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Modeling of Dispersion of Primary Pollutants from a Thermal Power Plant Using - Aermod

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Abstract:— **Power plants are the significant wellsprings of air contamination. Coal is the essential fuel utilized for era of power as a part of India and its use is consistently expanding to meet the developing vitality requests of the nation. Emissions of greenhouse gases and other pollutants such as Suspended Particulate Matter (SPM), Sulfur Dioxide (SO2), and Nitrogen Oxides (NOx) are increasing parallel to the growing demands of electricity. This paper presents the contextual investigation for Kakathiya Thermal Power Project (KTPP) for the expectation of the SPM, NOx, and SO2, contamination brought about by warm exercises near the villages of Bhoopalaallimandal of Warangal District, Telanagana State. An atmospheric dispersion model AERMOD-9.1(American Meteorological Environmental Protection Agency Regulatory Model) was used. Meteorological data for one year was processed using AERMET processor. The model was run for modeling of dispersion of pollutants SPM, SO2 and NOxfor all the months of the study period from January 2014 to December 2014 over study area. Model also runs for yearly averaged emission scenarios. The output files for the parameters Suspended particulate matter (SPM), Sulfur dioxide (SO2), and Nitrogen oxides (NOx) were evolved. The isopleths were plotted for the same and these concentration contours are very important in determining the spatial distribution of criteria pollutants over the modeled area. For the Ambient Air Quality Monitoring Stations, the predicted concentrations were found to be in good agreement with the measured concentrations. For AERMOD model, values of coefficient of determination R2 are in the range 0.73 to 0.85. The predictions are of reasonable accuracy and may be used for any other industry in its vicinity up to 50 km Diameter.**

Keywords:-- **AERMOD,Pollutant, Dispersion, Impact, Modeling, Isopleths.**

I. INTRODUCTION

Thermal Power plants are main means of electrical power generation and are also the major sources of the air pollution in India. One third of the population that lives in rural India does not have access to electricity. Even those with access in urban India have to endure frequent power cuts and load shedding, which results in use of in-situ diesel generator sets. In thermal power plants coal is used for electricity generation and its usage is continually increasing to meet the energy demands of the country. This results in more emissions of greenhouse gases and other criteria pollutants which lead to global warming, environmental damages and climatic changes too. During 1950 – 1951, the share of thermal power in the total electricity generation was 50.98% and has increased to 81.70 % during 2000 – 2001 and to 84.26 % in 2009 – 2010. Other renewable such as wind, geothermal, solar, and hydroelectricity represent a 2 percent share of the Indian fuel mix. Nuclear holds a one percent share. The share of coal and petroleum is expected to be about 66.8 per cent in total commercial energy produced and about 56.9 percent in total commercial energy supply by 2021-22. The demand for coal is projected to reach 980 MT during the 12th Plan period, whereas domestic production is expected to touch 795 MT in the terminal year (2016-17). Even though the demand gap will need to be met through imports, domestic coal production will also need to grow at an average rate of 8 per cent compared to about 4.6 per cent in the Eleventh Five Year Plan. The share of crude oil in production and consumption is expected to be 6.7 percent and 23 per cent respectively by 2021-22.

II. STUDY AREA

The study area selected for the present study is Kakatiya Thermal Power Plant (KTPP), located at Bhupalapalli village of Warangal district, Telangana state. The proposed power plant location falls between $79^0$45'32.43"E Longitude and $18^0$26'53.82"N. The power plant is one of the coal fired thermal power plants of Telangana State Power Generation Corporation (*TSGENCO*). The kakathiya Thermal Power Project of capacity 1x500 MW (1x600 MW under installation) is coal based one. This thermal power station is predominantly government assigned land covering total area of 1145.23 acres. Out of 114523 acres, government land is 627 acres and government assigned land is 388.27 acres and registered land is 129.36 acres. The average rainfall of the area is approximately 1005 mm, which span from mid-July & mid-October the ground elevation of the site ranges between 160 m–174 m above MSL.

III. METHODOLOGY

3.1 Dispersion modelling using AERMOD:

AERMOD is a steady-state plume model intended for short-range (up to 50 kilometers) dispersion of air contamination discharges from stationary industrial sources. The AERMOD AERMOD modeling system consists of one principle program (AERMOD) and two pre-processors AERMET and AERMAP. AERMET is a meteorological processor and it figures boundary layer parameters for use by AERMOD. AERMAP is terrain processor and it ascertains landscape statures and receptor lattices for AERMOD. Both AERMET and AERMAP require observational information to parameterize the development and structure of the atmospheric boundary layer. AERMOD utilizes terrain, boundary layer and source information model pollutant transport and dispersion for calculating temporally averaged air pollution concentrations.

3.2 Dispersion modelling along with necessary model inputs which are as follows:

AERMET: calculates boundary layer parameters for input to AERMOD

Model inputs: wind speed; wind direction; cloud cover; ambient temperature; morning sounding; albedo; surface roughness; Bowen ratio

Model outputs: wind speed; wind direction; ambient temperature; lateral turbulence; vertical turbulence; sensible heat flux; friction velocity; Monin-Obukhov Length

AERMAP: calculates terrain heights and receptor grids for input to AERMOD

Model inputs: DEM data [x, y, z]; design of receptor grid (pol.,cart., disc.)

Model outputs: [x, y, z] and hill height scale for each receptor

AERMOD: calculates temporally-averaged air pollution concentrations at receptor locations for comparison to the NAAQS.

Model inputs: source parameters (from permit application); boundary layer meteorology (from AERMET); receptor data (from AERMAP)

3.3 Meteorological Data For Aermet:

AERMET requires as input;

Surface characteristics in the form of

- albedo,
- Surface roughness and
- Bowen ratio plus standard meteorological observations.

Planetary boundary level parameters such as;

- Friction velocity,
- Monin-obukhov length,
- Convective velocity scale,
- Temperature scale,
- Mixing height and
- Surface heat fluxes are then estimated by AERMET.

AERMET basic input data includes following items:

- Hourly surface data
- Upper air data
- Location of the pertinent site
- Sectors and Surface data.

These are explained below,

Hourly surface data requirements include below listed parameters:

1. Cloud covers (tenths)
2. Ceiling height (m)
3. Dry bulb temperature (^{O}C)
4. Relative humidity (%)
5. Precipitation amount (hundredths of inches).
6. Station pressure (mb)
7. Wind direction (deg)
8. Wind speed (m/s)

Upper air data

Estimating upper air data is by upper air estimator in AERMET.

Upper air estimator

Estimates upper air data from hourly surface data. Location of the pertinent site, sectors and surface data: There are specific values assigned for albedo, Bowen ratio and surface roughness depending upon the land use types. Albedo is the proportion of sunlight that is reflected back into space without absorption. Albedo values range from 0.1 for thick deciduous forests to 0.9 for fresh snow. Bowen ratio indicates amount of moisture available to drive turbulent processes. It is the ratio of sensible heat flux to latent heat flux. During day time, Bowen ratio attains a fairly constant positive value ranging from 0.1 over water to 10 over desert at mid-day. Surface roughness length is an indicator of amount of drag the ground surface exerts on the wind. It is related to the height of obstacles to the wind flow and is in principle the height at which the mean horizontal wind speed is zero. Values range from less than 0.001m over calm water surface to 1m or more over a forest or urban area.

IV. RESULTS AND DISCUSSIONS

The AERMOD model used in this study requires input information on emission sources at the thermal power plant site-specific meteorological data. The input data that describe both the emission source and meteorology provide a comprehensive set of information which can be used to run the AERMOD model and thus simulate the ground level concentrations of Suspended Particulate Matters (SPM), Sulfur Dioxides (SO_2), and Nitrogen Oxides (NO_x) from stationary sources of a cement industry.

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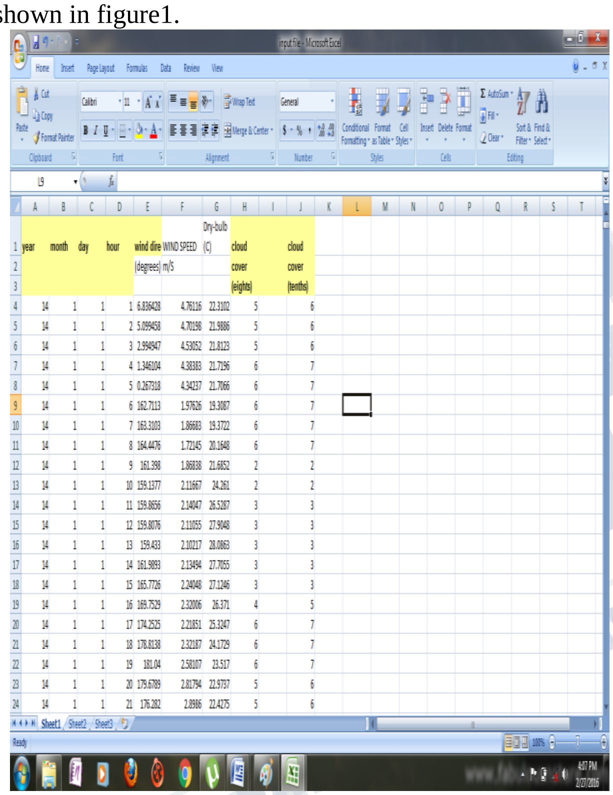
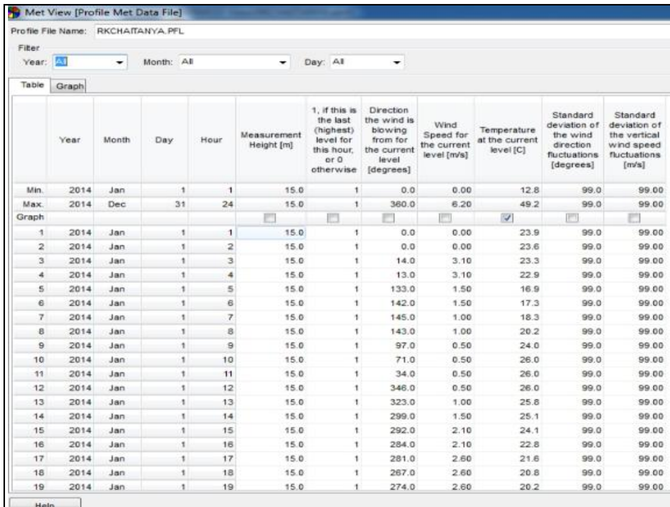
The emission source information that needs to be input into the model is restricted to the physical stack dimensions (height, location, internal diameter) as well as the velocity and temperature of the released gas, and the SPM, SO_2, and NO_xemission rates.

In addition the model requires the site-specific meteorological information as input data. The data were collected from Andhra Pradesh Pollution Control Board and from the website www.metcheck.com/in/ It should be . noted that the AERMOD model requires meteorological data to be used on an hourly basis format. Typical meteorological file developed for AERMOD format is shown in figure1.



	A	B	C	D	E	F	G	H	I	J
1	year	month	day	hour	wind dire	WIND SPEED	Dry-bulb (C)	cloud		cloud
2					(degrees)	m/S		cover		cover
3								(eights)		(tenths)
4	14	1	1	1	6.836428	4.76116	22.3102	5		6
5	14	1	1	2	5.099458	4.70198	21.9886	5		6
6	14	1	1	3	2.994947	4.53052	21.8123	5		6
7	14	1	1	4	1.346104	4.38383	21.7196	6		7
8	14	1	1	5	0.267318	4.34237	21.7066	6		7
9	14	1	1	6	162.7113	1.97626	19.3087	6		7
10	14	1	1	7	163.3103	1.86683	19.3722	6		7
11	14	1	1	8	164.4476	1.72145	20.1648	6		7
12	14	1	1	9	161.398	1.86838	21.6852	2		2
13	14	1	1	10	159.1377	2.11667	24.261	2		2
14	14	1	1	11	159.8656	2.14047	26.5287	3		3
15	14	1	1	12	159.8076	2.11055	27.9048	3		3
16	14	1	1	13	159.433	2.10217	28.0863	3		3
17	14	1	1	14	161.9893	2.13494	27.7055	3		3
18	14	1	1	15	165.7726	2.24048	27.1246	3		3
19	14	1	1	16	169.7529	2.32006	26.371	4		5
20	14	1	1	17	174.2525	2.21851	25.3247	6		7
21	14	1	1	18	178.8138	2.32187	24.1729	6		7
22	14	1	1	19	181.04	2.58107	23.517	6		7
23	14	1	1	20	179.6789	2.81794	22.9737	5		6
24	14	1	1	21	176.282	2.8986	22.4275	5		6

Fig.1. Typical meteorological data file developed AERMOD format



Met View [Profile Met Data File]
Profile File Name: RKCHAITANYA.PFL

	Year	Month	Day	Hour	Measurement Height [m]	1, if this is the last (highest) level for this hour, or 0 otherwise	Direction the wind is blowing from for the current level [degrees]	Wind Speed for the current level [m/s]	Temperature at the current level [C]	Standard deviation of the wind direction fluctuations [degrees]	Standard deviation of the vertical wind speed fluctuations [m/s]
Min.	2014	Jan	1	1	15.0	1	0.0	0.00	12.8	99.0	99.00
Max.	2014	Dec	31	24	15.0	1	360.0	6.20	49.2	99.0	99.00
1	2014	Jan	1	1	15.0	1	0.0	0.00	23.9	99.0	99.00
2	2014	Jan	1	2	15.0	1	0.0	0.00	23.6	99.0	99.00
3	2014	Jan	1	3	15.0	1	14.0	3.10	23.3	99.0	99.00
4	2014	Jan	1	4	15.0	1	13.0	3.10	22.9	99.0	99.00
5	2014	Jan	1	5	15.0	1	133.0	1.50	16.9	99.0	99.00
6	2014	Jan	1	6	15.0	1	142.0	1.50	17.3	99.0	99.00
7	2014	Jan	1	7	15.0	1	145.0	1.00	18.3	99.0	99.00
8	2014	Jan	1	8	15.0	1	143.0	1.00	20.2	99.0	99.00
9	2014	Jan	1	9	15.0	1	97.0	0.50	24.0	99.0	99.00
10	2014	Jan	1	10	15.0	1	71.0	0.50	26.0	99.0	99.00
11	2014	Jan	1	11	15.0	1	34.0	0.50	26.0	99.0	99.00
12	2014	Jan	1	12	15.0	1	346.0	0.50	26.0	99.0	99.00
13	2014	Jan	1	13	15.0	1	323.0	1.00	25.8	99.0	99.00
14	2014	Jan	1	14	15.0	1	299.0	1.50	25.1	99.0	99.00
15	2014	Jan	1	15	15.0	1	292.0	2.10	24.1	99.0	99.00
16	2014	Jan	1	16	15.0	1	284.0	2.10	22.8	99.0	99.00
17	2014	Jan	1	17	15.0	1	281.0	2.60	21.6	99.0	99.00
18	2014	Jan	1	18	15.0	1	267.0	2.60	20.8	99.0	99.00
19	2014	Jan	1	19	15.0	1	274.0	2.60	20.2	99.0	99.00

Fig2. Typical PROFILE file of AERMOD format

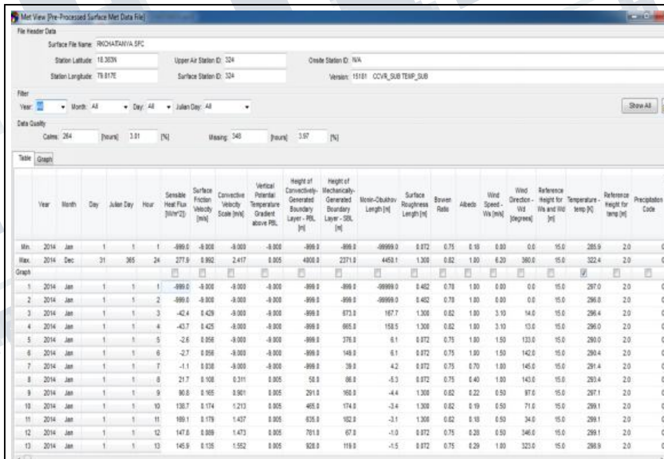


Fig3. Typical SURFACE file of AERMOD format

There are two basic types of inputs that are needed to run the AERMOD model. They are:

1. ***The surface file, and 2.The profile file***.

With MET data processed through AERMET processor and providing input for sources and receptors along with terrain features, dispersion model was prepared using AERMOD 9.1. The model was run for pollutants SPM, SO_2, NO_X

1. One year met data.
2. Monthly

The MODEL was run for SPM, SO_2 and NO_X.

The results in terms of concentration contours were represented in this chapter along with its interpretation. Output also includes pollutant concentration at key receptors

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locations (Villages) as well as nearby locations within a boundary of 50 km.

The model was run for one year met data the receptors concentrations were obtained for 2 hr ,8 hr, 12hr, 24 hr average (daily) , monthly and Annually. Results were compared with NAAQS, 2009 to check any violation of norms by the industry.

The Model was run with SPM, SO_2, NO_x pollutants.

- 2 Hr Average concentration- One year MET data
- 6 Hr Average concentration - One year MET data
- 12 Hr Average concentration - One year MET data
- 24 Hr Average concentration - One year MET data
- Annual Average concentration - One year MET data

Key Assumptions in the Model

- The emission rate is constant.
- Dispersion (diffusion) is negligible in the downwind (x) direction
- Horizontal meteorological conditions are homogenous over the space being modeled.

For each hour modeled

- An average wind speed is used
- Wind direction is constant
- Temperature is constant
- Atmospheric stability class is constant
- Mixing height is constant
- Pollutant are non-reactive gases or aerosols
- The plume is reflected at the surface with no deposition or reaction with the Surface
- The dispersion in the crosswind (y) and vertical (z direction) take form of Gaussian distributions about the plume centerline.

Spatial Distribution of Concentrations for Criteria Pollutants:

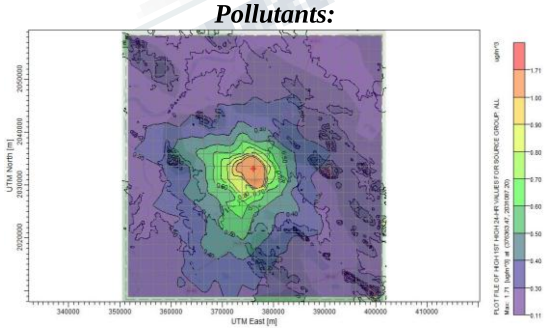

Fig.4. Isopleths of SPM-24 hr average concentration (one year met data)

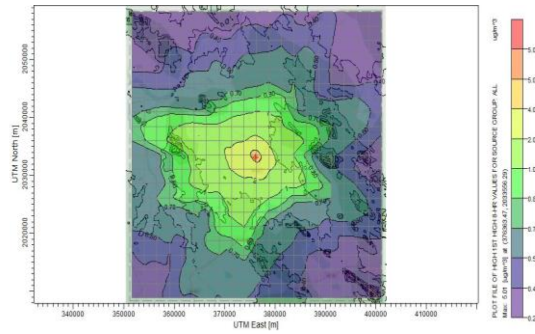

Fig.5. Isopleths of SPM – 8hr average concentration (one year met data)

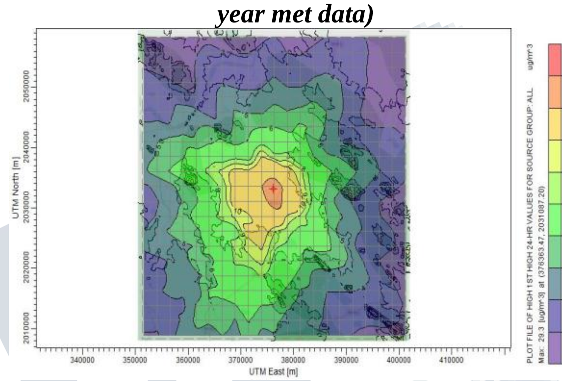

Fig.6. Isopleths of SO2-24 hr average concentration (one year met data)

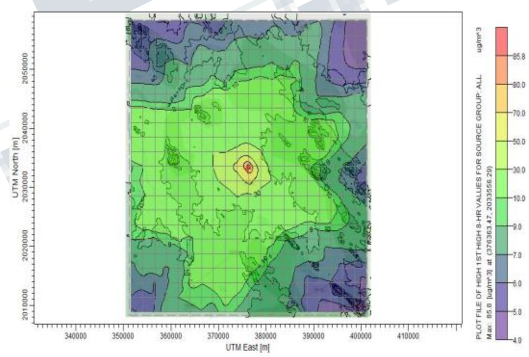

Fig.7. Isopleths of SO_2 - 8 hr average concentration (one year met data)

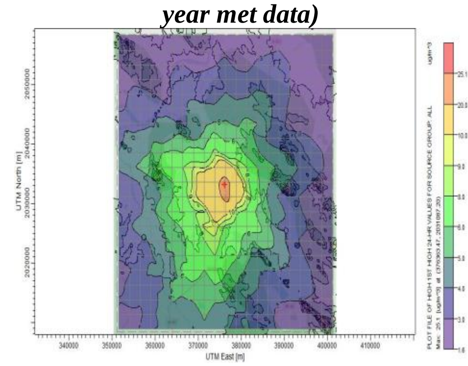

Fig.8. Isopleths of NO_X-24hr average concentration (one year met data)

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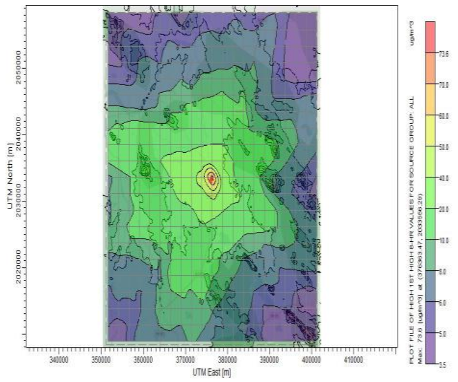

Fig.9. Isopleths of NO_X- 8 hraverage concentration (one year met data)

Typical Wind rose diagrams (Surface file and Profile files of study area):

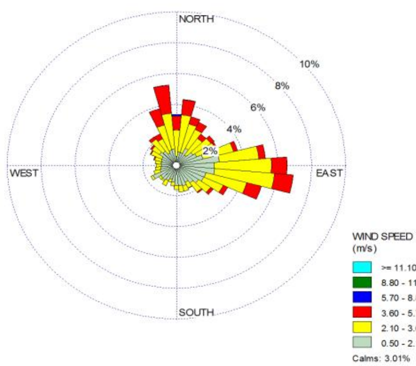

Fig.10. Wind Rose for Surface File

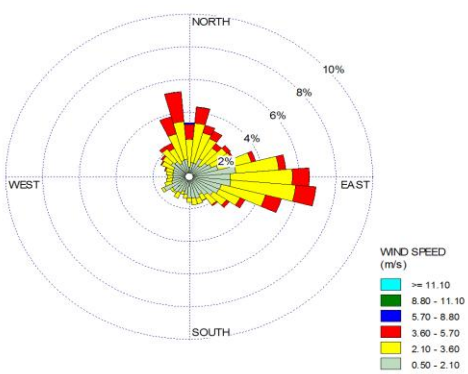

Fig.11. Wind Rose for Profile File

Spatial distribution of criteria pollutants over GOOGLE MAP of location:

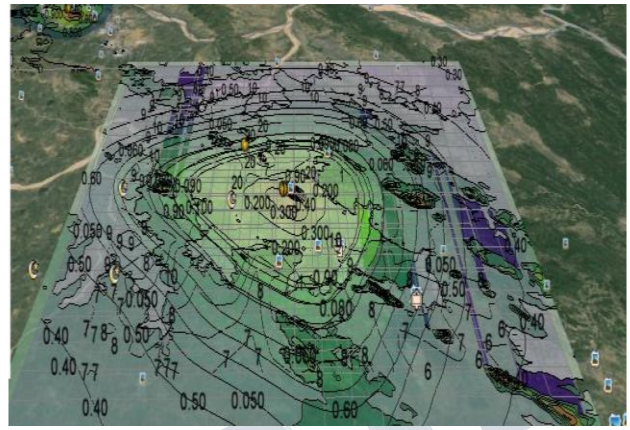

Fig.12.Spatial distribution of SPM over study area

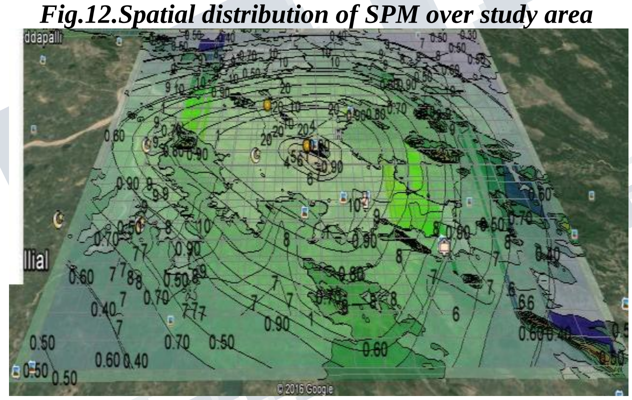

Fig. 13. Spatial distribution of SO_2 over study area

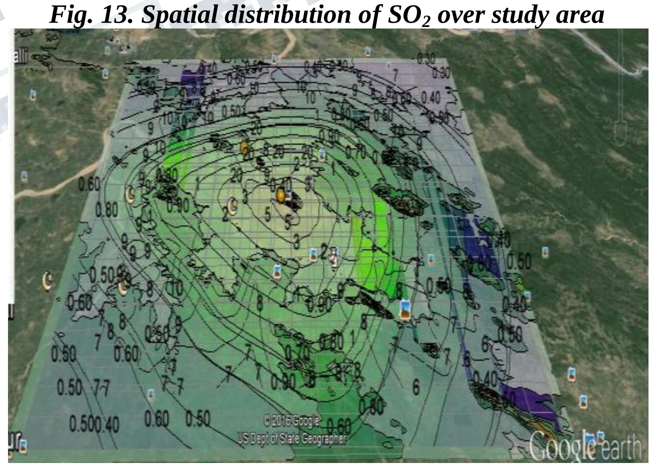

Fig.14. Spatial distribution of NO_X over study area

V. VALIDATION OF AERMOD:

Andhra Pradesh State Pollution Control Board (APPCB) established one Ambient Air Quality Monitoring Stations near the source point of KTPP. The coordinates of the monitoring stations are identified from the grid map.

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Modeled output values are collected from the output files of the AERMOD model, these values are not included with the background concentrations of the site. With reference to Recent Environmental Impact Assessment report of KTPP site. Predicted (P) values can be calculated by adding the background concentrations to the modeled output concentrations. APPCB provided the measured (M) values from monitoring stations for the period of January -2014 to December-2013. validation of modeling is carried out by comparing the predicted and measured concentrations of SPM, SO_2 and NO_X given in the tables 6.3,6.4 and 6.5 respectively.

Predicted values of criteria pollutants from output files of AERMOD

MONTHS:2014	POLLUTANT CONCENTRATIONS IN (μg/m^3)		
	SPM (bckgrnd conc 142 μg/m^3)	SO_2 (bckgrnd conc 9 μg/m^3)	NOx (bckgrnd conc 11 μg/m^3)
JAN	1.00274	14.71409	17.16643
FEB	1.04302	15.30515	17.58601
MAR	1.68185	24.6793	28.79251
APR	1.07817	15.82101	18.45785
MAY	0.91027	13.35715	15.58334
JUN	1.67178	24.53158	28.62017
JUL	1.58465	23.253	27.1285
AUG	1.23105	18.0643	21.07502
SEP	1.10641	16.2354	18.9413
OCT	1.13804	16.69949	19.48274
NOV	1.18413	17.3758	20.27177
DEC	1.06274	15.59453	18.1936

Source/Monitoring Station	Location	Latitude	Longitude	Coordinates	
				X	Y
Source point	Stack 1	18.3864	79.8283	0	0
AAQMS-1	Complex 2	18.5124	79.8008	1500	1000

Suspended Particulate Patters (SPM)
Predicted and measured concentrations of SPM

Months (2014)	AAQMS (Complex 1)	
	P	M
January	143.0027	162
February	143.043	154
March	143.6819	122.42
April	143.0782	184.02
May	142.9103	170.94
June	143.6718	102.33
July	143.5847	132.24
August	143.2311	159.25
September	143.1064	147.1
October	143.138	168.79
November	143.1841	154
December	143.0627	158

Sulfur Dioxides (SO_2)
Predicted and measured concentrations of SO_2

Months (2014)	AAQMS (Complex 1)	
	P	M
January	23.71409	26.67
February	24.30515	20.45
March	33.6793	38.24
April	24.82101	20.58
May	22.35715	22.54
June	33.53158	38.84
July	32.253	34.73
August	27.0643	23.56
September	25.2354	24.58

October	25.67	24.88
November	26.3758	27.24
December	24.59453	25.63

Nitrogen Oxides (NOx)

Predicted and measured concentrations of NO_X

Months (2014)	AAQMS (Complex 1)	
	P	M
January	28.16643	24.66
February	28.58601	20.47
March	39.79251	32.79
April	29.45785	23.24
May	26.58334	24.01
June	39.62017	38.02
July	38.1285	32
August	32.07502	29.88
September	29.9413	20.94
October	30.48274	24.08
November	31.27177	20.94
December	29.1936	26.02

VI. STATISTICAL PERFORMANCE

The coefficient of determination,R^2, is calculated using a Pearson correlation coefficient calculator for predicted concentrations from AERMOD and measured values from all the Ambient Air Quality Monitoring Stations. For the best curve fit R^2 must be 1. Table.1. provides a Statistical performance measure of AERMOD model.

Statistical Performance Measures of AERMOD Model

Parameter	Monitor ing station	R^2	Inference
SPM	AAQM S	0.7571	positive correlation
NO_X	AAQM S	0.7332	Moderate positive correlation
SO_2	AAQM S	0.8531	Strong positive correlation

VII. CONCLUSIONS

The replication of pollutant (SPM, SO_2 and NO_X) dispersion from Kakathiya Thermal Power Project (KTPP), located at Neredupalli Village Bhoopalapallimandal of Warangal District, Telanagana State was obtained by applying a AERMOD model and the results of predicted values were compared with the measured concentrations at the KTPP site from January 2014 to December 2014 made available by APPCB. For the Ambient Air Quality Monitoring Stations, the predicted concentrations were found to be in good agreement with the measured data. For AERMOD model, values of coefficient of determination R^2 are in the range 0.73 to 0.85. It may therefore be inferred that AERMOD model gives better results. The results demonstrated that the AERMOD model can be applied to study the dispersion of criteria air pollutant concentrations and that the predictions are of reasonable accuracy and may be used for any other industry in its vicinity upto 50 km Diameter.

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