# SPATIO-TEMPORAL ASSESSMENT OF AIR POLLUTION FROM THERMAL STATIONS AND VEHICULAR POLLUTION FROM URBAN PLACES IN TAMIL NADU

**V.E. Nethaji Mariappan[1], P. Mohana[2], C.A. Murrugesan[3], Joshua Amarnath[4]**

[1]Scientist-D, [2]Scientist-C,
[1&2]Centre for Remote Sensing and Geo informatics
[4]Prof and Head, Dept. of Chemical Engineering, Sathyabama University, Chennai, India
[3]Assistant Executive Engineer in TANGEDCO, TNEB, Chennai
E-mail: [1]nethajim@gmail.com

**Abstract**

*India has evolved as self reliance country at all forefronts. Demand for energy is on rise due to the robust development of sectors like Automobile, Chemical, Information Technology and ITES in most part of the metropolitan states in India. There is a great deficit on energy particularly with supply chain management in Tamil Nadu. Government is exploring new ways of harnessing clean and green energy to meet out the demand. Source of energy is derived from thermal, hydro, wind, solar etc., So far and so forth, maximum energy is harnessed from thermal using coal as the raw material. Type and quality of coal determines the energy conversion ratio and the pollution emission of* $SO_2$, $NO_X$ *and RSPM etc. This study attempts to spatially and temporally explore the pollution concentration and assess with respect to Air Quality Index (AQI) of the available data on thermal power stations in Tamil Nadu. A comparison between the vehicular pollution concentrations and thermal pollution concentration has entailed us that* $SO_2$ *and* $NO_X$ *emission was higher from vehicles and SPM was higher from thermal stations and that lead us to take precautionary measures in managing the environmental pollution. Thus this study gives an insight on the rise in pollution concentration and its effect on human health.*

**Key words:** Spatial mapping, Air Pollution, GIS, Thermal Stations, Industrial, Residential, Mixed.

## I. INTRODUCTION

Air pollution is the major source of pollution for the human kind. Such pollution is a common phenomenon in urban region than rural region. Unparallel growth of Industries in the recent past has led to steep demand in energy in Tamil Nadu. Nearly more than half of the total energy production is from thermal sector using coal as the raw material. Thermal stations use coal as combustion material for fuel and the chemical energy stored in coal is converted successively into thermal energy, mechanical energy and finally electrical energy for continuous use and distribution across a wide geographic area.

Coal for combustion in thermal power station is mainly drawn from Indian mines like Mahanadhi coal fields in table 1, Orissa (IB Valley, Talchar), Eastern coal field, Ranikanj and also imported coal from Australia & Indonesia and are fed into the mill plant for pulverizing through an elevated multi level conveyor system before feeding into the boiler area Balasubramanian et al. 2012a. Average daily consumption with plant utilization factor of 62% is 4350 MT [3]. With the average calorific value of 3200 Kcal/Kg, fly ash generated is at the rate of 43.2%.

**Table 1. Characteristics of Mahanadhi Coal & Foreign Coal (Indonesian) - Proximate Analysis**

| Main Characteristics | Indian Coal | Foreign Coal |
|---|---|---|
| Fixed Carbon | 31% | 48% |
| Ash Content | 42% | 12% |
| Volatile Matter | 21% | 30% |
| Moisture Content | 14% | 10% |

Coal which consist more carbon, high volatile matter and low moisture content has high calorific value. Coal with highest UHV (Utility Heat Value) which produce low ash has been characterized as Grade-A as in table 2, and coal with least UHV consist of low carbon, low volatile matter, more moisture content and very high ash content, has been characterized as Grade-G.

**Table 2. Ultimate analysis of Coal**

| Details % | Mahanadhi coal | Sipat | Indonesian coal | China |
|---|---|---|---|---|
| Carbon | 31.0 | 30.72 | 48.0 | 62.8 |
| Hydrogen | 1.88 | 2.30 | – | 5.6 |
| Nitrogen | 0.52 | 0.60 | – | 1.4 |
| Oxygen | 6.96 | 5.35 | – | 21.7 |
| Moisture | 14.0 | 15.0 | 10.0 | 11.0 |
| Sulphur | 0.13 | 0.40 | 0.30 | 0.9 |
| Ash | 42.0 | 45.0 | 12.0 | 7.7 |
| CV kcal/kg | 3805 | 3000 | 6300 | 6087 |

More than 40% of ash is generated by burning of coal and the balance is converted as heat energy. 'Fly ash' or Coal ash is substantially more dangerous than household garbage. The pollutants like arsenic, sulfate, selenium, magnesium, mercury, chlorides, iron and more in table 3 (David French and Jim Smitham, 2007), tend to disperse in atmosphere in many thermal power stations. Real time monitoring and preventing further pollution is on the anvil for maintaining the quality of air in the nearby residential areas. The characteristic of the fly ash is the main cause for leaching of minerals. The Table below illustrates the properties of both Indian coal ash as well as foreign coal ash.

**Table 3. Proximate analysis of Fly Ash**

| Parameter | Indian coal ash | Australian coal ash |
|---|---|---|
| $SiO_2$ Silicon dioxide | 57.90% | 56.80% |
| $Al_2O_3$ Alumina | 32.54% | 26.30% |
| $Fe_2O_3$ Ferric oxide | 2.69% | 9.50% |
| CaO Calcium oxide | 0.69% | 1.40% |
| MgO Magnesium oxide | 0.49% | 0.805 |
| LOI (Loss of Ignition) | 0.46% | – |
| $SO_3$ Sulphur tri-oxide | 0.13% | 0.30% |
| $Na_2O$ Sodium oxide | 1.44% | 0.20% |
| $K_2O$ Potassium oxide | 0.87% | 0.70% |

## II. MATERIALS AND METHODS

*Study Area*

Chennai is the capital of Tamil Nadu and considered to be Detroit of India having most of the automotive industries like Ford, Hyundai, BMW, Mitsubishi, Ashok Leyland, Nissan-Renault, Caterpillar etc., with a total area of about 5000 $Km^2$. In addition it houses two thermal power stations namely Ennore with and installed capacity of 450 MW functioning since 1970 (Balasubramanian et al., 2012b) and North Thermal Power stations to cater the needs of energy demand of Chennai city. Tuticorin Thermal Power Station is located at Toothukudi that cater Industrial energy needs of that district. Apart, National pollution monitoring stations are evenly distributed throughout Tamil Nadu. Air pollution and its health consequences has been a major concern for both citizens and urban planners and decision makers of this city. Regarding the special geographical situation of Chennai and expansion of spatial dispersion of the pollutants which belong to stationary and mobile sources, government and citizens in this metropolitan have to use the latest technology to develop air quality management. Air quality sensors measure the amount of Sulfur dioxide ($SO_2$), Nitrogen dioxide ($NO_X$) and Particulate Matter (PM) in polluted Chennai.

In this research the environmental pollution data from five stations with respect to residential areas in Chennai in 2010-2011 were collected as CAAQM, and then National Ambient Air Quality Stations of thirteen places that include (i) seven Industrial sites (ii) four mixed sites and (iii) two residential sites and of three thermal power stations were also utilized in this study (Murrugesan, 2012). The air quality stations are represented in figure 1 and table 4 with respect all station for the year 2010-2011 was collected cross checked for its validity. The accuracy of the data was assessed by using statistical analysis. To detect and remove error recorded data, the specific domain of each pollutant should be determined.

**Table 4. National Ambient Air Quality Stations Stations of Tamil Nadu**

| LONG | LAT | PLACES | CT |
|---|---|---|---|
| 78.10225 | 8.788965 | Raja Agencies - TTK | Industrial |
| 78.15264 | 8.804298 | AVM Buildings - TTK | Mixed |
| 78.07984 | 8.822851 | SIPCOT - TTK | Industrial |

| | | | |
|---|---|---|---|
| 78.12088 | 9.925686 | Avvai Girls Higher Secd. School - MDU | Mixed |
| 78.08585 | 9.932509 | M/s.Susee Cars & Trucks (P) Ltd., - MDU | Industrial |
| 78.13234 | 9.937606 | Highways project Buildings - MDU | Residential |
| 76.97916 | 10.94288 | SIDCO - CO | Industrial |
| 76.96557 | 11.00063 | G.D Matric School - CO | Mixed |
| 76.95745 | 11.01695 | Pooniyarajapuram - CO | Residential |
| 78.12867 | 11.63282 | Sowdeswari college building - SL | Mixed |
| 80.30009 | 13.15971 | Thirvottiyur - CH | Industrial |
| 80.26503 | 13.15974 | Manali - CH | Industrial |
| 80.31859 | 13.21556 | Kathivakkam - CH | Industrial |

The data was structured and stored in the temporal database and by using ArcGIS Desktop software each pollutant was spatially mapped. Attribute data were assigned to spatial objects and the system became ready for spatio- temporal analysis and management.

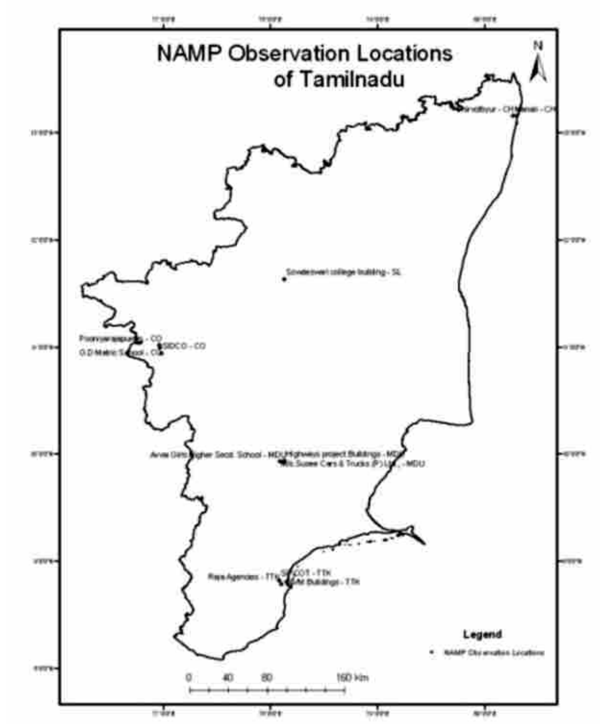


Fig. 1. National Ambient Air Quality Stations of Tamil Nadu

### Air Quality Index (AQI)

AQI universal standard has been used having a rating scale for reporting the ambient air pollution recorded at monitoring sites on a particular time scale (e.g., daily). The intention of comparing the present pollution levels with AQI are to create awareness to the public about the risk of exposure to daily pollution levels and ensure that they comply to certain management aspect on regulatory measures for mitigating the impact (Stieb et al., 2005).

Although the AQI itself is simply a number that reflects some aspects of air quality, in practice it is associated with color schemes, graphics, air quality category labels (e.g., “Good”, “Moderate”, or “Hazardous”), and various messages so that it’s meaning is easily understood by the public EPA: 1999. The values of the AQI determine the air quality according to Table 5.

**Table 5. Air Quality Index Categories**

| Levels of health concern | AQI | PM2.5 (g/m3) | PM10 (g/m3) | $SO_2$ (ppm) | $NO_2$ (ppm) |
|---|---|---|---|---|---|
| Good | 0-50 | 0.0–15.4 | 0– 54 | 0.000–0.034 | (b) |
| Moderate | 51-100 | 15.5–40.4 | 55–154 | 0.035–0.144 | (b) |
| Unhealthy for sensitive groups | 101-150 | 40.5–65.4 | 155–254 | 0.145–0.224 | (b) |
| Unhealthy | 151-200 | 65.5–150.4 | 255–354 | 0.225–0.304 | (b) |
| Very unhealthy | 201-300 | 150.5–250.4 | 355–424 | 0.305–0.604 | 0.65–1.24 |
| Hazardous | 301-500 | 250.5–500.4 | 425–604 | 0.605–1.004 | 1.25–2.04 |

## III. RESULTS AND DISCUSSION

GIS has the advantage of the high power of analyzing of spatial data and handling large spatial databases. Air pollution has a large amount of data that GIS can be used for their handling and manipulating it in a systematic way. Data on air pollutants, wind direction, wind speed, traffic flow, solar radiation, air temperature, mixing height will be used for modeling air quality. The integration of both GIS and remote sensing provides an efficient tool for the air pollution monitoring authorities (Zhou, 1995)

With GIS data and other types of digital data, such as air pollution measures can be used for assessing the air pollution through ArcGIS software for spatial mapping pollutants like $CO_2$, $SO_2$, $NO_x$ and SPM obtained from Urban areas like Chennai and other areas like Industrial, Residential and Mixed regions of Tamil Nadu. Presently, the air pollution data obtained from Ennore Thermal Power Station, North Thermal Power Station and Tutitcorin Thermal Power stations corresponding to the period of 2010-2011 were spatially mapped in GIS environment. The integration of the above information can be inserted into GIS software which can monitor and map high risk areas resulting air pollution. By using the pollution parameters and through the application of Inverse Distance Weighted Interpolation (IDW) algorithm spatial maps were generated for all the themes of the polluted areas.

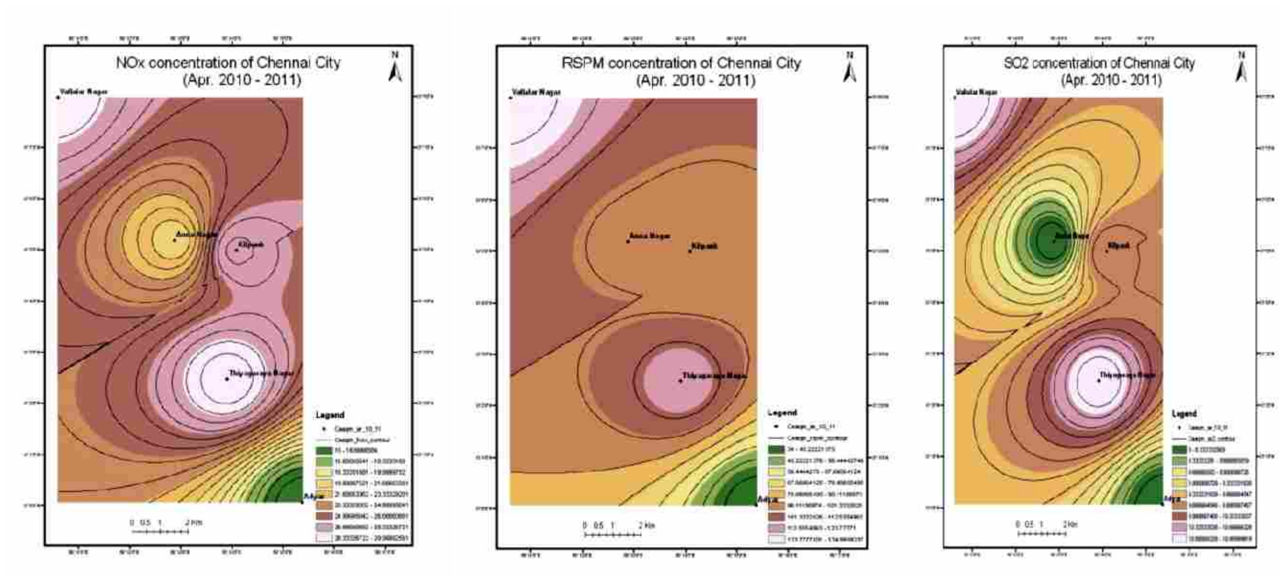


Fig. 2. NOx, $SO_2$ and SPM concentration of Chennai city

Spatial map of $NO_x$ indicated that highest concentration was observed at Vellalar Nagar of North Chennai and Thiyagaraya Road of T. Nagar (29 & 30 $\mu gm/m^3$) respectively. Lowest pollution in figure 2 was recorded at Adayar (15$\mu gm/m^3$). Higher pollution at Thiyagaraya Road of T. Nagar was due density of vehicular pollution at peak hours coupled with congregation commercial complex in and around this area. Vellalar region is surrounded by giant and medium and small scale industries resulting in emission $NO_x$ to the maximum level. $SO_2$ concentration was highest in Vallalar nagar and Thiyagaraya Road of T. Nagar (>10 $\mu gm/m^3$) and lowest was observed at Adayar and Anna Nagar (< 9.0 $\mu gm/m^3$). Such higher pollution concentration at winter may settle in the lower atmosphere and cause carcinogenic effect on human health.

There were of thirteen monitoring stations in Tamil Nadu under the ambit of National Air Quality Monitoring Programme. Data pertaining to the year of 2010-2011 were collected verified for the error, further used in ArcGIS environment for interpolation for all the thirteen station that include Industrial, Residential and Mixed environment in figure 3. Invariably higher levels (76-87.2 $\mu gm/m^3$) Residual Suspended Particulate Matter was noticed at Chennai and Tuticorin due to emission of soot particles Industries. Emission of $SO_2$ was highest (>11.0 $\mu gm/m^3$) from Chennai and Tuticorin. NOx pollution concentration was highest at Tuticorin, Moderate in Chennai. Coimbatore recorded

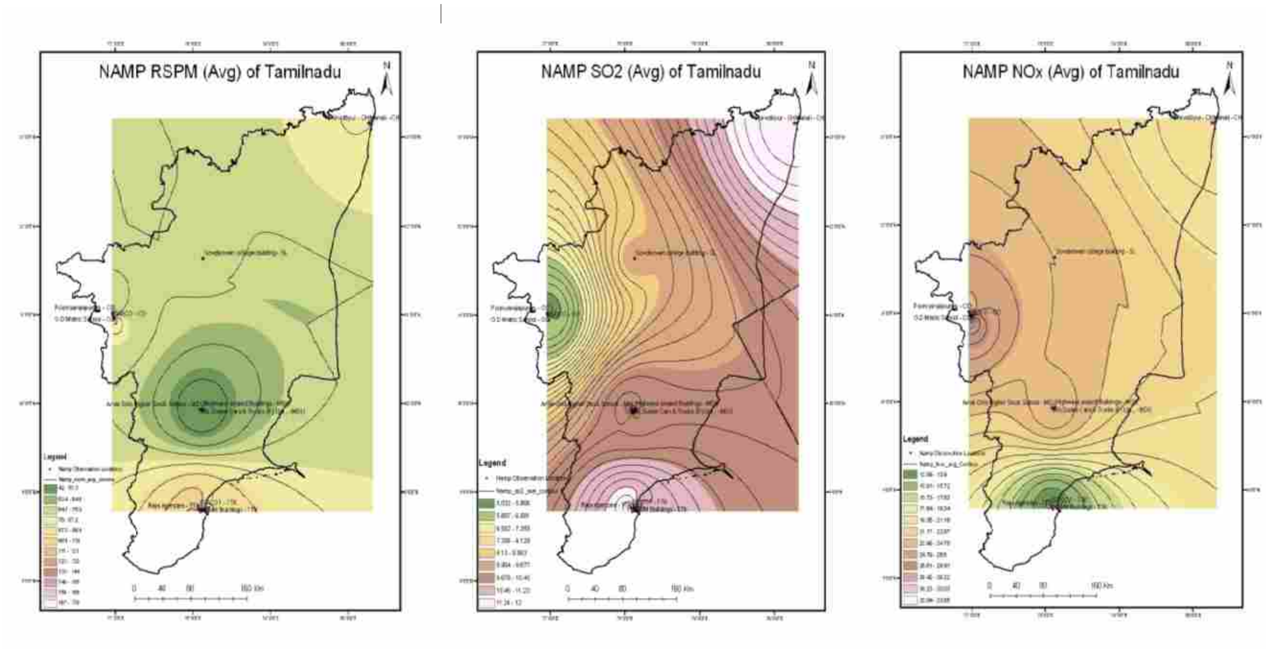


Fig. 3. RSPM $SO_2$ and $NO_x$ average value of Industrial, Mixed and Residential Areas of Tamil Nadu (duration monthly average data of 2010-2011)

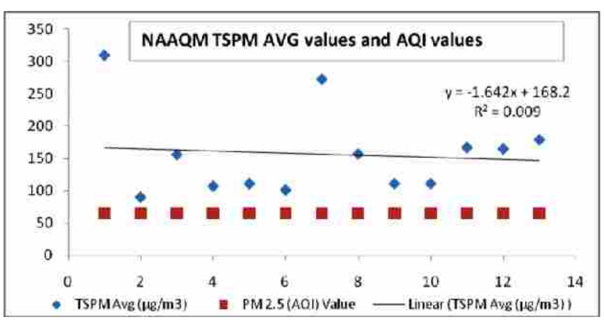


Fig. 4. Plotting TSPM average values of NAAQM station corroborate with AQI-PM values

overall low levels of TSPM, NOx and $SO_2$ for the period 2010-2011. The average TSPM values were above the Air Quality Index range for an unhealthy situation to human health as reported in figure 4.

These datasets were further compared with pollution datasets of Tamil Nadu corresponding to year 2004. are downloaded from the environment website of Tamil Nadu www.environment.tn.nic.in/SoE/images/Pollution.pdf. Results of this study indicated that $SO_2$ concentration during the period of 2004 were < 20 $\mu gm/m^3$ and of 2011 has shown a five fld increase (>11.0 $\mu gm/m^3$). NOx levels were more are less the same in comparison with data obtained from 2004. SPM concentration for the year 2004 data were of < 100 $\mu gm/m^3$ and as of 2011 values were > 100 $\mu gm/m^3$ of most the monitoring stations. This study signifies that there could be mean annual increment of $SO_2$, $NO_x$ and SPM at all the monitoring stations.

Overall emission of $SO_2$ of the thermal station ranged from 0.16 to 3.09 $\mu gm/m^3$ with a mean value of 1.178 $\mu gm/m^3$. NOx varied from 0.016-118.31 $\mu gm/m^3$ and a mean value of 3.20 $\mu gm/m^3$ in figure 5. Residual Suspended Particulate Matter concentration was highest 3180.46 $\mu gm/m^3$. It was realized that RSPM was at its highest emission from thermal stations. Dynamics of air pollution of $SO_2$, $NO_x$ and SPM might also be due to use of low calorific value or poor quality coal used for power generation as this coal could contain more contaminants at the time of fly ash emissions.

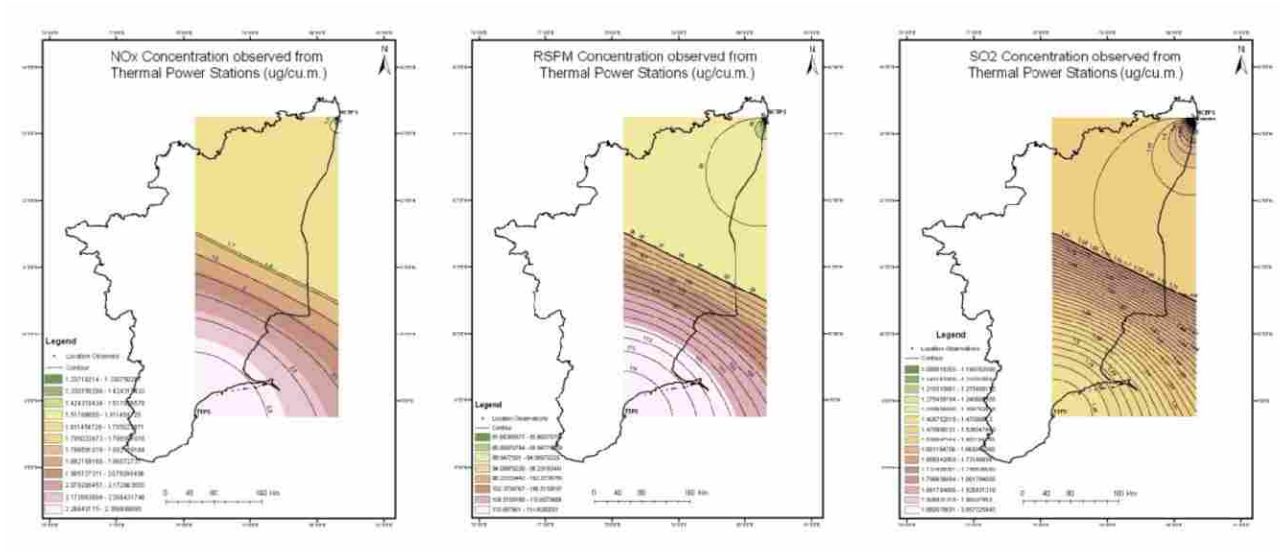


Fig. 5. $NO_X$, $SO_2$ and RSPM concentration of Ennore, North Chennai and Tutitcorin Thermal Power Stations of Tamil Nadu (duration monthly average data of 2010-2011)

**Table 6. Air Pollution data of Thermal Stations and Air Quality Index Categories marked in bold**

| S. No. | Station | Date | $SO_2$ ($\mu gm/m^3$) | $SO_2$ (ppm) | NOx ($\mu gm/m^3$) | NOx (ppm) | SPM ($\mu gm/m^3$) |
|---|---|---|---|---|---|---|---|
| 1 | Ennore | 28.01.2011 | 3.07 | 1.09 | 1.82 | 0.898 | 104.63 |
| | | 29.01.2011 | 1.935 | 0.686 | 3.19 | 1.57 | 65.42 |
| | | 31.01.2011 | 1.15 | 0.408 | 0.795 | 0.392 | 37.53 |
| | | 01.02.2011 | 0.67 | 0.238 | 0.49 | 0.242 | 86.98 |
| 2 | NCTPS | 22.02.11 | 0.57 | 0.202 | 1.41 | 0.696 | 32.99 |
| | | 24.02.11 | 0.56 | 0.199 | 2.375 | 1.172 | 76.4475 |
| | | 24.02.11 | 0.59 | 0.209 | 2.54 | 1.25 | 68.23 |
| | | 25.02.11 | 1.034 | 0.366 | 5.46 | 2.7 | 74.442 |
| 3 | TTPS | 27.06.11 | 0.98 | 0.347 | 0.588 | 0.29 | 98.876 |
| | | 28.06.11 | 1.66 | 0.589 | 1.86 | 0.918 | 134.8 |
| | | 29.06.11 | 0.77 | 0.273 | 1.56 | 0.77 | 122.55 |

Pollution data from Thermal stations of Ennore, North Chennai and Tuticorin were recorded in µgm/m$^3$. These data were converted from µgm/m$^3$ to ppm on volumetric basis using http://www.lenntech.com/calculators/ppm/converter-parts-per-million.htm. $SO_2$ values emitted from Ennore Thermal station were hazardous, while NOx values from North Thermal Power station were hazardous. Such an comparison gives an insight to the public to be aware for the situation and to take mitigation plans to avoid health risks. SPM level at 2.5 showed an unhealthy situation to the public at large in figure 5 and table 6.

Temporal data on pollution parameters like $SO_2$, $NO_x$ and SPM of Tuticorin Thermal Power station was recorded between 1$^{st}$ December 2011 and 31 January 2012 for approximately 60 days such dataset were plotted as graph in correspondence with the AQI hazardous values are represented in figure 6. The study revealed the interesting fact that daily observations of SO2 were above the AQI hazardous limits.

The study provided an overall status of air pollution let out form the vehicles and its influence of $SO_2$ and $NO_x$ levels were high as observed during the assessment. Thermal pollution concentration of $SO_2$ and $NO_x$ levels were comparatively low with respect to vehicular pollution. SPM from thermal stations were the highest in contrast to vehicular pollution. Relatively air pollution might spread approximately to a distance of 50 km from the source point.

## IV. CONCLUSION

Air pollution is a serious problem in Industrial, Residential and Mixed places of the developing countries and especially Tamil Nadu in India. Due to increasing industrial development, the Tamil Nadu state particularly urban region like Chennai, Coimbatore, Tuticorin is subjected to subsequent air pollution problem. An appropriate spatial and temporal assessment is need of the hour to assess the spate of environmental pollution on human health. A continuous assessment of the datasets would certainly aid in air pollution prediction and suitably formulate a local decision support system. An environment-health-monitoring-system for an

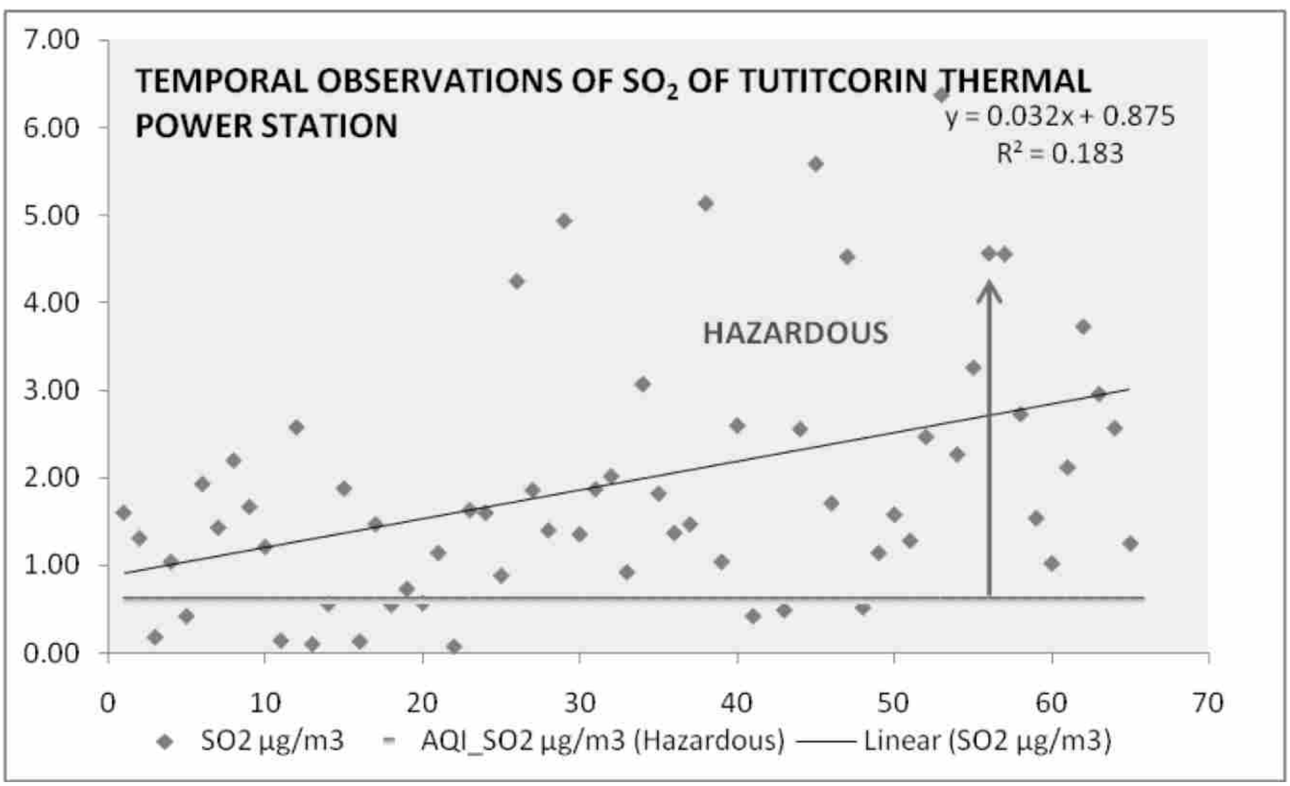


Fig. 6. Temporal $SO_2$ data of Tuticorin Thermal station

approximate distance 50 km from source emission points would be next in line for optimizing management plans.

## REFERENCES

[1] Balasubramanian P, Nethaji Mariappan V E, Joshua Amarnath D (2012a). A study on re-designing the existing ash storage pond for leachate control of thermal power station, Indian J. Innovations Dev., Vol.1, No.3, pp 136-141.

[2] Balasubramanian P, Nethaji Mariappan V E, Joshua Amarnath D 2012b. A study on utilization of discharged hot water for dm/potable water by LTTD method at Ennore thermal station, Indian J. Innovations Dev., Vol.1, No.3, pp 155-161.

[3] David French and Jim Smitham 2007. Fly Ash characteristics and feed coal properties. CSIRO Energy Technology, Australia.

[4] www.environment.tn.nic.in/SoE/images/Pollution.pdf.

[5] EPA: 1999, Air Quality Index Reporting; Final Rule, 40 CFR Part 58, American Environmental Protection Agency.

[6] Murrugesan CA 2012. Global Warming reduction through implementation of Clean Development Mechanism by establishing Hydro Electric Power Project in TANGEDCO / TNEB. M.E. Project Report submitted to Sathyabama University.

[7] Stieb, D.M., Doiron, M.S., Blagden, P. and Burnett, R.T. 2005. Estimating the public health burden attributable to air pollution: an illustration using the development of an alternative air quality index, Journal of Toxicology and Environmental Health 68 (13), 1275-1288.

[8] Zhou, Q. 1995. The integration of GIS and remote sensing for land resource and environment management. Proceedings of United Nation ESCAP Workshop on Remote Sensing and GIS for Land and Marine Resources and Environmental Management, 13-17 February, 1995. Suva, Fiji, p.p. 43-55.

## ACKNOWLEDGEMENT

The authors acknowledge Tamil Nadu Electricity Board, Tamil Nadu Pollution Control Board for providing data on air pollution of Thermal power station and Other Monitoring station for this constructive research work. They also thank the Management of Sathyabama University for providing infrastructural and moral support for carrying out this work.