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RESEARCH ARTICLE

ANALYSIS OF AMBIENT GASEOUS POLLUTANTS IN AND AROUND COAL BASED THERMAL POWER PLANT - A CASE STUDY

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ABSTRACT

In the present study, an effort has been made to study the status and trend of the gaseous pollutants such as Sulphur dioxide (SO_2) and Oxides of Nitrogen (NOx) in the ambient air in and around the rural villages located around a Coal Based Thermal Power Plant. A large portion (85%) of the total thermal power generation is through coal burning. On combustion of coal, pollutants generally emitted into the atmosphere are Sulphur dioxide (SO_2), Oxides of Nitrogen (NOx) and Carbon Monoxide (CO) along with ash. Probably the most common pollutant emitted is Sulphur dioxide (SO_2). Here, the annual maximum 8 Hours concentrations of Sulphur dioxide (SO_2) and Oxides of Nitrogen (NOx) data for the period of 10 years were analysed.

INTRODUCTION

Air pollution may be defined as "the presence in the outdoor atmosphere of one or more contaminants such as dust, fumes, gas, mist, odour, smoke or vapour in quantities of characteristics and of duration such as to be injurious to human, plant or animal life and to property or which unreasonably interferes with the comfortable enjoyment of life and property" (1). In other words it may be defined as limited to situation in which the outdoor ambient atmosphere contains material in concentration, which are harmful to man and his surroundings environment (2). Poor air quality is one of the most serious environmental problems in urban areas around the world, especially in developing countries. An assessment of health damages from exposure to the high levels of pollutants in 126 cities worldwide reveals that these damages may amount to near 1,30,000 premature deaths; over 5,00,000 new cases of chronic bronchitis and many more lesser health effects each year. A significant source of urban air pollution is the combustion of fuels by power plants, industrial boilers, residential stoves and vehicle engines (3).

Air Pollutants from Thermal Power Plants

Power generation is an essential component for any industrial activity and other development plans for the economic development of the country (4). India has at present a total power generation capacity of 1.05 lachs MW. Sector wise existing power generation is 72,000 MW by thermal power plants, 25,000 MW by hydropower, 5,500 MW by renewable energy sources, and 3,120 MW by nuclear power. A large portion (85%) of the total thermal power generation is through coal burning, 14% is by gas combustion, while only 1% of thermal power generation is by burning of oil or other petroleum products (5). Coal which is the back-bone of thermal power plants is abundantly found in India. Unfortunately, the quality of coal is not good as it contains low percentage of solid hydrocarbons. Its combustion is accompanied with production of CO_2 and H_2O. CO_2 evolution leads to "Green House Effect". On combustion of coal, other pollutants generally emitted into the atmosphere are Sulphur dioxide (SO_2), Oxides of Nitrogen (NOx) and Carbon Monoxide (CO) along with ash. Probably the most common pollutant emitted is Sulphur dioxide (6). United States of America produces about 39% of the total world's thermal electric power and thus produces about 20 million tons of SO_2 every year. Sulphur in most bituminous coals in the world varies from 1 to 4% and ash from 4 to 20%. Indian coals for power plants are generally of high ash content (30 to 50%) and contain up to 1% sulphur. In India fly ash is the major pollutant, followed by SO_2, CO and NOx (7).

India has about 21 billion coal reserves that are being mined at the rate of about 300 million tones per year ranking India as the third largest coal-producing nation in the world. But the Indian coal has high ash content and thus low calorific value. These results in higher coal consumption for each MW power produced in India. Although Indian coals are low in sulphur content, hence SO_2 emissions in India from coal-based thermal power plants for each MW are lower than elsewhere in the world, however due to enormous amounts of coal burnt, SO_2 emission is huge (8). Another environmental problem of great concern related to sulphur is the acid rain. There are certain speculations that tall stacks aid the long range transport of sulphur (up to 1000 km), making the acid rain problem a

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regional one, thereby killing the aquatic life (9). Environmental effects of acid rain probably include increased leaching of nutrients such as calcium from soil, changes in metabolic rates of organisms, corrosion of basic materials such as lime stone and marble (10)

Power Plant Emission and Health Hazard

The coal-fired thermal power plants have very low energy efficiency and large environmental impact as compared to gas fired power plants (11). Release of various types of gaseous impurities and particulate matter into the atmosphere from the power stations is a major health hazard. Among the power sectors, coal fired thermal power plants contribute massive pollution causing very high incidence of harmful diseases such as asthma, breathlessness, lung cancer and a host of other ailments among the people exposed to air pollutants. Pollution is likely to assume alarming proportions with increasing thrust on generation of power by thermal power plants based on coal consumption, if suitable control measures are not effectively applied to compact it (12). Thus environmental issues in "power sector" are of importance in our country in terms of human health (13). The quality of ambient air is of prime importance. All evidence of health is based only on these measurements (14).

MATERIALS AND METHODS

Study of air pollution requires scientific study and evaluation of its causes. Geographical study of air pollution takes into account, the pattern of pollutants in the atmosphere and level of pollution. It also examines its effect on human health as well as on plants and animals. Very limited work has been carried out on air pollution in the field of geography in India but sufficient work has been conducted in developed countries. Here an attempt has been made to analyse the status and trend of gaseous pollutants such as Sulphur dioxide (SO_2) and Oxides of Nitrogen (NOx) in and around a Coal Based Thermal Power Plant located at Mettur in Salem district of Tamil Nadu. The study is built upon the ambient air quality data collected from State Pollution Control Board. In this paper only 8 hours maximum concentrations of Sulphur dioxide (SO_2) and Oxides of Nitrogen (NOx) in a year (2 observations per year) have been considered for the study of trend analysis during the period 1999-2009.

Study Area

Mettur is one of the five major industrial areas in Tamil Nadu. It is about 52kms Northwest of Salem (Salem lies about 330KM Southwest of Chennai). Mettur is a Selection Grade Municipality and Taluk Head Quarters in Salem District. It is located at 11º 45′ of the Northern and 77º 45′ of Eastern longitude. Mettur is organized by geography as upper and lower Mettur lying in the Dams downstream (locally called Meal Mettur and Kizhl Mettur transliterated as up Mettur and down Mettur). It has an average elevation of 153 meters (501 feet). Mettur is known for its huge dam built in 1934 which is still one of the best dams in the country and attracts tourist from all over India. It is one of the major sources of power generation using the hydro-resources. A straight gravity structure, 1,615 m long rising 54 m above the Cauvery River bed, the dam is constructed across two hills of the Eastern Ghats. At the time of its construction, Mettur was the highest masonry dam in Asia and the largest in the world. The dam, constructed primarily to stabilize the irrigation in Thanjavur delta, caters to about one third of the irrigated area of the Tamil Nadu, besides generating hydro electric power of 240 MW. It is situated at an elevation of 243 m above mean sea level in the Salem district. It has a water spread of 15,346 ha and capacity of 2,646 million cubic meter at FRL, the average area being 9,324 ha. Stanley is the largest reservoir in Tamil Nadu. The town is well connected with the road services to Salem, Dharmapuri, Mysore, Bangalore and Erode. It is also well connected by rail with the Salem Town. The Mettur Municipal area spreads over to an extent of 14.55sq.km. Mettur taluk with an area of 59,136 hectares now comprises of 3 Blocks of Panchayat Unions Kolathur, Mecheri and Nangavalli. Mettur town is surrounded by the Stanley Reservoir on the North, Palamalai on the West and Vanavasi Panchayat Forest on the East. The River Cauvery traverses in the middle of the town and divides the town into two parts namely Mettur and Mettur Railway Stations.

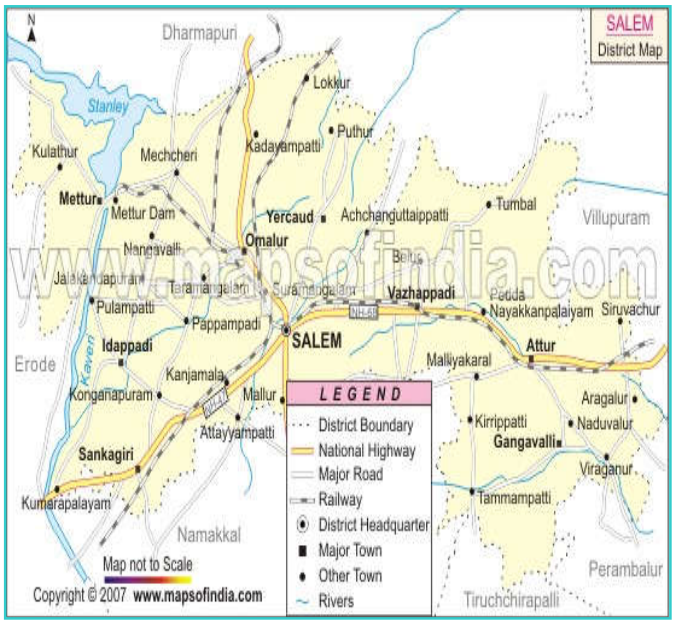

Fig. 1. Map showing the Location of Study Area

Climate and Meteorology

The climate of the region may be classified as of tropical dissymmetric type, with a moderate rainfall spread over an average period of six months. Two types of Metrological Phenomena bring rain to this region. They are Southwest Monsoon (June – August) and Northeast Monsoon (October-December). The mean annual rainfall is 964mm. The rainfall during winter and summer is uneven and inadequate. Normal rainfall is received during monsoon month i.e. June to November. The rainiest month is October and the driest month is January. The climate of the Mettur area can be divided into four seasons as follows:

I. Winter- December, January, and February
II. Summer or Pre Monsoon- March, April and May
III. Southwest Monsoon- June, July, August and September
IV. Northeast Monsoon- October and November

It is observed from the data obtained from meteorological observatory of Mettur Dam for the study period that from January, the ambient temperature gradually rises till June, which is the hottest month of the year with a maximum and minimum of 35.6º C and 24.7º C, respectively. The lowest temperature recorded was 16.0º C on January 16, 2002 and the highest was 41.8º C on May 24, 2008. The annual mean of maximum temperature was 37.8º C. Analysis of wind records during the study period shows that the winds are generally light to moderate in this area. It can be seen that the annual mean wind speed varies from 3.0 to 5.2 km/hour. The strongest winds are observed during March- June i.e. summer season and the weakest during October- November. The most predominant wind directions are Northeast-Southwest and Southwest-Northeast. The mean Relative Humidity varies from 59-69% (March-July) to 75-85% (October-September). The minimum Relative Humidity is 59% in May. The average Relative Humidity of the Mettur area is 67.0%. The length of the dry season on the average is 6 months in a year. Hail is an extremely rare phenomenon. Dew is noted till late March, it could be relatively important source of moisture to the plants.

Mettur Thermal Power Station

The Mettur Thermal Power Station (MTPS) located here is one of the four major thermal plants in the state with an installed capacity of 840 MW. It is designed to meet the energy needs of the State in general and industrial and agricultural requirements of Mettur and Salem in particular. The plant is located in Chinnakkavoor village of P.N.Patti Village Panchayat. It is 50 kms from Salem town, 60 kms from Erode. The nearest railway station is Mettur Dam. Located on the left flank of the Ellis Surplus course of the Cauvery, it is spread over an area of more than 1,300 acres. It has been developed at a cost of 840 crores of rupees to assure continuous and uninterrupted supply of power, especially during dry seasons. It is located at a distance of 5 km in southwest direction and Vanavasi reserved Forest is located at a distance of 2 km in southeast direction.

Sampling Sites

There are 8 sampling sites identified to assess the ambient air quality mostly found in rural areas. They are as follows: Stn.I-Thangamapuripattinam (N) Stn.II- Chinnakkavur (NE), Stn.III-Thalaiyur (E), Stn.IV- Pudhukkadu (SE), Stn.V- Erikattupudur (S), Stn.VI- Madhayankuttai (SW), Stn.VII-Thottilpatty (W) and Stn.VIII-Square Market-Mettur Township (NW). The distance of each sampling points from the tall stacks (2 Nos. with a height of 180m and 220m) of the plant ranges from 1000m to 2500 m. While almost all the sampling sites fall in the category of Rural Residential, the station located at Square Market-Mettur Township coming under Residential cum Commercial.

Measurement Techniques

Sulphur dioxide (SO_2)

Improved West and Gaeke (West- Gaeke, 1956) method has been notified as a standard method for determination of Sulphur dioxide. This method can measure concentrations over an approximate range of 0.005-5 ppm v with an accuracy of + 10% (including sampling and analysis) at the lower end of the range and + 5% at the upper end, with a precision of about 2%. A known quantity of ambient air is passed through an absorbing solution of potassium tetrachloro-mercurate (TCM) at a known flow rate and for a known period of time. Sulphur dioxide in the sampled air gets absorbed into the absorbing solution and forms dichlorosulphitomercurate complex. This complex is reacted with pararosaniline and formaldehyde to form coloured complex of pararosaniline methyl-sulphonic acid. The absorbance of this solution is measured at 560 mm to determine SO_2 concentration in ambient air. The solution is then discarded as laboratory waste and discharged down the drain. In this method, precaution has to be observed for the interference of nitrogen peroxide and some heavy metals. The interference of nitrogen oxide was estimated by including 0.06% Sulphamic Acid in the absorbing reagent while heavy metals especially iron salts were eliminated by including Ethylene Diamine Tetra Acetic in the absorbing medium. The detection range of the Sulphur dioxide (SO_2) concentration is 4-1050µg/m^3.

Oxides of Nitrogen (NOx)

Analysis of NO_2 has been done on the basis of Jacob and Hochheiser (Jacob and Hochheiser, 1958) modified method or Sodium Arsenic method (IS-5182, Part vi, 1975). According to this method, a known quantity of air is bubbled through an impinger containing Sodium hydroxide and Sodium arsenite solution to form stable solution of Sodium nitrite. The concentrate of nitrite ion (NO_2) produced during sampling is reacted with phosphoric acid, sulphanilamide and N-(I-naphthyl)- ethylene diamine dihydrochloride to form highly coloured azo dye which is determined calorimetrically at 540 nm for which calibration curve had already been prepared. The detection range of the Oxides of Nitrogen (NOx) concentration is 9-750µg/m^3.

RESULTS AND DISCUSSION

Trend in Maximum Concentration of Sulphur dioxide (SO_2)

The maximum concentrations of Sulphur dioxide (SO_2) at various sampling stations around Thermal Power Plant during the period 1999-2009 have been given in Table 1. It is observed from the above table that the annual maximum concentrations of Sulphur dioxide (SO_2) were ranged between 20.8µg/m^3-73.5µg/m^3 during the period 1999-2009. The highest value of 73.5µg/m^3 was observed at Stn.VI-Madhayankuttai during 2001-2002 while the lowest value 20.8µg/m^3 was observed at St.IV-Pudhukkadu during 2004-2005. No values were found to be exceeded the prescribed standard of 80µg/m^3 during the period of study. It is also observed that he values recorded during the last five years were found to be less than the beginning of the study period and understood the concentration of Sulphur dioxide (SO_2) is gradually declining. The station wise overall ten years period of study shows that the maximum concentrations of Sulphur dioxide (SO_2) were found to be in the range of 32.1µg/m^3-73.5µg/m^3. The highest value 73.5µg/m^3 was recorded at Stn.IV -Madhayankuttai (2001-2002) which is followed by 73.1µg/m^3 (Stn.V -Errikadu/2001-2002),66.5µg/m^3 (Stn.I-

Table 1. Maximum Concentration of Sulphur dioxide (µg/m^3) during 1999-2009

Stations	1999-00	2000-01	2001-02	2002-03	2003-04	2004-05	2005-06	2006-07	2007-08	2008-09
Stn. I	54.0	37.4	63.2	66.5	21.3	14.4	8.4	17.2	25.0	12.4
Stn. II	56.0	26.6	43.9	59.5	14.4	10.6	19.2	24.8	18.9	18.4
Stn. III	23.6	32.2	20.6	23.8	13.6	11.6	14.9	14.3	17.7	12.8
Stn. IV	22.7	16.6	32.1	23.0	26.5	20.8	27.5	11.6	29.7	28.8
Stn. V	20.0	18.2	73.1	40.6	29.6	7.6	17.3	21.9	25.6	19.6
Stn. VI	35.0	22.6	73.5	66.1	26.8	13.8	18.3	10.0	37.8	11.4
Stn.V1I	36.0	18.2	35.7	61.6	12.4	14.8	13.2	10.7	21.6	12.0
Stn. VIII	22.0	26.9	22.2	63.2	10.0	13.6	17.6	12.0	23.0	20.8
Min.	20.0	16.6	20.6	23.0	10.0	7.6	8.4	10.0	17.7	11.4
Max.	56.0	37.4	73.5	66.5	29.6	20.8	27.5	24.8	37.8	28.8

Note: The values are restricted to the sampling period of 8 Hours (Day Sampling).

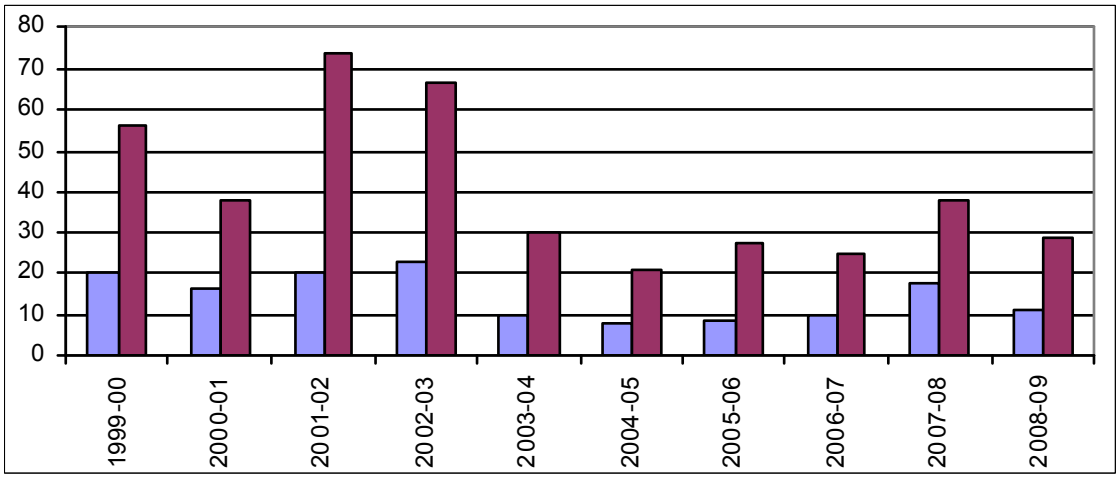

Fig.2 Sulphur dioxide (SO_2)-Annual Min and Max of 8 Hours Maximum Concentration

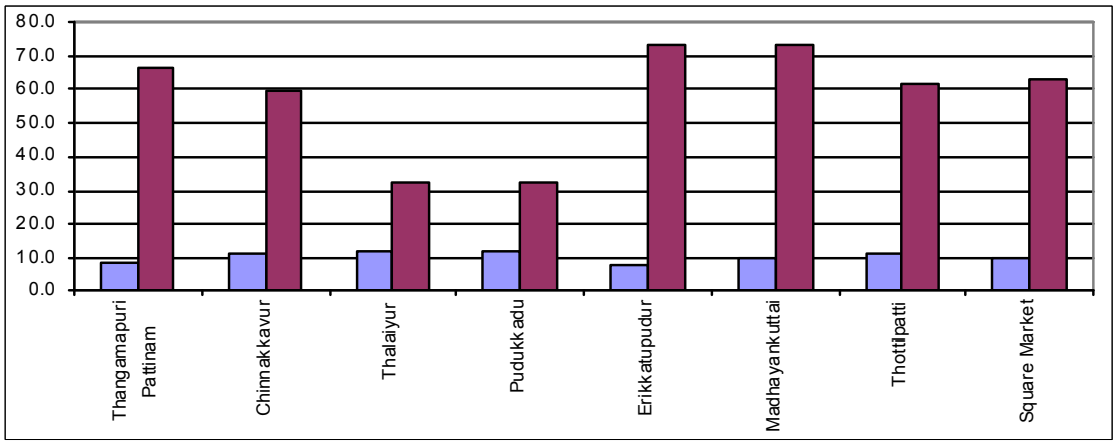

Fig. 3. Sulphur dioxide (SO_2) - Station wise Min and Max Values During 1999-2009

Thangamapuripattinam/ 2002-2003), 63.2µg/m^3 (Stn.VIII - Square Market/2002-2003), 61.6µg/m^3 (Stn. Vil. Thottilpatty / 2002-2003), 59.5µg/m^3 (Stn. II- Chinnakkavur/2002-2003), 32.2µg/m^3 (Stn. III- Thalaiyur/2000-2001) and 32.1µg/m^3 (St.V- Pudhukkadu/2001-2002). Trend in annual minimum and maximum of 8 hours maximum concentrations and station wise 10 years minimum and maximum of 8 hours maximum concentrations of Sulphur dioxide (SO_2) are depicted in Fig.2 and Fig.3 respectively. Station wise trend in maximum values of 8 hours concentration of Sulphur dixide (SO_2) are also depicted in Figures 4-11.

Trend in Maximum Concentration of Oxides of Nitrogen (NOx)

The maximum concentrations of Oxides of Nitrogen (NOx) at various sampling stations around Thermal Power Plant during the period 1999-2009 have been given in Table 2. It is observed from the above Table.2 that the annual maximum concentrations of Oxides of Nitrogen (NOx) were ranged from 37.1µg/m^3 to 85.1µg/m^3 during the period 1999-2009. The highest value 85.1µg/m^3 was recorded at Stn.V-Erikkattupudur/2001-2002 while the lowest value 37.1µg/m^3

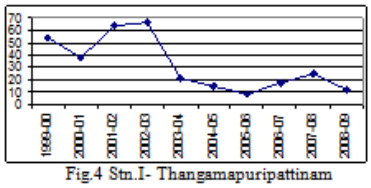
Fig.4 Stn.I- Thangamapuripattinam

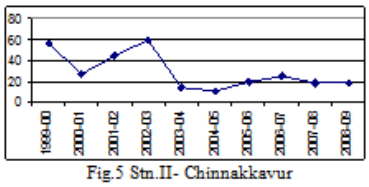
Fig.5 Stn.II- Chinnakkavur

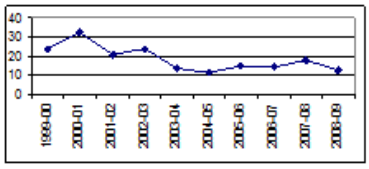
Fig.6 Stn.III-Thalaiyur

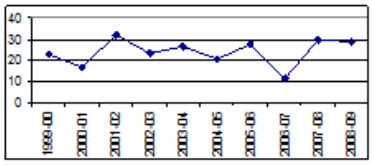
Fig.7 Stn.IV-Pudhukkadu

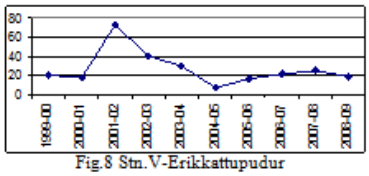
Fig.8 Stn.V-Erikkattupudur

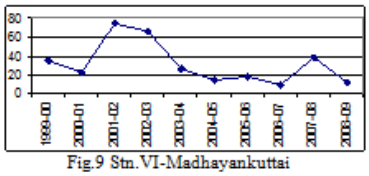
Fig.9 Stn.VI-Madhayankuttai

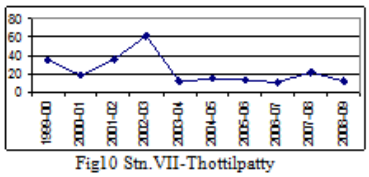
Fig10 Stn.VII-Thottilpatty

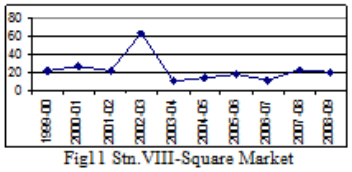
Fig11 Stn.VIII-Square Market

Station wise Trend-Fig.4-11.
Annual Maximum Concentration of Sulphur dioxide (SO_2): 1999-2009

Table 2. Maximum Concentration of Oxides of Nitrogen (µg/m^3) during 1999-2009

Stations	1999-00	2000-01	2001-02	2002-03	2003-04	2004-05	2005-06	2006-07	2007-08	2008-09
Stn. I	27.5	32.4	50.3	60.1	17.3	39.3	27.5	31.5	23.9	45.4
Stn. II	32.8	42.6	31.2	75.1	29.2	32.7	19.1	37.1	37.8	35.6
Stn. III	36.8	42.8	36.8	29.5	23.9	23.5	25.1	25.7	33.7	42.1
Stn. IV	36.8	28.0	46.8	39.6	26.1	31.9	37.7	27.0	33.7	46.6
Stn. V	26.2	22.8	85.1	61.4	38.6	32.6	19.7	33.7	39.0	20.8
Stn. VI	38.0	42.2	66.6	64.2	32.8	38.6	31.6	18.2	41.9	19.8
Stn.V1I	38.0	26.2	35.1	71.9	21.7	25.9	23.0	22.8	30.6	20.8
Stn. VIII	22.0	37.4	25.0	66.6	27.4	23.5	26.8	26.6	32.9	35.9
Min.	22.0	22.8	25.0	29.5	17.3	23.5	19.1	18.2	23.9	19.8
Max.	38.0	42.8	85.1	75.1	38.6	39.3	37.7	37.1	41.9	46.6

Note: The values are restricted to the sampling period of 8 Hours (Day Sampling).

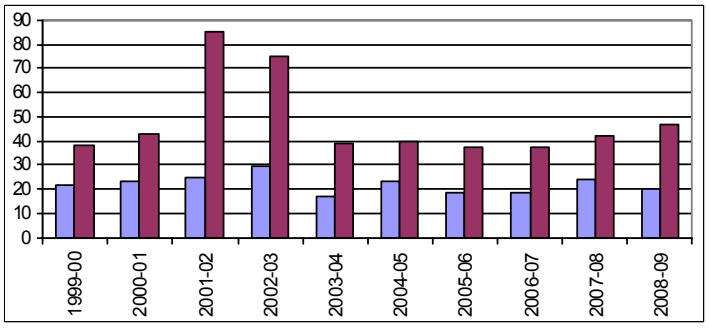

Fig.12. Oxides of Nitrogen (NOx)-Annual Min and Max of 8 Hours Concentration

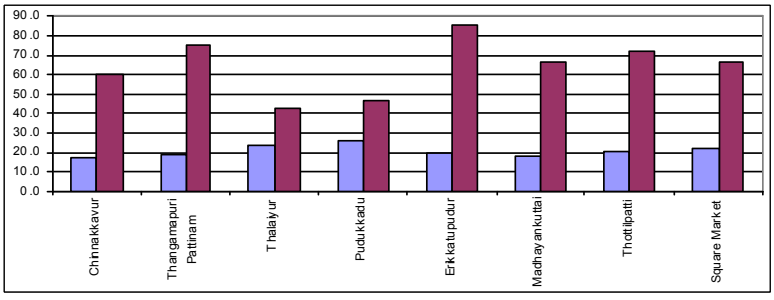

Fig.13. Oxides of Nitrogen (NOx)–Station wise Min and Max Values during 1999-2009

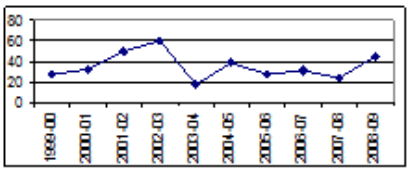

Fig.14 Stn.I- Thangamapuripattinam

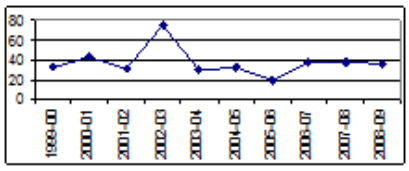

Fig.15 Stn.II- Chinnakkavur

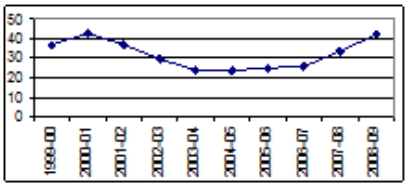

Fig.16 Stn.III-Thalaiyur

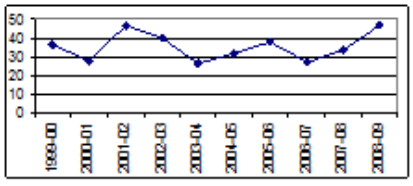

Fig.17 Stn.IV-Pudhukkadu

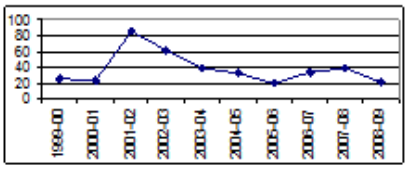

Fig.18 Stn.V-Erikkattupudur

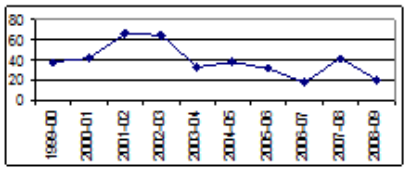

Fig.19 Stn.VI-Madhayankuttai

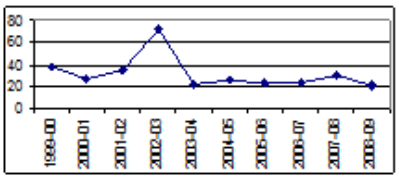

Fig.20 Stn.VII-Thottilpatty

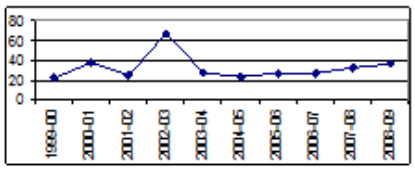

Fig.21 Stn.VIII-Square Market

Station wise Trend- Fig.14-21
Maximum Concentration of Oxides of Nitrogen (NOx): 1999-2009.

was observed at Stn.II-Thangamapuripattinam/2006-2007. Almost all the annual maximum values were found to be within the prescribed standard of 80µg/m^3 except the value observed at Stn.V-Erikattupudur where it is slightly exceeded the prescribed standard. The station wise over all 10 years period of study shows that the maximum concentrations of Oxides of Nitrogen (NOx) were in the range of 42.8µg/m^3-85.1µg/m^3. The highest value of 85.1µg/m^3 was recorded at Stn.V-Erikkattupudur/2001-2002 which is followed by 75.1µg/m^3 (Stn. II- Thangamapuripattinam/ 2002-2003), 71.9µg/m^3 (Stn. V- Thottilpatty/ 2002-2003), 66.6µg/m^3 (Stn.VI- Madhayankuttai/ 2001-2001 & Stn.VIII- Square Market/2002-2003), 46.8µg/m^3 St. IV-Pudukkadu/2001-2002) and 42.8µg/m^3 (Stn.III-Thalaiyur/2000-01). Trend in annual minimum and maximum of 8 hours maximum concentrations and station wise 10 years minimum and maximum of 8 hours maximum concentrations of Oxides of Nitrogen (NOx) are depicted in Fig.12 and Fig.13 respectively. Station wise trend in maximum values of 8 hours concentration of Oxides of Nitrogen (NOx) are also depicted in Figures.14-21

Conclusions

The main goal of the study was to quantify the maximum concentrations of gaseous pollutants such as Sulphur dioxide (SO_2) and Oxides of Nitrogen (NOx) which are responsible for various harmful effects at various locations around the Coal Based Thermal Power Plant during the ten years period from 1999-2009. The sampling sites are mostly in rural remote settlements at a distance in the range of 1000m-2500m and sampling has been carried out twice in a year. Agriculture is the main occupation of the people living in the surroundings of the thermal power plant. The following conclusion was drawn from the present study. The study clearly reveals that almost all the 8 hour maximum concentrations of Sulphur dioxide (SO_2) values were found to be well within the prescribed standard. However some of the higher values nearing the standard were also observed at Madhayankuttai, Erikkattupudur and Thangapuripattinam settlements. The annual maximum 8 hours concentrations of Oxides of Nitrogen (NOx) are also found to be well within the prescribed standard during this study period except one observation at Erikkattupudur settlement where the value is just abnormal. The study concludes that the higher values of gaseous pollutants at some locations may be due to the other industrial activities in this area where major industries are clustered.

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