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Measurements of Urban Ambient Air Quality of Chennai City

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Abstract

Chennai Metropolitan Area extends over 1180 sq. km and has a population of more than 8.5 million. Rapid increase in urbanization with vehicle congestion has increased menacingly on the roads of Chennai. As a result of this, gaseous pollutants (SO_2, NO_X) and respirable and suspended particulate matter pollutants are continuously increasing in the ambient air of Chennai city. These pollutants have been assessed using high volume sampler at residential and traffic intersection sampling stations in Chennai city. The main objective of this study has been to determine the background concentration of the pollutants in correspondence with different local activities. It has been observed that annual mean values of particulate matter exceed NAAQS values by a large amount. However, gaseous pollutant concentrations are well below the recommended values. The other important finding of this study is that data collected year-wise for SPM gives best curve fit for cubic equations. Several issues and remedies related to the probable sources of suspended particulate matter concentration have also been discussed.

Keywords: Concentration; SPM; NAAQS; ANOVA; cubic fit equations

1. Introduction

Chennai in Tamil Nadu is a coastal city. It is one of the large cities of the country. It is surrounded by sea and it has a harbour. Its climate is highly influenced by sea breeze and land breeze and more so during the months of monsoon. Further the air of the city is adversely affected by the continuous growth of industries and motor vehicles. The city stands witness to contribution to air pollution from these sources. Mixed traffic and earth moving activities related to the construction of many flyovers further add to this menace. The so-called adverse air quality is now the talk of the town. It needs to be monitored and improved. The present study has been made to understand air pollution aspects related to urbanization and industrialization in Chennai city.

2. Materials and Methods

2.1 Materials

2.1.1 Suspended Particulates

Suspended Particulate Matter (SPM) is constituted of aerosol dust or other particulates of size 1 to 200 microns suspended in air (Chandrasekaran et al, 1997; Senthilnathan, 2003-a). It is generated by crushing, chipping and grinding of rock and soil. Dust particles of size above 100 microns settle quickly on the ground. Dust particles of size 10 - 100 microns constitute coarse dust and settle on the ground in due course of time, particulates of size 2.5 – 10 microns constitute fine dust particles and take very long time to settle, while particles of size 1 micron and less constitute very fine dust particles and do not at all settle at all. They remain suspended in the air and get entry in the respiratory tract and pulmonary system of human beings and have a long term effect on health. Smoke is an aerosol of very fine carbon particles of size ranging from 0.5 to 1.0 micron and is produced by organic particles like coal and wood (Senthilnathan, 2006). The combination of smoke with fog results in smog. Soot is an agglomeration of carbon particles of size 1 to 10 microns. It is formed due to incomplete combustion of carbonaceous materials (Krishnamohan, 1996; Senthilnathan, 2005). Mist is an aerosol of liquid droplets formed by the condensation of vapour. The size of mist is less than 10 microns. Water mist is fog and it is a visible aerosol. Haze is an air pollution condition formed due to the presence of very fine dust, mist, fumes and so on in the atmosphere (Pandey et al, 1998; Senthilnathan, 2007-a). Suspended particulates of size 10 micron get increased due to the operation of fuel-burning plants and other industrial and commercial processes. In addition, chemical and physical processes in the atmosphere form significant portions of respirable dust particles (Kumar et al., 2004). The chemical processes range from relatively simple oxidation reaction of SO_2 to produce sulphate particles to complex multiple photochemical processes. These particles have the peculiarity of penetrating the respiratory system till they reach the pulmonary alveolus.

2.1.2 Gaseous Pollutants

Gaseous pollutants can be classified into organic and inorganic type based on their chemical compositions.The most important oxide emitted by pollution sources is sulphur dioxide. It is a colourless, nonflammable and non-explosive gas (Rao, 1993; Senthilnathan, 2003-a). It causes taste sensation at concentrations ranging from 0.3 to 1.0 ppm in air. At concentrations greater than 3 ppm, SO_2 gas has a pungent irritating odour. It is partially converted to sulphur trioxide or sulphuric acid and its salts by photochemical or catalytic processes in the atmosphere. In a polluted atmosphere, SO_2 reacts photo-chemically or catalytically with other pollutants. Sulphur-dioxide gas alone can irritate the upper respiratory tract and it can be carried deep into lungs (Scorer, 1968). Further, there are several oxides of nitrogen in which three oxides namely nitrous oxide (N_2O), nitric oxide (NO) and nitrogen dioxide (NO_2) are formed (Senthilnathan, 2007-a,b) in the atmosphere. Generally NO and NO_2 are analyzed together and are referred to as NO_X.

2.2 Sampling of Pollutants

Sampling constitutes the main part of the examination of air quality, it is thus very important to know various factors related to it, such as location of sampling station, size of the sample, duration and rate of sampling (Senthilnathan, 2003-d,2005, 2006).

2.2.1 Selection of Sampling Sites

The location of sampling station should be in the free atmosphere without interferences from stagnant spaces or from large buildings and so on. It should be located at a minimum height of 1.5 m but not exceeding 15 m from the ground level. Based on this sampling criterion, two sampling stations, Anna Nagar and Kilpauk were selected for the present study. Anna Nagar was in the residential zone while Kilpauk was a traffic intersection. The location of these sampling stations in Chennai city is shown in Fig.1.

2.2.2 Sampling of Particulates

The method for sampling of particulate pollutants is based on the size of the particulates to be sampled (Rao, 1993; Senthilnathan, 2003-b). If the size is greater than 10 microns, filtration based methods may be used. One of the popular and frequently used filtration based method for the determination of suspended particulate matter in air is employed in high volume sampler (Scorer, 1968; Rao, 1993). Herein particulates filtered from a known volume of air sample by a suction apparatus (a vacuum pump) are made to deposit on a porous filter paper. Fiber glass filter without any visible defects such as pinholes, deposits, and other imperfections are employed. The filter is equilibrated in the decicator for 24 hrs and weighed to the nearest milligrams before fixing it on the face plate of the filter holder. The weight of the material deposits on the filter paper is found in terms of the difference in weights of the final and initial weightings, while the volume of air sample passed through the sampler is computed from the flow rate of the air passing through the sampler and the time of sampling.

2.2.3 Sampling of Gaseous Pollutants

SO_2 concentration in the air is sampled by West-Geake method. This method of sampling SO_2 employs the high volume sampler. Herein air containing sulphur dioxide is passed through an absorbing solution of sodium tetra chloromercurate, forming stable dichloro-sulphitomercurate. Addition of p-rosaniline hydrochloride in this solution produces a colour whose measurement of intensity with a spectrophotometer the wavelength of 560 nm gives an estimate of the sulphurdioxide present in air.

NOx concentration in the air sample is measured by Jacob and Hochheiser method. Again high volume sampler is used to collect samples of NO_x present in the ambient air. Nitorgen-di-oxide is collected by bubbling air through sodium hydroxide solution to form a stable solution of sodium nitrate for spectrophotometer studies. Saltzmann's procedure is used to measure the concentration of NO_x present in the sample.

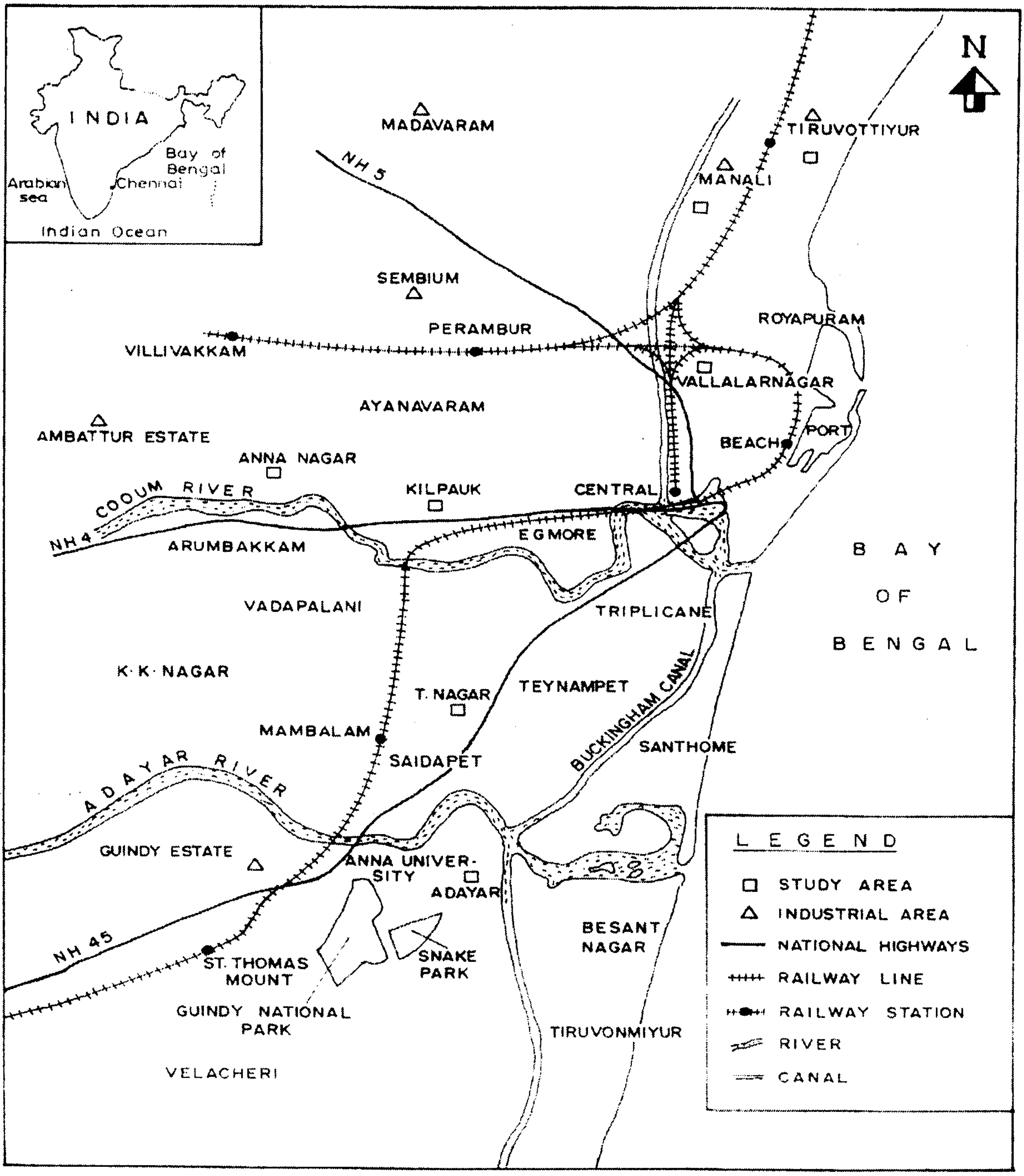

Figure 1: Sampling Stations in Chennai City for Ambient Air Quality Studies

3. Results and Discussion

Ambient air quality studies have been made for Chennai city for the year 2000-2002. The data so collected are subjected to statistical analysis to get an idea of the highly polluted stations. Analysis of variance (ANOVA) is used to study the significance of the difference of mean values of a large number of samples collected at the same time. The exceedence factor value is calculated by comparing these values with the standard NAAQS values given in Table 1.

Table 1: National Ambient Air Quality Standards (NAAQS)

Pollutants	Time weight average	Concentration in ambient air			Method of measurement
		Industrial area	Residential area	Sensitive area	
Sulfur dioxide (SO_2)	Annual average*	80 μg/m³	60 μg/m³	15 μg/m³	Improved West – Geake Method
	24 hours	120 μg/m³	80 μg/m³	30 μg/m³	
Oxides of Nitrogen (NO_x)	Annual average*	80 μg/m³	60 μg/m³	15 μg/m³	Jacob and Hochheiser method
	24 hours	120 μg/m³	80 μg/m³	30 μg/m³	
Suspended Particulate Matter	Annual average*	360 μg/m³	140 μg/m³	70 μg/m³	High Volume Sampling (Average flow rate not less than 1.1 m³/min.)
	24 hours	500 μg/m³	200 μg/m³.	100 μg/m³	
Respriable Dust Particles	Annual average*	120 μg/m³	60 μg/m³	50 μg/m³	
	24 hours	150 μg/m³	100 μg/m³	75 μg/m³	

- Annual arithmetic mean of minimum 104 measurements in a year or taken twice a week, 24 hourly at uniform interval

The annual mean concentrations of the various pollutants observed from sampling sites station no 1 and station no 2 are shown in Table 2, while the monthly mean, maximum, minimum and the exceedence factor values for the different pollutants pertained to these stations are displayed in Tables 3 - 8. Analysis of Variance (ANOVA) has also been carried out and is given in Table 9.

Table 2: Annual Mean Concentration (μgm/m³) of Various Air Pollutants during the Years 2000-2002.

Pollutant	Station	2000	2001	2002
SO_2	Station:1	2.564	2.321	2.133
	Station:2	6.82	5.12	3.59
NO_X	Station:1	17.10	18.33	30.52
	Station:2	32.43	34.76	26.58
SPM	Station:1	117.68	128.17	105.58
	Station:2	399.25	351.50	360.42

It may be gathered from the observed data that the annual mean values of SO_2 and NO_X concentrations at both the stations show low values and are well below the prescribed standard values. It is also gathered from the observations that concentrations of SO_2 are more during summer (April-June) and post monsoon (December-March) seasons at both the stations. However, as a thumb rule, concentrations of air pollutants should decrease both during monsoon and post monsoon seasons. One of the reasons for the lack of decrease in concentration during the post-monsoon season can be the failure of monsoon during the study period. The other reason that can only be valid for station no.2 is that it is a traffic junction and the emissions from the vehicular exhausts are non-ending during any season unless some bold decisions are taken to control the increasing traffic on Indian roads.

The results of ANOVA test for NO_X concentration at station 2 show high calculated values than the tabulated values failing the F-test. This implies that the variations in the collected data are high. The annual mean values of SPM during the sampling period are uniformly high. ANOVA test also confirms high calculated values at sampling stations. Station no.2 has registered a high value of 1424 $\mu g/m^3$ during May 2000. This is 7.5 times that of normally allowed value. It may be pertinent to state that as per the Tyndall effect, the SPM of mass 10μ will take more time to settle down on the earth's surface, sometimes even infinite time to settle down and hence tend to remain in the atmosphere itself.
One of the very important finding of this research work is that the observed data year-wise for gaseous and particulate pollutants is found to give the best fit for cubic equations. These cubic fit polynomials are displayed in Table 10. The concentration of air pollutants may be analyzed for future predictions using these equations.

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