

Spatio-Temporal Assessment of Air Pollution from Thermal Stations and Vehicular Pollution from Urban places in Tamil Nadu

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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 SO₂, 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 SO₂ 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.

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 4350MT [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%

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

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.

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 3¹, 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 ₂ O ₃ Alumina	32.54%	26.30%
Fe ₂ O 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 ₂ O Sodium oxide	1.44%	0.20%
K ₂ O Potassium oxide	0.87%	0.70%

MATERIALS AND METHODS

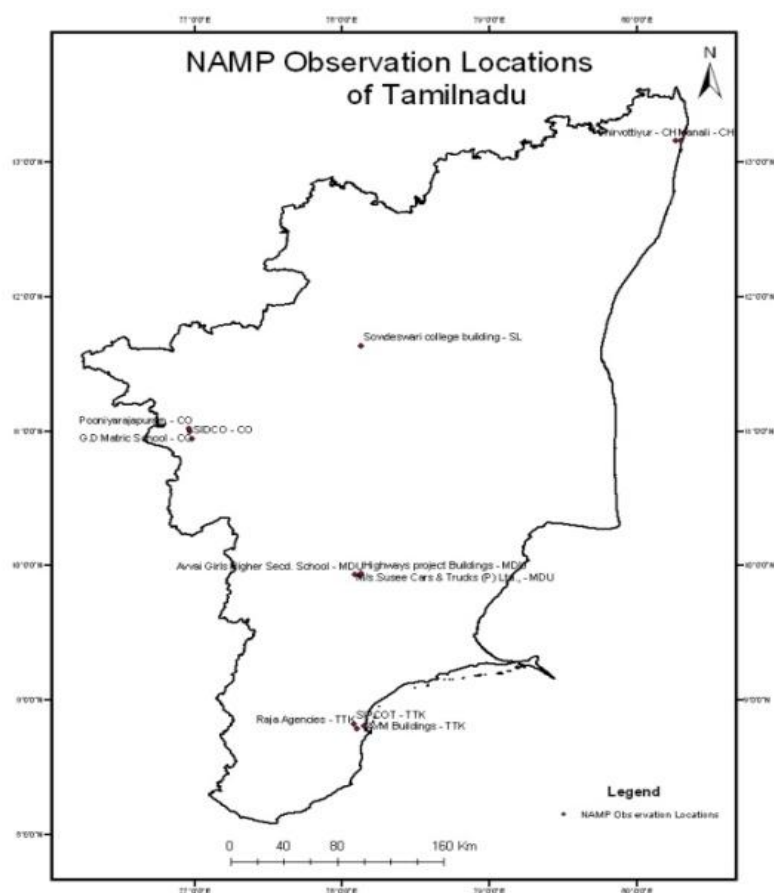
Study Area

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 Km². In addition it houses two thermal power stations namely Ennore with and installed capacity of 450 MW functioning since 1970² 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 (SO₂), 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 study³. 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.

Figure 1.National Ambient Air Quality Stations of Tamil Nadu



**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

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

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.

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 impact⁴.

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 public⁷. The values of the AQI determine the air quality according to Table 5.

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.⁵

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 CO₂, SO₂, 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.

Spatial map of NO_x indicated that highest concentration was observed at Vellalar Nagar of

North Chennai and Thiyagaraya Road of T. Nagar ($29 \text{ \& } 30 \text{ }\mu\text{g}/\text{m}^3$) respectively. Lowest pollution in figure 2 was recorded at Adayar ($15\mu\text{g}/\text{m}^3$). 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 ($>10 \text{ }\mu\text{g}/\text{m}^3$) and lowest was observed at Adayar and Anna Nagar ($< 9.0 \text{ }\mu\text{g}/\text{m}^3$). Such higher pollution concentration at winter may settle in the lower atmosphere and cause carcinogenic effect on human health.

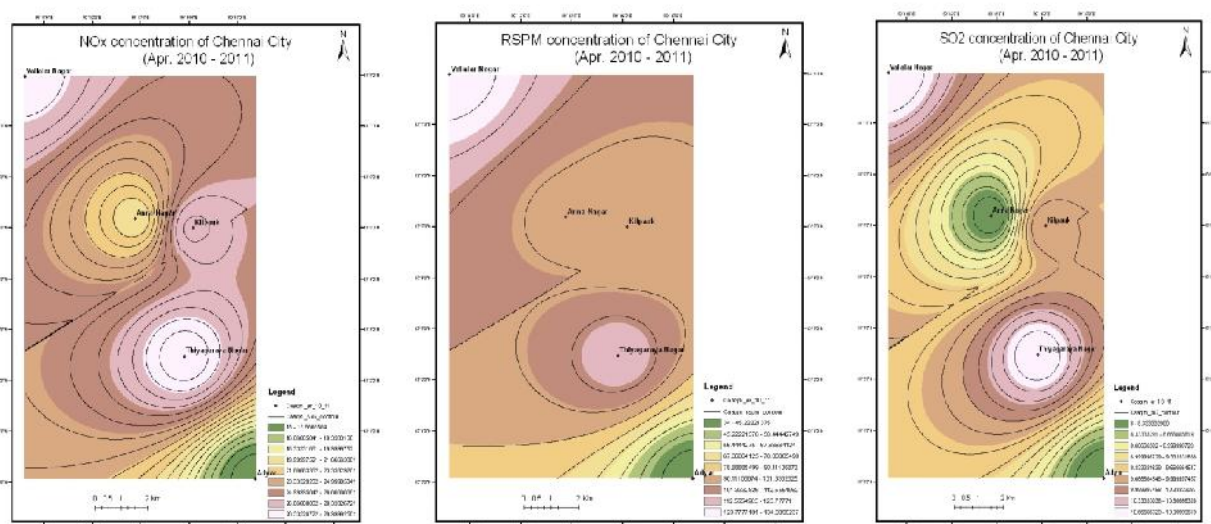


Figure 2. NO_x , SO_2 and SPM concentration of Chennai city

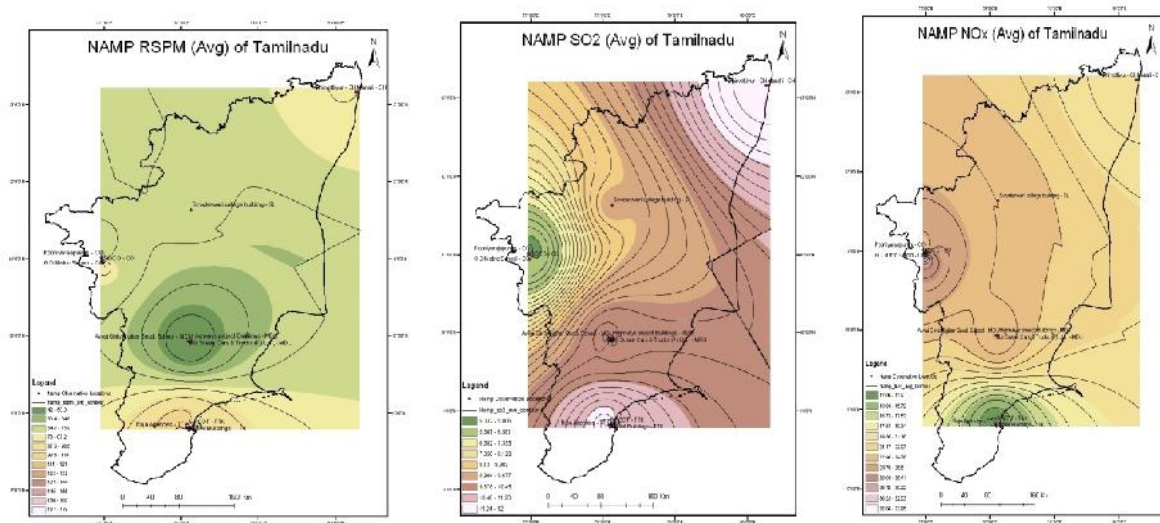


Figure 3. RSPM SO_2 and NO_x average value of Industrial, Mixed and Residential Areas of Tamil Nadu (duration monthly average data of 2010-2011)

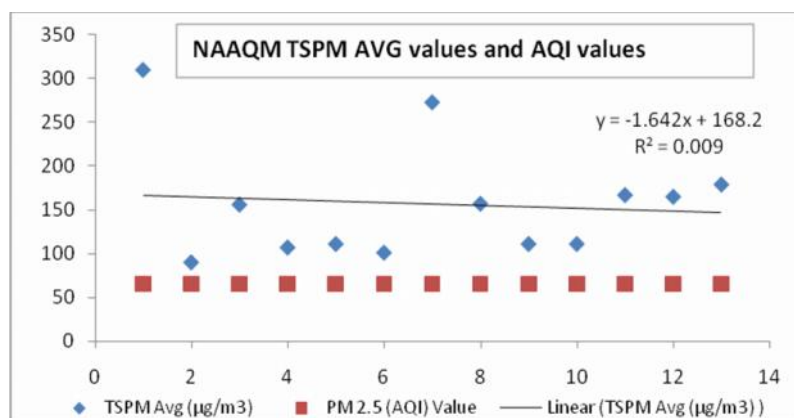


Figure 4. Plotting TSPM average values of NAAQM station corroborate with AQI-PM values

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 $\mu\text{g}/\text{m}^3$) Residual Suspended Particulate Matter was noticed at Chennai and Tuticorin due to emission of soot particles Industries. Emission of SO_2 was highest ($>11.0 \mu\text{g}/\text{m}^3$) from Chennai and Tuticorin. NO_x pollution concentration was highest at Tuticorin, Moderate in Chennai. Coimbatore recorded overall low levels of TSPM, NO_x 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.⁶ Results of this study indicated that SO_2 concentration during the period of 2004 were $< 20 \mu\text{g}/\text{m}^3$ and of 2011 has shown a five fold increase ($>11.0 \mu\text{g}/\text{m}^3$). NO_x levels were more are less the same in comparison with data obtained from 2004. SPM concentration for the year 2004 data were of $< 100 \mu\text{g}/\text{m}^3$ and as of 2011 values were $> 100 \mu\text{g}/\text{m}^3$ 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 $3.09 \mu\text{g}/\text{m}^3$ with a mean value

of $1.178 \mu\text{g}/\text{m}^3$. NO_x varied from 0.016 -118.31 $\mu\text{g}/\text{m}^3$ and a mean value of $3.20 \mu\text{g}/\text{m}^3$ in figure 5. Residual Suspended Particulate Matter concentration was highest $3180.46 \mu\text{g}/\text{m}^3$. 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.

Pollution data from Thermal stations of Ennnore, North Chennai and Tuticorin were recorded in $\mu\text{g}/\text{m}^3$. These data were converted from $\mu\text{g}/\text{m}^3$ to ppm on volumetric basis using <http://www.lenntech.com/calculators/ppm/converter-parts-per-million.htm>. SO_2 values emitted from Ennnore Thermal station were hazardous, while NO_x 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 1st 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 SO_2 were above the AQI hazardous limits.

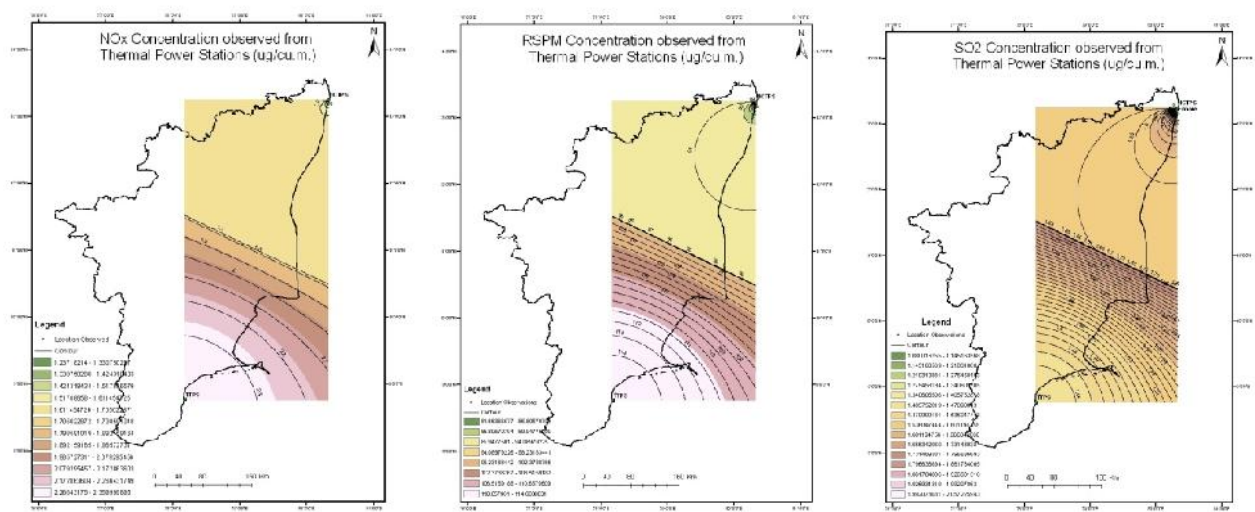
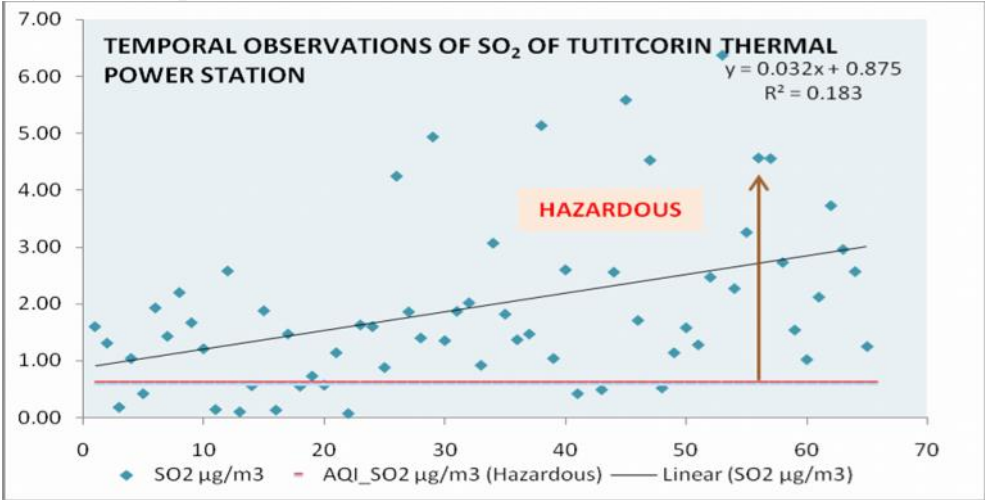


Figure 5. NO_x, SO₂ and RSPM concentration of Ennore, North Chennai and Tutitcorin Thermal Power Stations of Tamil Nadu (duration monthly average data of 2010-2011)

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

S.No.	Station	Date	SO ₂ (µgm/m3)	SO ₂ (ppm)	NO _x (µgm/m3)	NO _x (ppm)	SPM (µgm/m3)
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

Figure 6. Temporal SO₂ data of Tuticorin Thermal station



The study provided an overall status of air pollution let out from the vehicles and its influence of SO₂ and NO_x levels were high as observed during the assessment. Thermal pollution concentration of SO₂ 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.

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

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