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RESEARCH ARTICLE OPEN ACCESS

Simulate the dispersion pattern of Suspended Particulate Matter in the vicinity of Thermal Power plants at Neyveli

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ABSTRACT-
Air quality modeling is an essential tool for most air pollution studies. This work deals with the use of the Industrial Source Complex Short Term (ISCST3) model at a Thermal Power Plant. The study is performed over a period of 5-days. The objective of this study was to simulate the dispersion pattern of SPM in the vicinity of Thermal Power Plants at Neyveli. In order to simulate the dispersion pattern of Suspended Particulate Matter in Neyveli, a short term meteorological monitoring was conducted from 26.05.2008 to 30.05.2008. ISCST3 model was employed to simulate the concentration of Suspended particulate matter felt on the downwind locations of the neighbourhood of the Thermal power stations based on the observed wind data. The most predominant wind directions were from SSE and NW. Hence, the pollutants were transported towards NNW and SSE respectively. It is well evidenced from the pollution roses shown that diurnal variations of the dispersion of SPM in the neighbourhood of Thermal Power Plants. The concentrations of SPM were well below the 8 hour Ambient Air Quality standards.

I. INTRODUCTION

The United States Clean Air Act of 1970 and its amendments have established National Air Quality Standards to protect man and his total environment from damage by air pollutants (Maynard, 1984). The clean air act produced strong motivation for the application of mathematical models to air quality problems. Indeed the use of models was mandated specifically in the 1977 amendments. As regulatory procedures developed after the passage of these regulations, models have become a major factor in making expensive and important decisions (Maynard, 1984).In establishing ambient air quality standards, regulations, have been introduced in order to set limits on the emissions of pollutants in such a way that they cannot exceed certain prescribed maximum values. As a result of such regulations, it is important that the total mass of emission should be controlled and it is imperative also to know the effects of ambient atmospheric conditions on stack emissions. To achieve this, consideration must be given to mathematical and computer simulation models. Air pollution models constitute a set of formulae that taken into account: source of pollution in a given area, the amounts of pollutants emitted by each source, chemical reaction and transformations, different meteorological conditions, topographical features and other factors that affect dispersion of pollutants. Such models can be used for the calculation of pollutant concentrations at any given point in the area under study. The successful application of all models relies on a detailed emission inventory of all sources and accurate meteorological data applicable to the area, (Scupholome et al., 1977). Zannetti (1994) defined the process of computer modeling of air pollution as the ability to use computers to solve the basic equations that described the dynamics of meteorological and air pollution phenomena, and ultimately, the adverse effects of air pollution. Models are in many different styles and they can have quite different levels of complexity in the underlying theory and the set of assumptions they represent (Air-EIA, 2000). However, for planning purposes, models should be as simple as possible; otherwise the application of the model might be expensive and time-consuming (Scupholome et al., 1977). More details about the type of the models and their applications can be found elsewhere (Abdul-Wahab, 2001; Elkamel et al., 2001; adul-Wahab and Al-Alawi, 2002).

II. STATEMENT OF THE PROBLEM

Neyveli Lignite Corporation (NLC), an integrated industrial complex, situated in a massive campus of 480 sq. km area houses two mines, two Thermal Power Stations at Neyveli in Tamil Nadu, India. Presently, 17 million tones of lignite is mined and 2070 MW of power is generated. This study is essentially carried out when the NLC has proposals for greater exploration of the lignite deposit and power generations to an extent of 3810 MW capacities during the immediate future. Therefore, this study is important for simulating the Dispersion pattern of Air pollution in the vicinity of the Thermal Power Plants. In this regard, mathematical models have been recognized as powerful tools to estimate the Ground Level Concentrations more realistically after evaluating the Air Quality Models for known emission, meteorology and measured air quality.

The Objectives of the Study is to simulate the dispersion pattern of SPM in the vicinity of Thermal Power Plants at Neyveli.

III. INDUSTRIAL SOURCE COMPLEX (ISC) MODEL

Mathematical models are used to compute the distribution of pollutant concentrations in air, given the rate and height of emission and the relevant meteorological data. Mathematical models are the basic and very important tools to quality the impacts of existing (or) a proposed project. In this study, the industrial source complex short-term ISCST3 models have been used for estimating short-term concentrations of SPM. Hence, ISCST3 are the preferred model of USEPA, which have been validated with field data. These models are based on Gaussian dispersion equation, which is widely used all over the world.

The industrial source complex (ISC) short-term model provides options to model emissions from a wide range of sources that might be present at a typical industrial source complex. The basis of the model is the straight – line on steady state Gaussian Plume equation. The algorithm used to model point source types are described in detail in the following section, (EPA, 1995).

The Gaussian Equation

The ISC short-term model for stacks uses the steady-state Gaussian plume equation for a continuos elevates source. For each source and each hour, the origin of the source's coordinate system is placed at the ground surface at the base of the stack. The x-axis is positive in the downwind direction, the y-axis is crosswind (normal) to the x-axis and the z-axis extends vertically. Please see fig.1. The fixed receptor locations are converted to each source's coordinate system for each hourly calculation of concentrations. The hourly concentrations calculated for each source at each receptor are summed to obtain the total concentration produced at each receptor by the combined source emissions.

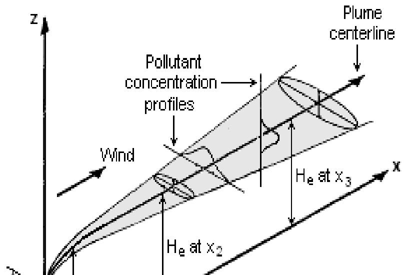

Fig. 1. Gaussian Dispersion Pattern of Air Pollutants

For a steady-state Gaussian plume, the hourly concentration at downwind distance x (meters) and crosswind distance y (meters) is given by:

$$X = \frac{QKVD}{2\pi u_s \sigma_y \sigma_s} \exp\left[-0.5\left(\frac{y}{\sigma_y}\right)^2\right]$$

Where,

Q= pollutant emission rate (mass per unit time)

K= a scaling coefficient to convert calculated concentrations to desired units (default value of 1 x 10^6 for Q in g/s and concentration in μg/m^3)

V= vertical term

D= decay term

F,F_z= standard deviation of lateral and vertical concentration distribution (m)

U_s= mean wind speed (m/s) at release height

Equation (1) includes a Vertical Term (V), a Decay term (D), and dispersion parameters (F_y and F_z).

DESCRIPTION OF NEYVELI LIGNITE CORPORATION (NLC)

The existence of extensive lignite deposits in the Neyveli region of Tamil Nadu came to be known in 1870. Detailed exploration of this deposit was carried out in 1943 by the Geological Survey of India (GSI), and based on their finding; the govt. of India formed the Neyveli Lignite Corporation

The Neyveli Lignite Corporation is India's energy-bridge to the 21^{st} century. NLC's growth is sustained and its contribution to India's social and economic development is significant. It is a Public-Sector Enterprise established in 1956, and its situated at Neyveli in Tamil Nadu State, about 200 Km south of Chennai. It lies between 11°28' and 11°37' latitude and 75°25' and 79°33'. Please see figure-2

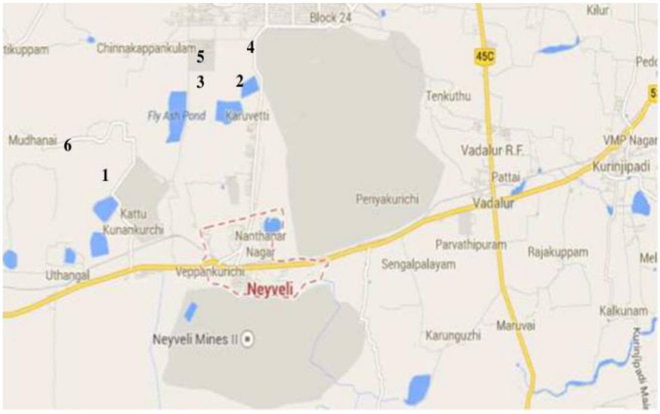

Fig.2 Description of Study Area

Thermal Power Station-I (TS-I)

Thermal power station-I in which the first unit was synchronized in May 1962 and the last unit in September1970 consisting of six sets of 50 MW each. Totally it has the power generation capacity of 600 MW.

Thermal Power Station-II (TS-II)

Thermal power station II consists of 7 sets of 210 MW each. In February 1978, the Government of India sanctioned the Second Thermal Power Station of 630 MW capacity (3×210 MW) and in February 1983, the Government of India sanctioned the Second Thermal Power Station Expansion from 630 MW to 1470 MW with an addition of 4 units of 210 MW each. Totally it has the power generation capacity of 1470 MW.

IV. METHODOLOGY

The data requirements for dispersion analysis consist of three important parts: the Meteorological Data, the Emission Inventory, and the Air Quality Monitoring Data.

METEOROLOGICAL MONITORING

The degree to which air pollutants discharged from various sources concentrate in a particular area depends largely on meteorological conditions. The application of dispersion theory and knowledge of local weather conditions are necessary to determine the required stack height for an emission and to evaluate the intensity of air pollution. Even though the total discharge of contaminants in to the atmosphere in a given area remain constant from day to day, the degree of air pollution may vary widely because of difference in meteorological conditions. In a specified place the emission of pollutants may be the same but it is the weather that can trigger an air pollution episode.

The various meteorological parameters necessary to be measured while carrying out prediction of air pollution modeling are, (i) Wind Direction and speed, (ii) Temperature,(iii) Atmospheric stability, and (iv) Mixing depth. The parameters vary widely as a function of latitude, season and topography. A short-term, meteorological monitoring was conducted for a period of 5 days at Neyveli from 26.05.2008 to 30.05.2008, in order to observe the prevailing weather in and around N.L.C campus.

Meteorological Observatory

Meteorological instruments were fixed at the roof-top of a single storied building at Neyveli, in such a way that the observation height was about 3 m above ground level. During this period of observations, wind direction, wind velocity, dry bulb temperature, wet bulb temperature, cloud-cover, etc., were measured.

Meteorological data

The most predominant wind direction during the period of study has been south-south-east (SSE) and north-west (NW). Wind velocity has varied from 0.2 m/sec (0.7kmph) to 1.3 m/sec (4.68kmph), and calm (no wind) conditions have prevailed for about 4.7 percent of the time periods. Cloud cover has varied from 29 degrees celzius to 39 degrees celzius. The relative humidity has varied from 37% to 96% during the period of study. The hourly meteorological data is shown in the Table .1.

Table.1 Hourly Meteorological data

Sl No.	Time	Wind direction	Wind speed in m/sec	Temperature in Celsius
1.	6.00	W	0.3	30
2.	7.00	NNW	0.5	32
3.	8.00	NNW	0.3	30
4.	9.00	N	0.6	32
5.	10.00	NNW	0.5	32
6.	11.00	S	0.5	34
7.	12.00	SSE	0.5	34
8.	13.00	SSE	0.7	36
9.	14.00	SSE	0.8	36
10.	15.00	SSE	0.6	34
11.	16.00	SE	0.5	33
12.	17.00	SE	0.4	32
13.	18.00	SE	0.3	30
14.	19.00	SSE	0.2	30
15.	20.00	SE	0.2	30
16.	21.00	SSE	0.3	29
17.	22.00	SSE	0.3	29
18	23.00	SSE	0.3	29
19	24.00	SSE	0.3	29

Emission rate

The air emissions in the NLC are mainly due to the quantities of fuel burned which results in the emission of various pollutants in to the atmosphere, including the SPM.

In order to find out the emission rate of SPM that results from the combustion, calculations should be done to calculate the composition of the flue gas from each stack. A total of 13-point sources are identified in the Neyveli.

APPLICATION OF ISCST3 MODEL TO THE NEYVELI

Input data requirement

The ISCST3 model used in this study requires input information on emission sources at the NLC site-specific meteorological data, as well as Concentration of SPM in the Ambient Air Quality. The input data that describe both the emission source and meteorology provide a comprehensive set of information which can be used to run the ISCST model and thus simulate the ground level concentrations of SPM.

The emission source information that needs to be input into the model is restricted to the physical stack dimensions (height, location, internal diameter) as well as the velocity and temperature of the released gas, and the SPM emission rates. The thermal power station includes a total of about 13 sources that are shows the stack height, exit stack diameter, emission rate of SPM, exit velocity and exit stack temperature. Typical Emission Inventory is shown in Table 2.

Table 2 Emission Inventory of Thermal Power Station I&II

S No	Source description	Capacity (MW)	x-coord (m)	y-coord (m)	Stack height (m)	Exit stack temperature ° C	SPM Emission rate (g/sec)	Stack velocity (m/sec)
1	TS-I UNIT-1	3 x 50	0	0	60	431	2142	10.8
	UNIT-2	3 x 50	-100.00	000.00	60	431	2142	10.8
	UNIT-3	2 x 50	-200.00	000.00	60	431	2856	16.2
	UNIT-4	4 x 50	-688.00	000.00	120	431	5998	21.5
	UNIT-5	2 x 210	-2752.00	-344.00	220	431	3000	25
2	TS-II UNIT-1	1 x 210	4000.00	3500.0	170	423	3000	25
	UNIT-2	1 x 210	3900.00	3500.0	170	423	3000	25
	UNIT-3	1 x 210	3800.00	3500.0	170	423	3000	25
	UNIT-4	1 x 210	4300.00	3400.00	220	423	3000	25
	UNIT-5	1 x 210	4472.00	3612.00	220	423	3000	25
	UNIT-6	1 x 210	4644.00	3784.00	220	423	3000	25
	UNIT-7	1 x 210	4816.00	3956.00	220	423	3000	25
	ST-CMS	1 x 210	8256.00	5504.00	220	423	3000	25

In addition the model requires the site-specific meteorological information as input data. The local meteorological information that was needed to be input into the model were restricted to the Julian day of the year, the average wind flow vector, wind speed, height of the mixing layer, ambient Air temperature and the Pasquill stability category. The data were collected by using the meteorological data recorded at a station located in NLC. It should be noted that the ISCST model requires meteorological data to be used on an hourly basis format. Typical meteorological file developed ISCST format is shown in Table 3.

Table 3: Typical meteorological file

```
 94823    08  94823    08
8042601     270.0000  0.3000  303.0  2  0400.0
000.0
08042602    337.5000  0.5000  305.0  2  0600.0
000.0
08042603    337.5000  0.3000  303.0  1  0800.0
000.0
08042604      0.0000  0.6000  305.0  1  1000.0
000.0
08042605    337.5000  0.5000  305.0  1  1200.0
000.0
08042606    180.0000  0.5000  307.0  1  1300.0
000.0
08042607    157.5000  0.5000  307.0  1  1400.0
000.0
08042608    157.5000  0.7000  309.0  1  1500.0
000.0
08042609    157.5000  0.8000  309.0  1  1300.0
000.0
08042610    157.5000  0.6000  307.0  2  1100.0
000.0
08042611    135.0000  0.5000  306.0  2  0900.0
000.0
08042612    135.0000  0.4000  305.0  2  0700.0
000.0
08042613    135.0000  0.3000  303.0  2  0500.0
000.0
08042614    157.5000  0.2000  303.0  2  0000.0
000.0
08042615    135.0000  0.2000  303.0  2  0000.0
000.0
08042616    157.5000  0.3000  302.0  2  0000.0
000.0
08042617    157.5000  0.3000  302.0  2  0000.0
000.0
08042618    157.5000  0.3000  302.0  3  0000.0
000.0
08042619    157.5000  1.3000  302.0  3  0000.0
000.0
08042620    157.5000  0.3000  302.0  3  0000.0
000.0
08042621    157.5000  0.3000  302.0  3  0000.0
000.0
08042622    157.5000  0.3000  302.0  3  0000.0
000.0
08042623    270.0000  0.3000  302.0  3  0000.0
000.0
08042624    270.0000  0.3000 302.0  3   0000.0
000.0
```

Where,

08042601- Julian day
270.0000- Wind direction (The direction towards wind blows)
0.3000- Wind speed
303.0- ambient temperature
2- Stability class 'B'
400.0- Mixing Height (Rural)
000.0 - Mixing Height (Rural)

V. RESULTS AND DISSCUSION

A short term comprehensive simulation of SPM using ISCST3 model has been attempted for 5 days at Neyveli from 26.05.2008 to 30.05.2008. The dispersion pattern of SPM in the neighbourhood of Thermal power stations has been drawn,in the form of pollution rose of SPM.

Pollution rose of SPM

During the Study Periods, the most predominant wind directions were from South South- East (SSE) and North-West (NW). Hence,It is evident from the figures 3-12 shown that the pollutants was being transported to the counter direction of the respective wind directions.

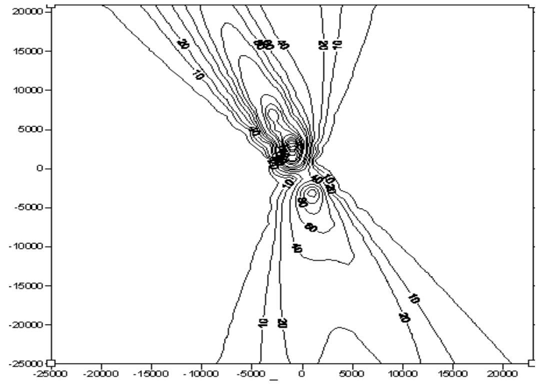

Figure. 3 isopleths of SPM in the vicinity of NLC on 26th April 2008

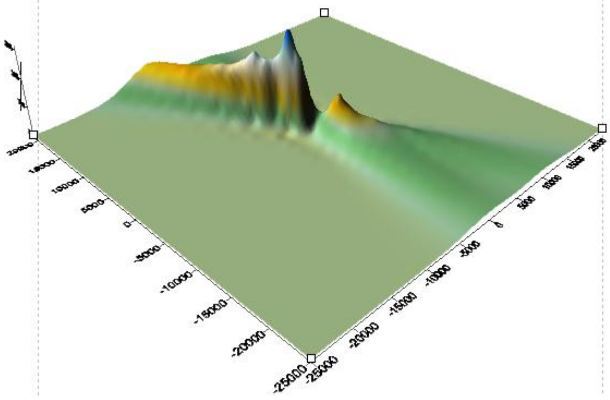

Figure 4. '3'Dimensional view of SPM Dispersion in the vicinity of NLC on 26th April 2008

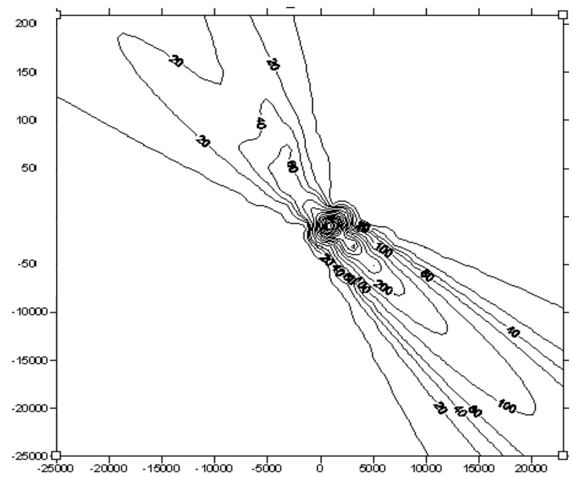

Figure. 5. isopleths of SPM in the vicinity of NLC on 27th April 2008

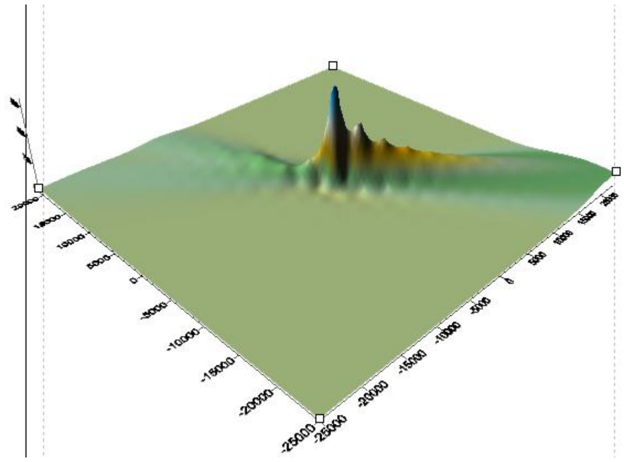

Figure 6. '3'Dimensional view of SPM Dispersion in the vicinity of NLC on 27th April 2008

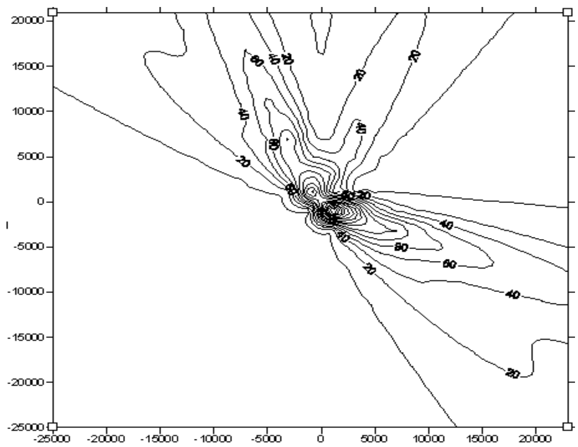

Figure. 7. isopleths of SPM in the vicinity of NLC on 28th April 2008

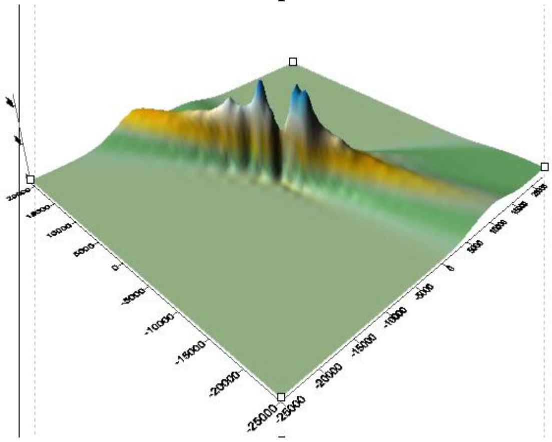

Figure 8. '3'Dimensional view of SPM Dispersion in the vicinity of NLC on 28th April 2008

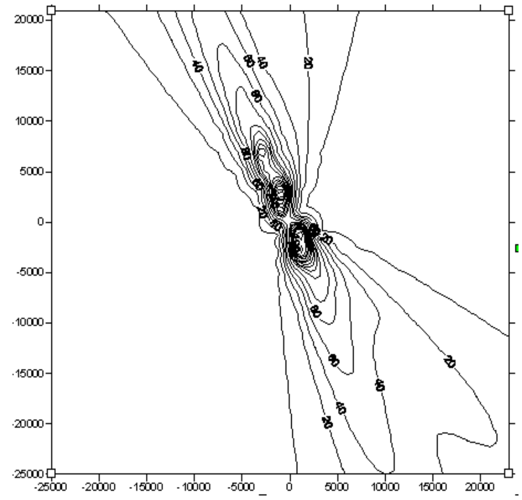

Figure. 9. Isopleths of SPM in the vicinity of NLC on 29th April 2008

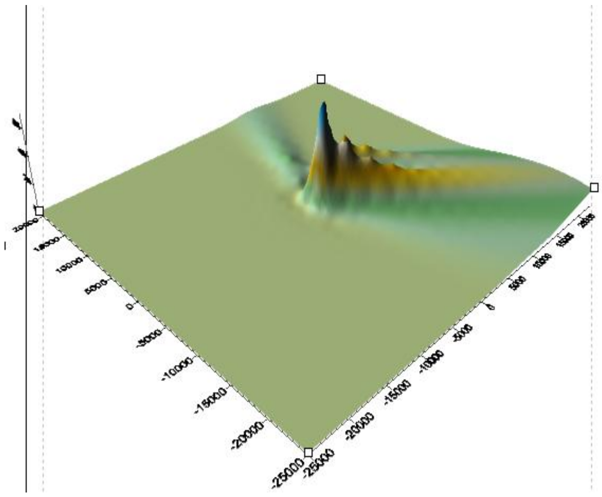

Figure 10. '3'Dimensional view of SPM Dispersion in the vicinity of NLC on 29th April 2008

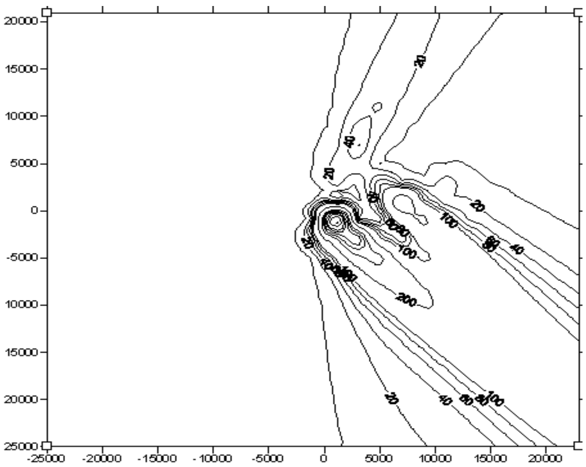

Figure. 11. Isopleths of SPM in the vicinity of NLC on 30th April 2008

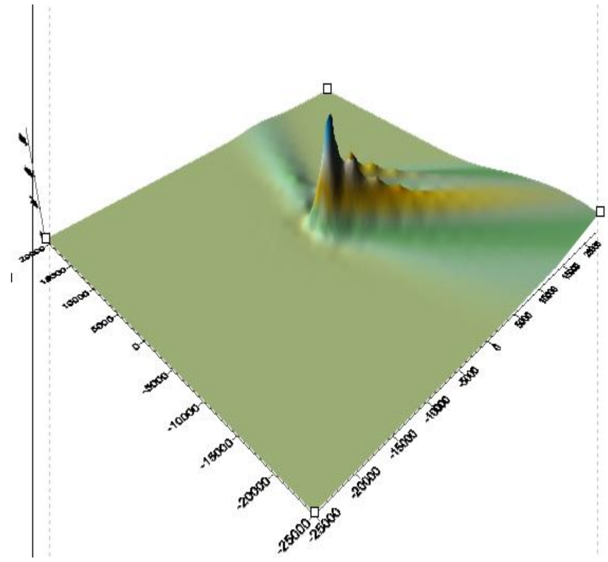

Figure 12. '3' Dimensional view of SPM Dispersion in the vicinity of NLC on 30th April 2008

VI. CONCLUSION

In order to simulate the dispersion pattern of Suspended Particulate Matter in Neyveli, a short term meteorological monitoring was conducted from 26.05.2008 to 30.05.2008. ISCST3 model was employed to simulate the concentration of Suspended particulate matter felt on the downwind locations of the neighbourhood of the Thermal power stations based on the observed wind data.

The most predominant wind directions were from SSE and NW. Hence, the pollutants were transported towards NNW and SSE respectively. It is well evidenced from the pollution roses shown that diurnal variations of the dispersion of SPM in the neighbourhood of Thermal Power Plants . The concentrations of SPM were well below the 8 hour Ambient Air Quality standards.

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