portion is occupied by a forest area (49 %). The built-up area, open space, roads and water bodies spread about 24 %, 19 %, 5 % and 3 %, respectively in this grid.

Figure 3.1a. Details of IIT Madras (background) 2km x 2 km grid area

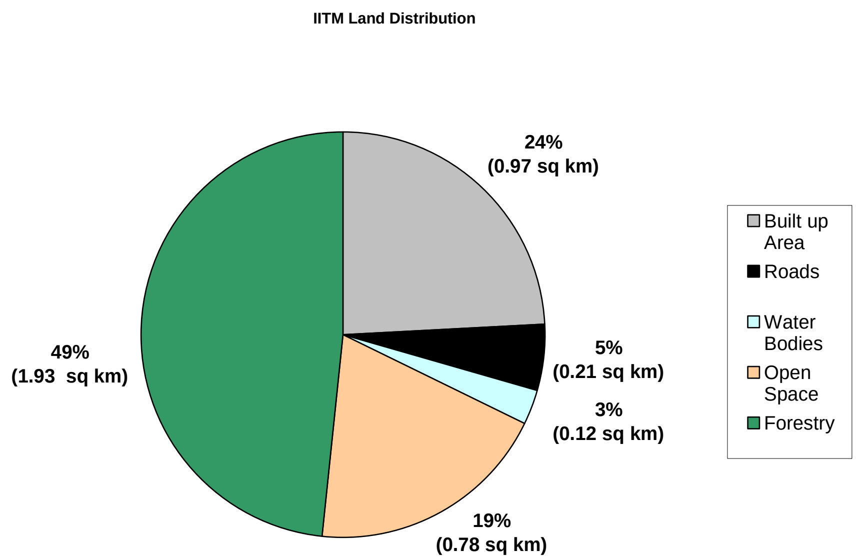


Figure 3.1b. Land use pattern at IIT Madras (background) 2 km x 2 km grid.

Figure 3.2(a) and (b) shows the details of the study area and land use pattern at the Mylapore (residential) 2 km x 2 km grid. Since it is residential area, built up area is dominated in this grid (78 %). The open space and roads spread about 8 % in this area. Remaining 6 % of the area is covered by greenery (4 %) and water bodies (2 %).

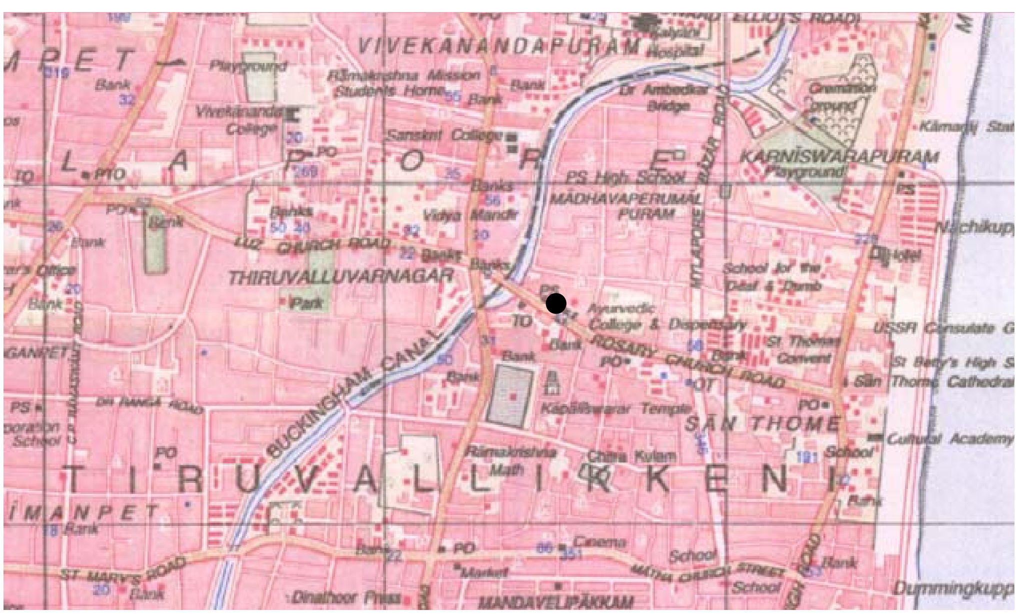


Figure 3.2a. Details of Mylapore (Residential) 2km x 2 km grid area.

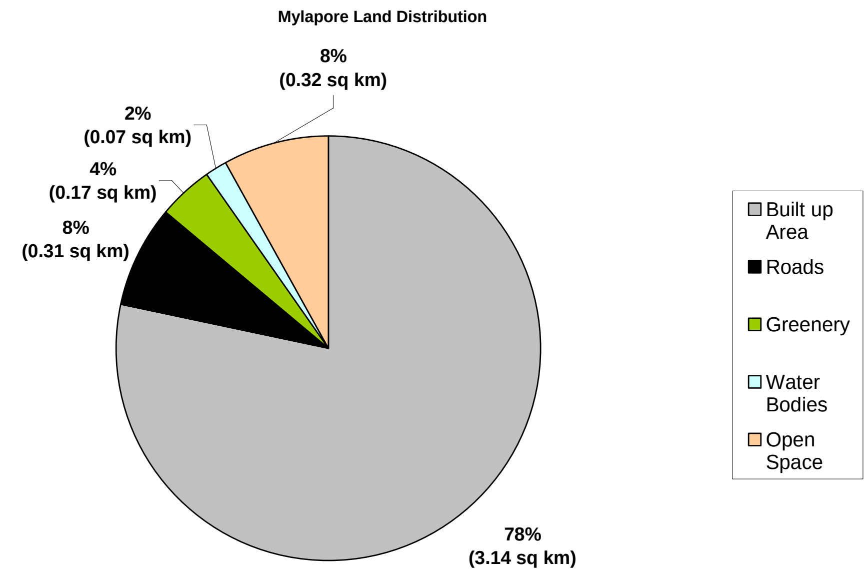


Figure 3.2b. Land use pattern at Mylapore (Residential) 2 km x 2 km grid area.

Figure 3.3(a) and (b) shows the details of the study area and land use pattern at the Triplicane (residential) 2 km x 2 km grid. In this site about half of the land is covered with built up area and remaining half is dominated open space (33%).

Figure 3.3a. Details of Triplicane (Residential) 2km x 2 km grid area.

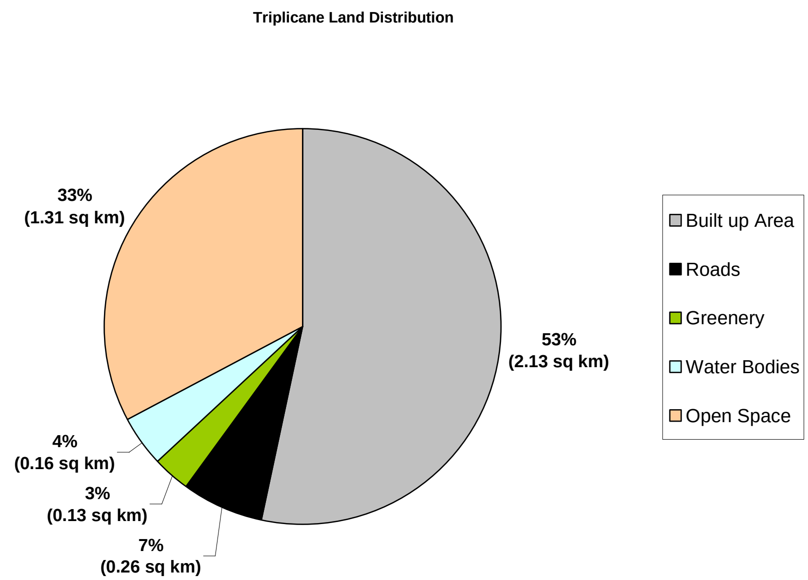


Figure 3.3b. Land use pattern at Triplicane (Residential) 2 km x 2 km grid area.

Figure 3.4(a) and (b) shows the details of the study area and land use pattern at the Adyar (kerb side) 2 km x 2 km grid. In this site, large portion of the land is built up area and 20 % of the land is covered with greenery.

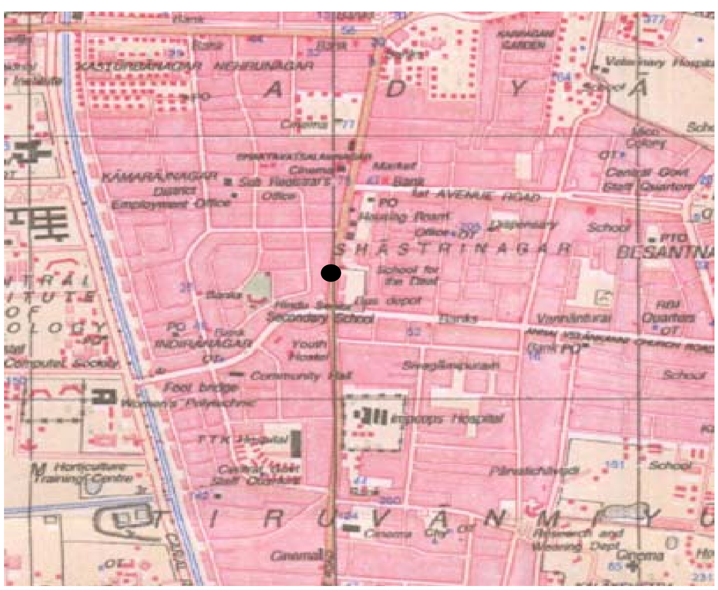


Figure 3.4a. Details of Adyar (Kerb side) 2km x 2 km grid area.

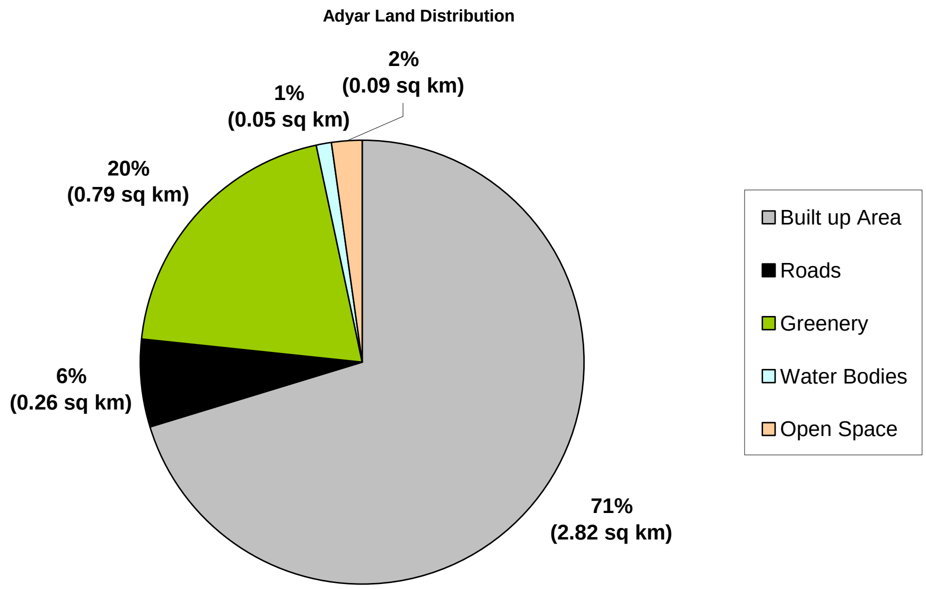


Figure 3.4b. Land use pattern at Adyar [Kerb side) 2 km x 2 km grid area.

Figure 3.5(a) and (b) shows the details of the study area and land use pattern at the Saidapet (kerb side) 2 km x 2 km grid. This study area shows that large portion is occupied by a built up area (60 %). The open space (15%) and greenery (14%) covers about 29 % of the total grid area.

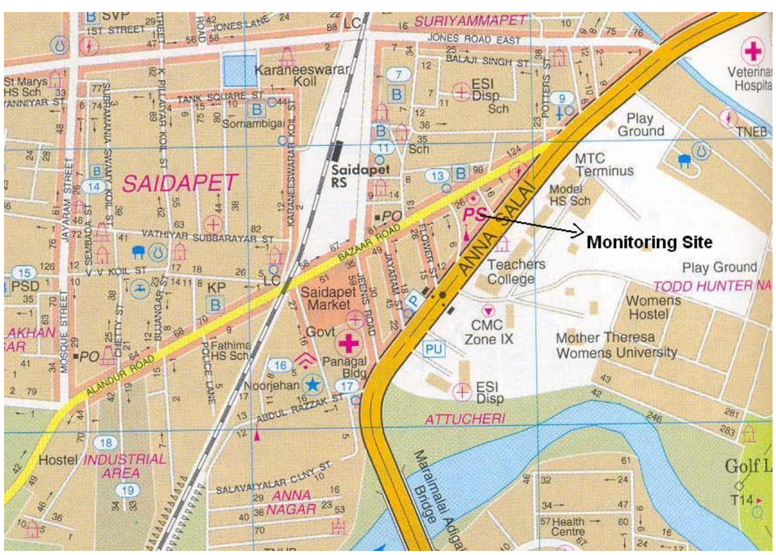


Figure 3.5a. Details of Saidapet (Kerb side) 2km x 2 km grid area.

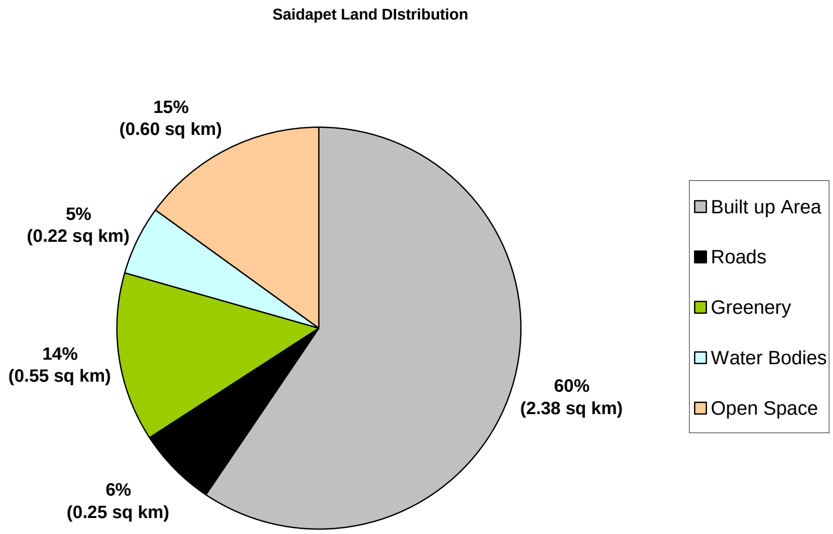


Figure 3.5b. Land use pattern at Saidapet [Kerb side) 2 km x 2 km grid area.

Figure 3.6(a) and (b) shows the details of the study area and land use pattern at the RK Nagar (industrial) 2 km x 2 km grid. This study area is predominated with open space area followed by built up area, green space, water bodies and roads.

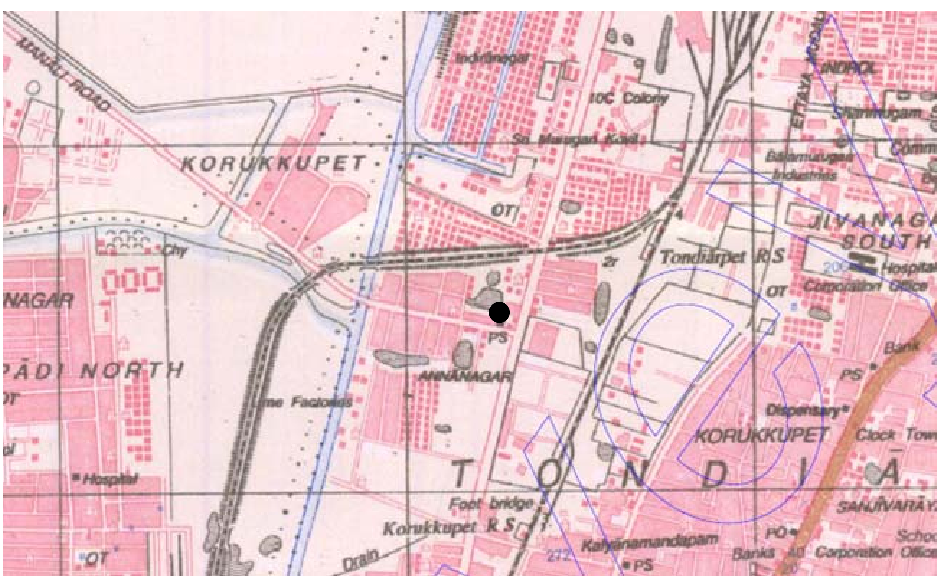


Figure 3.6a. Details of RK Nagar (Industrial) 2km x 2 km grid area.

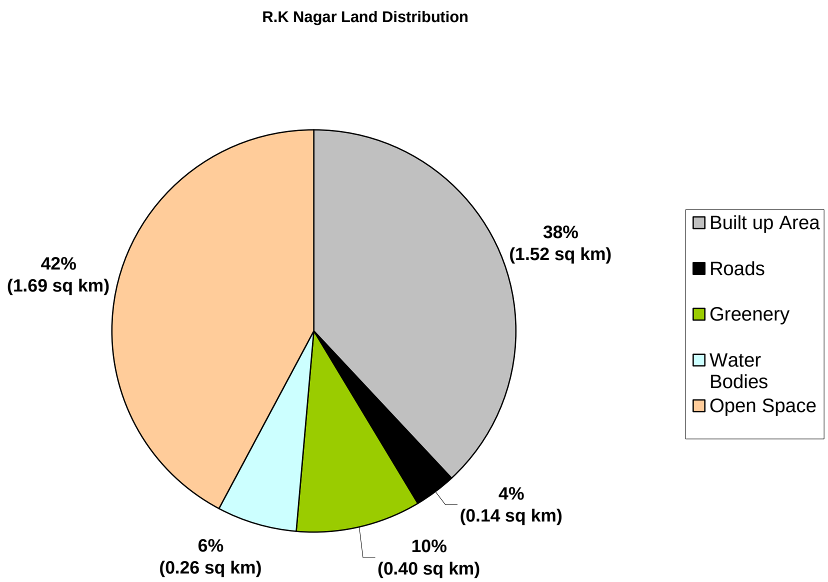


Figure 3.6b. Land use pattern at RK Nagar [Industrial) 2 km x 2 km grid area.

Figure 3.7(a) and (b) shows the details of the study area and land use pattern at the Ambattur (industrial) 2 km x 2 km grid. In this site, half of the area is dominated by industries and reaming half is dominated by open area. Open space and roads share equal amount of land use area at this site (7 %).

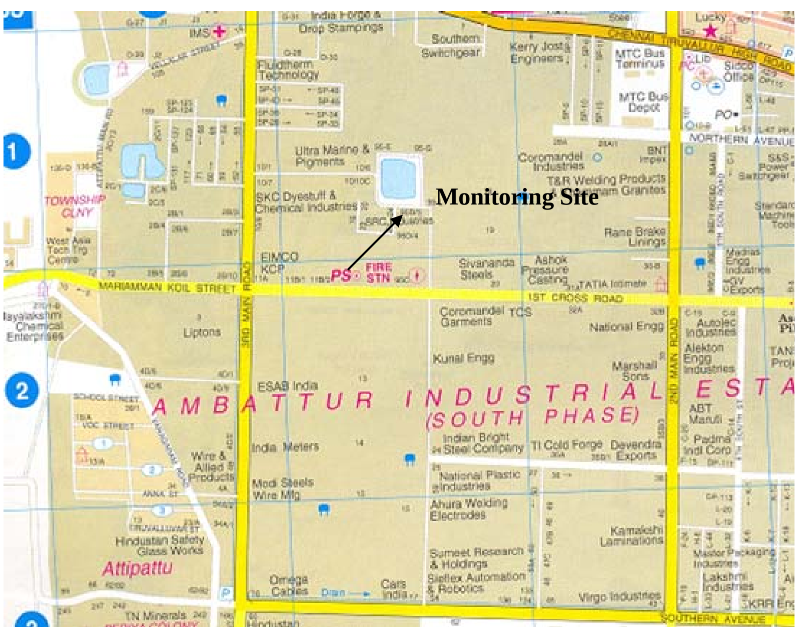


Figure 3.7a. Details of Ambattur (Industrial) 2km x 2 km grid area.

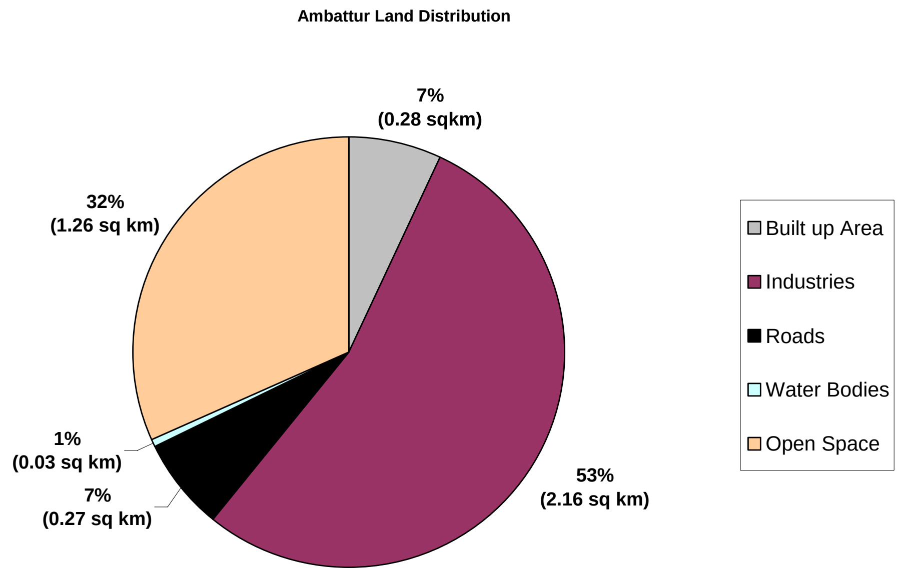


Figure 3.6b. Land use pattern at Ambattur [Industrial) 2 km x 2 km grid area.

3.2.1. Area source emission estimation

Following equation is used to estimate the emissions from domestic sources:

$$AE_{p,j} = EF_p * GC_j * 10^{-3} \qquad (3.2)$$

Where;

$AE_{p,j}$ = Daily emission of pollutant *p* in grid cell *j*, tonne yr^{-1}

EF_p = Emission Factor for pollutant *p*, kg

$GC_{s,j}$ = Gas Consumption in grid cell *j*, per day

Bakery emission: Several air pollutants are emitted from a bakery during the bakery process. In the present study emissions have estimated based on fuel (LPG/wood) consumed by the each bakery at the study area. Number of bakery at the study area and fuel consumption in each bakery was identified through questionnaire survey data. Equation 3.2 is used to estimate the emissions from the bakeries at the study site.

Crematoria: The Chennai Corporation The city has 38 burial/cremation grounds. However, these cremations are not located in the any of the seven 2 km x 2 km grid area considered in this study. Hence, it is not considered.

Open eat outs: these are assumed as bakery, emissions are estimated as bakery emissions.

Hotel & restaurants: Emissions are estimated (using equation 3.2) based on LPG/wood consumption by the hotels/restaurants.

Domestic sector: The actual LPG/wood (in kg) consumed by individual house per month (questionnaire survey data) and corresponding LPG/wood emission factors have been used to quantify the emissions from the each 2 km x 2 km grid area using the equation 3.2.

Open burning : Open burning contributes to particulate matter (PM), volatile organic compounds (VOC), nitrogen oxides (NOx), carbon monoxide (CO), and sulfur dioxide (SO2), as well as hazardous air pollutant (HAP) emissions. Generally, emissions from open burning are estimated by applying emission factors (e.g., pounds pollutant per ton refuse or fuel) to activity data (e.g., tons of waste burned). Emission factors for open burning depend on the type of waste, the type of fire, and the fuel loading. Following equation is used to quantify the emissions from the open burning.

Eop= total population in the grid x per capita waste generation x fraction of waste burned x emission factor (kg/day)

Paved & unpaved road dust:

Dust Entrainment from Paved Roads

Dust emissions from paved roads have been found to vary with silt loading, the mass of silt size material (equal to or less than 75µm in physical diameter) /unit area of the travel surface, present on the surface as well as the average weight of vehicles traveling on the road. The total road surface dust loading consists of loose material that can be collected by vacuuming or broom sweeping of known area of the travel portion of the road. Here the slit fraction is collected from an area of $5x4m^2$ using vacuum cleaner. The silt fraction is determined by measuring the proportion of the loose dry surface dust that passes through a 200-mesh screen (75µm) by sieve analysis. 24hr dusts are collected for Week days and Week ends from three different sites.

This procedure applies to all traffic on paved roads. This procedure estimates the dust entrainment due to vehicular travel on paved surfaces. (haul trucks)

$$E = E_f \times V$$

E = Particulate matter emissions rate in pounds per year
E_f = Emission factor in units of pounds of pollutant per mile traveled
V = Annual travel in units of vehicle miles traveled

$$E_f = k \times \left(\frac{sL}{2}\right)^{0.65} \times \left(\frac{W}{3}\right)^{1.5}$$

k = Aerodynamic particle size multiplier (see below)
sL = Roadway silt loading, in grams per square meter
W = Mean vehicle weight in tons

Dust Entrainment from Unpaved Roads

This procedure applies to all traffic on unpaved roads. This procedure estimates the dust entrainment due to vehicular travel on unpaved surfaces.

$$E = E_f \times V$$

E = Particulate matter emissions rate in pounds per year
E_f = Emission factor in units of pounds of particulate per mile traveled
V = Annual travel in units of vehicle miles traveled
s = Unpaved surface silt content in percent (%)
W = Average vehicle weight in tons
M = Unpaved surface moisture content in percent (%)

Paved road

$$E_{f(TSP)} = 10 \times \left(\frac{s}{12}\right)^{0.8} \times \left(\frac{W}{3}\right)^{0.5} \times \left(\frac{M}{0.2}\right)^{-0.4}$$

$$E_{f(PM_{10})} = 2.6 \times \left(\frac{s}{12}\right)^{0.8} \times \left(\frac{W}{3}\right)^{0.4} \times \left(\frac{M}{0.2}\right)^{-0.3}$$

$$E_{f(PM_{2.5})} = 0.38 \times \left(\frac{s}{12}\right)^{0.8} \times \left(\frac{W}{3}\right)^{0.4} \times \left(\frac{M}{0.2}\right)^{-0.3}$$

Construction / Demolition/ Alteration [Buildings, roads, flyovers]: Heavy construction is a source of dust emissions that may have substantial temporary impact on local air quality. The quantity of dust emissions from construction operations is proportional to the area of land being worked and to the level of construction activity. Number of construction activity at the study area and their level of construction was identified through questionnaire survey data. Using the method specified in AP-42, USEPA emissions have been estimated.

Locomotive: This type of source is not located in the any of the seven 2 km x 2 km grid area considered in this study. Hence, it is not considered.

Aircraft: Aircraft emissions were based on aircraft landing and takeoffs and emission factors. Emissions from aircraft originate from fuel burned in aircraft engines. Greenhouse gas emissions are the combustion products and by-products. CO2 and NOx are most important, but also methane, nitrous oxide and other by-product gases are emitted. The fuel use and emissions will be dependent on the fuel type, aircraft type, engine type, engine load and flying altitude. However, this type of source is not located in the any of the seven 2 km x 2 km grid area considered in this study. Hence, it is not considered.

Marine Vessels: This type of source is not located in the any of the seven 2 km x 2 km grid area considered in this study. Hence, it is not considered.

Any other sources specific to Chennai city: None.

Percentage distribution of area sources at the study regions

Questionnaire survey and filed survey has been carried out at each site to identify the type of sources, number of sources and fuel characteristics. Annexure 3.A provides the questionnaires used for area source data collection at the study area. Table 3.1 to 3.7 gives the details of area sources identified at IITM, Mylapore, Triplicane, Adyar, Saidapet, RK Nagar and Ambattur, respectively. The percentage distribution of area sources at each site is summarized in Table 3.8.

Table 3.1. Summary of area sources identified at IIT Madras study region.

Sources	**Nos**	**Type of Fuel used**	**Consumption /Month**
Residential Houses	1140	LPG	Average 1.5 Cylinder/Month
Generators in IITM	9	Diesel	11468 litres/Month
Open Burning	Nil	Nil	Nil
Hostel Mess, Hotels & Restaurants	8	LPG (59 Cylinders/day)	1770 Cylinders/Month
Construction	3	-	-

Table 3.2. Summary of area sources identified at Mylapore study region.

Sources	Nos	Type of Fuel used	Consumption /Month
Residential Houses	4883	LPG	Average 1.5 Cylinder/Month
Residential Houses (Huts)	627	Kerosene	18 litres/Month
Generators	47	Kerosene & Diesel	Approx 3-4 litres/Month
Open Burning	Nil	-	-
Tea Shops	48	LPG	2 Cylinders/Month
Hotels & Restaurants	76	LPG	8 Cylinders/Month
Road Side Hotels & Tea Shops	12	Kerosene	10 litres/ Month
Bakery Shops	12	Wood	300 Kg/ Month

Table 3.3. Summary of area sources identified at Triplicane study region.

Sources	Nos	Type of Fuel used	Consumption /Month
Residential Houses	3655	LPG	Average 1 Cylinder/Month
Residential Houses (Huts)	140	Kerosene	Average 15 litres/ Month
Generators in houses	117	Kerosene	2 litres/Month
Open Burning	Nil	-	-
Tea Shops	62	LPG	3 Cylinders/Month
Hotels & Restaurants	91	LPG	8 Cylinders/Month
Road Side Hotels & Tea Shops	13	Kerosene	15 litres/ Month
Generators in Shops	76	Kerosene	20 litres/Month
Bakeries	28	Wood	300 Kg/ Month

Table 3.4. Summary of area sources identified at Adyar study region.

Sources	Nos	Type of Fuel used	Consumption /Month
Residential Houses	2772	LPG	Average 1.5 Cylinder/Month
Residential Houses (Huts)	Nil		
Generators in houses	83	Kerosene	4-5 litres/Month
Open Burning	Nil		
Tea Shops	46	LPG	3 Cylinders/Month
Hotels & Restaurants	29	LPG	150 Cylinders/Month
Road Side Hotels & Tea Shops	18	Kerosene	30 litres/ Month
Big Generators in Shops	6	Diesel	8910 litres/Month
Bakery Shops	7	Wood	450 Kg/ Month

Table 3.5. Summary of area sources identified at Saidapet study region.

Sources	Nos	Type of Fuel used	Consumption /Month
Residential Houses	759	LPG	Average 1 Cylinder/Month
Open Burning			
Tea Shops	23	LPG	3 Cylinders/Month
Hotels & Restaurants	13	LPG	8 Cylinders/Month
Road Side Hotels & Tea Shops	17	Kerosene	60 litres/ Month
Big Generators in Shops	4	Generators	142560 litres/Month
Bakery Shops	7	Wood	150 Kg/ Month

Table 3.6. Summary of area sources identified at RK Nagar study region.

Sources	**Nos**	**Type of Fuel used**	**Consumption /Month**
Residential Houses	257	LPG	Average 1 Cylinder/Month
Residential Houses (Huts)	203	Kerosene	15 litres/Month
Tea Shops	9	LPG	2 Cylinders/Month
Hotels & Restaurants	12	LPG	4 Cylinders/Month
Road Side Hotels & Tea Shops	15	Kerosene	30 litres/ Month
Bakery Shops	4	Wood	150 Kg/ Month
Open Burning	Yes	4 Km away from Monitoring Site	

Table 3.7. Summary of area sources identified at Ambattur study region.

Sources	**Nos**	**Type of Fuel used**	**Consumption /Month**
Residential Houses (Police Quarters Only)	17	LPG	Average 1.5 Cylinder/Month
Tea Shops	13	LPG	2 Cylinders/Month
Hotels & Restaurants	15	LPG	4 Cylinders/Month
Road Side Hotels & Tea Shops	7	Kerosene	60 litres/ Month
Generators in Shops	Nil		
Road side Hotel	2	Wood	250 Kg/ Month

Table 3.8 summarizes the percentage distribution of area sources at the seven study areas in Chennai city.

Sl. No	Name of the study region	Percentage distribution of area source in 2 km x 2 km grid		
		Built up area	Road	Total
1	IIT Madras (background)	24	5	29
2	Mylapore (Residential)	78	8	86
3	Triplicane (Residential)	68	7	75
4	Adyar (Kerb side)	71	6	77
5	Saidapet (Kerb side)	60	6	66
6	R K Nagar (Industrial)	38	4	42
7	Ambattur (Industrial)	7	7	14

Table 3.9 provides the contribution of pollutants load from different area sources in the study area.

Table 3.9. Summary of the pollutants load form the area sources in the seven study areas.

Study region	Sources	Pollutant load in kg/day				
		CO	HC	NO_X	PM	SO_X
IITM	Domestic	0.70	13.76	5.07	0.16	0.03
	Resturants	0.80	15.79	5.82	0.18	0.04
	DG Sets	5.39	0.03	12.04	0.44	6.38
	Road Dust				138.77	
	Construction				40.77	
	Total	**6.89**	**29.58**	**22.94**	**180.32**	**6.46**
Mylapore	Domestic	4.70	92.59	34.03	1.06	0.72
	Resturants	6.19	121.82	44.83	1.39	0.68
	Bakeries	11.02	1.73	0.31	1.46	0.02
	DG Sets	1.42	0.45	3.20	0.12	2.14
	Road Dust				366.22	
	Construction				31.98	
	Total	**23.32**	**216.58**	**82.36**	**402.23**	**3.56**
Triplicane	Domestic	4.28	84.59	30.93	0.96	1.40
	Resturants	4.49	88.55	32.49	1.01	0.94
	Bakeries	6.31	1.19	0.25	0.84	0.01
	DG Sets	1.00	0.48	2.25	0.08	1.66
	Road Dust				62.48	
	Construction				6.70	

	Sources	CO	HC	NO_X	PM	SO_X
	Total	**16.07**	**174.80**	**65.91**	**72.07**	**4.01**
Adyar	**Domestic**	3.93	77.38	28.53	0.89	0.19
	Resturants	3.36	66.16	24.31	0.76	0.54
	Bakeries	6.29	0.97	0.17	0.84	0.01
	DG Sets	2.41	0.26	5.39	0.20	3.11
	Road Dust				306.26	
	Construction				81.34	
	Total	**15.99**	**144.78**	**58.40**	**390.27**	**3.85**
Saidapet	**Sources**	**CO**	**HC**	**NO_X**	**PM**	**SO_X**
	Domestic	4.42	87.26	32.00	0.99	0.99
	Resturants	3.61	71.01	26.13	0.81	0.41
	Bakeries	4.74	1.04	0.24	0.63	0.01
	DG Sets	1.15	0.32	2.58	0.09	1.68
	Road Dust				76.68	
	Construction				8.61	
	Total	**13.91**	**159.63**	**60.95**	**87.82**	**3.09**
R.K.Nagar	**Domestic**	1.55	31.14	10.92	0.34	2.64
	Resturants	5.53	108.94	40.07	1.24	0.71
	Bakeries	4.73	0.83	0.16	0.63	0.01
	DG Sets	0.88	0.09	1.97	0.07	1.13
	Open Burning	289.17	149.25	20.42	54.44	3.41
	Road Dust				473.04	
	Construction				14.10	
	Total	**300.31**	**259.11**	**62.62**	**543.51**	**5.26**
Ambattur	**Domestic**	1.04	20.66	7.41	0.23	0.99
	Resturants	15.61	82.09	29.74	2.45	1.01
	Bakeries	9.44	1.40	0.23	1.25	0.02
	DG Sets	1.93	0.11	4.31	0.16	2.38
	Road Dust				275.01	
	Construction				127.01	
	Total	**28.01**	**104.26**	**41.69**	**406.10**	**4.40**
Total emissions from area sources from seven sites						
	Sources	**CO**	**HC**	**NO_X**	**PM**	**SO_X**
	Domestic	20.63	407.38	148.88	4.62	6.96
	Resturants	39.58	554.35	203.39	7.84	4.33
	Bakeries	42.52	7.15	1.36	5.65	0.08
	DG Sets	14.17	1.74	31.74	1.16	18.48
	Open Burning	289.17	149.25	20.42	54.44	3.41
	Road Dust				1698.46	
	Construction				310.50	
	Total	**345.85**	**158.14**	**53.51**	**2070.20**	**21.97**

3.2.2. point source emission estimation

Emissions from point sources are based either on direct measurements or are estimated based on measurements from similar types of facilities, and are often differentiated into fugitive and non-fugitive (or stack) sources. Stack emissions are distinct points that are associated with emissions, such as industrial boiler exhausts. In contrast, fugitive emissions are associated with multiple small sources within an industrial facility, such as small leaks from storage tanks, piping, pumps and valves. While single fugitive sources are generally small, collectively fugitive emissions are often comparable to stack emissions from point sources. Equation 3.1 is used as the basic equation for the quantification of point source emissions with ER = 0., ie., Point Emission = Activity rate * Emission Factor

Percentage distribution of point sources at the study regions

Questionnaire survey and filed survey has been carried out at each site to identify the type of sources, number of sources and fuel characteristics. Annexure 3.B provides the questionnaires used for point source data collection at the study area. Table 3.10 gives the details of point sources identified at IITM, Mylapore, Triplicane, Adyar, Saidapet, RK Nagar and Ambattur, respectively. This table provides the contribution of pollutants load from the point source at Industrial study region.

Table 3.10. Summary of point sources identified at IIT Madras study region.

Study region	Number of Industries	Pollutants load in kg/day)				
		CO	HC	NO_X	PM	SO_X
IITM	Nil	-	-	-	-	-
Mylapore	Nil	-	-	-	-	-
Triplicane	Nil	-	-	-	-	-
Adyar	Nil	-	-	-	-	-
Saidapet	Nil	-	-	-	-	-
RK Nagar#	5*	-	-	-	-	-
Ambattur	64**	703.82	3.44	1572.35	57.40	833.60

List of industries in RK nagar- Valliammal lime clean factory, Indian oil Corporation Limited, Jhansirani Engineering Works (welding work), Amirdham Tiles (P) Ltd, Asssociate Steel Re-Rolling Mills

* List of industries in Ambattur- R. K .National Engineering Works, Ashok Pressure Castings (P) Limited (Company Closed), Lucas -TVS India Service Limited , Colour Plus Fashion Limited, G. V. Exports, Metal Finishers Electro Platers, Sundaram Fastners Autotech Division, UPSAWA Engineering Limited, Toshniwel Instruments (Madras) Private Limited, Madras Engineering Industries, C-Mos Automation India Private Limited, Fabrication Private Limited, Southern Product and services, Vendir Engineering Service, Steel Fast Enterprises Private Limited, Autowing Industries, Kunal Engineering Works, Sivananda Steels (P) Limited, Minica Services (P) Limited, Southern Ceramics (P) Limited, Friends Metal Limited, Suitall Polypro Limited, Delta Control Systems, Ketaki Engineering Private Limited, Chennai Auto Forging

Private Limited, AG Sons (exporters of pickles, spices), Pass Tech Private Limited, Lloyds Industrial Works, Polycrest Innovations India (P) Limited, India Land and Property Limited, Saravanan Electroplating and polishing work, Sri Krishna Screen Printers, Heat Tech Industry, Sekar and Sekar Engineering Works, Lakshmiram Engineers, Leela Scottish Lace Procuring Unit, Super Stall India Limited (Engineering Works), Stand 21 Expert Leather Division, Tube Investment Limited, Nelcest Limited, Altura Welding, Santhi Engineering Works, The EIMCO-KCP (P) Limited , VGP Engineering (P) Limited, AG Bros Glass works (P) Limited, TI-Cycle of India (P) Limited, Swathanthra Industries, Plasma Weld (P) Limited, SKC Dyestuff & Chemical Industries, Ultra Marine and Pigments, Fluid Therm Technology, R.K.S. Welding Company, Sundaram – Clayton Brakes (P) Limited, Rane Brake Linings (P) Limited, KK Polycolor (P) Limited, ETA Enginering Private Limited, Ambattur Clothing Limited, UGP Engineering Private Limited, Hindustan Photo Film Manufacturing Company, Tamil Nadu Minerals Limited, K. Dhakshinamoorthy Industrial Estate, Mukunth Engineering Works, MODI Steel Wires (P) Limited, ESAB India (P) Limited,

The point sources at RK Nagar were mainly due DG sets, they were considered in area source emissions estimation.

***3.2.3.* Line Source**:

The inventory of vehicle exhaust emissions and the contribution from various vehicle categories can be made fairly complete as all cities have a reasonable data on the vehicle fleet and fuel consumption. In the present study, the emissions factor, calculated by ARAI are used for estimation of the pollution load, generated by transport sector.

The quantity of air pollutants emitted by the different categories of vehicles is directly proportional to the average distance traveled by each type of vehicles, number of vehicles plying on the road, quantity & type of fuel being used, age and technology of vehicle in use, etc. However, several other factors like geographical locations, unplanned developed business areas, inadequate and poorly maintained roads as well as adopted practices of inspection & maintenance of vehicles, unplanned traffic flow, meteorological conditions and non availability of effective emission control technology would also affect emissions. Following equation (3.3) is used to calculate the emission load from vehicles:

$$\text{Emission load} = \text{length of the road} * \text{no of vehicles} * \Sigma\,(\text{Vintage of vehicles} * \text{emission factor}) \qquad (3.3)$$

Primary data collection

Traffic Volume is the number of vehicles crossing a section of road per unit time. The hourly vehicle volume data have been collected at important roads in the 2 x 2 km grid area by manual count (mid block method). Vehicle parking lot survey has been conducted to identify the vintage of the vehicles. In order quantify the emissions form the vehicles, roads were classified into minor roads and major roads.

Vehicles Kilometer Traveled (VKT) estimation

The vehicle kilometer traveled was estimated through questionnaire survey based on number of trips made by each category of vehicles.

Vehicles Count

The hourly traffic census has been conducted for 24 hours at major and minor roads in the seven study regions. The vehicles are classified into five major groups, for which emission factors are developed by AIRI, Pune. The traffic census, at 15 minutes intervals for 24 hours, was carried out on two different days –weekday and weekends. Table 3.11(a) and (b) to Table 3.17 (a) and (b) gives the major and minor roads in the seven sites (IITM, Mylapore, Triplicane, Adyar, Saidapet, RK Nagar and Ambattur), respectively.

Table 3.11 (a) Summary of major roads in IIT Madras 2 km x 2 km grid area and their daily average traffic flow.

Major Roads	Length of Road (km)	2W	3W (P)	3W (D)	4W(P)	4W(D)
Delhi Avenue Road	1	698	195	17	272	16
Ramakrishna Road	1.7	4877	2397	270	1208	3363
Alumini Road	1	293	77	28	72	10
East Coast Road	1.8	21351	6963	767	4689	13026
Bonn Avenue Road	1	2276	246	69	425	44
Hostel Road	1	293	74	2	8	8

Table 3.11 (b) Summary of minor roads in IIT Madras 2 km x 2 km grid area.

Minor Roads	Length of Road (km)
Gandhi Road	0.75
Velachery Road	1.5
Taramani Road	0.65
Kanagam Road	0.37

Table 3.12 (a) Summary of major roads in Mylapore 2 km x 2 km grid area and their daily average traffic flow.

Average Daily Traffic Flow (Week Day)

Major Roads	Length of Road (km)	2W	3W (P)	3W (D)	4W(P)	4W(D)
Dr. Ranga Road	0.96	31329	22174	2459	9840	3038
Rosary Church Road	1.1	19526	6362	705	9015	2780
TTK Road	1.4	12862	2781	308	2374	6616
C.P.Ramasamy Road	0.8	13714	3132	345	7554	2325
Luz Church Road	1.2	46041	17660	1966	22607	6977
Royapettah High Road	2.02	34857	10177	1134	14468	4460
Dr. Radhakrishnan Road	1	15224	3711	417	14355	1031
Mylapore Bazaar Road	1.24	15384	5473	621	7477	2310

Average Daily Traffic Flow (Weekends)

Major Roads	Length of Road (km)	2W	3W (P)	3W (D)	4W(P)	4W(D)
Dr. Ranga Road	0.96	21617	15300	1697	6790	2096
Rosary Church Road	1.1	17378	5662	627	8023	2474
TTK Road	1.4	14405	3115	345	2659	7410
C.P.Ramasamy Road	0.8	15732	3624	399	8696	2725
Luz Church Road	1.2	37293	14305	1592	18312	5651
Royapettah High Road	2.02	30674	8956	998	12732	3925
Dr. Radhakrishnan Road	1	16591	4080	555	13168	1300
Mylapore Bazaar Road	1.24	17845	6349	720	8673	2680

Table 3.12 (b) Summary of minor roads in Mylapore 2 km x 2 km grid area.

Minor Roads	Length of Road (km)
Mundakanni Amman Street	1.1
P. P. V Koil Street	0.7
Arunandal Street	1
East Mada Street	1.3
Kutchery Lane	0.7
SengaluneerPilliyar Koil Street	0.8
East Tank Square Street	0.5

Ponnambala Vathiyar Street	0.7
North Mada Street	1.7
South Mada Street	2
R. K. Mutt Road	1.5
Kutchery Road	1.4

Table 3.13 (a) Summary of major roads in Triplicane 2 km x 2 km grid area and their daily average traffic flow.

Average Daily Traffic Flow (Week Day)

Major Roads	Length of Road (km)	2W	3W (P)	3W (D)	4W(P)	4W(D)
T.P.High Road	1.1	21660	8724	984	2047	1128
Dr. Besant Road	1.3	20676	7398	897	3424	1241
Pycrofts Road-Bells Road Junction	2	37254	12145	4662	8114	2995

Average Daily Traffic Flow (Weekends)

Major Roads	Length of Road (km)	2W	3W (P)	3W (D)	4W(P)	4W(D)
T.P.High Road	1.1	22784	7085	920	2546	1394
Dr. Besant Road	1.3	15812	5737	696	2626	932
Pycrofts Road-Bells Road Junction	2	32538	9641	3562	7685	2459

Table 3.13 (b) Summary of minor roads in Triplicane 2 km x 2 km grid area.

Minor Roads	Length of Road (km)
Easwaran Doss Street	0.8
Singarchari Street	0.6
T.P.Koil Street	0.9
Chengalrayan Street	1.1
Car Street	0.5
Kanthappan Street	0.4
Pavyalvar Street	0.6
V.R.Pillai Street	0.5
New Fire Wood Street	0.8
Sunguwar Street	0.7

Table 3.14 (a) Summary of major roads in Adyar 2 km x 2 km grid area and their daily average traffic flow.

Average Daily Traffic Flow (Week Day)

Major Roads	Length of Road (km)	2W	3W (P)	3W (D)	4W(P)	4W(D)
Adyar Road	1	8603	3282	2459	691	4703
Besant Nagar Road	1	4042	1733	1625	1695	1720
Indra Nagar Road	1	2429	643	215	1074	302
Thiruvanmiyur Road	1	10428	1434	1069	1271	1513
Lattice Bridge Road	2	41655	12580	1401	11031	3401

Old Mahabalipuram Road	1.8	15472	5046	556	10196	3147
Velachery Road	1	21777	2491	276	926	282

Average Daily Traffic Flow (Weekends)

Major Roads	Length of Road (km)	2W	3W (P)	3W (D)	4W(P)	4W(D)
Adyar Road	1	9721	3709	2779	781	5314
Besant Nagar Road	1	5416	2322	2178	2271	2305
Indra Nagar Road	1	1482	392	131	655	184
Thiruvanmiyur Road	1	16655	2411	1716	2242	2358
Lattice Bridge Road	2	50403	15222	1695	13348	4115
Old Mahabalipuram Road	1.8	22589	7367	812	14886	4595
Velachery Road	1	19164	2192	243	815	248

Table 3.14 (b) Summary of minor roads at Adyar 2 km x 2 km grid area.

Minor Roads	Length of Road (km)
Dr. R. K. Nagar Main Road	0.8
Malaviya Avenue Road	1.1
Indra Nagar 1st Main Road	1.6

Sastri Nagar Road	1
Venkatrathinam Nagar	0.7
Balram Road	1
Justice Ramanujam Street	0.6
Parameswari Nagar	1
Mahatma Gandhi 1st Main Road	1.2

Table 3.15 (a) Summary of major roads in Saidapet 2 km x 2 km grid area and their daily average traffic flow.

Average Daily Traffic Flow (Week Day)

Major Roads	Length of Road (km)	2W	3W (P)	3W (D)	4W(P)	4W(D)
Towards Little Mount Junction	1.8	39778	2098	393	4248	665
Towards West Saidapet Road	1.2	26056	2414	513	3273	418
Saidapet Bazzar Road	1.2	29919	716	225	582	55
Towards Anna Salai Road	2	37490	2685	770	4494	1031
Towards T.Nagar	2	18565	1645	513	4226	892
Saidapet Post Office Road	0.8	14097	770	225	356	44
Towards Guindy Road	1.5	33516	1765	440	4136	1398
Towards West Mambalam Road	2	18548	1229	288	2661	364

Average Daily Traffic Flow (Weekends)

Major Roads	Length of Road (km)	2W	3W (P)	3W (D)	4W(P)	4W(D)
Towards Little Mount Junction	1.8	48131	2539	476	5140	805
Towards West Saidapet Road	1.2	28401	2631	559	3568	456
Saidapet Bazzar Road	1.2	18273	488	147	380	47
Towards Anna Salai Road	2	46660	3331	955	5590	1270
Towards T.Nagar	2	23985	2141	668	5487	1173
Saidapet Post Office Road	0.8	12662	688	201	317	39
Towards Guindy Road	1.5	26815	1428	356	3308	1119
Towards West Mambalam Road	2	14185	953	223	2041	273

Table 3.15 (b) Summary of minor roads at Saidapet 2 km x 2 km grid area.

Minor Roads	Length of Road (km)
Jeenis Road	1.3
Jones Road	1.2
Flower Street	0.8
Dharmaraj Koil Street	1
Seshasalam Street	0.5

Abdul Razzak Street	1.2
Pillayar Koil Street	0.8
Balaji Singh Street	1

Table 3.16 (a) Summary of major roads in RK Nagar 2 km x 2 km grid area and their daily average traffic flow.

Average Daily Traffic Flow (Week Day)

Major Roads	Length of Road (km)	2W	3W (P)	3W (D)	4W(P)	4W(D)
Ennore High Road	1.8	5751	1197	5644	3230	4889
Manali High Road	1.5	3597	1284	4789	667	5472

Average Daily Traffic Flow (Weekends)

Major Roads	Length of Road (km)	2W	3W (P)	3W (D)	4W(P)	4W(D)
Ennore High Road	1.8	4881	1256	4429	2776	4585
Manali High Road	1.5	4174	1290	4548	878	6011

Table 3.16 (b) Summary of minor roads in RK Nagar 2 km x 2 km grid area.

Minor Roads	Length of Road (km)
Nehru Street (Slums)	0.8
Sastri Street (Slums)	0.5
Kamarajar Street (Slums)	1.1

Thiruvallur Nagar (Slums)	0.7
Devi Karumariamman First Street	1.2
Lime Clean Road (Slums)	0.5
Thoppai Vinayagar Koil Street	1
Parthasarathy Street	1.3
Coronation Nagar	0.7
Kathivakkam High Road	1.1

Table 3.17 (a) Summary of major roads in Ambattur 2 km x 2 km grid area and their daily average traffic flow.

Average Daily Traffic Flow (Week Day)

Major Roads	Length of Road (km)	2W	3W (P)	3W (D)	4W(P)	4W(D)
Chennai-Tiruvallur Road	1.8	14765	1850	204	8037	2071
Telephone Exchange Road	0.75	48687	17660	1966	30142	3756
Ambattur Estate Road	1	3887	1443	248	1596	740
Mannika Vinayagar Koil Street	1.2	31329	11484	1486	13123	3293
Ambattur-MTH Road	1	46041	17660	1966	20804	1660
South Park Street	1.75	26938	1080	2254	13013	2908

Average Daily Traffic Flow (Weekends)

Major Roads	Length of Road (km)	2W	3W (P)	3W (D)	4W(P)	4W(D)
Chennai-Tiruvallur Road	1.8	10188	1277	141	5546	1429
Telephone Exchange Road	0.75	39923	14481	1612	24716	3080
Ambattur Estate Road	1	4893	1720	289	1903	841
Mannika Vinayagar Koil Street	1.2	24123	8843	1144	10105	2536
Ambattur-MTH Road	1	29927	11479	1278	13523	1079
South Park Street	1.75	18857	756	1578	9109	2036

Table 3.17 (b) Summary of minor roads in Ambattur 2 km x 2 km grid area.

Minor Roads	Length of Road (km)
Ambattur Estate 1st Cross Road	1.8
Ambattur Estate 1st Main Road	1.2
Ambattur Estate 2nd Main Road Mud Road (LS)	400-500m
Ambattur Estate 2nd Main Road Mud Road (RS)	800m
3rd Main Road (Right Side)	1.1
3rd Main Road 1st Cross (Right Side)	500-800m
3rd Main Road (Left Side)	1

Vehicle Emission Inventory

Table 3.18 presents the summary of emissions from the line sources from different category of vehicles in the study regions.

Emission Inventory Summary

Table 3.18 to 3.24 presents the summary of total emission load in seven sites namely IITM, Mylapore, Triplicane, Adyar, Saidapet, RK Nagar and Ambattur, respectively

Table 3.18. Total Summary of Emissions from 2 x 2 km grid in IITM

SUMMARY	CO (T/day)	HC(T/day)	NO_X(T/day)	CO_2(T/day)	PM(T/day)	SO_X(T/day)
Line sources	0.007527	0.003615	0.002934	0.460201	0.000325	0
Domestic sources	0.000455	0	0.003301	3.0495	0.000103	2.19 E-05
Other sources	0.011042	2.64 E-05	0.053046	38.9262	1.507192	0.006655
Point Sources	0	0	0	0	0	0

Table 3.19 Total Summary of Emissions from 2 x 2 km grid in Mylapore

SUMMARY	CO (T/day)	HC(T/day)	NO_X(T/day)	CO_2(T/day)	PM(T/day)	SO_X(T/day)
Line sources	0.042648	0.020608	0.007661	1.66636	0.00097	0
Domestic Sources	0.00217447	0	0.0149518	13.96490	0.00045715	0.006585
Other sources	0.012846	0	0.00219969	2.06044	2.8906581	0.0001042
Point Sources	0	0	0	0	0	0

Table 3.20 Total Summary of Emissions from 2 x 2 km grid in Triplicane

SUMMARY	CO (T/day)	HC(T/day)	NO_X(T/day)	CO_2(T/day)	PM(T/day)	SO_X(T/day)
Line sources	0.0186690	0.010153	0.002715	0.5770491	0.0004400	0
Domestic Sources	0.00150088	0	0.0107352	9.94512	0.00033224	0.00127804
Other sources	0.02968193	0	0.00301641	2.85171	0.15809197	0.00018048
Point Sources	0	0	0	0	0	0

Table 3.21. Total Summary of Emissions from 2 x 2 km grid in Adyar

SUMMARY	CO (T/day)	HC(T/day)	NO_X(T/day)	CO_2(T/day)	PM(T/day)	SO_X(T/day)
Line sources	0.0248103	0.012329	0.004777	0.8856623	0.00058195	0
Domestic Sources	0.00110649	0	0.00802725	7.4151	0.0002494	0.00005313
Other sources	0.01698239	2.049 E-05	0.0225241	13.00974	1.26050972	0.0053755
Point Sources	0	0	0	0	0	0

Table 3.22. Total Summary of Emissions from 2 x 2 km grid in Saidapet

SUMMARY	CO (T/day)	HC(T/day)	NO_X(T/day)	CO_2(T/day)	PM(T/day)	SO_X(T/day)
Line sources	0.040792	0.020108	0.004308	0.840654	0.000601	0
Domestic Sources	0.000303	0	0.002198	2.030325	6.83 E-05	1.45 E-05
Other sources	0.071981	0.000328	0.159188	21.8289	0.137151	0.080014
Point Sources	0	0	0	0	0	0

Table 3.23. Total Summary of Emissions from 2 x 2 km grid in R. K. Nagar

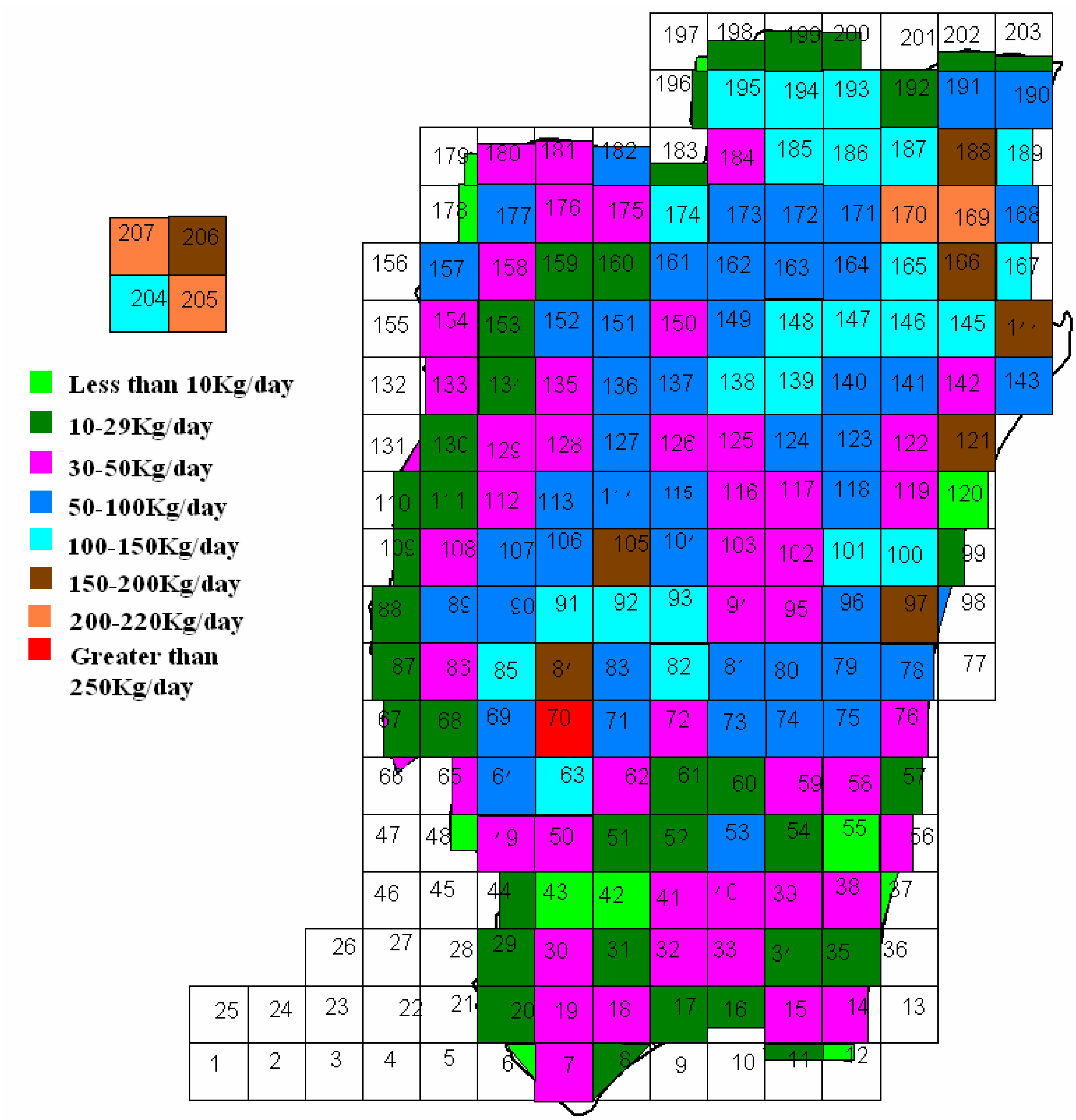
SUMMARY	CO (T/day)	HC(T/day)	NO_X(T/day)	CO_2(T/day)	PM(T/day)	SO_X(T/day)
Line sources	0.00489748	0.00155209	0.002327	0.3873748	0.00028969	0
Domestic sources	0.00016338	0	0.00096316	0.931075	2.7901 E-05	0.0017565
Other sources	0.00212913	0	0.0002488	0.24049	0.53939625	0.00026375
Point Sources	0	0	0	0	0	0

Table 3.24. Total Summary of Emissions from 2 x 2 km grid in Ambattur

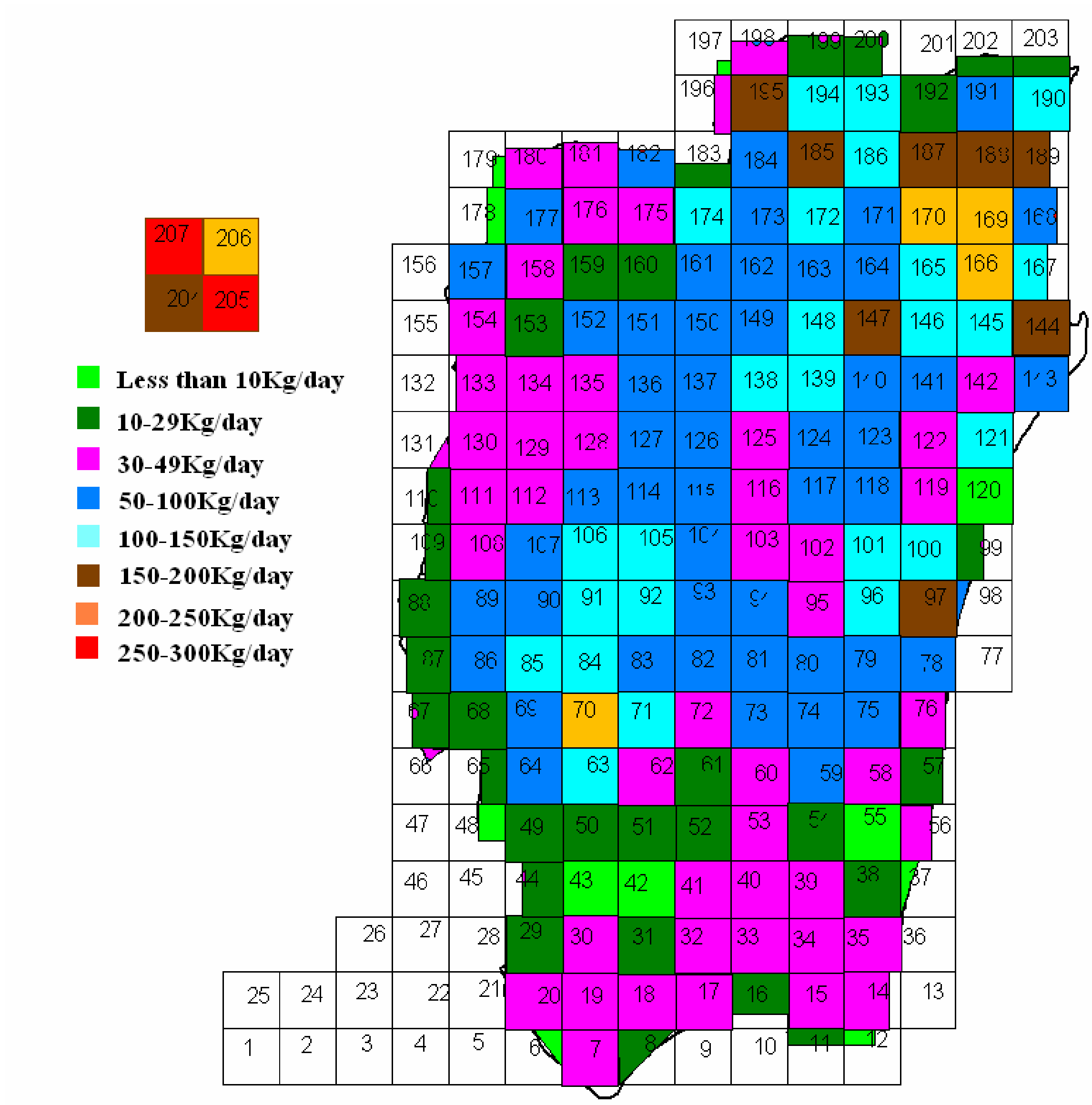
SUMMARY	CO (T/day)	HC(T/day)	NO_X(T/day)	CO_2(T/day)	PM(T/day)	SO_X(T/day)
Line sources	0.033863	0.0153615	0.0049206	1.1917727	0.00066705	0
Domestic Sources	3.991 E-06	0	2.8958 E-05	0.02675	0.0000009	1.191 E-07
Other sources	0.001083	0	0.0002485	0.237495	0.97149285	0.0002447
Point Sources	0.7038156	0.003444	1.572354	136.8846	0.05740	0.835972

The total PM and NOx emissions for the Chennai city has been estimated based on pollution density and land use pattern. For 2007 they are found to be 12,142 and 11,006 kg/day respectively. For 2012 they are found to be 17,112 and 16,890 kg/day respectively. For 2017 they are found to be 25,090 and 26,255 kg/day respectively. Following figures shows the emissions estimation for BAU scenarios in Chennai city.

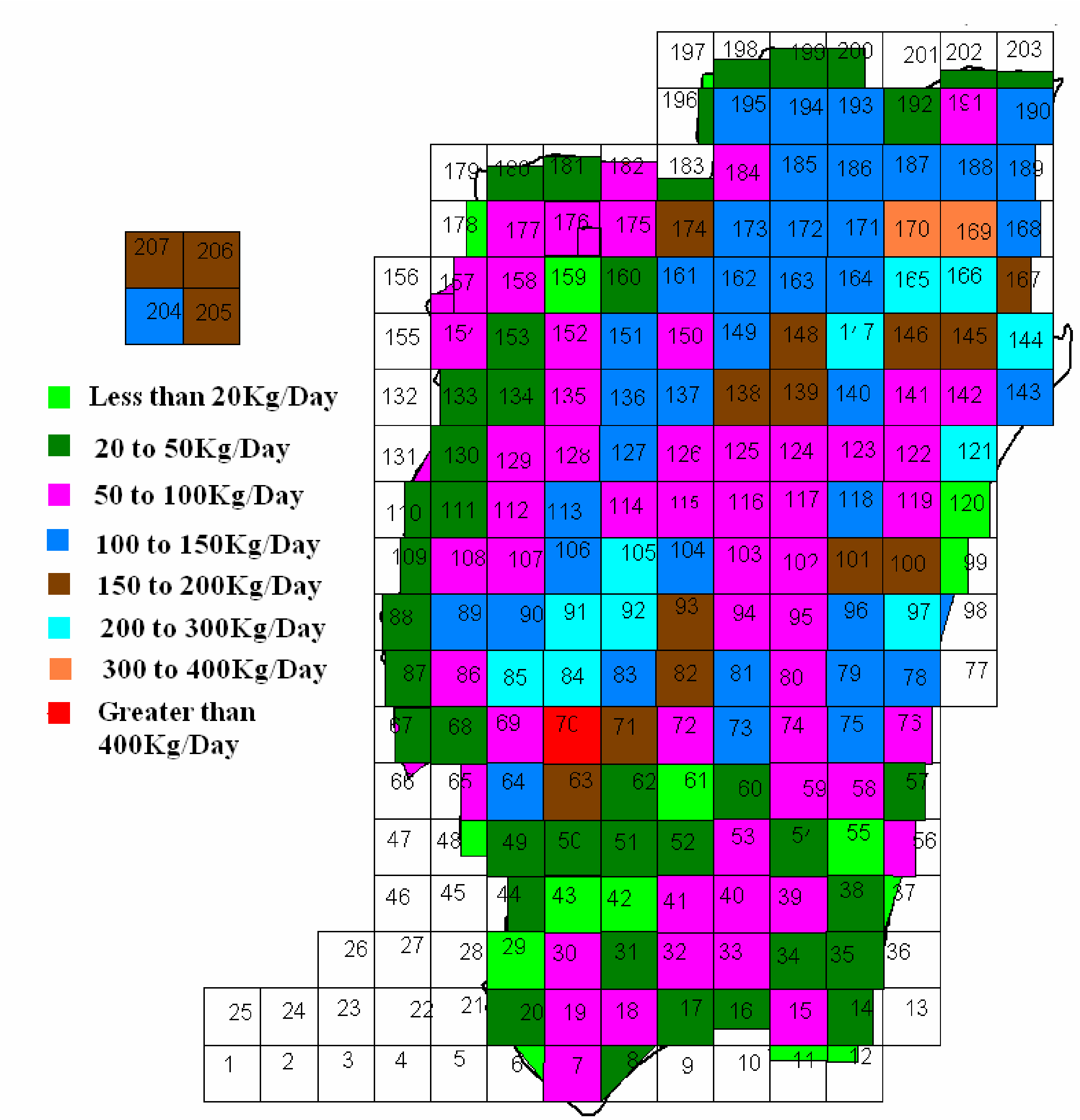
Future Growth Scenario



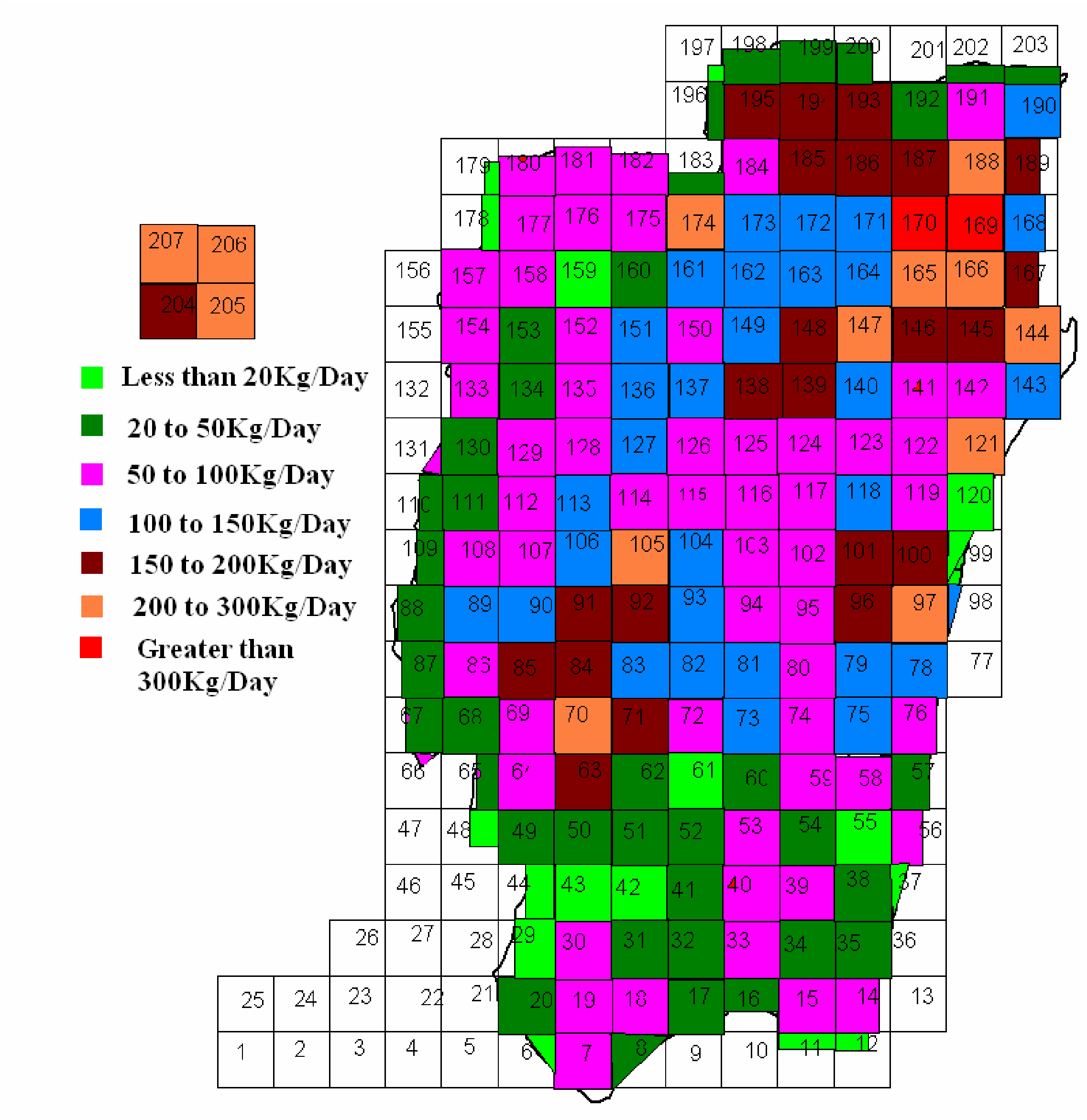
3.1(a) BAU Emission Load for Chennai city PM, 2007



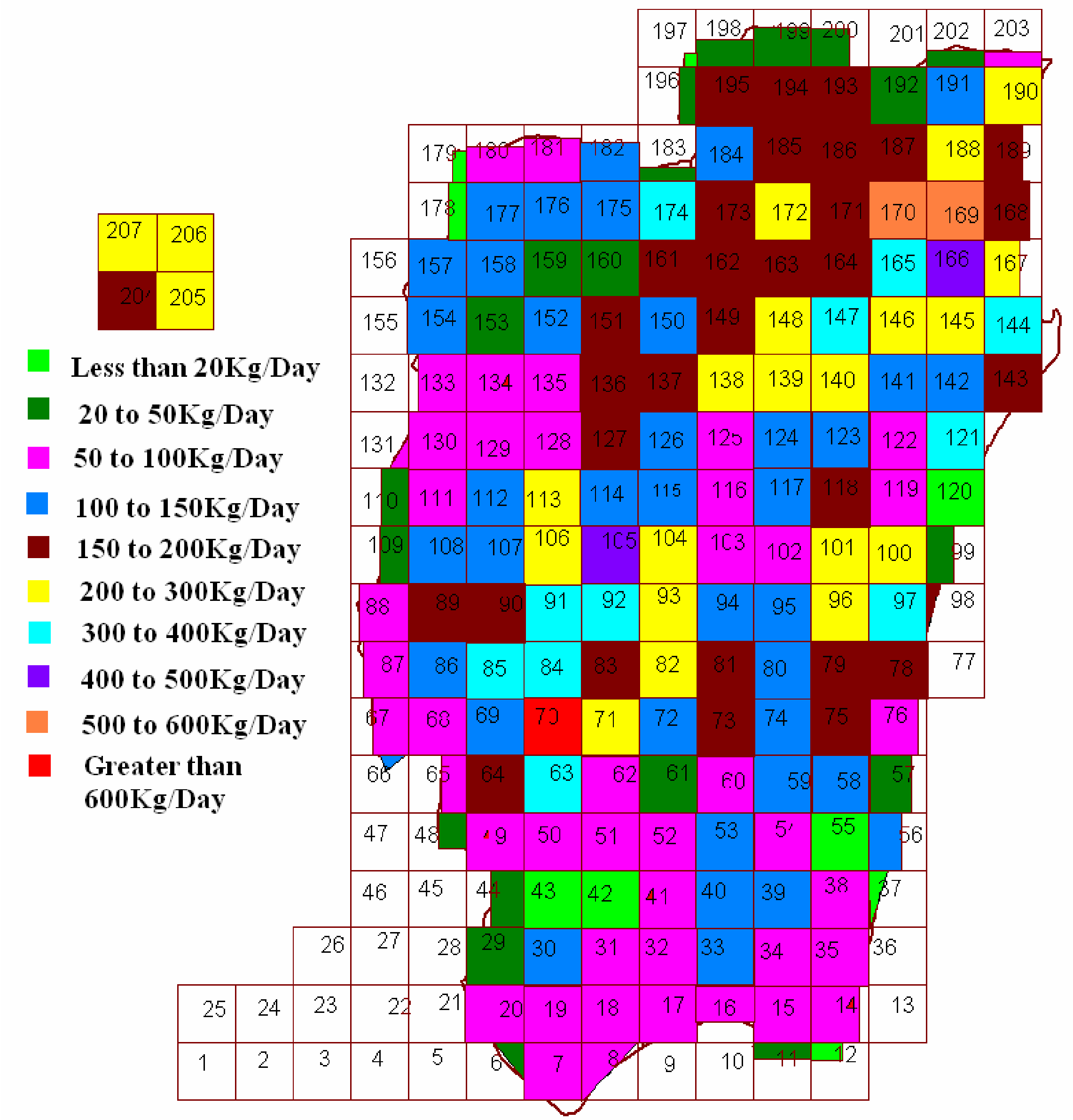
3.1(b) BAU Emission Load for Chennai city NOx, 2007



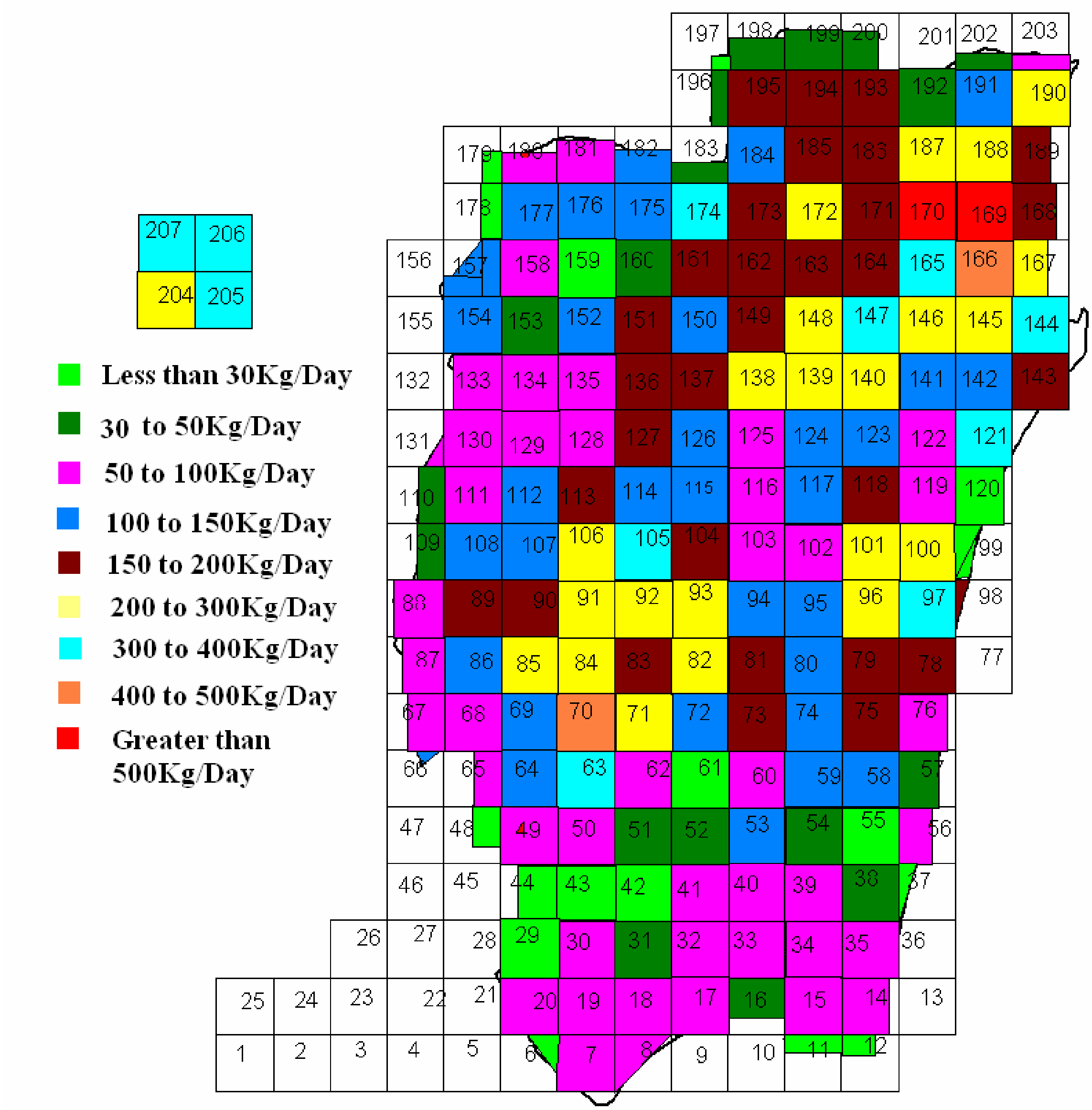
3.2(a) BAU Emission Load for Chennai city PM, 2012



3.2(b) BAU Emission Load for Chennai city NOx, 2012



3.3(a) BAU Emission Load for Chennai city PM, 2017



3.3(b) BAU Emission Load for Chennai city NOx, 2017

Projection for whole city

Total Emission Loads (kg/day) in Chennai

Emission Rate(Nox)-2007						
Site Name	Saidapet	Adyar	Mylapore	Triplicane	R.K.Nagar	Ambattur
Vehicles	155.71	216.53	378.01	118.52	130.24	251.91
Domestic	32.00	28.53	34.03	30.93	10.92	7.41
Resturants	26.13	24.31	44.83	32.49	40.07	29.74
Bakeries	0.24	0.17	0.31	0.25	0.16	0.23
DG Sets	2.58	5.39	3.20	2.25	1.97	4.31
Industries	-	-	-	-	-	1572.35
Open Burning	-	-	-	-	20.42	-
Total	216.65	274.93	460.37	184.43	203.77	1865.96

Emission Rate(NOx)-2012						
Site Name	Saidapet	Adyar	Mylapore	Triplicane	R.K.Nagar	Ambattur
Vehicles	248.70	348.59	608.79	190.88	209.75	405.70
Domestic	32.00	28.53	34.03	30.93	10.92	7.41
Resturants	26.13	24.31	44.83	32.49	40.07	29.74
Bakeries	0.24	0.17	0.31	0.25	0.16	0.23
DG Sets	2.58	5.39	3.20	2.25	1.97	4.31
Industries	-	-	-	-	-	1572.35
Open Burning	-	-	-	-	20.42	-

Total	309.65	406.98	691.15	256.78	283.29	2019.75

Emission Rate(NOx)-2017						
Site Name	Saidapet	Adyar	Mylapore	Triplicane	R.K.Nagar	Ambattur
Vehicles	398.47	561.27	980.46	307.41	337.81	653.39
Domestic	32.00	28.53	34.03	30.93	10.92	7.41
Resturants	26.13	24.31	44.83	32.49	40.07	29.74
Bakeries	0.24	0.17	0.31	0.25	0.16	0.23
DG Sets	2.58	5.39	3.20	2.25	1.97	4.31
Industries	-	-	-	-	-	1572.35
Open Burning	-	-	-	-	20.42	-
Total	459.41	619.66	1062.82	373.32	411.34	2267.43

Note: All Units are in Kg/Day

Emission Rate PM(2007)						
Site Name	Saidapet	Adyar	Mylapore	Triplicane	R.K.Nagar	Ambattur
Vehicles	29.70	40.95	68.18	28.29	26.70	46.43
Domestic	0.99	0.89	1.06	0.96	0.34	0.23
Resturants	0.81	0.76	1.39	1.01	1.24	2.45
Bakeries	0.63	0.84	1.46	0.84	0.63	1.25
DG Sets	0.09	0.20	0.12	0.08	0.07	0.16
Industries	-	-	-	-	-	57.40
Open Burning	-	-	-	-	54.44	-
Road Dust	76.68	306.26	366.22	62.48	473.04	275.01
Construction	8.61	81.34	31.98	6.70	14.10	127.01

Total	117.52	431.21	470.41	100.36	570.55	509.94

Emission Rate PM(2012)						
Site Name	Saidapet	Adyar	Mylapore	Triplicane	R.K.Nagar	Ambattur
Vehicles	47.42	65.92	109.81	45.55	43.00	74.78
Domestic	0.99	0.89	1.06	0.96	0.34	0.23
Resturants	0.81	0.76	1.39	1.01	1.24	2.45
Bakeries	0.63	0.84	1.46	0.84	0.63	1.25
DG Sets	0.09	0.20	0.12	0.08	0.07	0.16
Industries	-	-	-	-	-	57.40
Open Burning	-	-	-	-	54.44	-
Road Dust	122.86	493.03	589.54	99.99	761.39	442.85
Construction	8.61	81.34	31.98	6.70	14.10	127.01
Total	181.42	642.96	735.36	155.13	875.20	706.12

Emission Rate PM (2017)						
Site Name	Saidapet	Adyar	Mylapore	Triplicane	R.K.Nagar	Ambattur
Vehicles	75.95	106.15	176.85	73.37	69.25	120.43
Domestic	0.99	0.89	1.06	0.96	0.34	0.23
Resturants	0.81	0.76	1.39	1.01	1.24	2.45
Bakeries	0.63	0.84	1.46	0.84	0.63	1.25
DG Sets	0.09	0.20	0.12	0.08	0.07	0.16
Industries	-	-	-	-	-	57.40
Open Burning	-	-	-	-	54.44	-

Road Dust	197.22	760.65	949.20	160.39	1225.77	713.14
Construction	8.61	81.34	31.98	6.70	14.10	127.01
Total	284.32	950.82	1162.05	243.35	1365.84	1022.08

Note: All Units are in Kg/Day

ANNEXURE 3A

SOURCE CODE USED IN EMISSION INVENTORY

Source Code: 10 DIGIT NUMBER:1010101010

First tow digit indicates the nature of the source: i.e. 10–point source; 20–line source and 30-area source. Next two digits indicate type of source (01-99). The fifth and sixth digits indicate source category: RS-residential; IN-industrial; DO-domestic and OS-other sources. The seventh and eighth digits indicate the reference 2x2 km grid number (01-99) and the last two digits indicate the season (WS-winter season, SS-summer season, MS-monsoon season, and PS-post monsoon season)

ANNEXURE 3B

INDIAN INSTITUTE OF TECHNOLOGY MADRAS

EMISSION INVENTORY QUESTIONAIRE

FOR RESIDENTIAL EMISSIONS

1. Age group <20 | 20-30 | 31-40 | 41-50 | 51-60 | > 60

2. Gender ----- M / F

3. Type of house (i) Independent (ii) flat (floor level--------) (iii) any other

4. Type of fuel you use (i) bio gas (ii) kerosene (iii) LPG (iv) Mixed (v) Wood

5. What is the quantity of fuel consumed per month in your house…………

6. Mode of transportation to office/shop Bus | Motorcyc | Auto | Car

    3.1 Vehicle type:………………….. (if it is car / motorcycle)

    3.2 Year of registration /purchase ______________________________

    3.3. Type of fuel used per day (i) Petrol …… liters (ii) Diesel ……..liters

    (iii) Oil…..ml

7. Distance between office and home:…………(km)

8. Approximate distance traveled by the vehicle per day (in km):……………

9. Total kilometer run by the vehicle as of now…………………….

10. Vehicle exhaust emissions standard check: once in ………months.

11. Most often used route for travel (roads name):………………………………………...

………………………………………………………………………………………..

12. Specify the location/place which you normally visit during weekends/holidays
name:……………………………,approximate distance from your home…….(km)

13. Please provide details of the open burning sites, if any exist at your residential
locality………………………………………………………………………..………….

14. Please provide details of any work shops/service centers at your locality …………
…………………………………………………………………………….. ………………

15. Are you using generators as an alternate source during power failure---Yes/No, if yes
number of hours in a day ----------------. Type of fuel used --------- and average fuel
consumption per month ----------liter

Optional. For commercial / flats

1. Number of vehicles visiting commercial complex/flat ………

2. Generator Type:

   Type of fuel:

   Fuel consumption per month ……

   Average usage of generator in a day…………..

3. Number of air polluting industries in this location:

   Name of the industry

   Type of industry

Year of establishment

Stack height

Working hours -8 hours, 16 hours, 24 hours

Number of employees

Any air pollution complaint from the residents

4. Number of non-air polluting industries in this location:

Name of the industry

Type of industry

Year of establishment

Stack height

Working hours -8 hours, 16 hours, 24 hours

Number of employees

Any air pollution complaint from the residents

EMISSION INVENTORY QUESTIONAIRE

FOR RESIDENTIAL EMISSIONS

1. Age group | <20 | 20-30 | 31-40 | 41-50 | 51-60 | > 60 |

2. Gender ----- M / F

3. Type of house (i) Independent (ii) flat (floor level--------) (iii) any other

4. Type of fuel you use (i) bio gas (ii) kerosene (iii) LPG (iv) Mixed (v) Wood

5. What is the quantity of fuel consumed per month in your house…………

6. Mode of transportation to office/shop | Bus | Motorcyc | Auto | Car |

   3.1 Vehicle type:………………….. (if it is car / motorcycle)

   3.2 Year of registration /purchase ______________________________

   3.3. Type of fuel used per day (i) Petrol …… liters (ii) Diesel ……..liters

   (iii) Oil…..ml

7. Distance between office and home:…………(km)

8. Approximate distance traveled by the vehicle per day (in km):……………

9. Total kilometer run by the vehicle as of now…………………….

10. Vehicle exhaust emissions standard check: once in ……….months.

11. Most often used route for travel (roads name):………………………………………...

…………………………………………………………………………………………..

12. Specify the location/place which you normally visit during weekends/holidays

name:……………………………,approximate distance from your home…….(km)

13. Please provide details of the open burning sites, if any exist at your residential

locality…………………………………………………………………..…………

14. Please provide details of any work shops/service centers at your locality …………
………………………………………………………………………….. ………………

15. Are you using generators as an alternate source during power failure---Yes/No, if yes

number of hours in a day ----------------. Type of fuel used --------- and average fuel

consumption per month ----------liter

Optional. For commercial / flats

1. Number of vehicles visiting commercial complex/flat ………

2. Generator Type:

Type of fuel:

Fuel consumption per month ……

Average usage of generator in a day…………..

3. Number of air polluting industries in this location:

Name of the industry

Type of industry

Year of establishment

Stack height

Working hours -8 hours, 16 hours, 24 hours

Number of employees

Any air pollution complaint from the residents

4. Number of non-air polluting industries in this location:

Name of the industry

Type of industry

Year of establishment

Stack height

Working hours -8 hours, 16 hours, 24 hours

Number of employees

Any air pollution complaint from the residents

EMISSION INVENTORY QUESTIONAIRE

FOR TRAFFIC EMISSIONS

1. Age _____

2. Gender ----- M / F

3. Mode of transportation to office/shop [Bus] [Motorcyc] [Auto] [Car]

   3.1 Vehicle type:………………….. (if it is car / motorcycle)

   3.2 Year of registration /purchase ____________________________

   3.3. Type of fuel used per day (i) Petrol …… liters (ii) Diesel ……..liters

   (iii) Oil…..ml

   3.4. Mostly visiting fuel station:………………………………………….

4. Distance between office and home:…………(km)

5. Time taken for reaching office from home (mins) [<15] [15 – 30] [30-60] [>60 min]

6. Time taken for reaching home from office (mins) [<15] [15 – 30] [30-60] [>60 mins]

7. Approximate distance traveled by the vehicle per day (in km):……………

8. Total kilometer run by the vehicle as of now……………………

9. Vehicle exhaust emissions standard check: once in ………months.

10. Most often used route for travel (roads name):………………………………………...

……………………………………………………………………………………………..

11. Specify the location/place which you normally visit during weekends/holidays

name:……………………………,approximate distance from your home…….(km)

Optional:

Number of fuel stations located close to this traffic monitoring site:

Average fuel sales: (i) Petrol (ii) Diesel (iii)LPG (iv) Oil

ANNEXURE 3C

DESCRIPTION OF THE STUDY REGION AND SUMMARY OF EMISSION INVENTORY QUESTIONAIRAE SURVEY

1. IIT MADRAS

The Indian Institute of Technology Madras (IIT Madras) is an elite engineering and technology school located in Chennai (formerly Madras) in southern India. It is officially recognized as an Institute of National Importance by the Government of India and is regarded as one of the finest engineering institutions in India. Founded in 1959 with technical and financial assistance from the Government of the erstwhile West Germany, *IIT Madras* was third among currently seven Indian Institutes of Technology established by the Government of India through an Act of Parliament, to provide world-class education and research facilities in engineering and technology.

The IIT Madras is a residential institute located in 2.5 km^2 (620 acres) campus that was formerly part of adjoining Guindy National Park. IIT Madras has nearly 360 faculty, 4,000 students and 1,250 administrative & supporting staff. It has been growing ever since it obtained its charter from the Indian Parliament in 1961 and has established itself as a premier centre for teaching, research and industrial consultancy in the country.

The Institute has 15 academic departments and a few advanced research centres in various disciplines of engineering and pure sciences, with nearly 100 laboratories. The IITs are rated among the finest educational institutions in the world in terms of peer-ranking. Most of the campus is a protected forest, carved from Guindy National Park, and home to chital (spotted deer) and the black buck, amongst other wild life. There is a natural lake inside IITM, to where most of the rainwater inside IIT drains. This lake was deepened in the year 2003.

In 1956, the German Government offered technical assistance for establishing an institute of higher education in engineering in India. The first Indo-German agreement in Bonn, West Germany for the establishment of the Indian Institute of Technology at Madras was signed in 1959. IIT Madras was started with technical, academic and financial assistance from the Government of West Germany; and at the time was the largest educational project sponsored by the West German Government outside West Germany. This has led to several collaborative research efforts with universities and institutions in Germany over the years. Although official support from the German government has ended, several research efforts involving the DAAD program and Humboldt Fellowships exist.

The Institute was formally inaugurated in 1959 by Prof. Humayun Kabir, the then Union Minister for Scientific Research and Cultural Affairs. In 1961, the IITs were declared to be Institutions of national importance. The IIT circuit spans seven Institutes of Technology located at Kharagpur (estb. 1951), Mumbai (estb. 1958), Chennai (estb. 1959), Kanpur (estb. 1959), Delhi (estb. 1961), Guwahati (estb. 1994) and Roorkee (estb. 1847, upgraded to an IIT in 2001).

The main entrance of IIT Madras is located on Chennai's Sardar Patel Road, and is flanked by the affluent residential districts of Adyar, and Velachery. The campus is close to the Raj Bhavan, the official seat of the Governor of Tamilnadu state. IIT Madras is recognized as a separate postal zone (PIN 600036). There are secondary entrances for IIT Madras campus in Velachery, Gandhi Road and Tharamani.

Campus

The campus is located about 10 km from the Chennai Airport and 12 km from the Chennai Central Railway station and is well connected by buses.

Two parallel roads, Bonn Avenue and Delhi avenue, lead through the residential zone for the faculty, under a canopy of green, to the Gajendra Circle (otherwise called GC) and the administrative block. Buses ply between the gate and other locations on campus at regular intervals. Named after mountains, the IITM buses and electric mini buses ply to and from the GC, academic zone and hostels for a nominal fare.

Summary of questionnaire results

Questionnaires Circulated = 160 Nos
Questionnaires Collected = 122 Nos

- Number of Ladies = 14 Nos
- Number of Gents = 108 Nos

Number of Ladies using Two-wheelers = 11 Nos
Number of Ladies using Four-wheelers = 3 Nos
Number of Gents using Scooters = 24 Nos
Number of Gents using Motor-cycles = 56 Nos
Number of Gents using Four-wheelers = 17 Nos
Percentage of ladies using vehicles = 11.5%
Percentage of gents using vehicles = 79.5%
Percentage of people using other mode of transportation = 9%

Vehicle usage pattern (ladies) = 2W – 78.5%
4W – 21.4%

Vehicle usage pattern (gents) = 2W – 82.47%
4W – 17.53%
Scotter – 30.00%
Motorcycle – 70.00%

Average fuel (petrol) consumption per day (ladies) = 0.9333 litres
Average fuel (petrol) consumption per day (gents) = 0.782 litres

Average distance covered in a day (ladies) = 14.805 km/day
Average distance covered in a day (gents) = 17.74 km/day

Residential Survey

Type of fuel used for cooking in residence = (100% LPG)

Average number of LPG cylinders used in campus per day: 38 Nos

Average number of LPG cylinder consumption in hostel messes per day:
Himalaya – 30 Nos (3 Caterers)
Vindhya – 5 Nos
Krishna – 4 Nos
Cauvery – 5 Nos

Average number of cylinder consumption in refresh centers per day:
Tiffany – 5 Nos
Campus Café – 4 Nos
Basera Night Hotel = 3 Nos
Gurunath Stores = 3 Nos

Average consumption of LPG consumption in one approximate ½ cylinder quarters per month in residential houses.

Generator Locations in IITM Campus

Location	Product Name	Rating KW/KVA	Fuel Type	Fuel consumption (100% load with fan) L/hr	Power Generation Capacity (Volts)	Noise Limit Db(A)	Combustion air inlet flow rate m^3/min	Exhaust Gas Flow Rate m3/min	Exhaust Gas Temp (°C)
CDC	Caterpillar	600	Diesel	162.7	480	35	48.4	141.3	552.8
ICSR	Cummins	340	Diesel	101.8	415	75	32.7		538
BTB	Cummins	200	Diesel	42.8	415	75	11.9		598
ESB	Cummins	180	Diesel	38.9	415	75	11.8		569
CFDC	Greaves	2*25 = 50	Diesel	3.75	415				
MGH	Simpson	25	Diesel	2	415				
MOBILE	Greaves	110	Diesel	23.7	415				
P.O.	Greaves	10	Diesel	1	220				
SBI	Greaves	75	Diesel	5.6	415				
Total Emissions (g/hr)		**382.25**							

CDC – Computer Data Centre	MGH – Main Guest House
ICSR – Industrial Consultancy and Sponsored Research	P.O. – Post Office
BTB – Biotechnology Block	MOBILE – Open Air Theatre
ESB – Electrical Sciences Block	SBI – State Bank of India

CFDC – Computational Fluid Dynamics Cen

2. MYLAPORE

Mylapore is the *cultural hub*, and a bustling neighborhood, just south of Chennai (formerly Madras) city, the capital of Tamil Nadu, India.

The town of Mylapore predates British rule by several centuries. As per available historical and archaeological evidence, it could well be the oldest part of Chennai; with written records of early settlements going back to the 1st century BC.

The Tamil sage of the Sangam Period Thiruvalluvar, and author of great Tamil work Thirukkural is said to have been born in Mylapore, although this claim is disputed. The temple dedicated to Thiruvalluvar is one of the major attractions at Mylapore.

This place is also associated with Ptolemy the Egyptian traveller. He is supposed to have arrived at this place, which was once a thriving port city.

Mylapore is also associated with the legend of St.Thomas who, according to some accounts, is believed to have been buried at a place called Mylapore. However, as is evident from these accounts, Mylapore, at that time, was larger than modern-day Mylapore and included the neighboring suburbs of Chennai city.

Marco Polo is believed to have visited Mylapore. Marco Polo has left a detailed description of the land, the people and their customs and religion.

Mylapore was occupied by the Portuguese in 1523 who established the viceroyalty of 'Sao Tome de Meliapore' or 'San Thome and Mylapore'. Portuguese rule lasted until 1749, except for brief interrum between 1662 and 1687 when it was occupied by the French. Hindu nationalist sources attribute an orgy of violence, relgious intolerance and iconoclasm to this period of Portuguese rule which is believed to have occurred in tandem with the Goa Inquisition. The Santhome Church was believed to have been constructed by the Portuguese over the remains of a Hindu temple dedicated to Lord Kabaleeswarar. The Kabaleeswara Temple built in the 17th century (at a different site) is believed to be in commemoration of this seashore temple destroyed by the Portguese.

Portuguese rule eventually came to an end in 1749 when the town fell into the hands of the British East India Company who took possession of the settlement in the name of Muhammad Ali Khan Wallajah, the Nawab of Arcot. In that same year, Mylapore was incorporated into the administration of the Presidency of Madras. The settlement known as "Luz" developed during this period. As early as 1760, an English writer James Taylor applied for land in the region known as "Luce".

Mylapore began to capture the limelight in the late 19th and early 20th centuries when it rose as the commercial and intellectual hub of Madras city and home to a vast array of British-educated lawyers and statesmen. This was also the time when it acquired a distinct flavour as the principal abode of the city's Brahmin community. Though, with the passage of time, Brahmins have dispersed all over Chennai, Mylapore still remains one of mainstays of Chennai's Brahmin community.

In recent times, increasing commercialization has changed its looks. Today, Mylapore is known for its residential colonies, temples, shopping malls, kutcheri halls and sabhas and old 19th century residential buildings and houses.

Mylapore is a major commercial center, and one of the oldest residential parts of the city. It is well-connected by roads and Metro railway network, MRTS. It is famous for its tree-lined avenues, the famous 7th century Kapaleeswarar Temple, its kutcheri season and Ramakrishna Math.

Location

Mylapore is located a few kilometers to the south of Chennai city. It extends from Triplicane and Teynampet in the west up to the sea-coast. It is bounded by Royapettah and the river Coovum to the north. Its southern frontier corresponds roughly with that of River Adyar. It extends for around 4 kilometers from north to south and 2 kilometers from east to west.

Demographics

Present-day population of Mylapore is estimated to be around 150,000 to 300,000. Accurate statistics are not available as Mylapore is not a different township by itself but only a part of Madras city. The different neighborhoods within Mylapore have been parcelled out amongst the different wards of the Chennai Corporation.

Education

Mylapore boasts of renouned educational institutions such as Vivekananda College, St.Raphael's Girls Hr.Sec.School, P.S.Senior Secondary School, Vidya Mandir Secondary School, Sivaswami Kalalaya School, P.S Higher Secondary School, which is over a hundred years old.

Transportation

Buses

MTC buses connect Mylapore to important areas like Chennai Central, T. Nagar

MRTS

Mylapore's MRTS railway station, called Thirumylai Railway Station, connects it to other MRTS areas of Chennai.

Temples in Mylapore

Kapaleeswararar Temple
Kesava Perumal Temple
Srinivasa Temple
NavaShakti Vinayaka temple, near Luz
Madhava Perumal Temple

MundakaKanni Amman temple

Kozha Vizhi Amman temple

Velleeswarar Temple (Near Kapaleeswarar temple)

Veerabadra Swami temple - This temple has a separate shrine dedicated to Lord Sarabeshwara

Apparswamy temple

Shirdi Sai temple

Culture

Mylapore is widely regarded as the cultural hub of the city. Mylapore is the home of a number of music sabhas (cultural organizations) and distinguished musicians. The last month of the year is often set aside as Music Season when regular and continuous kutcheris are organized by the different Sabhas in Mylapore. There are performances by leading Carnatic Music vocalists and artists during this period. The Parthasarathy Swami Sabha in Mylapore is the oldest Sabha (Assembly) in Tamil Nadu. The Madras Music Academy, Mylapore is also an important nucleus of Art events in the city. Bharatiya Vidhya Bhavan Auditorium is also known for conducting cultural events.

Nageshwara Rao Garden is known for its play area, shrubs and also cultural events. Mylapore Times, a weekly neighbourhood newspaper, covers relevant issues relating to the neighbourhood of Mylapore.

Shopping

There are a number of shops and exhibition halls in Mylapore. Nilgiris 1905 is the most prominent departmental store in Mylapore. Some prominent industries which are based at Mylapore include Amrutanjan Limited. Chennai City Centre is a popular shopping mall in Mylapore. There are also halls such as Sankara Hall where book fairs and handloom and art exhibitions are held. Most of the Marina beach is located within Mylapore thereby making up a fine weekend recreation destination.

Localities in Mylapore

- Santhome
- Mandaveli
- Luz
- Madhavaperumalpuram
- Othavadi
- Quibble Island
- Raja Annamalaipuram
- Robertsonpet
- Trustpakkam

Places of importance in Mylapore

- Sri Ramakrishna Math & Universal Temple
- Thiruvalluvar Temple
- Madras Music Academy

Major Roads

1) Kutchery Road (1.4 km)

2) North Mada Street (1.7 km)

3) South Mada Street (2 km)

4) R. K. Mutt Road (1.5 km)

5) Luz Church Road (1.2 km)

6) Royapettah High Road (2 km)

Minor Roads

1) Mundakanni Amman Street (1.1 km)

2) P. P. V Koil Street (0.7 km)

3) Arunandal Street (1 km)

4) East Mada Street (1.3 km)

5) Kutchery Lane (0.7 km)

6) SengaluneerPilliyar Koil Street (0.8 km)

7) East Tank Square Street (0.5 km)

8) Ponnambala Vathiyar Street (0.7 km)

Kutchery Road

M.L.A. Office

Vasanth & Co

Shopping Apartments = 3 Nos

Chennai Corporation

Sriram Chit Funds

Auto Stand

Stamp Depot

Western Union Money Transfer

Hospital

Ration Shop

Sri Kamatchi Flats

Electrical Shops = 3 Nos

Food Nest Bakery

Dinakaran Newspaper Office

Pharmacy Shops = 4 Nos

Small Restaurants using LPG Cylinders = 5 Nos

Police Station (Monitoring Site)

Apartments (Residential) = 21 Nos (5-7 houses in 1 apartment)

Vinayagar Nagar Individual Houses = 197 Nos

Bharani Pathipagam

Ayurvedic Treatment Clinic

Flour Mill = 1 Nos

Vinayagar Temple

Jewellery Shops = 1 Nos

Hero Honda Show Room

United bank

Auto Workshop

Spencers Express

More for U (Departmental Stores)

Tea Stalls in this road using LPG Cylinder = 7 Nos

Hardware Shops = 3 Nos

Raja Marriage Hall

Jain Temple

Apartments (Office) = 3 Nos (2-3 offices in 1 apartment)

Private Clinics = 3 Nos

Wastewater Drainage Flowing below Metro train Station

Biryani Stalls = 8 Nos

Grocery Shops = 6 Nos

Departmental Stores = 4 Nos

Small shops along this road = 28 Nos

Juice Stalls = 4 Nos

Arasu Magalir Kappagam

<u>North Mada Street</u>

Saravana Bhavan Hotel

Indian Bank with ATM

Small Jewellery Shops = 8 Nos

Bank

Apartments (Residential) = 17 Nos (7-10 houses in 1 apartment)

Fancy Stores = 6 Nos

Bakery = 2 Nos

Aavin Milk Booth

Andhra Bank with ATM

Flour Mill = 2 Nos

Small hotels = 6 Nos

Gold smith Workshop = 6 Nos

Biryani Shops = 3 Nos

Tea shops using LPG = 5 Nos

School

Textile shops along road side = 11 Nos

Kabaleeswarar Temple Pond

Kabaleeswarar Temple

Radha Silk Emporium

Ambika appalam

Garland and Flower Shops = 27 Nos

Road side hotels = 4 Nos

South Mada Street

Bookstalls = 4 Nos

Small Hotels = 6 Nos

Small shops along road side = 22 Nos

Tea shops using LPG = 3 Nos

Individual Houses = 7 Nos

R. K. Mutt Road

Bus Stop

Petrol Bunk (Hindustan Petroleum)

Two-wheeler Workshop = 3 nos

Allianz Book Store

Sri Kumaran Textiles

Bakery Shops = 4 Nos

Tea stalls using LPG = 5 Nos

Marriage Hall

Bank

Jewellery Shop (small) =2 Nos

Road side normal shops = 13 Nos

Metro train (MTRS) Junction

Luz Church Road

Lodges in Church Road = 4 Nos

Small Hotels = 10 Nos

Apartments (Residential) =3 Nos (7-10 houses in 1 apartment)

Individual houses = 17 Nos

Bank of India

Bank of Baroda with ATM

Mylapore Club

Jewellery Shops = 2 Nos

Housing Board Office

Trisla Dress Mart

Auto Stand

Indian Overseas Bank with ATM

Bharat Petroleum Petrol Bunk

Sangeetha Boarding and Lodging

MGM Tyre Centre

SBI ATM

Rex Fashion Square

Ranade Library

Co-optex

Nagamarriamman Temple

Vinayagar Temple

Tea shops using LPG = 6 Nos

Bakery = 3 Nos

Small shops along road side = 21 Nos

Bus Stop

Kamadhenu Theatre

Royapettah High Road

Bus Stop

Canara Bank with ATM

School

Vivek Home Appliances

Optical Shops = 2 Nos

Nalli Silks

Bata Footwear Shop

Other small footwear shops = 4 Nos

Vidhyamandhir School

Bombay Halwa Sweets

Sundaram Finance

UCO Bank

Medical shops = 5 Nos

Market selling (Vegetables, Garland)

Sri Ram Temple

Appar Swamy Temple

MDS Sanskrit college

AIDS Prevention & Control Society

Indian Oil Petrol Bunk

MDS Law Journal Office

Dress Marts = 30 Nos

Road side shops = 39 Nos

Juice Stalls = 5 Nos

Tea shops using LPG = 3 Nos

Snacks (Chips) shop using Kerosene = 1 Nos

Bakery = 2 Nos

Small hotels = 6 Nos

Apartment (Residential) = 6 Nos (10-12 houses in 1 apartment)

Mundakanni Amman Street

Waste Paper Shops = 13 Nos

Furniture Workshops = 7 Nos

Residential Apartments = 29 Nos (10-12 houses in 1 apartment)

Individual houses = 16 Nos

Grocery Shops = 4 Nos

Small Temples = 3 Nos

Car Workshop

Furniture Workshop

Construction Work going on in 1 location in this street

Departmental Stores =2 Nos

Tea shops using LPG = 2 Nos

Small hotels = 1 Nos

Madhava Perumal Street

Perumal Temple

Residential Houses = 142 Nos

(Fully Residential Zone)

P. P. V Koil Street

Apartments (Residential) = 78 Nos (7-10 houses in 1 apartment)

Individual houses = 43 Nos

Tea shops using LPG = 2Nos

Small hotels = 2 Nos

Departmental stores = 1 Nos

Grocery = 2 Nos

Mathala Narayan Street (Devadi Street)

Tamil Nadu Police Housing Quarters = 500 Houses

State Bank of Mysore

Karur Vysya Bank

Mosque

Residential Apartments = 243 Nos (5-7 houses in 1 apartment)

Post Office

Parrryware Hardware Shop

Natchiappa Street

Residential Houses = 183 Nos

(Fully Residential Zone)

Natta Veerachi Street

Residential Houses = 81 Nos

(Fully Residential Zone)

Arunandal Street

Small hotels = 3 Nos

Hardware Shops (Iron Rods) = 7 Nos

Medical Shops = 2 Nos

Mosque

Vinayagar Temple

Residential (Apartments) = 22 Nos (10-12 houses in 1 apartment)

Individual houses = 43 Nos

Road side Fast food Shops = 3 Nos

Tea shops using LPG = 7 Nos

Departmental Stores = 2 Nos

Bakery = 2 Nos

Appumudhali Street

Apartments (Residential) = 137 Nos (5-7 houses in 1 Apartment)

Individual Houses = 238 Nos

(Fully Residential Zone)

Ganapathi Colony

Construction work going on

50-70 Residential Houses in this colony (Fully residential Zone)

East Mada Street

Small Shops = 34 Nos

Small hotels = 6 Nos

Bank of Maharashtra

SBI Bank

Residential (Apartments) = 31 Nos (5-7 houses in 1 apartment)

Individual houses = 47 Nos

Road side Fast food Shops = 4 Nos

Tea shops using LPG = 6 Nos

Kutchery Lane

Residential (Apartments) = 52 Nos (5-7 houses in 1 apartment)

Individual houses = 33 Nos

Tea shops using LPG = 3 Nos

Gold Smithy Workshop = 4 Nos

Arun Ice Creams

Road side Fast food Shops = 1 Nos

Grocery shops = 3 Nos

Bakery = 1 Nos

Departmental Stores = 2 Nos

Sengaluneer Pilliyar Koil Street

Residential (Apartments) = 72 Nos (5-7 houses in 1 apartment)

Individual houses = 27 Nos

Tea shops using LPG = 2 Nos

Road side Fast food Shops = 3 Nos

Gold Smithy Workshop = 2 Nos

Departmental Stores = 1 Nos

Bakery = 2 Nos

East Tank Square Street

Residential (Apartments) = 56 Nos (5-7 houses in 1 apartment)

Individual houses = 67 Nos

Tea shops using LPG = 3 Nos

Bakery = 1 Nos

Departmental Stores = 2 Nos

Road side Fast food Shops = 2 Nos

Ponnambala Vathiyar Street

Residential (Apartments) = 48 Nos (7-10 houses in 1 apartment)

Individual houses = 69 Nos

Tea shops using LPG = 5 Nos

Road side Fast food Shops = 1 Nos

Bakery = 2 Nos

Departmental Stores = 1 Nos

Small shops = 34 Nos

Groceries = 2 Nos

Residential Survey in Mylapore (according to age groups)

Total number of survey questionnarie circulated: **101 Nos**

Gender : Male						Vehicles				
Age Group	No of people answered to Survey	Living in Independent Houses	Living in Flats	LPG used	Kerosene used	MC	Car	Auto	Bus	No Response
<20	0	0	0	0	0	0	0	0	0	0
20-30	12	12	7	12	0	8	3	0	1	0
31-40	17	11	6	17	0	13	2	0	2	0
41-50	15	4	11	13	2	6	3	1	5	0
51-60	6	0	6	6	0	0	0	0	6	0
>60	8	2	6	6	2	0	0	0	8	0

Gender : Female						Vehicles				
Age Group	No of people answered to Survey	Living in Independent Houses	Living in Flats	LPG used	Kerosene used	MC	Car	Auto	Bus	No Response
<20	2	0	2	0	1	0	0	0	0	1
20-30	7	3	4	7	0	3	1	0	2	1
31-40	8	3	5	8	0	4	0	0	3	1
41-50	13	8	5	13	0	2	3	0	8	0
51-60	9	2	7	8	1	0	0	0	8	1
>60	4	0	4	3	1	0	0	0	4	0

Other Sources from Survey

Fuel Consumed	Number of houses consuming 1Cylinder/Month	Number of houses consuming 1.5 Cylinder/Month	Number of houses consuming 2 Cylinder/Month	Total Number of Houses	Total Number of Cylinders Used	Fuel consumed/Month (Average)
LPG	43	33	19	95	131	1.5 Cylinder
Kerosene				6		8 litres/Month

Open burning near the location = **Nil**

Workshop/Service Centre nearby = **Nil**

Houses having generators = **4 houses**

How much kerosene consumed/Month (Average) = **3 litres/Month**

Houses Having UPS service = **16 Nos**

Major Roads used by People in this Area:

R.A.Puram Road, Mylapore Bazzar Road, Greenways Road, R.K.Mutt Road, Dr.Ranga Road, C.P.Ramasamy Road, Luz Church Road, Dr.Radhakrishnan Road

Locations Visiting during Weekends:

Theatres, Beach, Shopping Malls, Kapaleeswarar Temple, City Centre, Sabhas, Music Academy.

3. TRIPLICANE

Triplicane or Tiruvallikeni is an important tourist destination in Chennai city. The place constitutes one of the centrally located suburbs of the city. The place shares its boundaries with the George Town, the center of Chennai city. Triplicane as such bears a great importance, much of which is attributed to the popular worshipping place located here. The place bears quite a strategic importance due to its close proximity with the city center and the presence of beautiful Marina Beach that lines the eastern boundary.

Triplicane, according to the popular belief has been derived from the term Tiru-Alli-Keni which means flowers in the pond. The place is believed to be inhabited since ancient times and featured beautiful gardens during those times. The ancient landmarks that bear the secrets of the past still hold up against the ravages of time. The famous Parthasarathy Temple is one such popular site. The temple is the single highly acclaimed tourist destination in Triplicane area. Dedicated to Lord Krishna, the temple is a much revered place for Hindus.

The existing temple structure is said to be built by the Pallavas in the 8th century A.D. One more important attraction in Triplicane is that of Aamir Mahal, the legacy of the Nawabs. The monument has served as residential place to the Nawab Family of Arcot. The Wallajah Mosque, popular by the name Big Mosque is equally fascinating. The mosque too was built by the Nawab and is frequently visited by the Muslim community living here.

The Chepauk Palace on the Marina promenade features the in distinctive Indo-Sarcenic building. It is one out of several architectural treasures housed in the Triplicane area. For popular entertainment the place features the noted grounds of the M.A.Chidambaram Stadium. The coveted cricket stadium witnesses a great crowd of cricket fans during the sessions. The place is further provided with cinema halls, hotels and restaurants and some reputed educational institutes.

Some reputed establishments grounded in the region include Presidency College, Dayanand College of Commerce, Kasturba Gandhi Hospital, Zohra Madani Hospital, Mysaan Hospital, etc.

Accessibility

- Triplicane is about a kilometer far from Chennai city centre. One can easily reach the place by taxi or bus.
- The Tiruvallikeni and Chepauk Railway station provide the services in the region.
- Chennai Airport, the nearest airport to Triplicane is located south west of the place. The airport is about 11 kms far from Triplicane.

Areas under Triplicane

- Chepauk

Bus Routes:

- Transportation by bus is frequent in this area.

Railways:

- Chennai Suburban Railway – MRTS (From Velachery to Chennai Beach Junction)

Areas Covered in the Survey:

1) Pollution Due to Traffic

The major roads where traffic count was done near the monitoring stations are:

Major Roads

- T. P. High Road (1.1 km)
- Pycrofts Road – Bells Road Junction (1.5 km)
- Dr. Besant Road (1.3 km)

2) Residential Areas

Triplicane is called the Bachelors Paradise of Chennai. The locality has a large number of *mansions* - a local synonym for guest houses. Many of these are suitable for students, single professionals and visitors. Walking around the lanes of Triplicane during evening time, one is apt to come across hosts of youngsters conversing in different languages - English, Hindi, Telugu, Tamil and Malayalam. The place is known for its educational book stalls and used bikes. Triplicane's Pycrofts Road is a mini T. Nagar where one can buy all kinds of garments and luggage.

a) Easwaran Doss Street

Number of residential houses, including mansions = 234

Two-wheeler workshops = 6

Number of teashops using LPG = 2

Number of teashops using kerosene = 1

b) Bells Road Junction Joint with Wallajah Road (Chepaukam)

Number of houses (apartments) = 447 (10 houses in 1 apartment)
Number of teashops = 36
Number of bookstalls = 4
Number of two-wheeler automobile sellers = 62
New Park Hotel (Restaurant) = 1 (2-3 cylinders/day) consumed
Number of Small hotels using LPG in this road = 29
Number of Schools in this locality = 1
Number of road side hotels using kerosene as fuel = 11

Others

Electricity Board Office
Chepaukam cricket club stadium
Mosque
Kasthuribha Gandhi Government Hospital

c) Pycrofts Road

Book shops = 26 Nos (including road side 2nd hand book shops)
Juice Shops = 34 Nos
SBI Bank with ATM
Vijaya Bank with ATM
Canara Bank
Bank of India
Auto Stand = 7 Nos
ZamBazar Police Station
Corporation School
Temple North Entrance
Amir Mahal Mosque
Small Mosques = 4 Nos
Bakeries = 22 Nos
Road side Hotel = 17 Nos
Teashops using LPG Cylinders = 26 Nos
Sangeetha Hotel, Aradhana Hotel, Vasantha Bhavan, Sagar and Muniyandi Vilas Hotel
Ice Cream Parlor = 6 Nos
Small Shops in this area = 50 – 60 Nos
Garment shops = 13 Nos
Small Jewellery Shops = 8 Nos
Tanishq Jewellery
TASMAC Wine Shop = 2 Nos
Market (selling grocery, vegetables-around 130 shops)
Regmath Chicken Centre
Brindhavan School

d) T. P. High Road

Number of schools = 1
Number of medical stores = 5
Number of teashops using LPG as fuel = 9 Nos
Number of hospitals (Big) = 2
Bank of Baroda with ATM
Venkateshwara Students Hostel
Jewellery Shops (small) = 3 Nos
Mobile Shops = 7 Nos
Surana Engineers Private Limited
Hospitals = 2 Nos
Union Bank with ATM
Hero Honda Showroom
Number of Apartments = 116 (10-12 residential houses in 1 apartment)
Number of road side hotels = 13 Nos

e) Dr. Beasant Road

Number of apartments = 31 (7-10 residential houses in 1 apartment)
Individual houses = 22 Nos
Number of teashops using LPG = 7 Nos
Pharmacy Shops = 3 Nos
Bakery shops = 2 Nos
Small Hotels = 4 Nos
Thirunalachariar Girls Higher Secondary School
Footwear Shops = 5 Nos
Saloon = 2 Nos
Mayland Lodge
Police Quarters
SBI ATM
Icehouse Wastage and drinking Water Board
Number of hospitals = 1 Nos
Road side fast food shops = 3 Nos
Total number of shops in this road = 42 Nos
Number of small clinics in this road = 3 Nos

f) Singarachari Street

Number of apartments = 47 nos (5-7 residential houses in 1 apartment)
N. Samaroa Primary School
Heart & Diametic Clinic
Triplicane Fund Kalyana Mandapam
Number of individual houses (agraharam) = 28 Nos
Punjab National Bank with ATM
Medical shops = 3 Nos

Uttaradi Math
Canara Bank ATM
Elementary School Teachers Federation
Krishna sweets
Temple = 2 Nos
Number of teashops using LPG cylinders = 4 Nos
Two-wheeler automobile Sellers = 2 shops

Others

Lord Vinayagar Temple
Lathe workshop = 2 Nos

g) T. P. Koil Street

Number of big apartments = 62 Nos (5-7 residential houses in 1 apartment)
Provisional & General Merchants = 2 Nos
Brindavana Enterprises
Thirumalachariar Boys Higher Secondary School
Raghavendra Swamy Mutt
Ladies Multitech Institute
Number of small Clinics = 5 Nos
Mahakavi Subramani Bharathiyar Ninaiv Illam
Temples = 1 Nos
Subiksha Departmental Stores
Brindavana Higher Secondary School
Vimal Jewellery Shop
Number of Bakery shops = 1
Number of teashops using LPG = 4 Nos
Number of road side hotels using LPG = 2 Nos
Total Number of Shops in this Street = 17 Nos
Number of small apartments = 6 (4 residential houses in 1 apartment)
Number of individual houses (agraharam) = 29 Nos

h) Chengalrayan Street

Number of apartments = 16 Nos (7-10 houses in 1 apartment)
Number of individual houses in this street = 33 Nos
Number of teashops using LPG = 6 Nos
Number of Shops in this street = 12 Nos

i) Car Street

Tamil Nadu Government Employees Association
Number of apartments = 27 Nos (5-7 houses in 1 apartment)
Number of individual houses in this street = 38

Number of Shops in this street = 6 Nos
Number of Hotels (small) = 2

j) Kanthappan Street

Number of apartments = 13 (5 homes in 1 apartment)
Number of individual houses = 23
Number of teashops in this street using LPG = 3
Number of road side hotels = 6

k) Payyalvar Street

Number of apartments = 9 Nos (15 homes in 1 apartment)
Number of individual houses = 16 Nos
Number of Teashops using Kerosene = 1
Number of teashops using LPG = 4
Road side fast food hotels = 2 Nos

L) V. R. Pillai Street

Number of houses in this street = 71 Nos
Number of Apartments (Residential) = 11 Nos (7-10 Houses in 1 apartment)
Number of teashops using LPG = 4 Nos
Temples = 2 Nos
Rex Matriculation School
Medical shops = 2 Nos
Bakeries = 1
Number of roadside hotels (fast food) = 2 Nos

M) New Fire Wood Street (Slums)

Number of huts in this street = 140 huts (15 litres/month)
Number of teashops using Kerosene = 3 Nos
Number of teashops using LPG = 5 Nos
Road side Fast food shops = 1

O) Sunguwar Street

Number of apartments = 24 Nos (10 houses in 1 apartment)
Number of Teashops using LPG = 4 Nos
Number of Small Hotels = 3 Nos
Bakery = 2 Nos
Road side fast food shops= 1 Nos
Departmental stores = 2 Nos

3) Fuel Stations

- Bharat Petroleum (Towards Royapettah Road)
- Indian Oil (Towards Royapettah Road)
- Hindustan Petroleum (Towards Royapettah Road)

4) Industries

- Nil

5) Hospitals: Kasthuriba Gandhi Government Hospital

6) Educational Institutions

- Kalaivani Vidyalayam Matriculation School

7) Religious Centres

- Parthasarathy Temple

Residential Survey in Triplicane (according to age groups)

Total number of survey questionnarie circulated: **104 Nos**

Gender : Male						**Vehicles**				
Age Group	No of people answered to Survey	Living in Independent Houses	Living in Flats	LPG used	Kerosene used	MC	Car	Auto	Bus	No Response
<20	4	2	2	4	0	4	0	0	0	0
20-30	14	7	7	14	0	11	0	1	2	0
31-40	20	11	9	20	0	13	2	3	2	0
41-50	14	9	5	14	0	5	1	3	5	0
51-60	8	4	4	8	0	2	2	0	4	0
>60	4	2	2	4	0	1	0	0	3	0
Gender : Female						**Vehicles**				
Age Group	No of people answered to Survey	Living in Independent Houses	Living in Flats	LPG used	Kerosene used	MC	Car	Auto	Bus	No Response
<20	0	0	0	0	0	0	0	0	0	0
20-30	9	6	3	9	0	6	2	0	1	0
31-40	13	12	1	13	0	3	5	0	5	0
41-50	13	6	7	13	0	2	1	0	10	0
51-60	4	1	3	4	0	0	1	0	3	0
>60	1	0	1	1	0	0	0	0	1	0

Other Sources from Survey

Fuel Consumed	Number of houses consuming 1Cylinder/Month	Number of houses consuming 1.5 Cylinder/Month	Number of houses consuming 2 Cylinder/Month	Total Number of Houses	Total Number of Cylinders Used	Fuel consumed/Month (Average)
LPG	56	27	21	104	139	1.5 Cylinder
Kerosene				0		

Open burning near the location = **Nil**

Workshop/Service Centre nearby = **Automobile Workshops = 10 Nos**

Lathe Workshops = 2 Nos

Electric Wire Turning Centre = 1 Nos

Houses having generators = **7 houses**

How much kerosene consumed/Month (Average) = **2 litres/Month**

Houses Having UPS service = **17 Nos**

Major Roads used by People in this Area:

Pycrofts Road, Mount Road, Beach Road, Temple Road, T.P.High Road, Santhome Road, Queen Mary's College Road, Singarchari Street, Towards Broadway Road

Locations Visiting during Weekends:

Theatres, Beach, Shopping Malls, Parthasarathy Temple, Spencers Plaza, Sabhas.

4. ADYAR

Adyar is a large neighborhood south of Chennai (previously Madras) in the state of Tamil Nadu in India. It is located on the southern banks of the Adyar river which joins into the Adyar Creek now being re-constructed as the Adyar Eco Park/ Adyar Poonga. It is bounded by the Buckingham Canal to the west, Tiruvanmiyur to the south, and Besant Nagar to the east.

Adyar includes various sub-localities like Gandhi Nagar, Kasturibai Nagar, Nehru Nagar, Indira Nagar, Padmanabha Nagar, Bhaktavatsalam Nagar, Parameshwari Nagar, Jeevaratnam Nagar, Shastri Nagar, Karpagam Garden, etc. Adyar is one of the posh localities in Chennai.

The literacy rate in Adyar is very high. The residents include IT professionals, Business persons, Engineers, High Court Judges and Advocates, Tamil Cinema Stars, Professors etc.

Adyar is noted for housing the Theosophical Society, which provides a calm environment along the south bank of the river for quiet contemplation on comparative religion. The Elliot's beach in nearby Besant Nagar is the nearest point to the sea, and a popular recreation spot.

IIT Madras, one of the top technical institutes in the world and Anna University, one of the best universities in India is situated near Adyar. Adyar is also home to the Central Leather Research Institute, the world's largest leather research institute and the Adyar Cancer Institute.

The locality has developed significantly through the late 1970s and early 1980s as a residential area to accommodate Chennai's sprawl. Since the late 1990s, it has become part of the *IT corridor*, the name given to the part of southeast Chennai where several IT companies have set up base. It is also home to many birds which primarily flock the Adyar estuary close to the Theosophical Society.

Adyar Estuary and Creek and the Theosophical Society on its southern side has been a haven for migratory and resident birds for years. Although the number has been in decline due to pollution and anthropogenic activities, they still attract hundreds of birds. Even before few years the Theosophical Society has come out with a CD on 'Birds of Adyar', compiled by Trust for Environment Monitoring and Action Initiating. The proposed 'Adyar Poonga' may be a first towards restoring this fragile but vibrant eco-system.

The land rates have gone up tremendously in a short period. The center of the city runs along Main Road, between Gandhinagar and Kasturbainagar, and is by far the heart of the expensive housing in the town. The modern area of Adyar includes parts of the older villages of Pallipattu, Urur and Thiruvanmiyur. The regions were annexed into the Chennai Corporation in 1977. Gandhi Nagar was planned and developed first. Later it grew to merge with the old village of Thiruvanmiyur.

Adyar has a number of good schools including The Hindu School, Bharath, Bala Vidya Mandir, Sri Sankara School, Sishya, St Johns School and the twin schools of St. Miachael's Academy and St. Patrick's which lie within the same compund. NIFT (National Institite of Fashion Technology) and Tamil Nadu's first IT center TIDEL PARK is very close to Adyar. The Mass

Rapid Transit System (Chennai) runs through Adyar and has predominant stations like Kasturbai Nagar, Indira Nagar and Thiruvanmiyur which connects Adyar from Madhya Kalash Circle to Southern parts including Tidel Park and Ascendas through the 6-lane IT corridor.

Adyar is quite near to Prarthana Cinema Theatre which is the only beach drive in theatre in the world, amusement parks like MGM Dizee world, Little Folks, VGP Golden Beach, Discotheques and Resorts and rain forest.

Localities

- Kotturpuram
- Anna University
- Raj Bhavan

Major Roads

1) Tiruvanmiyur Road (1 km)

2) Lattice Bridge Road (2.5 km)

a) Dr.Muthulaksmi Road

b) Kalki Krishnamoorthy Road (Tiruvanmiyur Side)

3) M. G. Road (Besant Nagar Road) (1 km)

4) Indra Nagar 2^{nd} Main Road (1 km)

Minor Roads

1) Dr. R. K. Nagar Main Road (0.8 km)

2) Malaviya Avenue Road (1.1 km)

3) Indranagar 1^{st} Main Road (1.6 km)

4) Sastri Nagar Road (1 km)

Indra Nagar 1^{st} Main Road

Number of Big apartments in this area = 25 (10-15 houses in 1 apartment)

Sewage pumping station (XB) area

Individual Houses = 109

Big Bakery near the School = 1

Buildings refuse dumping area (Backside of the monitoring site)

Number of teashops around this area using LPG cylinders = 10

Small Bakeries in this area = 2 Nos

Gas agencies = 2 Nos

Construction going on in 2 sites

Spencers world (Departmental Stores) = 1

Small departmental stores = 3

Padmapriya Multi Speciality Hospital

APC Customer Care

MicroDevices Methrohm Limited

Meenakshi Diagnostic Centre (Clinic)

Vachan (Garment Shop)

State Bank of India with ATM

Sanjeevan Restaurant

Indian Overseas Bank with ATM

Vegetable Shops = 2 Nos

Fast food road side hotels = 4

Small hotels = 2

Indra Nagar 2nd Main Road

The Hindu Matriculation Senior School

Number of residential small apartments around Hindu matriculation school = 238

(5-7 houses in 1 apartment)

Bhogar Drugless Hospital

General Provisional Stores = 3 Nos

Corporation Bank with ATM

Cellular Shops (Major Shops) = 3 Nos

Cellular Shops (Small) = 7 Nos

VLCC Slimming Beauty Fitness Centre

2 Big apartment constructions going on nearby to each other in this area near the main road side.

Residential houses near the construction zone

Small apartments = 72 (5-8 houses in 1 apartment)

Big departmental stores = 1

Small departmental stores = 6

Tea shops near the construction site using Kerosene = 4

Road side hotels near the construction zone using LPG cylinders = 3 Nos

Number of Bakeries in this road = 1

Indra Nagar Avenue Road

Fracture& Ortho Clinic

Isha Homes Private Limited

Hero Honda (Adyar Motors Private Limited

Jabagreen Coffees

Apartments (Residential) = 20-25 Nos (8-10 houses in 1 apartment)

Venkatrathinam Nagar

Apartments (Residential) = 35-40 Nos (10-12 houses in 1 apartment)

Individual Houses = 60-70 Nos

Teashops using LPG cylinders in this road = 2 Nos

Road side hotels (Fast foods) = 3 Nos

Bakery – 1 Nos

Lattice Bridge Road

Dr.Muthulaksmi Road

Anjugam Chettinadu Restaurant = 1

Hotel Coronet

Balaji Thanga Kadal Jewellery Shop

Police Station and Passport Office (Monitoring Site)

Temple, Mosque and Dharga

Bus Depot

SSS Mineral Water Agency

P. M .Hospitals

BSNL Exchange Office

Allahabad Bank

Chennai Corporation Zone -10

Arihant and Park (7^{th} Floor)

Bharat Matriculation School

Sangeetha Dress Mart

Standard Chartered Bank

Maruthi Showroom

ICICI Bank

Indian Oil Petrol Bunk – 2 Nos

Adyar Ananda Bhavan Sweet Shop (Branch)

Krishna Sweets (Branch)

Number of small restaurants along road side = 14

Building construction going on near petrol bunk

Big shopping complex

Suguna Chicken Shop

ACT India Limited

Lancer Mitsubhishi Car Showroom

Ganapathi Ram Cinema Theatre

Bombay Dyeing Showroom

Venkateswara Engineering Workshop

Co-operative Bank with ATM

UCO Bank with ATM

Canara Bank with ATM

2 storey shopping complex = 3 Nos

Indian Bank with ATM (near the monitoring site)

Nathans arcade shopping centre

Small Ganapathi Temple

Karur Vysya Bank with ATM

Theatre

Dream plaza

Vasantha Bhavan Hotel

Andal Marriage Hall

Bus Depot

Reliance Fresh (Fruits and vegetables)

Shopping complex near the theatre

ICICI Bank with ATM

Number of Big Hotels = 17 Nos

Number of Road side hotels = 60 Nos

Hardware Shops = 22 Nos

Footwear Shops = 13 Nos

Mobile Retail Shops = 26 Nos

Jewellery Shops (Small) = 5 Nos

Pharmacy = 11 Nos

Apartments (Residential) =16 Nos (8-10 houses in 1 apartment)

Individual houses = 12 Nos

Grocery Shops = 17 Nos

Shopping Complex (small) = 28 Nos

Plywood Shops = 19 Nos

Bakeries (Big) = 11 Nos

Tea shops using LPG cylinders along the road side = 34 Nos

Road side Briyani Centres = 22 Nos

Furniture Shops = 17 Nos

Hospitals (Small) = 4 Nos

Construction going on in 2 places

Primary schools = 2 Nos

Small Bakeries = 16 Nos

Road side hotels = 7

Kalki Krishnamoorthy Road - Lattice Bridge Road (Tiruvanmiyur Side)

Olympic Cards

HDFC Bank with ATM

Appasamy Real Estates

15 floors construction going on in this road

Plywood shops = 4 Nos

Bakeries = 5 Nos

Departmental Stores = 12 Nos

Apartments (Residential) = 8 Nos (10-12 houses in 1 apartment)

Teashops using LPG cylinders in this road = 3 Nos

Road side hotels = 2 Nos

Mahatma Gandhi 1st Main Road

Indian Bank

Woodlands

Raymonds Show Room

HDFC Bank

Bus Stop

Kotak Mahindra Bank

Malar Hospital

Besant Nagar Road

Mahatma Gandhi Road Bus Stop

Rice Mundi (Rice Shop)

Tanishq Jewellery

SBI Bank

Adyar Anandha Bhavan Sweet Shop

Indane Gas Agency

Kovai Palamudhir Nilayam Juice Shop

Raasi Diamonds Jewellery Shop

Building construction going on in 2 places in this road.

Medium apartments in this road = 184 Nos (10-12 houses in 1 apartment)

Private Matriculation school

Chinese Dragon Restaurant

Building construction of 2 apartments going on opposite to R. K. Nagar main road

Individual houses in this road = 76 Nos

Tea shops using LPG = 13 Nos

Small hotels = 6

Bakeries = 2 Nos

Shopping complex = 2

Departmental Stores = 7

Road side fast food hotels = 8

Canara Bank with ATM

Auto Stand near to matriculation school

Vegetable and fruits Market

Balram Road

Juice Shops = 2 Nos

Hardware Shops = 5 Nos

Groceries = 12 Nos

Apartments = 23 Nos (7-10 houses in 1 apartment)

Individual Houses = 63 Nos

Teashops in this road = 2 Nos

Fast food Shops = 3 Nos

Dr. R. K. Nagar Main Road

Small apartments in this area = 34 Nos (5-7 houses in 1 apartment)

Number of big apartments = 3 (15-20 houses in each apartment)

Shopping complex = 2 Nos

Departmental stores = 4

Bakeries = 2 Nos

Tea shops using LPG Cylinder = 3 Nos

Fast food hotels along the road side = 4 Nos

Tea shops using kerosene = 1

Individual houses = 26 Nos

Karumarri amman Temple

Gas Agency – 1 Nos

Bajaj Allianz

Balaji Nursing Home

Road side fast food shops = 2 Nos

Malaviya Avenue Road

Number of small apartments in this area = 19 (5 -7 houses in 1 apartment)

Number of individual houses = 23

Bakeries = 1 Nos

Construction of a big apartment is going on near SBI Bank ATM

Tea shops using LPG Cylinder = 4

Road side Hotels near the construction site = 3 Nos

Small hotels = 6

Private departmental stores = 4

Small shopping complex = 1

Justice Ramanujam Street

Sri Vasla Foundation (P) Limited

Ample Technologies

Apartments = 4 Nos (10-12 houses in 1 apartment)

Individual houses = 19 Nos

Teashops using LPG in this street = 2 Nos

Bakeries = 1 Nos

Shastri Nagar Road

Tasmac Wine Shop

Fish Market along road side

Number of shopping complexes in this area = 3

Post Office

Indian Overseas Bank with ATM

Axis Bank with ATM

Community Marriage Hall -2

Very Big Apartment near marriage hall = 2 (25 -30 houses in 1 apartment)

Small apartments = 9 (5-7 houses in 1 apartment)

Departmental stores = 5

Aavin Milk Booth

Individual houses = 12 Nos

Road side hotels = 4

Small restaurants = 2

Number of tea shops using LPG cylinder in this area = 4 Nos

Private Hospital = 2 Nos

Priya Diagnostic Centre

Maruthi Showroom

Shastri Nagar 1st Main Road

State Bank of Mysore

Individual Houses = 8 Nos

Number of Apartments = 3 Nos (8-10 houses in 1 apartment)

Teashops using LPG in this road = 2 Nos

Road side Hotels in this road = 4 Nos

Shastri Nagar 1st Cross Street

Apartments (Residential) = 4 Nos (15-20 Houses in 1 apartment)

Individual Houses = 6 Nos

Parameswari Nagar

Bala Clinic

Apartments (Residential) = 6 Nos (8-10 houses in 1 apartment)

Individual Houses = 5 Nos

Residential Survey in Adyar (according to age groups)

Total number of survey questionnarie circulated: **105 Nos**

Gender : Male						**Vehicles**				
Age Group	No of people answered to Survey	Living in Independent Houses	Living in Flats	LPG used	Kerosene used	MC	Car	Auto	Bus	No Response
<20	1	1	0	1	0	0	0	0	1	0
20-30	9	5	4	9	0	9	0	0	0	0
31-40	14	9	5	14	0	10	2	2	0	0
41-50	11	8	3	11	0	6	2	0	3	0
51-60	14	5	9	13	1	0	1	1	8	4
>60	8	2	6	5	3	0	0	0	2	6

Gender : Female						**Vehicles**				
Age Group	No of people answered to Survey	Living in Independent Houses	Living in Flats	LPG used	Kerosene used	MC	Car	Auto	Bus	No Response
<20	4	2	2	4	0	1	0	0	2	1
20-30	7	6	7	7	0	4	2	0	0	1
31-40	11	8	3	11	0	6	2	0	3	0
41-50	6	2	4	6	0	1	2	0	2	1
51-60	10	2	8	8	2	0	0	0	2	8
>60	10	5	5	8	2	0	0	0	1	0

Other Sources from Survey

Fuel Consumed	**Number of houses consuming 1Cylinder/Month**	**Number of houses consuming 1.5 Cylinder/Month**	**Number of houses consuming 2 Cylinder/Month**	**Total Number of Houses**	**Total Number of Cylinders Used**	**Fuel consumed/Month (Average)**
LPG	46	34	17	97	131	1.5 Cylinder
Kerosene				8		9 litres/Month

Open burning near the location = **Nil**

Workshop/Service Centre nearby = **Nil**

Houses having generators = **5 houses**

How much kerosene consumed/Month (Average) = **4 litres/Month**

Houses Having UPS service = **26 Nos**

Major Roads used by People in this Area:

Indra Nagar Road, Besant Nagar Road, Old Mahabalipuram Road, Towards Adyar Road, Raja Annamalaipuram Road, Tidel Park Road, Tiruvanmiyur Road

Locations Visiting during Weekends:

Theatres, Beach, Shopping Malls, Spencer Plaza, Temples, City Centre, Sabhas.

5. SAIDAPET

Saidapet is a suburb of the city of Chennai, India. Mambalam, T.Nagar, Guindy, Nandanam, K. K. Nagar are its neighbourhood suburbs. A subway joining Alandur road and Anna Salai (earlier Mount Road) has been constructed recently. This allows easier access to Anna Salai, the arterial road in Chennai. Saidapet is largely a residential area with very less number of shopping places. However, shopping places are gradually developing here.

Saidapet is named after Sayyid Shah, a high-ranking 18-century official of the court of the Nawab of Arcot. The then Nawab of Arcot gifted these parts to Sayyid Shah in 1730. However, Saidapet at that time also included Kotturpuram and Nandanam.

The Maraimalai Adigal Bridge (previously the *Marmalong Bridge*) connects the northern banks of the River Adyar with the south. This bridge was originally built in 1726 by Armenian Coja Petrus Uscan. The dilapidated old bridge was replaced by a new one in the 1960s built as part of reconstruction and modernization efforts. The name Marmalong might have originated from the neighbourhood of Mambalam.

If one boundary of Saidapet is the Adyar River, then a significant place in it is the Maraimalai Adigal Bridge. It was called the Marmalong Bridge for over 200 years. The Armenian trader who built the steps in St. Thomas Mount constructed this bridge. In the 1970s this bridge was broadened. This was a time when Tamil enthusiasm was prevalent everywhere and every non-Tamil name was replaced by a Tamil name. This bridge was also renamed. Even then for many it is just the Saidapet Bridge. But Saidapet itself is a very big bridge. It is the bridge that links the South Tamil Nadu and Chennai.

In those days, in Saidapet, quite a number of washermen steam-washed the clothes in large urns kept there, rinsed them in the Adyar River and dried them in bright sunshine. The increase in the Chennai population has proportionally increased the number of washermen and the clothes they wash. The size of the Adyar banks has shrunk today. But in that available space we see thousands of clothes being dried up and it is a very special scene to view. The open sewer lines along the streets have vanished in Saidapet. Even now the main streets and houses in Saidapet resemble those of a traditional small town. Large multi-storey buildings and apartments have not yet occupied the area. There was a time, when the construction of more than one floor was banned in Saidapet. The reason for that was its proximity to the airport. These regulations have been liberalized to a large extent now. In Guindy, which is close to Saidapet, large, tall buildings have come up.

The Karaneeswarar Temple and the washing area in the Adyar River are not the only aspect that adds fame to Saidapet. An educational institution makes Saidapet very distinguished. That is the Teachers' Training College that has completed 100 years, whence thousands of trained teachers have come out and enlightened lakhs and lakhs of students. This college, located in an extensive area, has buildings that are spacious and beautiful. Since one building is in a dilapidated condition it has been kept closed. Efforts are being taken to renovate that building. Just half a kilometre away from the Teachers' Training College there is another spacious institution. The former imparted intellectual education to students, while the latter gave physical education. The YMCA school at Saidapet is a training centre for the physical education instructors. This is also a very reputed institution. In the past 20 years, dozens of Tamil and Telugu movie shootings have been held in this open field. In these 20 years in our film industry, if the hero has to share a few words with the heroine then there should be 50 identically clad persons dancing behind them. It is a compulsion for the heroine too. To accommodate 50 persons at a time for them to dance and to do somersault and all such acrobatics a large open space is inevitable. The Saidapet swimming pool, maintained by YMCA, is also famous. There was a time when there were only two swimming pools in Chennai. One is the swimming pool on the Beach in Marina. The next one is the YMCA pool at Saidapet.

Despite being next to a Police Station, Saidapet is known for the abundant availability of drugs especially marijuana.

Transportation:

Railway station

There is a suburban railway station towards the north is Mambalam and Guindy towards the south.

Buses

Saidapet has a MTC bus terminus located on Anna Salai. it is well connected by no of buses to central chennai. saidapet is enroute to most of the buses to central chennai. There is a proposal to construct another bus terminus in west saidapet. some of the famous bus service from this area is 18 k.

Temples

Karaneeswarar Temple
Narasimha Perumal
Kadumbaadi Chinnamman Kovil
Anjaneyar Temple

Churches

Saidapet has about seven churches, St. Thomas church has a congregation of 500 families and is situated on LDG Street, the NLAG Church is situated across the bridge. It is the biggest Assembly of God church in Tamil Nadu.

Bridges

1. The bridge located near the market on Jeenis road serves as a vital link to Mount Road from West Saidapet.
2. Jones road underpass (currently under construction) when built will serve an important link for West Saidapet.
3. Aranganathan subway serves to connect Ashok Nagar and Mambalam

Saidapet is an important administrative center. The health district in Chengalpet district is split into Saidapet hub and Kanchipuram hub. Panagal building which is a part of saidapet is a famous landmark.

Saidapet had a large weaver population and handlooms were in operation as late as 1990. It was quite notorious for filariasis in the olden days.

Saidapet has a very busy shopping market place called the Bazaar Road. It is famous for its fish market attracting buyers from faraway places.

St Marys Matriculation Higher Secondary School is one of the Schools situated here

One other school of prominence is Model higher Secondary school, which has been serving the local population since the 40's. Model Higher sec school is another popular school situated in saidapet.

Major Roads

1) Bazaar Road (1 km)

2) Grand Southern Trunk (GST) Road (1.8 km)

3) Jeenis Road (1.3 km)

Minor Roads

1) Jones Road (1.2 km)

2) Flower Street (0.8 km)

3) Dharmaraj Koil Street (1 km)

4) Seshasalam Street (0.5 km)

5) Abdul Razzak Street (1 km)

6) Pillayar Koil Street (0.5 km)

7) Balaji Singh Street (1 km)

<u>Bazaar Road</u>

Police Station (Monitoring Site)

Private Hospital – 1 Nos

Tea shops using LPG cylinders in this road = 6 Nos

Bakeries = 1 Nos

Udipi Hotel

Private Jewellery Shop

Small Hotels = 3

Medical Stores = 2 Nos

Small Apartments (Residential) = 19 Nos (5-8 houses in 1 apartment)

Individual Houses = 28 Nos

Market inside this road

Apartments (Offices) = 2 Nos

Departmental Stores = 3 Nos

Indian Bank ATM

Road side shops along the road side = 43 Nos

Grand Southern Trunk (GST) Road

Indian Oil Petrol Bunk

Tea shops using LPG cylinder = 4 Nos

Small hotels = 5 Nos

Small Apartment Houses (Residential) = 13 Nos (5 houses in 1 apartment)

Iyengar Bakery

Bakeries = 2 Nos

ICICI Bank ATM

Golden Dragon Chinese Restaurant

Medium Apartment Houses (Residential) = 4 Nos (8-10 houses in 1 apartment)

Fast food road side hotels = 2 Nos

Athapar Restaurant

Departmental Stores = 2 Nos

Spencers World Departmental stores

Jeenis Road

Panagal Buildings (13 offices inside this building, Department of Environment, Government of Tamil Nadu Adminisrtation office in 2nd floor)

Private Hospital = 1 Nos

Small Dispensaries = 2 Nos

Tea shops using LPG cylinders = 7 Nos

Small hotels near panagal buildings = 2 Nos

Sweet Stall = 1 Nos

Road side hotels using Kerosene = 9 Nos

Bakeries = 3 Nos

Small Apartments (Residential) = 8 Nos (5 houses in 1 apartment)

Medical stores = 1 Nos

Individual houses = 13 Nos

<u>Jones Street</u>

Tea shops using LPG Cylinders = 6 Nos

Private Matriculation School

Individual Houses = 7 Nos

Private Clinics = 2 Nos

Bharat Petroleum Petrol Bunk

SBI Bank ATM

Departmental stores = 3 Nos

Apartments (residential) = 6 nos (8-10 houses in 1 apartment)

Road side hotels = 11 Nos

Meat Stall

<u>Flower Street</u>

Individual Houses = 4 Nos

Apartments (Residential) = 3 Nos (10-12 houses in 1 apartment)

Departmental Stores = 1 Nos

Selva Vinayagar Temple

Small shops in this street = 23 Nos

Road side eateries = 3 nos

Tea shops using LPG cylinders = 2 Nos

Dharmaraj Koil Street

Flat apartments = 17 Nos (5-7 houses in 1 apartment)

Individual houses = 13 Nos

Sweet stall = 1 Nos

Tea Shops using LPG cylinder = 2 Nos

Small shops in this street = 11 Nos

Road side hotels = 2 Nos

Seshasalam Street

Number of houses in this street = 19 Nos

Apartments (Residential) = 16 Nos (8-10 houses in 1 apartment)

Teashops along road side using LPG cylinders = 1 nos

Medical stores = 1 nos

Construction work is going on near the residential apartments

Departmental stores = 1 nos

Small shops in this street = 17 nos

Narasimha Perumal Temple

Bakery = 1 nos

Automobile workshop = 1 Nos

<u>Abdul Razzak Street</u>

Kalyana Mandabam (Marriage Hall)

Teashops along the road side using LPG cylinders = 4 Nos

Theatre

Apartments (Residential) = 8 Nos (8-10 houses in 1 apartment)

Individual houses = 13 Nos

Aavin Milk Booth

Corporation Bank with ATM

Road side Tea shops using Kerosene = 1 Nos

Small hotels = 3 Nos

Meat Stalls = 2 Nos

Road side Hotels = 6 Nos

Departmental Stores (small) = 4 Nos

Departmental Stores (Big) = 1 Nos

Small Mosque

<u>Pillayar Koil Street</u>

Private School

Mandabam (Hall) = 2 Nos

Individual houses = 46 nos

Apartments (Residential) = 13 Nos (5-7 Houses in 1 apartment)

Departmental stores = 4 Nos

Tea shops using LPG cylinders = 3 Nos

Road side Hotels = 6 Nos

Small Hotel = 1(Ariya Bhavan)

Pillayar Temple in this street

Indane LPG cylinder office and godown

Construction work of 2 apartments is going on

Balaji Singh Street

Number of houses in this street = 38

Number of residential apartments = 17 nos (5 houses in 1 apartment)

Teashops using LPG cylinders = 2 Nos

Small hotels = 2 Nos

Road side hotels (Fast foods) = 3 Nos

Medical shop = 1 nos

Departmental Stores (small) = 2 nos

Small shops along the road = 31 nos

Video library selling CD's for rent

Lathe workshop = 2 nos (nearby to each other)

6. R. K. NAGAR

R. K. Nagar lies adjacent to Chennai city center. The place (George Town) is a couple of kilometers away and towards the south of Tondiarpet. The place has got its railway station, grounded within the suburban area, called Tondiarpet Railway Station. The nearest airport is Chennai Airport, which lies in the south west region of Tambaram. The place is about 16 km away.

R. K. Nagar constitutes an important suburban region of Chennai city. The place is located in the northern outskirts and close to the nearby sea that is Bay of Bengal. R. K. Nagar is one important commercial centre in the north of the city. The place shares its boundaries with other important regions of Chennai including the city center, George Town. The extensive road and railway network connects this suburban region with the rest of the city.

R. K. Nagar houses some important offices in the Chennai city. The place constitute the Zone-I and houses the zonal office of the Corporation of Chennai. The Corporation is responsible for the administration in its zonal area and city at large.

Trade and commerce flourishes in the township of R. K. Nagar. The place features a number of commercial enterprises that operate in this part of the city. Manufacturing and distributing enterprises are abundantly found at R. K. Nagar. The region has a good number of export houses which primarily deal in silk apparels and jewellery. A good number of outlets merchandising plastic ware and metal ware are prevalent in the suburbs.

R. K. Nagar is dotted with banks and hospitals. The southern end of the suburbs has a maximum concentration of these institutes. The region also features the fishing harbour built on the eastern sea shores. The Fish Marketing Office situated here is quite popular.

Banks and hospitals are spread throughout the suburban region. The southern part of the suburbs has a maximum concentration of these institutes. Some reputed medical facility providers include Apollo Hospital, Malinga Hospital, Government Peripheral Hospital, Communicable Diseases Hospital, etc.

With the completion of development project that was undertaken by Corporation of Chennai in the year 2004, the place took a real sigh of relief. The Corporation was responsible for the installation of public toilets, Corporation schools, gymnasia and health centers.

Bus Routes:

- 44A Chennai Beach Junction-R.K.Nagar

<u>Areas Covered in the Survey:</u>

1) Pollution Due to Traffic

Pollution emitted from vehicles are mainly observed in these roads given below.

<u>Major Roads</u>

- Ennore High Road (1.8 km)
- Manali High Road (1.5 km)

The major vehicles plying on these roads are lorries and share autos.

2) Residential Areas

R. K. Nagar mainly consists of slum dwellers along road side. However very few streets around the monitoring site, people reside in individual houses and apartments. The following streets covered in manali high road and ennore high road for residential emissions and non mobile sources are:

Manali High Road

a) Nehru Street (Slums)

Number of houses = 51
Teashops using LPG = 1
Teashops using Kerosene = 2

b) Sastri Street (Slums)

Number of houses = 22
Teashops using Kerosene = 1

c) Kamarajar Street (Slums)

Number of houses = 22

d) Sanjay Gandhi Street (Slums)

Number of houses = 35
Teashops using Kerosene = 4
Bakeries (using fire wood) for baking = 1

e) Thiruvallur Nagar (Slums)

Number of houses (apartments) = 2 (Total 7 to8 families in 1 apartment)
Slum dwellers along street side = 21
Teashops using LPG = 3
Teashops using Kerosene = 1
Construction site using generators = 1

f) Devi Karumariamman First Street

Number of residential houses = 12

g) Devi Karumariamman Main Road

Number of apartments using LPG as fuel = 3 apartments
Number of residential houses (slums) = 14

Bakeries (using firewood) for baking = 1
Petrol Station = Bharat Petroleum (1)
Hospital = 1

<u>h) Lime Clean Road (Slums)</u>

Industries = Valliammal lime clean factory
Hotels (using firewood) = 1
Fast food shops (using LPG) = 12

<u>I) Others</u>

Number of slum dwellers along road side in manali high road = 138

<u>Ennore High Road</u>

a) Parthasarathy Street

Number of houses using LPG = 12
Slum dwellers along road side = 22
Tea shops using kerosene = 3

b) Marimuthu Street

Number of houses (slums) = 28
Teashops using LPG = 1
Teashops using kerosene = 2

c) Ramasamy Street

Number of houses (using LPG) = 10
Slum dwellers = 15
Teashops using kerosene = 1

d) Coronation Nagar

Number of houses (Slums) = 32
Teashops using kerosene = 1
Bakeries (using fire wood for baking) = 1

e) Kathivakkam High Road

Number of road side teashops using kerosene = 5
Slum dwellers along road side = 14
Industries = Indian Oil Corporation (Marketing Division)

f) Others

Petrol Stations = Indian Oil (1)
Industry = Associated steel re-rolling mill
Number of slum dwellers residing in ennore high road main street = 14

3) Fuel Stations

- Bharat Petroleum (Manali High Rd)
- Indian Oil (Ennore High Rd)

4) Industries

- Indian Oil Corporation (Marketing Division)
- Associated Steel Re-Rolling Mill
- Valliammal Lime Clean Factory (Lime dust)

5) Hospitals

- Government Suburban Hospital
- ESI Dispensary

6) Educational Institutions

- Kalaivani Vidyalayam Matriculation School

7) Other Sources

- Open Burning (60 acres) –3.5 km away from monitoring grid

7. AMBATTUR

Ambattur is a major municipality in Thiruvallur district in the state of Tamil Nadu, India It is an industrial area north-west of Chennai. Though considered a part of Chennai for all practical purposes, Ambattur technically belongs to the Tiruvallur district. Closer to Anna Nagar, Ambattur is a fast developing.

Administration

Ambattur comes under the North Chennai parliamentary constituency and Villivakkam assembly constituency. Once a major panchayat, Ambattur was made a township in the 1960s. It has now attained the status of Municipal Corporation. Ambattur municipal corporation includes Padi, Korattur, Anna Nagar Western Extension, Moggapair and Ambattur Industrial Estate areas.

Demographics

As of 2001 India census, Ambattur had a population of 302,492. Males constitute 52% of the population and females 48%. Ambattur has an average literacy rate of 70%, higher than the national average of 59.5%; with 54% of the males and 46% of females literate. 10% of the population is under 6 years of age.

Economy

Companies like Britannia Industries Limited, TI Cycles of India, Dunlop, TVS have their plants in Ambattur. Videsh Sanchar Nigam Limited has its Satellite earth station at the Ambattur-Red Hills road. Jaya TV, Vijay TV, Asianet and Kairali relay signals from this facility. Moreover the HVF Factory which manufactures Military tanks is just 5 km from this place. That also makes this place important.

Ambattur Industrial Estate

The AIE (Ambattur Industrial Estate), spread over an area of 4.9 km² is the biggest small scale industrial estate in South Asia. Textile industries like ACL (Ambattur Clothing Limited), Bombay Fashions have their facilities here and employ thousands of women. Software companies like HCL Technologies and Tata Consultancy Services have their development centres in the Ambattur industrial estate. There are also a few BPO centres like Perot Systems in AIE.

Ambattur Industrial Estate had its functioning commissioned in the year 1964, by the Government of Tamil Nadu. Several factors such as suitability of the soil communication facilities, availability of raw materials and a large volume of ground water suitable for industrial and domestic purposes, etc., were responsible for seeking this place for the setting up of this industrial Estate, an extent of 4 km² adjoining the estate was acquired by the Tamil Nadu Housing Board for housing purposes.

Chennai Tech Park, a 2.4 Million state-of-the-art-Futuristic Information Technology Park, is being developed on 10 acres of land offering the finest of IT & ITES office spaces at Ambattur Industrial Estate, Chennai.

Transport

The Madras-Tiruvallur Highway (MTH Road or NH205) passes through Ambattur and the Chennai-Kolkata highway is just about 7km from the place making it a strategic location. The new Chennai Bypass between Maduravoyal and Madhavaram would pass through Ambattur IE. The completed first phase of the Bypass connects NH45 with NH4. The second phase, under construction, connects NH4 with NH5 and NH205 via Ambattur Industrial Estate.

The Chennai Central-Arakkonam railway line passes through Ambattur and has a railway station at Ambattur. Suburban Broad Gauge EMU trains daily operate from Chennai Central and

Chennai Beach to Arakkonam, Avadi, Tiruttani via Ambattur. By rail, Ambattur is 30 minutes from Chennai Central, 20 mins from Perambur and 10 minutes from Villivakkam.

Institutions

Among the various schools in Ambattur, Sir Ramaswami Mudaliar Higher Secondary School, T.I Matriculation Higher Secondary School, (both run by AMM Foundation), Sri Maha Ganesa Vidhyasala, GK Shetty Vivekananda Vidyalaya, Hussain Memorial school, Sethu Bhaskara Matriculation Higher Secondary School and Ebenezer Marcus are notable. Velammal Engineering College is located about 5km from Ambattur on the Ambattur-Red Hills road. Ambattur also houses the Chennai Zonal Training Center of Life Insurance Corporation of India.

Sir Ivan Stedeford Hospital, managed by the AMM Foundation, is a modern multi-speciality hospital serving 300,000 patients a year. Dr. Rabindran's Health Care Center is another notable hospital located near the town centre.

There are two temples here, one of Sri Vinnaraya Perumal and another for Lord Shiva. Temples for Lord Muruga and for the local deity Kannatamman can be seen here. The Mounaswami Matam, which has a temple for Sri Bhuvaneswari Amman inside, attracts a large number of the devotees of Mounaswami. There are several churches among the one prominently located close to the bus stand. The Mosque is near the railway station.

PTR is one of the big marriage halls in Ambattur. Rakki Theater entertains people by screening Tamil and English movies.

Major Roads

1) Ambattur – MTH Road (1 km)

2) Chennai – Tiruvallur Road (1.8 km)

3) Telephone Exchange Road (0.75 km)

4) Ambattur Industrial Estate Road (1.4 km)

Minor Roads

1) Mannikavinayagar Street (1.2 km)

2) South Park Street (1.75 km)

Ambattur Industrial Estate Road

1st Cross Road (1.4 km)

Tata Consultancy Services (Office Only):

Vehicles Parked Inside = Cars = 4, Vans = 3, Two-wheelers = 19

East Coast Constructions

Prince Info Park:

Parking of Vehicles = Cars = 300 Nos; Two-Wheelers = 1200

Ashok Pressure Castings (P) Limited (Company Closed)

Lucas India Service Limited = company workshop = No. of cars in workshop = 13

Sivananda Steels (P) Limited

Teashops using LPG cylinders = 4 Nos

Fire Station:

Fire Engine Vans = 2 Nos

Swaraj Mazda Vans = 2 Nos

T-2 Police Station (Monitoring Site):

Autos seized = 9 Nos

Lorry Seized = 1 Nos

Teashops using Kerosene = 1 Nos

Tamil Nadu Police Quarters = 1 Nos (10 houses)

Minica Services (P) Limited

Southern Ceramics (P) Limited

Tamil Nadu Electricity Board opposite to Police station

Road side hotels using LPG = 6 Nos

Towards 2nd Main Road

Mud Road (Left Side) – (400-500 m)

Polycrest Innovations India (P) Limited

India Land and Property Limited

Teashops using Kerosene along road side = 2Nos

Road side hotels using LPG for cooking = 2 Nos

Construction site going on after Polycrest Innovations India (P) Limited

Mud Road (Right Side) – (800m)

Construction site going on in this road

Teashops using LPG along road side = 3 Nos

Road side hotels using LPG for cooking = 3 Nos

Road side hotels using Wood for cooking = 1 Nos

Industrial Estate 3rd Main Road

3rd Main Road (Right Side) – (1.1 km)

The EIMCO-KCP (P) Limited = Cranes in Shed = 8 Nos

VGP Engineering (P) Limited

AG Bros Glass works (P) Limited

TI-Cycle of India (P) Limited

Teashops using Kerosene along road side = 1 Nos

Road side hotels using LPG for cooking = 2 Nos

3rd Main Road 1st Cross (Right Side) - (500-800 m)

Swathanthra Industries

Plasma Weld (P) Limited

R.K.S. Welding Company

Teashops using LPG along this road side = 2 Nos

3rd Main Road (Middle)

Sundaram – Clayton Brakes (P) Limited

Teashops using LPG along this road side = 2 Nos

3rd Main Road (Left Side) – (1 km)

Rane Brake Linings (P) Limited

KK Polycolor (P) Limited

Teashops using LPG along this road side = 2 Nos

ESAB India (P) Limited

Teashops using Kerosene along this road side = 3 Nos

Anna Auto Garage = Fiat Service Centre

MODI Steel Wires (P) Limited (Company Closed)

6 construction sites with 8 generators going on after MODI Steel Wires (P) Limited

Road side hotels using LPG along this road side = 2 Nos

Hotels along this road side using Wood for cooking = 1 Nos

Industries with Stacks:

1) M/S MODI Steel Wire Manufacturers Company (Company Closed)

3rd Main Road, Industrial Estate

Ambattur, Chennai – 58

2) M/S Ashok Pressure Casting (P) Limited (Company Closed)

31 – A, Industrial Estate, 1st cross Road

Ambattur, Chennai – 58

3) M/S TI – Cycle of India

Location: P. O Box No.5

Industrial Estate

Ambattur, Chennai-58

Name of the Products& its annual installed capacity: Bi- Cycles

Mild Steel Tubes = 900 T/Month

Mild Steel Stripes = 500 T/Month

List of Raw Materials consumption: Paints = 283 KL/Month

Solvents = 131/KG/Month

Phosphating Chemicals = 41.82 KL/Month

Sulphuric Acid = 137 MT/Month

Hydrochloric Acid = 2.1 MT/Month

Caustic Soda Lye = 52.63 MT/Month

Grease = 7.9 MT/Month

SKO = 327.77 KL/Month

HSD = 48.16 KL/Month

FO = 285.16 KL/Month

Process Chart: Tube Preparation → Frame & Fork Assembly → Frame & Fork Brazing → Pickling → Filing & Polishing → Phosphating → Enamelling → Assembly of Frame, Fork etc. → Kitting → Despatch

Stack Information:

a) Name of Equipment to which stack is attached: Diesel Generator – 1100 KVA (YANMAR)

Stack Dia = 0.5 m

Stack height = 8 m

Remarks = Operational Standby

b) Name of Equipment to which stack is attached: Diesel Generator – 1250 KVA (CUMMINS)

Stack Temperature = 92°C

Stack Dia = 0.45 m

Stack height = 8 m

Velocity = 14.1 m/s

Gas Discharge = 49662.3 Nm^3/day

Type of Fuel = High Speed Diesel

Remarks = Operational

c) Name of Equipment to which stack is attached: Phosphating STAT Field System

Stack Dia = 0.3 m

Stack Height = 12 m

Remarks = Operational

d) Name of Equipment to which stack is attached: Oven

Stack Dia = 0.3 m

Stack Height = 11 m

Remarks = Operational

Open Burning near the Monitoring Site: Nil

4) M/S ESAB India Limited

Location: Plot No.13, 3rd Main Road

Industrial Estate

Ambattur, Chennai-58

Name of the Products& its annual installed capacity: Welding Electrodes = 47 T/day

Submerged arc welding flux = 22 T/day

Blend Powder = 5.76 T/day

List of Raw Materials consumption: Steel = 7.7 T/day

Silicate = 4.75 T/day

Lime stone, Jute Stick Powder, Iron Powder = 18 T/day

Process Chart: Straightening → Cutting→ Dry Mixing of Flux → Wet mixing of Flux → Prepartion of slugs → Preparation of paste → Extrusion → Drying of Electrodes → Peeling and Dispatching

Expansion Proposal: Stack for Baking Ovens

Fume chamber with exhaust

Treatment Tank

Stack

Dry Blending Area

Bag Filter

Stack Information:

a) Name of Equipment to which stack is attached: Thermic Fluid Heater -6 Lakh KCal – 2 Nos

Stack Dia = 350 Ø mm each

Stack height = 21.34 m each (height from ground level)

Velocity = 7.8 m/s

Gas Discharge = 763 m^3/hr

Type of Fuel = High Speed Diesel 14 litres/hr

Average Operational hour = 6.30am -11.30pm

Remarks = Operational

b) Name of Equipment to which stack is attached: Diesel Generator – 500 KWA

2 Nos

Stack Dia = 150 Ø mm each

Stack height = 11.5 m each (height from ground level)

Velocity = 5 m/s

Gas Discharge = 931 m^3/hr

Type of Fuel = High Speed Diesel 66 litres/hr

Average Operational hour = 6.30am -11.30pm

Remarks = Operational

Open Burning near the Monitoring Site: Nil

5) M/S Rane Brake Linings Limited
Location: Plot No: 307, Industrial Estate
Ambattur, Chennai – 58

Name of the Products& its annual installed capacity: Brake Linings and Clutch Facings (5400MT)

List of Raw Materials consumption: Asbestos = 3000 T/Year

Resin = 700 T/Year

Friction Dust = 800 T/Year
Metal Powders & Others = 1100 T/Year

Stack Information:

a) Name of Equipment to which stack is attached: Dust Collector Finishing – 874 -

Stack Temp = 30°C

Stack Dia = 0.5 m

Stack height = 10 m

Velocity = 15.8 m/s

Remarks = Operational

b) Name of Equipment to which stack is attached: Dust Collector Clutch Facing – 873 -

Stack Temp = 31°C

Stack Dia = 0.5 m

Stack height = 10 m

Velocity = 16.38 m/s

Remarks = Operational

c) Name of Equipment to which stack is attached: Dust Collector Finishing – 875 -

Stack Temp = 31°C

Stack Dia = 0.5 m

Stack height = 10 m

Velocity = 16.1 m/s

Remarks = Operational

d) Name of Equipment to which stack is attached: Diesel Generator (SKODA) – 1500 KVA

Stack Temp = 31°C

Stack Dia = 0.3 m

Stack height = 10 m

Velocity = 16.4 m/s

Type of Fuel = High Speed Diesel

Remarks = Operational

Open Burning near the Monitoring Site: Nil

6) M/S Sundaram – Clayton Limited
Location: Plant 2, Plot No.3 (SP)
3rd Main Road, Industrial Estate
Ambattur, Chennai – 58

Name of the Products& its annual installed capacity:

Manufacture of Air & Air Assisted Braking System Products for Commercial Vehicles

List of Raw Materials consumption: Steel Sheet = 525 T/Month

Steel Bar = 175 T/Month

Aluminium Bar = 27 T/Month

Ferrous Castings = 175 T/Month

Plastic Parts = 12 T/Month

Rubber Parts = 20 T/Month

Lube Oil = 2.5 T/Month

Cutting Oil = 1 T/Month

Process Chart: Machining → Assembling→ Testing→ Chromating→ Anodizing→ Packing → Despatch

Stack Information:

a) Name of Equipment to which stack is attached: Chromating Section

Stack Dia = 400 mm

Stack height = 12 m

Air Pollution Control Measures Provided: LEP Extraction System

Remarks = Dismantled at the time of Inspection

b) Name of Equipment to which stack is attached: Anodising/ Phosphorising Section

Stack Dia = 400 mm

Stack height = 12 m

Air Pollution Control Measures Provided: Packed Bed Scrubber

Remarks = not commissioned

c) Name of Equipment to which stack is attached: Boiler

Stack Dia = 380 mm

Stack height = 12 m

Remarks = Under Operation

d) Name of Equipment to which stack is attached: Diesel Generator set (1000 KVA)

Stack Dia = 200 mm

Stack height = 12 m

Air Pollution Control Measures Provided: Electrode Pipe

Remarks = Under Operation

e) Name of Equipment to which stack is attached: Diesel Generator set (750 KVA)

Stack Dia = 200 mm

Stack height = 12 m

Air Pollution Control Measures Provided: Electrode Pipe

Remarks = Under Operation

Open Burning near the Monitoring Site: Nil

Chapter 4 Receptor modeling and Source Apportionment

4.1 Receptor Modeling

The monitoring work was carried out at seven different sites and for three seasons in this study. Each season had data monitored for 30 to 35 days. The samples collected on filter papers were analysed for the ion content, element content as well as the organic carbon and elemental carbon content. The information of the content of various species in the particulate matter is used to estimate the contribution of various sources to the pollution levels at a site. In this chapter we discuss two approaches used for the source apportionment. The first is based on factor analysis and is a qualitative approach which helps us identify important factors which can explain the variations in the data set measured. The second is based on chemical mass balance and it helps us quantitatively estimate the contributions of various sources.

Factor analysis is an approach which allows us to determine the important factors which can explain the variations in the experimental data set. Thus the variations in a large set of data is explained using a small set of factors. The factors are allowed to qualitatively determine the sources contributing to a particular site.

The finger print of each source in the form of a source profile can be used to determine the quantitative contribution of a source. This method is based on the principal of conservation of mass for each species and is called the Chemical Mass Balance approach. The software package CMB 8.2 is available in the public domain and is used to quantify the contributions. This methodology is based on solving a system of linear equations of the form Ax=b. Here A is a non square matrix. The uncertainity involved in the source profile, elements of A and the uncertainity involved in the receptor concentrations measured i.e. b have to be included in determining the solution to this set of equations. The uncertainty information is used to give different weightings to the various elemental measurements. Another typical challenge in using this package stems from the collinearity in the source profiles of various sources being considered.

In Factor analysis, it must be remembered that we use the information from the receptor measurements for all thirty days simultaneously while when we use CMB we determine the quantitative contributions for each particular day and analyse it one day at a time.

4.2 Factor Analysis and its interpretation:

This methodology is a statistical technique which examines the variations in the data measured at a site. It then estimates the number of factors which can explain the variations in the data set measured. This number of factors is usually less that the number of variables measured. The different variables are grouped together so that the variables which occur in a factor can be thought of as a group which can explain the variations observed in the monitored data.

The factors that are identified using this method are non-unique. In order to render the factors unique we use an additional condition that the factors must be able to explain the variations observed in the raw data to a maximum extent. This is called the principal of varimax rotation.

The number of factors is determined by looking at the singular values of the receptor data matrix. Thus if we have a receptor data matrix A of size EX D , where E represents the number of species being measured and D represents the number of days for which the data is measured we determine the eigen-values of $A^T A$ which is an EXE matrix. The eigen-values of this matrix are determined. The spread of the eigen values is found out and the number of significant eigen-values in magnitude represents the number of factors. This represents a minimum number of factors which can explain a significant amount of the variations observed.

To this end we have used the package from the public domain WinSTAT to determine the factors which explain our receptor data. This was cross-checked with the factors obtained using MATLAB. The two methodologies were found to give identical results. This confirmed and validated the methodology used.

Factor Analysis (1) *reduces* the number of variables and (2) *detects structure* in the relationships between variables, that is it *classifies the variables* It summarizes the structure in large amounts of data. It shows how variables co-vary and how samples differ from each other. Large data tables usually contain a large amount of information, which is partly hidden because the data are too complex to be easily interpreted. Factor Analysis is a projection method that helps visualizing all the information contained in a data table. FA helps in finding out in what respect one sample is different from another, which variables contribute most to this difference, and whether those variables contribute in the same way (i.e. are correlated) or are independent of each other. It also enables us to detect sample patterns, like any particular grouping. Finally, it quantifies the amount of ***useful information***

Factor analysis is used to uncover the latent structure (dimensions) of a set of variables. It reduces attribute space from a larger number of variables to a smaller number of factors

> ***With reference to the air quality measurement project , the variables refer to the elemental /ionic species whose concentration in the particulate matter have been measured. The concentration values have been taken over a period of 3 seasons, each season consisting of approximately 30 days. The values for each day are considered as a sample. FA results in the elemental/ionic species or variables being grouped into a set of unrelated factors. These factors can be identified as specific sources of the emissions.***

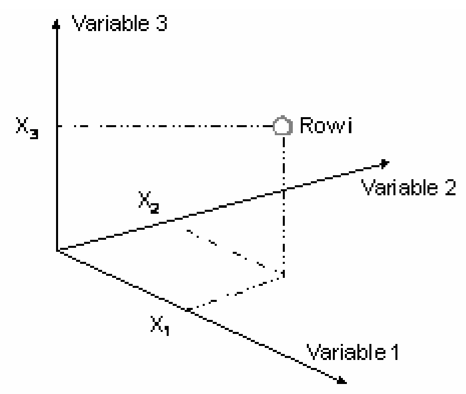
Thus Factor analysis could be used for any of the following purposes:

- To reduce a large number of variables to a smaller number of factors
- To establish that multiple tests measure the same factor, thereby giving justification for administering fewer tests.
- To validate a scale or index by demonstrating that its constituent items load on the same factor, and to drop proposed scale items which cross-load on more than one factor.
- To select a subset of variables from a larger set, based on which original variables have the highest correlations with the principal component factors.

- To create a set of factors to be treated as uncorrelated variables as one approach to handling multicollinearity in such procedures as multiple regression
- To identify clusters of cases and/or outliers.

Geometric Explanation:

Let each sample be represented as a point in a multidimensional space (figure below). The location of the point is determined by its coordinates, which are the cell values of the corresponding row in the input data table. Each variable thus plays the role of a coordinate axis in the multidimensional space.



Let us consider the whole data table geometrically. Two samples can be described as ***similar*** if they have close values for most variables, which means close coordinates in the multidimensional space, i.e. the two points are located in the same area. On the other hand, two samples can be described as ***different*** if their values differ a lot for at least some of the variables, i.e. the two points have very different coordinates, and are located far away from each other in the multidimensional space.

We find the directions in space along which the distance between data points is the largest. This can be translated as finding the linear combinations of the initial variables that contribute most to making the samples different from each other. These directions, or combinations, are called ***Factors***. They are computed iteratively, in such a way that the first factor is the one that carries most information

$$\mathbf{Y_1 = \alpha_{11}F_1 + \alpha_{12}F_2 + \ldots + \alpha_{1m}F_m,}$$
$$\mathbf{Y_2 = \alpha_{21}F_1 + \alpha_{22}F_2 + \ldots + \alpha_{2m}F_m,}$$
$$\mathbf{Y_3 = \alpha_{31}F_1 + \alpha_{32}F_2 + \ldots + \alpha_{3m}F_m,}$$

. . .

. . .

. . .

$$\mathbf{Y_n = \alpha_{n1}F_1 + \alpha_{n2}F_2 + \ldots + \alpha_{nm}F_m,}$$

Here Y represents the variables with known data. F represents the unobservable factors and α represents the factor loadings.

The most often employed techniques of factor analysis--centroid and principal axis--are applied to a matrix of correlation coefficients among all the variables.

- The coefficients of correlation express the degree of linear relationship between the row and column variables of the matrix. The closer to zero the coefficient, the less the relationship; the closer to one, the greater the relationship. A negative sign indicates that the variables are inversely related.

- To interpret the coefficient, square it and multiply by 100. This will give the *percent variation in common* for the data on the two variables.

Factors :

The dimensions (or latent variables) identified with clusters of variables, as computed using factor analysis. Technically speaking, *factors* (as from PFA -- principal factor analysis, a.k.a. principal axis factoring, a.k.a. common factor analysis) represent the common variance of variables, excluding unique variance, and is thus a correlation-focused approach seeking to reproduce the intercorrelation among the variables.

FA is generally used when the research purpose is to identify latent variables which contribute to the common variance of the set of measured variables, excluding variable-specific (unique) variance.

Factor loadings: The factor loadings are the correlation coefficients between the variables (rows) and factors (columns). The squared factor loading is the percent of variance in that indicator variable explained by the factor. To get the percent of variance in all the variables accounted for by each factor, add the sum of the squared factor loadings for that factor (column) and divide by the number of variables.This is the same as dividing the factor's eigenvalue by the number of variables.

- *The sum of the squared factor loadings* for all factors for a given variable (row) is the variance in that variable accounted for by all the factors, and this is called the *communality*.The ratio of the squared factor loadings for a given variable (row in the factor matrix) shows the relative importance of the different factors in explaining the variance of the given variable. Factor loadings are the basis for imputing a label to the different factors. **Communality,(h^2)** is the *squared multiple correlation* for the variable as dependent using the factors as predictors. The communality measures the percent of variance in a given variable explained by all the factors jointly and may be interpreted as the *reliability of the indicator*.

- **Uniqueness** of a variable is 1 - h^2. That is, uniqueness is the variability of a variable minus its communality.
- **Eigenvalues:** Also called *characteristic roots*. The eigenvalue for a given factor measures the variance in all the variables which is accounted for by that factor. The ratio of eigenvalues is the ratio of explanatory importance of the factors with respect to the variables. If a factor has a low eigenvalue, then it is contributing little to the explanation of variances in the variables and may be ignored as redundant with more important factors.

. Eigenvalues measure the amount of variation in the total sample accounted for by each factor. Note that the eigenvalue is not the percent of variance explained but rather a measure of amount of variance in relation to total variance (since variables are standardized to have means of 0 and variances of 1, total variance is equal to the number of variables

- **Factor scores:** Factor scores are the scores of each case (row) on each factor (column). To compute the factor score for a given case for a given factor, one takes the case's standardized score on each variable, multiplies by the corresponding factor loading of the variable for the given factor, and sums these products. Computing factor scores allows one to look for factor outliers. Also, factor scores may be used as variables in subsequent modeling.

- **Rotation :**Rotation serves to make the output more understandable and is usually necessary to facilitate the interpretation of factors. ***Varimax rotation*** is an orthogonal rotation of the factor axes to maximize the variance of the squared loadings of a factor (column) on all the variables (rows) in a factor matrix, which has the effect of differentiating the original variables by extracted factor. Each factor will tend to have either large or small loadings of any particular variable. A varimax solution yields results which make it as easy as possible to identify each variable with a single factor. This is the most common rotation option.

Interpretation of Factor Loadings: Loadings show how data values vary when you move along a factor. Loadings can have negative or positive values; so can scores. Factors build a link between samples and variables by means of scores and loadings.

- If a variable has a ***very small loading***, whatever the sign of that loading, it should not be used for interpretation, because that variable is badly accounted for by the factor.

- If a variable has a ***positive loading***, it means that all samples with positive scores have higher than average values for that variable. All samples with negative scores have lower than average values for that variable;

- If a variable has a ***negative loading***, it means just the opposite. All samples with positive scores have lower than average values for that variable. All samples with negative scores have higher than average values for that variable;

- The higher the positive score of a sample, the larger its values for variables with positive loadings and vice versa;

- The more negative the score of a sample, the smaller its values for variables with positive loadings and vice versa;

- The larger the loading of a variable, the quicker sample values will increase with their scores.

To summarize, if the score of a sample and the loading of a variable on a particular factor have the same sign, the sample has higher than average value for that variable and vice-versa. ***The larger the scores and loadings, the stronger that relation***.

We now proceed to discuss the applications of factor analysis to the data obtained in each site and for each sampling period.

ADYAR FACTOR ANALYSIS

SEASON 1

Adyar First season Factor analysis results

Pollutant	Factor 1	Factor 2	Factor 3	Communality
FEIC	**0.9513**	-0.1544	-0.0435	0.9306
CUIC	**0.9474**	-0.1754	-0.0729	0.9337
CAIC	**0.9179**	-0.1007	-0.1460	0.8740
MNIC	**0.8939**	-0.1385	-0.0534	0.8210
SIIC	**0.8499**	-0.0008	0.1213	0.7371
ZNIC	**0.7972**	-0.0364	-0.0988	0.6467
NIIC	**0.7547**	-0.1728	0.1105	0.6116
PBIC	**0.5750**	-0.3238	0.0528	0.4382
VIC	**0.3960**	-0.2435	0.1325	0.2337
ALIC	**0.1927**	0.0521	-0.1358	0.0583
NAICPC	-0.2353	**0.9110**	-0.0795	0.8917
S4ICPC	0.0496	**0.8715**	-0.1000	0.7720
N3ICPC	-0.1917	**0.8025**	-0.0804	0.6873
KIC	-0.2653	**0.7174**	0.0419	0.5868
CLIC	-0.0302	**0.7058**	-0.0105	0.4991
OCTC	0.0146	-0.0338	**0.9320**	0.8699
ECTC	0.0073	-0.2083	**0.8556**	0.7755
N4ICPC	-0.0379	0.2749	**0.3018**	0.1681
Sum of Squares	6.0637	3.6483	1.8231	11.5352
Percent of Variance	33.6872	20.2685	10.1285	**64.0842**

Factor 1: **Soil dust**
Factor 2: **Bakeries**
Factor 3: **DG Sets**

SEASON 2

Adyar Second season Factor analysis results

Pollutant	Factor 1	Factor 2	Factor 3	Communality
ALIC	**0.9587**	-0.0387	0.0996	0.9305
CRIC	**0.8984**	0.0638	0.0942	0.8200
KICPC	**0.8352**	0.0117	0.3093	0.7934
FEIC	**0.7317**	-0.1020	0.5551	0.8539
CUIC	**0.5830**	-0.0435	0.1421	0.3620
VIC	**0.5529**	-0.0950	0.3972	0.4724
CLIC	-0.1411	**0.8530**	0.1255	0.7632
ECTC	0.1750	**0.8472**	-0.1240	0.7637
N3ICPC	-0.0348	**0.8241**	0.0656	0.6846

NAICPC	-0.3020	**0.8190**	0.1017	0.7723
S4ICPC	-0.0764	**0.7854**	0.0666	0.6271
OCTC	0.0570	**0.7537**	-0.0780	0.5775
N4ICPC	0.0957	**0.5817**	-0.2232	0.3973
ZNIC	0.1128	0.0850	**0.9010**	0.8318
MNIC	0.5245	-0.0894	**0.7996**	0.9225
PBIC	0.2128	-0.0921	**0.6838**	0.5213
NIIC	0.5656	0.0699	**0.6441**	0.7396
CAIC	0.2285	-0.0619	**0.6111**	0.4296
SIIC	0.1059	0.1390	**0.3017**	0.1216
KIC	0.0724	0.0734	**-0.1111**	0.0230
Sum of Squares	4.4876	4.4027	3.5171	12.4073
Percent of Variance	22.4380	22.0133	17.5853	**62.0366**

Factor 1: **Bakeries**
Factor 2: **DG Sets**
Factor 3: **Soil dust**
Factor 4: **Paved Road dust**

SEASON 3

Adyar Third season Factor analysis results

Pollutant	**Factor 1**	**Factor 2**	**Factor 3**	**Factor 4**	**Factor 5**	**Communality**
FEIC	**0.9691**	0.1924	0.1111	0.0639	0.0478	0.9948
MNIC	**0.9668**	0.2241	0.0553	0.0746	-0.0473	0.9958
BAIC	**0.8814**	0.0357	0.2596	0.0052	0.2056	0.8878
ALIC	**0.8576**	0.2536	0.0462	0.0050	-0.0364	0.8033
CUIC	**0.7964**	0.0346	0.2993	0.1774	0.2161	0.8031
S4IC	**0.6967**	0.6400	-0.0594	0.1063	-0.2256	0.9607
CDIC	**0.5982**	0.0941	-0.0646	-0.0885	0.3474	0.4994
PBIC	**0.5728**	0.0900	0.0623	0.4555	0.1472	0.5692
NAIC	0.1368	**0.7267**	-0.1427	-0.1151	0.1810	0.6132
NAICP	-0.0640	**0.6938**	0.4434	-0.0586	0.0626	0.6893
N4IC	0.5172	**0.6114**	-0.0161	0.2567	-0.4742	0.9324
MGIC	0.3634	**0.6074**	0.5349	-0.0030	-0.1038	0.7979
N3IC	0.6065	**0.6073**	-0.2072	0.2066	0.1218	0.8372
KPIC	0.4435	**0.4941**	-0.1943	0.4427	0.3676	0.8097
CRIC	0.1104	-0.0882	**0.9349**	0.0285	-0.1094	0.9069
NIIC	0.1200	0.0438	**0.9165**	-0.0009	0.0365	0.8576
ECTC	-0.2027	0.0182	0.0157	**0.8117**	-0.0303	0.7015
OCTC	0.3519	-0.0890	0.0093	**0.7662**	0.1048	0.7298
CLIC	0.1901	0.0900	-0.0426	0.1209	**0.7070**	0.5605
Sum of Squares	6.4063	2.9718	2.4864	1.8504	1.2354	14.9503
Percent of Variance	33.7175	15.6413	13.0861	9.7389	6.5019	**78.6857**

Factor 1: **Soil dust**

Factor 2: **DG set**
Factor 3: **Liquefied petroleum gas**
Factor 4: **Diesel vehicles**
Factor 5: Gasoline

Summary of factor analysis results of Adyar

AMBATTUR FACTOR ANALYSIS

SEASON 1

For the factor analysis results we have considered a total of eight variables and twenty samples. Elements which could not be measured in all samples were deleted .

The WinStat software package was used to determine the factors. This was also verified by NCSS 2007 package. The results of Factor Analysis are:

	Factor 1	**Factor 2**	**Commu-nality**
S4IC	**0.9810**	-0.0481	0.9647
N3IC	**0.9651**	-0.0417	0.9331
CLIC	**0.8044**	-0.1065	0.6583
NAIC	**0.7267**	-0.2614	0.5964
KPIC	**0.6917**	-0.2657	0.5491
N4TC	**0.4729**	-0.0914	0.2320
ECTC	-0.1490	**0.9704**	0.9638
OCTC	-0.1517	**0.9689**	0.9619
Sum of Squares	3.8162	2.0431	5.8593
Percent of Variance	47.7021	25.5389	**73.2410**

Factor 1: DG SetsFactor 2: Vehicles

From the elements present in the various factors i.e., the factor loadings the fingerprints of the first factor is that of DG Sets, the second factor is that of Vehicles These factors explain round 73% of the variation in the data set.

.

SEASON 2

For the factor analysis results we have considered a total of nineteen variables and twenty eight samples. Elements which could not be measured in all samples were deleted , also three samples were deleted because of lack of values.The WinStat software package was used to determine the factors. This was also verified by NCSS 2007 package. The results of Factor Analysis are:

	Factor 1	**Factor 2**	**Factor 3**	**Factor 4**	**Commu-nality**
CAIC	**0.9812**	0.1433	0.0722	-0.0380	0.9900
ZNIC	**0.9803**	0.1695	0.0501	-0.0511	0.9948
CUIC	**0.9793**	0.1459	0.0743	-0.0656	0.9902
NIIC	**0.9643**	0.2491	0.0499	-0.0043	0.9944
PBIC	**0.9578**	0.2409	0.0960	-0.0403	0.9862
KPAC	**0.9491**	0.2673	0.0782	-0.0374	0.9798
CRIC	**0.8756**	0.4339	-0.0322	0.0369	0.9574
MNIC	**0.7102**	0.6870	-0.0239	0.1232	0.9920
VAIC	**0.4625**	0.4400	0.0945	0.4390	0.6091
FEIC	0.3661	**0.8889**	-0.0703	0.2056	0.9714
OCTC	0.1535	**0.8167**	-0.0711	0.4335	0.8836
N3IC	0.3687	**0.7024**	0.5193	-0.2429	0.9578
KPIC	0.2505	**0.5245**	0.2957	-0.1896	0.4613
NAIC	0.0638	-0.0973	**0.8614**	0.1486	0.7777
CLIC	0.0037	0.2008	**0.7467**	0.1320	0.6153
S4IC	0.4122	0.5380	**0.5510**	-0.4155	0.9356
ECTC	0.0550	0.1151	0.0960	**0.5946**	0.3790
N4TC	-0.0658	-0.1041	0.4683	**-0.5374**	0.5233
ALIC	-0.1664	-0.0411	0.0799	**0.3626**	0.1672
Sum of Squares	7.6811	3.7065	2.2468	1.5318	15.1661
Percent of Variance	40.4268	19.5077	11.8252	8.0620	**79.8217**

From the elements present in the various factors i.e., the factor loadings the fingerprints of the first factor is that of Bakeries, the second factor is that of vehicle exhausts and the third and fourth factor is of construction activities and DG sets .

SEASON 3

For the factor analysis results we have considered a total of eighteen variables and thirty four samples. Elements which could not be measured in all samples were deleted , also 4 samples were deleted because of lack of values or the values were below detection limit. The WinStat software package was used to determine the factors. This was also verified by NCSS 2007 package. The results of Factor Analysis are:

	Factor 1	**Factor 2**	**Factor 3**	**Commu-nality**
FEIC	**0.9661**	0.0726	0.0893	0.9466
ALIC	**0.9417**	0.0725	0.1225	0.9070
MNIC	**0.9277**	0.1163	0.0544	0.8771
OCTC	**0.9185**	-0.0591	0.1893	0.8830
N3IC	**0.8356**	0.0747	0.3747	0.8441
VAIC	**0.8329**	0.2800	-0.0206	0.7726
KPAC	**0.7830**	0.0442	0.1270	0.6312
CAIC	**0.7543**	0.2999	-0.0594	0.6624
CUIC	**0.6100**	0.2743	-0.1216	0.4621
ECTC	**0.4743**	0.2105	0.1550	0.2932
PBIC	**0.3789**	-0.1911	0.2521	0.2436
NAIC	**-0.2931**	-0.2732	-0.0661	0.1650
CRIC	0.1274	**0.9229**	-0.0883	0.8758
NIIC	0.2674	**0.8999**	-0.1005	0.8915
ZNIC	0.1927	**0.6008**	0.0861	0.4055
CLIC	0.1007	**-0.2300**	-0.0684	0.0677
S4IC	0.4809	0.1099	**0.8265**	0.9265
N4TC	-0.1373	-0.0492	**0.7934**	0.6507
KPIC	0.3491	0.3451	**0.4798**	0.4712
Sum of Squares	7.4318	2.6431	1.9018	11.9767
Percent of Variance	39.1147	13.9109	10.0095	**63.0351**

From the elements present in the various factors i.e., the factor loadings the fingerprints of the first factor is that of soil dust, the second factor is that of vehicle exhausts and the third is of DG sets.

Summary of factor analysis results of Ambattur

Season	Factor 1	Factor 2	Factor 3	Factor 4
1 73.24%	**DG Sets** 47.7%	**Vehicles** 25.5%		
2 79.82%	**Bakeries** 40.42%	**Vehicles** 19.5%	**Construction** 11.82%	**DG sets** 8.06%
3 63.035%	**Soil Dust** 39.11%	**Bakeries** 13.91%	**DG sets** 10%	

Factor analysis of 3 Seasons for the Ambattur region show that emissions from vehicles, Construction, DG sets, bakeries are important factors affecting the air quality in the site.

DG Sets and Bakeries explain a significant amount of variation in the data.

Ammonia has a high negative loading on DG Sets implying that an increase in concentration of ammonia would decrease the contribution of DG sets.

Season 2 explains maximum variation in the data. Season 1 is explained only by 2 factors because of the smaller number of species observed during that period. Season 1 accounts only for elemental species.

IITM FACTOR ANALYSIS SEASON 1

For the factor analysis results we have considered a total of eight variables and twenty one samples. Elements which could not be measured in all samples were deleted, also seven samples were deleted because of lack of values.
The results of Factor Analysis are:

	Factor 1	Factor 2	Commu-nality
NAIC	**0.9028**	-0.0774	0.8211
KPIC	**0.7092**	0.0931	0.5116
S4IC	**0.6625**	0.3179	0.5400
N4TC	**0.6019**	0.0980	0.3718
CLIC	**0.5832**	-0.0136	0.3403
N3IC	**0.3616**	-0.0150	0.1310
ECTC	0.0856	**0.9897**	0.9868
OCTC	0.0098	**0.9529**	0.9082
Sum of Squares	2.5975	2.0132	4.6107
Percent of Variance	32.4684	25.1656	**57.6340**

From the elements present in the various factors i.e., the factor loadings the fingerprints of the first factor is that of construction activities or vehicle exhausts and the second factor is that of DG sets or vehicles.

SEASON 2

For the factor analysis results we have considered a total of sixteen variables and twenty seven samples. Five Elements which could not be measured in all samples were deleted. The results of Factor Analysis are:

	Factor 1	Factor 2	Factor 3	Factor 4	Commu-nality
FEIC	**0.9849**	-0.0398	0.0086	0.0960	0.9809
MNIC	**0.9728**	-0.0598	0.0457	0.1482	0.9739
CAIC	**0.9614**	-0.0154	0.1205	0.1512	0.9620
ECTC	**-0.2921**	-0.1634	0.2363	0.1808	0.2006
S4IC	-0.0739	**0.9632**	0.0103	0.2791	1.0000
N3IC	0.0384	**0.9112**	-0.2492	0.0032	0.8938
CLIC	-0.0599	**0.5316**	-0.0006	-0.1621	0.3125
OCTC	-0.2091	**-0.2556**	-0.0432	0.0710	0.1160
CRIC	0.2966	-0.0656	**0.7981**	0.0590	0.7328
NIIC	0.4905	0.1939	**0.7071**	0.3391	0.8931
NAIC	0.0841	0.2033	**-0.5637**	0.1496	0.3885
KPIC	0.0517	-0.0235	**-0.3714**	-0.1083	0.1529
CUIC	-0.0351	0.0063	0.5559	**0.6140**	0.6872
PBIC	0.0673	-0.1441	-0.0822	**0.5309**	0.3139
N4TC	-0.0080	0.2582	-0.0425	**0.5067**	0.3252
ALIC	0.0469	-0.0246	0.1175	**0.4978**	0.2644
KPAC	0.0947	-0.0464	0.1546	**0.3414**	0.1516
Sum of Squares	3.3356	2.3120	2.0845	1.6284	9.3605
Percent of Variance	19.6213	13.6002	12.2615	9.5789	**55.0619**

From the elements present in the various factors i.e., the factor loadings the fingerprints of the first factor is that of vehicles, the second factor is that of Bakeries and the third and fourth factor is of DG sets and soil dust.

SEASON 3

For the factor analysis results we have considered a total of seventeen variables and thirty samples. Four Elements which could not be measured in all samples were deleted .The The results of Factor Analysis are:

	Factor 1	Factor 2	Factor 3	Commu-nality
NIIC	**0.9753**	0.0020	-0.1207	0.9657
CAIC	**0.9718**	0.0041	-0.2366	1.0000
ALIC	**0.9710**	0.0822	-0.0016	0.9497
CRIC	**0.9706**	0.0044	-0.1802	0.9745
CUIC	**0.9706**	0.0044	-0.1802	0.9745
KPAC	**0.9552**	0.1259	-0.1541	0.9521
FEIC	**0.9218**	0.0604	0.2279	0.9053
MNIC	**0.9117**	0.1613	0.2025	0.8982
ZNIC	**0.7367**	-0.0870	0.2232	0.6001
PBIC	**0.7159**	-0.1434	0.0314	0.5341
VAIC	**0.5492**	0.0928	0.2426	0.3691
S4IC	-0.0157	**0.9466**	0.0692	0.9012
N4TC	-0.2245	**0.8291**	0.0101	0.7380
N3IC	0.4921	**0.5711**	-0.1221	0.5832
OCTC	0.2309	0.3139	**0.7620**	0.7326
ECTC	0.5030	0.2921	**0.7168**	0.8521
NAIC	0.1674	0.2722	**-0.5848**	0.4441
CLIC	0.2638	0.1062	**-0.4062**	0.2459
Sum of Squares	9.3695	2.2680	1.9830	13.6205
Percent of Variance	52.0529	12.5999	11.0167	**75.6696**

From the elements present in the various factors i.e., the factor loadings the fingerprints of the first factor is that of bakeries, the second factor is that of DG Sets and the third factor is that of vehicle exhausts.

Summary of factor analysis results of IITMadras:

Season	Factor 1	Factor 2	Factor 3	Factor 4
1 **57.63%**	**Construction/ Vehicles** 32.16%	**DG sets/ Vehicles** 25.17%		
2 **55.06%**	**Vehicles** 19.62%	**Bakeries** 13.6%	**DG sets** 12.26%	**Soil Dust** 9.57%
3 **75.66%**	**Bakeries** 52%	**DG Sets** 12.5%	**Vehicles** 11%	

Factor analysis of 3 Seasons for the IITM region show that emissions from vehicles, Construction, DG sets, soil dust and bakeries are important factors affecting the air quality in the site.

Season 3 explains a significant portion of variance in the data compared to Seasons 1&2.

Negative loadings of elements like sodium, potassium, chloride on vehicles and DG sets show that as their concentrations increase the contribution of the corresponding factors decrease.

A significant amount of bakery emissions is observed only in Season 3.

Also, the fact that Season 1 observed only eight species(ie only elemental species) while 2 and 3 analyze around sixteen species accounts for the variation in the number of factors.

Absence of constructional /soil dust as a factor in season 3 can be explained by reduction in constructional activities or weather changes.

MYLAPORE FACTOR ANALYSIS

SEASON 1

For the factor analysis results we have considered a total of eight variables and thirty one samples. Thirteen elements which could not be measured in all samples were deleted .
The results of Factor Analysis are:

	Factor 1	Factor 2	Commu-nality
CLIC	**0.8249**	-0.1219	0.6954
N3IC	**0.8228**	0.2207	0.7257
NAIC	**0.7256**	0.1557	0.5508
KPIC	**0.5563**	0.1407	0.3293
S4IC	**0.5273**	0.2686	0.3502
ECTC	0.4174	**0.8876**	0.9621
OCTC	0.4231	**0.8757**	0.9459
N4TC	-0.0411	**0.2228**	0.0513
Sum of Squares	2.8266	1.7841	4.6107
Percent of Variance	35.3323	22.3017	**57.6341**

From the elements present in the various factors i.e., the factor loadings the fingerprints of the first factor is that of construction activities, the second factor is that of DG sets.

SEASON 2

For the factor analysis results we have considered a total of eight variables and twenty five samples. Thirteen elements which could not be measured in all samples were deleted The WinStat software package was used to determine the factors. This was also verified by NCSS 2007 package.

The results of Factor Analysis are:

	Factor 1	Factor 2	Commu-nality
S4IC	**0.9053**	0.2238	0.8696
N3IC	**0.8351**	0.3147	0.7965
NAIC	**0.8279**	-0.0282	0.6863
CLIC	**0.8234**	0.1235	0.6932
KPIC	**0.4917**	0.2413	0.3000
N4TC	**0.4389**	0.0684	0.1973
OCTC	0.1733	**0.9754**	0.9814
ECTC	0.1587	**0.9725**	0.9710
Sum of Squares	3.3701	2.1253	5.4953
Percent of Variance	42.1261	26.5656	**68.6917**

From the elements present in the various factors i.e., the factor loadings the fingerprints of the first factor is that of construction activities, the second factor is that of vehicle exhausts.

SEASON 3

For the factor analysis results we have considered a total of sixteen variables and twenty nine samples. Five elements which could not be measured in all samples were deleted , also two samples were deleted because of lack of values. The WinStat software package was used to determine the factors. This was also verified by NCSS 2007 package. The results of Factor Analysis are:

	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	Communality
FEIC	**0.8289**	0.2241	0.1283	-0.0707	0.1470	0.7804
ECTC	**0.8194**	0.2201	0.1078	-0.0113	-0.0732	0.7370
OCTC	**0.7490**	0.4214	-0.1262	0.0520	0.2484	0.8189
MNIC	**0.7269**	0.2049	0.5024	-0.0603	0.2248	0.8769
CRIC	**0.6241**	-0.2238	-0.1558	-0.0251	-0.0098	0.4645
NIIC	**0.5864**	-0.3507	0.0184	0.0980	0.0724	0.4821
PBIC	**0.4088**	0.2200	0.0531	-0.1885	-0.0030	0.2539
S4IC	0.0305	**0.9854**	0.0197	0.0440	-0.0585	0.9777
N4TC	0.0126	**0.8319**	-0.0202	-0.1247	-0.1039	0.7190
N3IC	0.4216	**0.7500**	-0.1251	-0.0341	0.2413	0.8153
CAIC	-0.2405	0.0084	**0.8083**	-0.0796	0.1520	0.7407
ZNIC	0.1756	-0.0854	**0.6952**	-0.0469	-0.2981	0.6125
KPAC	0.3944	-0.0898	**0.5741**	-0.0449	0.4243	0.6752
CLIC	0.0361	-0.1950	-0.0227	**0.9329**	-0.1186	0.9242
NAIC	-0.1046	0.0890	-0.1080	**0.8392**	0.1489	0.7569
CUIC	0.2827	-0.1313	0.0415	0.1018	**0.6585**	0.5429
VAIC	0.4538	-0.1818	0.0246	0.1156	**-0.4901**	0.4931
Sum of Squares	4.0695	2.8770	1.8210	1.6847	1.2191	11.6714
Percent of Variance	23.9385	16.9237	10.7120	9.9098	7.1711	**68.6551**

From the elements present in the various factors i.e., the factor loadings the fingerprints of the first factor is that of DG Sets, the second factor is that of soil dust and the third and fourth factor is of gasoline and diesel vehicle exhausts and the fifth factor is that of bakeries .

Summary of factor analysis results of Mylapore

Season	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5
1 57.6%	Construction 35.3%	DG sets 22.3%			
2 68.68%	Construction 42.12%	Vehicles 26.56%			
3 68.65%	DG sets 23.93%	Soil Dust 16.9%	**Gasoline** Vehicles 10.71%	**Diesel vehicles** 9.9%	Bakeries 7.17%

Factor analysis of 3 seasons for the Mylapore region show that emissions from vehicles, Construction and DG sets are important factors affecting the air quality in the site. Other factors include Bakery emissions and soil dust.

The number of species observed in seasons 1&2 are eight compared to sixteen in season 3 , resulting an increase in number of factors . Absence in elemental species in the first two seasons resulted in lower number of species.

Constructional dust explains a significant portion of the variance.

RK NAGAR FACTOR ANALYSIS

SEASON 1

For the factor analysis results we have considered a total of seventeen variables and thirty three samples. Elements which could not be measured in all samples were deleted , also three samples were deleted because of lack of values.The results of Factor Analysis are:

	Factor 1	**Factor 2**	**Factor 3**	**Factor 4**	**Commu-nality**
FEIC	**0.9273**	-0.0652	0.1802	-0.0044	0.8966
CAIC	**0.9193**	-0.1354	0.1103	0.0132	0.8758
VAIC	**0.8406**	0.2455	0.1561	-0.1117	0.8037
ZNIC	**0.7808**	-0.0365	0.0623	0.3629	0.7466
CUIC	**0.7514**	0.1564	0.1736	0.5891	0.9663
PBIC	**0.6339**	-0.0918	0.0917	0.2387	0.4757
ALIC	**0.5281**	-0.1428	-0.0777	0.0799	0.3117
NAIC	-0.0578	**0.9486**	-0.1168	0.0293	0.9178
CLIC	0.0553	**0.8958**	0.1600	-0.0380	0.8325
N4TC	0.0535	**0.8436**	-0.0495	-0.0542	0.7199
S4IC	-0.0943	**0.8202**	-0.0810	-0.0051	0.6882
KPIC	-0.0730	**0.7828**	0.0464	0.0088	0.6204
N3IC	-0.0898	**0.7797**	0.1466	-0.0180	0.6379
ECTC	0.0646	0.0276	**0.9215**	0.1577	0.8790
OCTC	0.2606	0.0356	**0.8654**	0.1060	0.8293
NIIC	0.5382	0.0460	0.1276	**0.8349**	1.0000
MNIC	0.0196	-0.0719	0.1048	**0.6534**	0.4435
Sum of Squares	4.6604	4.4543	1.8147	1.7204	12.6499
Percent of Variance	27.4143	26.2019	10.6750	10.1201	**74.4113**

From the elements present in the various factors i.e., the factor loadings the fingerprints of the first factor is that of Bakeries, the second factor is that of DG Sets and the third and fourth factor is of Vehicles and Domestic cooking.

SEASON 2

For the factor analysis results we have considered a total of twenty variables and thirty seven samples. Six samples were deleted . The results of Factor Analysis are:

	Factor 1	**Factor 2**	**Factor 3**	**Factor 4**	**Factor 5**	**Commu-nality**
NIIC	**0.9013**	-0.0268	-0.0709	-0.2288	-0.1978	0.9096
CRIC	**0.8250**	0.3632	-0.1102	-0.1833	-0.1992	0.8979
MNIC	**0.7530**	0.4826	0.1877	-0.0381	0.0535	0.8394
VAIC	**0.7448**	0.0706	-0.0863	0.2038	-0.0049	0.6087
ZNIC	**0.3909**	0.0200	0.1024	-0.0904	0.0064	0.1719
PBIC	**0.3622**	0.1935	-0.1008	-0.1231	0.0917	0.2024
KPAC	0.3332	**0.8961**	0.0412	-0.0503	-0.0502	0.9208
ALIC	0.1915	**0.7666**	0.1451	0.0779	-0.0527	0.6543
FEIC	0.6031	**0.6212**	0.2730	0.0972	0.0202	0.8341
CUIC	0.1681	**0.6191**	-0.1405	-0.2294	-0.0144	0.4841
CAIC	0.2611	**0.4065**	0.0088	0.0514	-0.2695	0.3087
KPIC	-0.1171	**0.2610**	-0.0186	-0.0215	0.0889	0.0906
CLIC	0.0791	0.1089	**0.8352**	0.0536	-0.0397	0.7201
NAIC	-0.0731	-0.0287	**0.8310**	0.0891	-0.1432	0.7252
S4IC	0.0062	-0.0666	0.2275	**0.8887**	-0.2114	0.8907
N3IC	-0.0356	-0.0655	0.5659	**0.7070**	-0.1160	0.8391
N4TC	-0.2251	-0.0135	-0.1251	**0.4295**	0.0250	0.2516
OCTC	0.0484	0.2336	-0.1118	-0.0283	**0.8863**	0.8558
ECTC	-0.1229	-0.3321	-0.1402	-0.2198	**0.7844**	0.8087
Sum of Squares	3.6012	2.9882	2.0059	1.7602	1.6583	12.0138
Percent of Variance	18.9538	15.7273	10.5575	9.2640	8.7278	**63.2304**

From the elements present in the various factors i.e., the factor loadings the fingerprints of the first factor is that of bakeries, the second factor is that of soil dust and the third and fourth factor is of constructional activities and DG Sets and the fifth is vehicle exhausts.

SEASON 3

For the factor analysis results we have considered a total of eighteen variables and twenty samples. Three Elements which could not be measured in all samples were deleted, further ten samples were deleted due to lack of values . The results of Factor Analysis are:

	Factor 1	**Factor 2**	**Factor 3**	**Factor 4**	**Factor 5**	**Commu-nality**
NIIC	**0.9465**	0.0652	0.0570	0.0796	-0.0336	0.9107
FEIC	**0.9087**	-0.2327	0.0446	0.1878	0.2388	0.9742
CAIC	**0.8945**	0.0685	-0.0271	0.0174	0.1643	0.8328
CRIC	**0.8817**	0.0223	0.0198	0.1555	-0.1061	0.8138
VAIC	**0.8083**	-0.0374	0.1300	0.2662	-0.0093	0.7425
MNIC	**0.7843**	-0.2081	0.1269	0.2937	0.4368	0.9515
N4TC	-0.0120	**0.8940**	-0.0514	-0.3129	0.0300	0.9008
S4IC	0.0197	**0.7970**	0.1990	-0.1676	0.4451	0.9013
NAIC	0.0421	**-0.5200**	-0.0438	-0.4274	0.3408	0.5730
OCTC	0.1090	0.0284	**0.8943**	-0.0657	0.1367	0.8354
ECTC	0.1321	0.0903	**0.7626**	-0.0799	-0.0326	0.6146
N3IC	-0.2452	0.5006	**0.6303**	0.0403	0.1652	0.7368
CLIC	0.0303	-0.1626	**0.4112**	0.2823	0.0815	0.2828
PBIC	0.2288	-0.0162	-0.0424	**0.7226**	0.1438	0.5973
CUIC	0.1361	-0.1822	0.0577	**0.6214**	0.1108	0.4535
ZNIC	0.4438	-0.0878	-0.0786	**0.5773**	0.0864	0.5516
KPAC	0.4759	0.0260	0.0703	0.2878	**0.7966**	0.9495
KPIC	-0.0264	0.1289	0.1171	0.1073	**0.6314**	0.4412
Sum of Squares	5.1551	2.1575	2.0611	1.9599	1.7297	13.0634
Percent Variance	28.6396	11.9863	11.4506	10.8884	9.6096	**72.5746**

From the elements present in the various factors i.e., the factor loadings the fingerprints of the first factor is that of Bakeries, the second factor is that of DG Sets and the third and fourth factor is of vehicle exhausts and Soil Dust and the fifth is constructional activities.

Summary of factor analysis results of R.K.Nagar

Season	**Factor 1**	**Factor 2**	**Factor 3**	**Factor 4**	**Factor 5**
1 74.4%	Bakeries 27.4%	DG Sets 26.2%	Vehicles 10.67%	Domestic 10.12%	
2 63.32%	Bakeries 18.95%	Soil Dust 15.7%	construction 10.5%	DG Sets 9.2%	Vehicles 8.7%
3 72.57%	Bakeries 28.6%	DG sets 12%	Vehicles 11.45%	SoilDust 10.8%	Construction 9.6%

Factor analysis of 3 seasons for the RK Nagar region show that emissions from vehicles, Bakeries, DG sets, and soil dust are important factors affecting the air quality in the site. Other factors include Constructional activities and Domestic (or LPG) emissions.

Seasons 1& 3 explain a significant percent of variance in the data than Season 2.

In season 3, Sodium has a negative factor loading on DG Sets. This implies that as the concentration of sodium increases contribution of soil dust to the variance in the data decreases or vice versa.

Factor 5 in season 3 , namely constructional dust consists of predominantly only potassium ions while the same factor consists of sodium and chloride ions in season 2.

Climatic and seasonal changes explain the variation of factors.

SAIDAPET FACTOR ANALYSIS

SEASON 1

For the factor analysis results we have considered a total of nineteen variables and twenty nine samples. Elements which could not be measured in all samples were deleted , also ten samples were deleted because of lack of values.The results of Factor Analysis are:

	Factor 1	Factor 2	Factor 3	Commu-nality
FEIC	**0.9317**	-0.2076	-0.0272	0.9120
CAIC	**0.8848**	-0.1064	-0.0421	0.7960
CUIC	**0.8258**	-0.2485	-0.0527	0.7465
SIIC	**0.8201**	-0.1490	0.0273	0.6955
MNIC	**0.7463**	-0.3890	-0.0233	0.7088
NIIC	**0.7356**	0.0859	-0.0479	0.5507
VAIC	**0.7342**	0.0171	-0.1107	0.5516
ZNIC	**0.7177**	-0.0998	0.0222	0.5255
PBIC	**0.3432**	-0.0464	-0.1017	0.1303
ALIC	**0.3203**	-0.3193	0.0616	0.2084
KPAC	**0.0016**	0.0013	0.0012	0.0000
S4IC	-0.2484	**0.8967**	0.0920	0.8742
N3IC	-0.1168	**0.8894**	0.0834	0.8116
CLIC	-0.0991	**0.7361**	0.5447	0.8483
N4TC	-0.1603	**0.4356**	0.0637	0.2195
KPIC	-0.2806	**0.3938**	0.1791	0.2659
SUIC	0.0977	**0.2476**	-0.0131	0.0710
ECTC	0.0072	-0.1329	**0.8175**	0.6859
OCTC	-0.0693	0.2065	**0.7124**	0.5550
NAIC	-0.1966	0.4948	**0.6440**	0.6982
Sum of Squares	5.6206	3.2595	1.9747	10.8548
Percent of Variance	28.1032	16.2975	9.8735	**54.2742**

From the elements present in the various factors i.e., the factor loadings the fingerprints of the first factor is that of bakeries, the second factor is that of construction activities and the third is of DG sets.

SEASON 2

For the factor analysis results we have considered a total of eighteen variables and thirty five samples. Three Elements which could not be measured in all samples were deleted. The WinStat software package was used to determine the factors. This was also verified by NCSS 2007 package. The results of Factor Analysis are:

	Factor 1	Factor 2	Factor 3	Factor 4	Commu-nality
CRIC	**0.9251**	0.0009	0.0369	0.0994	0.8671
NIIC	**0.8434**	-0.0135	0.2425	0.2172	0.8175
ALIC	**0.7338**	0.1298	0.2519	0.1717	0.6482
FEIC	**0.6963**	0.0889	0.6552	0.0417	0.9237
PBIC	**0.5817**	0.1833	0.2171	-0.0740	0.4246
ECTC	**0.2164**	0.8020	-0.1299	-0.2300	0.7598
N3IC	-0.0721	**0.7931**	0.4213	0.1652	0.8391
OCTC	0.2297	**0.7518**	0.2491	-0.2235	0.7300
S4IC	-0.0420	**0.6743**	0.5059	0.4060	0.8772
N4TC	0.1004	**0.6256**	0.1124	0.2420	0.4726
TIIC	-0.2422	**0.2727**	-0.0559	0.0165	0.1364
MNIC	0.5001	0.0479	**0.8320**	0.0199	0.9449
KPAC	0.6246	0.2555	**0.6450**	-0.0132	0.8717
CAIC	0.1697	0.2128	**0.6230**	0.0851	0.4695
VAIC	0.3829	-0.0507	**0.4899**	-0.0348	0.3904
CUIC	0.0181	0.0905	**0.1514**	0.1094	0.0434
NAIC	0.0467	0.1481	-0.0255	**0.9627**	0.9515
CLIC	0.0556	-0.1123	-0.0382	**0.9281**	0.8785
KPIC	0.1806	0.0239	0.2621	**0.7668**	0.6899
Sum of Squares	3.9580	2.9751	2.9583	2.8448	12.7362
Percent of Variance	20.8317	15.6587	15.5697	14.9724	**67.0325**

From the elements present in the various factors i.e., the factor loadings the fingerprints of the first factor is that of bakeries, the second factor is that of soil dust and the third and fourth factor is of DG sets and construction activities and the fifth factor is that of vehicle exhausts.

SEASON 3

For the factor analysis results we have considered a total of seventeen variables and twenty eight samples. Four Elements which could not be measured in all samples were deleted , also three samples were deleted because of lack of values. The results of Factor Analysis are:

	Factor 1	**Factor 2**	**Factor 3**	**Factor 4**	**Commu-nality**
MNIC	**0.9435**	0.2669	0.0846	-0.0704	0.9735
FEIC	**0.9241**	0.2856	0.0747	-0.0610	0.9448
CRIC	**0.8407**	-0.1686	0.2841	0.0673	0.8204
KPAC	**0.8148**	0.1715	0.0520	0.0810	0.7026
NIIC	**0.7901**	-0.1467	0.2871	0.1158	0.7416
PBIC	**0.7218**	0.1547	-0.0769	-0.2613	0.6191
KPIC	**0.6289**	0.3901	-0.0987	-0.0549	0.5605
VAIC	**0.6274**	-0.0644	0.3829	0.0698	0.5493
N3IC	**0.5897**	0.4112	-0.0778	-0.5166	0.7897
ECTC	0.0440	**0.8337**	-0.0218	0.0182	0.6978
OCTC	0.5130	**0.7014**	0.0129	-0.2885	0.8385
NAIC	0.0228	**0.5111**	-0.0755	0.0372	0.2688
ZNIC	0.0859	-0.0631	**0.9501**	0.1655	0.9414
CAIC	0.1689	-0.0402	**0.9392**	-0.0215	0.9127
CUIC	0.1532	0.0470	-0.0025	**0.7147**	0.5365
N4TC	0.5405	0.2658	-0.1277	**-0.6526**	0.8050
S4IC	0.5957	0.4042	-0.0852	**-0.6129**	0.9012
CLIC	0.1257	0.3917	0.1244	**0.5334**	0.4692
Sum of Squares	6.3847	2.4250	2.1771	2.0859	13.0727
% Variance	35.4708	13.4725	12.0948	11.5882	**72.6261**

From the elements present in the various factors i.e., the factor loadings the fingerprints of the first factor is that of bakeries, the second factor is that of DG sets and the third and fourth factor is of vehicular exhausts and construction activities

Summary: of factor analyis results of Saidapet

Season	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5
1 54.2%	**Vehicles** 28.1%	**Construction** 16.2%	**DG sets** 9.87%		
2 67.032%	**Bakeries** 20.83%	**Soil Dust** 15.65%	**DG sets** 15.6%	**Construction** 15.6%	**Vehicle**s 14.9%
3 72.62%	**Bakeries** 35.47%	**DG sets** 13.47%	**Vehicles** 12.09%	**Construction** 11.58%	

Factor analysis of 3 seasons for the RK Nagar region show that emissions from vehicles, Construction, DG sets, and soil dust are important factors affecting the air quality in the site. Other factors include Bakeries and Domestic (or LPG) emissions.

Season 3 explains maximum variation in data.

Sulfate has a high negative loading on construction implying that an increase in concentration of Sulfate would decrease the contribution of constructional activities.
Bakeries explain a significant portion of variance.

TRIPLICANE FACTOR ANALYSIS

SEASON 1

For the factor analysis results we have considered a total of seventeen variables and thirty three samples. Elements which could not be measured in all samples were deleted , also three samples were deleted because of lack of values. The results of Factor Analysis are:

	Factor 1	Factor 2	Factor 3	Factor 4	Commu-nality
S4IC	**0.9557**	0.072324	0.014705	-0.01562	0.919006
N3IC	**0.9188**	0.06812	-0.02932	0.082049	0.856401
CLIC	**0.9183**	0.097859	0.001422	-0.04973	0.85529
NAIC	**0.6186**	-0.0719	-0.11355	-0.12593	0.416605
N4TC	**0.5437**	-0.03373	-0.07983	-0.14628	0.324546
KPIC	**0.4535**	-0.14973	-0.13868	0.16647	0.275002
CRIC	-0.0636	**0.992135**	0.064683	-0.06931	0.997371
ALIC	-0.0276	**0.981065**	0.068924	-0.08468	0.975171
NIIC	-0.061	**0.958077**	0.184313	-0.14018	0.975258
CUIC	0.3212	**0.391914**	-0.09363	-0.2088	0.309139
FEIC	-0.2	-0.02276	**0.967431**	0.013028	0.976593
CAIC	-0.2177	0.252278	**0.928795**	-0.00098	0.973679
PBIC	-0.0703	-0.01363	**-0.14086**	-0.12859	0.041507
OCTC	-0.0373	-0.17513	0.086267	**0.805799**	0.688814
ECTC	-0.1262	-0.11267	-0.03866	**0.673227**	0.483363
Sum of Squares	3.706	3.174216	1.918608	1.268893	10.06774
Percent of Variance	24.7069	21.16144	12.79072	8.459285	**67.1183**

From the elements present in the various factors i.e., the factor loadings the fingerprints of the first factor is that of bakeries, the second factor is that of DG sets and the third factor is of vehicle exhausts.

SEASON 2

For the factor analysis results we have considered a total of seventeen variables and thirty three samples. Elements which could not be measured in all samples were deleted , also three samples were deleted because of lack of values. The results of Factor Analysis are:

	Factor 1	Factor 2	Factor 3	Commu-nality
KPAC	**0.8880**	0.0612	0.0108	0.7925
NIIC	**0.8837**	0.2570	-0.0446	0.8490
CAIC	**0.8696**	0.2592	-0.0514	0.8259
CUIC	**0.7879**	-0.1582	0.1366	0.6645
CRIC	**0.7216**	-0.2827	-0.0306	0.6015
FEIC	**0.6289**	-0.3336	0.1922	0.5437
N3IC	-0.0525	**0.9295**	0.0110	0.8668
S4IC	-0.1149	**0.8376**	-0.0969	0.7241
NAIC	0.1286	**0.7883**	-0.3764	0.7797
CLIC	0.1753	**0.6306**	-0.3925	0.5824
N4TC	-0.1090	**0.6090**	0.0280	0.3835
PBIC	0.2760	**0.2860**	-0.1295	0.1747
OCTC	0.0247	-0.1285	**0.9232**	0.8695
ECTC	-0.0078	-0.3177	**0.8455**	0.8160
KPIC	0.1628	0.1667	**0.2216**	0.1034
Sum of Squares	4.0411	3.5357	2.0005	9.5773
Percent of Variance	26.9408	23.5711	13.3368	**63.8487**

From the elements present in the various factors i.e., the factor loadings the fingerprints of the first factor is that of soil dust or DG sets, the second factor is that of bakeries and the third factor is of construction activities.

SEASON 3

For the factor analysis results we have considered a total of seventeen variables and thirty three samples. Elements which could not be measured in all samples were deleted , also three samples were deleted because of lack of values.The results of Factor Analysis are:

	Factor 1	Factor 2	Factor 3	Communality
KPAC	**0.9162**	0.1897	-0.0640	0.8794
N3IC	**0.9149**	-0.0099	-0.0013	0.8372
FEIC	**0.8306**	0.4007	-0.0754	0.8563
ALIC	**0.8109**	0.4013	-0.1950	0.8567
MNIC	**0.7978**	0.1839	-0.1054	0.6813
OCTC	**0.7228**	0.4181	0.1683	0.7256
CUIC	**0.6733**	0.1535	-0.0951	0.4859
ECTC	**0.6676**	0.5612	0.1785	0.7926
S4IC	**0.6414**	-0.3223	-0.4308	0.7009
N4TC	**0.5524**	-0.2663	-0.0615	0.3799
CAIC	**0.2003**	0.0955	-0.0097	0.0494
NIIC	0.0027	**0.7203**	0.0140	0.5190
VAIC	0.0712	**0.7159**	0.1639	0.5444
CRIC	0.2836	**0.6181**	-0.1252	0.4782
NAIC	-0.2005	**-0.5995**	0.1679	0.4278
ZNIC	0.0931	**0.4719**	-0.0862	0.2388
KPIC	0.0591	0.0035	**0.9243**	0.8579
CLIC	-0.1582	-0.2285	**0.8935**	0.8756
TIIC	-0.0349	0.0043	**0.2979**	0.0900
Sum of Squares	6.0028	3.1365	2.1375	11.2767
Percent of Variance	31.5936	16.5076	11.2498	**59.3511**

From the elements present in the various factors i.e., the factor loadings the fingerprints of the first factor is that of vehicle exhausts, the second factor is that of construction activities and the third factor is of DG sets.

Summary of factor analyis results of Triplicane

Season	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5
1 67.11%	Bakeries 24.7%	DG sets 21.16%	Vehicles 12.79%		
2 63.84%	Soil Dust/ DG sets 26.94%	Bakeries 23.57%	Construction 13.33%		
3 59.53%	Vehicles 31.59%	Construction 16.5%	DG sets 11.24%		

Factor analysis of 3 seasons for the Triplicane region show that emissions from vehicles, Construction, DG sets, and bakeries are important factors affecting the air quality in the site.
Season 1 explains maximum variation in the data.

For the factor analysis of the data a statistical software called WinSTAT was used. The software generates an output of the different factors and their loadings. The results of WinSTAT were verified by another software package NCSS2007 and also by using MATLAB. The results obtained using all three programs were identical.

CMB 8.2 Methodology and Results

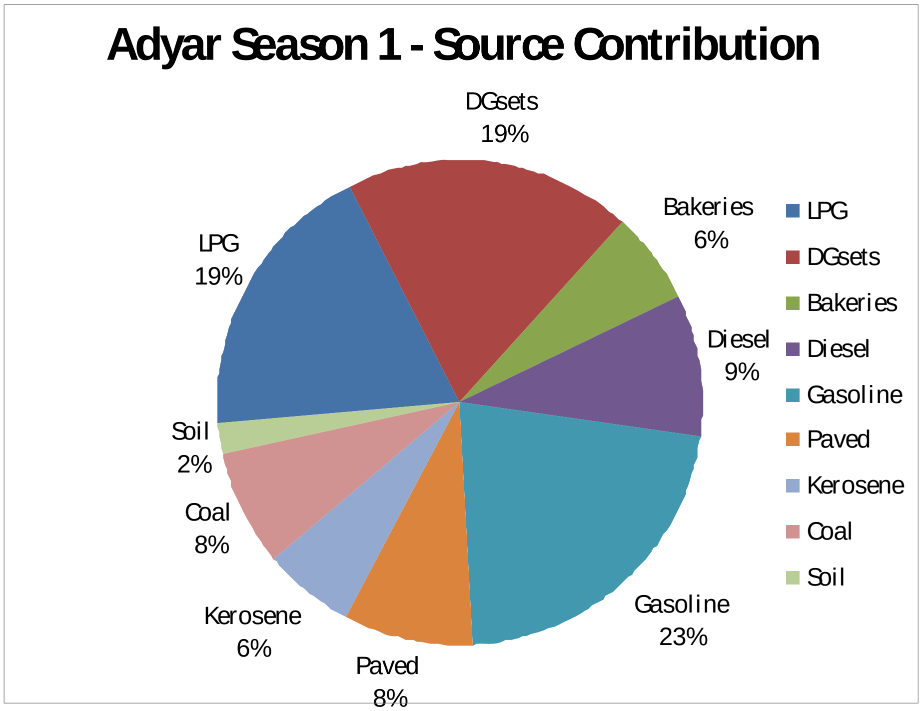
Factor analysis uses the information in the entire data set that is monitored for thirty days and each season and establishes the number of hidden factors in the set. It is only a qualitative measure of the various sources present in a region. In order to obtain a quantitative measure of the contributions of various sources we have also carried out receptor modeling using the classical CMB 8.2 package. This is a well tested package and it uses as inputs source profiles which are characteristic of the emissions of various sources. The sources profiles used in this study were obtained from the studies of IIT Mumbai and ARAI Pune. The latter gave the profiles for vehicular sources and the former for non-vehicular sources.

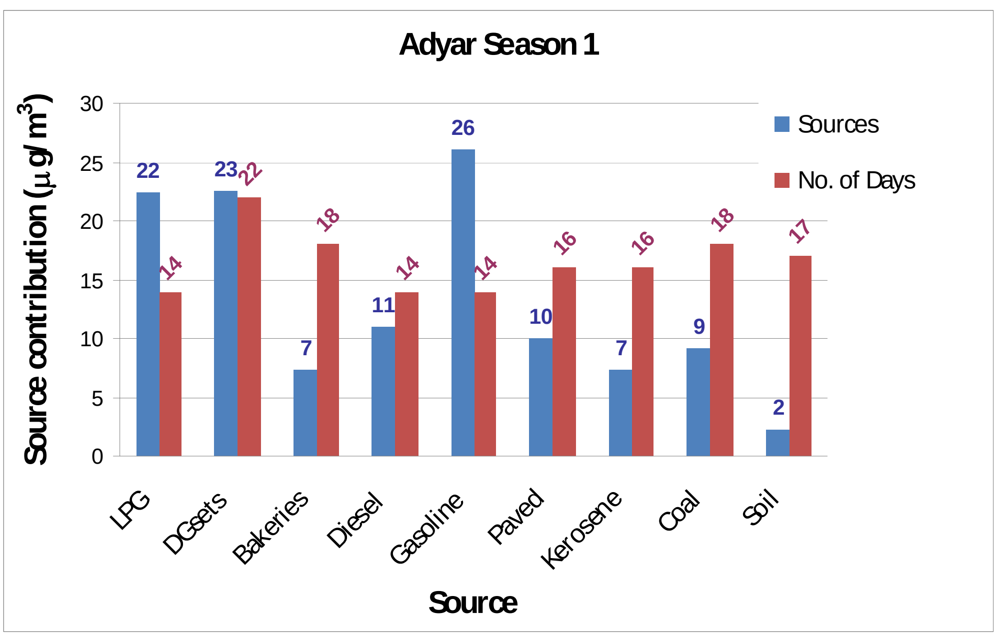
CMB requires the use of daily data that was observed. Hence for each day the measured concentrations from the speciation analysis consisting of ions, elements and carbon content were used to estimate the various source contributions.

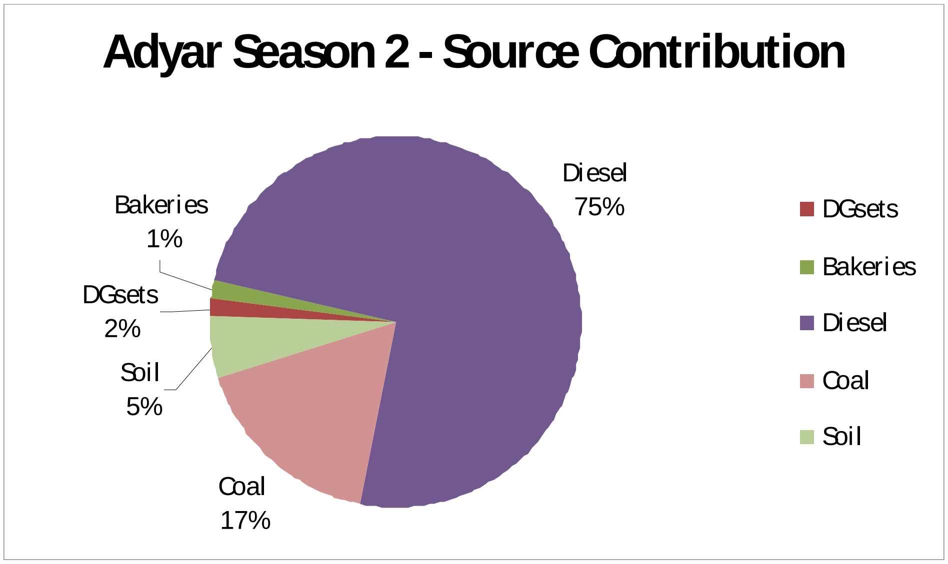
The primary emission survey gave us insight into the various sources present in an area. This was used to identify the sources as inputs for the CMB. The corresponding profiles were input in the format required. The receptor values was also input in the format required. The performance of the numerical algorithm depends on the uncertainities involved in the source profiles and receptor concentrations. These were calculated and fed into the software package.

For each site and season the results of the analysis are presented below in a graphical form. The pie diagram gives us insight into the average contribution over the entire monitoring period for a particular season and site. Here we find the contributions of each source and then average it over thirty days. The bar diagram represents the source contribution in microgram/ cubic meter as well as the number of days for which this value was observed to lie between plus or minus one standard deviation of the average value. Thus while the relative value or % contribution is given by the pie-chart the bar diagram gives the absolute value in microgram/m3. The bar chart also identifies the number of days for which the source had a contribution between one standard deviation of the mean value as well as the actual mean and standard deviation values. We now describe the results obtained for each sampling period and site.

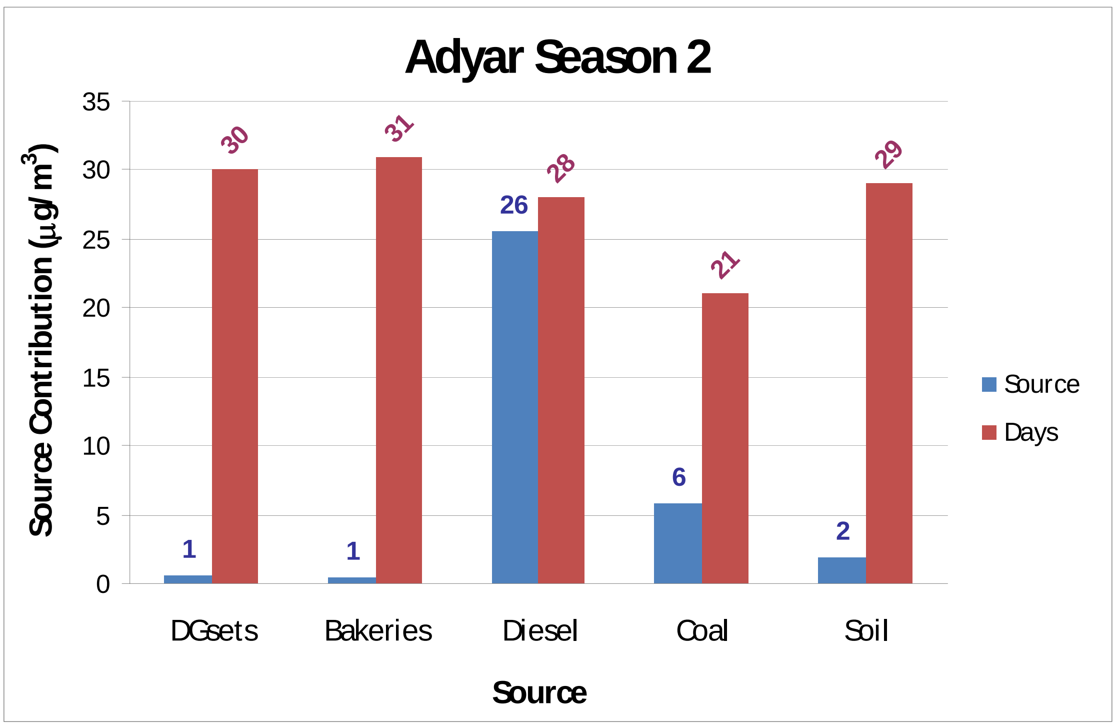
ADYAR


Adyar Season 1 - Source Contribution
DGsets 19%
Bakeries 6%
Diesel 9%
Gasoline 23%
Paved 8%
Kerosene 6%
Coal 8%
Soil 2%
LPG 19%
LPG
DGsets
Bakeries
Diesel
Gasoline
Paved
Kerosene
Coal
Soil


Adyar Season 1
Source contribution (µg/m³)
30
25
20
15
10
5
0
22
14
23
22
7
18
11
14
26
14
10
16
7
16
9
18
2
17
LPG
DGsets
Bakeries
Diesel
Gasoline
Paved
Kerosene
Coal
Soil
Source
Sources
No. of Days

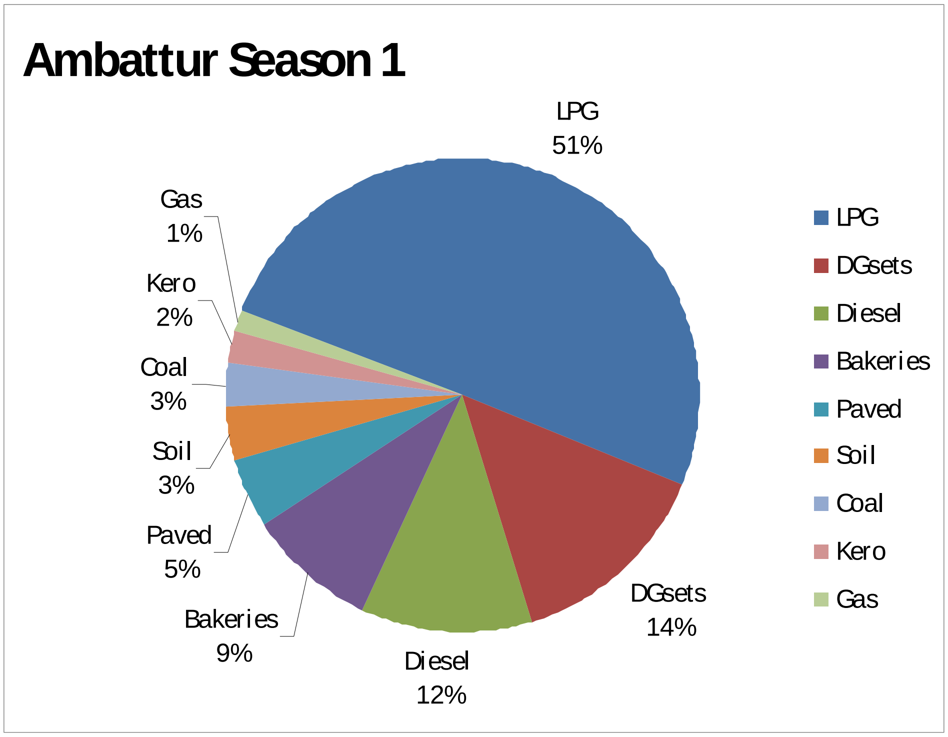


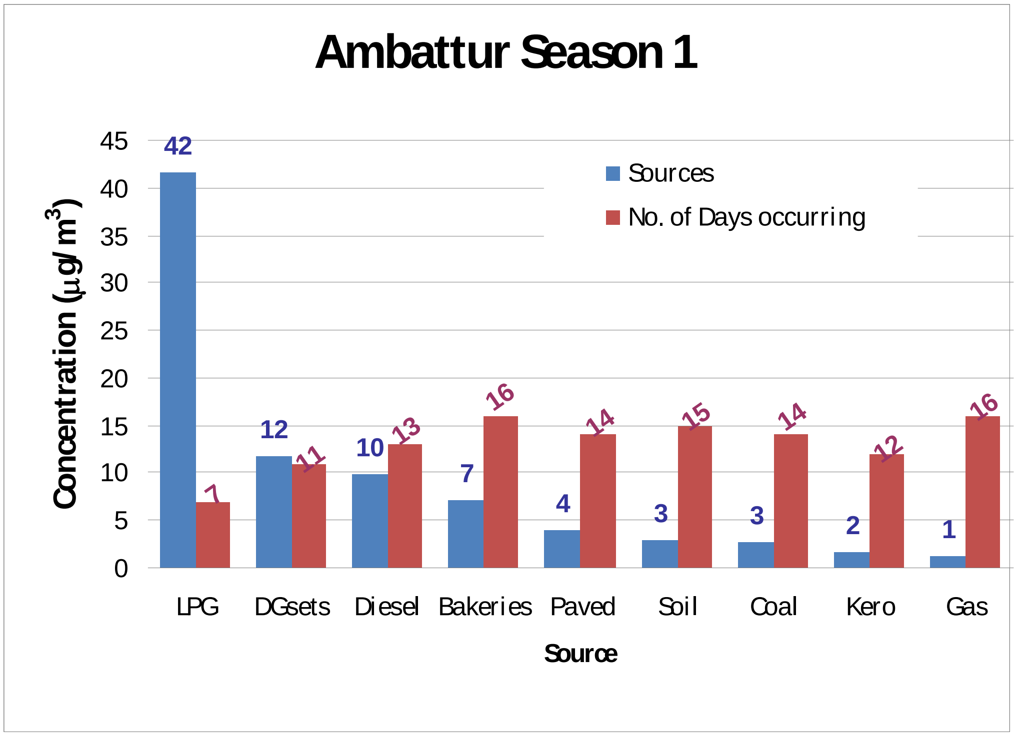
Adyar Season 2 - Source Contribution
Diesel 75%
Bakeries 1%
DGsets 2%
Soil 5%
Coal 17%
DGsets
Bakeries
Diesel
Coal
Soil

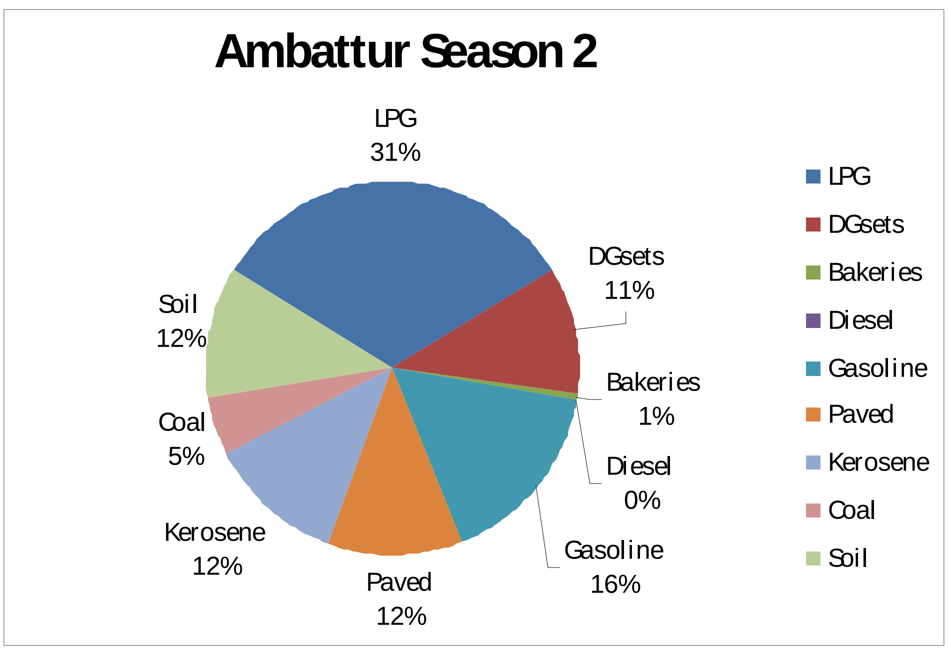


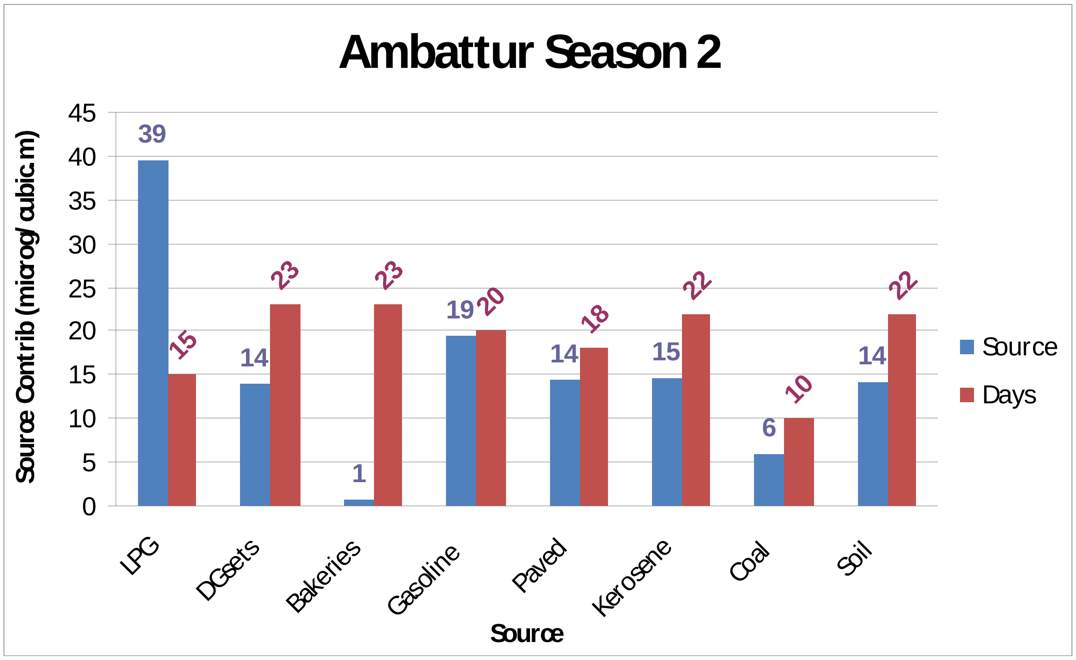
Adyar Season 2
Source Contribution (µg/m3)
35
30
25
20
15
10
5
0
1
30
1
31
26
28
6
21
2
29
DGsets
Bakeries
Diesel
Coal
Soil
Source
Source
Days

AMBATTUR

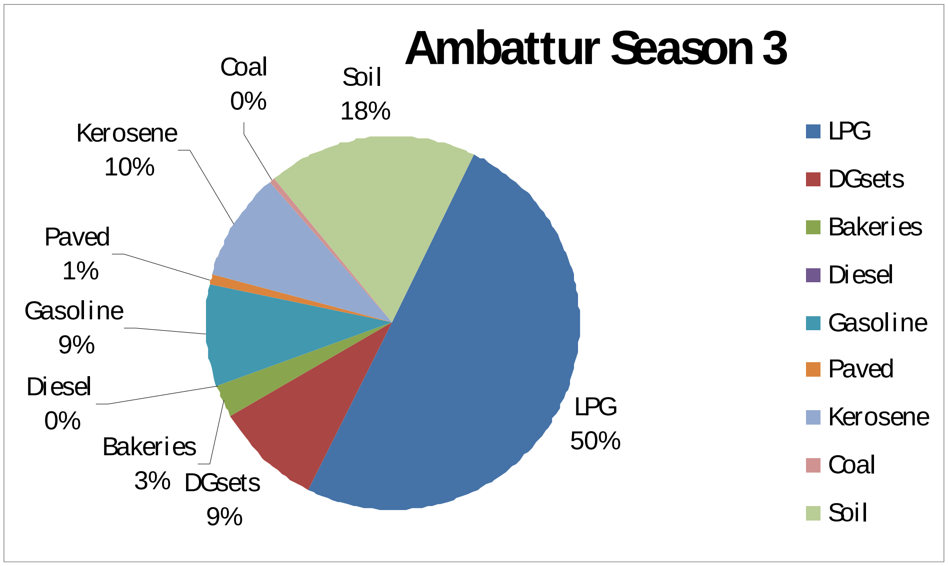

Ambattur Season 1
LPG 51%
DGsets 14%
Diesel 12%
Bakeries 9%
Paved 5%
Soil 3%
Coal 3%
Kero 2%
Gas 1%
LPG
DGsets
Diesel
Bakeries
Paved
Soil
Coal
Kero
Gas


Ambattur Season 1
Concentration (µg/ m3)
45
40
35
30
25
20
15
10
5
0
Sources
No. of Days occurring
42
7
12
11
10
13
7
16
4
14
3
15
3
14
2
12
1
16
LPG
DGsets
Diesel
Bakeries
Paved
Soil
Coal
Kero
Gas
Source

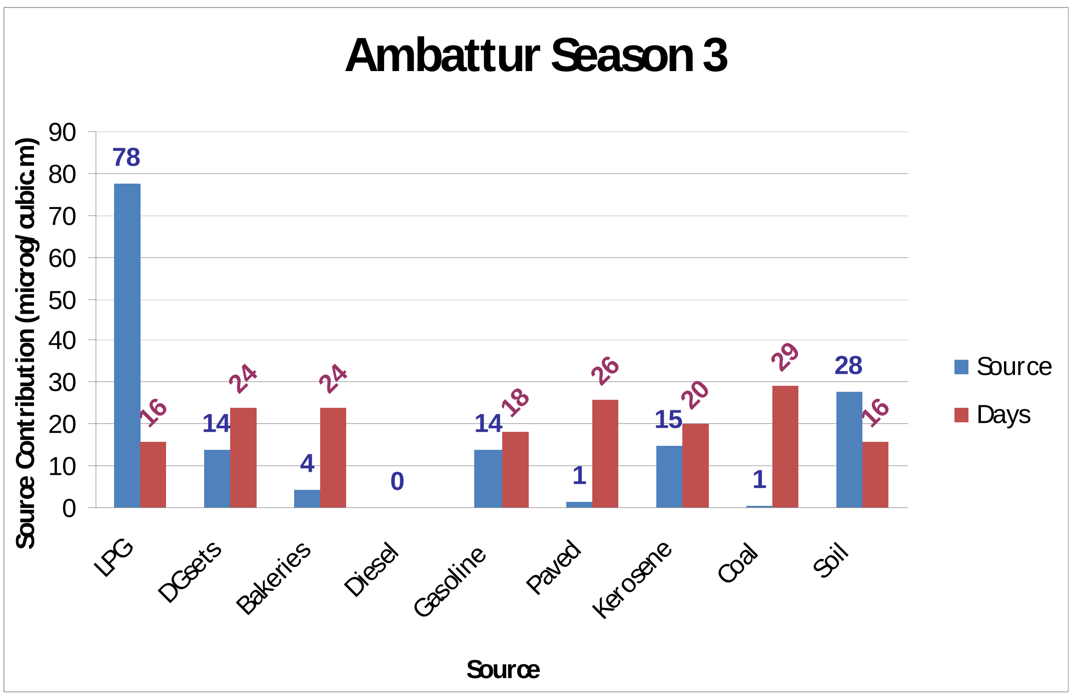

Ambattur Season 2
LPG
31%
DGsets
11%
Bakeries
1%
Diesel
0%
Gasoline
16%
Paved
12%
Kerosene
12%
Coal
5%
Soil
12%
LPG
DGsets
Bakeries
Diesel
Gasoline
Paved
Kerosene
Coal
Soil



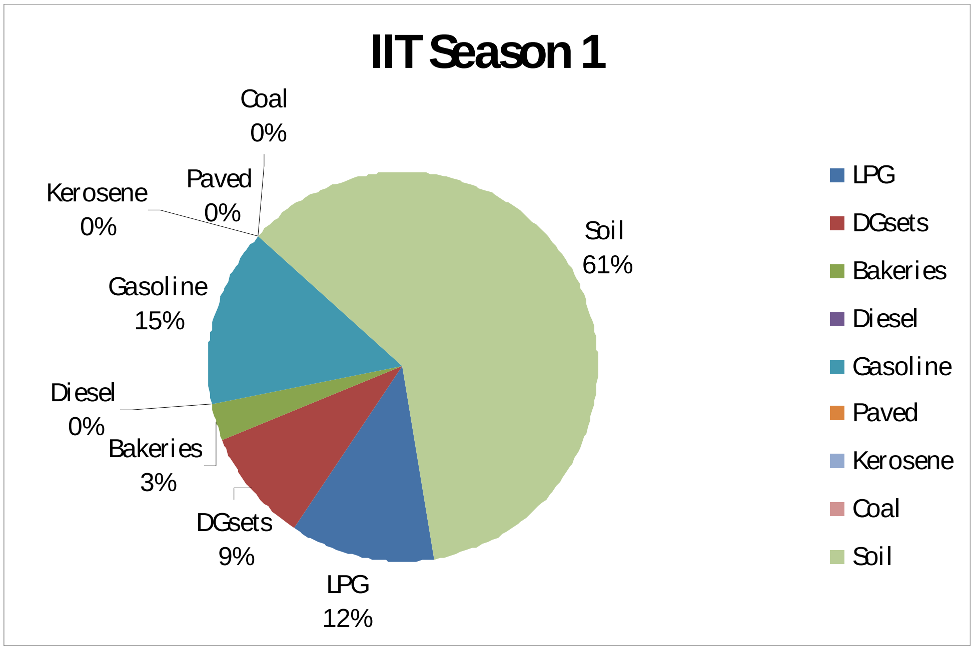
Ambattur Season 2
Source Contrib (microg/ cubic.m)
45
40
35
30
25
20
15
10
5
0
39
15
14
23
1
23
19
20
14
18
15
22
6
10
14
22
LPG
DGsets
Bakeries
Gasoline
Paved
Kerosene
Coal
Soil
Source
Source
Days

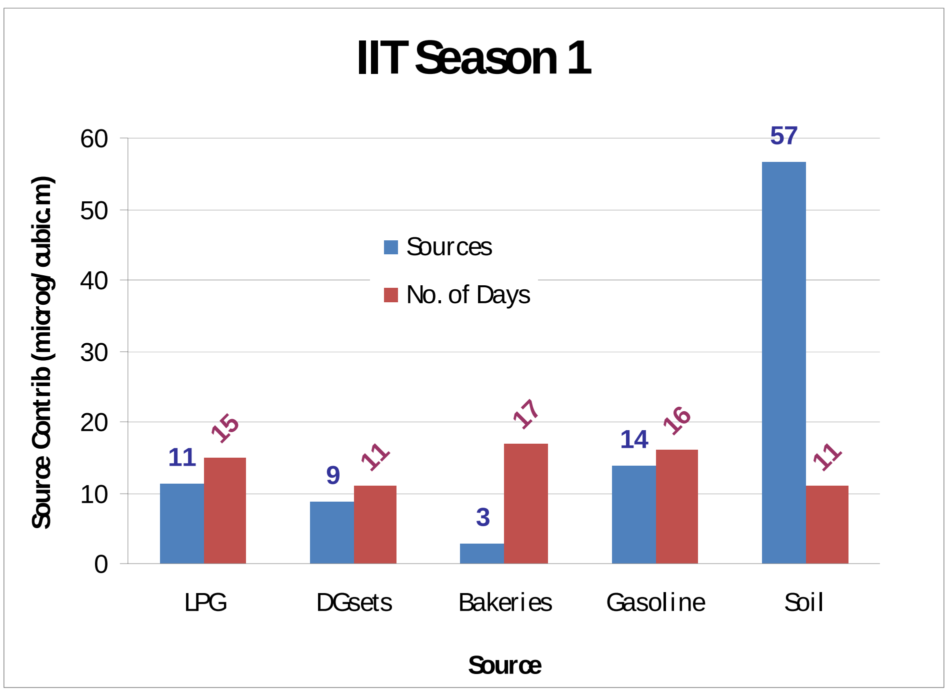


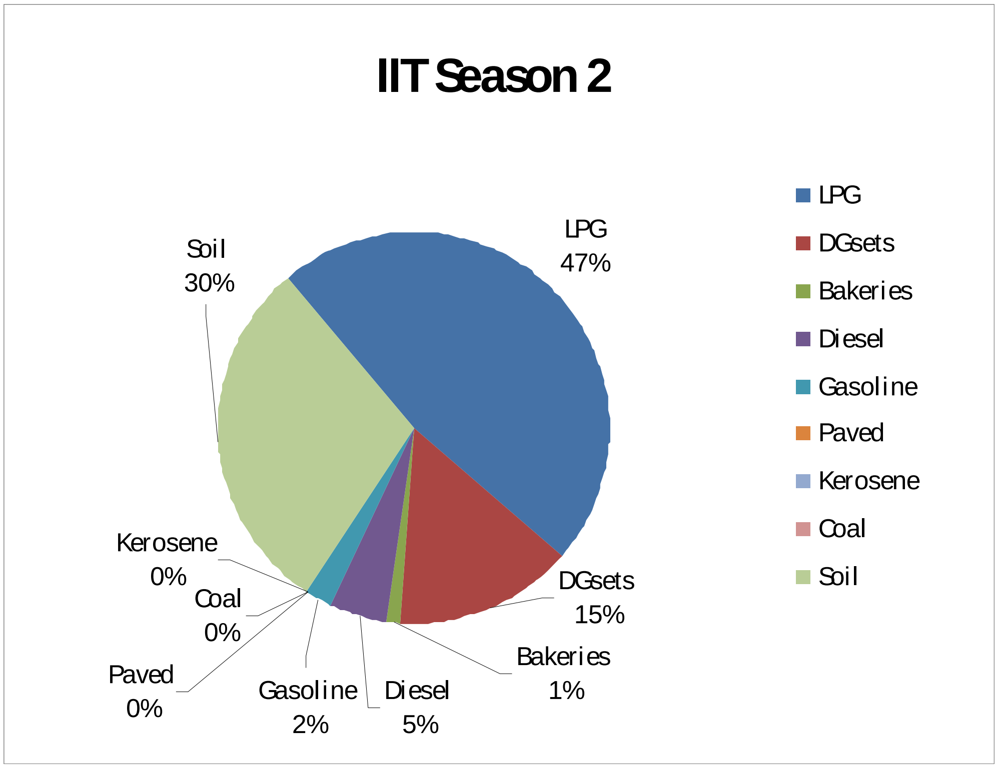
Ambattur Season 3
Coal 0%
Soil 18%
Kerosene 10%
Paved 1%
Gasoline 9%
Diesel 0%
Bakeries 3%
DGsets 9%
LPG 50%
LPG
DGsets
Bakeries
Diesel
Gasoline
Paved
Kerosene
Coal
Soil

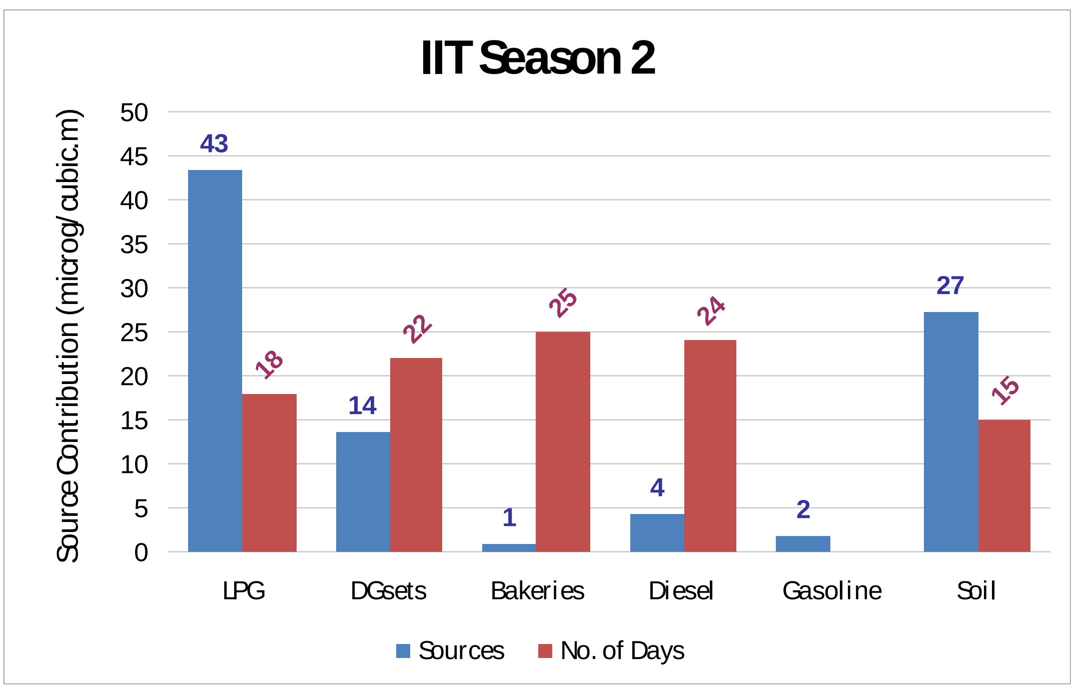


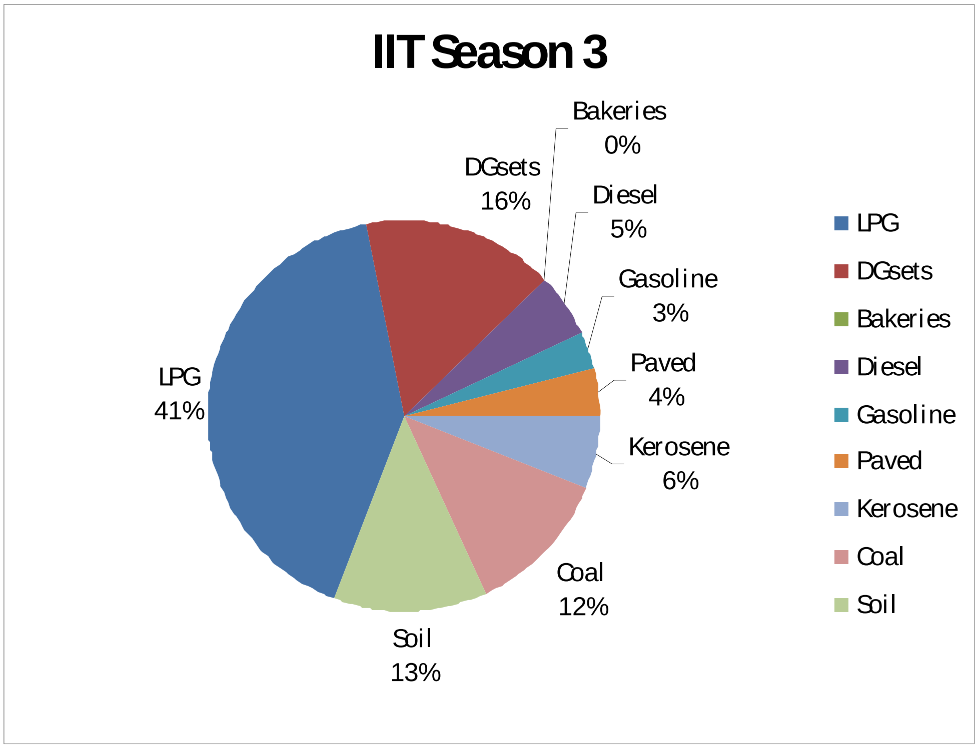
Ambattur Season 3
Source Contribution (microg/ cubic.m)
90
80
70
60
50
40
30
20
10
0
78
16
14
24
4
24
0
14
18
1
26
15
20
1
29
28
16
LPG
DGsets
Bakeries
Diesel
Gasoline
Paved
Kerosene
Coal
Soil
Source
Source
Days

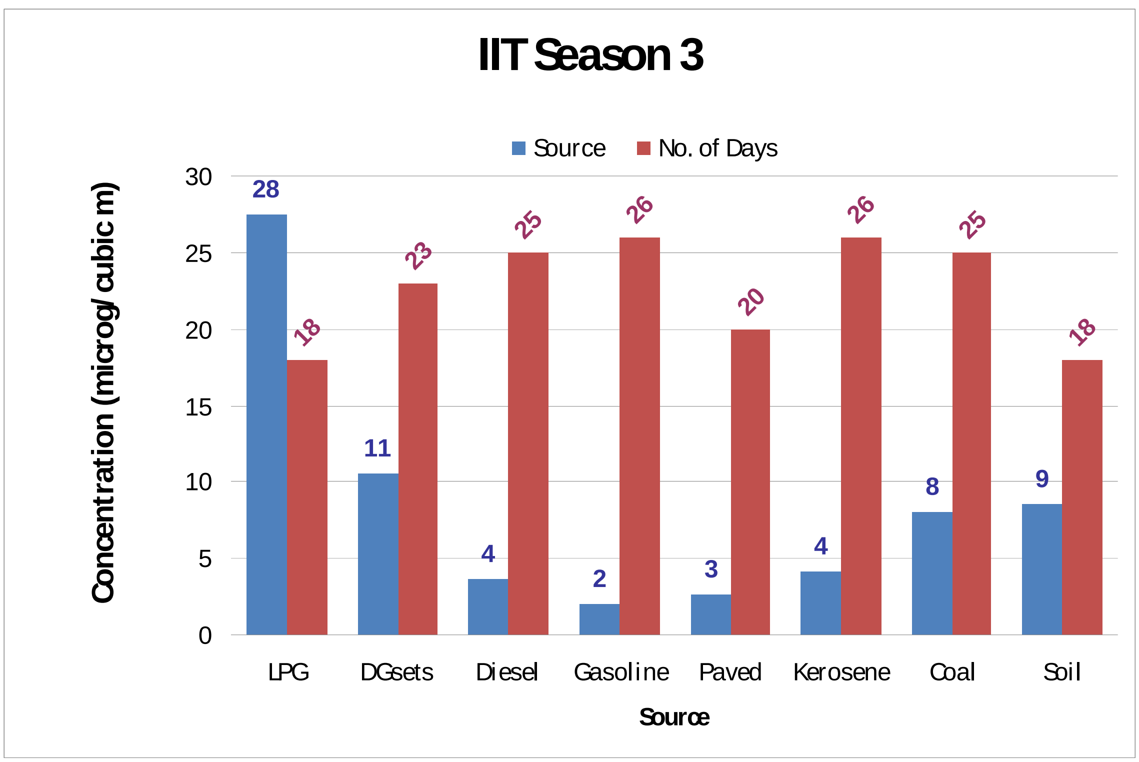

IIT Season 1
Coal
0%
Paved
0%
Kerosene
0%
Gasoline
15%
Diesel
0%
Bakeries
3%
DGsets
9%
LPG
12%
Soil
61%
LPG
DGsets
Bakeries
Diesel
Gasoline
Paved
Kerosene
Coal
Soil


IIT Season 1
Source Contrib (microg/ cubic.m)
60
50
40
30
20
10
0
Sources
No. of Days
11
15
9
11
3
17
14
16
57
11
LPG
DGsets
Bakeries
Gasoline
Soil
Source

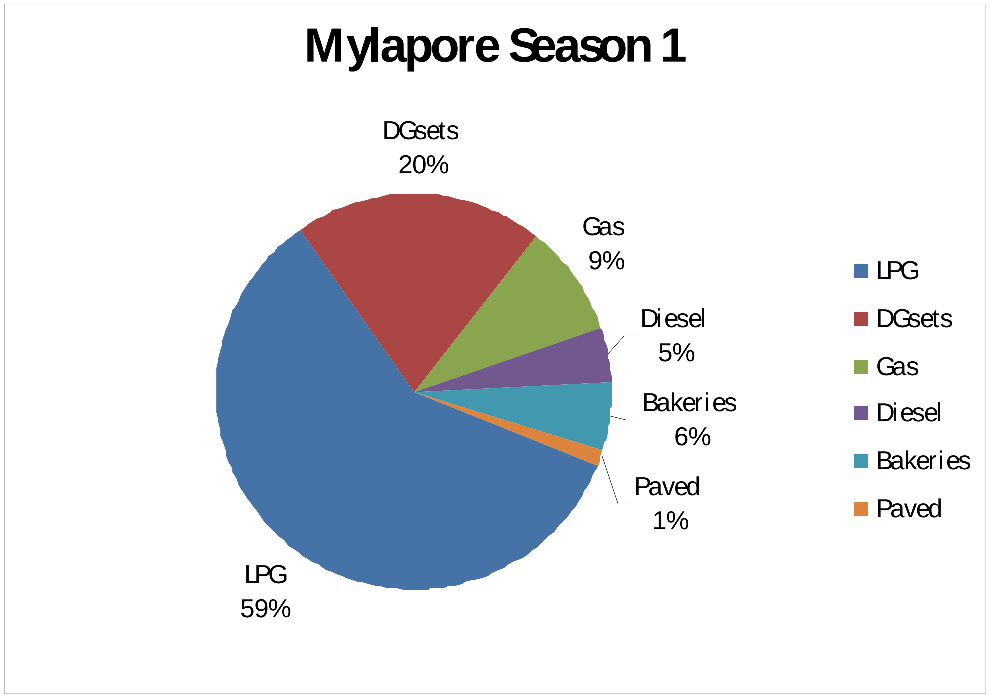

IIT Season 2
LPG 47%
DGsets 15%
Bakeries 1%
Diesel 5%
Gasoline 2%
Paved 0%
Coal 0%
Kerosene 0%
Soil 30%
LPG
DGsets
Bakeries
Diesel
Gasoline
Paved
Kerosene
Coal
Soil


IIT Season 2
Source Contribution (microg/cubic.m)
50
45
40
35
30
25
20
15
10
5
0
43
18
14
22
1
25
4
24
2
27
15
LPG
DGsets
Bakeries
Diesel
Gasoline
Soil
Sources
No. of Days

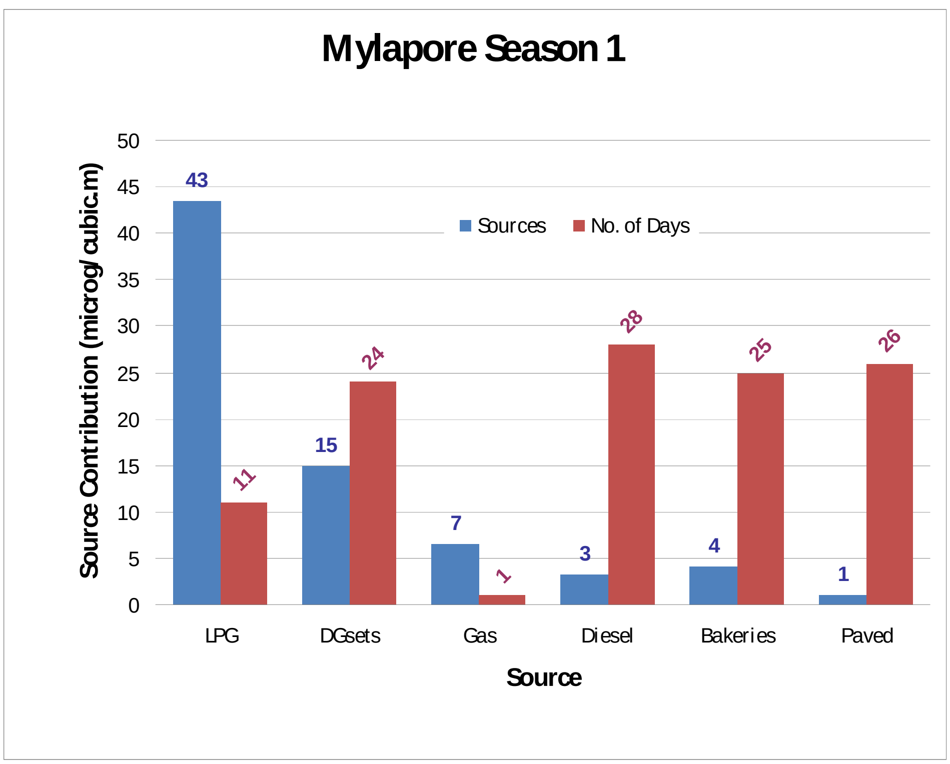

IIT Season 3
Bakeries 0%
DGsets 16%
Diesel 5%
Gasoline 3%
Paved 4%
Kerosene 6%
Coal 12%
Soil 13%
LPG 41%
LPG
DGsets
Bakeries
Diesel
Gasoline
Paved
Kerosene
Coal
Soil


IIT Season 3
Source
No. of Days
Concentration (microg/ cubic m)
30
25
20
15
10
5
0
28
18
11
23
4
25
2
26
3
20
4
26
8
25
9
18
LPG
DGsets
Diesel
Gasoline
Paved
Kerosene
Coal
Soil
Source

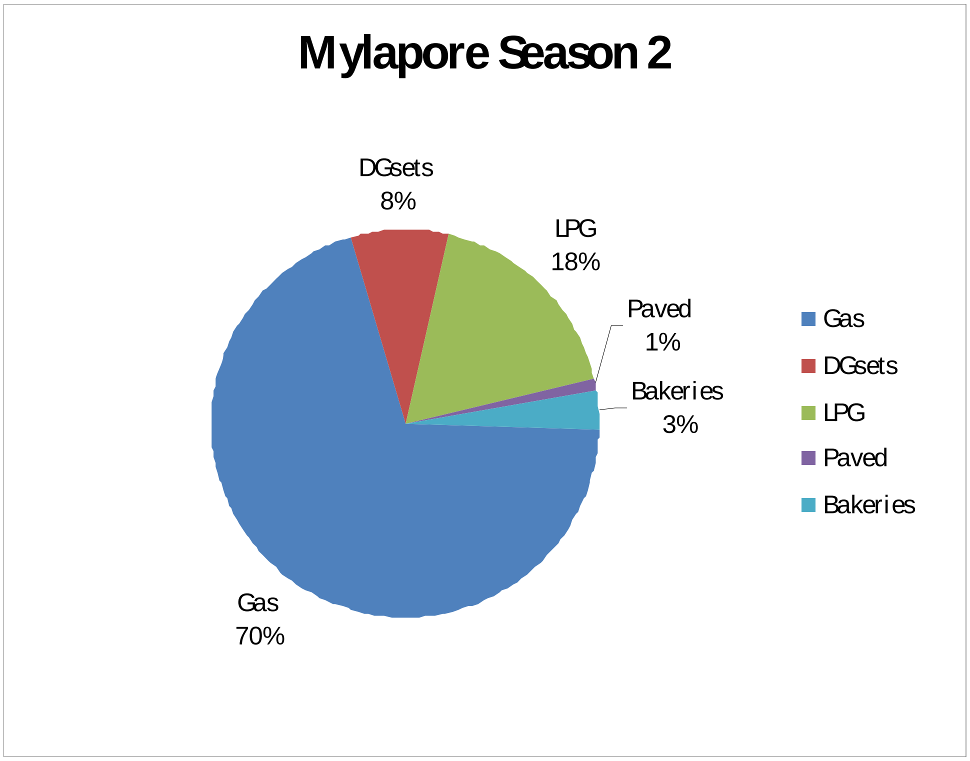
MYLAPORE

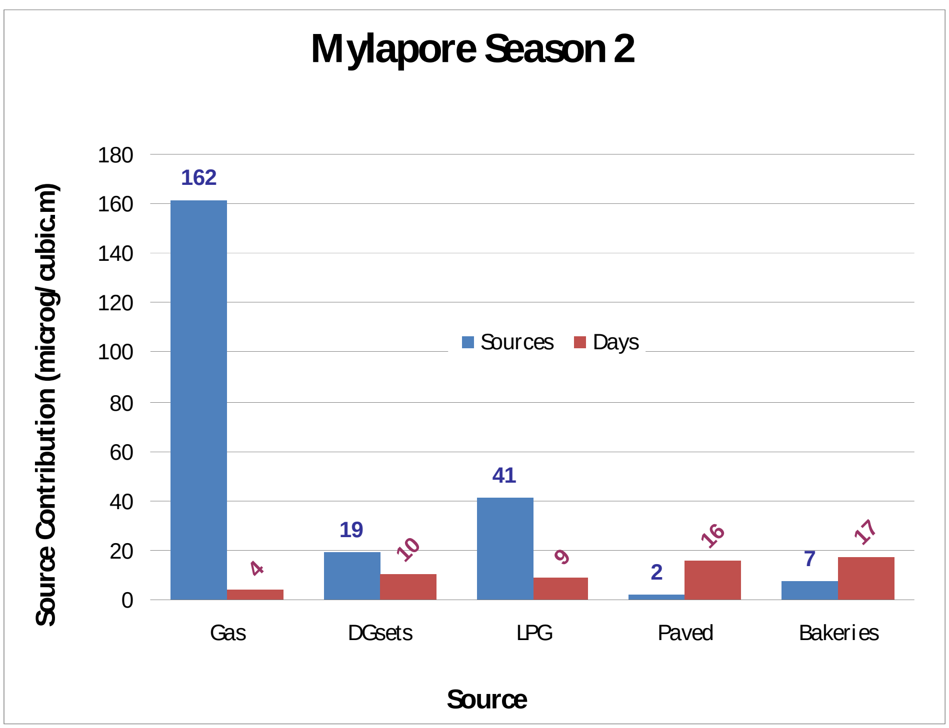


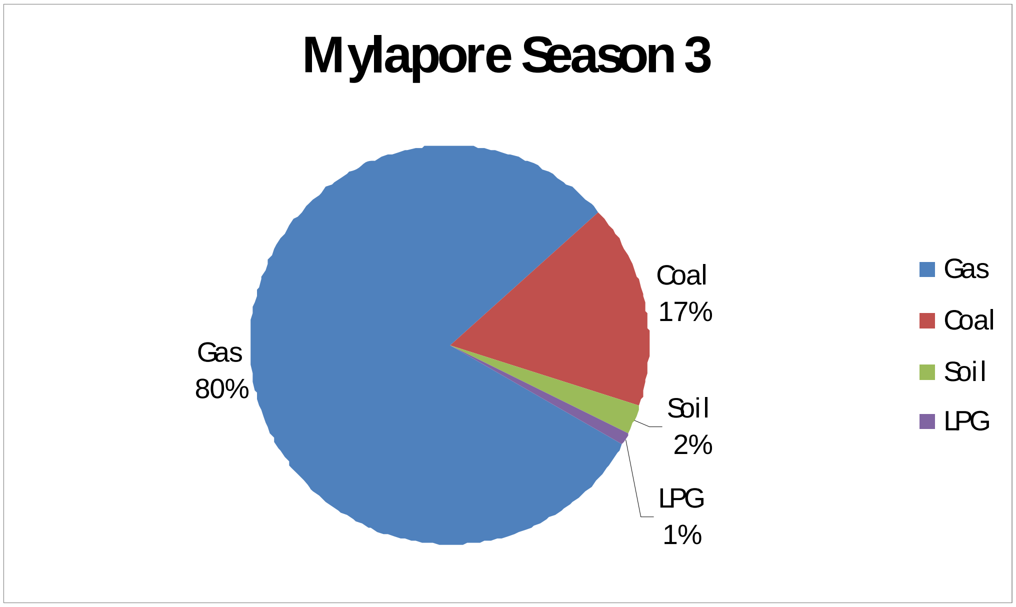
Mylapore Season 1
DGsets
20%
Gas
9%
Diesel
5%
Bakeries
6%
Paved
1%
LPG
59%
LPG
DGsets
Gas
Diesel
Bakeries
Paved

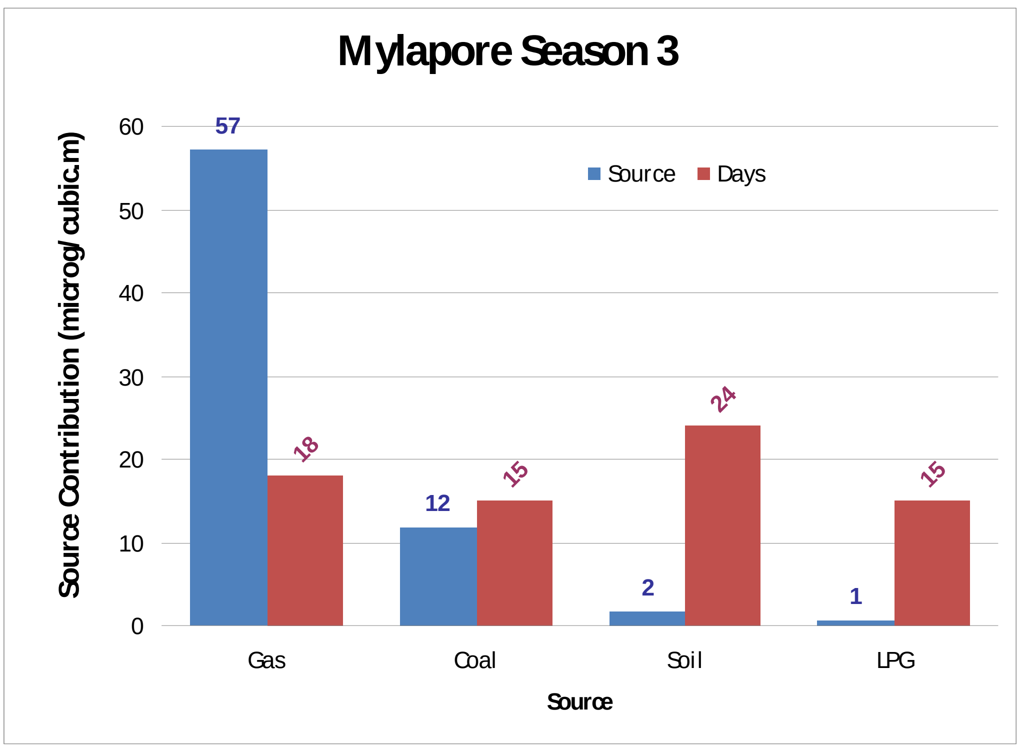


Mylapore Season 1
Source Contribution (microg/cubic.m)
50
45
40
35
30
25
20
15
10
5
0
Sources
No. of Days
43
11
15
24
7
1
3
28
4
25
1
26
LPG
DGsets
Gas
Diesel
Bakeries
Paved
Source

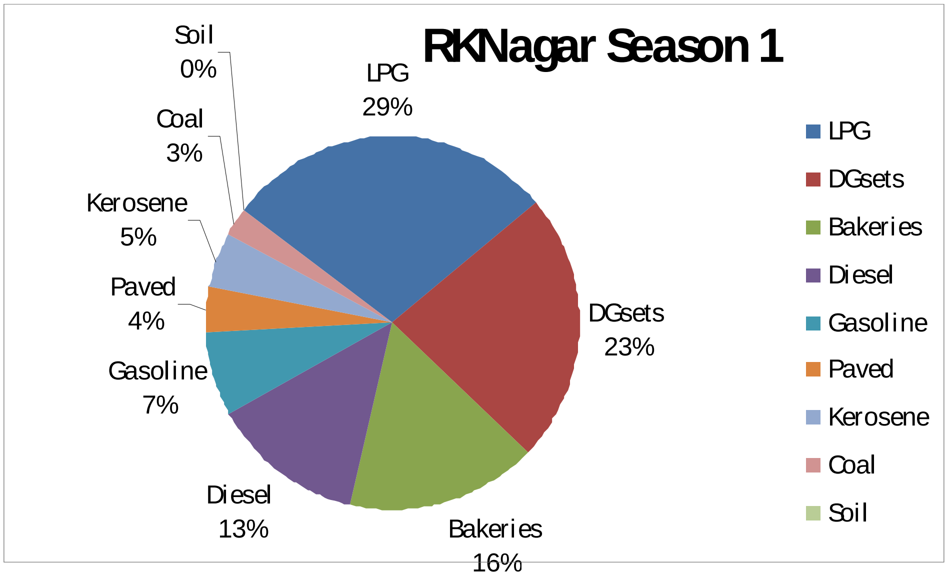

Mylapore Season 2
DGsets
8%
LPG
18%
Paved
1%
Bakeries
3%
Gas
70%
Gas
DGsets
LPG
Paved
Bakeries

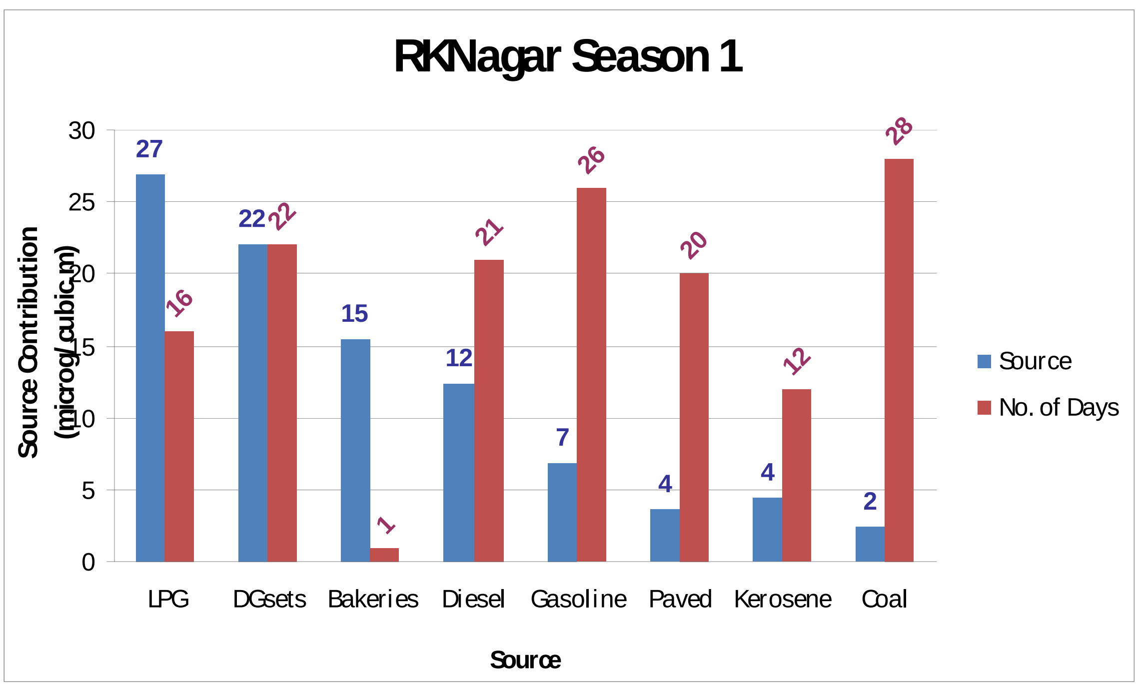

Mylapore Season 2
Source Contribution (microg/cubic.m)
180
160
140
120
100
80
60
40
20
0
162
4
19
10
41
9
2
16
7
17
Sources
Days
Gas
DGsets
LPG
Paved
Bakeries
Source

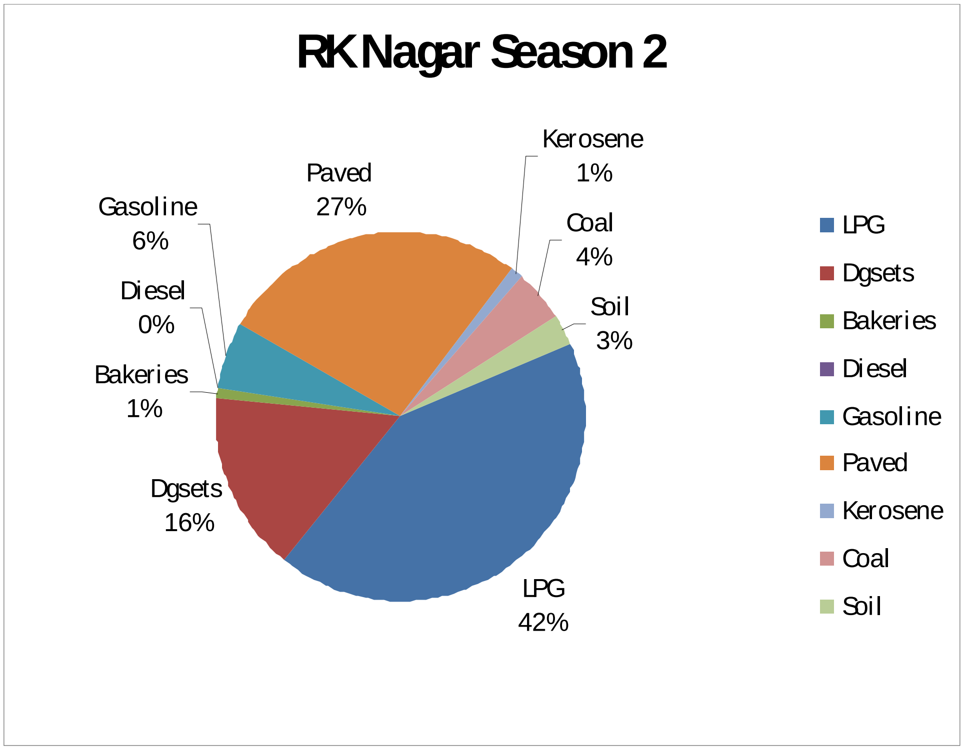

Mylapore Season 3
Gas
80%
Coal
17%
Soil
2%
LPG
1%
Gas
Coal
Soil
LPG

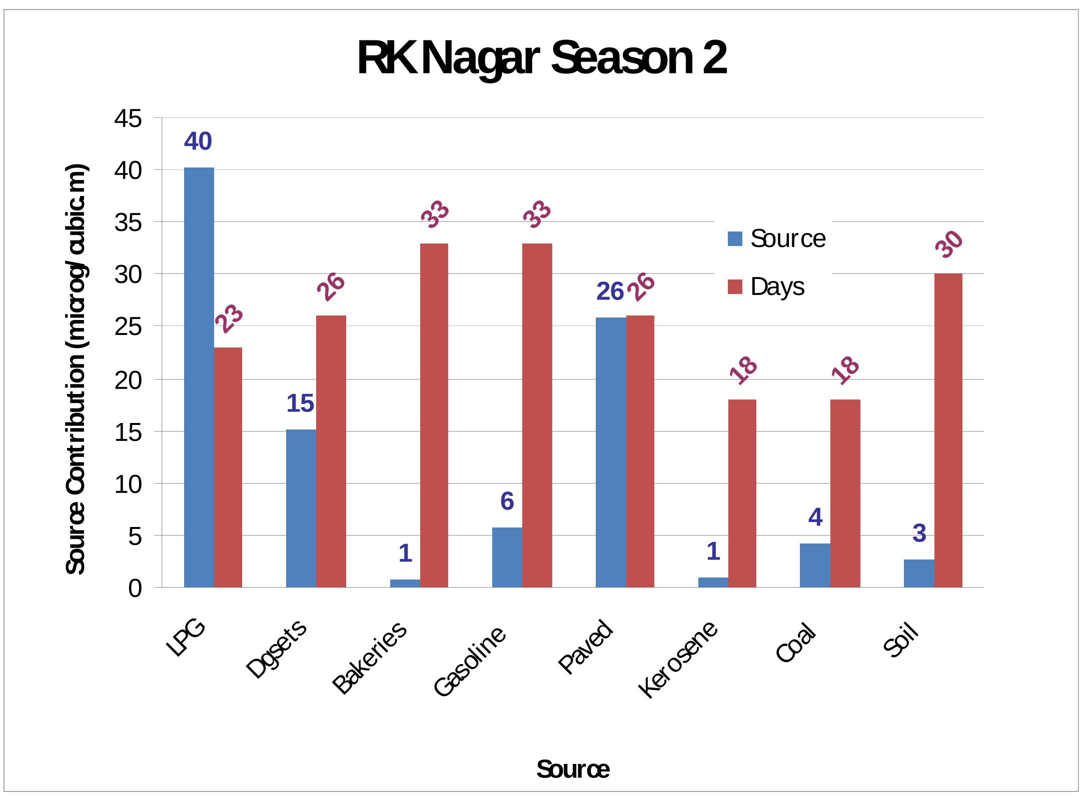

Mylapore Season 3
Source Contribution (microg/ cubic.m)
60
50
40
30
20
10
0
Source
Days
57
18
12
15
2
24
1
15
Gas
Coal
Soil
LPG
Source

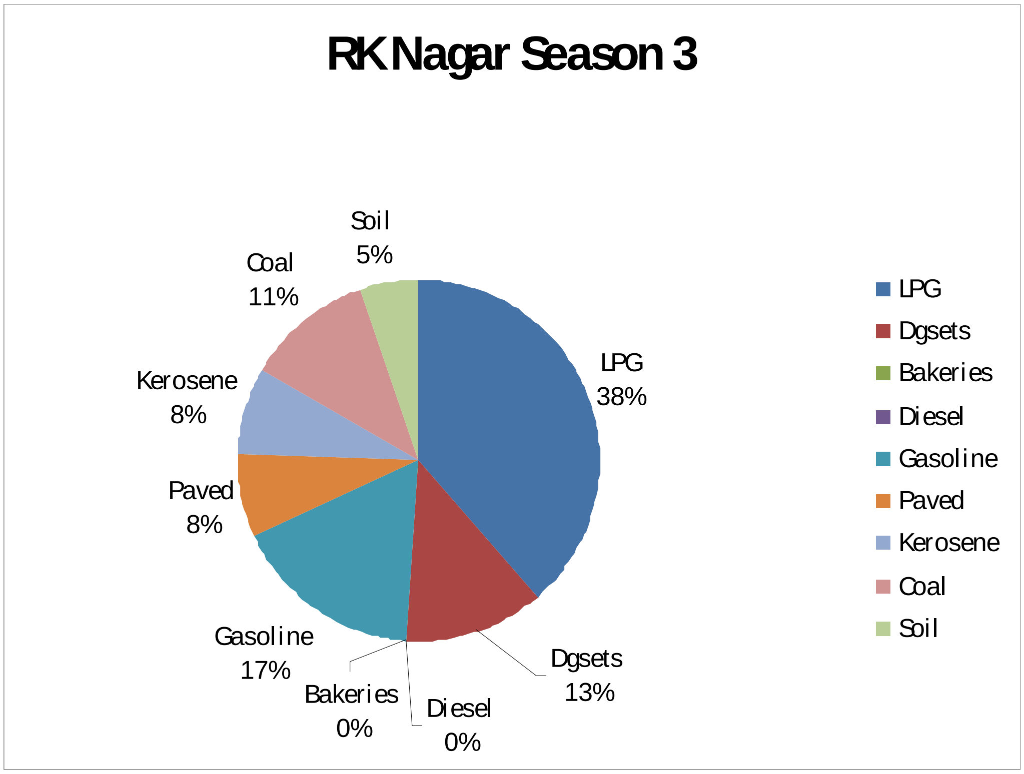
RK NAGAR


RKNagar Season 1
Soil
0%
Coal
3%
Kerosene
5%
Paved
4%
Gasoline
7%
Diesel
13%
LPG
29%
DGsets
23%
Bakeries
16%
LPG
DGsets
Bakeries
Diesel
Gasoline
Paved
Kerosene
Coal
Soil

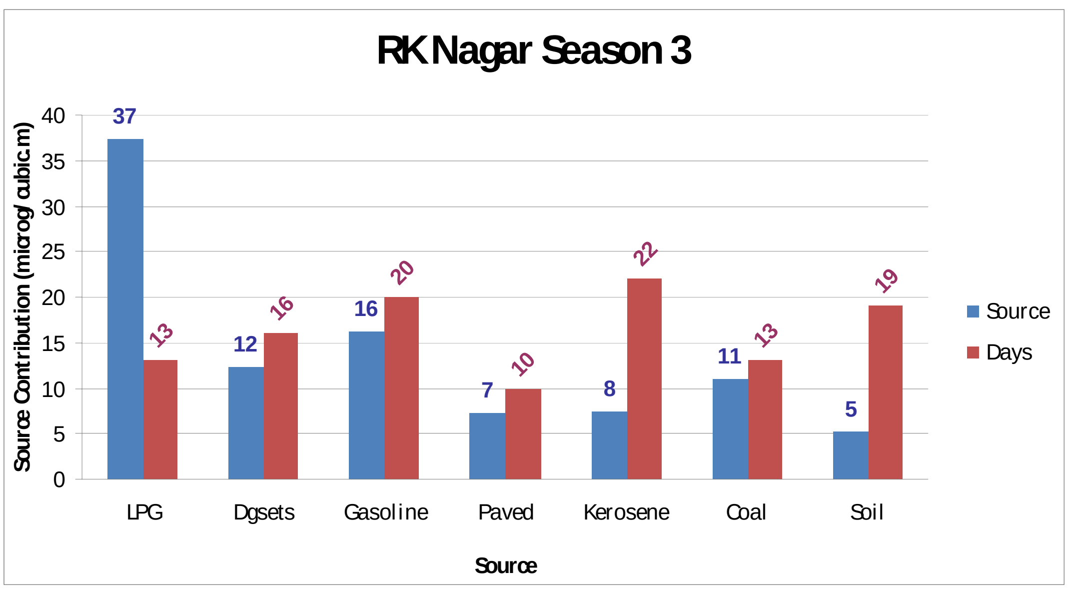

RKNagar Season 1
Source Contribution (microg/cubic m)
30
25
20
15
10
5
0
27
16
22
22
15
1
12
21
7
26
4
20
4
12
2
28
LPG
DGsets
Bakeries
Diesel
Gasoline
Paved
Kerosene
Coal
Source
Source
No. of Days


RK Nagar Season 2
Kerosene 1%
Paved 27%
Gasoline 6%
Coal 4%
Diesel 0%
Soil 3%
Bakeries 1%
Dgsets 16%
LPG 42%
LPG
Dgsets
Bakeries
Diesel
Gasoline
Paved
Kerosene
Coal
Soil


RK Nagar Season 2
Source Contribution (microg/ cubic m)
45
40
35
30
25
20
15
10
5
0
40
23
15
26
1
33
6
33
26
26
1
18
4
18
3
30
Source
Days
LPG
Dgsets
Bakeries
Gasoline
Paved
Kerosene
Coal
Soil
Source

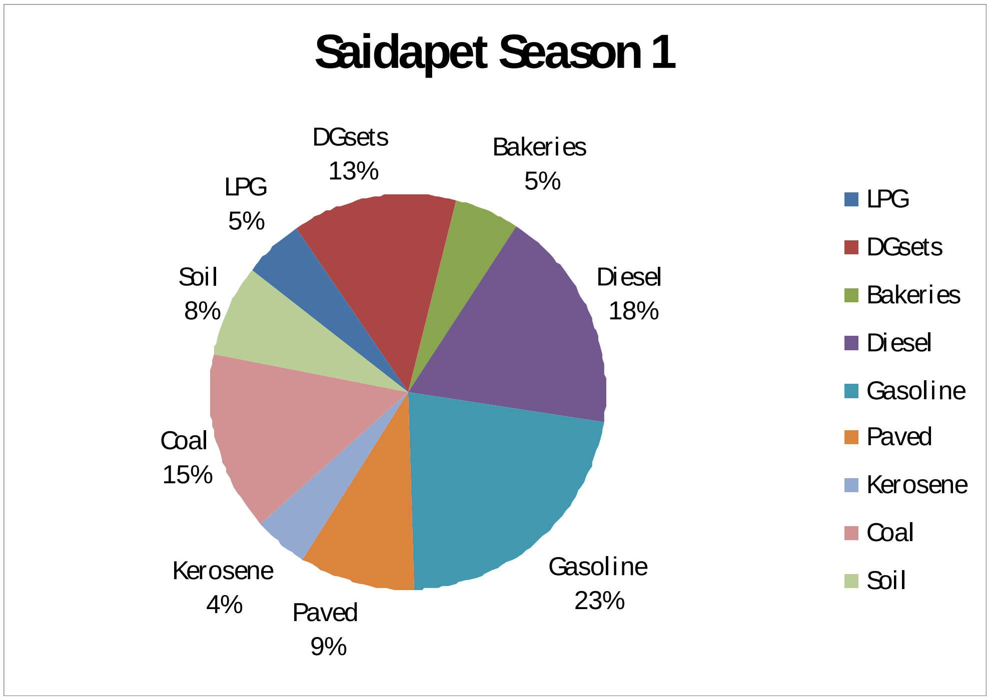


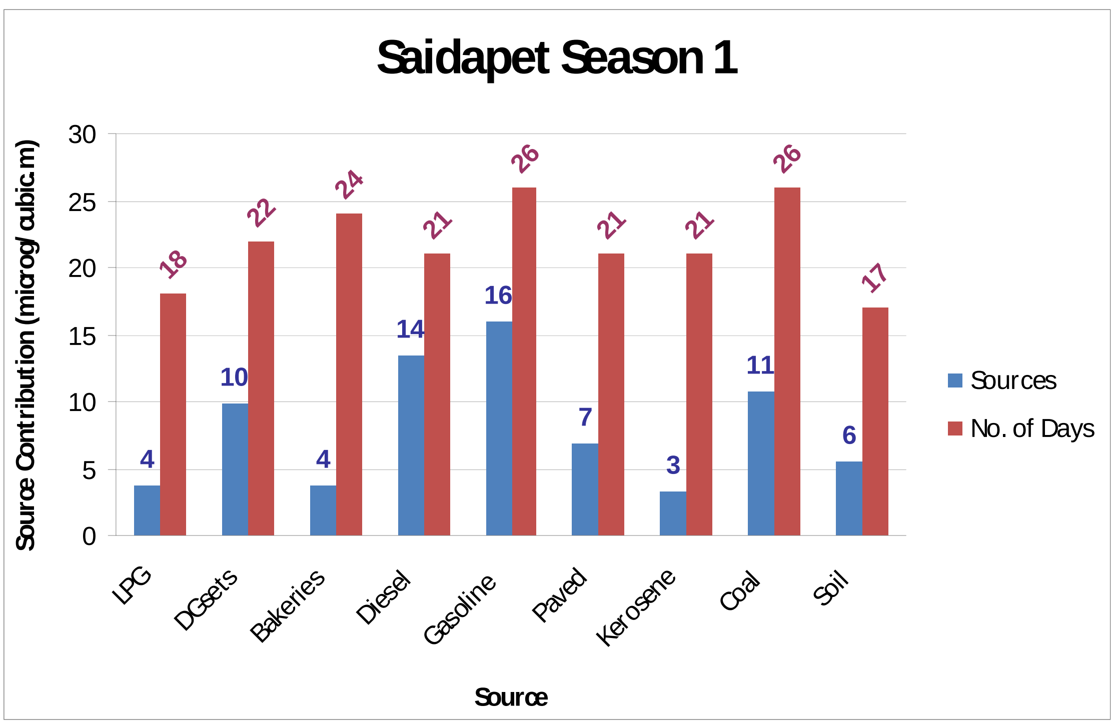
RK Nagar Season 3
Soil 5%
Coal 11%
Kerosene 8%
Paved 8%
Gasoline 17%
Bakeries 0%
Diesel 0%
Dgsets 13%
LPG 38%
LPG
Dgsets
Bakeries
Diesel
Gasoline
Paved
Kerosene
Coal
Soil

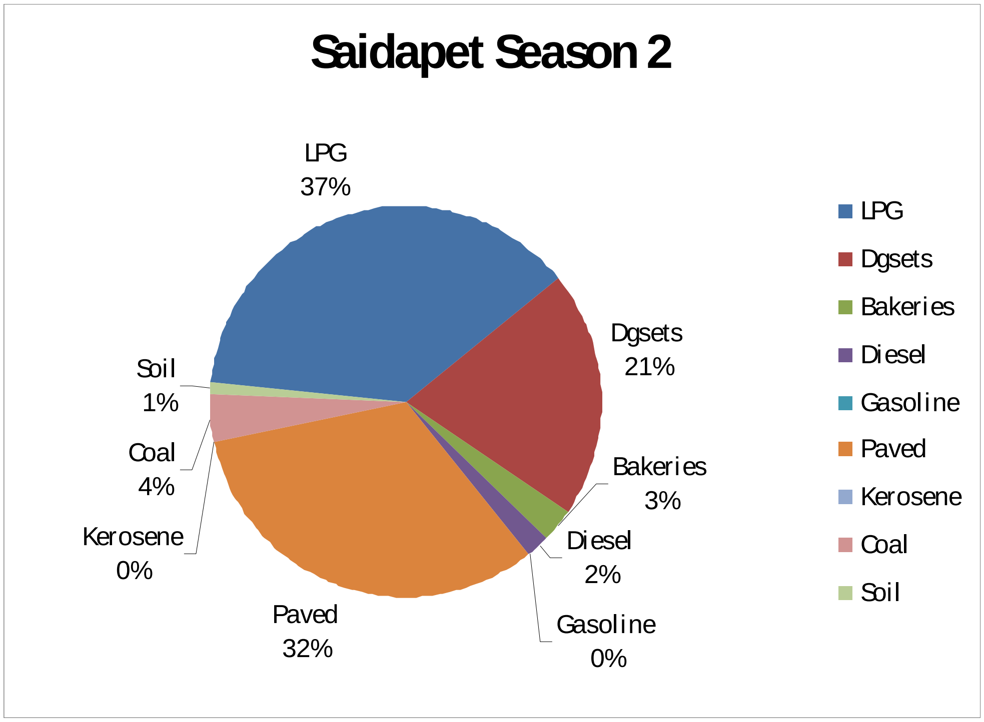


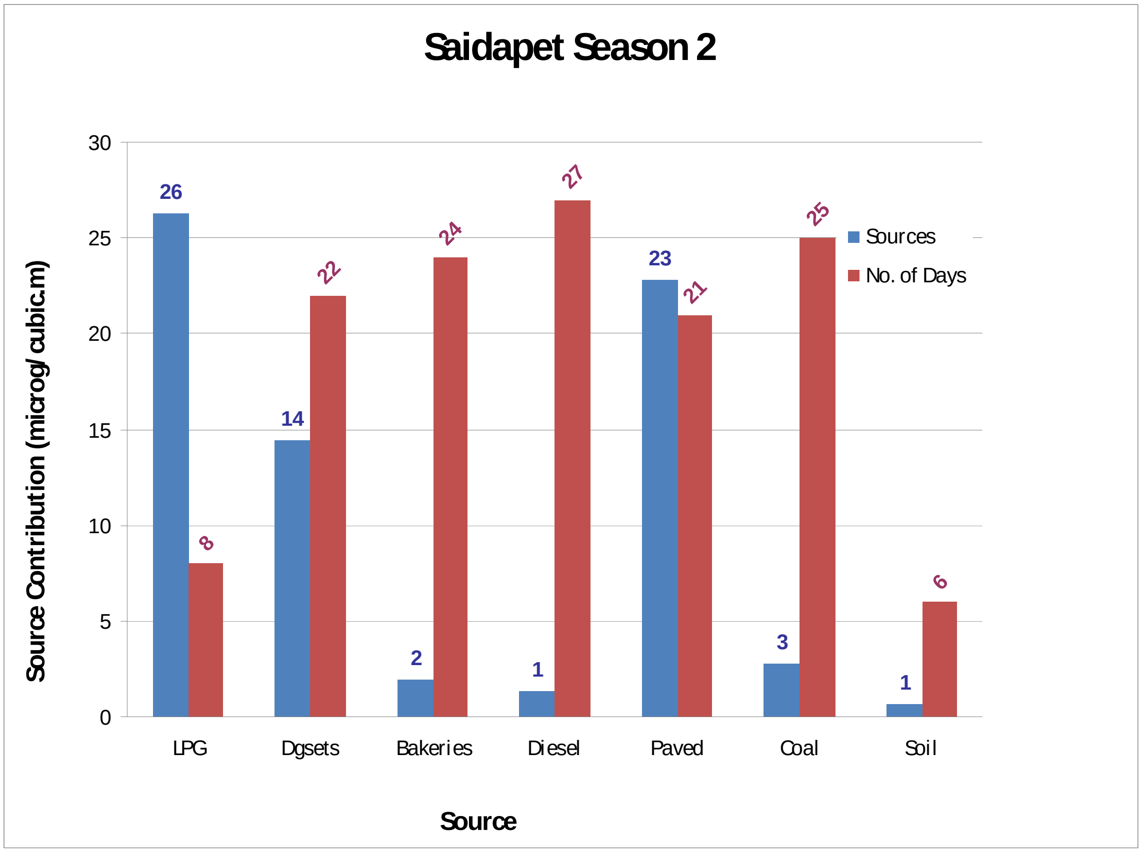
RK Nagar Season 3
Source Contribution (microg/ cubic m)
0
5
10
15
20
25
30
35
40
37
13
12
16
16
20
7
10
8
22
11
13
5
19
LPG
Dgsets
Gasoline
Paved
Kerosene
Coal
Soil
Source
Source
Days

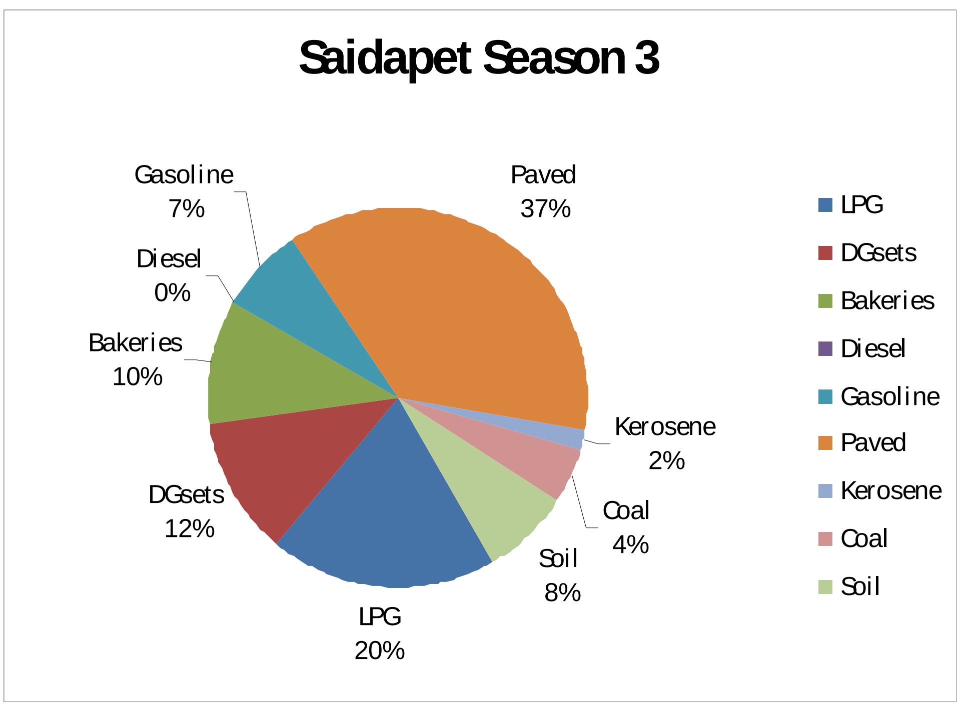
SAIDAPET

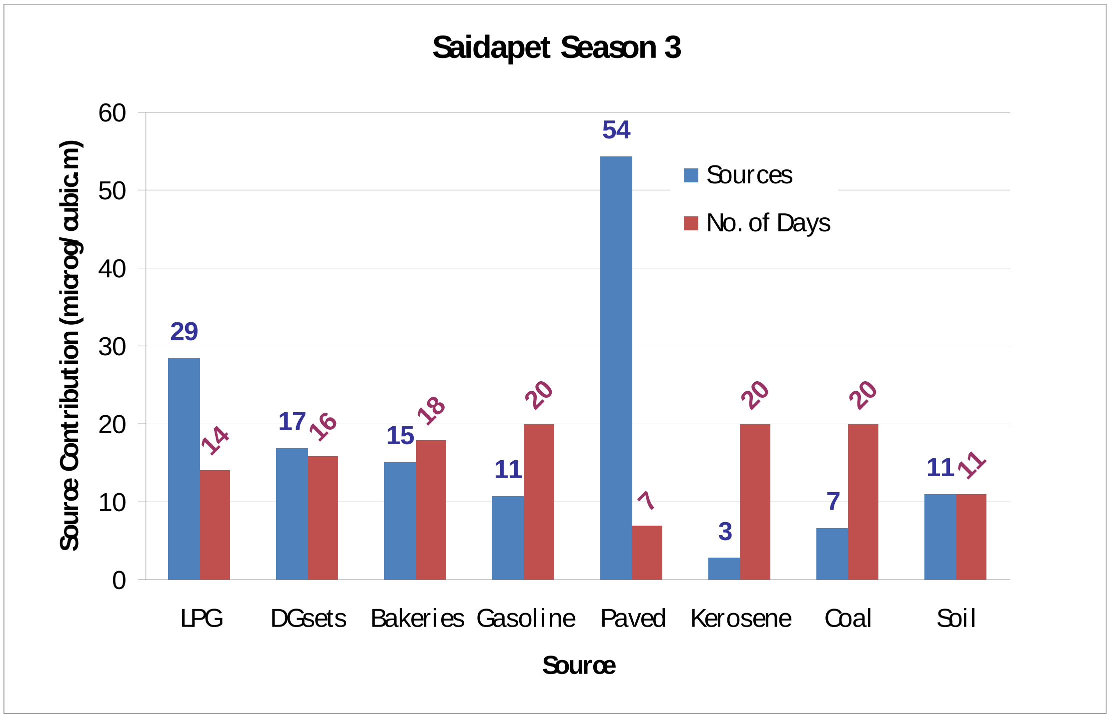

Saidapet Season 1
DGsets
13%
Bakeries
5%
LPG
5%
Soil
8%
Diesel
18%
Coal
15%
Kerosene
4%
Paved
9%
Gasoline
23%
LPG
DGsets
Bakeries
Diesel
Gasoline
Paved
Kerosene
Coal
Soil


Saidapet Season 1
Source Contribution (microg/ cubic.m)
30
25
20
15
10
5
0
18
22
24
21
26
21
21
26
17
4
10
4
14
16
7
3
11
6
LPG
DGsets
Bakeries
Diesel
Gasoline
Paved
Kerosene
Coal
Soil
Source
Sources
No. of Days


Saidapet Season 2
LPG
37%
Dgsets
21%
Bakeries
3%
Diesel
2%
Gasoline
0%
Paved
32%
Kerosene
0%
Coal
4%
Soil
1%
LPG
Dgsets
Bakeries
Diesel
Gasoline
Paved
Kerosene
Coal
Soil

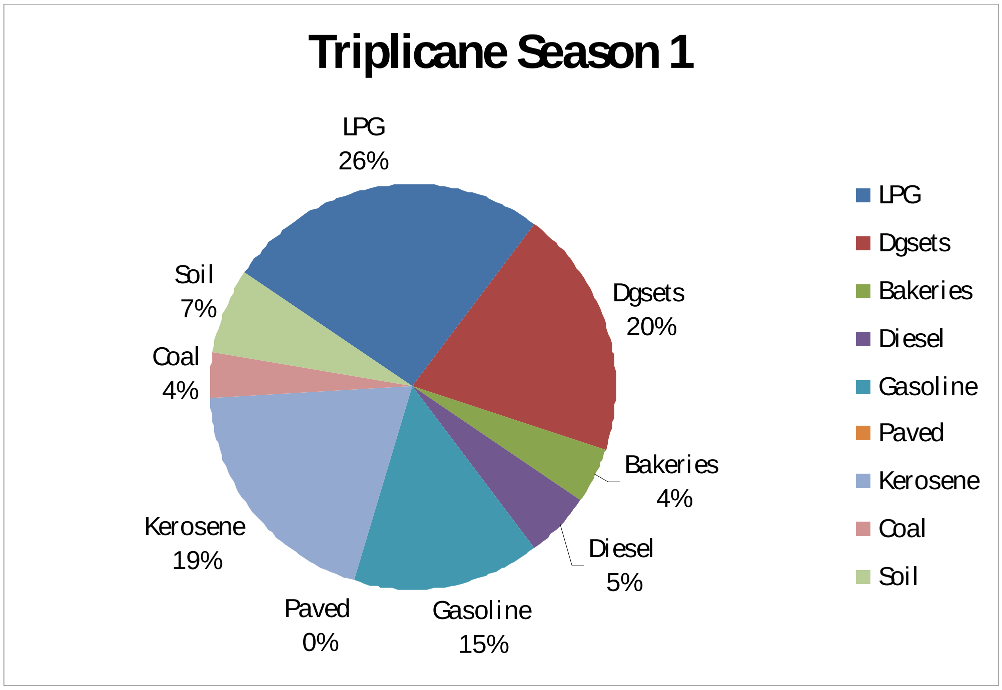

Saidapet Season 2
Source Contribution (microg/ cubic.m)
30
25
20
15
10
5
0
26
8
14
22
2
24
1
27
23
21
3
25
1
6
Sources
No. of Days
LPG
Dgsets
Bakeries
Diesel
Paved
Coal
Soil
Source

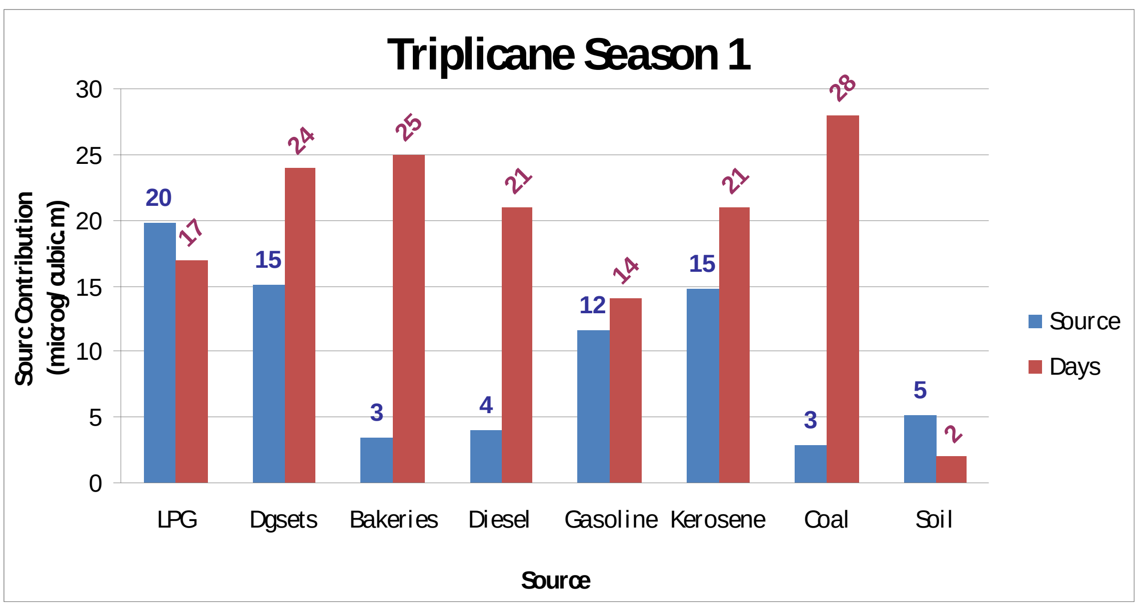

Saidapet Season 3
Gasoline 7%
Paved 37%
Diesel 0%
Bakeries 10%
Kerosene 2%
Coal 4%
DGsets 12%
Soil 8%
LPG 20%
LPG
DGsets
Bakeries
Diesel
Gasoline
Paved
Kerosene
Coal
Soil

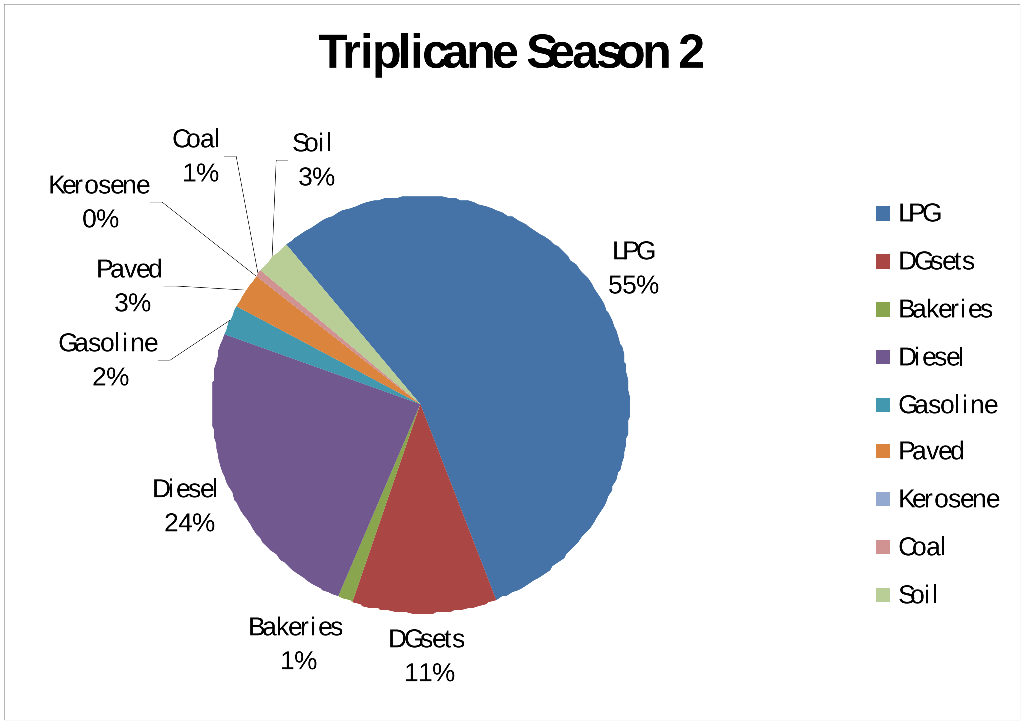


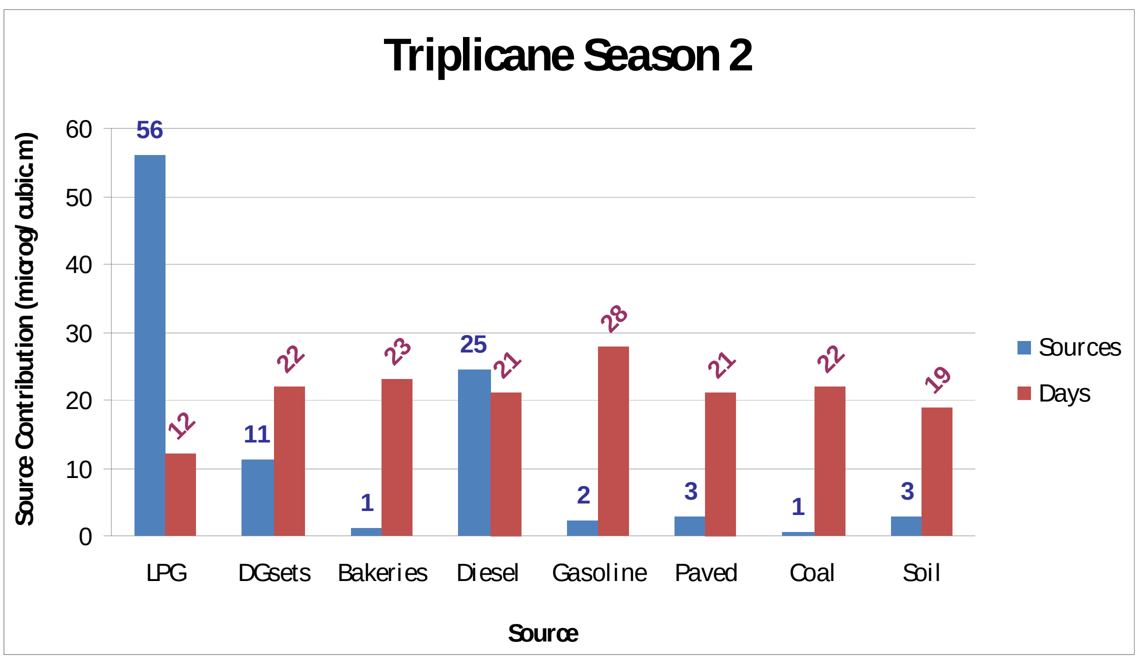
Saidapet Season 3
Source Contribution (microg/cubic.m)
60
50
40
30
20
10
0
Sources
No. of Days
29
14
17
16
15
18
11
20
54
7
3
20
7
20
11
11
LPG
DGsets
Bakeries
Gasoline
Paved
Kerosene
Coal
Soil
Source

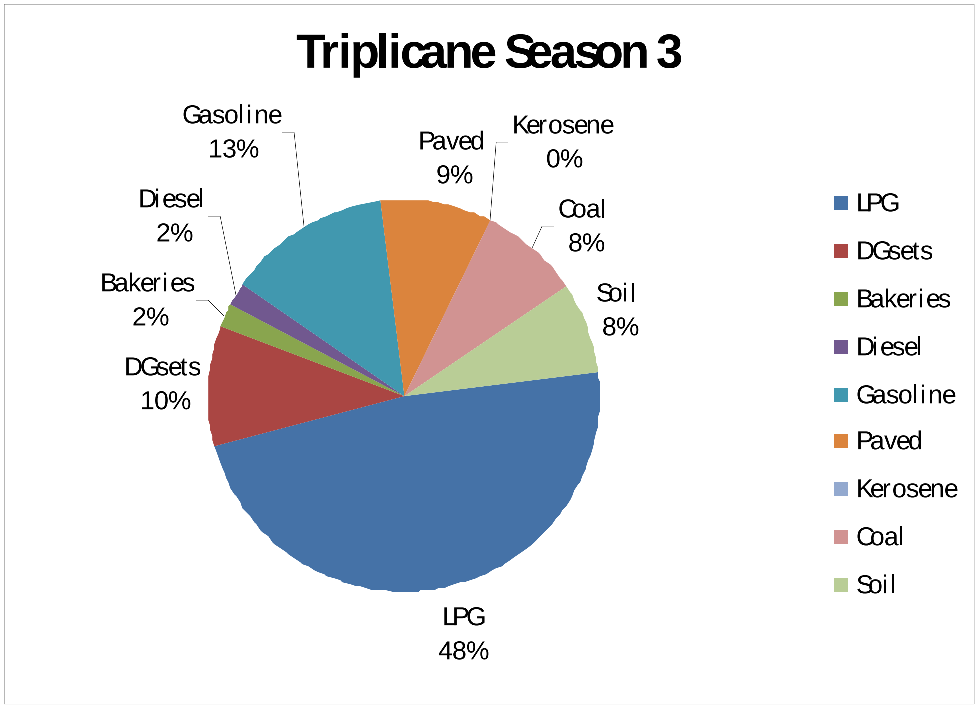
TRIPLICANE

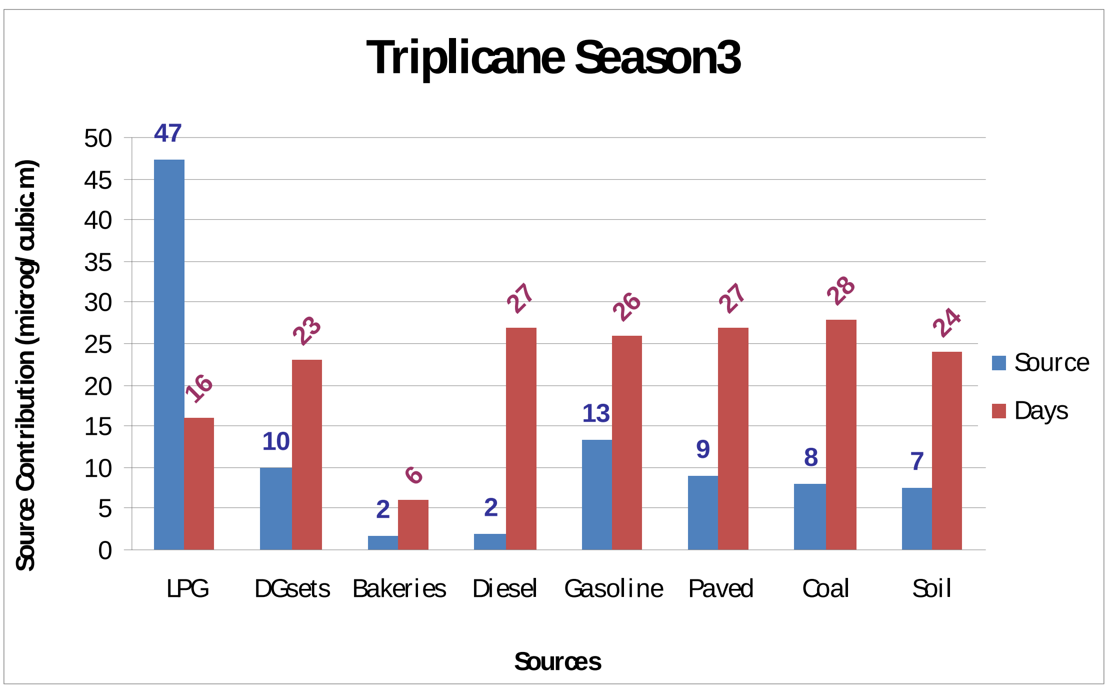

Triplicane Season 1
LPG
26%
Dgsets
20%
Bakeries
4%
Diesel
5%
Gasoline
15%
Paved
0%
Kerosene
19%
Coal
4%
Soil
7%
LPG
Dgsets
Bakeries
Diesel
Gasoline
Paved
Kerosene
Coal
Soil


Triplicane Season 1
Sourc Contribution (microg/cubic m)
30
25
20
15
10
5
0
20
17
15
24
3
25
4
21
12
14
15
21
3
28
5
2
LPG
Dgsets
Bakeries
Diesel
Gasoline
Kerosene
Coal
Soil
Source
Source
Days


Triplicane Season 2
Coal
1%
Soil
3%
Kerosene
0%
Paved
3%
Gasoline
2%
Diesel
24%
Bakeries
1%
DGsets
11%
LPG
55%
LPG
DGsets
Bakeries
Diesel
Gasoline
Paved
Kerosene
Coal
Soil


Triplicane Season 2
Source Contribution (microg/ cubic m)
60
50
40
30
20
10
0
56
12
11
22
1
23
25
21
2
28
3
21
1
22
3
19
LPG
DGsets
Bakeries
Diesel
Gasoline
Paved
Coal
Soil
Source
Sources
Days


Triplicane Season 3
Gasoline 13%
Paved 9%
Kerosene 0%
Diesel 2%
Coal 8%
Bakeries 2%
Soil 8%
DGsets 10%
LPG 48%
LPG
DGsets
Bakeries
Diesel
Gasoline
Paved
Kerosene
Coal
Soil


Triplicane Season3
Source Contribution (microg/cubic.m)
50
45
40
35
30
25
20
15
10
5
0
47
16
10
23
2
6
2
27
13
26
9
27
8
28
7
24
LPG
DGsets
Bakeries
Diesel
Gasoline
Paved
Coal
Soil
Source
Days
Sources

4.4 Summary of the factor analysis and CMB results are given below.

Factor Analysis				
Site	**Season**			Sources occurring in at least two seasons
	1	**2**	**3**	
Ambattur	DG Sets, Vehicles	Bakeries, Vehicles, Construction, DG Sets	Soil Dust, Bakeries, DG Sets	DG Sets, vehicles, Bakeries
IITM	Vehicles, Construction, DG Sets	Vehicles, Bakeries, DG Sets, Soil Dust	Bakeries, DG Sets, Vehicles	Vehicles, DG sets, bakeries
Mylapore	Construction, DG Sets	Construction, Vehicles	DG Sets, Soil dust, Vehicles, Bakeries	DG sets, construction, Vehicles
RK Nagar	Bakeries, DG Sets, Vehicles, Domestic	Bakeries, soil dust, construction, DG sets, vehicles	Bakeries, DG Sets, Vehicles, soil dust, construction	Bakeries, DG sets, vehicles, soil dust
Saidapet	Bakeries, construction, DG Sets	Bakeries, soil dust, DG sets, construction	Bakeri es, DG sets, vehicles, construction	Bakeries, DG Sets, construction
Triplicane	Bakeries, DG Sets, Vehicles	Soil dust, DG sets, bakeries, Construction	Vehicles, construction, DG Sets	Bakeries, DG Sets, Vehicles, construction
			Sources identified in most seasons in most sites	**DG Sets, Vehicles, Bakeries, construction**

CMB				
Site	Season			Sources occurring at least in two seasons
	1	2	3	
Ambattur	LPG, DG Sets, Diesel	LPG, Gasoline, Kerosene, Paved Road Dust	LPG, Soil Dust, Kerosene, DG Sets/Gasoline	LPG, DG Sets, Gasoline, Road Dust, Kerosene
IITM	Soil Dust, Gasoline, LPG, DG Sets	LPG, Soil Dust, DG Sets	LPG, DG Sets, Soil Dust, Coal	LPG, Soil Dust, DG Sets
Mylapore	LPG, DG Sets, Gasoline	Gasoline, LPG, DG Sets	Gasoline, Coal	Gasoline, DG Sets, LPG
RK Nagar	LPG, DG Sets, Bakeries, Diesel	LPG, Paved Road Dust, DG Sets	LPG, DG Sets, Gasoline	LPG, DG Sets
Saidapet	Gasoline, Coal, Diesel, DG Sets	LPG, DG Sets, Paved Road Dust	Paved Road Dust, LPG, DG Sets, Bakeries	LPG, DG Sets, Paved Road Dust
Triplicane	LPG, DG Sets, Kerosene, Gasoline	LPG, Diesel, DG Sets	LPG, Gasoline, DG Sets, Paved Road	LPG, DG Sets, Gasoline
			Sources identified in most seasons in most sites	**LPG, DG Sets, Gasoline, soil dust**

CONCLUSIONS: Based on the factor analysis results, the following conclusion can be made: DG Sets, Vehicles, Bakeries and construction are the major sources of pollution in most of the sites and in most of the seasons. Based on the CMB analysis results, we conclude that LPG, DG Sets, Gasoline vehicles and soil dust are the major sources of pollution in most of the sites and in most of the seasons.

However it is to be noted that the emission from DG sets may have a very similar signature as the emission from diesel based vehicles. Thus, what is identified as DG set pollution may actually come from diesel vehicles. Also, Factor Analysis is only a qualitative indicator.

Soil dust is identified as a significant source at least in some seasons in some sites, by CMB. However, factor analysis identifies construction as a significant source in some seasons in some sites. It is likely that both soil dust and construction activities contribute to the pollution and the uncertainties associated with the analysis and the measurements lead to the different conclusions.

Similarly, bakeries which are identified as major source of pollution in factor analysis rarely occur in CMB results. Conversely, LPG which is identified as a significant source in CMB does not occur frequently in Factor Analysis. Since most of the households in Chennai use LPG and since the household emission is expected to be much more than the emission from bakeries, it is likely that the CMB results are more representative of the actual situation.

Considering the results of both factor analysis and CMB, the receptor modeling indicates that, in Chennai City, the major sources of pollution are

1. Diesel based engines (DG sets and vehicles)
2. Gasoline based behicles
3. LPG and
4. Soil dust.

CHAPTER 5: DISPERSION MODELING: EXISTING SCENARIO

In this chapter the methodology and the results obtained from the dispersion modeling in the seven sites chosen for the study are discussed. The calculation of the emission loads, the meteorological data which are used as inputs to the dispersion model are also discussed. The receptor location is chosen as the mid point of the area of interest and a square grid of size 2X2 km is chosen around the point for the analysis. The emission sources in this grid are identified from the primary and secondary emission inventory surveys conducted in the area of interest as described in chapter 3. The micro-meteorology in this region as determined during the monitoring is recorded. This is then used as inputs to determine the dispersion of the two pollutants NOx and PM10. The concentration profiles in the grid is then determined and depicted in the form of concentration contours at the ground level. This chapter contains results of the concentration profiles as existing at the moment and in the seven sites analyzed. The values predicted from the dispersion model are also compared with those measured experimentally.

5.1 Methodology followed: The primary emission inventory collected from the field studies along with the inventory information obtained from secondary sources was used to estimate the emission loads in each of the seven sites selected. For this purpose a 2 X 2 km square area was selected around the monitoring point and the various sources of emissions in the area were identified. These emissions were characterized into point sources, line sources and area sources.

Point sources: These include primarily the emissions from industrial stacks as well as from large DG sets from industries. These are characterized by specifying the geographical location i.e., the spatial co-ordinates as well as their emission loads. Any temporal variation in the emission loads is incorporated in the input data file.

Line sources: These primarily include the emissions from the vehicles moving along the major roads. The vehicular sources are categorized into different categories i.e., petrol vehicles, diesel vehicles. They are then categorized as two-wheeler, three-wheeler and four wheelers. They are also identified as belonging to commercial or private category. This split up into different categories is necessary since it facilitates the evaluation of different scenarios.

The line source is specified geometrically by dividing the road into rectangular grids. These grids are specified uniquely using the location of the south west corner of the grid and the angle which the grid makes with an axis. The information from the traffic count on each road is then used to determine the emission load in each grid. This is then fed as an input to the software.

Area sources: These sources include all other emissions such as domestic emissions, emissions from restaurants and bakeries, paved road dust, soil dust, as well as emissions from vehicles moving on minor roads. Here the emission sources are treated as emanating from an area. For this purpose each grid is divided into 16 equi-spaced sub grids and the sources in these sub-grids are categorized. This requires specification of the length and breadth of the area sources as well as the co-ordinates of the center of the area source. The emission inventory data base was built in Microsoft Excel in such a manner that the contributions of the various categories of sources could be identified easily. For example the vehicular sources are divided into different categories as two wheelers, three wheelers, four wheelers, private and commercial vehicles as well as on the basis of the fuel consumed as discussed above. The emission factors of the various sources were used to determine the emission rates and the pollution loads of the various pollutants.

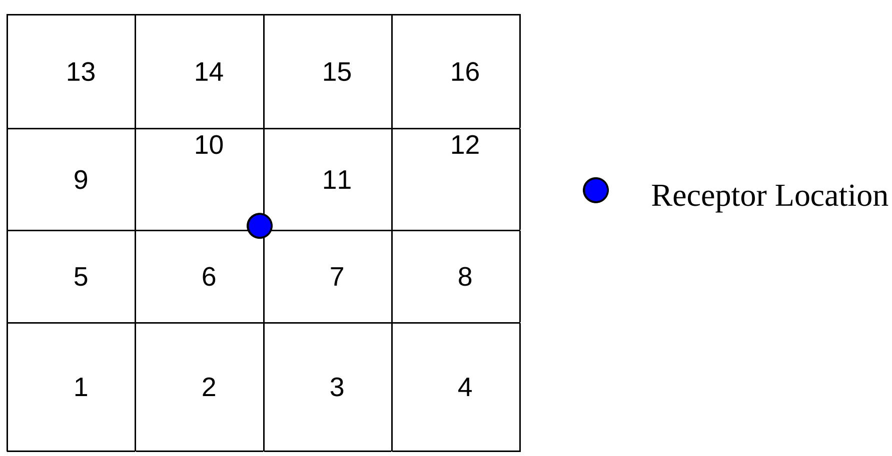
In addition to the estimations of the pollution loads their geographical locations were also specified. For this each 2km X 2 km area was divided into 16 grids of 500m X 500m each. The sources in each grid were identified.

As mentioned earlier the point sources are characterized by their emission loads as well as their location. As far as the line sources are concerned the main roads with the dominant vehicular emissions were divided into different line segments. These segments were rectangular in shape. This is specified in the sub-grid by the location of the south-west point of the area of the segment and the inclination of the area (road). These two values uniquely determine the source of the pollution represented as a line source.

The emissions from restaurants, households and minor roads were treated as emanating from area sources.. The emission factors were used to determine the loads from these sources as described in chapter 3.

In addition to this diurnal variation of the emission inventory is determined and incorporated as an input to the software package ISC. The input file was created in the format required by the package.

5.2 Emission loads: The emission loads determined in each of the 4 sq.km areas in this study are discussed below. The emission loads were calculated using the emission factors and these are summarized in the tabular form below. The various pollutants considered are carbon monoxide, Hydrocarbons, NOx, PM10 and SOX. The emissions from various point, line and area sources in each of the seven sites are enumerated separately now.
The sites are subdivided into grids of 0.5 km x 0.5 km. Hence there are 16 such grids in each site. The relative location of each grid is given in the schematic below.



Summary of IIT Emission Inventory

The major sources of pollution are found to be DG sets, construction activities, domestic sources and restaurants. In addition to this there are five major roads which contribute to the pollution in this grid as line sources.

Table 5.1: Area source results:

Grid Number	Nox Emission (g/s)	PM Emission (g/s)
1	0.000E+00	0.000E+00
2	6.658E-03	2.069E-04
3	6.658E-03	2.069E-04
4	4.647E-02	9.097E-02
5	0.000E+00	0.000E+00
6	4.212E-02	1.309E-03
7	2.391E-02	8.271E-04
8	0.000E+00	0.000E+00
9	6.196E-02	2.261E-03
10	1.549E-02	5.653E-04
11	7.566E-03	2.351E-04
12	7.566E-03	2.351E-04
13	0.000E+00	0.000E+00
14	3.198E-02	3.836E-01
15	7.566E-03	2.351E-04
16	7.566E-03	2.351E-04

Line Source results:

Name	Nox Emission(g/s)	PM Emission(g/s)
Alumini Avenue Road	4.415E-03	3.190E-06
Bonn Avenue Road	6.679E-03	3.058E-06
Delhi Avenue Road	6.184E-03	3.244E-06
Taramani Road	5.443E-01	1.423E-03
Hostel Road	3.769E-03	1.841E-06
Total	5.654E-01	1.434E-03

Summary of Mylapore Emission Inventory : The primary sources of contribution in the residential site of Mylapore is domestic households, restaurants, bakeries, DG sets, construction activities, paved road dust from minor roads and vehicles from minor roads. These are all classified as area sources. The quantitative summary of these sources in terms of emission loads are given below in Table 5.2 The line source results arise from eight major roads.

Table 5.2

Area source results:

Grid Number	Nox Emission (g/s)	PM Emission (g/s)
1	3.794E-03	1.860E-04
2	6.810E-02	2.917E-03
3	7.857E-02	3.409E-03
4	5.248E-02	2.295E-03
5	8.091E-02	5.941E-03
6	6.097E-02	5.165E-03
7	5.802E-02	3.689E-02
8	2.117E-02	4.166E-02
9	7.764E-02	3.493E-03
10	6.431E-02	3.017E-03
11	6.887E-02	3.184E-03
12	4.973E-02	8.599E-02
13	8.838E-02	3.875E-03
14	7.975E-02	3.497E-03
15	7.924E-02	3.570E-03
16	7.115E-02	2.266E-01

Line source results:

Name	Nox Emission(g/s)	PM Emission(g/s)
C.P.Ramasamy Road	2.044E-01	2.335E-01
Luz Church Road	9.732E-01	1.015E+00
TTK Road	7.390E-01	1.516E+00
Dr.Ranga Road	4.367E-01	3.402E-01
Rosary Church Road	3.551E-01	3.655E-01

Mylapore Bazzar Road	3.315E-01	3.467E-01
Royapettah High Road	1.061E+00	1.048E+00
Dr.Radhakrishnan Road	2.108E-01	1.469E-01
Total	4.312E+00	5.012E+00

Summary of Triplicane Emission Inventory: The primary sources of contribution in the residential site of Triplicane is domestic households, restaurants, bakeries, DG sets, construction activities, paved road dust from minor roads and vehicles from minor roads. These are all classified as area sources. The quantitative summary of these sources in terms of emission loads are given below in Table 5.3 The line source results arise from three major roads.

Table 5.3 :

Area source Results

Grid Number	Nox Emission (g/s)	PM Emission (g/s)
1	7.140E-02	4.674E-03
2	7.124E-02	4.199E-03
3	8.615E-03	3.614E-03
4	0.000E+00	7.595E-04
5	8.124E-02	5.363E-03
6	8.909E-02	1.798E-02
7	1.771E-02	4.096E-03
8	0.000E+00	7.595E-04
9	7.796E-02	7.588E-03
10	9.253E-02	6.261E-03
11	9.259E-02	2.002E-02
12	2.482E-02	5.617E-02
13	7.425E-02	4.993E-03
14	8.888E-02	5.601E-03
15	8.539E-02	5.415E-03
16	1.749E-02	1.686E-03

Line Source Results

Name	Nox Emission(g/s)	PM Emission(g/s)
Dr.Besant Road	2.402E-01	1.746E-01
Pycrofts Road-Bells Road Junction	8.468E-01	7.233E-01
T.P.High Road	1.925E-01	1.259E-01
Total	1.280E+00	1.024E+00

Summary of Saidapet Emission Inventory: The primary sources of contribution in the residential site of Saidapet is domestic households, restaurants, bakeries, DG sets, construction activities, paved road dust from minor roads and vehicles from minor roads. These are all classified as area sources. The quantitative summary of these sources in terms of emission loads are given below in Table 5.4 The line source results arise from eight major roads.

Table 5.4

Area source results:

Grid Number	Nox Emission (g/s)	PM Emission (g/s)
1	0.000E+00	0.000E+00
2	7.024E-02	4.109E-03
3	6.746E-02	4.336E-03
4	8.128E-03	5.742E-04
5	6.342E-02	4.056E-03
6	6.471E-02	6.140E-02
7	2.435E-02	4.297E-02
8	5.470E-03	1.997E-04
9	5.988E-02	4.224E-03
10	6.007E-02	6.196E-03
11	7.593E-02	6.719E-03
12	1.298E-02	9.172E-04
13	6.248E-02	4.407E-03
14	5.992E-02	6.191E-03
15	8.143E-02	4.894E-03
16	5.988E-02	4.224E-03

Line source results:

Name	Nox Emission(g/s)	PM Emission(g/s)
Bazaar Road	8.916E-02	4.315E-02
Jeenis Road	5.076E-02	2.775E-02
Towards Anna Salai Road	3.904E-01	2.665E-01
Towards Guindy Road	3.077E-01	2.874E-01
Towards Little Mount Jn	3.003E-01	1.337E-01
Towards T-Nagar	2.775E-01	2.871E-01
Towards West Mambalam	1.753E-01	9.502E-02
Towards West Saidapet	1.400E-01	6.411E-02
Total	1.731E+00	1.205E+00

Summary of Adyar Emission Inventory The primary sources of contribution in the residential site of Adyar is domestic households, restaurants, bakeries, DG sets, construction activities, paved road dust from minor roads and vehicles from minor roads. These are all classified as area sources. The quantitative summary of these sources in terms of emission loads are given below in Table 5.5 The line source results arise from seven major roads.

Table 5.5

Area source results:

Grid Number	Nox Emission (g/s)	PM Emission (g/s)
1	0.000E+00	2.402E-04
2	4.089E-02	2.631E-03
3	6.571E-02	3.568E-03
4	2.422E-02	1.723E-03
5	6.055E-03	6.110E-04
6	5.577E-02	2.999E-02
7	7.242E-02	9.450E-03
8	6.038E-02	1.079E-01
9	1.817E-02	1.353E-03
10	8.163E-02	4.740E-01
11	8.471E-02	3.372E-01
12	4.650E-02	3.088E-03

13	3.552E-02	2.190E-03
14	9.341E-02	6.857E-03
15	8.315E-02	1.348E-02
16	3.792E-02	2.332E-03

Line source results:

Name	Nox Emission(g/s)	PM Emission(g/s)
Adyar Road	3.922E-01	1.088E+00
Besant Avenue Road	1.919E-01	4.311E-01
Indra Nagar Road	3.738E-02	5.313E-02
Lattice Bridge Road	9.035E-01	1.054E+00
Old Mahabalipuram Road	6.168E-01	1.094E+00
Thiruvanmiyur Road	1.523E-01	2.524E-01
Velachery Road	8.148E-02	1.989E-02
Total	2.376E+00	3.993E+00

Summary of R.K.Nagar Emission Inventory The primary sources of contribution in the residential site of R.K.Nagar is domestic households, restaurants, bakeries, DG sets, construction activities, paved road dust from minor roads and vehicles from minor roads. These are all classified as area sources. The quantitative summary of these sources in terms of emission loads are given below in Table 5.6 The line source results arise from two major roads.

Table 5.6

Area source results:

Grid Number	Nox Emission (g/s)	PM Emission (g/s)
1	8.753E-03	5.056E-04
2	8.150E-02	4.500E-03
3	6.652E-02	3.843E-03
4	7.957E-02	4.389E-03
5	2.489E-04	8.950E-06
6	7.543E-02	6.337E-03
7	1.655E-02	7.479E-04

8	8.392E-02	6.934E-03
9	3.943E-02	5.308E-02
10	4.692E-02	2.300E-03
11	2.801E-02	4.200E-02
12	4.830E-03	1.764E-04
13	1.882E-01	4.732E-01
14	1.062E-01	1.622E-01
15	5.528E-02	7.449E-02
16	1.115E-02	4.064E-04

Line source results:

Name	Nox Emission(g/s)	PM Emission(g/s)
Ennore High Road	7.882E-01	2.817E+00
Manali High Road	6.777E-01	2.952E+00
Total	1.466E+00	5.768E+00

Summary of Ambattur Emission Inventory The primary sources of contribution in the residential site of Ambattur is domestic households, restaurants, bakeries, DG sets, construction activities, paved road dust from minor roads and vehicles from minor roads. These are all classified as area sources. The quantitative summary of these sources in terms of emission loads are given below in Table 5.7 The line source results arise from six major roads.

Table 5.7

Area source results:

Grid Number	Nox Emission (g/s)	PM Emission (g/s)
1	0.000E+00	0.000E+00
2	0.000E+00	0.000E+00
3	6.486E-03	2.605E-03
4	6.639E-03	2.610E-03
5	3.336E-02	2.440E-03
6	4.389E-02	1.598E-02
7	0.000E+00	2.179E-02

8	0.000E+00	0.000E+00
9	1.405E-02	1.124E-03
10	2.458E-02	4.527E-01
11	1.580E-02	7.046E-02
12	6.419E-03	1.995E-04
13	0.000E+00	2.827E-01
14	0.000E+00	0.000E+00
15	1.534E-01	6.478E-01
16	1.815E-01	1.869E-02

Line source results:

Name	Nox Emission(g/s)	PM Emission(g/s)
Ambattur MTH Road	4.182E-01	3.289E-01
Industrial Estate Road	7.794E-02	1.389E-01
Chennai Tiruvallur Road	4.269E-01	6.992E-01
Mannikavinayagar Koil Street	5.196E-01	6.904E-01
South Park Street	6.471E-01	9.260E-01
Telephone Exchange Road	8.223E-01	9.353E-01
Total	2.912E+00	3.719E+00

Point source Results:

Name	Nox Emission(g/s)	PM Emission(g/s)
Rane Brakes ltd.	3.430E+00	1.252E-01
Ti Cycles	6.859E+00	2.504E-01
Sundaram Clayton Ltd	6.859E+00	2.504E-01
ESAB India Ltd	1.050E+00	3.833E-02
Total	1.820E+01	6.644E-01

5.3 Meteorological data

Dispersion modeling in each of the 2X2 km grids: The objective is to carry out the dispersion modeling using ISC and determine the concentration contours in the grid. These contours represent the dispersion of the pollutant NOX or PM10 in each of the grid.

For the purpose of simulating the concentrations at the receptor location and in the 2 X 2 km area, the information from meteorology i.e. wind velocity , temperature , mixing height etc are also needed. These parameters were measured by the weather stations at the different sites for the various seasons. The micro meteorology was fed in the format required for the software package.

The software package used for simulating the system behavior is ISC3ST from US EPA. This needs the inputs of the emissions as well as the weather data to be in a specific format. The data was used to predict the concentrations at different locations in the 2X2 km area of interest. The predicted value at the receptor location is compared with the measured value at the location.

The underlying assumption of the methodology discussed above is that only sources in the 4 sq km area are relevant. However, in cases where some significant source of pollution existed close to the grid but outside the area of interest, this was included in the simulations.

The focus of this chapter is in determining the concentrations of NOx as well as PM10 in each of the areas. For this purpose, the short term prediction features available in the software was used. PM10 was treated as gas, since this requires only meteorological information for a short time horizon.

The meteorological data are represented in the form of wind rose diagrams. A sample of wind rose diagram is given in the following figure.

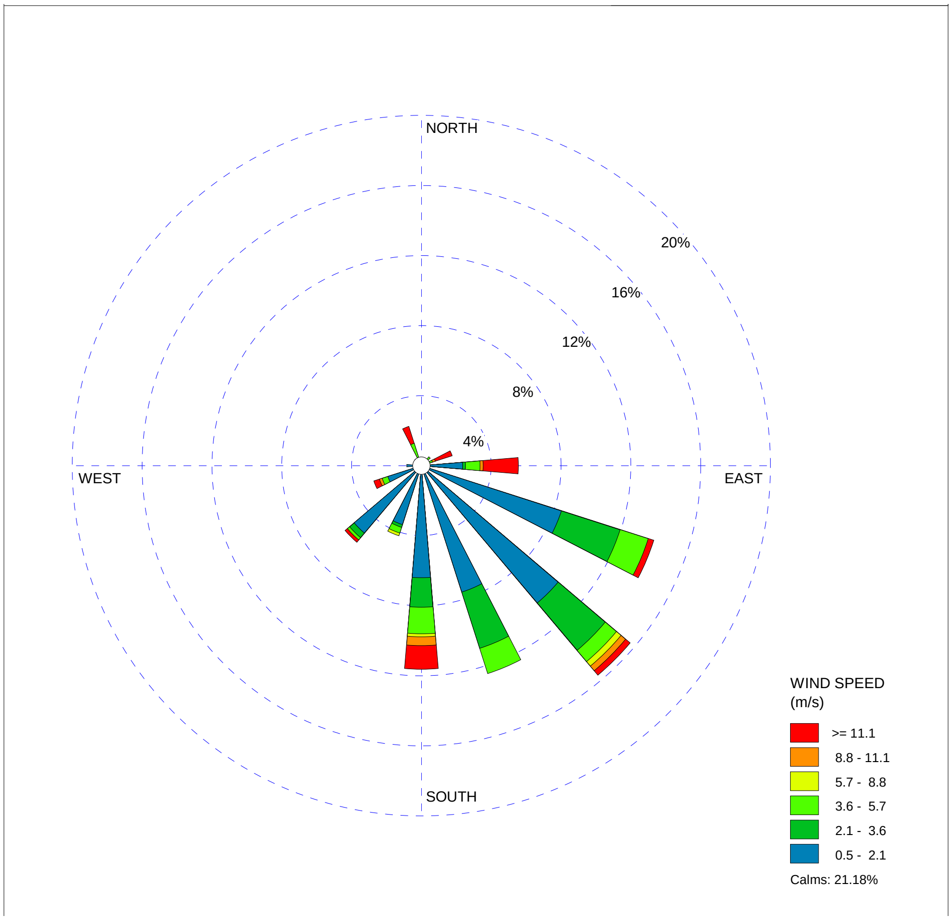


Fig 5.1 Wind rose diagram for Adyar (kerbside)

5.4 Concentration Profiles.

The concentration values for NOx and PM 10, at the receptor locations (coordinates 1000,1000) have been predicted for each site for each season. The comparison between the predicted values and the measured values is given below. Since we do not have emission inventory of three seasons, the worst season will be used for further studies and predictions in various business as usual cases and control scenarios.

Comparison of Values: IIT-Madras (Background)

Season	NOx Conc. (exp)	NOx Conc. (model)	PM Conc. (exp)	PM Conc. (model)
1	8	3	51	5
2	14	2	179	2
3	27	4	56	7

It is seen that the concentrations of NOx and PM10 predicted in the background site are both lower than that measured experimentally.

Comparison of Values: Mylapore (Residential)

Season	NOx Conc. (exp)	NOx Conc. (model)	PM Conc. (exp)	PM Conc. (model)
1	15	24	70	25
2	12	25	77	26
3	28	17	77	16

Here it is seen that the NOx values are in reasonable agreement with the monitored values however the PM10 values predicted by the model are much lower than that observed in the field.

Comparison of Values: in Triplicane (Residential)

Season	NOx Conc. (exp)	NOx Conc. (model)	PM Conc. (exp)	PM Conc. (model)
1	17	29	200	17
2	29	32	86	19
3	32	13	82	7

Here again the NOX values are in reasonable agreement with the monitored values however the PM10 values predicted are completely different from that measured.

Comparison of Values: Saidapet (Kerbside)

Season	NOx Conc. (exp)	NOx Conc. (model)	PM Conc. (exp)	PM Conc. (model)
1	33	19	111	9
2	43	49	144	29
3	49	27	111	16

Here again the values of NOx determined are within acceptable limits however the PM values measured are much higher that that predicted by the model.

Comparison of Values: Adyar -- Kerbside

Season	NOx Conc. (exp)	NOx Conc. (model)	PM Conc. (exp)	PM Conc. (model)
1	25	20	85	42
2	25	37	271	60
3	45	13	87	20

It is seen that in this kerbside the NOX values are in agreement with the model predictions and the PM concentrations are lower than the monitored values.

Comparison of Values: R.K. Nagar (Industrial area)

Season	NOx Conc. (exp)	NOx Conc. (model)	PM Conc. (exp)	PM Conc. (model)
1	20	34	115	158
2	36	49	117	225
3	39	55	108	283

Comparison of Values: Ambattur (Industrial)

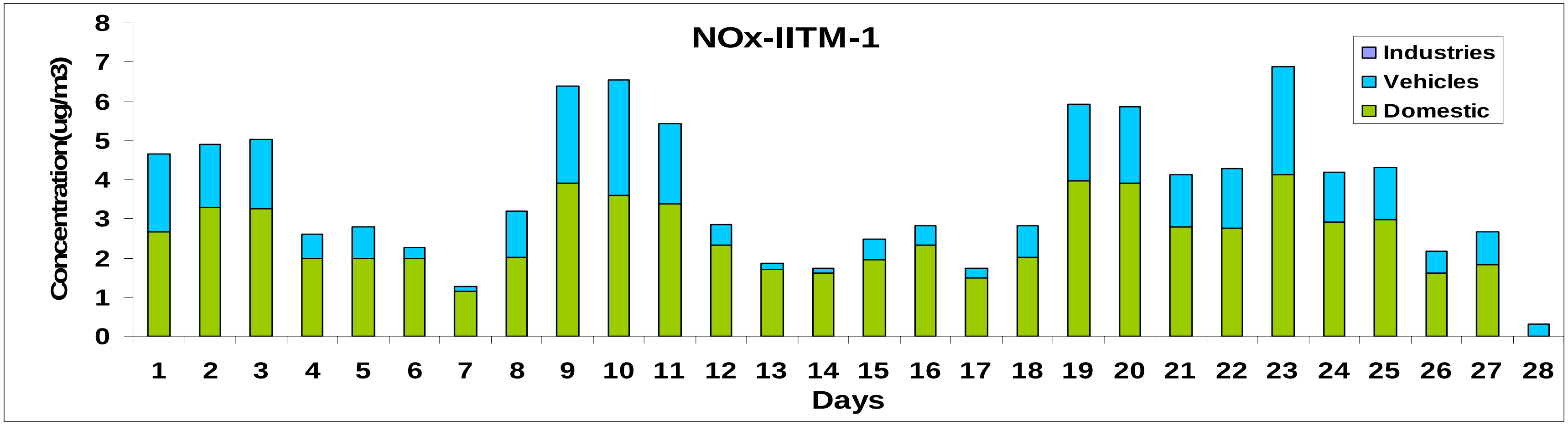
Season	NOx Conc. (exp)	NOx Conc. (model)	PM Conc. (exp)	PM Conc. (model)
1	17	39	128	58
2	42	86	141	81
3	45	64	138	64

In the industrial site RK Nagar, the NOx and PM10 values monitored both agree reasonably well with the model predictions. In the industrial site of Ambattur, the modeled NOx is higher than the measured NOx, while the modeled PM10 is lower than the measured PM 10.

The lowest concentration of NOx and PM were found at the background site IITM. The highest concentration of PM was predicted to be at the industrial site of RK Nagar,while the highest concentration of NOx was predicted to be at the industrial site of Ambattur.

The daily variation of the Nox and PM10 are given in the following set of figures. Figures 5.2 to 5.22 present the predicted air quality at seven locations for PM10 and NOx for all the three seasons.

Figure 5.2 Results from ISCST3 Predictions for NOx and PM10 at IITM for Season-1



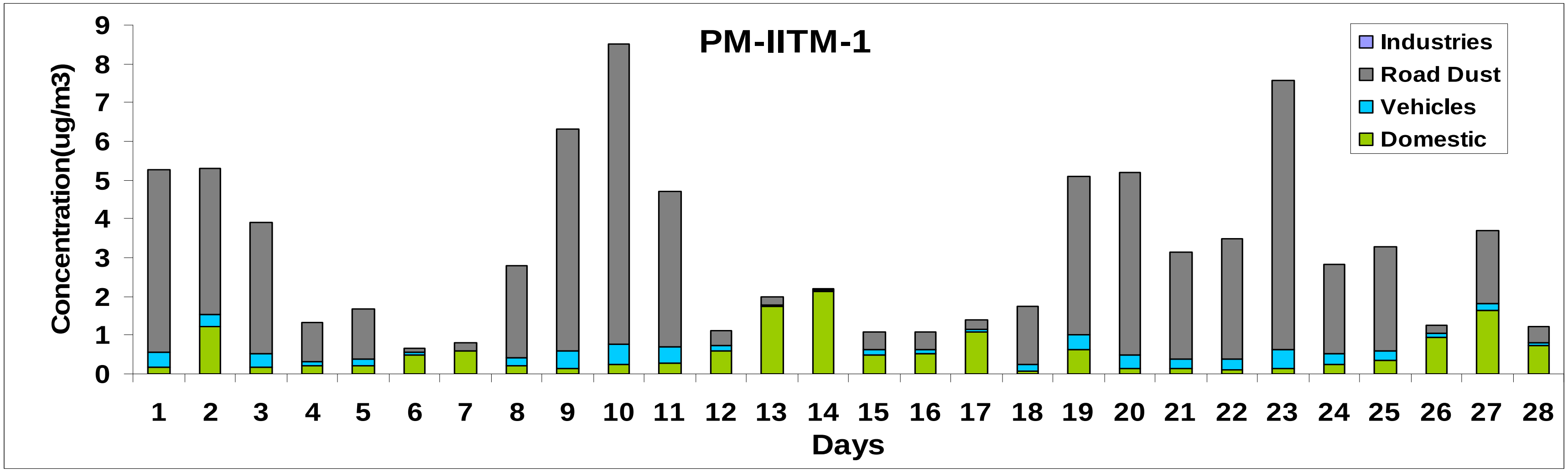
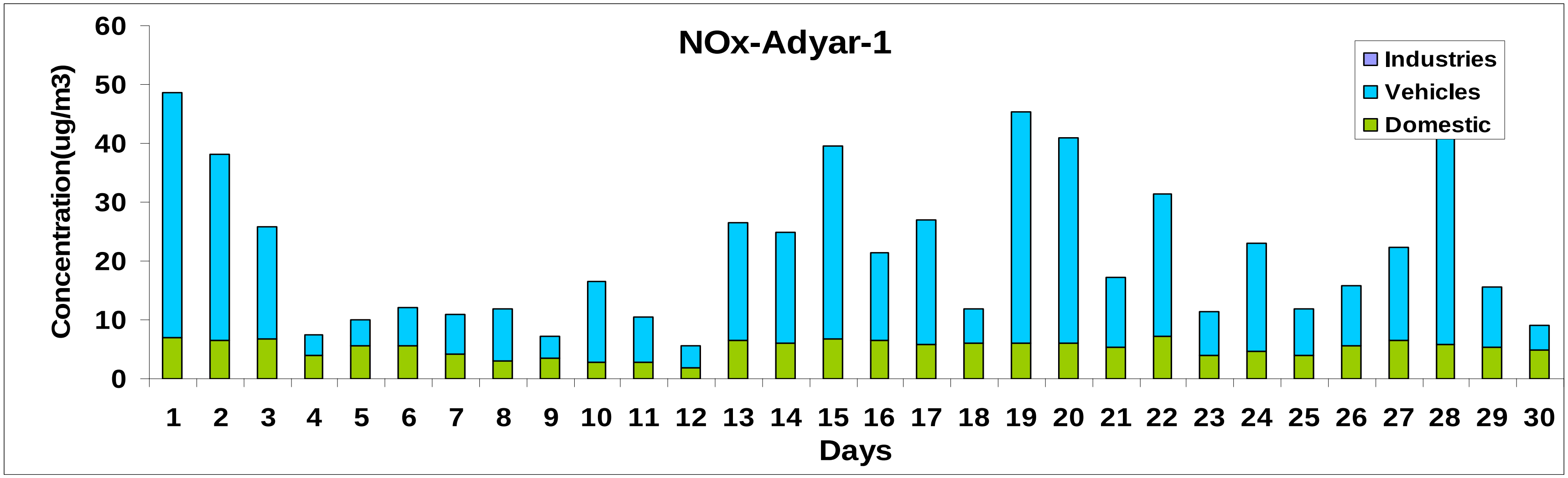


Figure 5.3 Results from ISCST3 Predictions for NOx and PM10 at Adyar for Season-1



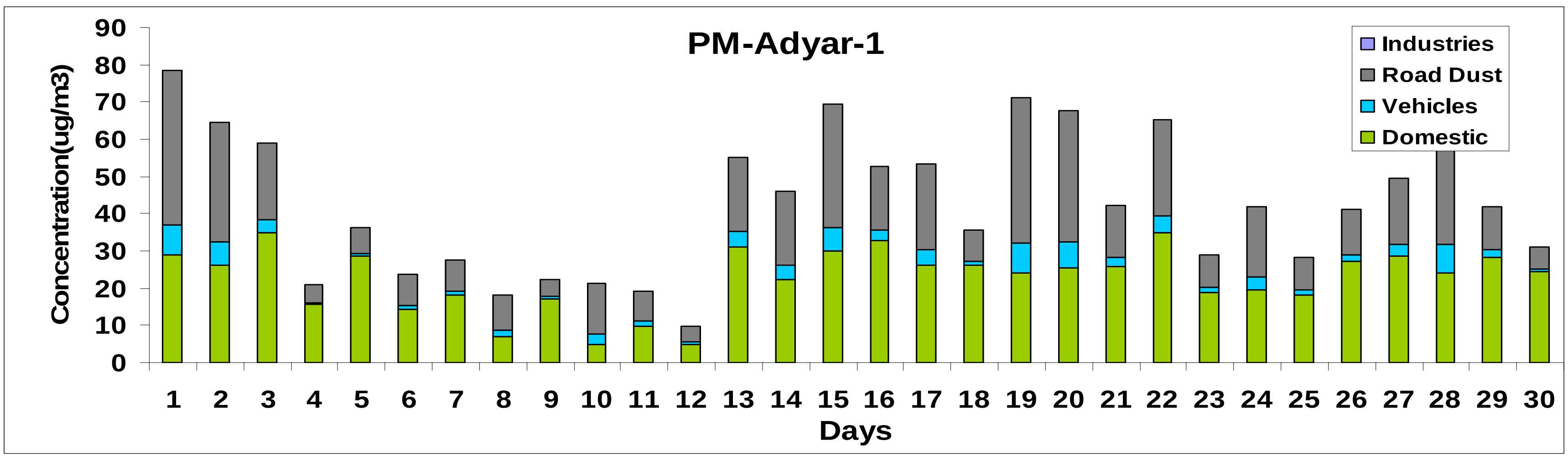
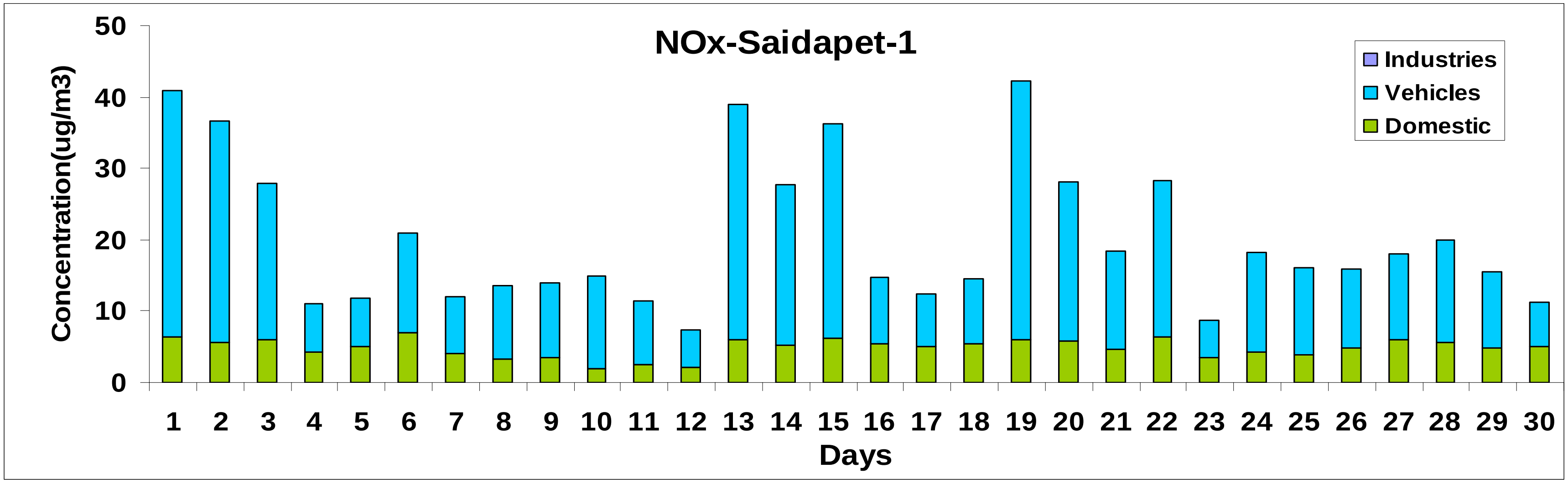


Figure 5.4 Results from ISCST3 Predictions for NOx and PM10 at Saidapet for Season-1



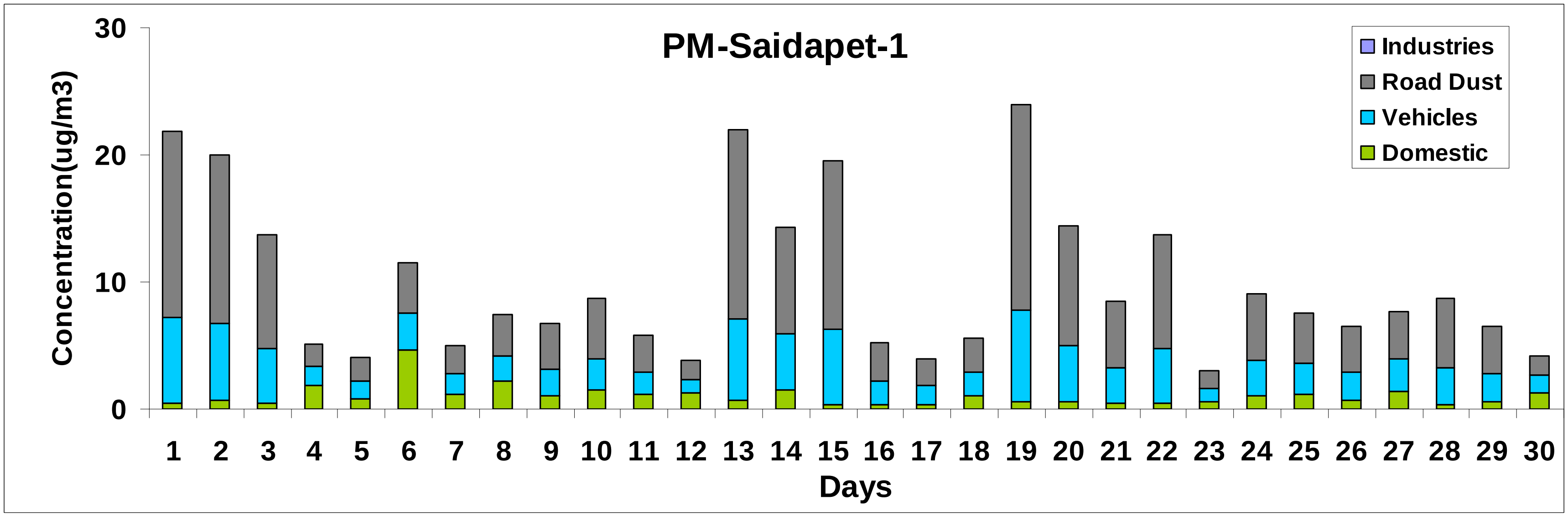
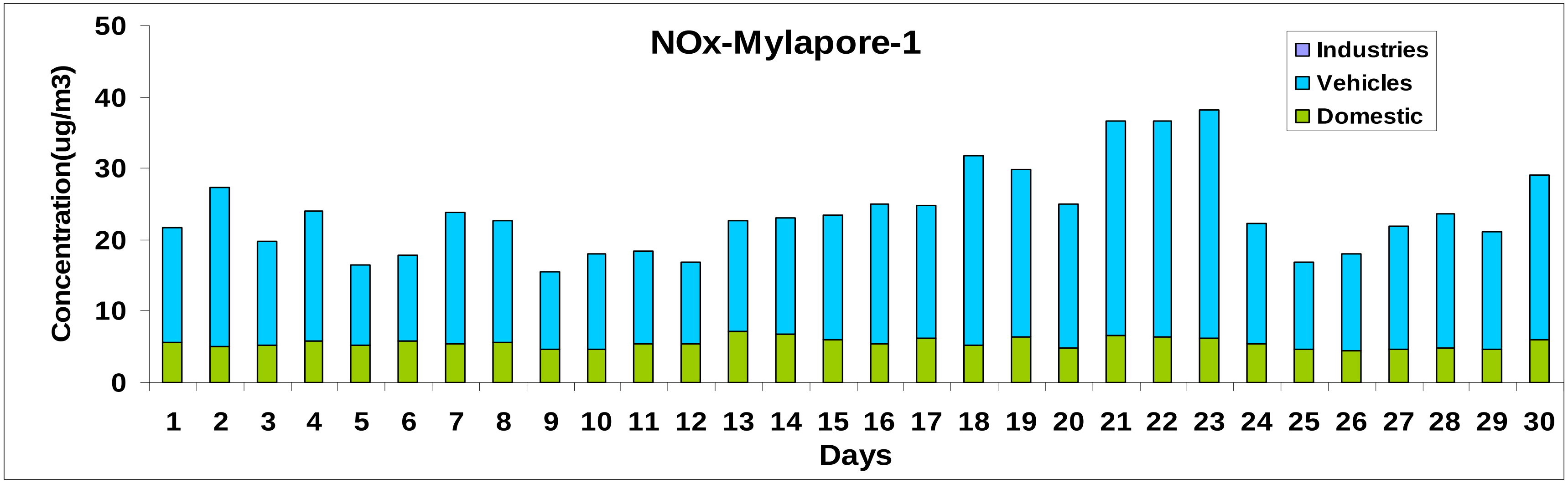


Figure 5.5 Results from ISCST3 Predictions for NOx and PM10 at Mylapore for Season-1



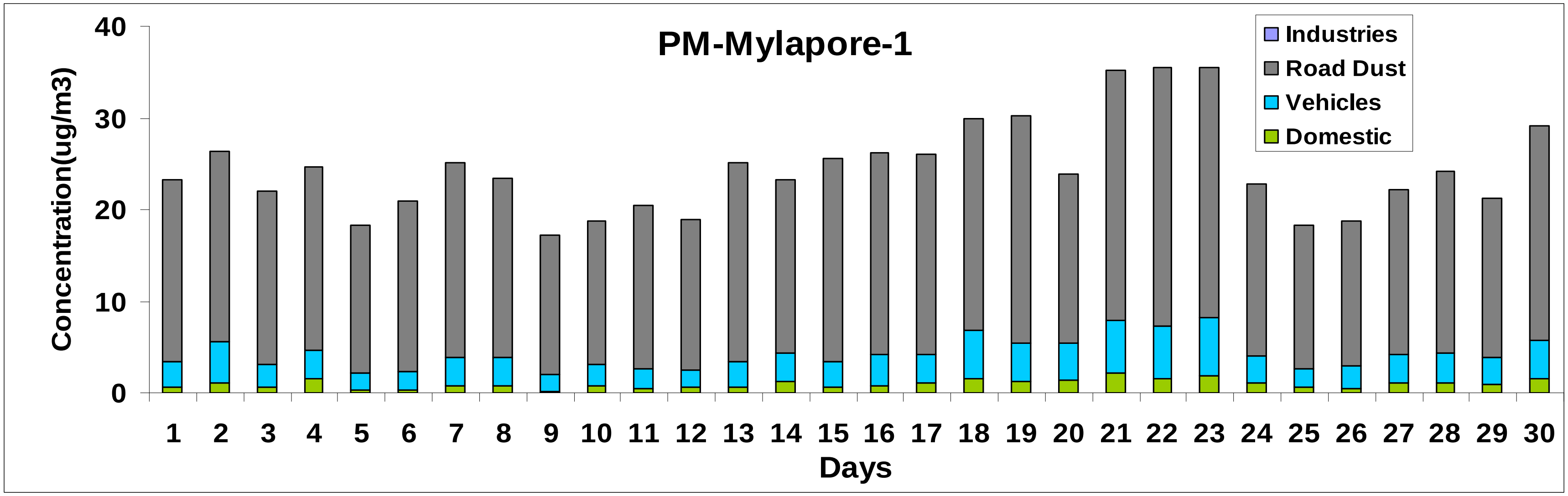
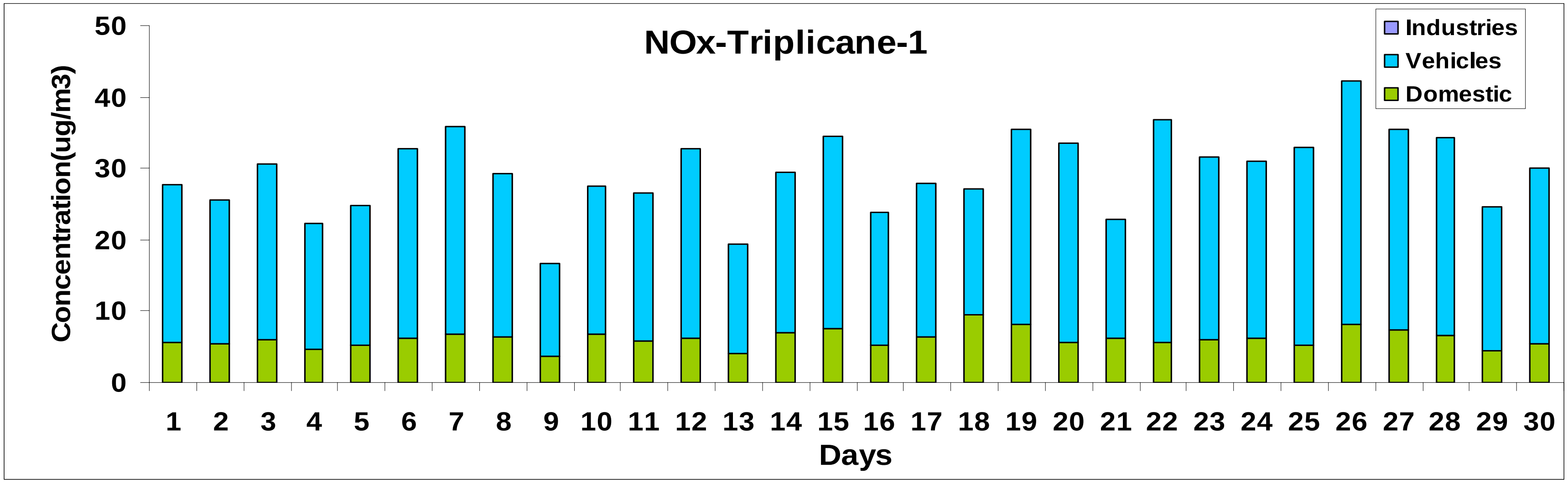


Figure 5.6 Results from ISCST3 Predictions for NOx and PM10 at Triplicane for Season-1



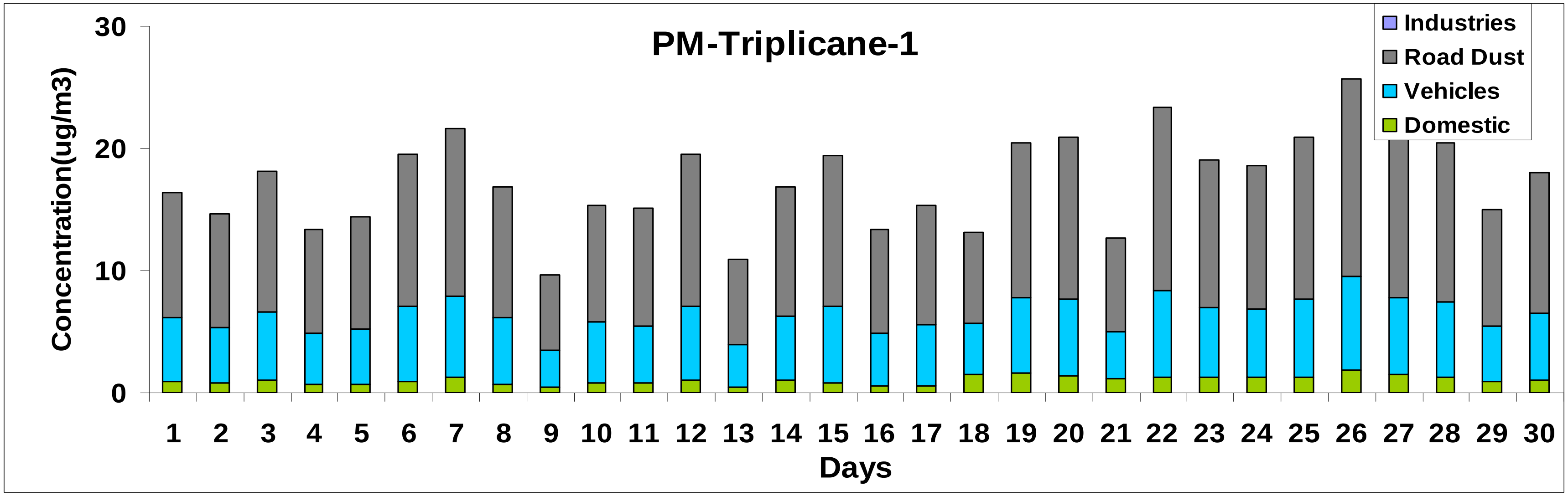


Figure 5.7 Results from ISCST3 Predictions for NOx and PM10 at RK Nagar for Season-1

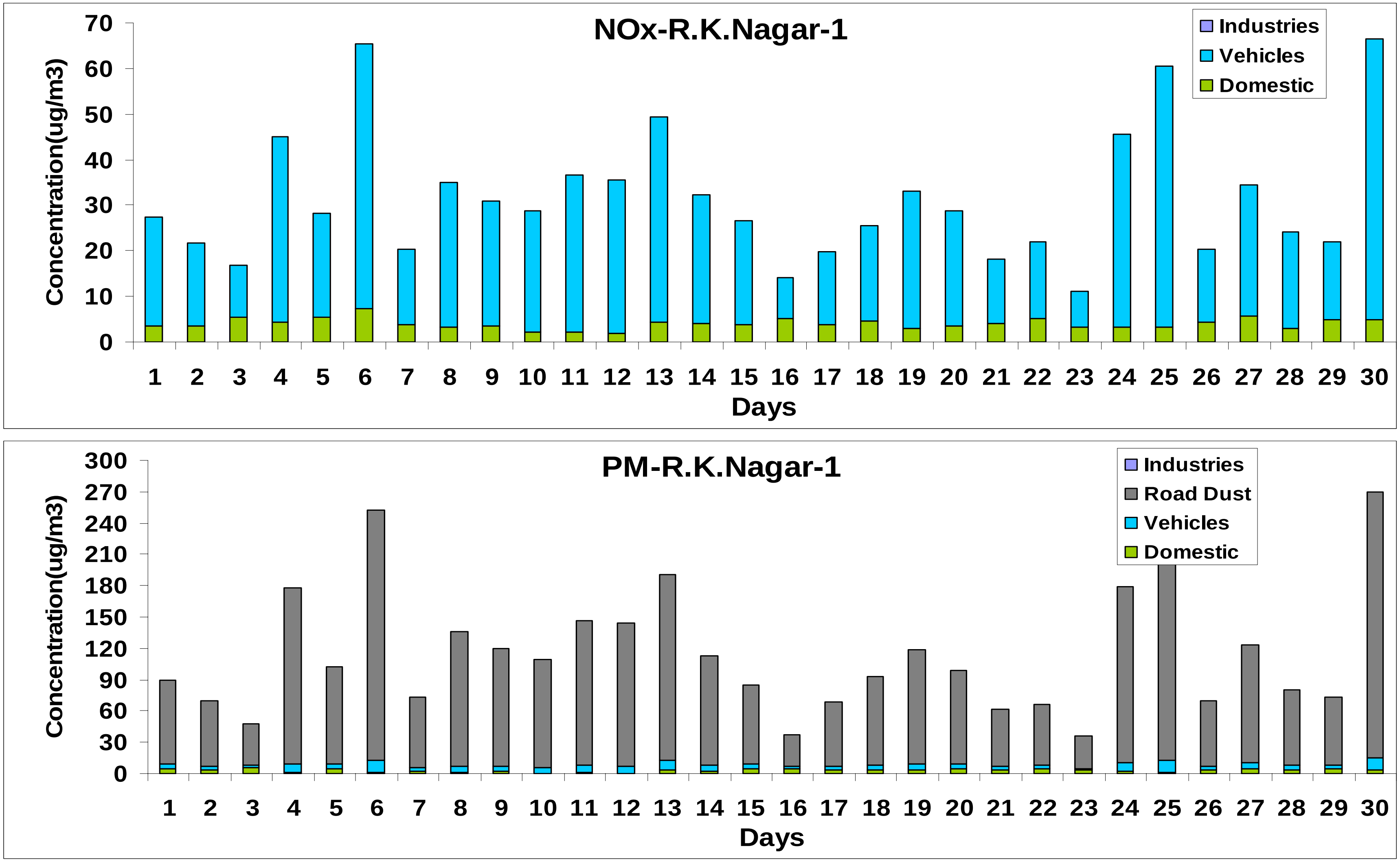
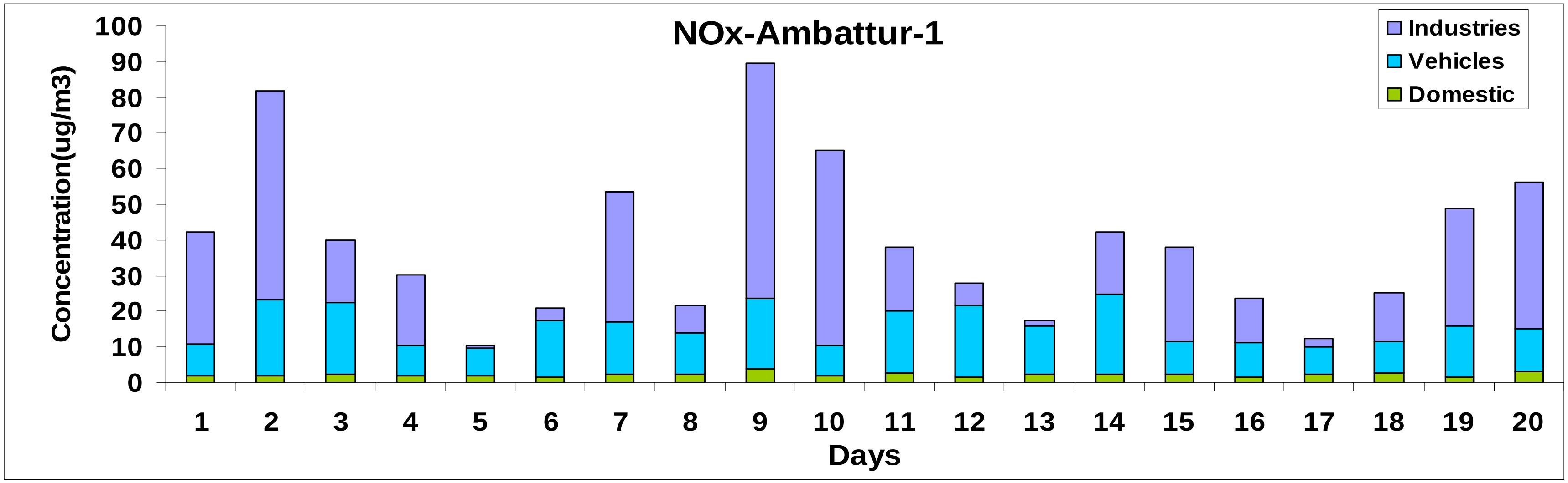


Figure 5.8 Results from ISCST3 Predictions for NOx and PM10 at Ambattur for Season-1



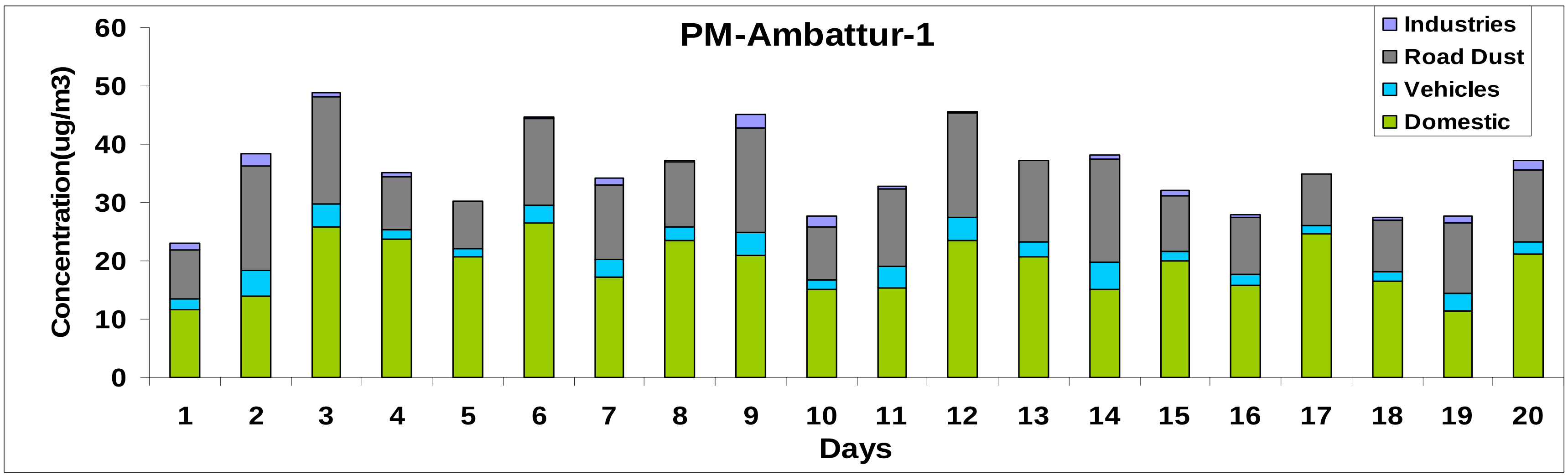
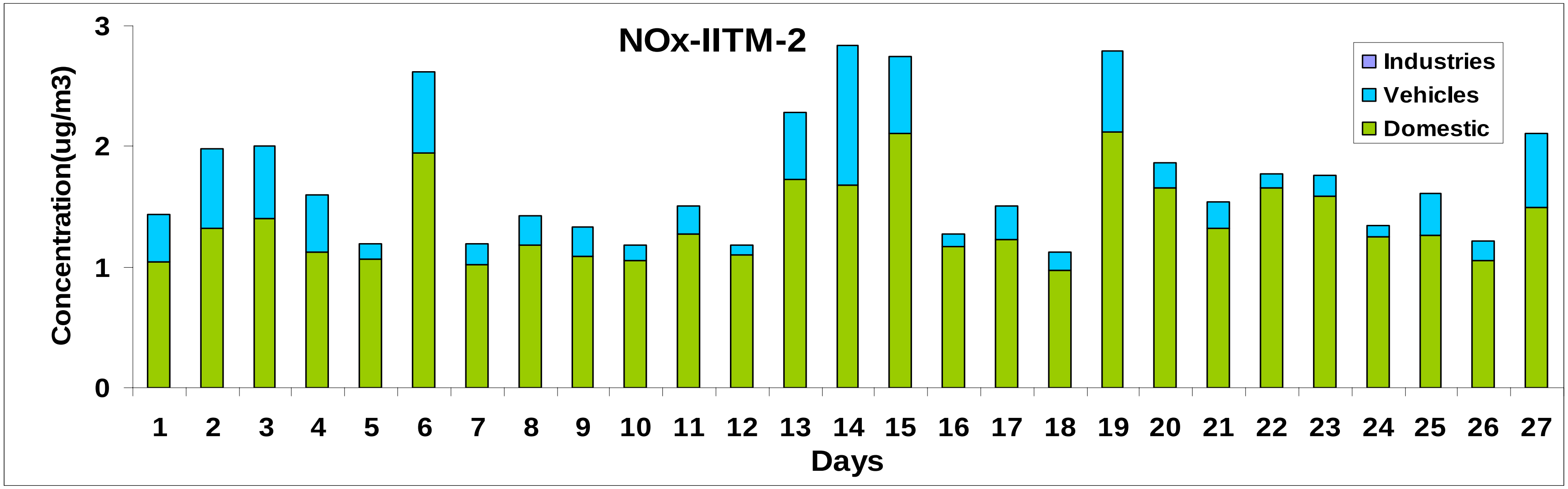


Figure 5.9 Results from ISCST3 Predictions for NOx and PM10 at IITM for Season-2



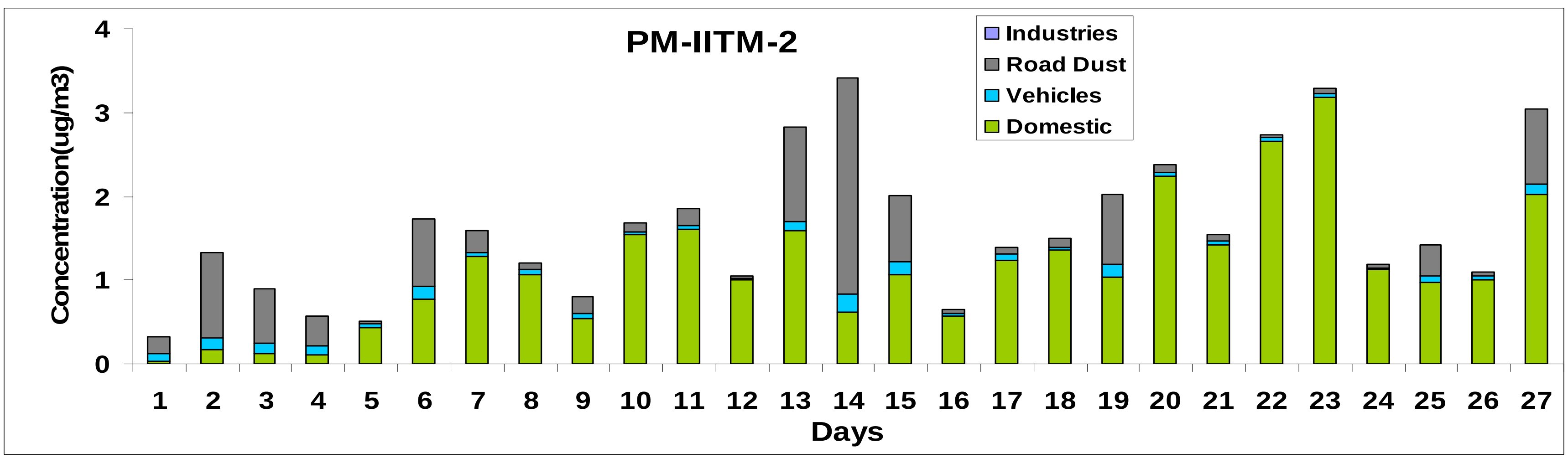
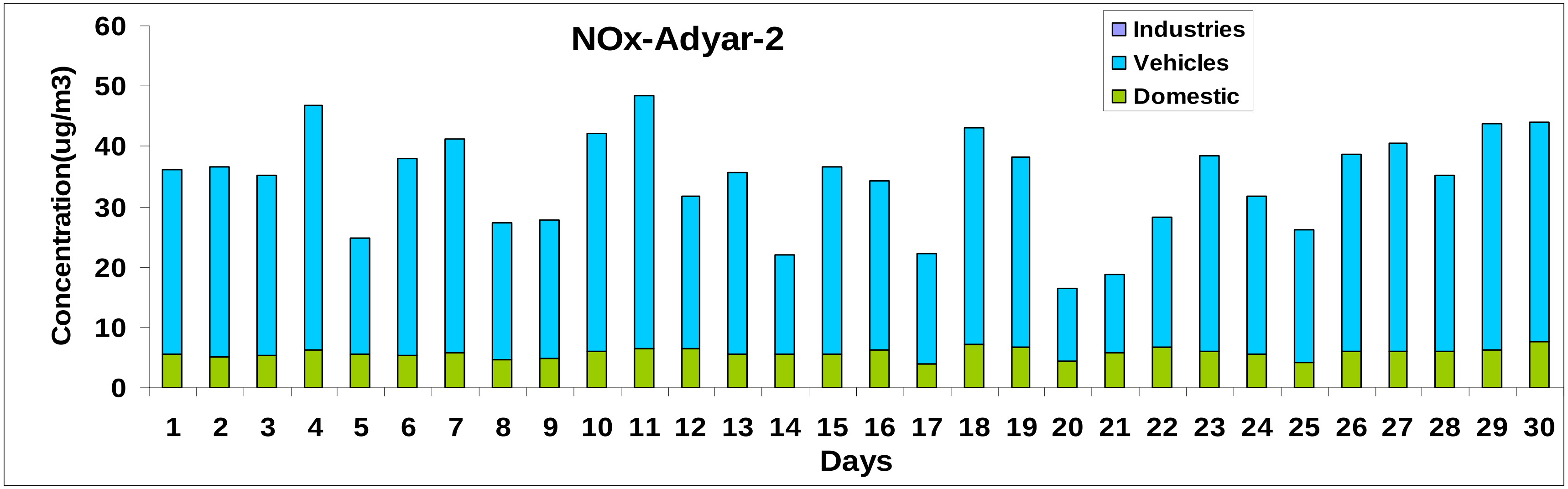


Figure 5.10 Results from ISCST3 Predictions for NOx and PM10 at Adyar for Season-2



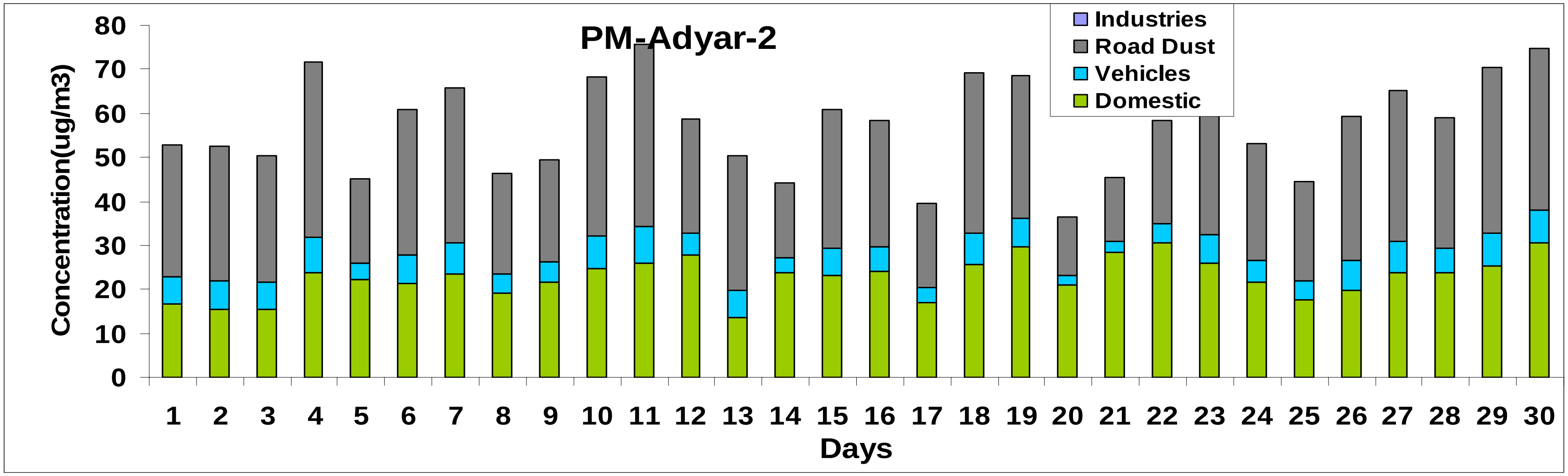
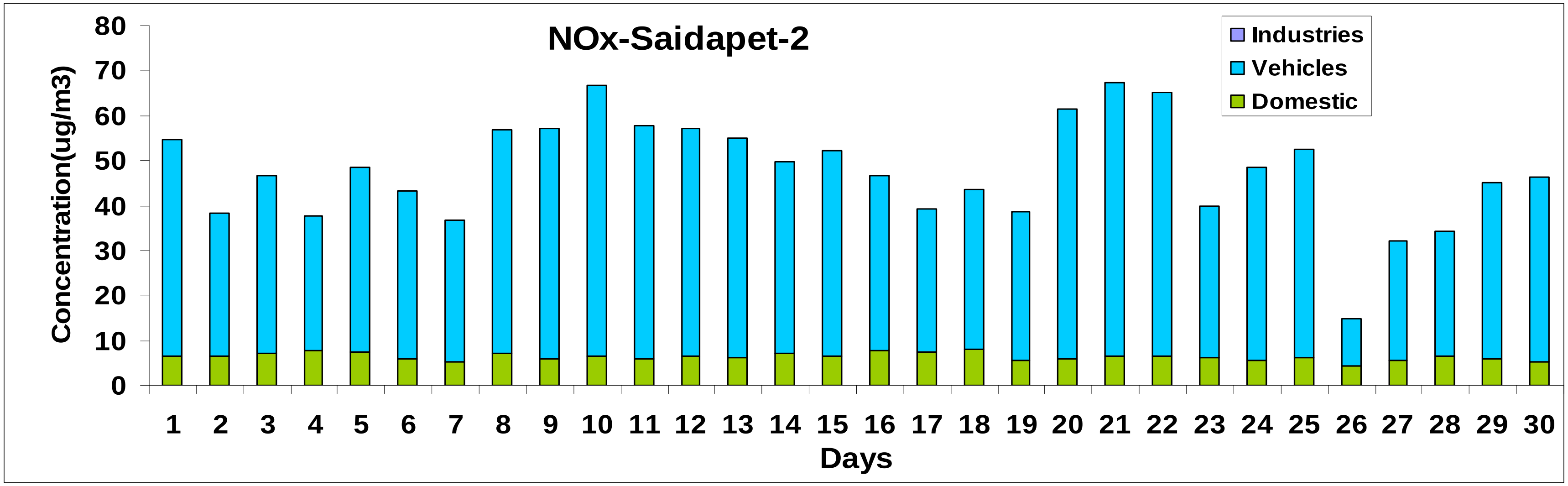


Figure 5.11 Results from ISCST3 Predictions for NOx and PM10 at Saidapet for Season-2



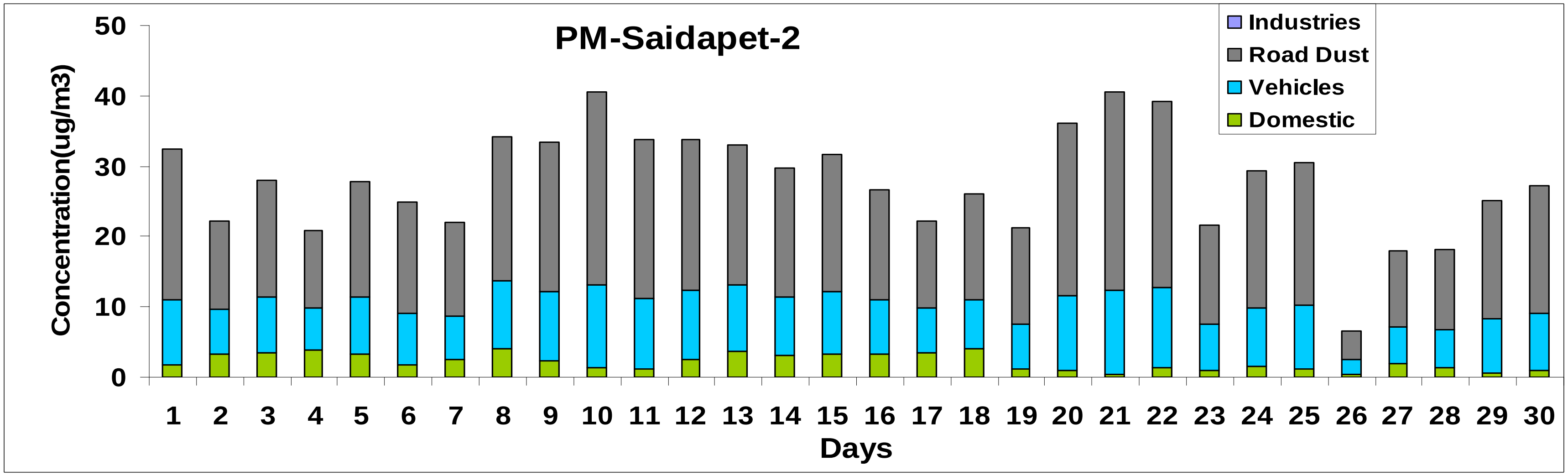


Figure 5.12 Results from ISCST3 Predictions for NOx and PM10 at Mylapore for Season-2

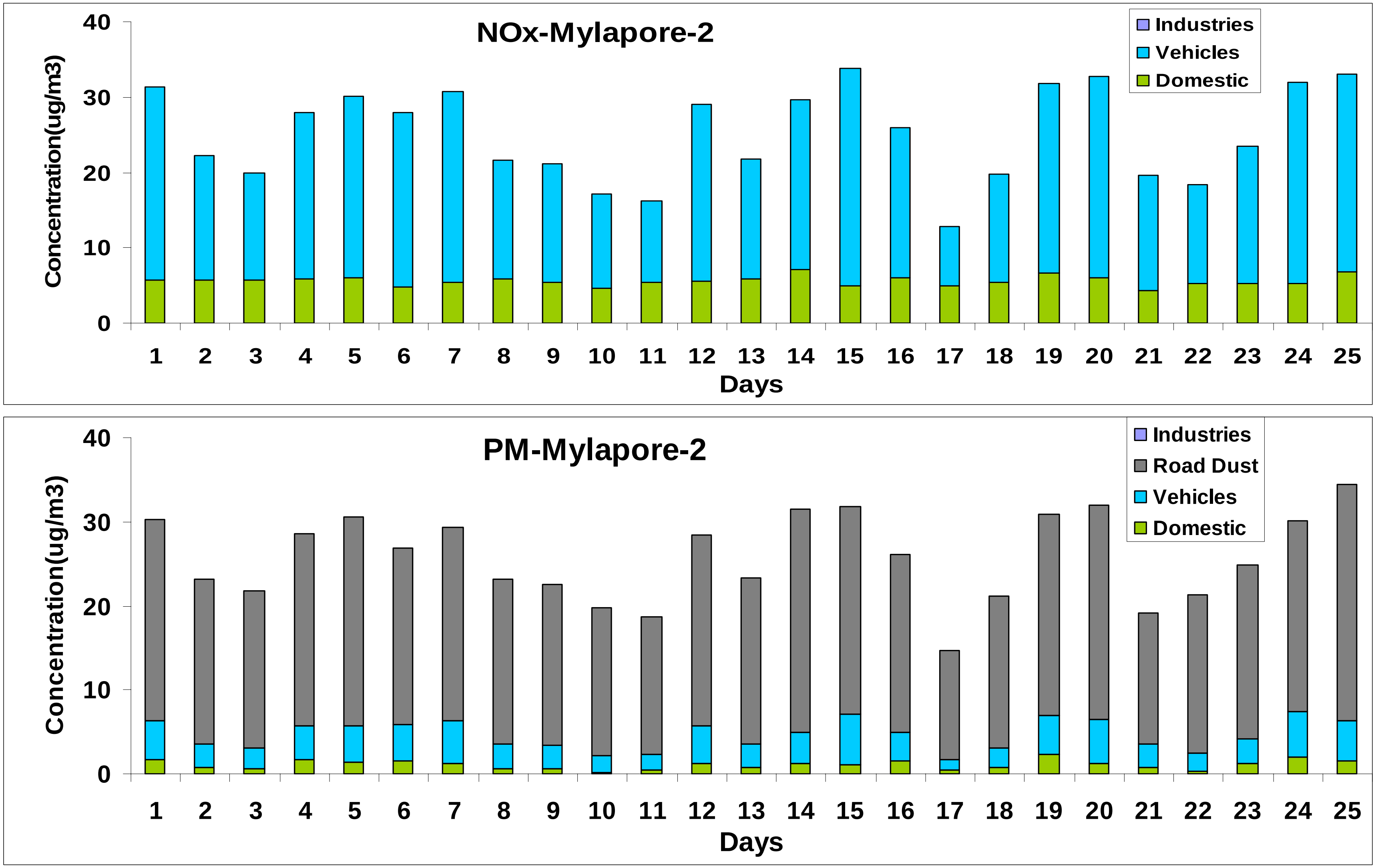
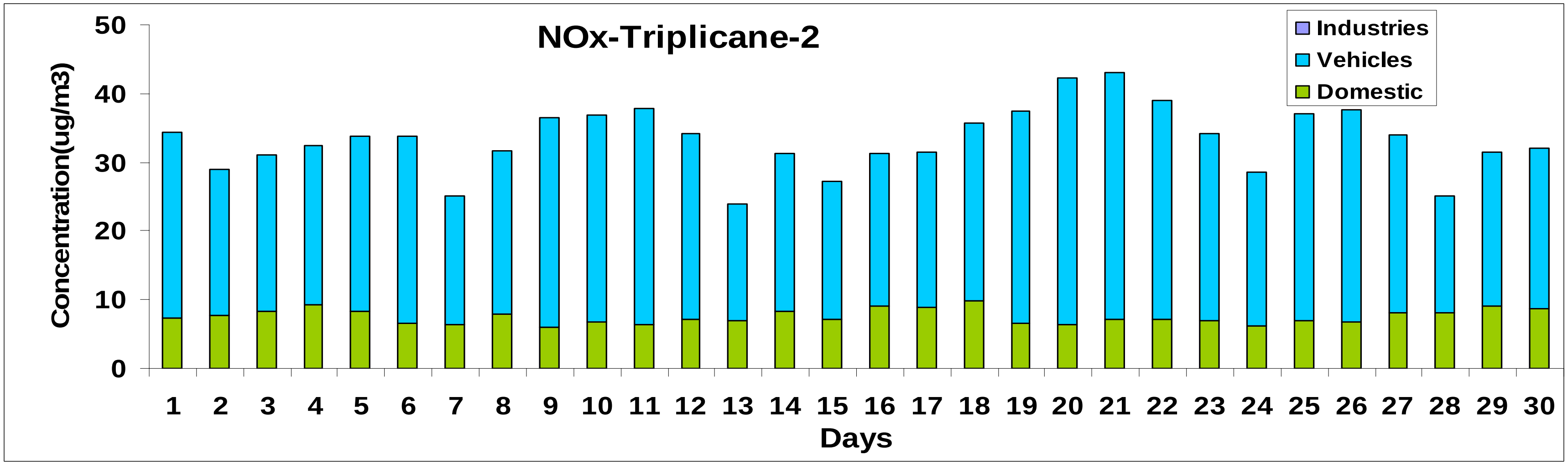


Figure 5.13 Results from ISCST3 Predictions for NOx and PM10 at Triplicane for Season-2



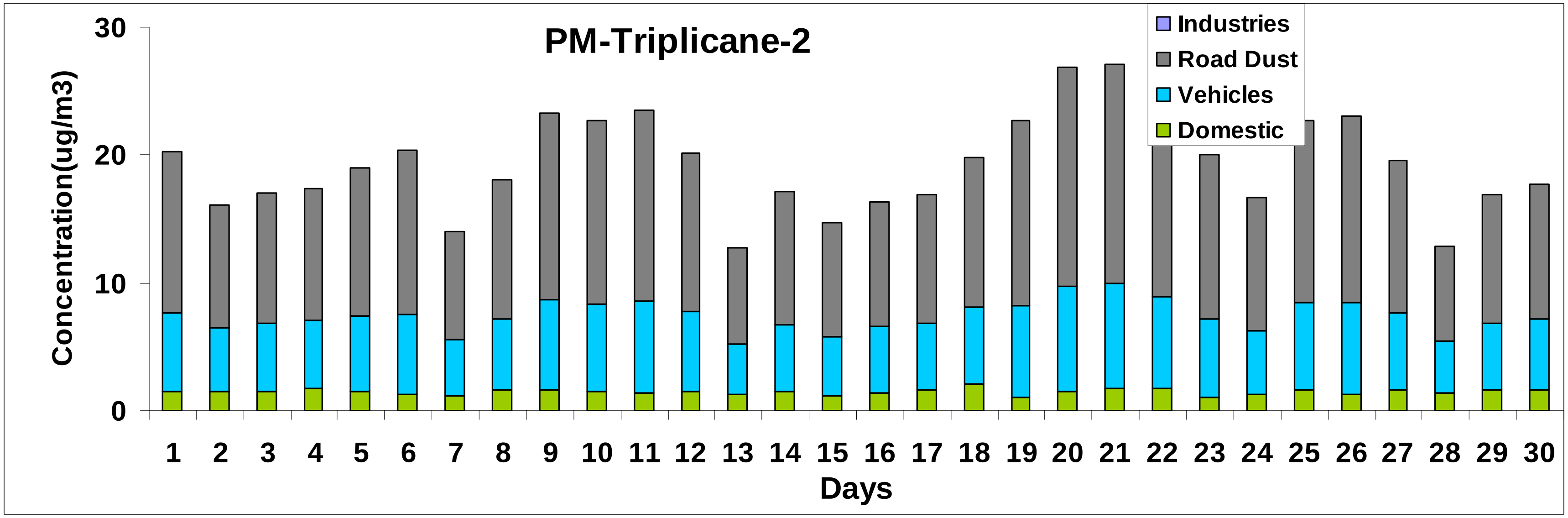
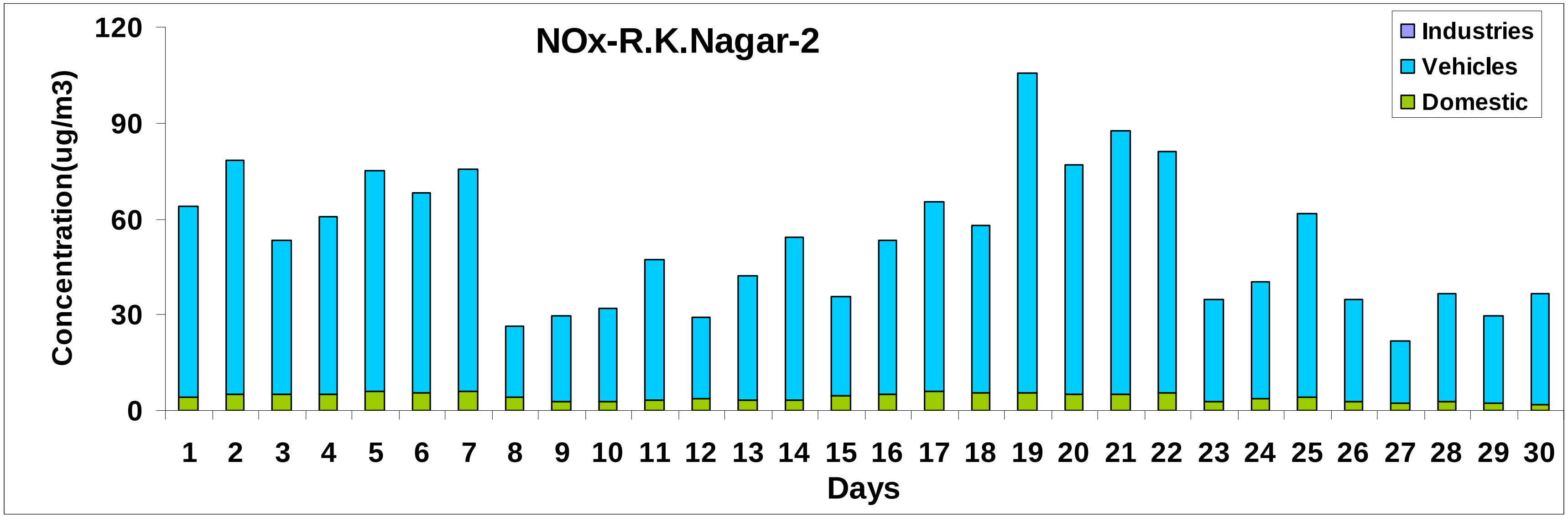


Figure 5.14 Results from ISCST3 Predictions for NOx and PM10 at RK Nagar for Season-2



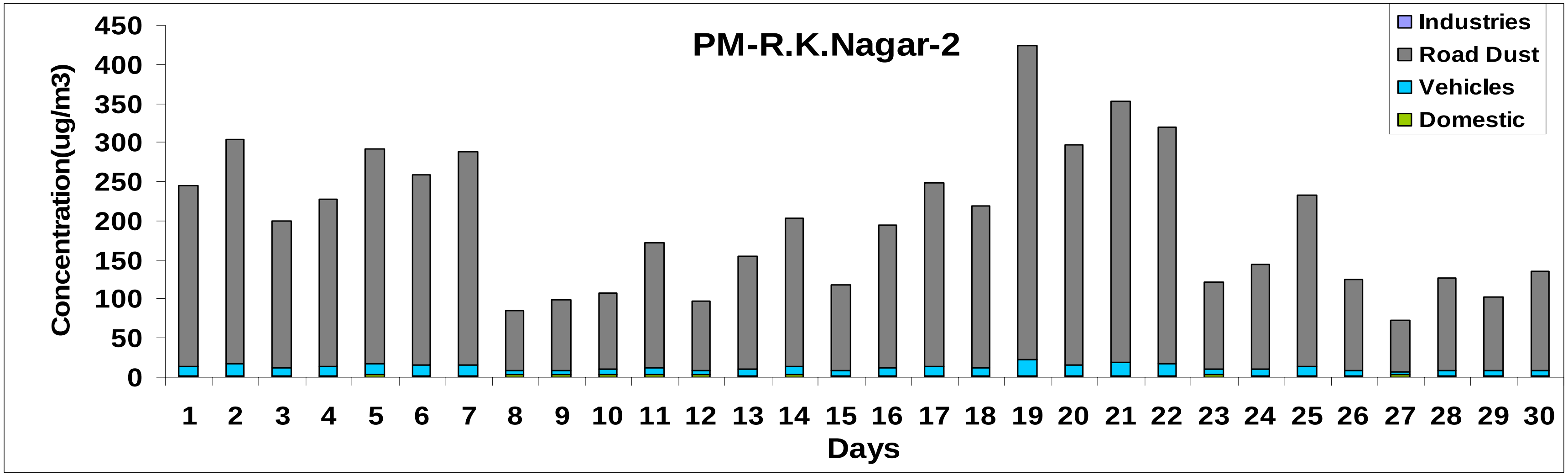


Figure 5.15 Results from ISCST3 Predictions for NOx and PM10 at Ambattur for Season-2

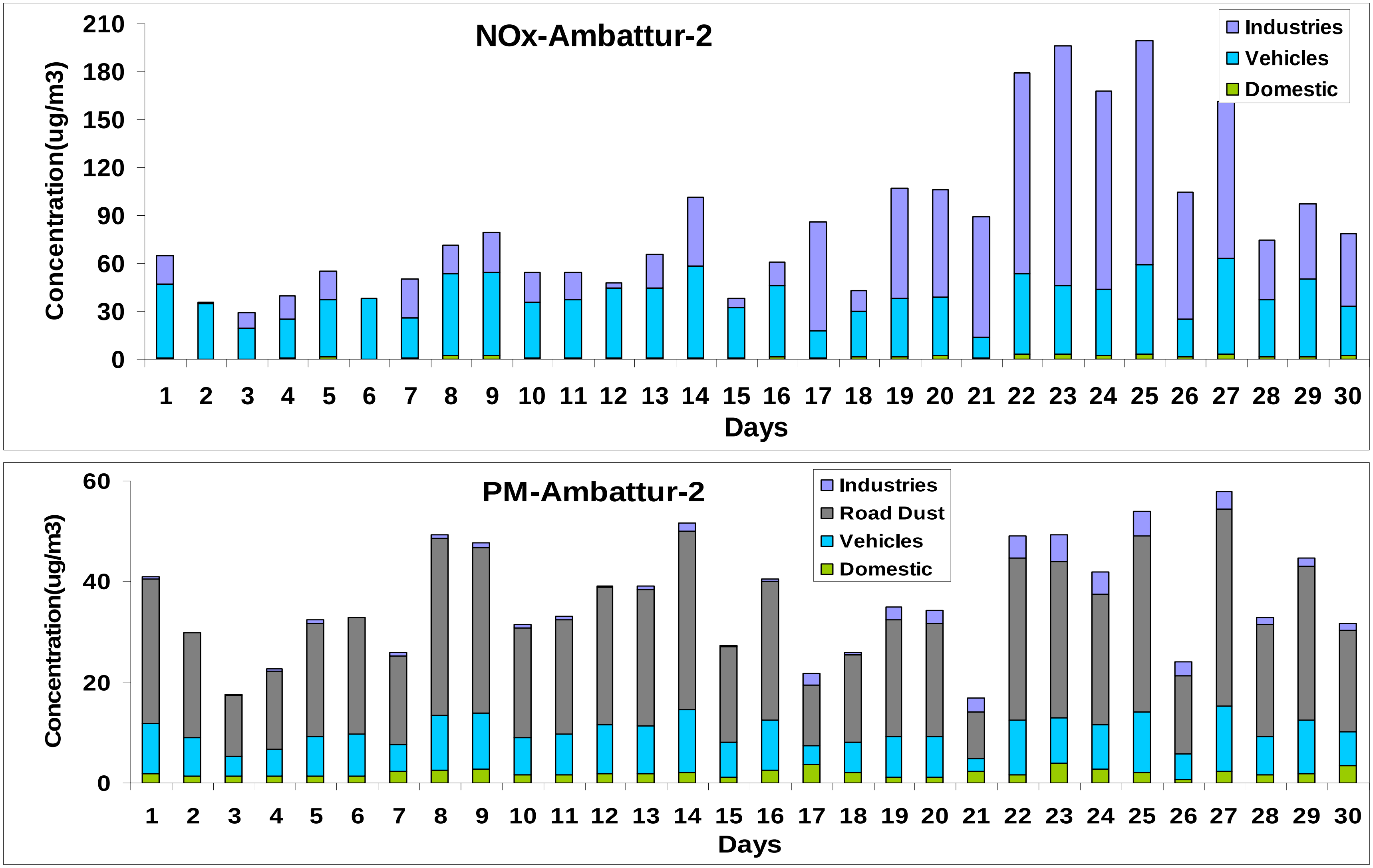
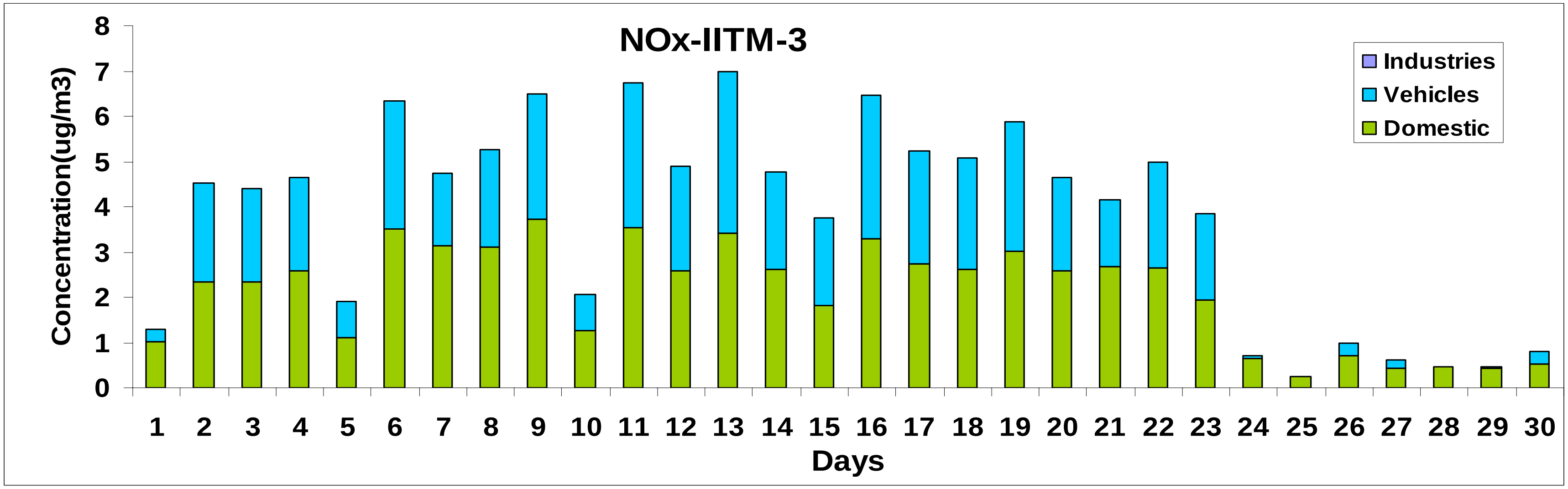


Figure 5.16 Results from ISCST3 Predictions for NOx and PM10 at IITM for Season-3



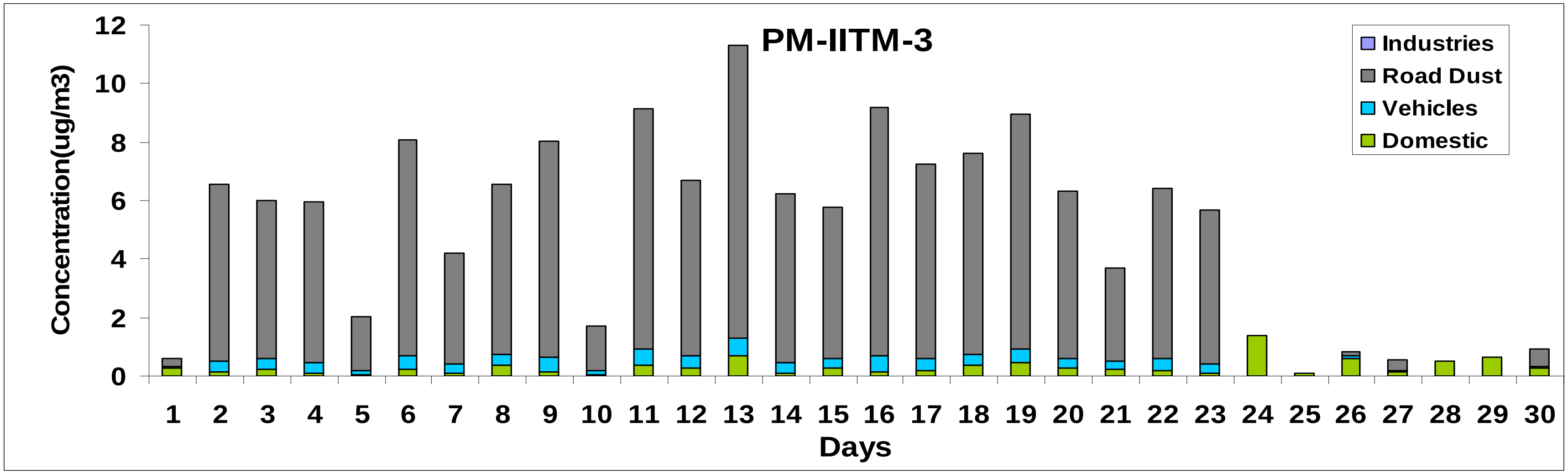
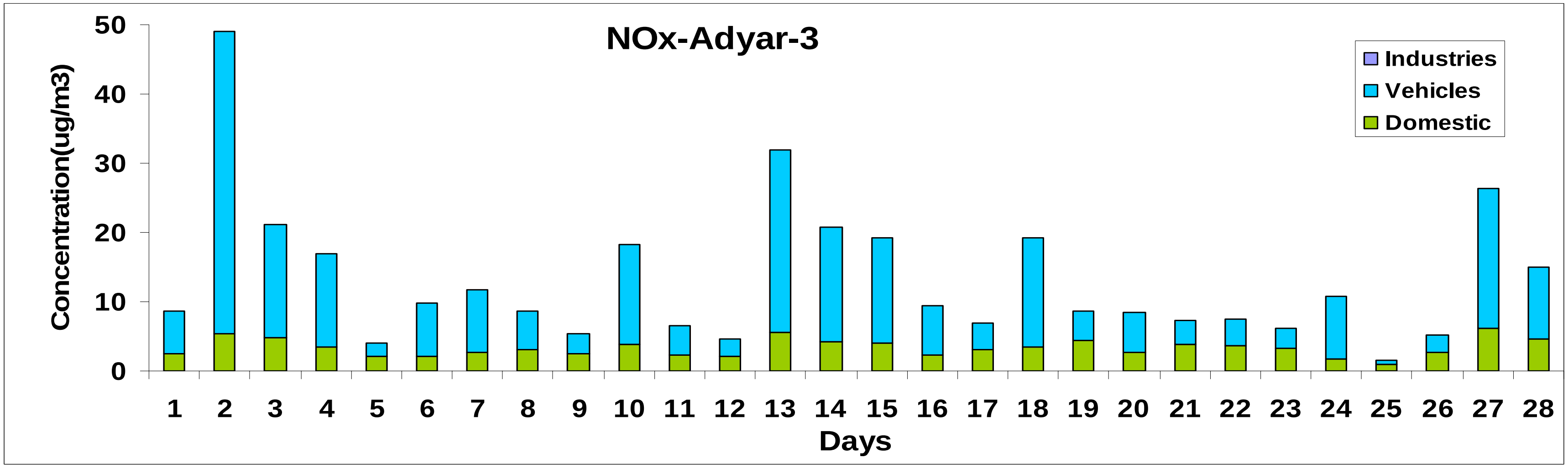


Figure 5.17 Results from ISCST3 Predictions for NOx and PM10 at Adyar for Season-3



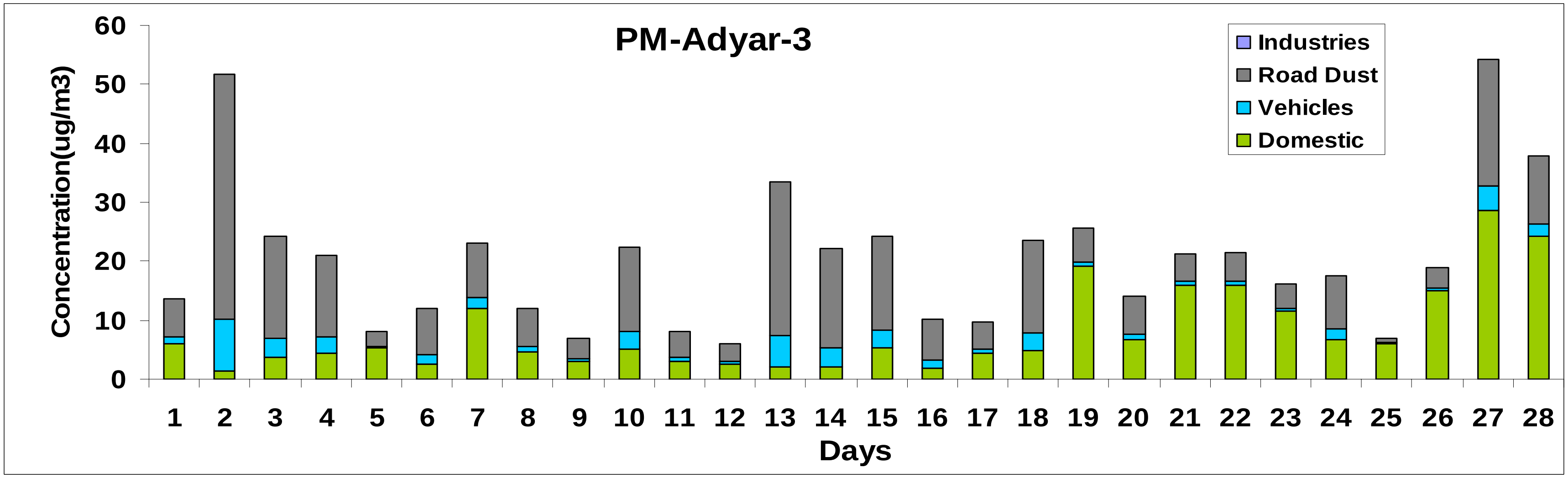
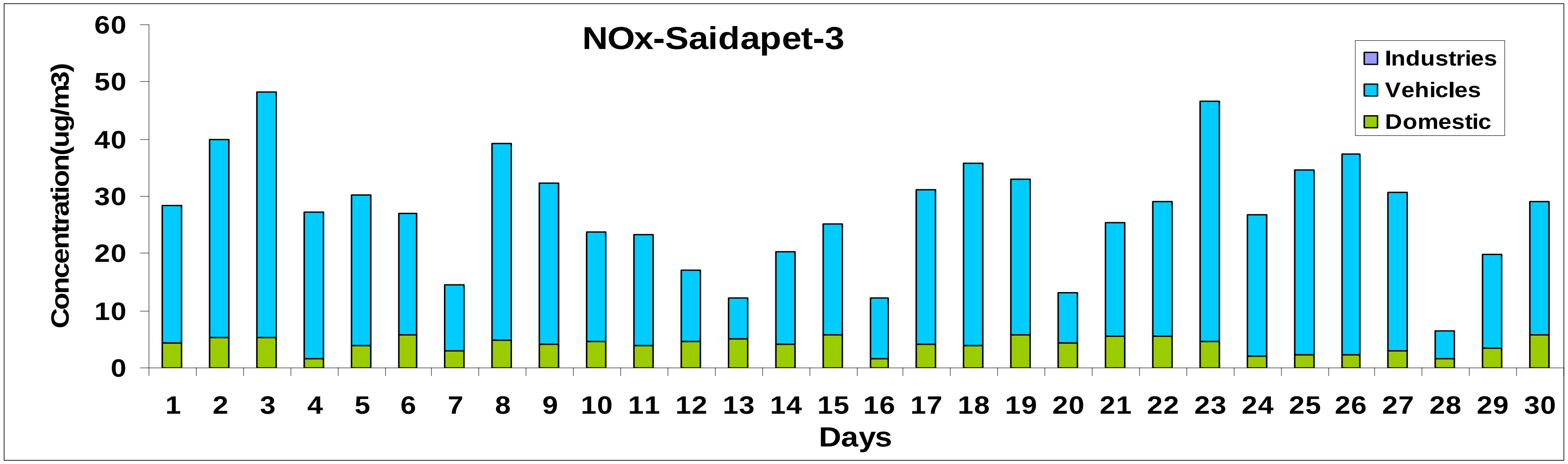


Figure 5.18 Results from ISCST3 Predictions for NOx and PM10 at Saidapet for Season-3



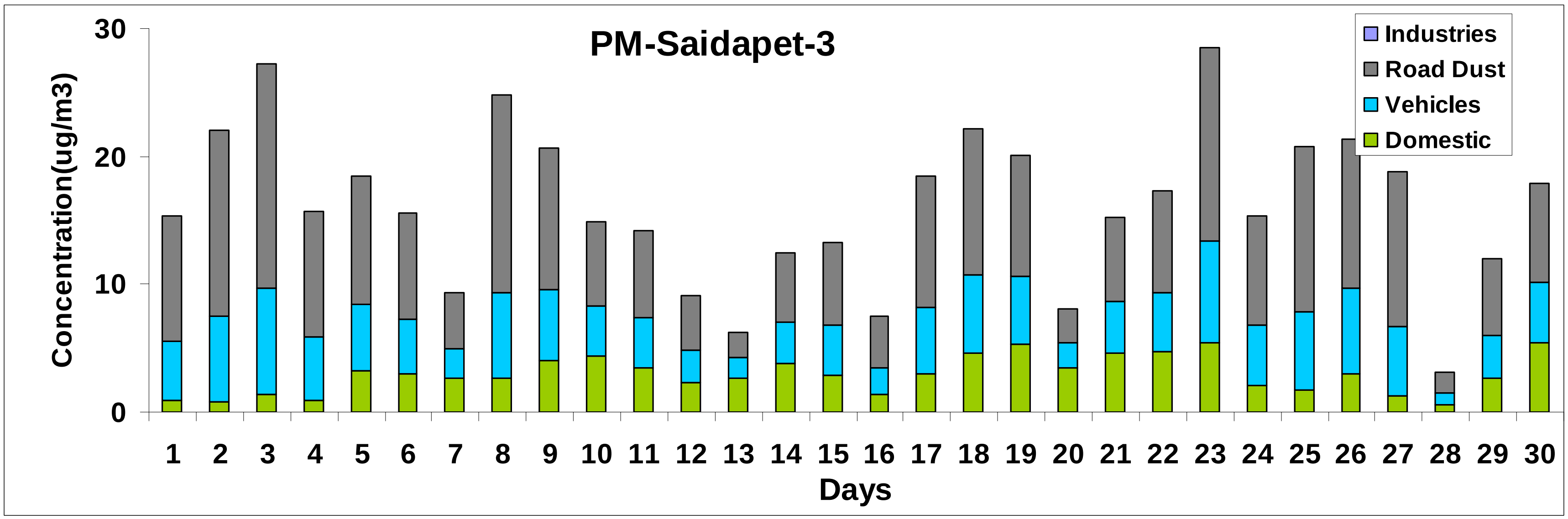


Figure 5.19 Results from ISCST3 Predictions for NOx and PM10 at Mylapore for Season-3

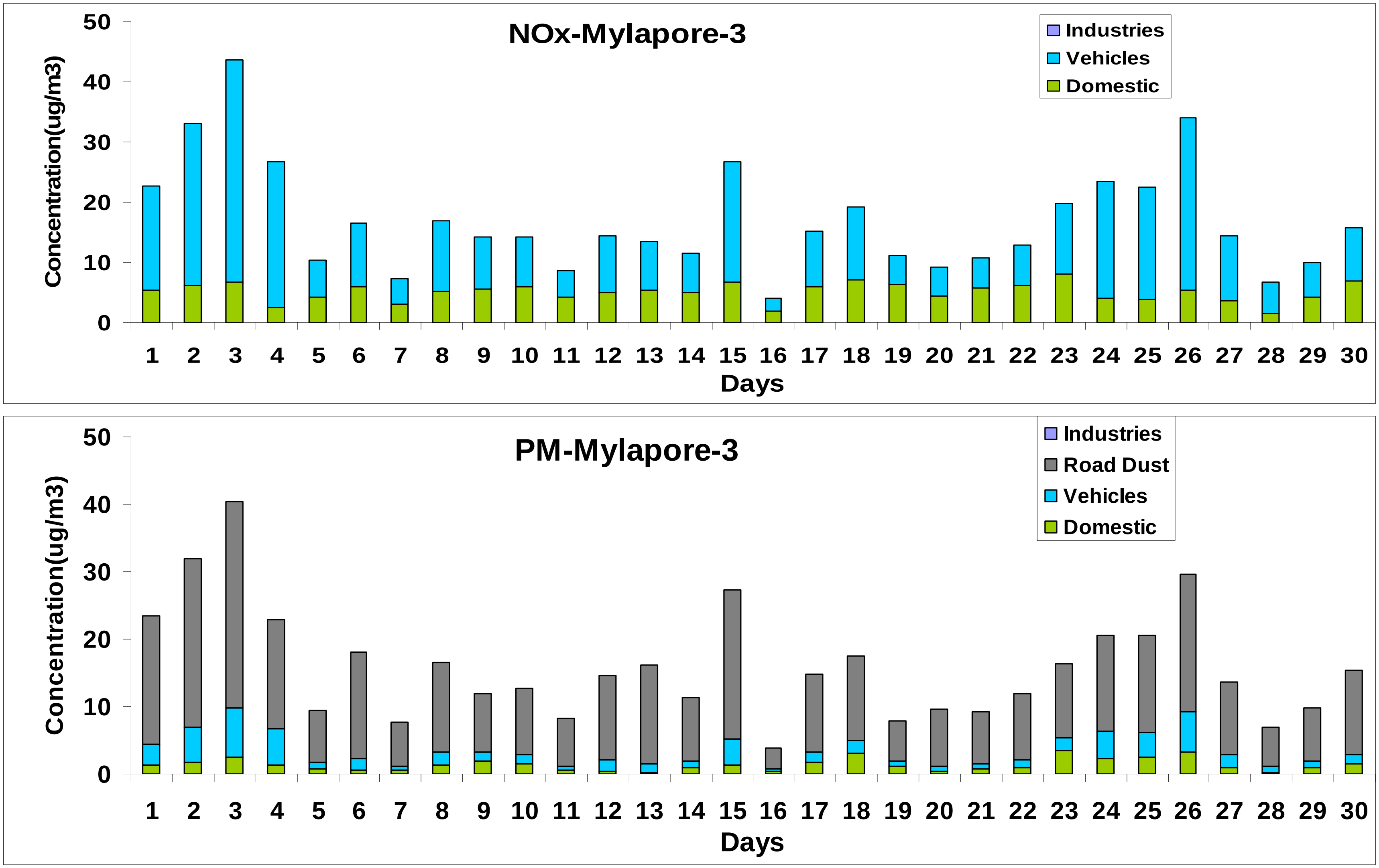


Figure 5.20 Results from ISCST3 Predictions for NOx and PM10 at Triplicane for Season-3

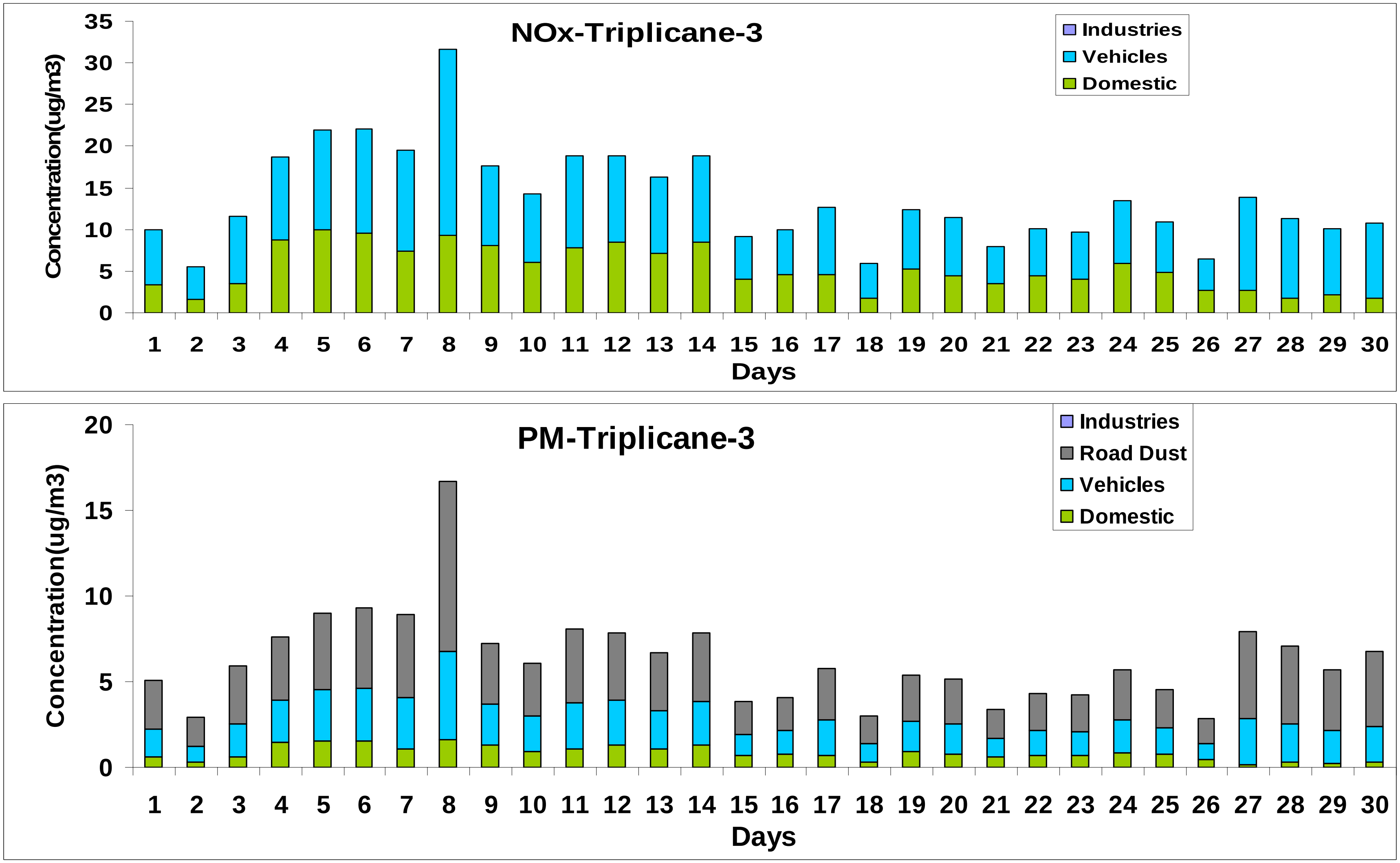
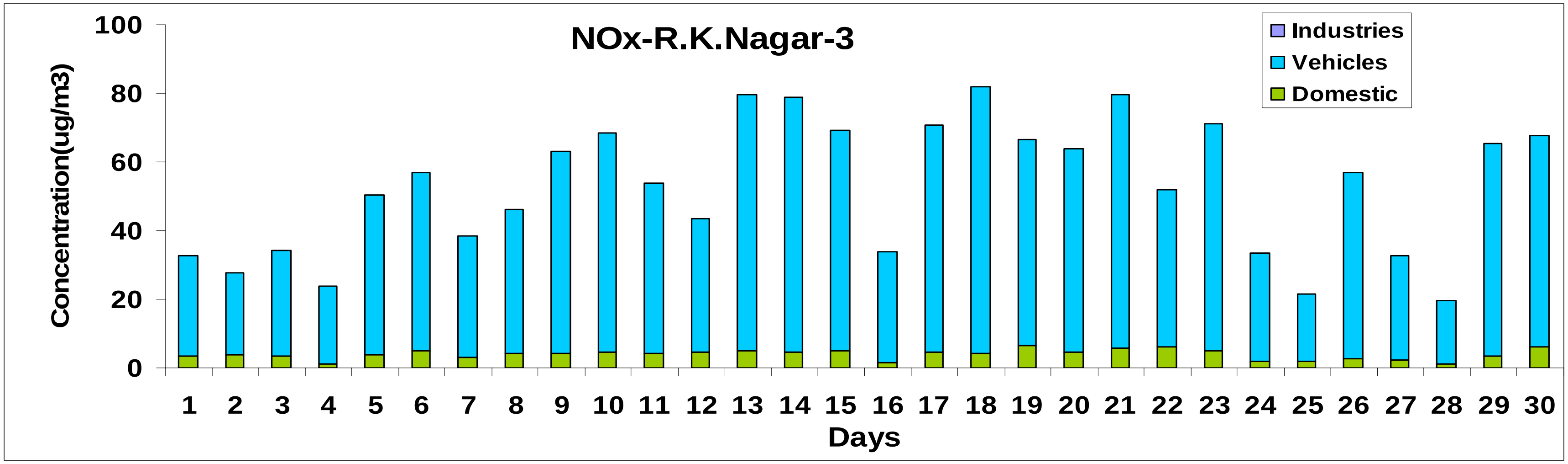


Figure 5.21 Results from ISCST3 Predictions for NOx and PM10 at RK Nagar for Season-3



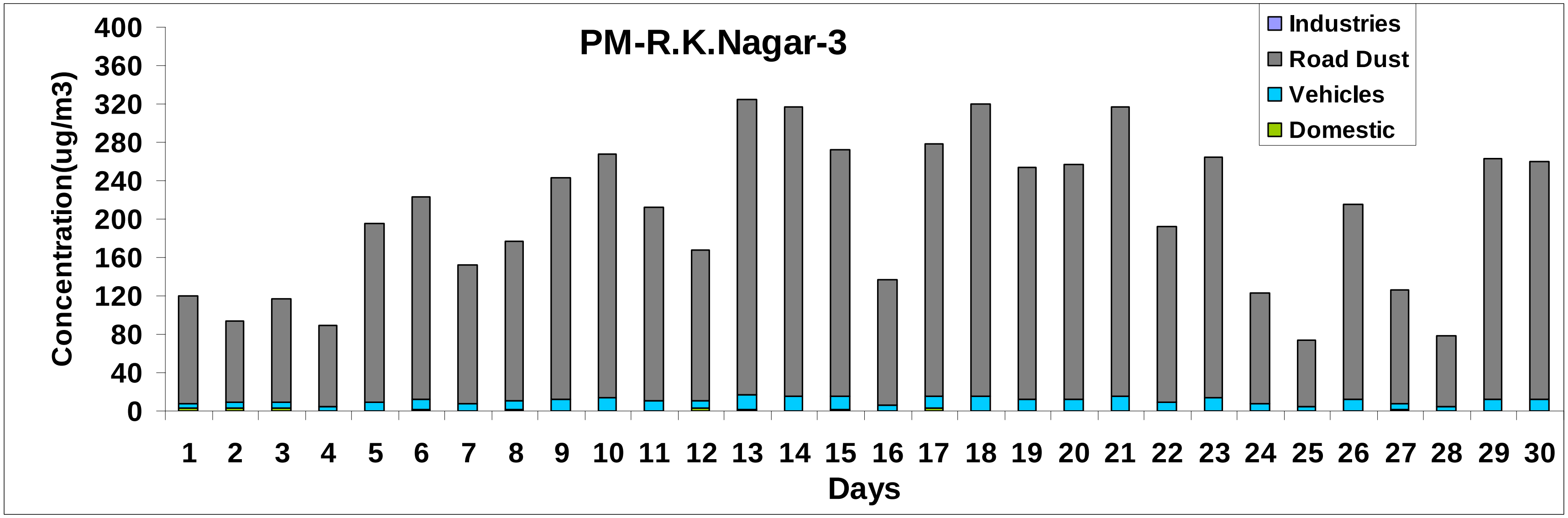
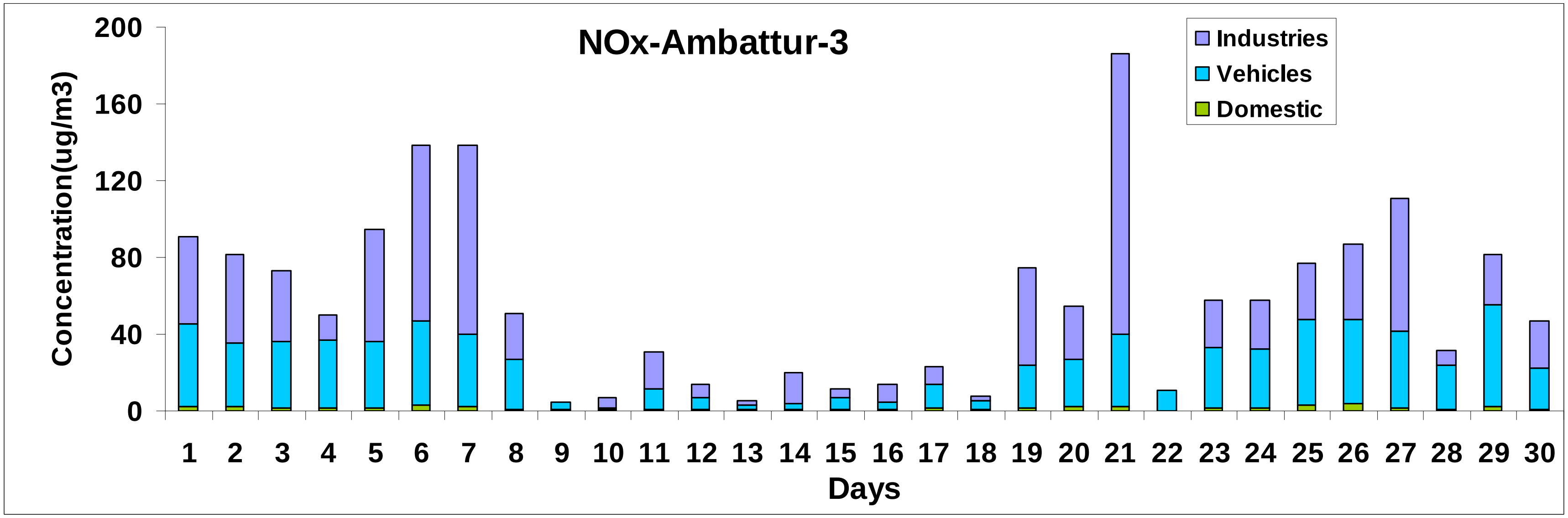
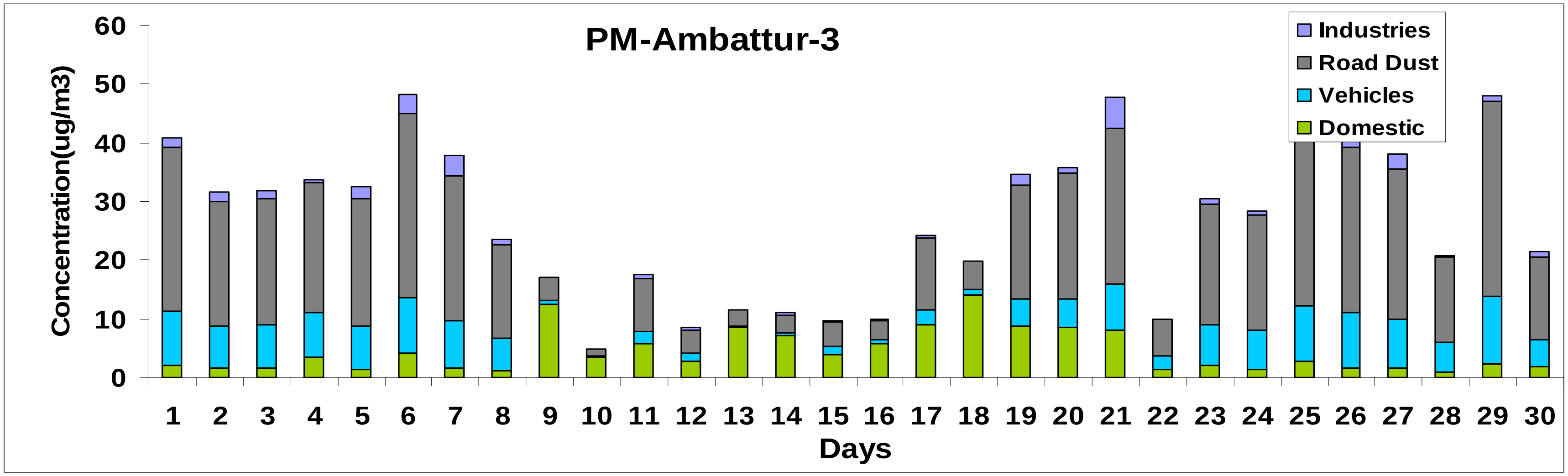


Figure 5.22 Results from ISCST3 Predictions for NOx and PM10 at Ambattur for Season-3





The season wise modeling results are given from Fig. 5.23 to 5.28, for NOx and PM.

Figure 5.23: Results from ISCST3 Predictions for NOx for season-1

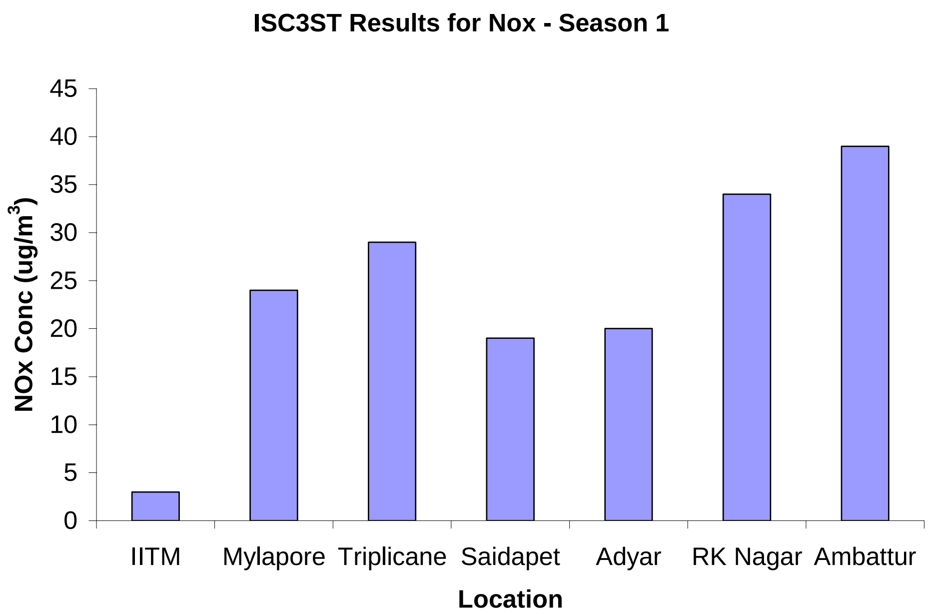


Figure 5.24: Results from ISCST3 Predictions for PM for season-1

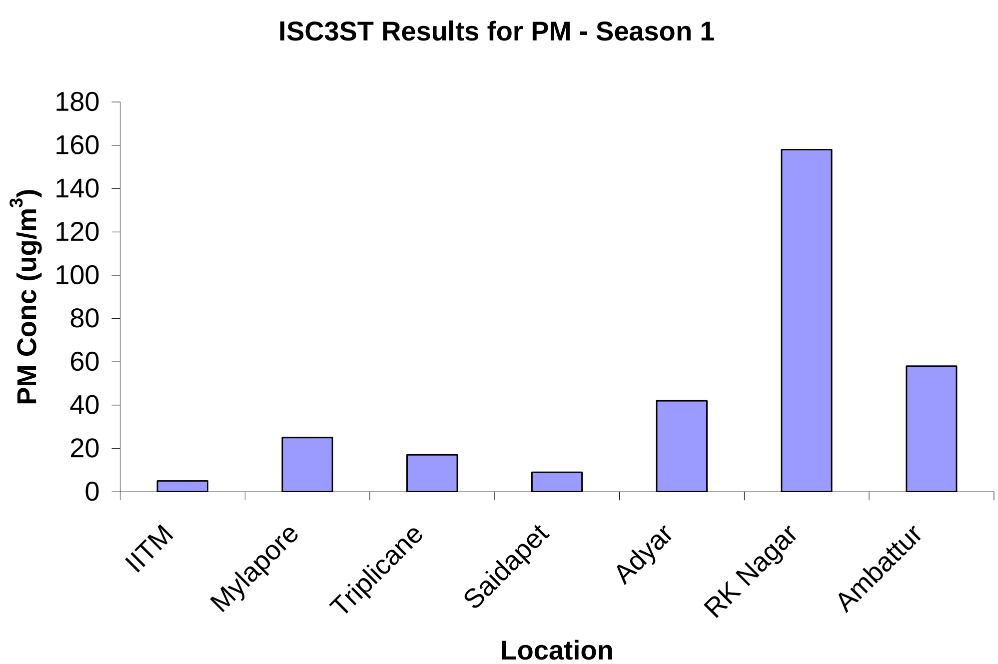


Figure 5.25: Results from ISCST3 Predictions for NOx for season-2

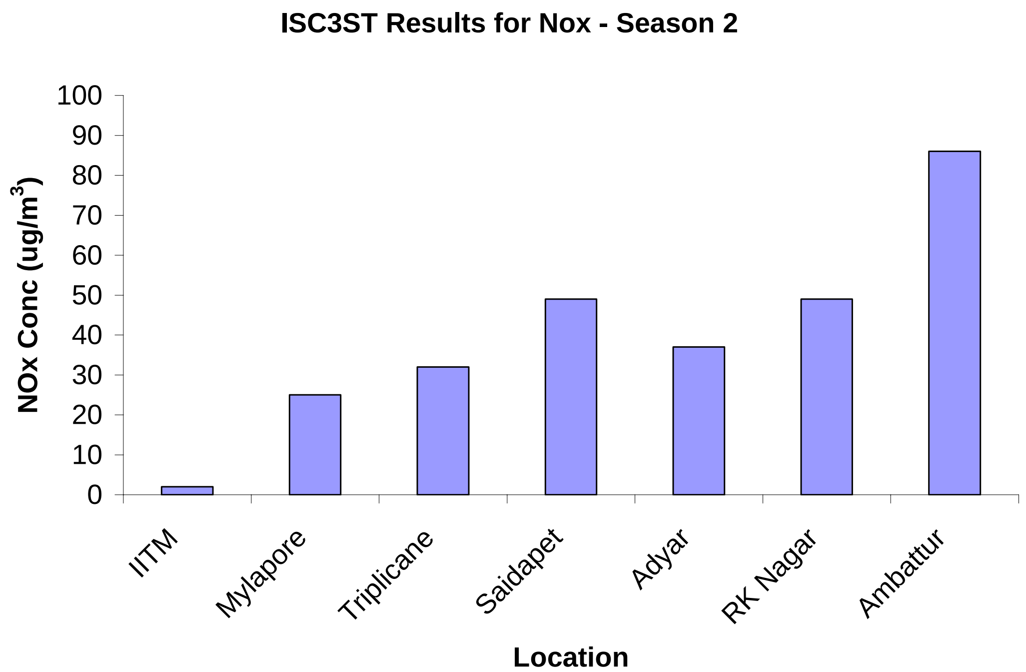


Figure 5.26: Results from ISCST3 Predictions for PM for season-2

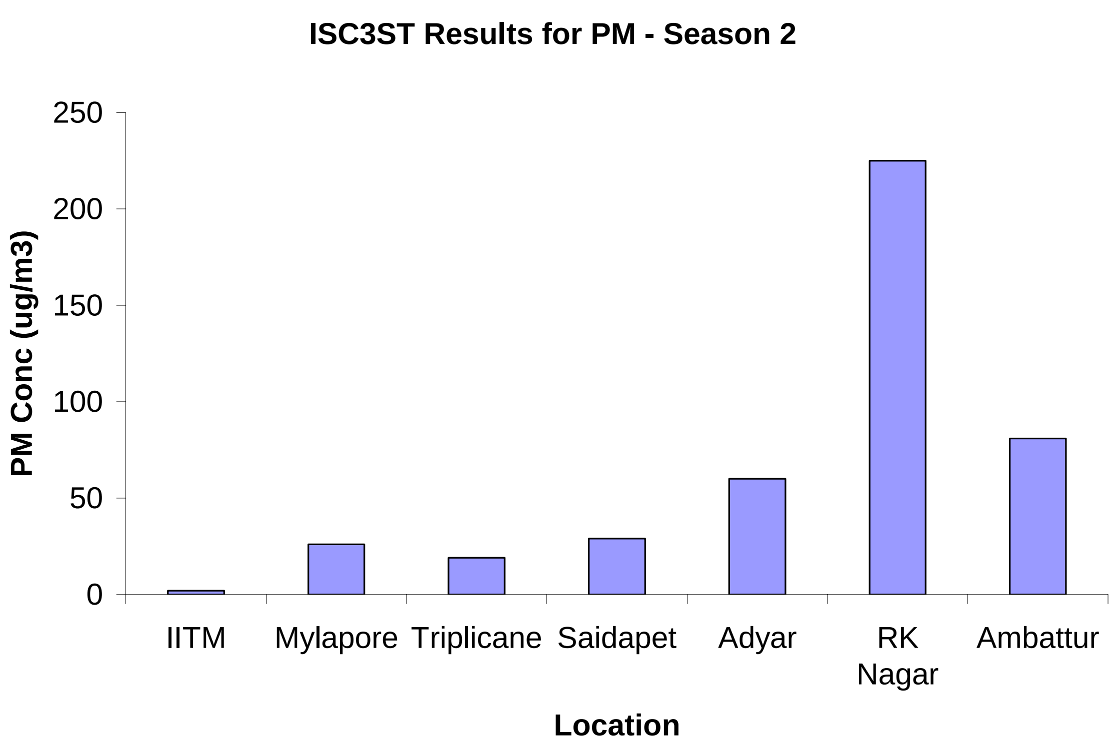


Figure 5.27: Results from ISCST3 Predictions for NOx for season-3

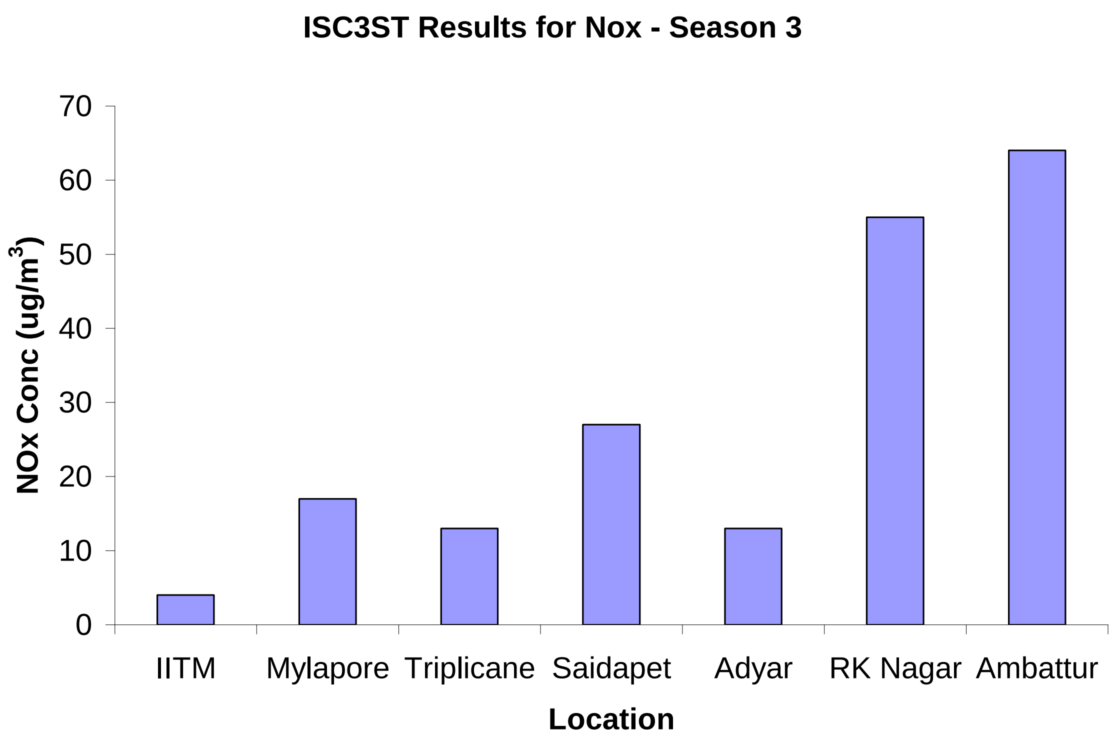


Figure 5.28: Results from ISCST3 Predictions for PM for season-3

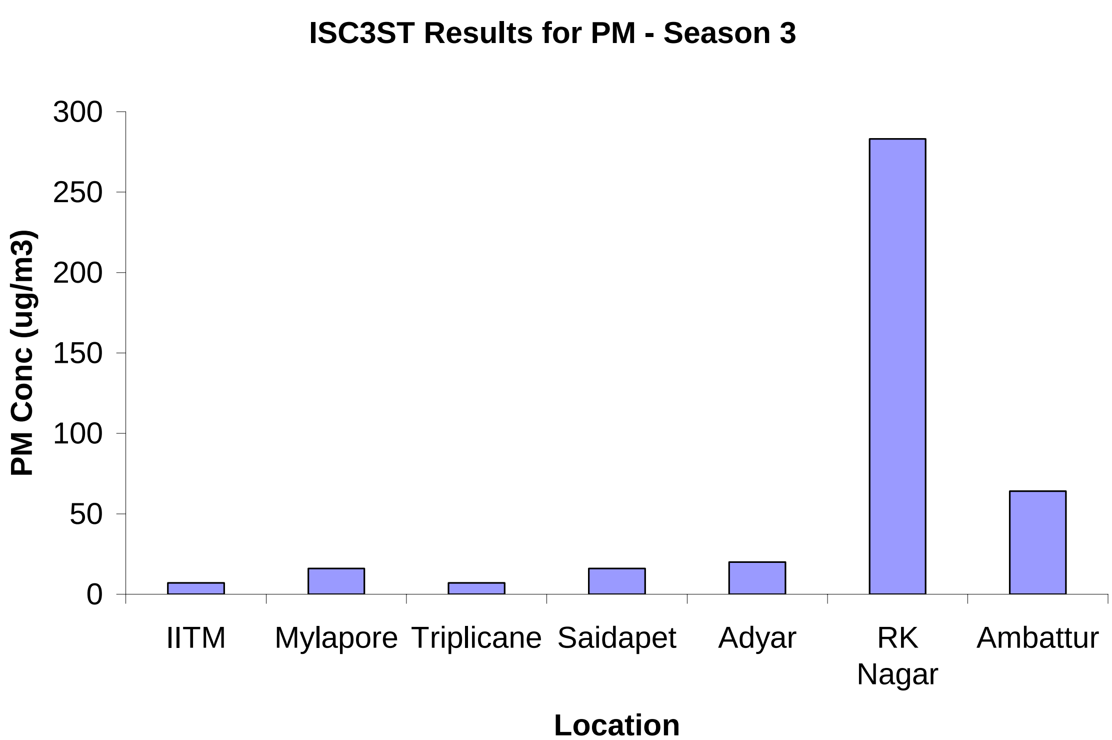
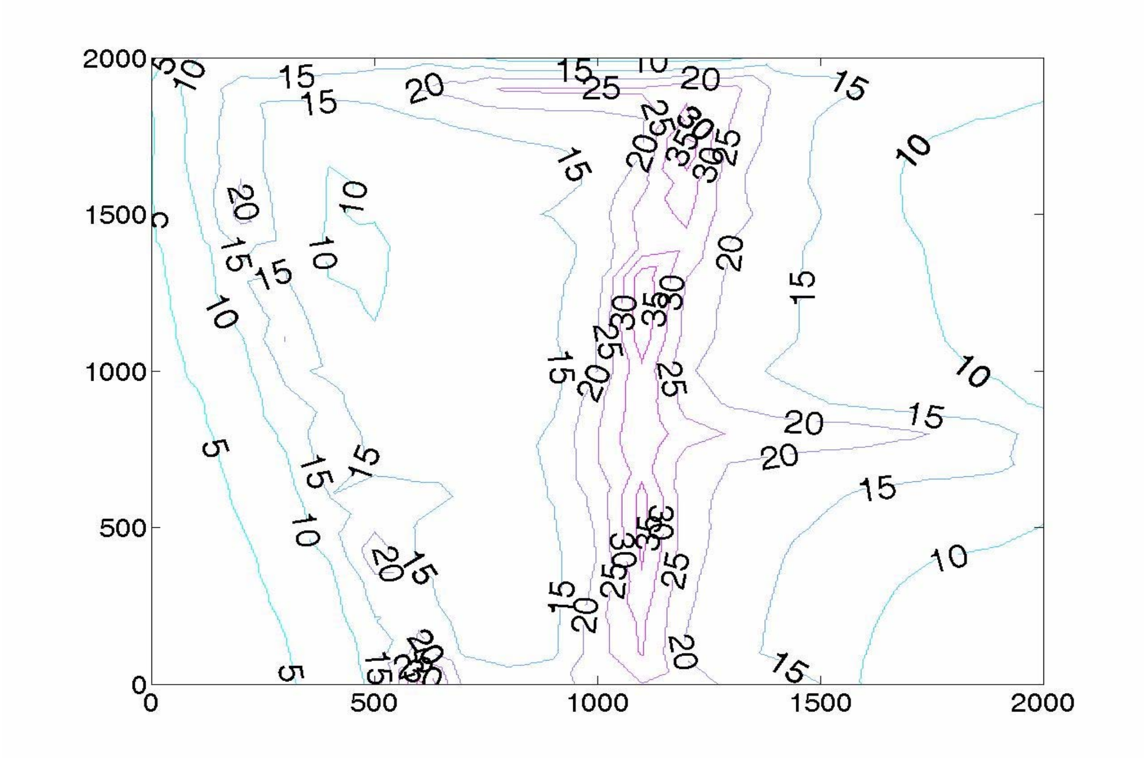


Fig. 5.24, 5.26 and 5.28 show that the PM level in RK Nagar (industrial site) is above the standard limit in all the three seasons. This site has the highest PM level among all the 7 sites. The next highest occurs in the other industrial site, Ambattur, where the pollution level is within the specified national limit. Fig 5.7, 5.14 and 5.21 show tha thte in RK Nagar, the PM level is consistently high in many days and that it is not due to any aberration in the weather for a few days.

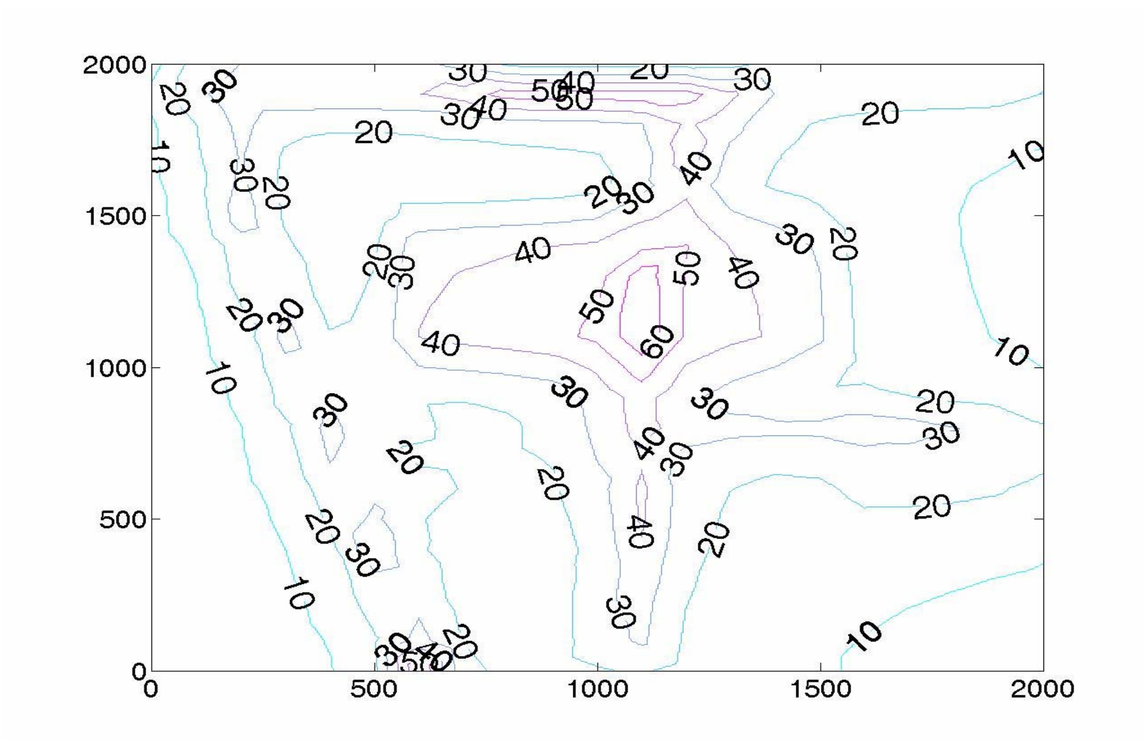
Fig. 5.23, 5.25 and 5.27 show that Ambattur (industrial site) is predicted to have the highest concentration of NOx among all the 7 sites. The monthly average is below the limit specified for annual average limit (There is no monthly average specified in national standards and hence the annual average is used for comparison). However, Fig. 5.8, 5.15 and 5.22 show that occasionally the daily average exceeds the national limits specified for industrial areas.

In addition to the above quantitative results we now depict the concentration contours in each of the seven 2X2 km regions of interest. For this we computed the concentrations at 200 receptor points in the grid of interest for season 1 and after this used Matlab to obtain the contour plots. They are given from Fig. 5.29 to 5.35



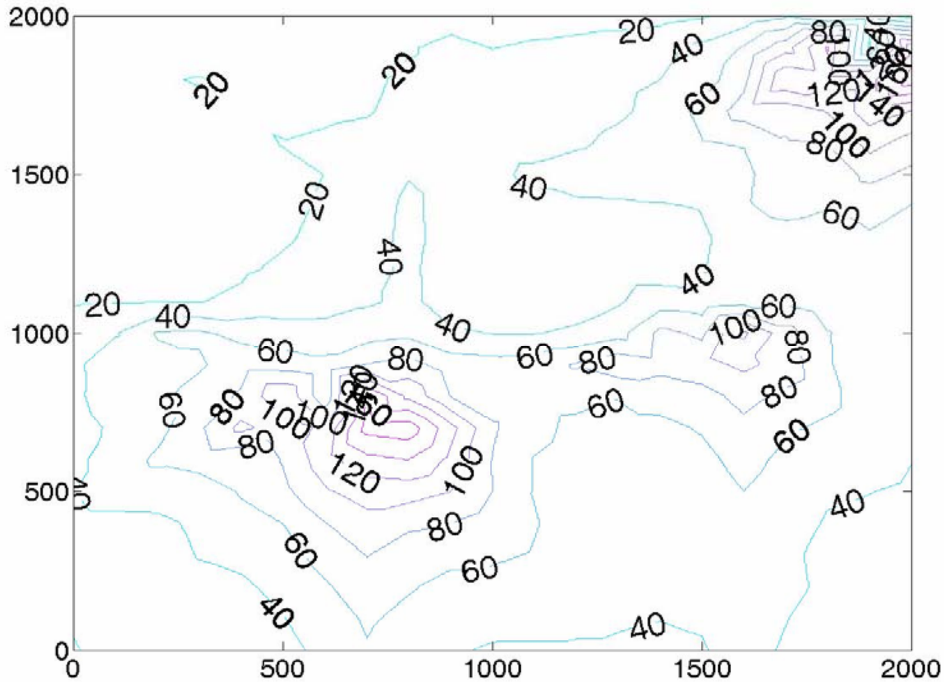
(a)

.

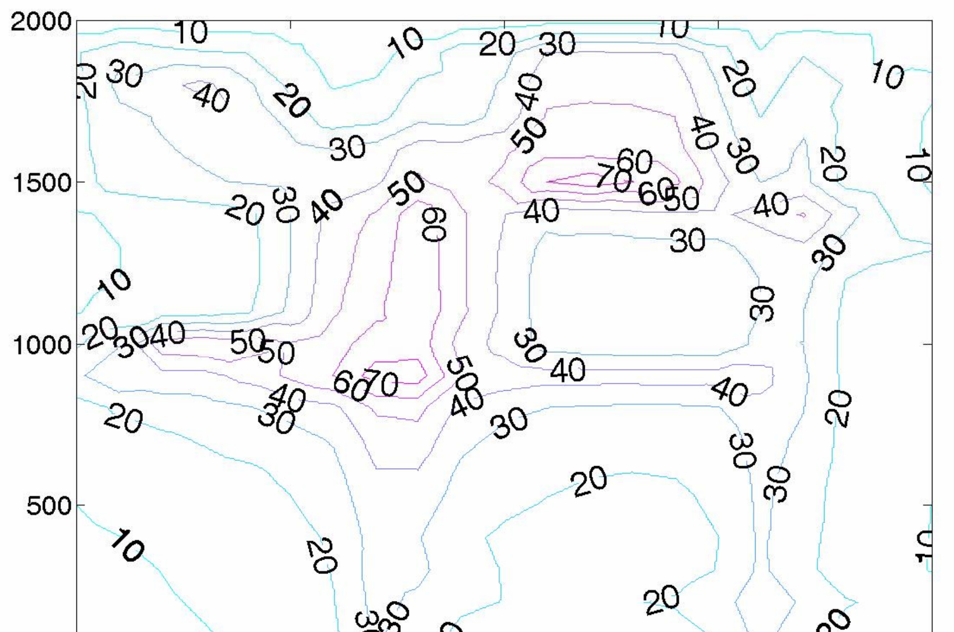


(b)

Fig 5.29 Contour plots for the area of Adyar a)NOx b)PM10

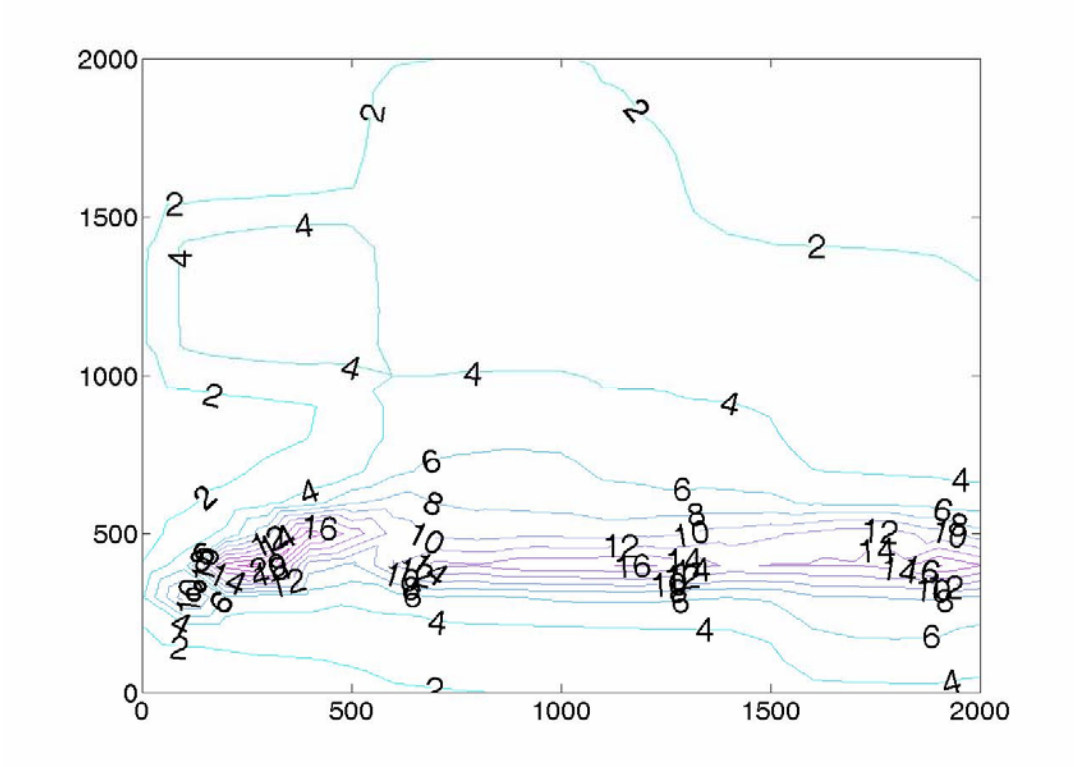


(a)

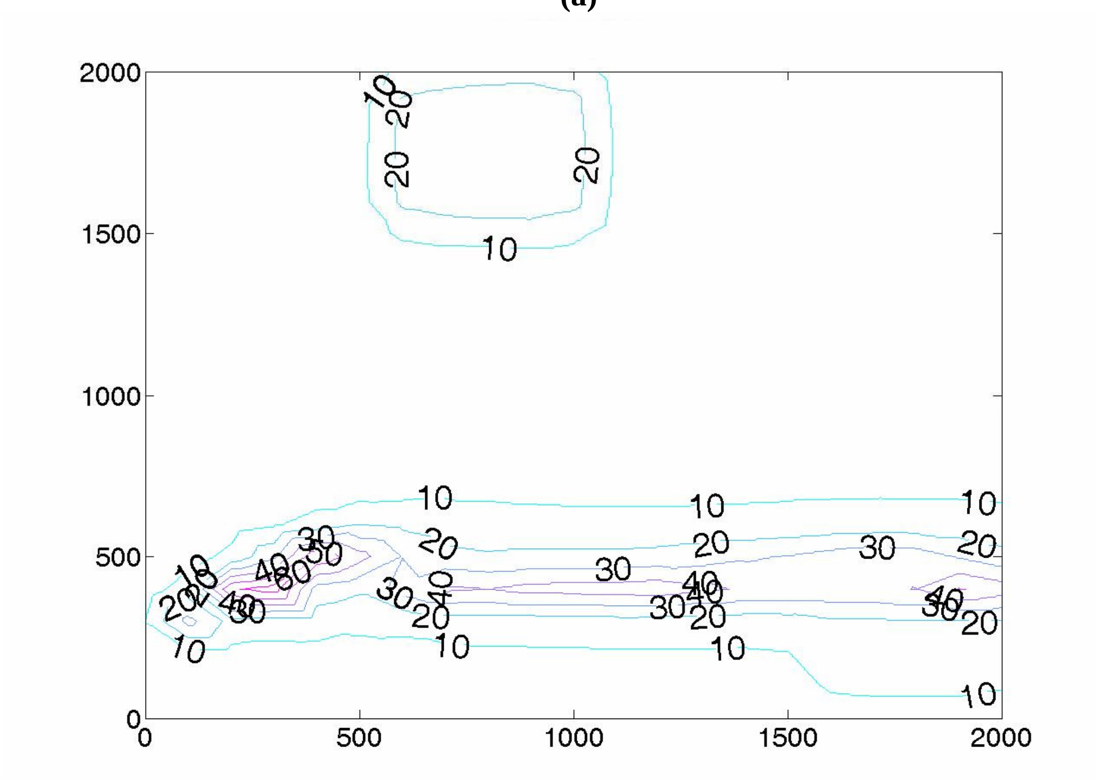


(b)

Fig 5.30 Contour plots for the area of Ambattur a)NOx b)PM10

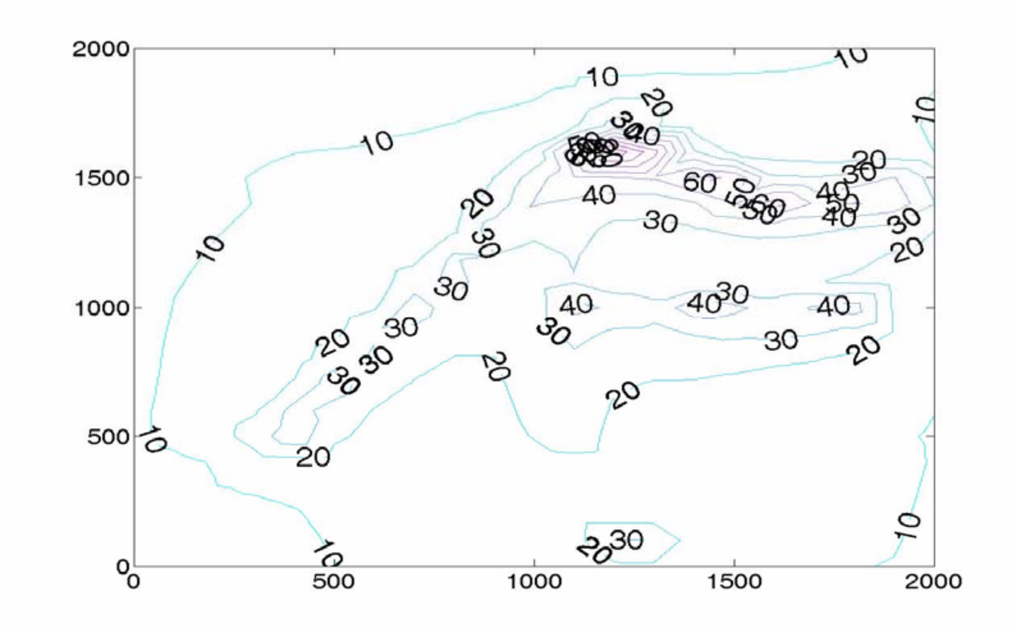


(a)

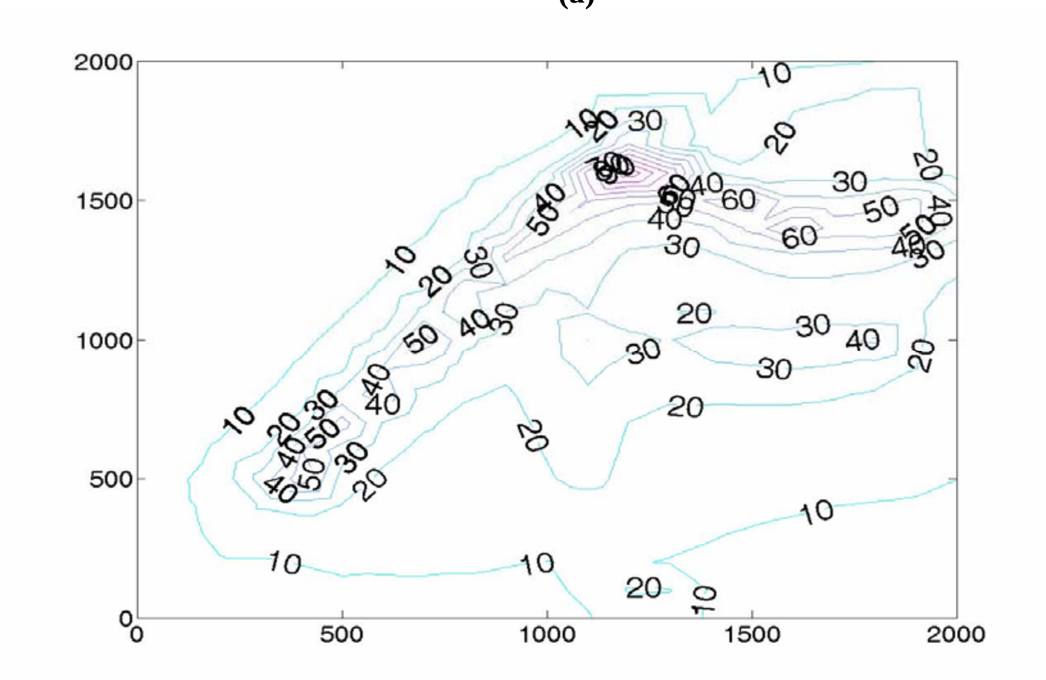


(b)

Fig5.31 Contour plots for the area of IITM a)NOx b)PM10

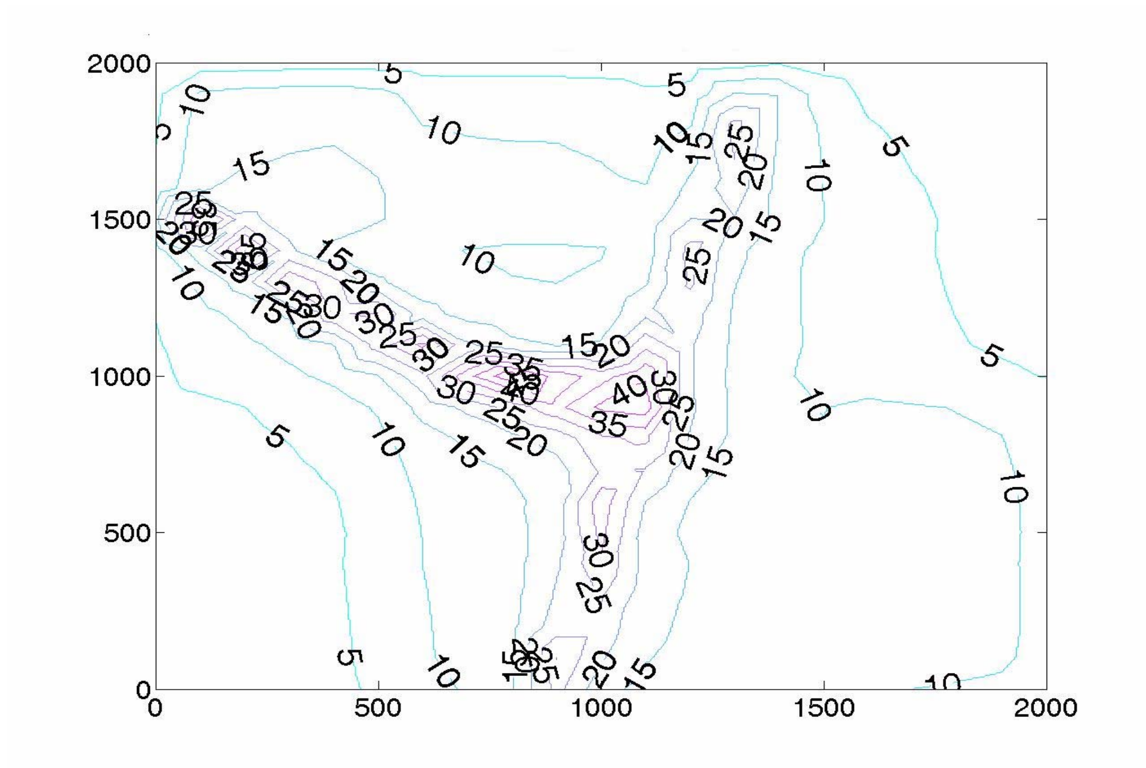


(a)

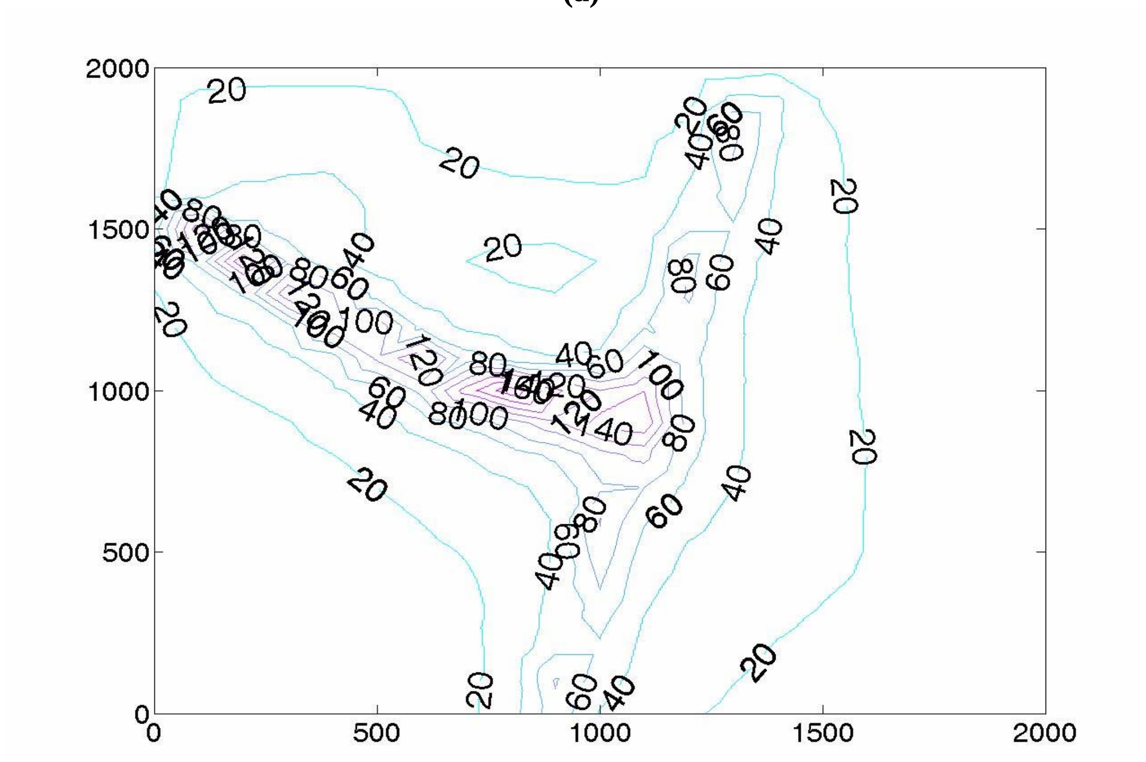


(b)

Fig5.32 Contour plots for the area of Mylapore a)NOx b)PM10

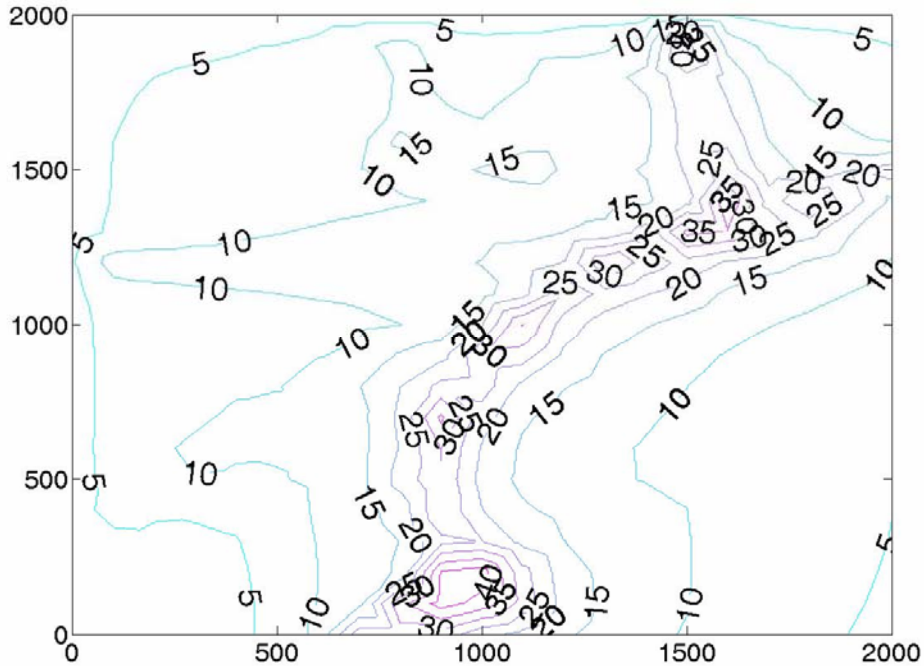


(a)

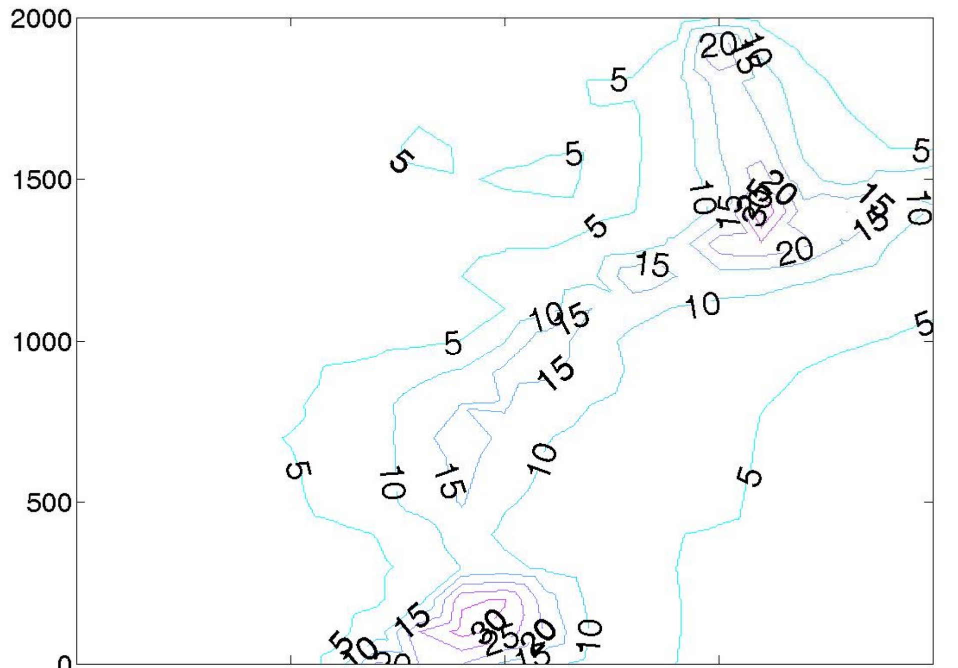


(b)

Fig5.33 Contour plots for the area of RK Nagar a)NOx b)PM10

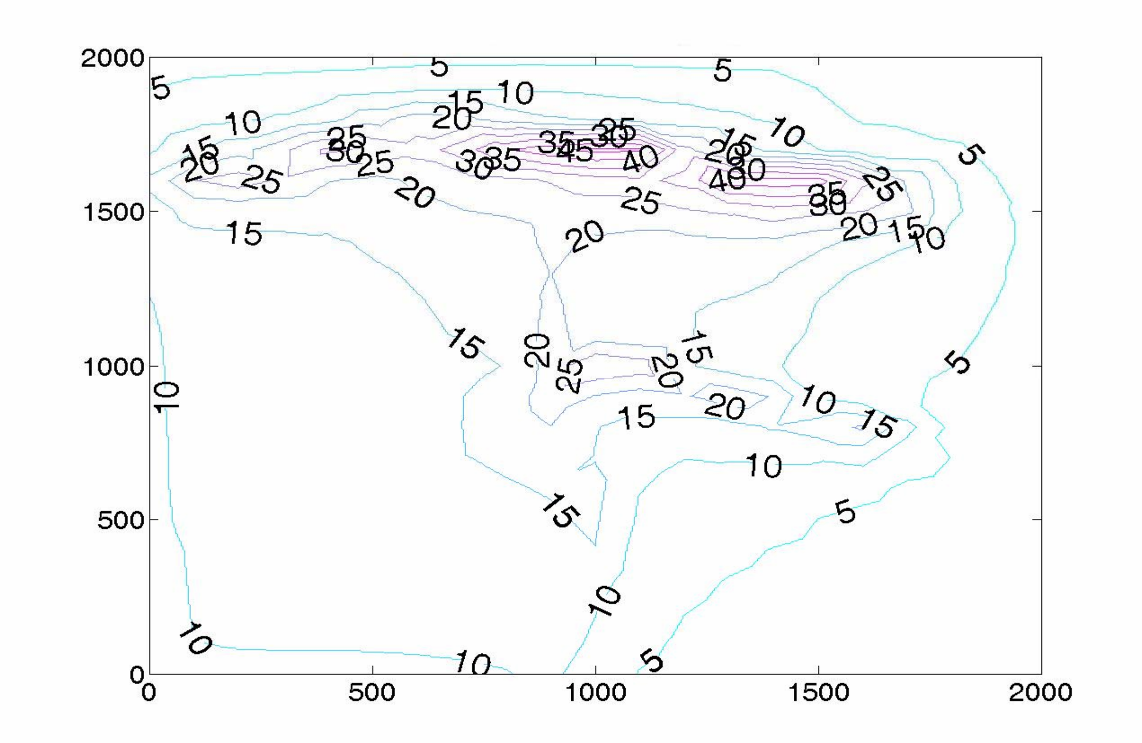


(a)

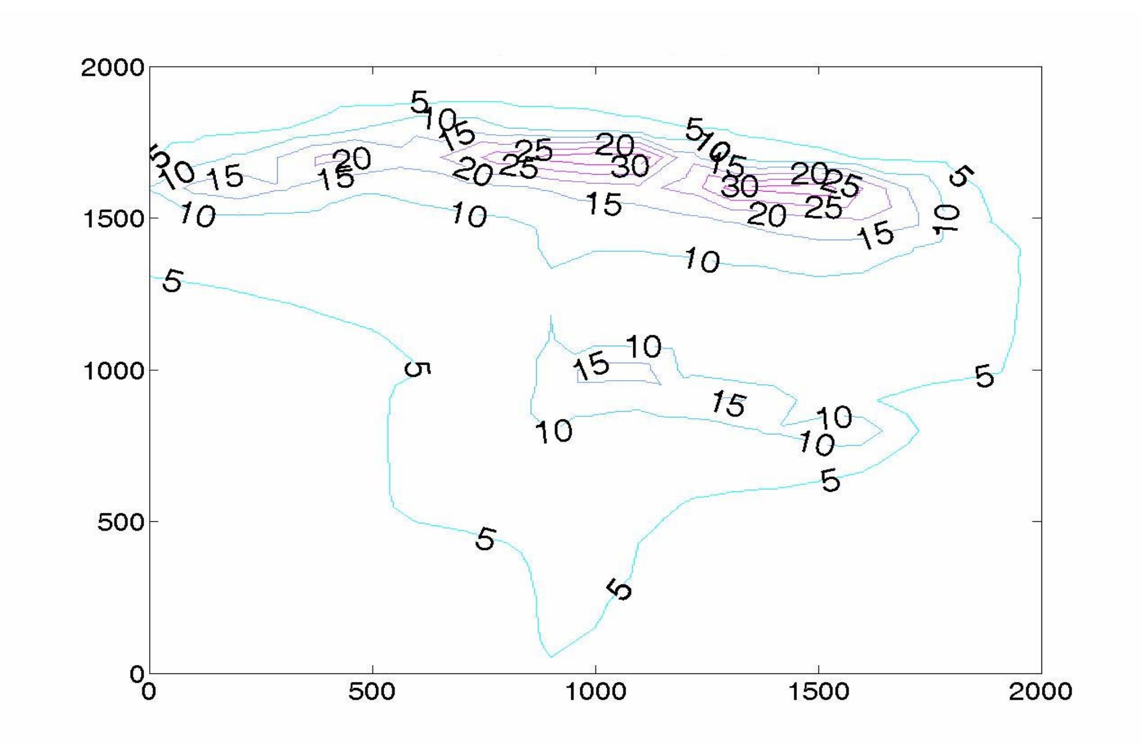


(b)

Fig5.34 Contour plots for the area of Saidapet a)NOx b)PM10



(a)



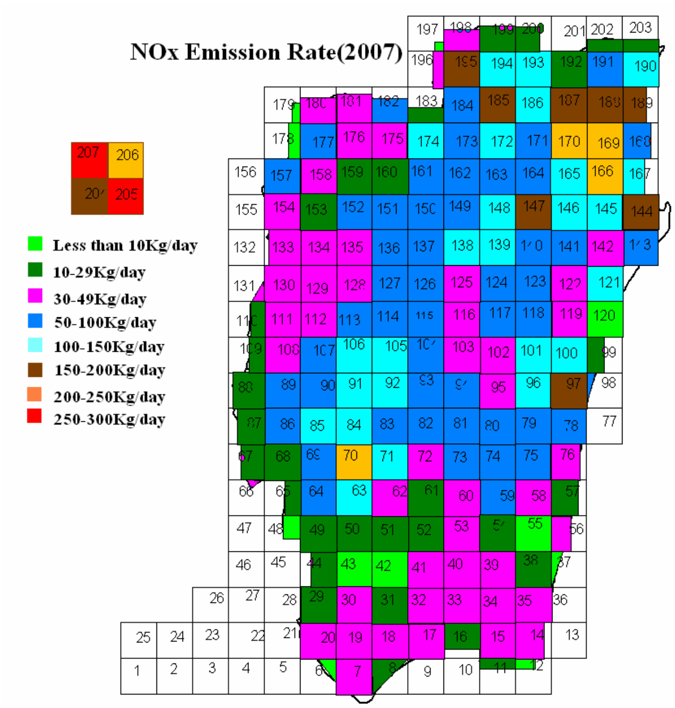
(b)

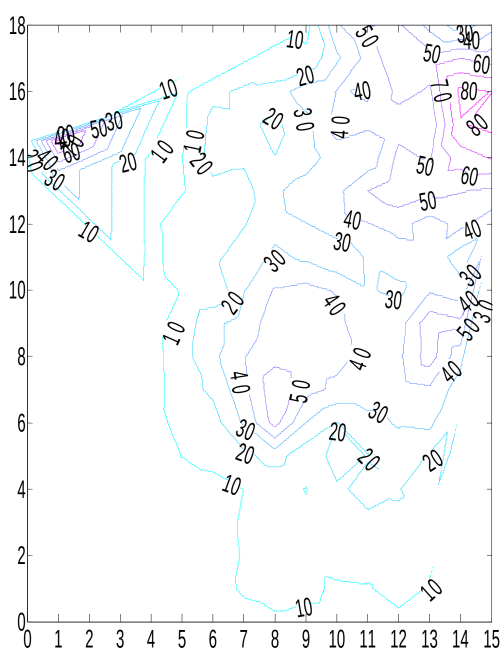
Fig5.35 Contour plots for the area of Triplicane (a)NOx (b)PM10

City level modeling

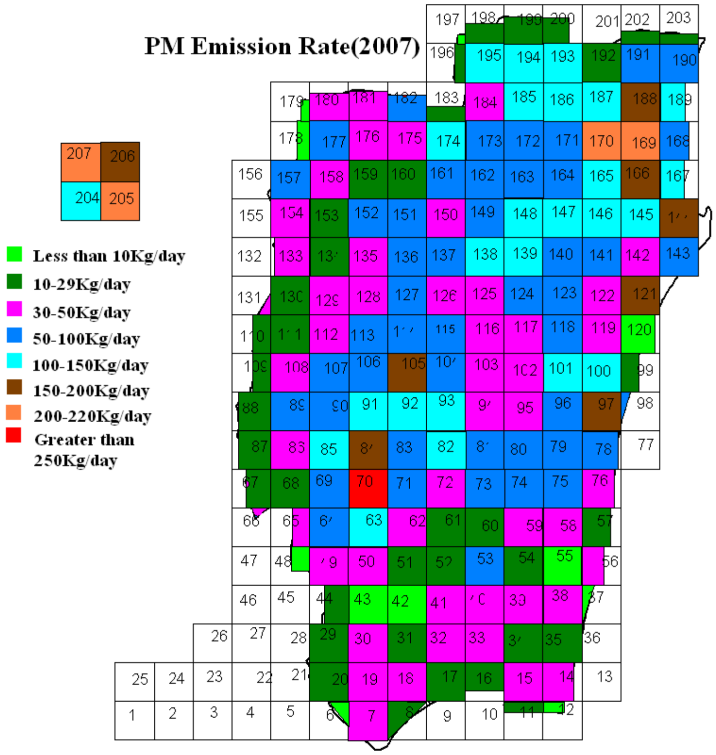
The contour plots for city level NOx and PM concentrations are given below.

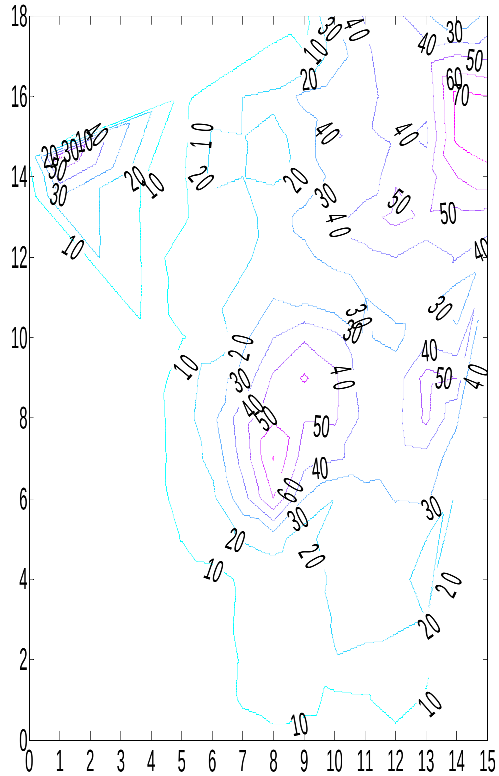
5.36 Distribution of Emission loads and concentration contour plot for the city of Chennai NOx





5.37 Distribution of emission loads for the city of Chennai, PM10





5.5 Conclusions:

Based on the comparison between the measured data and the dispersion model predictions, it can be concluded that

1. There is a general match between the concentrations predicted in the 2x2 km and the concentration measured for PM 10 and NOx. i.e. the concentration measured falls within the minimum and maximum concentrations predicted within the 2x2 km grid.
2. However, there is no one-to-one correspondence between the values predicted exactly at the monitoring site and the values measured.
3. There is no consistent over prediction or under prediction of the concentrations for PM10 or NOx.
4. Model results show that the pollutant concentrations are the worst in season 2
5. In RK Nagar, PM levels exceed the specified limits. The monthly average is higher than the annual average limit specified and in many days, the daily average is higher than the specified limit.
6. In Ambattur, the NOx level is the highest, among the 7 sites. While the monthly average is below the annual average limit specified, occasionally the daily average exceeds the specified limit.
7. City specific modeling for the worst season shows that there are four hotspots. While one is Ambattur industrial area in the western zone, there is one hotspots in the eastern zone. That is the region comprising of Royapuram, Tondaiarpet, Washermanpet and Korrukupet area, which is close to the Manali industrial zone. There are two hotspot in the southern zone, (i) in the Alwarpet area and (ii) in the K.K. Nagar area. In these locations, the predicted values are relatively high, but are within the specified national limits.

Chapter 6 Emission control options and analysis

6.1 Summary of prominent sources: The detailed emission inventory carried out in this study has identified the important sources of pollution in the seven areas chosen for the study. The important sources in the various areas are vehicles along major roads as line sources. In addition to this there are area sources in the form of paved road dust from minor roads, domestic households, emissions from restaurants , construction activities, small scale DG sets used as a back up of power supply. Emissions from industry stacks, as well as large DG sets, are treated as point sources. While the emissions from various sources yield hydrocarbons, SOx and CO we concentrate on NOx and PM 10 emissions from these sources.

In this chapter we concentrate primarily on the city level analysis of emission loads at present i.e., 2007. We also use information on the growth of population and the vehicles to estimate the loads in the years 2012 and 2017. A detailed emission inventory on the basis of our field study was carried out for each of the seven grids. This information is used to estimate the emission loads in the entire city of Chennai for the years 2007, 2012 and 2017. This was achieved by identifying various regions in the city as belonging to either kerbside or residential or industrial from a knowledge of the predominant activities in the area. The average per capita load was determined for each type of site. The per capita load was used to compute the load in all grids and make predictions of concentration levels using dispersion modeling.

6.2 Methodology followed for estimating the future growth scenario

The detailed calculations of the seven different grids was used to obtain the projections of the emission inventory estimates and dispersion modeling results for the entire city of Chennai. Table 6.1 and 6.2 contains information on the distribution of the emission loads for PM and NOx in the seven sites where the study was carried out. The tables contain the amounts of pollutants coming from the different types of sources. It is seen that as far as PM is concerned the major contributor is from the paved road dust in most sites. The NOx emissions are primarily coming from vehicular sources except in the site of R.K.Nagar where there is a dominance of contribution from the large D.G sets used in industries. More specifically the contribution of vehicular sources to PM levels is only around one-fifth of the contribution of the paved road dust emissions. The area of interest in the city consists of 172 sq km and the digital map of the city was divided into square grids of 1 x 1km each. Using this approach we obtained 202 such grids since the grids at the boundaries were having an area of less than 1 sq.km and were not perfect squares.

In each 1 sq.km grid the information of the population, green areas, water ways, major roads ,minor roads, hospitals , malls etc. was obtained. For each category of site, kerbside, residential and industrial the average emissions per person was determined in the seven different sites chosen. Information of the current population density and emission loads was used to obtain this. This was obtained for PM as well as NOx emissions. Each of the grids in the city from the 202 grids was identified as being similar to a residential location, kerbside location or an industrial location from our knowledge of the activities in the grid.

The population information was obtained from the database for each ward. The area information for each ward is known and this is converted to a population density. When a grid falls in two or more wards the weighted average information is used to calculate the population of the grid. The information of the population is then used to compute and estimate the emission load in each grid. For this, the per capita emission of a characteristic site, and the population were multiplied to determine the total load. This load is treated as an area source and is used in the dispersion modeling to obtain the concentration contours for the entire city level.

To obtain the city level Business as usual (BAU) scenarios for the years 2012 and 2017 we use the information from the Chennai Master Draft plan which has projections of population growth and vehicle growth rates. Population is expected to grow at the rate of 1.23% while the vehicles are expected to grow at the rate of 12% compounded on a yearly basis. These growth rates were assumed to be uniform in all the grids. (see Chennai Draft Master Plan)

This growth rate information is used to estimate the population and the number of vehicles of the seven sites chosen for the study. The increased number of vehicles result in an increase in the emissions of NOx and PM10. This increased load for the seven sites is computed for the years 2012 and 2017 (see Table 6.1,2). It is seen that the primary contribution to PM levels comes from paved road dust. This is around five times more than the contribution from vehicles. Similarly as far as NOx levels are concerned the contribution comes from vehicles in almost all sites. In the industrial site of Ambattur the industries have large DG sets. This results in a significant contribution from the industries to the NOx load.

The population in 2012 and 2017 are estimated from the growth rate and the population in 2007. The emissions coming from the increased vehicles are computed and the per capita emission of PM and NOx were determined again for these two years. This value is determined as an average for each category of the grid i.e., residential, kerbside or industrial. For example for the residential grid the value taken was the average of the areas Triplicane and Mylapore which are residential areas.

The per capita emission load of PM and NOx in each of the categories of the areas was determined in the BAU scenario for 2007 and this is shown in Table 6.3. The population of the grids was determined from the census data and this was used to normalize the emission load on a per capita basis. The data in this Table is a normalized load (mass per unit time per person) and is presented in this format so that it will facilitate comparison across cities.

Table 6.1 : Distribution of the contribution of various source categories to PM load in the seven grids for 2007,2012 and 2017 (All units are in kg/day)

Emission Rate PM(2007)						
Site Name	Saidapet	Adyar	Mylapore	Triplicane	R.K.Nagar	Ambattur
Vehicles	29.70	40.95	68.18	28.29	26.70	46.43
Domestic	0.99	0.89	1.06	0.96	0.34	0.23
Resturants	0.81	0.76	1.39	1.01	1.24	2.45
Bakeries	0.63	0.84	1.46	0.84	0.63	1.25
DG Sets	0.09	0.20	0.12	0.08	0.07	0.16
Industries	-	-	-	-	-	57.40
Open Burning	-	-	-	-	54.44	-
Road Dust	76.68	306.26	366.22	62.48	473.04	275.01
Construction	8.61	81.34	31.98	6.70	14.10	127.01
Total	117.52	431.21	470.41	100.36	570.55	509.94

Emission Rate PM(2012)						
Site Name	Saidapet	Adyar	Mylapore	Triplicane	R.K.Nagar	Ambattur
Vehicles	47.42	65.92	109.81	45.55	43.00	74.78
Domestic	0.99	0.89	1.06	0.96	0.34	0.23
Resturants	0.81	0.76	1.39	1.01	1.24	2.45
Bakeries	0.63	0.84	1.46	0.84	0.63	1.25
DG Sets	0.09	0.20	0.12	0.08	0.07	0.16
Industries	-	-	-	-	-	57.40
Open Burning	-	-	-	-	54.44	-
Road Dust	122.86	493.03	589.54	99.99	761.39	442.85
Construction	8.61	81.34	31.98	6.70	14.10	127.01
Total	181.42	642.96	735.36	155.13	875.20	706.12

Emission Rate PM(2017)						
Site Name	Saidapet	Adyar	Mylapore	Triplicane	R.K.Nagar	Ambattur
Vehicles	75.95	106.15	176.85	73.37	69.25	120.43
Domestic	0.99	0.89	1.06	0.96	0.34	0.23
Resturants	0.81	0.76	1.39	1.01	1.24	2.45
Bakeries	0.63	0.84	1.46	0.84	0.63	1.25
DG Sets	0.09	0.20	0.12	0.08	0.07	0.16
Industries	-	-	-	-	-	57.40
Open Burning	-	-	-	-	54.44	-
Road Dust	197.22	760.65	949.20	160.39	1225.77	713.14
Construction	8.61	81.34	31.98	6.70	14.10	127.01
Total	284.32	950.82	1162.05	243.35	1365.84	1022.08

The data in these tables represent that the primary contribution of PM emissions is arising from paved road dust in almost all categories of sites. This contributes from 60 to 90% in almost all sites. In comparison to this the contribution of PM emissions from vehicle exhaust varies from 10 to 30%. This feature has an important ramification when various control options and scenarios are considered for the control of pollution in the city of Chennai.

Table 6.2 Contribution of various source categories to pollution load of NOx in the seven sites for 2007,2012 and 2017. All units are in kg/day

Emission Rate(NOx)-2007						
Site Name	Saidapet	Adyar	Mylapore	Triplicane	R.K.Nagar	Ambattur
Vehicles	155.71	216.53	378.01	118.52	130.24	251.91
Domestic	32.00	28.53	34.03	30.93	10.92	7.41
Resturants	26.13	24.31	44.83	32.49	40.07	29.74
Bakeries	0.24	0.17	0.31	0.25	0.16	0.23
DG Sets	2.58	5.39	3.20	2.25	1.97	4.31
Industries	-	-	-	-	-	1572.35
Open Burning	-	-	-	-	20.42	-
Total	216.65	274.93	460.37	184.43	203.77	1865.96

Emission Rate(NOx)-2012						
Site Name	Saidapet	Adyar	Mylapore	Triplicane	R.K.Nagar	Ambattur
Vehicles	248.70	348.59	608.79	190.88	209.75	405.70
Domestic	32.00	28.53	34.03	30.93	10.92	7.41
Resturants	26.13	24.31	44.83	32.49	40.07	29.74
Bakeries	0.24	0.17	0.31	0.25	0.16	0.23
DG Sets	2.58	5.39	3.20	2.25	1.97	4.31
Industries	-	-	-	-	-	1572.35
Open Burning	-	-	-	-	20.42	-
Total	309.65	406.98	691.15	256.78	283.29	2019.75

Emission Rate(NOx)-2017						
Site Name	Saidapet	Adyar	Mylapore	Triplicane	R.K.Nagar	Ambattur
Vehicles	398.47	561.27	980.46	307.41	337.81	653.39
Domestic	32.00	28.53	34.03	30.93	10.92	7.41
Resturants	26.13	24.31	44.83	32.49	40.07	29.74
Bakeries	0.24	0.17	0.31	0.25	0.16	0.23
DG Sets	2.58	5.39	3.20	2.25	1.97	4.31
Industries	-	-	-	-	-	1572.35
Open Burning	-	-	-	-	20.42	-
Total	459.41	619.66	1062.82	373.32	411.34	2267.43

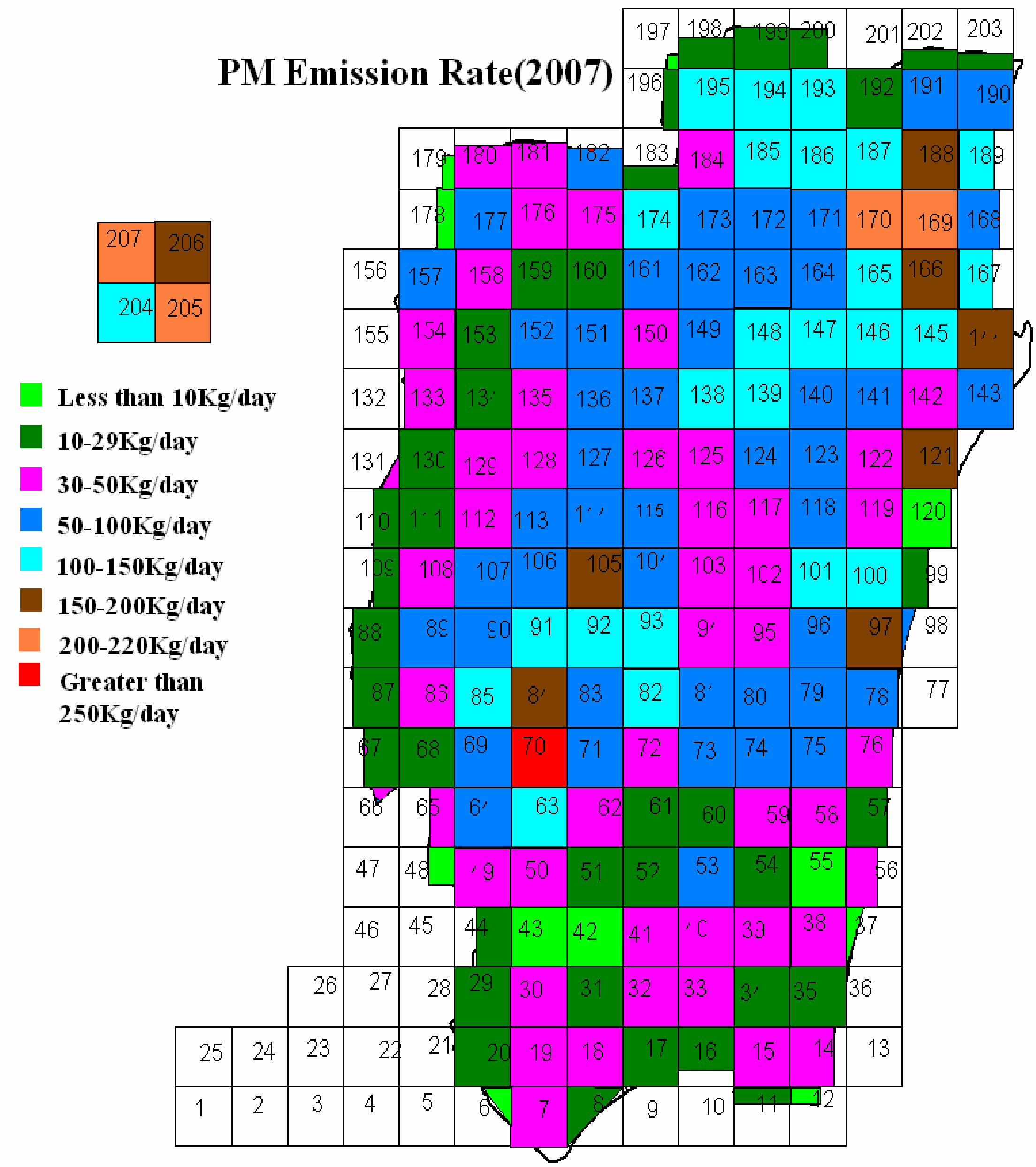
In contrast to the PM emissions the emissions of NOx arises primarily from vehicles. We see that the vehicles contribute almost 90% to the pollution in all sites except in Ambattur. In Ambattur though the emissions from vehicles is significantly high it is dominated by the emissions from the Industries which contribute almost 1572 kg/day as opposed to the contribution of 653 kg/day from vehicles. This particular aspect again has important ramifications in determining the control options and control scenarios which are most effective in reducing the pollution load in the future.

Table 6.3 Per capita emission of NOx and PM10 in the three categories of sites residential, curbside and industrial as determined from primary data analysis of the seven sites. (All units are in kg/day/person)

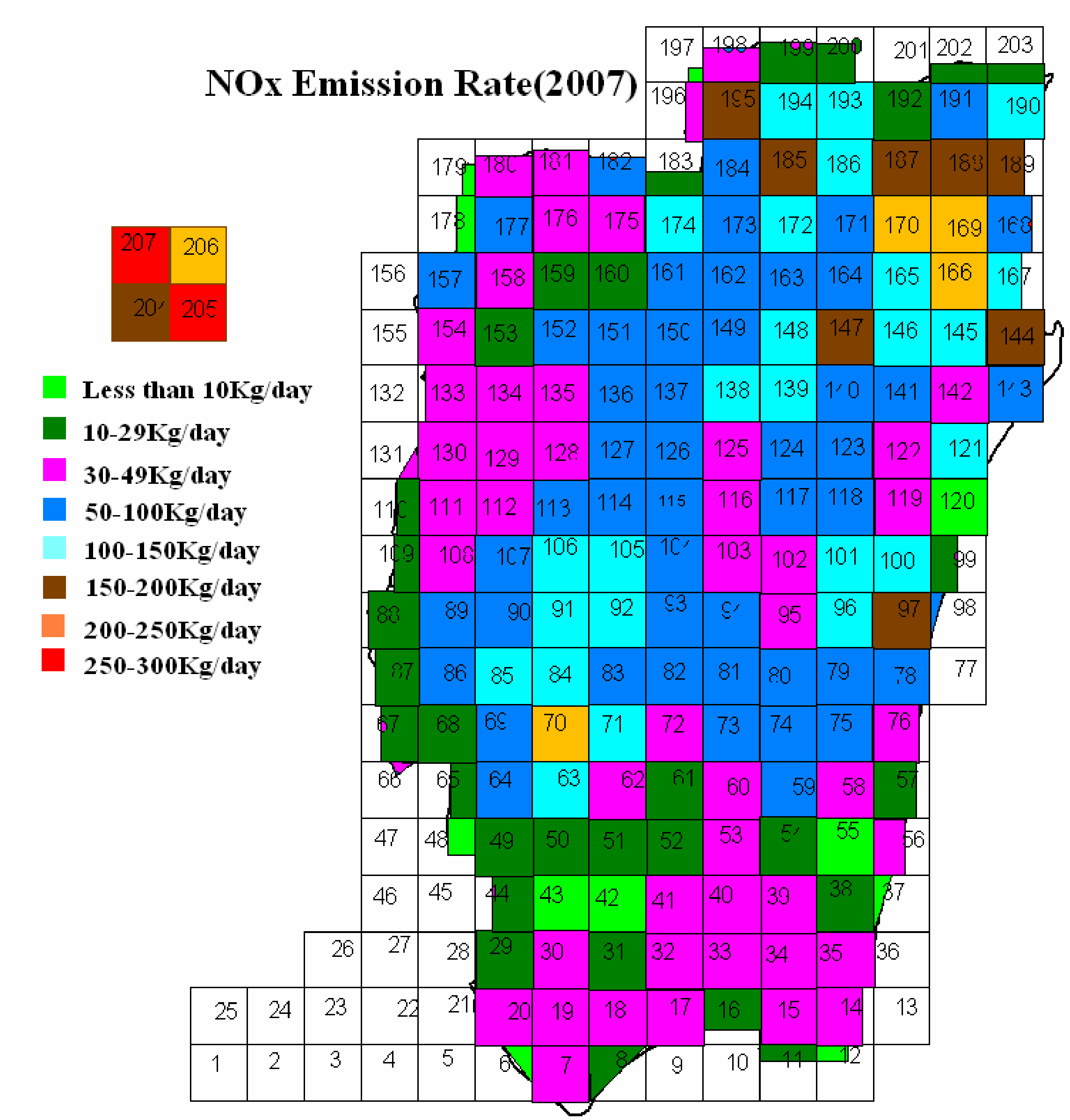
2007			
Scenarios	Residential	Kerb	Industrial
NOx	0.00187	0.00277	0.00809
PM	0.00171	0.00375	0.00423

The calculated emission loads for the city of Chennai for the years 2007, 2012 and 2017 are shown in Figures 6.1-3 The population of each of the 202 grids is estimated from information obtained from the Chennai Metropolitan Development Authority and the Chennai Master Draft Plan taking into account the growth of the population for each grid from the 2007 levels. The category of each grid is used to determine the per capita pollution load prevailing for each grid. This is then used as the basis to quantify the emissions from each grid. For each grid the per capita load is multiplied by the population to determine the load.

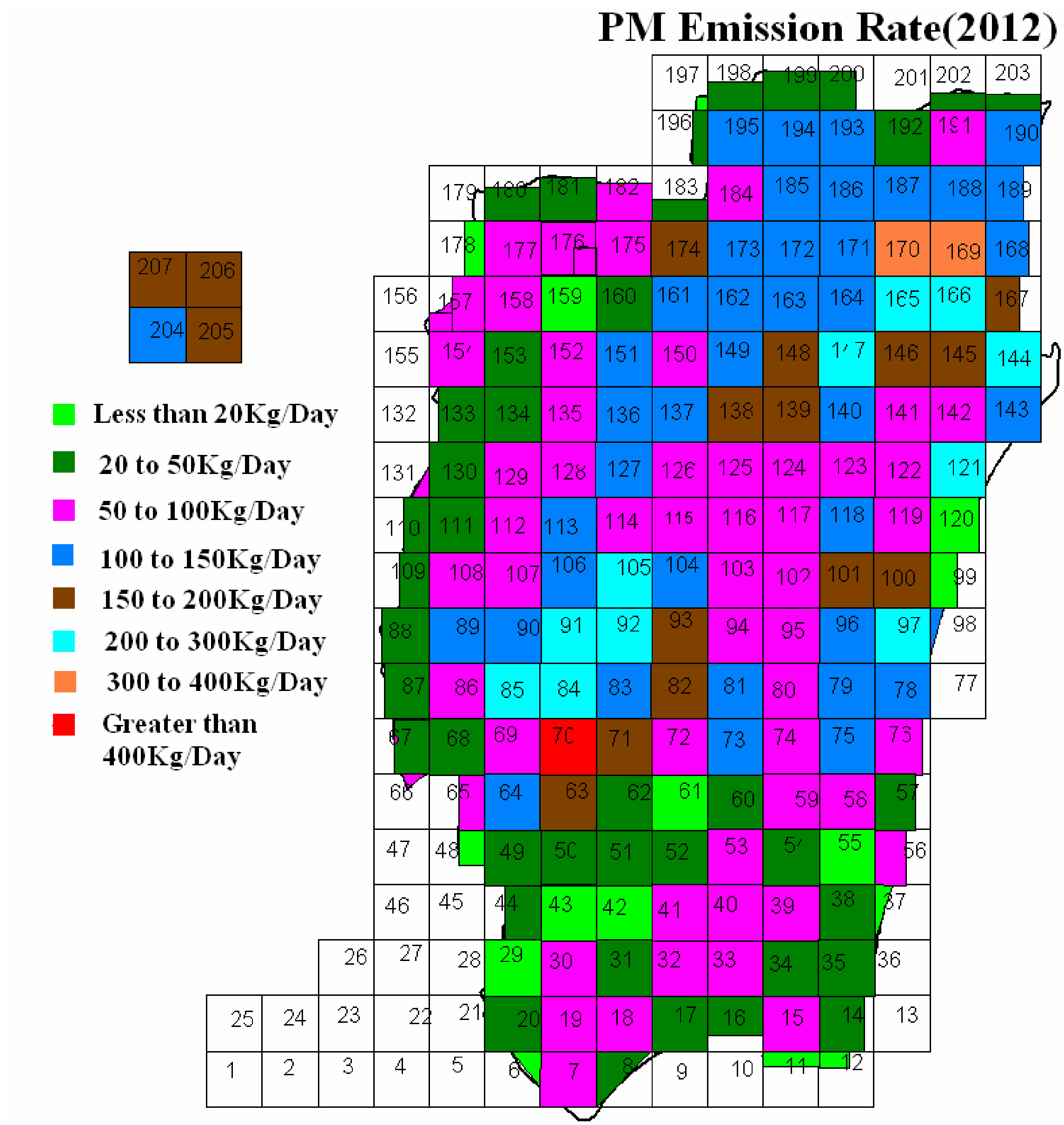
The distribution of the loads in each of the grid is shown in Fig.6.1-6.3 for the years 2007,2012 and 2017 respectively as described in section 6.2 The emissions from each grid are then transformed into the format required by ISC to obtain the concentration values of PM and NOx in the entire Chennai city to determine the BAU concentration levels for the years 2012 and 2017



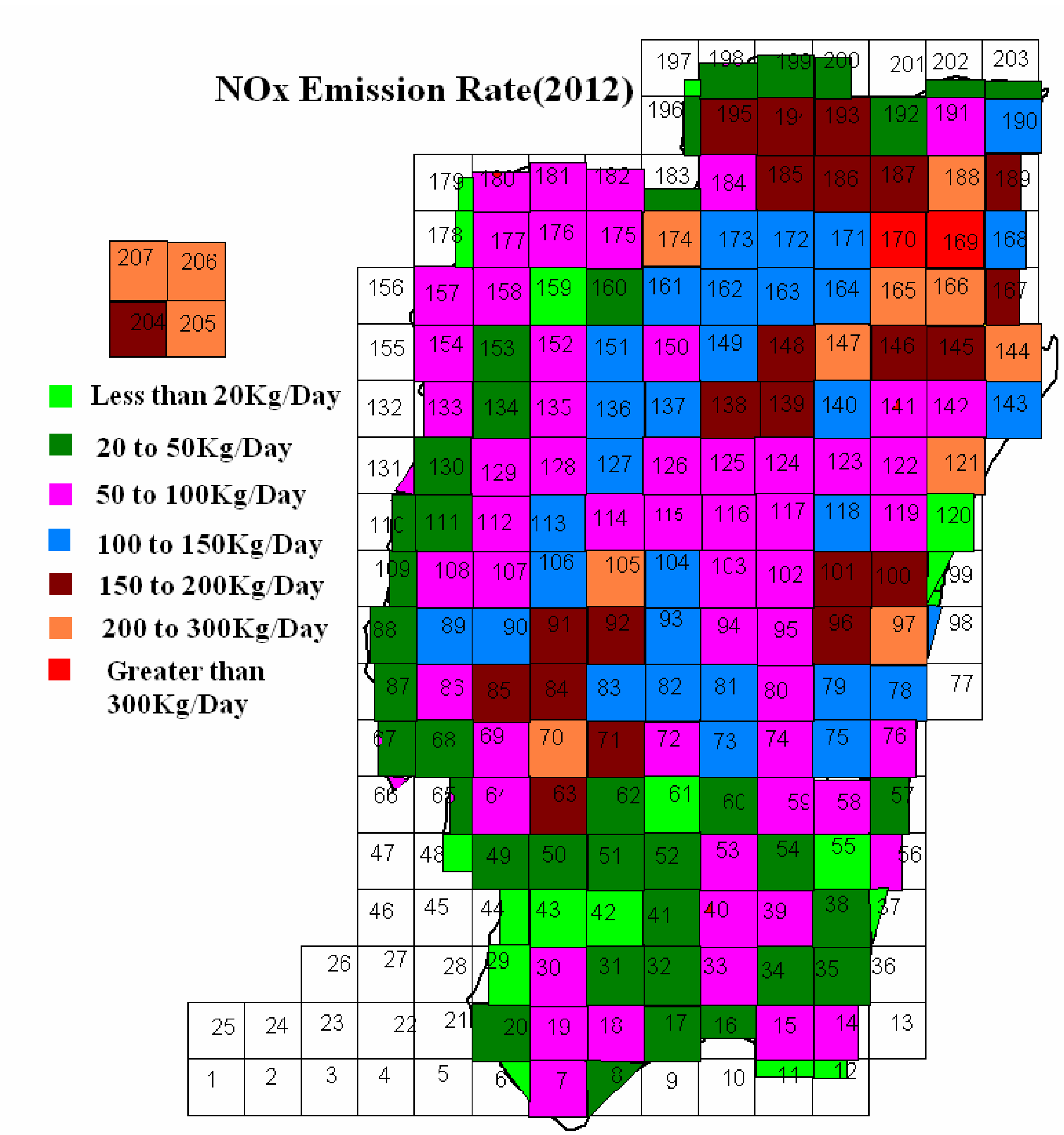
6.1(a) Distribution of emission loads for the city of Chennai, PM10, BAU, 2007



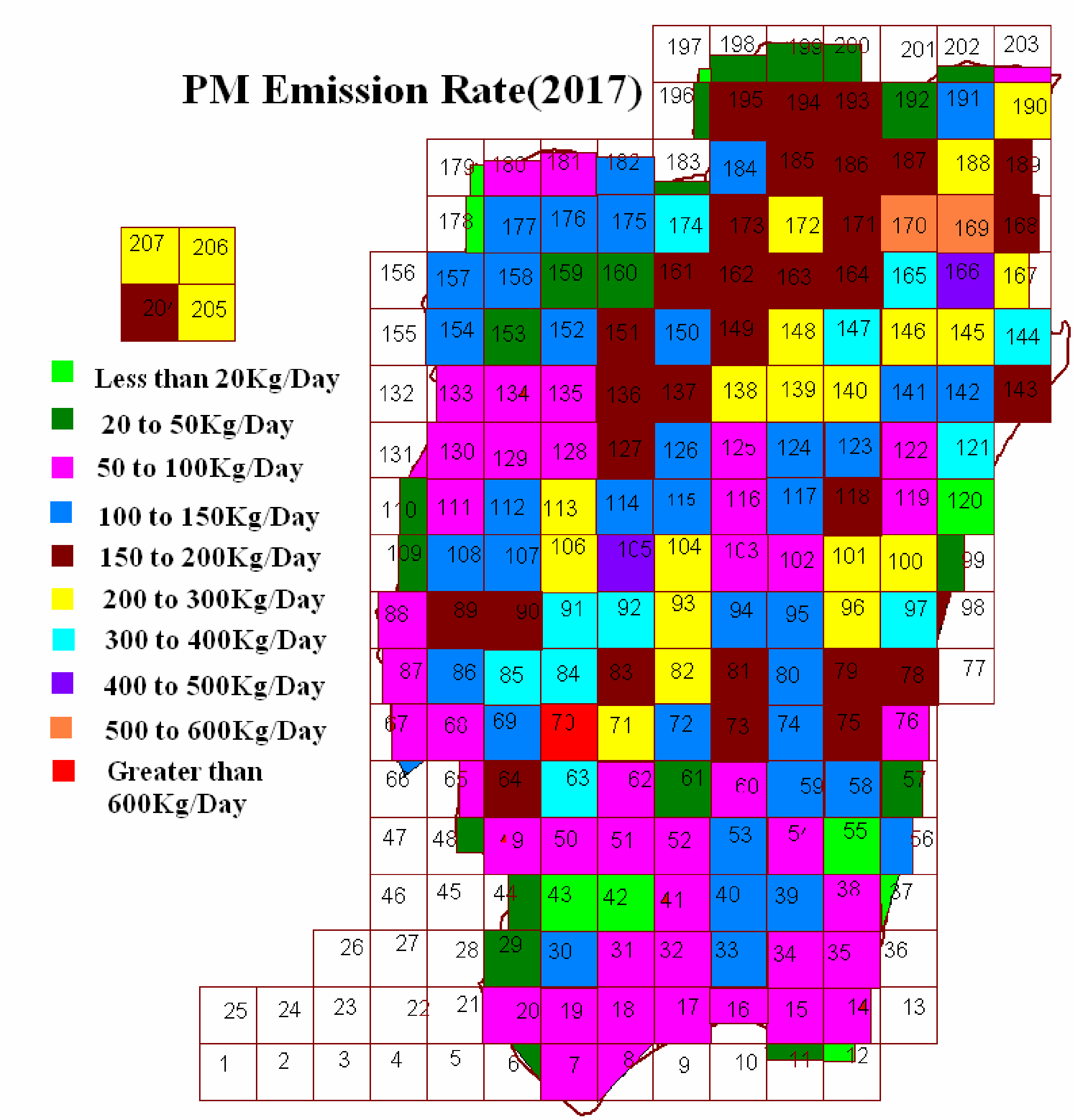
6.1(b) Distribution of Emission loads for the city of Chennai NOx , BAU, 2007



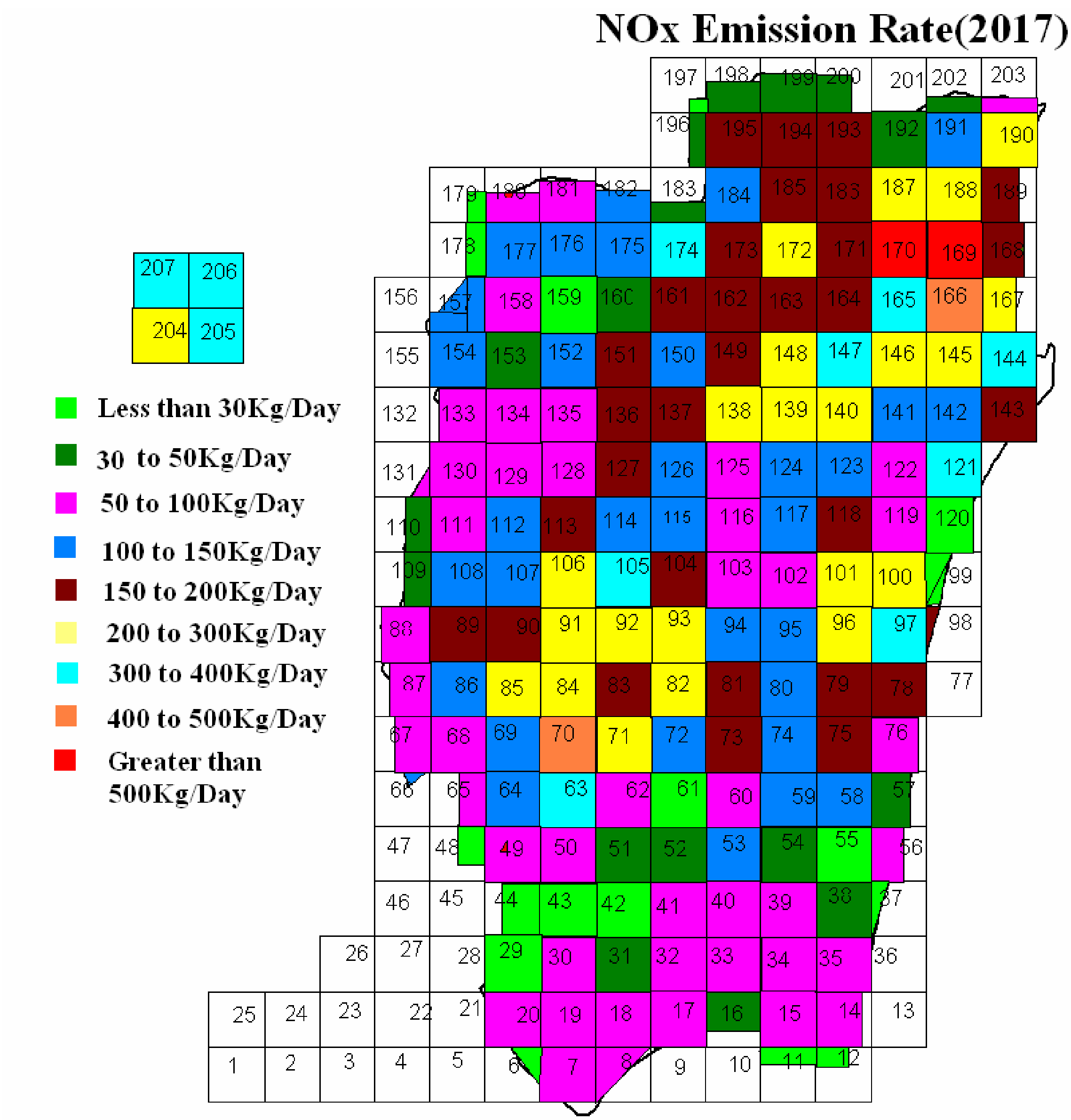
6.2(a) Distribution of emission loads for the city of Chennai, PM10, BAU, 2012



6.2(b) Distribution of emission loads for the city of Chennai, NOx, BAU, 2012



6.3(a) Distribution of emission loads for the city of Chennai, PM10, BAU, 2017



6.3(b) Distribution of emission loads for the city of Chennai, NOx, BAU, 2017

Table 6.4 Emission load of PM, NOx for 2012 for different categories of sites. BAU scenario as well as the effect of applicable control options is shown in the table with the expected reduction in emissions.

2012-PM						
Options	Residential	% Reduction	Kerb	% Reduction	Industrial	% Reduction
BAU	0.00251		0.00527		0.00582	
2012+CS1	0.00249	1.11	0.00524	0.68	0.00579	0.51
2012+Inspection	0.00250	0.60	0.00524	0.60	0.00580	0.30
2012+Point	0.00251	0.20	0.00527	0.03	0.00573	1.50
2012+OB	0.00251	0.20	0.00527	0.03	0.00572	1.67
2012+RD	0.00193	23.26	0.00407	22.79	0.00449	22.82
2012+Ban of 10yrs com vehicles	0.00219	12.92	0.00468	11.22	0.00520	10.61
2012+Ban of 15 yrs private vehicles	0.00199	20.87	0.00420	20.33	0.00470	19.21
2012+Improvement of Public Transport	0.00249	0.86	0.00519	1.59	0.00562	3.31

2012-Nox						
Options	Residential	% Reduction	Kerb	% Reduction	Industrial	% Reduction
BAU	0.00260		0.00383		0.00847	
2012+CS1	0.00241	7.28	0.00356	7.05	0.00828	2.28
2012+Inspection	0.00253	2.61	0.00373	2.56	0.00840	0.85
2012+Point	0.00260	0.00	0.00383	0.00	0.00616	27.29
2012+OB	0.00260	0.00	0.00383	0.00	0.00843	0.50
2012+RD	0.00260	0.00	0.00383	0.00	0.00847	0.00
2012+Ban of 10yrs com vehicles	0.00221	14.93	0.00330	13.79	0.00807	4.75
2012+Ban of 15 yrs private vehicles	0.00217	16.47	0.00308	19.54	0.00804	5.10
2012+Improvement of Public Transport	0.00247	4.74	0.00366	4.43	0.00833	1.65

Table 6.5 Emission load of PM, NOx for 2017 for different categories of sites. BAU scenario as well as the effect of applicable control options is shown in the table with the expected reduction in emissions.

2017-PM						
Options	Residential	%Reduction	Kerb	%Reduction	Industrial	% Reduction
BAU	0.00374		0.00737		0.00826	
2017+BSIV	0.00362	3.18	0.00722	2.10	0.00814	1.51
2017+BSIV,V	0.00355	4.96	0.00715	2.95	0.00809	2.11
2017+BSIV,VI	0.00355	4.96	0.00715	2.95	0.00809	2.11
2017+Inspection	0.00370	0.94	0.00732	0.70	0.00823	0.41
2017+Point sources	0.00374	0.00	0.00737	0.00	0.00810	1.98
2017+Open burning	0.00374	0.00	0.00737	0.00	0.00808	2.22
2017+Road dust	0.00195	47.79	0.00388	47.36	0.00424	48.69
2017+Ban of 10yrs com vehicles	0.00325	12.99	0.00650	11.82	0.00732	11.42
2017+Ban of 15 yrs private vehicles	0.00294	21.29	0.00581	21.18	0.00658	20.37
2017+Improvement of Public Transport	0.00370	0.83	0.00748	-1.50	0.00797	3.51

2017-Nox						
Options	Residential	%Reduction	Kerb	%Reduction	Industrial	% Reduction
BAU	0.00372		0.00545		0.00927	
2017+BSIV	0.00291	21.63	0.00430	21.22	0.00845	8.87
2017+BSIV,V	0.00283	23.75	0.00418	23.37	0.00837	9.69
2017+BSIV<VI	0.00275	26.05	0.00407	25.46	0.00828	10.67
2017+Inspection	0.00359	3.37	0.00528	3.19	0.00914	1.40
2017+Point sources	0.00372	0.00	0.00545	0.00	0.00492	46.93
2017+Open burning	0.00372	0.00	0.00545	0.00	0.00920	0.76
2017+Road dust	0.00372	0.00	0.00545	0.00	0.00927	0.00
2017+Ban of com veh.	0.00313	15.75	0.00466	14.56	0.00866	6.58
2017+Ban of priv. veh.	0.00307	17.36	0.00433	20.61	0.00861	7.12
2017+Improvement of Public Transport	0.00353	5.02	0.00520	4.61	0.00906	2.29

6.3 Control Options: The pollution load as well as concentration levels of various pollutants increases with successive years. To ensure that the levels are withing permissible limits it is necessary to take certain control actions to reduce emissions so that concentration levels are within limits which will not affect human health. These options can accrue from an improvement in technology or through a management option being exercised or both**.**

Several control options can be visualized for the different categories of sources. For vehicles these include the implementation of BS IV norms, BS V norms, BS VI norms, conversion to electric vehicles, using hybrid vehicles, blending with ethanol, shifting to bio-diesel, shifting to CNG/LPG for commercial vehicles, blending of hydrogen and CNG, retrofitment of diesel oxidation catalyst in public transport, retrofitment of diesel particulate filter in public transport, banning of older private and commercial vehicles, synchronization of traffic signals, improvement of public transport, ban on open burning, fuel change in industries, cleaner technology in industry, fugitive emission control, particulate emission control, converting unpaved road to paved roads, sweepng and monitoring mechanisms etc. All these options were analysed. Some of these options are not relevant to Chennai city. For example by the nature of the weather there is no open burning in Chennai city, where it is always warm. So the ban on open burning is not an effective control option. Similarly households use LPG for cooking as the government has proactively decided to give an LPG cylinder to all households this connection. Some of the control options like the actions for point sources will have only a local effect and not affect the air quality throughout the city of Chennai.

We have determined the per capita emission when various options are exercised. This is a parameter which can indicate the effectiveness of the option exercised and is a normalized factor which helps us compare across various cities. This is indicated in Table 6.4-6.5. This table contains information of how this per capita emission parameter changes when the different control options are implemented. This then is used to calculate the emission loads in all the grids of the city and the concentration values are obtained using the dispersion models.

The calculations given in these Tables depict the percentage change in the per capita emissions when a control option is exercised. This is calculated for the three different characteristic grids and are shown in Tables 6.4-5. As a consequence of this analysis it is seen that certain types of sources have an affect only on certain types of grids. Thus point sources effect only the industrial grids and not the residential or kerbside grids. From Tables 6.4-5 it is seen that as far as PM emissions are concerned, the most significant and sensitive control options are those which involve controlling road dust emissions, the ban on older commercial vehicles and the ban on the private vehicles. This can be easily understood as being consistent with the contributions of various categories of sources to the loads as seen in Tables 6.1-2. Since paved road dust makes a significant contribution to the pollution levels, it has to be controlled. Similarly the ban on commercial vehicles results in lowering the average weight of the vehicles on the roads. Consequently there is decrease in the PM emissions from the exhausts as well as the indirect contribution which arises from the road dust emissions. The contribution to the control when private vehicles are banned can be explained along similar grounds.

It is also seen that as far as NOx emissions are concerned the options which involve control of vehicular emissions are effective. Thus the introduction of BS IV norms in 2010 and introducing BSV norms in 2015 and introduction of BSVI norms in 2015 are effective in lowering the NOx emissions from vehicles. This is reflected in the percentage values given in the Tables. When discussing the control options one must also keep in mind the ground realities. For example, certain options like ban on open burning may not be very effective since in general in Chennai we do not have open burning except in one or two areas where there is solid waste to be treated.

As discussed earlier, the pollution loads in all the grids of the city using the information of the vehicular growth and population growth were determined. This is then used to calculate the total emission load in the city of Chennai for the different control options. This is reported in Tables 6.6-7 where we show the total emission load as well as the reduced value and the percentage reduction when individual options are exercised. It is seen that as far as PM emissions are concerned the load is reduced if we control paved road dust and ban older commercial and private vehicles. Similarly as far as NOx emissions are concerned, the control of vehicular emissions by way of adopting higher BS standards is effective.

Different control scenarios and their effect on pollution loads were analyzed, so that one can determine which combination of control options need to be adopted for controlling the two parameters of PM and NOx levels in the atmosphere. The results of these calculations for the pollution load in the city of Chennai are shown in Tables 6.6-7. These help us determine the quantitative effect of the different control options

Table 6.6 Emission Load for individual options for the entire Chennai city for the year 2012

Options	NOx(Kg/Day)	% Reduction	PM(Kg/Day)	% Reduction
2012 BAU	17112		16890	
2012+BSIV	16007	6.46	16768	0.72
2012+Inspection	16712	2.34	16817	0.43
2012+Point	16433	3.97	16863	0.16
2012+Open Burning	17109	0.01	16860	0.18
2012+Road Dust	17112	0.00	13007	22.99
2012+10yrs com vehicle ban	14855	13.19	14832	12.18
2012+15yrs private vehicle ban	14475	15.41	13429	20.49
2012+improvement of Public Transport	16367	4.35	16684	1.22

Table 6.7 Emission Load for individual options for the entire Chennai city for the year 2017

Options	NOx(Kg/Day)	% Reduction	PM(Kg/Day)	% Reduction
2017 BAU	25090		26255	
2017+BSIV	20055	20.07	25524	2.78
2017+BSIV,V	19551	22.07	25118	4.33
2017+BSIV,VI	19053	24.06	25118	4.33
2017+Inspection	24313	3.10	26014	0.92
2017+Point	23733	5.41	26204	0.19
2017+Open Burning	25089	0.00	26198	0.22
2017+Road Dust	25090	0.00	13705	47.80
2017+10yrs com vehicle ban	21473	14.42	22935	12.65
2017+15yrs private vehicle ban	20864	16.84	20674	21.26
2017+improvement of Public Transport	23936	4.60	26058	0.75

The impact of the various options that can be exercised to reduce the atmospheric pollution are discussed below.

6.3.1. Line source control options and analysis: The various options for the line or vehicular sources are discussed here. All the options were analyzed to determine their impact on the pollution or emission loads. It was found that some of the options had a very limited impact on the pollution loads. The reduction in pollution loads because of these options is not depicted. The options which had a minimal impact are introduction of electric vehicles, shifting to bio-diesel, going over to ethanol blended fuels and shifting to hybrid vehicles. The estimated number of vehicles which would come under these categories is very small compared to the actual numbers plying on the roads today and hence their impact is small.

Similarly, the impact of emission load for the other control options, i.e., introduction of BS IV (in 2010) (CS1) and BS V(in 2015) (CS2) were calculated. The effect of introducing BS VI in 2015 (CS3) directly was also calculated to determine their effect on emission loads. The decrease in the loads of the PM10 emissions and NOx emissions for each of these options is determined on a per capita basis and is given in Table 6.5-6 for each category of grids.

The results of the control policy on the pollution load of PM10 are discussed below. It is seen that if CS1 is exercised, (i.e. the policy of BS IV norms being implemented in 2010), the per capita change in the PM emissions is only around 1%. Hence this measure per se will not result in any significant change in pollution levels. Similarly it is seen that the reduction in the load is very insignificant if this control option is combined with inspection and maintenance of vehicles, reduction in emissions from point sources and open burning (only around a 5% decrease in the pollution load). However if the emissions from road dust are reduced, it is seen that there is a drastic reduction of around 20 to 25% of the emissions. It is found that when 10 year old commercial vehicles and 15 year old private vehicles are banned, the reduction in the emission load is close to 15-20 % for the year 2012.

It is found that in the year 2017 similar trends are exhibited. Here the option of introducing BS V norms for the vehicles in 2015 was also considered, but this does not have a significant effect since the contribution of the vehicular sources to the PM levels is much lower than that of the road dust. Here again it is seen that mitigating the load from road dust and banning the older commercial vehicles and private vehicles can give rise to a significant improvement in the pollution load in the city of Chennai. This fact is not very surprising as it is found that the effect of the vehicles on the emissions of PM are not as significant as that of the road dust emissions (please refer to Table 6.1-2). In fact when the road dust emissions are reduced it is seen that there is a significant reduction in the pollution load. It is also found that the option of banning old vehicles has a significant effect on pollution loads and this effect has been considered to estimate the pollution load. This is an effective measure since the percentage of vehicles falling in this category is much higher.

Various control options for NOx in the years 2012 and 2017 are considered below. As can be seen from the contribution of various sources towards the NOx load, the vehicles contribute to a large extent to the pollution levels for NOx. Hence it is anticipated that the NOx levels would improve by shifting to tighter emission norms stipulated by BS IV and BS V. It is seen that the percentage reduction in the NOx emissions is more than that of the PM10 emissions and this is consistent with the expectations. Banning the older commercial vehicles and private vehicles results in a decrease in the load of around 15%. Shifting to BS IV norms in 2010 results in a reduction of around 5% in the load for 2012 but a reduction of around 20% in 2017. This can be explained by the fact that now more vehicles would be compliant to the stricter norms in 2017.

6.3.2 Area source options: The contribution of the area sources i.e. domestic sources, restaurants , malls etc is minimal towards both PM and NOx levels. We find that the control options for these sources i.e. towards reducing open burning etc will not have a significant effect in the city level picture. This is because they do not contribute to pollution load extensively in Chennai where the weather is warm round the year. However in the local sense i.e., the grids where these are predominant sources of pollution they would have an important effect. Including these effects in the city level picture may lead to incorrect conclusions. Similarly control actions on construction activities have a local and only an ephemeral effect.

6.3.3 Point source control options: The sources from points are essentially emissions from chimney stacks of industries. These again are present only in some distinct grids in the city of Chennai. There are a few grids in the industrial area where we find that point sources have a dominant contribution. The effect of point sources is hence likely to have an effect only locally in these areas and not throughout the city. One should hence be careful in interpreting the results of these options in the city wide scenario.

Table 6.8 Concentration levels of NOx for the years 2012 and 2017 at ten locations (hot spots) where the concentration levels are maximum. The location X,Y coordinate and the concentrations in μg/m^3 is shown for different relevant individual options.

X	Y	2012BAU Conc.	2012 (BSIV) Conc.	2012(Ban of com vehicles) Conc.	2012(Ban of private vehicles) Conc.
15000	15000	120.48	112.08	103.22	101.13
14000	15000	114.64	106.63	98.12	96.31
14000	16000	110.52	104.22	97.51	96.13
15000	16000	106.53	100.38	93.83	92. 46
15000	14000	103.20	95.95	88.45	85.90
14000	14000	95.01	88.28	81.16	79.59
13000	9000	83.52	77.55	71.24	69.69
12000	13000	83.42	77.48	71.17	69.80
8000	7000	82.75	76.95	71.19	67.27
1000	14500	82.64	80.64	78.47	78.13

X	Y	2017BAU Conc.	2017(BSIV) Conc.	2017(BSIV,V) Conc.	2017+Ban of comm.vehicles Conc.	2017(Ban of private Vehicles) Conc.
15000	15000	180.99	142.71	135.10	153.31	149.79
14000	15000	172.25	135.78	128.53	145.77	142.89
14000	16000	155.81	127.15	121.42	134.95	132.72
15000	14000	155.47	122.46	115.91	131.82	127.76
15000	16000	150.80	122.79	117.20	130.42	128.22
14000	14000	143.35	112.75	106.67	121.15	118.65
13000	9000	126.52	99.32	93.92	106.84	104.36
12000	13000	126.15	99.10	93.72	106.52	104.34
8000	7000	125.15	98.64	93.36	106.67	100.41
13000	8000	122.95	96.49	91.23	103.80	101.42

The reduced emission loads for the different control options have been investigated and dispersion modeling was employed to determine the NOx and PM10 concentration levels. These are estimated at ten hot spots in the city of Chennai where the concentration levels are the highest. The weather data chosen for the simulation was one which gave us the worst case scenario (highest concentration levels). The values of the concentrations at these locations (Table 6.8) shows that we have a marginal reduction in the NOx concentrations at the hot spots for the year 2012 when BSIV norms are introduced. This is because the percentage of vehicles on which these norms will be applicable are very small, i.e., only those which were added in the last two years. In contrast to this the NOx concentrations reduce significantly when we ban old commercial and private vehicles. This is to be expected since the number of vehicles which would be off the road and which are highly polluting will be now significant. For the year 2017 however the options of introducing better vehicles complying to higher standards as well as banning the older and more inefficient private and commercial vehicles are equally effective i.e. result in approximately a decrease of 15 to 25%. This is so because the number of vehicles which will comply to the higher standards is now significant as opposed to the year 2012.

Table 6.9 shows the effect of individual control options on PM 10 levels at ten hot spots. For the year 2012, the actions of controlling road dust emissions is effective to the tune of 25%. The ban on commercial vehicles results in a decrease in concentration levels due to the secondary emissions of the road dust that they contribute. This however results in only a 15% reduction. The ban on the older private vehicles results in slightly better control of PM levels as opposed to the ban on commercial vehicles. For the year 2017, cleaning the roads results in an almost 50% reduction of the pollution levels where as the ban on commercial vehicles and private vehicles results in a reduction to the tune of only 15%. The effects of the other control options were found to be less significant and have a lower impact on the pollution levels.

Table 6.9 Concentration levels of PM10 for the years 2012 and 2017 at ten locations (hot spots) where the concentration levels are maximum. The location X,Y coordinate and the concentrations in microgram/m3 is shown for different relevant individual scenarios.

X	Y	2012BAU Conc.	2012+Road Dust control Conc.	2012+Ban of Commercial Vehicles Conc.	2012+Ban of private vehicles Conc.
15000	15000	115.92	89.18	101.31	91.96
14000	15000	109.76	84.42	95.88	87.08
8000	7000	105.54	81.44	93.44	84.04
15000	14000	101.18	77.90	88.54	80.24
14000	16000	97.78	75.26	85.84	77.88
15000	16000	94.70	72.88	83.11	75.40
14000	14000	91.64	70.48	80.04	72.69
9000	9000	90.96	70.20	80.56	72.44
8000	6000	90.89	70.06	80.09	72.27
8000	8000	87.15	67.25	77.17	69.40

X	Y	2017BAU Conc.	2017+Road dust control Conc.	2017+Ban of Comm. Vehicles Conc.	2017+Ban of Private Vehicles Conc.
15000	15000	182.77	95.35	159.05	143.71
14000	15000	173.36	90.37	150.79	136.34
15000	14000	158.89	83.07	138.40	124.88
8000	7000	158.70	83.39	139.59	125.05
14000	16000	152.93	79.47	133.54	120.59
15000	16000	148.21	77.04	129.39	116.85
14000	14000	144.75	75.48	125.89	113.81
8000	6000	139.04	72.87	121.80	109.47
9000	9000	136.62	71.80	120.21	107.66
8000	8000	130.99	68.83	115.23	103.22

Summary and Conclusions

The primary contribution to NOx comes from vehicular sources and to PM10 comes from the road dust emissions. The per capita emissions of each variable is also determined to allow a fair comparison across cities. The pollution load was determined for the years 2012 and 2017.

Different control options were analyzed and only some of these were found to have a significant effect. Thus for example the cleaning of the roads gave rise to a significant reduction in the pollution loads in the PM while the actions on vehicles gave a significant reduction in pollution loads of NOx.

The approach used in this chapter allowed us to determine the variables which are most effective to control the pollution levels at the hot spots. For this dispersion model was used to identify ten points where the pollution levels were high in the entire city. The reduction at these points were analyzed and this gave us insight into the reduction which would prevail throughout the city when these critical options were analyzed.

Chapter 7: Prioritization of control options

7.1 Dispersion modeling for select options for 2012 and 2017.

The various options were examined in detail for their effect on emission loads in the previous chapter. It was found that some of the options had a very negligible effect on the emission loads of PM and NOX. Keeping this in mind few combinations of select few control options (for which one would expect a significant impact on the concentration levels) are evaluated. A combination of control options is called a scenario. Different control scenarios and their effect on the air quality are discussed here. This helps one to identify scenarios which will enable one to meet the air quality standards in the future.

For each option, the emission loads of PM and NOX in each of the grids of Chennai city have been computed, using the methodology discussed in the earlier chapter. The different sources were treated as point, or line or area sources and the concentration contours for the city of Chennai were obtained at several points in the region of interest. The results of these calculations are now depicted as contour plots. Ten hot spots where the concentrations are a maximum are also identified. If the concentration of the ten hot spots can be controlled to within permissible limits, the concentrations everywhere else will also be within permissible limits. The results of the dispersion models are also depicted as contour plots for the sake of completeness.

The total emission loads for the city of Chennai in kg/day are given below. This information for the various control scenarios for the year 2012 and then for the year 2017 is given in Table 7.1-2. It is seen that as far as PM10 is concerned, the most effective options are those which involve control of road dust emissions and banning older commercial vehicles and private vehicles. As far as NOx emissions are concerned, the control of vehicular emissions plays a dominant role again.

As in the earlier chapter, the normalized emissions under the different scenarios for each class of site, residential, kerbside or industrial are calculated. These are shown in Tables 7.3-4. This normalized information helps us to compare values across different cities.

The dispersion model results were evaluated for different scenarios. The results of these scenarios are shown in the form of contour plots. In these plots the x-axis and y-axis are in kilometers and the concentration levels are indicated in $\mu g/m^3$. Figures 7.1-7.3 depict the contour plots for PM and NOx for the Business as Usual scenario for the years 2007, 2012 and 2017 respectively. It is seen that as far as PM10 levels are concerned the maximum values in these years in the city is predicted as 60,110 and 160 $\mu g/m^3$ respectively. The average values which are predominant in the region for these three years are in the range of 50,75 and 100 respectively.

As far as the NOx concentrations are concerned, the maximum values are 80, 110 and 160 $\mu g/m^3$ respectively for the three years of 2007, 2012 and 2017 in the BAU. For 2007, the maximum concentration of NOx and PM10 predicted are 80 and 70 $\mu g/m^3$ respectively. For 2012, the maximum concentrations of NOx and PM10 predicted are 110 μg/m^3 and for the year 2017, the maximum concentration of NOx and PM10 are estimated to be 160 μg/m^3. Having determined the location of the hot spots for these two parameters we now consider the effect exercising different options will have on the concentration levels.

Tables7.5-8 contain the concentration levels predicted at the hot spots for the BAU and the different control scenarios. The location of the hot spots is also indicated by specifying the co-ordinates. In each table the ten maximum values of the concentrations are indicated for the BAU as well as different control scenarios. For purposes of brevity in representing information in the Table, control option numbers are used, which are described now

Control Option Number	Description
1	Adoption of BSIV norms
2	Adoption of BSV norms
3	Adoption of BSVI norms
4	Inspection and Maintenance of Vehicles
5	Point sources control
6	Ban on open burning
7	Ban on old commercial vehicles
8	Ban on old private vehicles
9	Improvement in public transport system
10	Control of Road dust

As far as NOx levels are concerned, the maximum levels observed in the year 2012 is 120 μg/m^3. When one adopts BSIV norms, and in addition implement inspection of vehicles(4), control of point sources(5),ban open burning(6) and ban the older commercial vehicles and private vehicles it is seen that the concentration reduces to 83 μg/m^3. This is to be expected, since the number of vehicles which are subject to BSIV is only for two years and hence the decrease in concentration on adoption of BSIV is not significant. Similarly, in the year 2017, it is seen that the BAU predicts a concentration level of 181 μg/m^3. When we adopt BSVI standards(3), and in addition to that go with options 4 to 6 we see a reduction in the maximum concentration to 126 μg/m^3. A further imposition of a ban on old private vehicles results in a max. conc. of 107 μg/m^3 and when additionally the ban of commercial vehicles is implemented, it is seen the maximum concentration drops to 95 μg/m^3 . This is shown in Tables 7.5-6

For the year 2012, it is seen that the control option 1 alone, or option-1 in conjunction with controls on point sources(5), inspection of vehicles(4) and controls on open burning(6) does not have a significant impact on the PM and NOx levels as shown in Tables7.7-8.. However when we take control action to control the emissions from the Road Dust(10) we see that the PM level falls from a maximum of 116 to 87 μg/m^3. This is expected since we see that the road dust contributes almost 70% to the PM emissions from the inventory estimates. Hence it is expected that this control option will result in a scenario where the PM concentration at the hot spot will reduce by around 30%. If, in addition to this, we also impose a ban on the older commercial vehicle and private vehicles there is a further drop in the maximum concentration to 61 (a 50% reduction). Similarly, in the year 2017, we see that adopting the policy of control of road dust emissions results in a decrease in the maximum concentration from 183 to 88 $\mu g/m^3$ and if we additionally impose a ban on the older commercial vehicles and private vehicles the concentration reduces to 59 $\mu g/m^3$.

A combination of control options is called control scenario. For the sake of brevity, various control scenarios are denoted by numbers, as given below.

Control Scenario Number	Control Options Used	Description
CS 1	1	Adoption of BSIV norms
CS 2	1+4	Adoption of BSIV norms+ Inspection and Maintenance of Vehicles
CS 3	1+4+5	Adoption of BSIV norms+ Inspection and Maintenance of Vehicles+ Point sources control
CS 4	1+4+5+6	Adoption of BSIV norms+ Inspection and Maintenance of Vehicles+ Point sources control + Ban on open burning
CS 5	1+4+5+6+10	Adoption of BSIV norms+ Inspection and Maintenance of Vehicles+ Point sources control + Ban on open burning + Road Dust control
CS 6	1+4+5+6+7+10	Adoption of BSIV norms+ Inspection and Maintenance of Vehicles+ Point sources control + Ban on open burning +Ban on old commercial vehicles + Road Dust control
CS 7	1+4+5+6+7+8+10	Adoption of BSIV norms+ Inspection and Maintenance of Vehicles+ Point sources control + Ban on open burning +Ban on old commercial vehicles + Ban on old private vehicles + Road Dust control
CS 8	1+2	Adoption of BSIV and V norms
CS 9	1+3	Adoption of BSIV and VI norms
CS 10	1+3+4	Adoption of BSIV and VI norms + Inspection and Maintenance of Vehicles
CS 11	1+3+4+5	Adoption of BSIV and VI norms + Inspection and Maintenance of Vehicles+ Point sources control
CS 12	1+3+4+5+6	Adoption of BSIV and VI norms + Inspection and Maintenance of Vehicles+ Point sources control + Ban on open burning
CS 13	1+3+4+5+6+10	Adoption of BSIV and VI norms + Inspection

		and Maintenance of Vehicles+ Point sources control + Ban on open burning + Road Dust control
CS 14	1+3+4+5+6+7+10	Adoption of BSIV and VI norms + Inspection and Maintenance of Vehicles+ Point sources control + Ban on open burning +Ban on old commercial vehicles + Road Dust control
CS 15	1+3+4+5+6+7+8+10	Adoption of BSIV and VI norms + Inspection and Maintenance of Vehicles+ Point sources control + Ban on open burning +Ban on old commercial vehicles + Ban on old private vehicles + Road Dust control

Table 7.1 Emission Load for different scenarios, comparison of loads with BAU for the year 2012

Scenario	NOx (Kg/Day)	% Reduction	PM (Kg/Day)	% Reduction
2007	12142		11006	
2012	17112		16890	
CS-1	16007	6.46	16768	0.72
CS-2	15595	8.86	16650	1.42
CS-3	14904	12.90	16623	1.58
CS-4	14895	12.95	16593	1.76
CS-5	14895	12.95	12665	25.02
CS-6	12872	24.78	11129	34.11
CS-7	11632	32.02	9014	46.63

Table 7.2 Emission Load for different scenarios, comparison of loads with BAU for the year 2017

Scenario	NOx (Kg/Day)	% Reduction	PM (Kg/Day)	% Reduction
2017	25090		26255	
CS-1	20055	20.07	25524	2.78
CS-8	19551	22.07	25214	3.96
CS-9	19053	24.06	25214	3.96
CS-10	18237	27.31	24826	5.44
CS-11	16860	32.80	24775	5.64
CS-12	16838	32.89	24718	5.85
CS-13	16838	32.89	12589	52.05
CS-14	14429	42.49	10723	59.16
CS-15	12797	49.00	8630	67.13

Table 7.2: Per capita emissions (NOx) for the different scenarios in the year 2012 and 2017. The percentage reduction is also shown to establish the sensitivity of the control option on the pollution load for three categories of grids.

2012-NOx						
Scenarios	Residential	% Reduction	Kerb	% Reduction	Industrial	% Reduction
BAU	0.00260		0.00383		0.00847	
CS-1	0.00241	7.28	0.00356	7.05	0.00828	2.28
CS-2	0.00234	9.92	0.00346	9.67	0.00821	3.11
CS-3	0.00234	9.92	0.00346	9.67	0.00589	30.42
CS-4	0.00234	9.92	0.00346	9.67	0.00586	30.86
CS-6	0.00199	23.55	0.00300	21.73	0.00550	35.03
CS-7	0.00179	31.00	0.00264	31.06	0.00530	37.46

2017-NOx						
Scenarios	Residential	% Reduction	Kerb	% Reduction	Industrial	% Reduction
BAU	0.00372		0.00545		0.00927	
CS-1	0.00291	21.63	0.00430	21.22	0.00845	8.87
CS-8	0.00283	23.75	0.00418	23.37	0.00837	9.69
CS-9	0.00275	26.05	0.00407	25.46	0.00828	10.67
CS-10	0.00262	29.53	0.00388	28.93	0.00815	12.09
CS-11	0.00262	29.53	0.00388	28.93	0.00380	59.05
CS-12	0.00262	29.53	0.00388	28.93	0.00373	59.81
CS-14	0.00223	39.98	0.00335	38.52	0.00333	64.13
CS_15	0.00198	46.61	0.00292	46.41	0.00308	66.81

Table 7.4: Per capita emissions (PM) for the different scenarios in the year 2012,2017. The percentage reduction is also shown to establish the sensitivity of the control option on the pollution load for three categories of grids.

Scenarios	Residential	% Reduction	Kerb	% Reduction	Industrial	% Reduction
2012 BAU	0.00251		0.00527		0.00582	
CS-1	0.00249	1.11	0.00524	0.68	0.00579	0.51
CS-2	0.00247	1.88	0.00521	1.21	0.00577	0.84
CS-3	0.00247	1.88	0.00521	1.21	0.00568	2.30

CS-4	0.00247	1.88	0.00521	1.21	0.00558	4.02
CS-5	0.00188	25.31	0.00401	23.98	0.00425	26.86
CS-6	0.00164	34.96	0.00357	32.23	0.00380	34.60
CS-7	0.00132	47.47	0.00293	44.48	0.00312	46.30

2017 BAU	0.00374		0.00737		0.00826	
CS-1	0.00362	3.18	0.00722	2.10	0.00814	1.51
CS-8	0.00357	4.38	0.00715	2.95	0.00809	2.11
CS-9	0.00354	5.34	0.00710	3.67	0.00805	2.56
CS-10	0.00354	5.34	0.00710	3.67	0.00789	4.48
CS-11	0.00354	5.34	0.00710	3.67	0.00771	6.76
CS-12	0.00175	53.13	0.00361	51.08	0.00368	55.48
CS-13	0.00153	59.15	0.00322	56.35	0.00327	60.41
CS-14	0.00123	66.94	0.00265	64.09	0.00267	67.70

Table 7.5 Concentration at ten locations arranged in descending order for the year 2012 for NOx under the effect of different scenarios.

		2012(BAU)	2012(1)	2012(1+4)	2012(1 +4+5)	2012(1+4 +5+6)	2012(1 +4 to 7)	2012(1+4 to 8)	2012(9)
X	**Y**	**Conc.**	**Conc.**	**Conc.**	**Conc.**	**Conc.**	**Conc.**	**Conc.**	**Conc.**
15000	15000	120	112	109	107	107	92	83	115
14000	15000	115	107	104	102	102	87	79	109
14000	16000	111	104	102	93	92	81	74	106
15000	16000	107	100	98	90	89	78	71	102
15000	14000	103	96	93	92	92	79	71	98
14000	14000	95	88	86	85	85	72	65	90
13000	9000	84	78	75	75	75	64	57	79
12000	13000	83	77	75	75	75	64	57	79
8000	7000	83	77	75	75	75	64	57	79
1000	14500	83	81	80	58	58	54	52	81

Table 7.6 Concentration at ten locations arranged in descending order for the year 2017 for NOx under the effect of different scenarios.

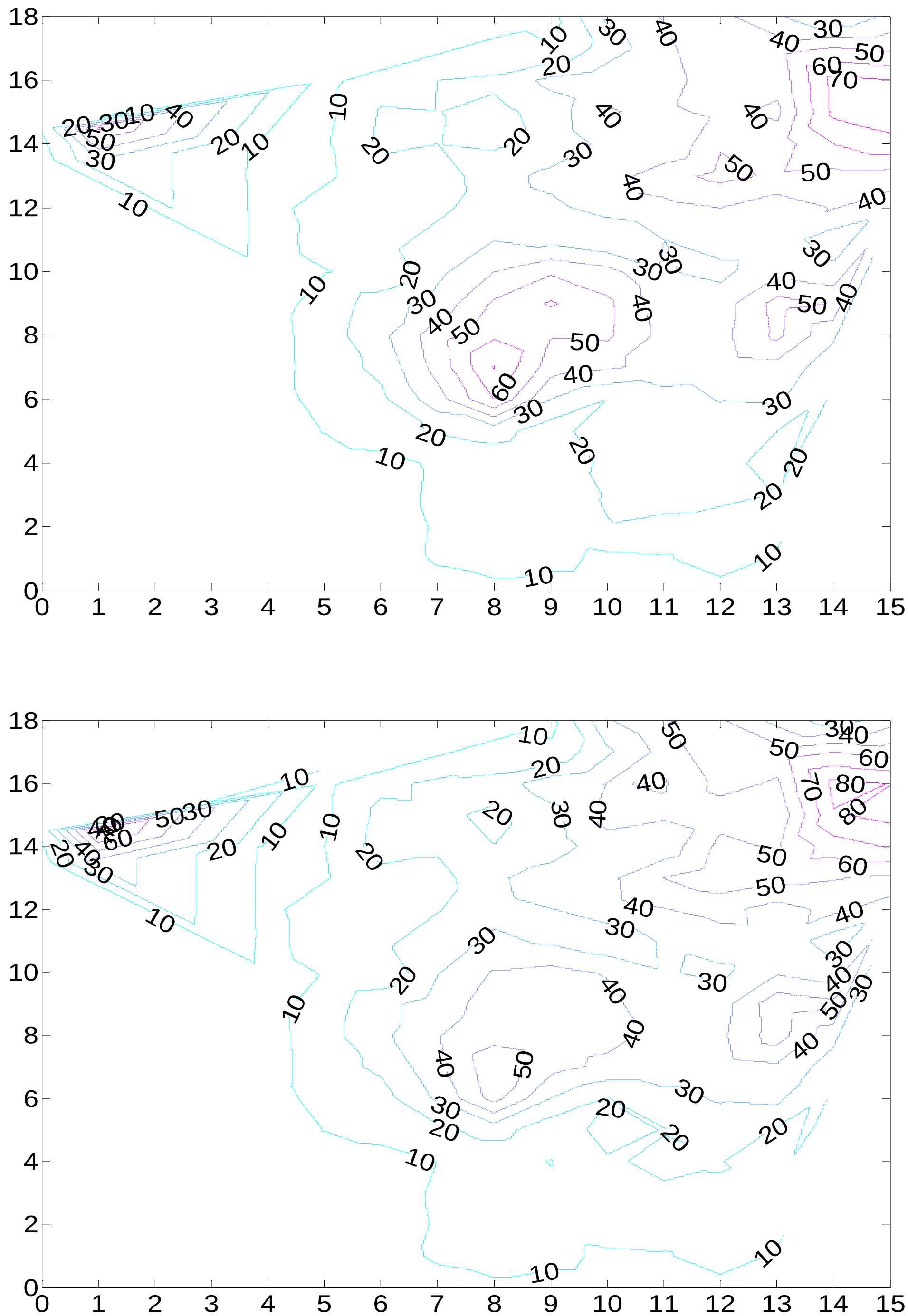
		2017BAU	2017(1)	2017(2)	2017(3)	2017(3+4)	2017(3 to 5)	2017(3 to 6)	2017(3 to 7)	2017(3 to 8)	2012(9)
X	**Y**	**Conc.**	**Conc.**	**Conc.**	**Conc.**	**Conc.**	**Conc.**	**Conc.**	**Conc.**	**Conc.**	**Conc.**
15000	15000	181	143	139	135	129	126	126	107	95	172
14000	15000	172	136	132	129	123	120	120	102	91	164
14000	16000	156	127	124	121	117	98	98	84	75	149
15000	14000	155	122	119	116	111	109	109	93	82	148
15000	16000	151	123	120	117	113	96	95	82	73	144
14000	14000	143	113	110	107	102	100	100	85	76	136
13000	9000	127	99	97	94	90	89	89	76	67	120
12000	13000	126	99	96	94	89	88	88	75	67	120
8000	7000	125	99	96	93	89	89	89	76	67	119
13000	8000	123	96	94	91	87	86	86	74	65	117

Table 7.7 Concentration at ten locations arranged in descending order for the year 2012 for PM10 under the effect of different scenarios.

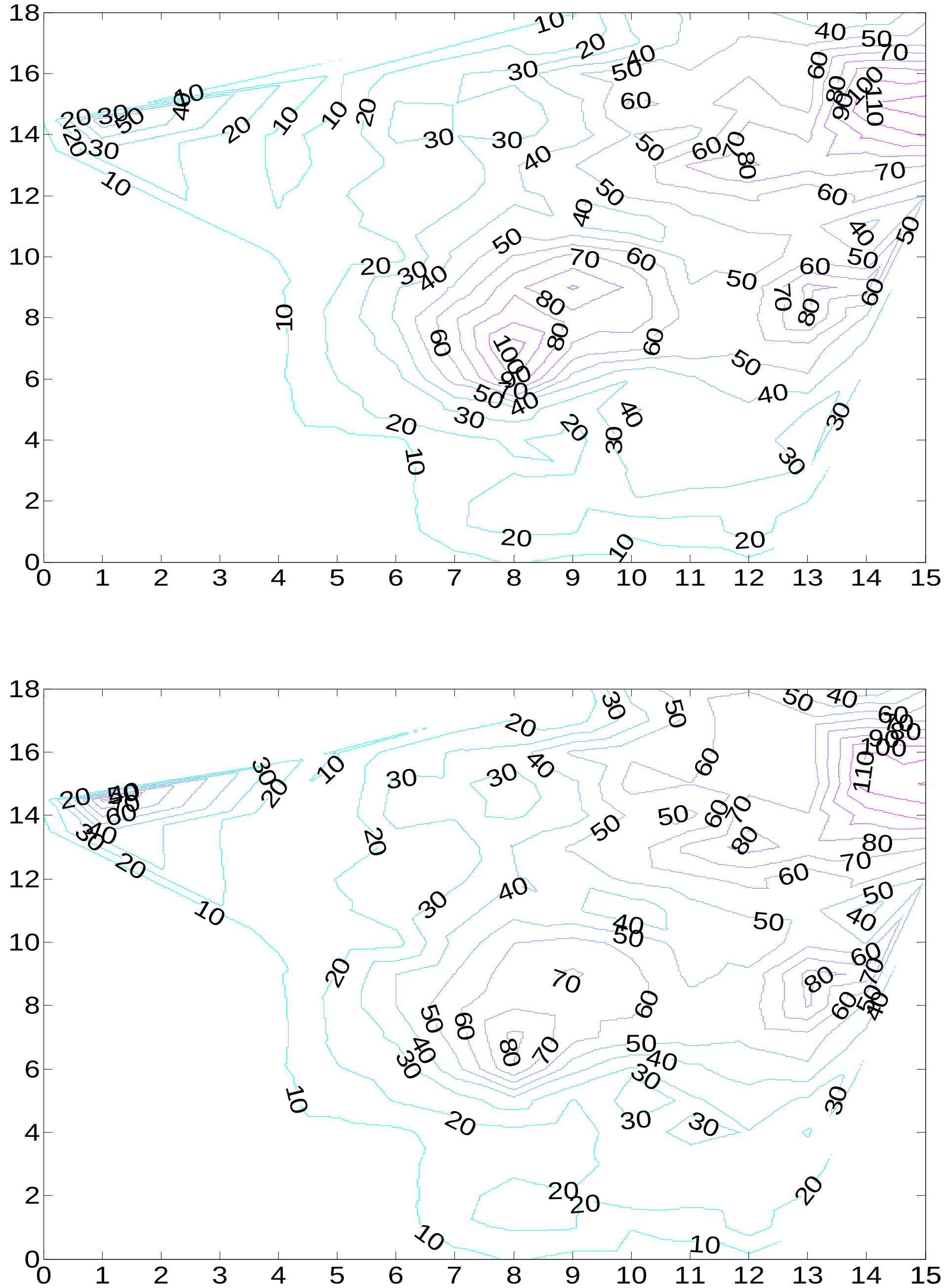
		2012BAU	2012(1)	2012(1+4)	2012(1+4+5)	2012(1+4 to 6)	2012(1 + 10 + 4 to 6)	2012(1 + 10 + 4 to 7)	2012(1 + 10+ 4 to 8)	2012(9)
X	**Y**	**Conc.**	**Conc.**	**Conc.**		**Conc.**	**Conc.**	**Conc.**	**Conc.**	**Conc.**
15000	15000	116	115	114	114	114	87	76	61	115
14000	15000	110	109	108	108	108	82	72	58	109
8000	7000	106	105	104	104	104	80	71	58	104
15000	14000	101	100	100	100	100	76	66	54	100
14000	16000	98	97	96	96	96	73	64	52	96
15000	16000	95	94	93	93	93	71	62	50	93
14000	14000	92	91	90	90	90	69	60	48	91
9000	9000	91	90	90	90	90	69	61	50	90
8000	6000	91	90	90	90	90	69	61	49	90
8000	8000	87	87	86	86	86	66	59	48	86

Table 7.8 Concentration at ten locations arranged in descending order for the year 2017 for PM10 under the effect of different scenarios.

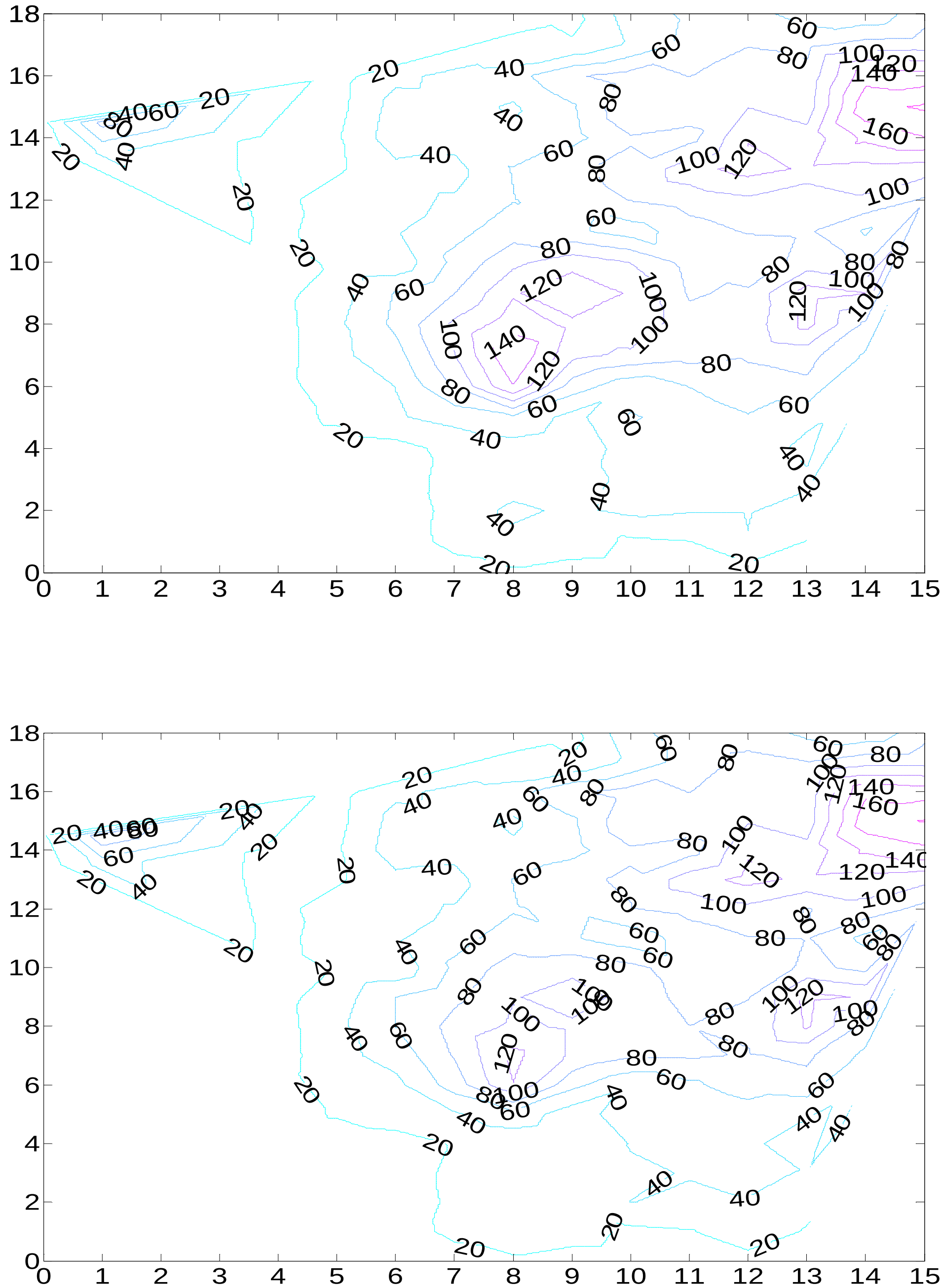
		2017BAU	2017(1)	2017(2)	2017(3)	2017(3 to 5)	2017(3 to 6)	2017(3 to 7 + 10)	2017(3 to 8 + 10)	2017(3 to 9 + 10)	2017(9)
X	**Y**	**Conc.**	**Conc.**	**Conc.**	**Conc.**	**Conc.**	**Conc.**	**Conc.**	**Conc.**	**Conc.**	**Conc.**
15000	15000	183	177	175	172	171	171	88	74	59	181
14000	15000	173	168	166	163	162	162	83	70	56	171
15000	14000	159	154	152	149	149	149	77	65	52	158
8000	7000	159	155	154	152	152	152	77	68	55	160
14000	16000	153	149	147	145	144	143	72	61	49	151
15000	16000	148	144	142	140	139	139	70	59	48	146
14000	14000	145	140	138	136	136	136	70	58	47	143
8000	6000	139	135	134	132	132	132	67	58	47	139
9000	9000	137	134	132	131	131	131	67	59	47	138
8000	8000	131	128	127	126	126	126	64	56	45	132



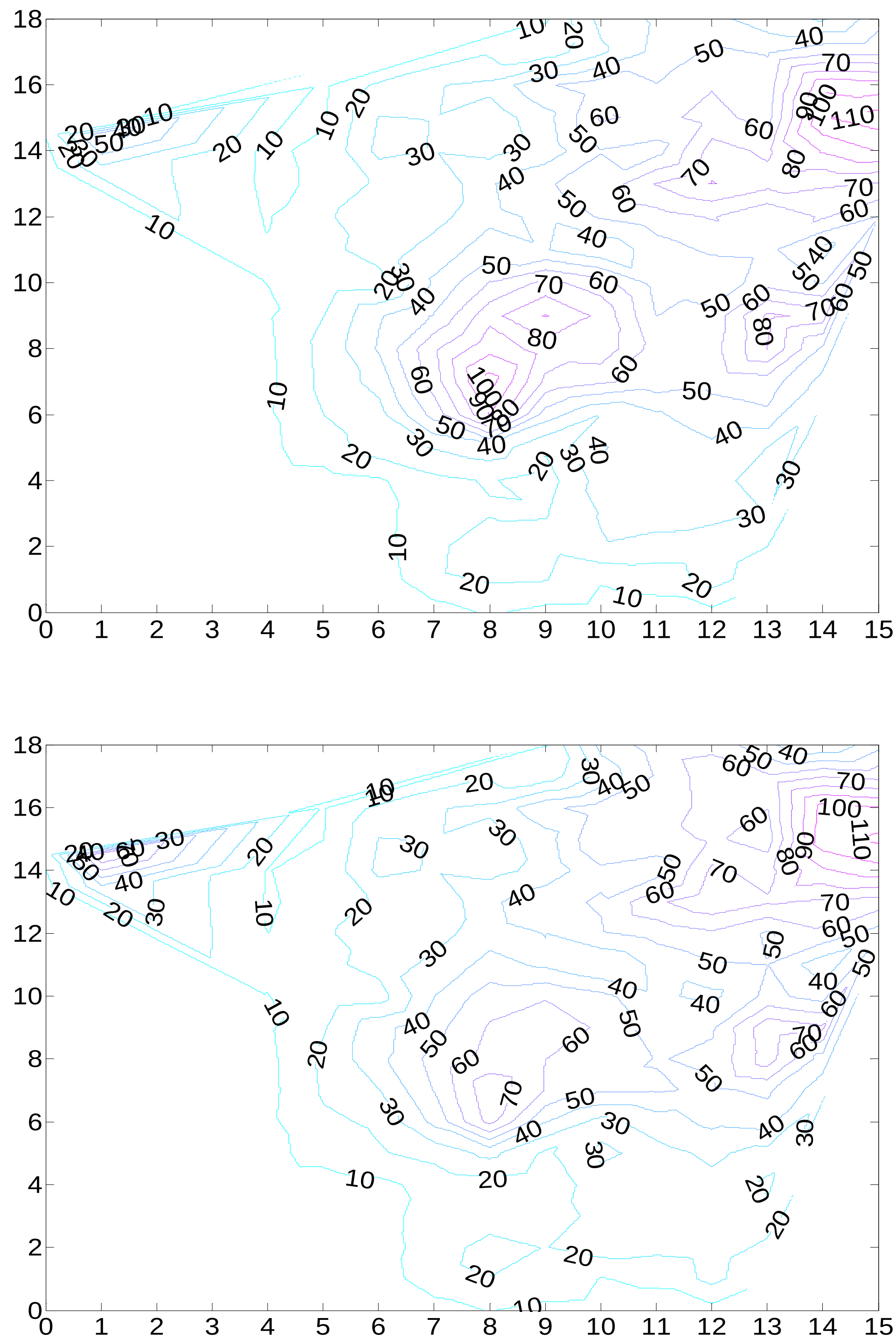
7.1 Concentration contour for 2007 BAU (a) PM (b) NOx



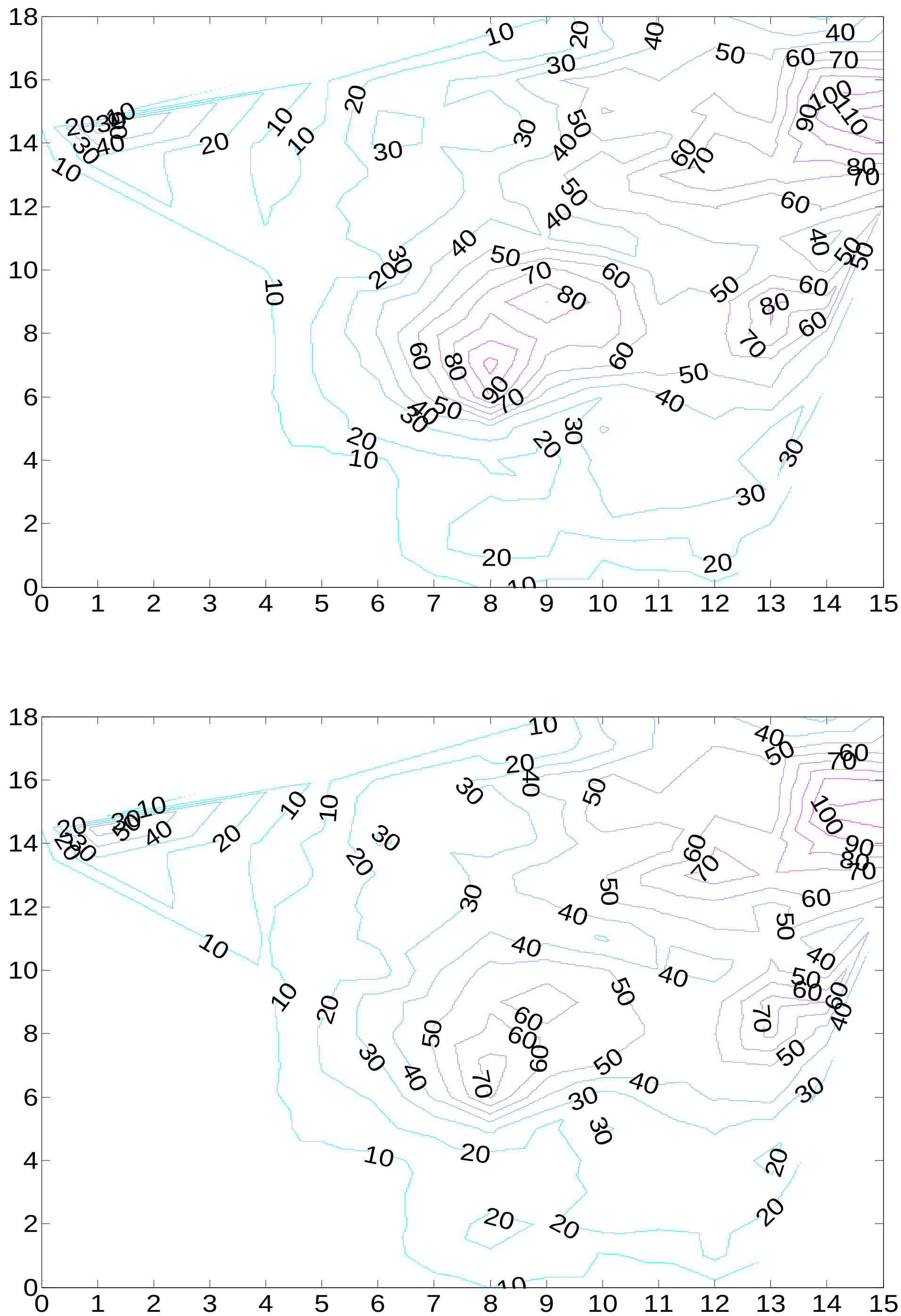
7.2 Concentration contour for 2012 (a) PM (b) NOx



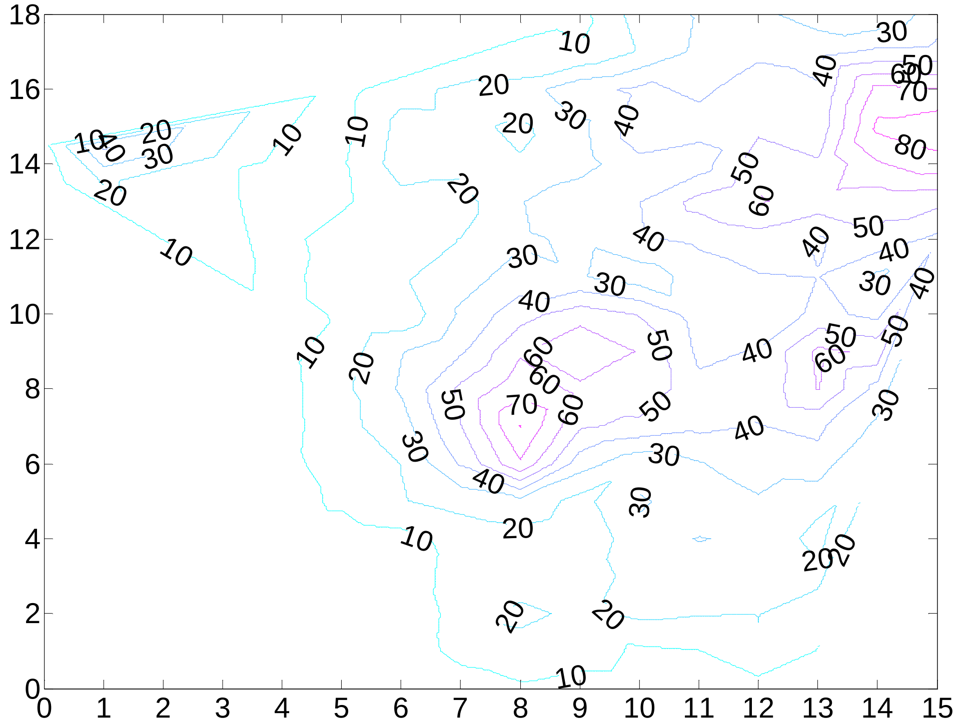
7.3 Concentration contour for 2017 (a) PM (b) NOx



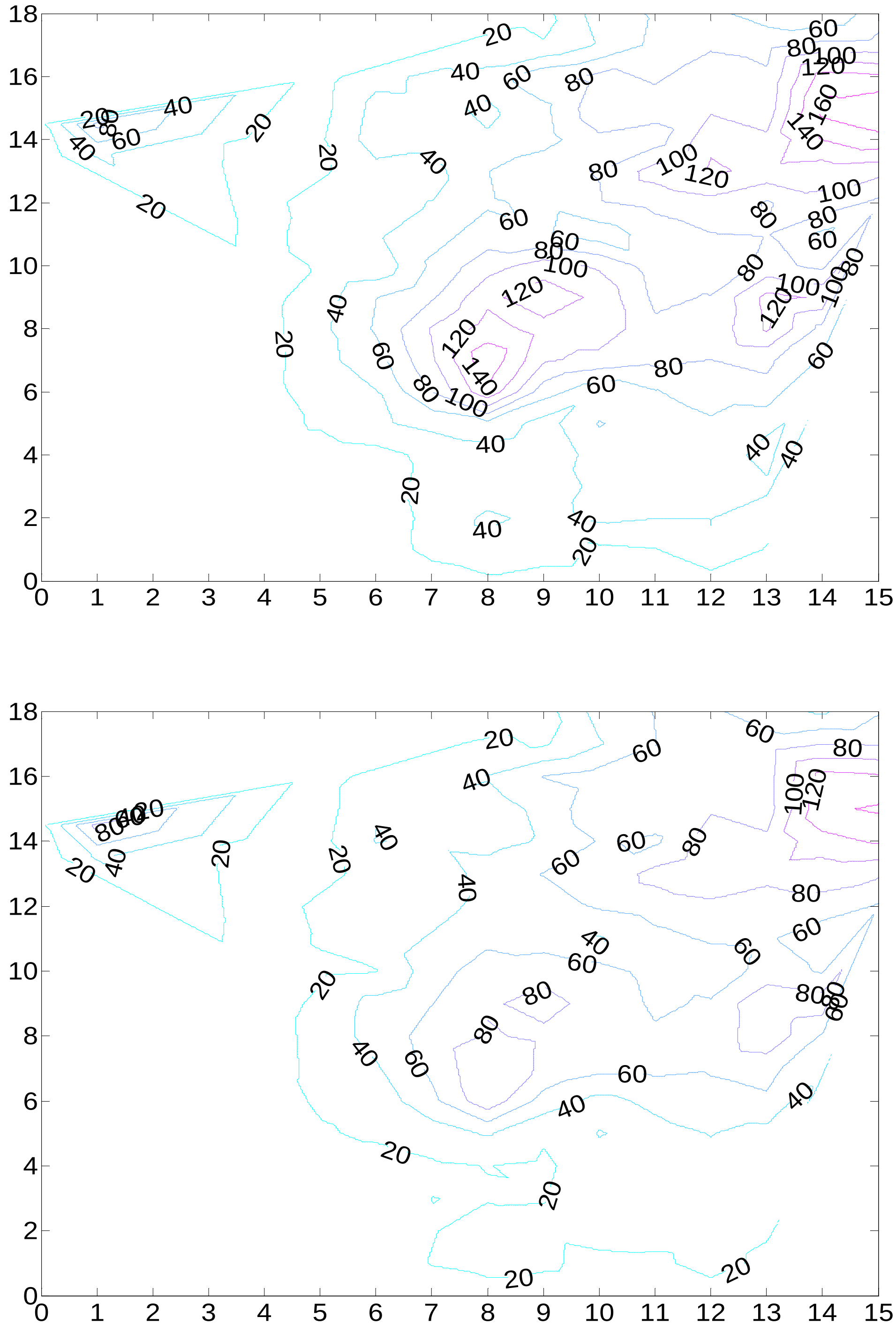
7.4 Concentration contour for 2012 with CS1 (a) PM (b) NOx



7.5 Concentration contour for 2012 (CS1+Inspection+Point+Open Burning) (a) PM (b) NOx

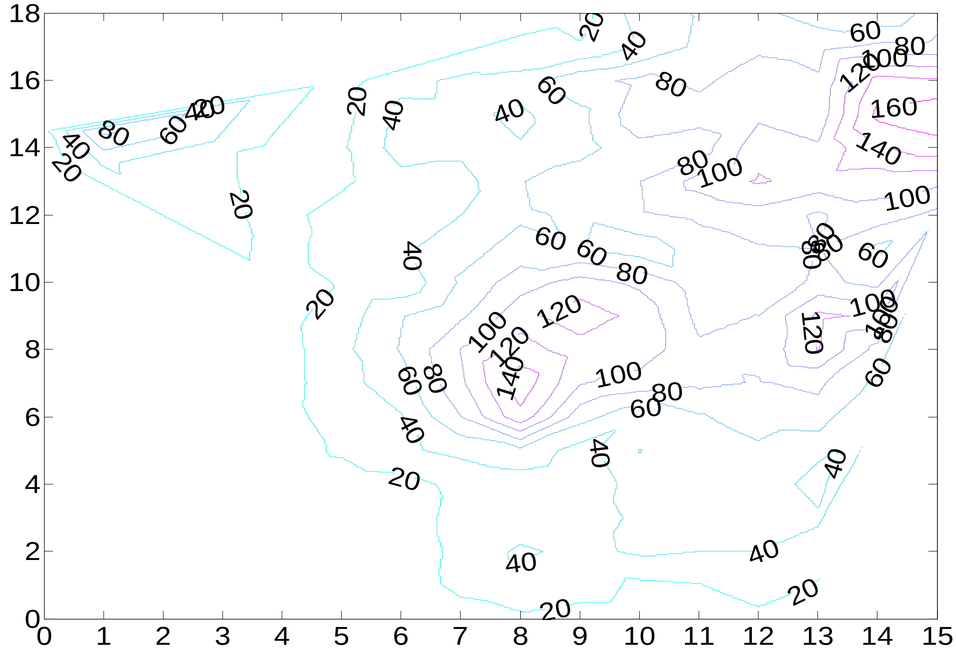


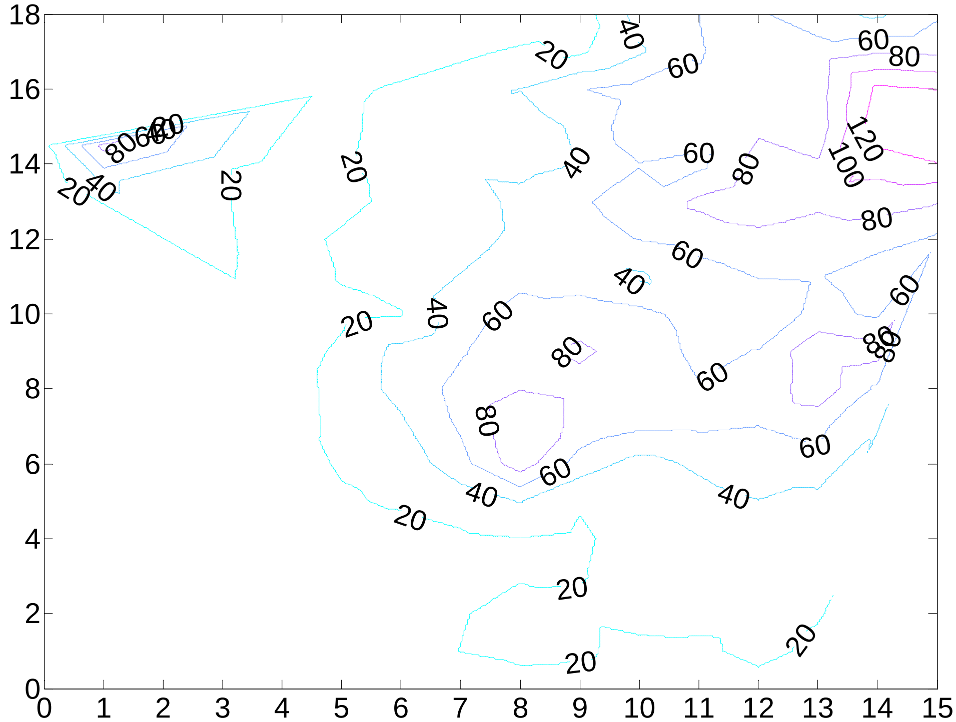
7.6 Concentration contour for 2012 PM(CS1+Inspection+Point+Open Burning and Road Dust)



7.7Concentration contour for 2017 with CS1 (a) PM (b) NOx

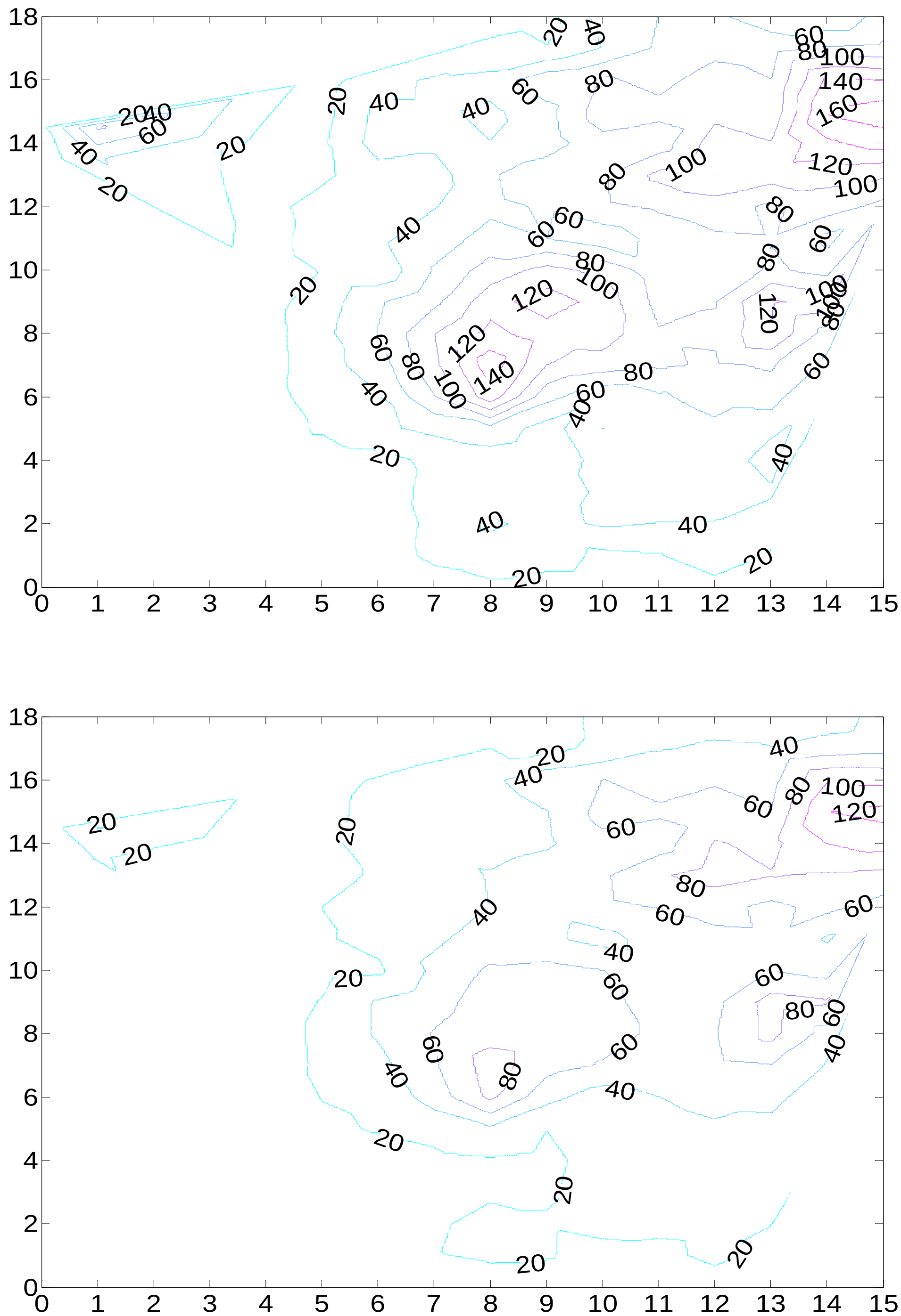
Figure 7.7 shows the contours when CS1 is implemented. This scenario involves the introduction of lower polluting vehicles in the year 2010. Since now the vehicles with lower pollution are larger in number we see that the impact on NOx is seen and the maximum in the NOx concentration is reduced from 180 to 126 but the impact on PM10 is not significant as the contribution from vehicular sources is very small compared to that from the paved road dust.





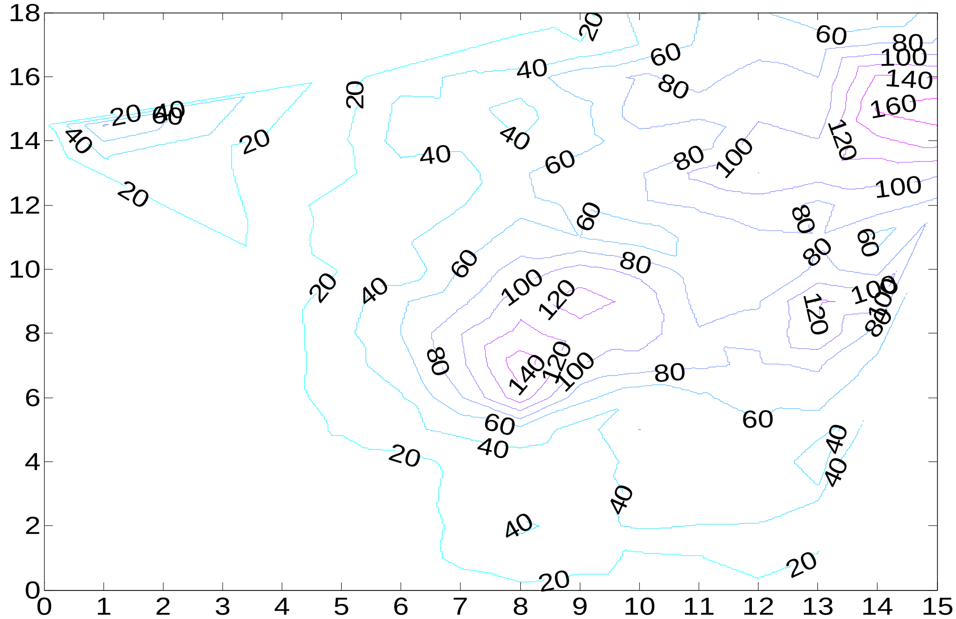
7.8Concentration contour for 2017 with CS1 and CS2 (a) PM (b) NOx

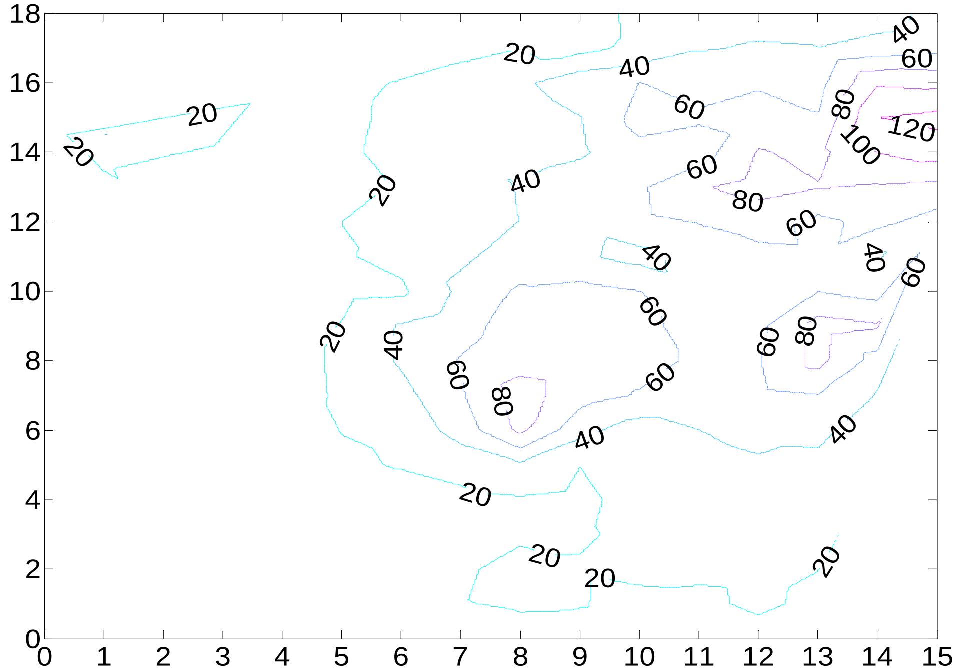
Figure 7.8 shows the concentration contours of PM and NOx levels when we introduce BSV standards in 2015 and BSIV standards in 2010. We see that the introduction of the stricter norms in 2015 does not have a significant impact as compared to the situation when BSIV norms were introduced in 2010 alone. The reason for this is again that the number of vehicles with the stricter norms would be very low since this accounts for the vehicles which have been added in the last two years.



7.9 Concentration contour for 2017 with CS3+Inspection+Point (a) PM (b) NOx

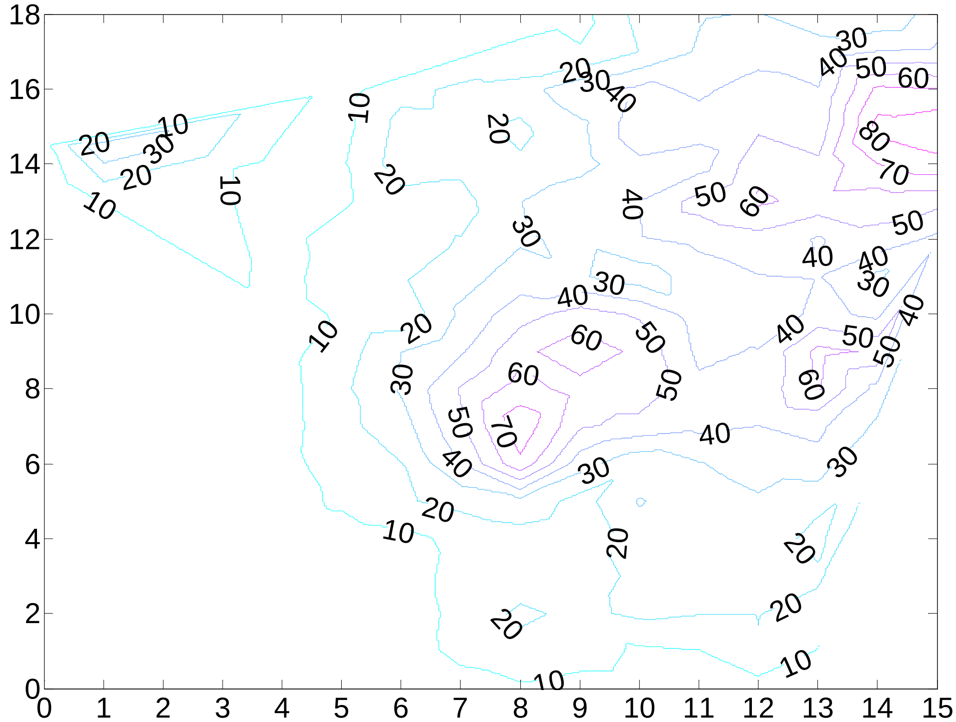
We see that introducing inspection and controls on the point sources has no significant impact on the concentration levels at the hot spots. However there is an effect of the point sources in some local regions where their effect is pronounced as can be seen in Fig.7.9





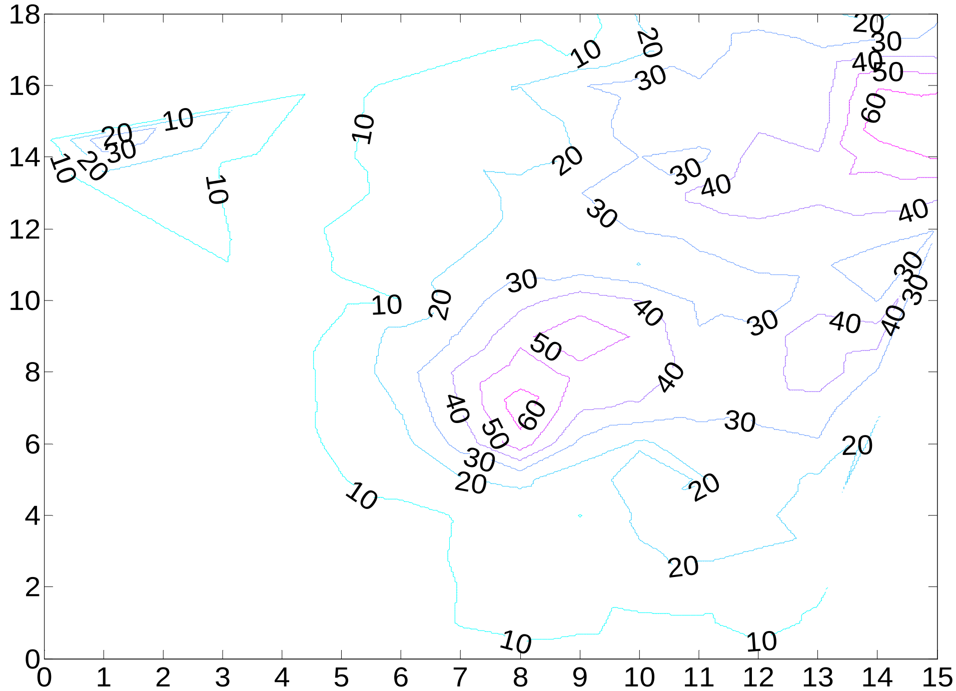
7.10 Concentration contour for 2017 with CS3+Inspection+Point+Open Burning (a) PM (b) NOx

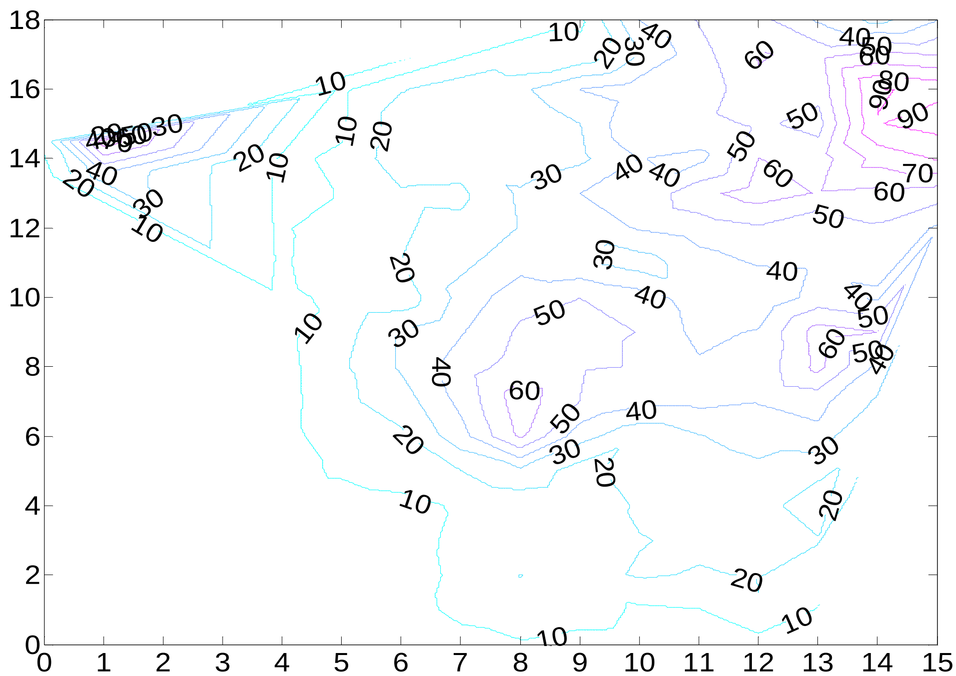
Figure 7.10 shows that when we take action to reduce the emissions from open burning in addition to point sources and inspection and CS3 we see no significant change in the concentration levels. There is some reduction in the areas where there are point sources but it does not have a significant impact on the air quality at the city level as the number of point sources is very small at the city level.



7.11 Concentration contour for 2017 PM with CS3+ Inspection+ Point+ Open Burning+ Road Dust

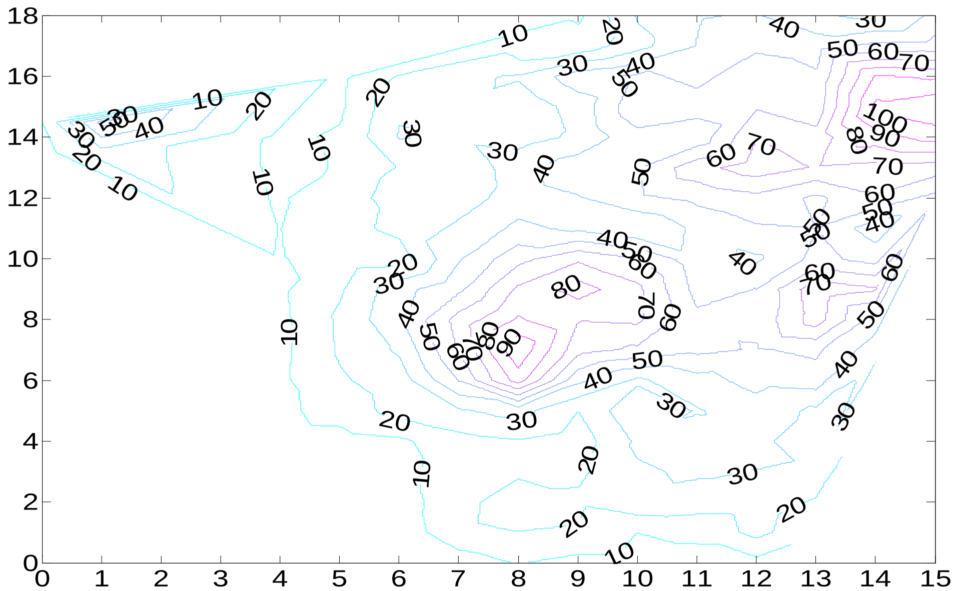
When the emissions from the road side are reduced, we do not expect to see any effect on the NOX concentrations in the area of interest. On the other hand, when the control is initiated on road dust emissions, we see that there is a drastic reduction in the PM concentration levels from 160 to 80 $\mu g/m^3$. This is consistent with the fact that the contribution of the road dust to the PM levels is around 70% amongst all the sources,. as seen in Chapter 6.

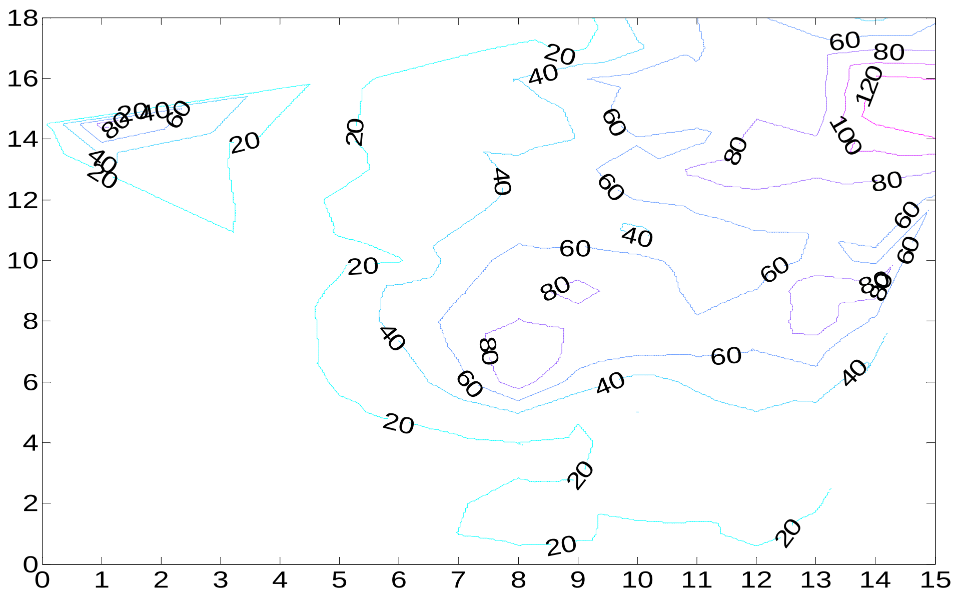

0 2 4 6 8 10 12 14 16 18
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15


0 2 4 6 8 10 12 14 16 18
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

7.12 Concentration contour for 2012 with ban of 10yrs commercial vehicles (a)PM (b) NOx

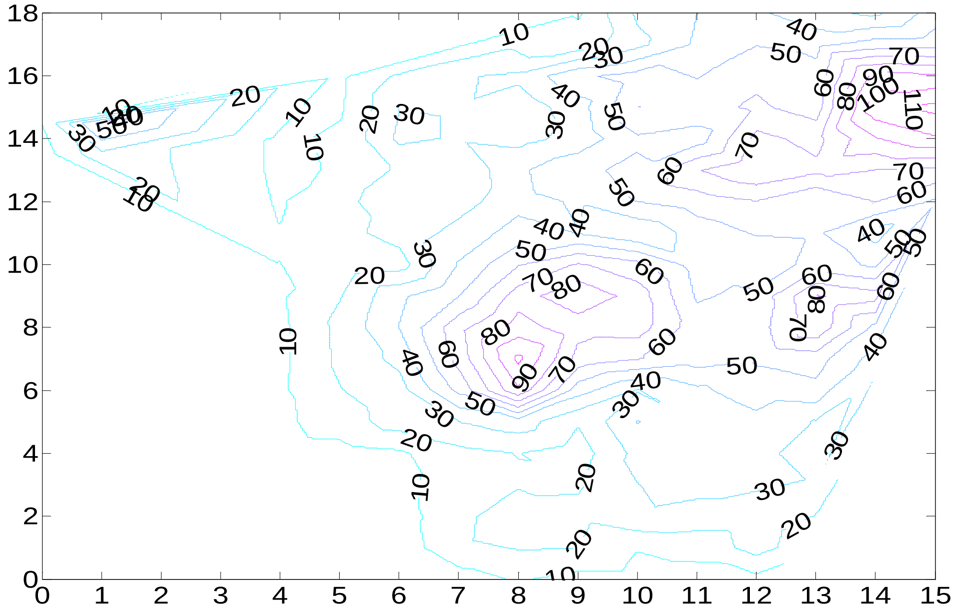
We next discuss the option of banning all commercial vehicles which are older than 10 years. No other control action is contemplated here. We see that this action results in a decrease in the pollution levels of both PM and NOx. Here the hotspot values for these two parameters is reduced to 60 and 90 from the BAU value of 110.

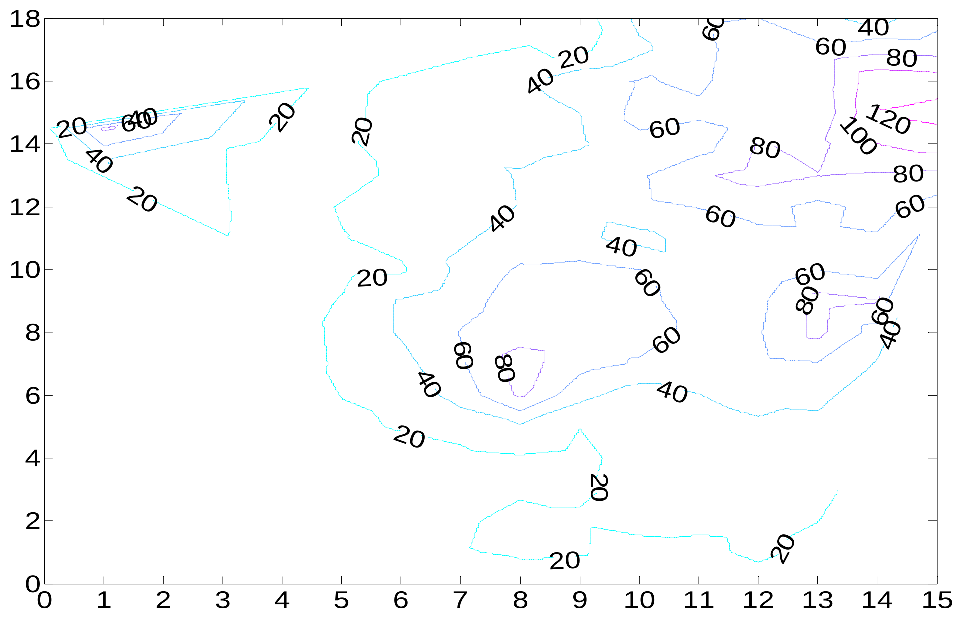




7.13 Concentration contour for 2017 with ban of 10yrs commercial vehicles (a)PM (b) NOx

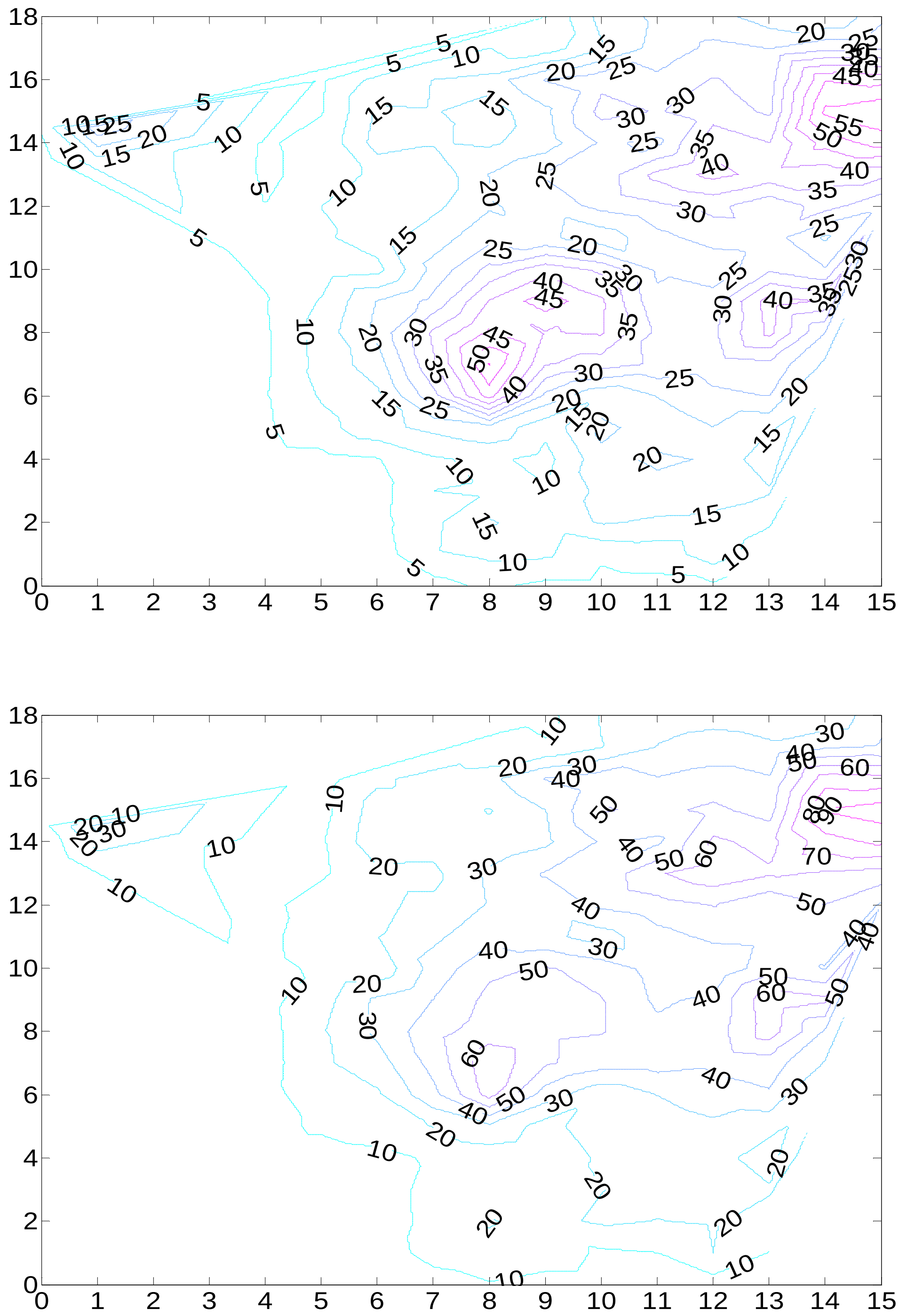
When we take the same action of banning only the commercial vehicles which are more than 10 years old we see a drastic reduction in PM and NOx levels. Now the maximum values have reduced from 160 to 100 and 120 for PM10 and NOx.





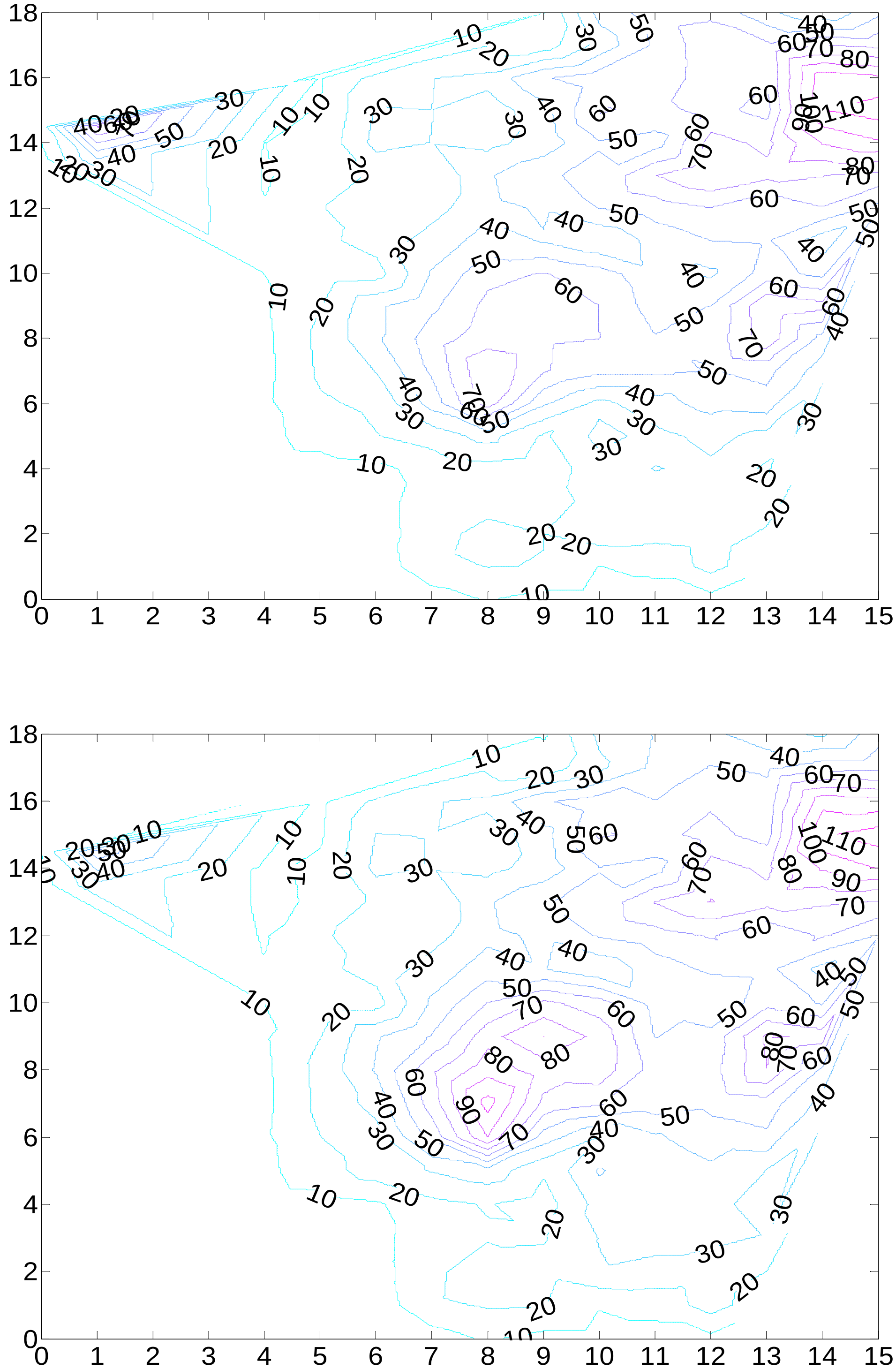
7.14 Concentration contour for 2017 with ban of 10yrs commercial +15yrs private vehicles (a)PM (b) NOx

In the scenario for 2017 when we ban 10 year old commercial vehicles and 15 year old private vehicles we see that the reduction from the ban on private vehicles does not have a very significant effect on the pollution levels in the atmosphere.



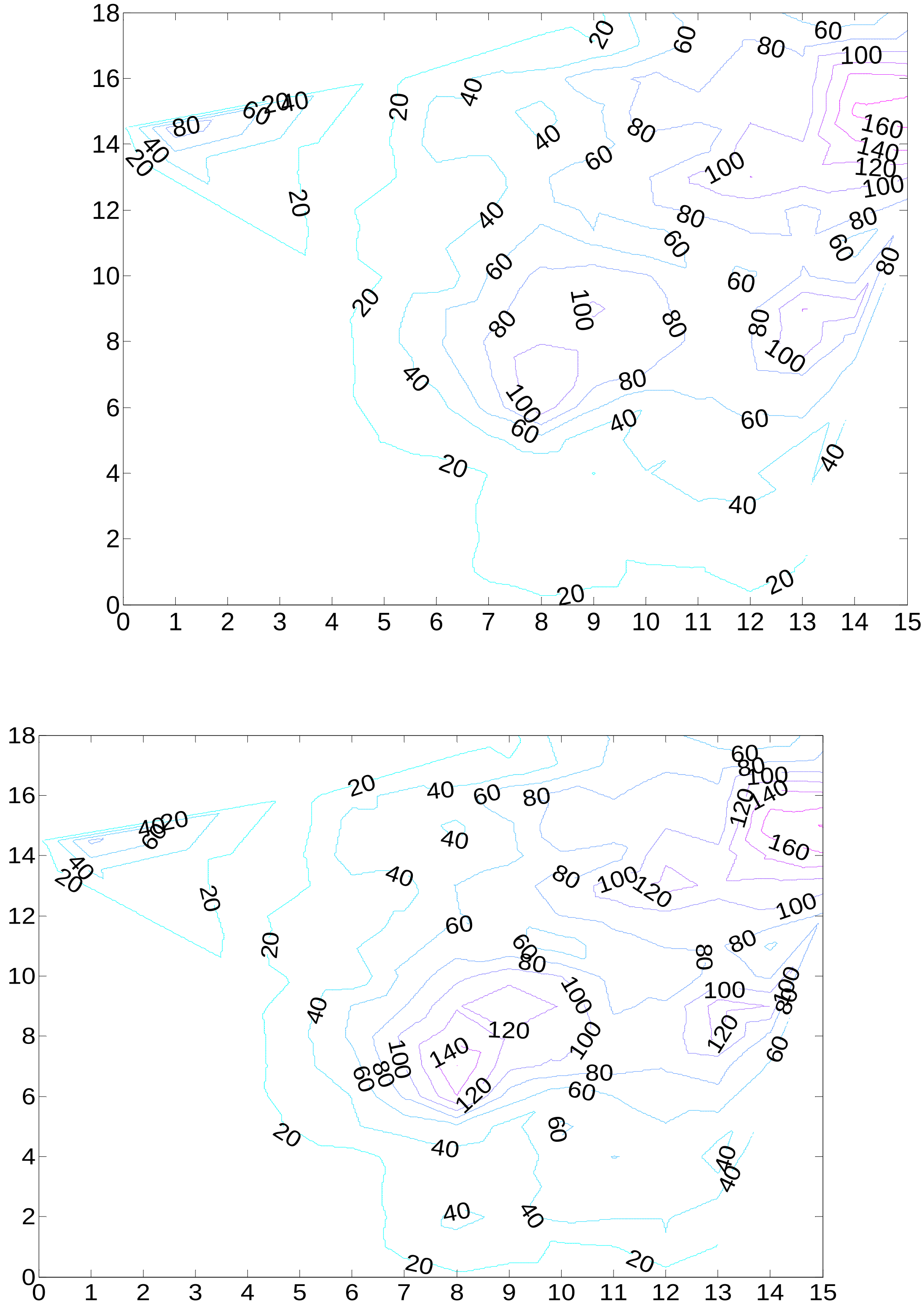
7.15 Concentration contour for 2017 with CS3+ban of 10yrs commercial +15yrs private vehicles (a) PM (b) NOx

If we impose on top of the ban on commercial vehicles and private vehicles the control option of BSV in 2015 we see a reduction in the concentration levels in the PM to around 60 and in NOx to around80 from the BAU value of 160.



7.16 Concentration contour for 2012 Improvement of Public Transport (a) PM (b) NOx

In Figures 7.16 and 7.17 we see that there is no significant improvement in the pollution levels when we improve the public transport system.



7.17 Concentration contour for 2017 Improvement of Public Transport (a) PM (b) NOx

7.2 prioritized list of control options:

On the basis of the effect on emission loads as well as on the concentration levels of PM10 and NOx we see that the control options which are most effective are

i) Control of emissions from road dust. This has a significant impact on the emissions and concentration levels of PM10. This however does not include the effect on NOx levels.

ii) Control of emissions from vehicles. This does not influence PM emissions significantly nor the PM levels. However this does have a significant improvement on NOx emissions and NOx levels in the atmosphere.

iii) Other control options such as action on point sources and open burning have a more local impact since their contribution to the air quality in the city level is low

iv) The banning of commercial vehicles and private vehicles of a critical age also has a significant impact on the pollution load and pollution levels. This is hence a worthwhile option to consider.

Keeping this in mind we propose the following control scenario for controlling both PM and NOx levels in the ambient air quality.

i) Cleaning of the roads to reduce the emissions of paved road dust. This is very critical for control of PM10 levels

ii) Introducing BSVI norms along with ban of older commercial and private vehicles. This would help in the reduction of NOx levels to within permissible levels

iii) The control of point sources has predominantly a local effect on the air quality and affects only the grids in the neighbourhood of which they are present.

iv) Similarly the ban on open burning has only a marginal effect on air quality levels

7.3 Benefits anticipated from implementing management/control options:

The implementation of the management and control options would result in lower levels of NOx and PM10 in the atmosphere. The air quality standards would be then complied with as far as the levels of these two parameters are concerned throughout the city. This would go a long way in leading a healthy, less stressful life since they will enable compliance with the norms of PM10 (100 ug/m3) and NOx (80 ug/m3).

Chapter 8
Highlights and recommendations

We conclude this report by enumerating some of the highlights and summarizing the recommendations. This study is the first of its kind in India where in an exhaustive analysis was conducted to determine the sources of pollution using a detailed emission inventor analysis. The quality of air was determined at seven sites one of which was a background and two sites each wer chosen to represent residential, kerbside and industrial areas. Monitoring was done in each site for 30 days. Micrometeorology was studied with emission inventory analysis. This was used as inputs to a dispersion model and the predictions of the model were compared with the experimentally observed values.

In addition to this source apportionment was carried out using factor analysis and chemical mass balance modeling and the important sources and their contributions were identified.

It is found that the contribution of paved road dust is significant to the air quality level as far as the pollution levels of PM10 is concerned. On the other hand the vehicle emissions were a significant contributor to NOx levels.

The **primary findings** of the study are

- The concentration of Sox levels is sufficiently low in the atmosphere. However the aerosols or particulate matter showed a high content of sulphate levels thus indicating that most of the sulfur was present in the particulate phase.
- For nitrates the reverse is true. Here the concentrations of the NOx levels in the gas is found to be high, however the ion coneentration in the particulate matter is low.
- The EC/OC ratio present in the particulate matter indicated the contribution of vehicular sources.
- The CO concentrations showed a diurnal variation.
- The emissions from the paved road dust contribute significantly to the pollution load as far as PM10 is concerned. The contributions from the vehicular sources towards PM is only around 10% in the city of Chennai.
- As far as NOx pollution load is concerned the contribution from vehicles is appreciable.
- The receptor modeling using chemical mass balance allows us to identify the different sources. Here we have found that paved road dust and vehicular sources are significant contributors.
- A normalized contribution , i.e., pollution load per capita was determined for NOx and PM10 so that this could be compared with the values in other cities.

- The dispersion modeling was carried out for the seven grids. The pollution loads from these grids were extended to the city level and the pollution loads were determined for the year 2012 and 2017 using the growth patterns of the population and vehicles.
- This was used to determine the pollution levels in the BAU scenarios. Various control options were analysed and it was found that cleaning of the roads would result in a drastic decrease of the concentrations of the PM.
- Similarly adopting the BSVI norms along with the banning of old commercial vehicles and private vehicles would result in complying with the norms for NOx.

The **recommendations for policy** to be adopted for meeting the pollution levels are

- Sweeping and watering of the paved roads to reduce the emissions of the particulate matter.
- Adoption of BSV or VI norms to reduce the emissions from vehicular sources of NOx in particular.
- Banning of 10 year old commercial vehicles and 15 year old private vehicles to reduce the emissions of NOx.
- Controlling the emissions from point sources and open burning would result in a local effect of controlling air quality in and around the grids in which they are present.
- The other control options investigated, for instance inspection and maintenance of vehicles etc have a negligible effect on the air quality.