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Prediction of Ground Level Concentrations of No_x in a Thermal Power Project using ISCST3 Model

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Abstract

Background: Present study deals with the prediction of nitrogen oxides in the vicinity of the Rayalaseema Thermal Power Project, Andhra Pradesh, India. It provides information to the public and the control agencies to efficiently implement the control strategies of the air quality management program. **Methods:** In this prediction, the industrial source complex short-term version 3 (ISCST3) model was used. ISCST3 is the preferred model of USEPA. ISCST3 is a refined dispersion modeling technique using site specific input data. **Findings:** Predictions were made around the power plant with the radius of 10,000 meters; for the period of one year from June 2012 to May 2013. ISCST3 and Golden software surfer version 8 was used to produce Isopleths and 3-Dimensional view of NO_x in the vicinity of the Rayalaseema Thermal Power Project. Similarity beside measurements of Ambient Air Quality Monitoring Stations (AAQMS) was made. Genuine results were found well with measured data. Coefficients of determination (R^2) were found in the range between 0.76 to 0.96. The ISCST3 model can be used for NO_x prediction with good accuracy. **Application and Improvement:** Further forecasting can be carried out in coal fired power stations for using wide ranging parameters, which will have significant impact on human health and environment using ISCST3 modeling technique.

Keywords: Dispersion Model, Ground Level Concentrations, ISCST3, Nitrogen Oxides, Thermal Power Project

1. Introduction

Nitrogen Oxides (NOx), particularly nitrogen dioxide, are produced from the combustion of fossil fuels under high temperature conditions. Thermal power plants are the major sources of Nitrogen oxides. Higher concentrations of NO_2 damage the leaves of plants, retard the photosynthetic activity and cause chlorosis. NO_2 has irritating effect onmucous membranes; it causes bronchitis and respiratory problems. Higher concentrations of NO_2 cause gum inflammation, internal bleeding, lung cancer, pneumonia and oxygen deficiency[7]. NO_X fades away the number of textile dyes. It produces peroxides with hydrocarbons which combine with ozone and cause crack in the rubber. Oxides of nitrogen are involved in the generation of serious air pollutants such as ozone, PAN and photochemical smog. Hence prediction of nitrogen oxides is the prime requisite in industrial sites for impact assessment[9]. The Industrial Source Complex - Short Term version 3 (ISCST3) is a steady state, Gaussian based dispersion model[6] which, can be widely applied to forecast pollutant concentrations. The ISCST3 dispersion model from the United States Environmental Protection Agency was intended to sustain the EPA's authoritarian modeling options[8].

2. Study Area

The Rayalaseema Thermal Power Project Stage-I (420 MW) comprises of two units each one established with 210MW power. The Rayalaseema Thermal Power Project Stage-II (420 MW) comprising 2 Units of 210 MW each. The Rayalaseema Thermal Power Project Stage-III (210 MW) comprising 1 Unit. Stage-IV (600 MW) works are under progress.

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The Project is situated in Chennai-Guntakal Broad gauge line. The project site is at 180 m above MSL and it lies on latitude of 14° – 42'-30"N and longitude of 78°-28' E. The project is located in an area of 1650 Hectares. The site for power project at Kalamala is located near by the towns Yerraguntla, Produtur and Muddanur. The area is rural, the total regional population is more than 4, 00,000 residing within a radius of 10 Km. The location map of RTPP is shown in Figure 1.

Thermal power plant is a major source of local pollution and health damages. The major pollutants affecting the site are suspended particulate matter, sulfur dioxide and nitrogen oxides. Current air quality forecasting efforts focus on predicting nitrogen oxides (NO_X) using ISCST3 model[3].

3. Application of ISCST3 Model for Rayalaseema Thermal Power Project

3.1 Input Data

The application of ISCST3 model in the present study needs input data from emission sources at the RTPP site and site-specific meteorological data. The input data that explain both the emission source and meteorological conditions give total data which can be used to run the ISCST model and thus reproduce the ground level concentrations of nitrogen oxides (NOx) from stationary source of a thermal power plant[4]. The information of emission source that requirements to be input into the model is limited to the physical stack dimensions i.e., stack height, stack location, internal diameter of the stack, as well as the velocity and temperature of the flue gas, and the nitrogen oxides emission rates[1]. In addition the model needs the site-specific meteorological data as input data[11]. The local meteorological data that was required to be input into the model were limited to the Julian day, wind direction, wind speed, mixing height, ambient atmospheric temperature and the Pasquill stability class[12]. The data were collected from India meteorological department and from the web site www.metchec.com. The ISCST3 model requires meteorological data to be used on an hourly basis format. Typical meteorological file developed ISCST3 format is shown in Figure 2.

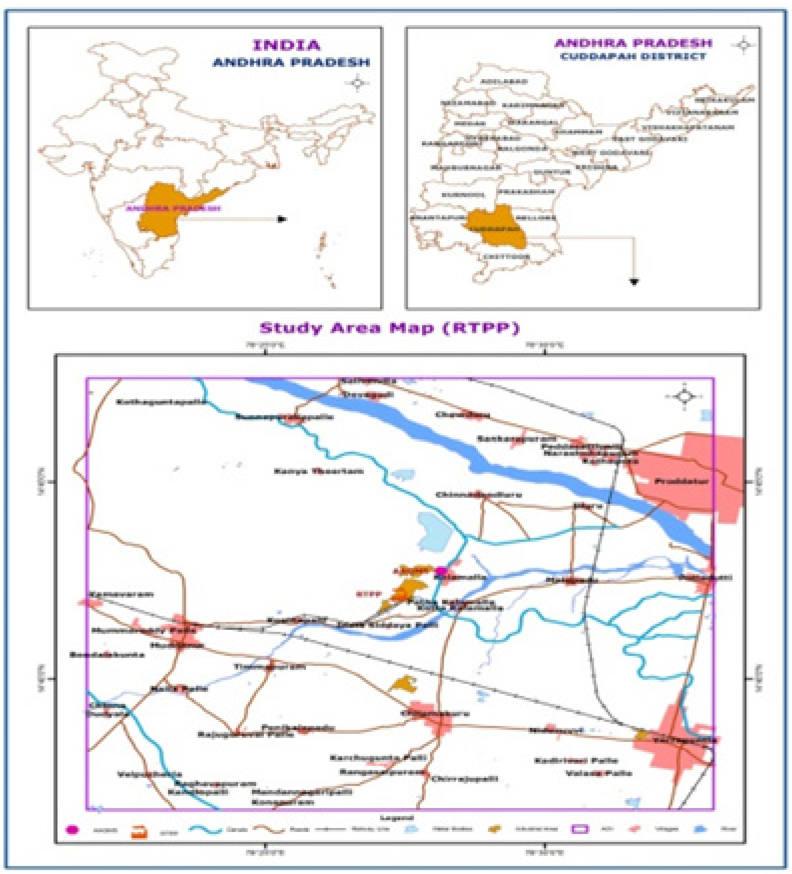
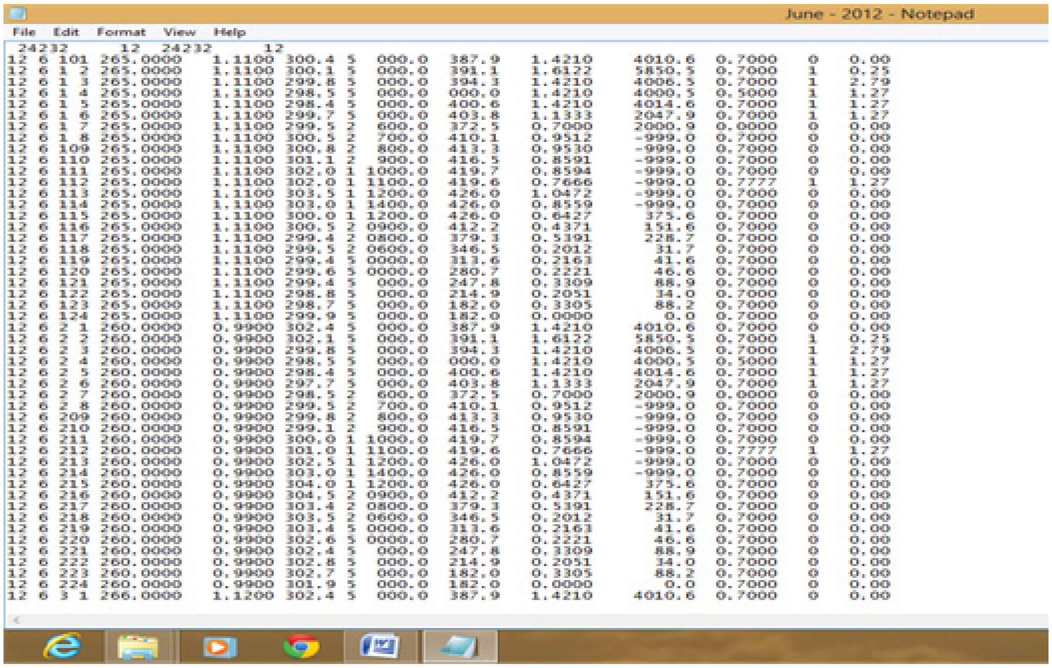


Figure 1. RTPP location map.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12 6 2 7 260.0000    0.9900 298.5 2   600.0  372.5   0.7000    2000.9 0.0000   0   0.00
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12 6 212 260.0000    0.9900 301.0 1  1100.0  419.6   0.7666    -999.0 0.7777   1   1.27
12 6 213 260.0000    0.9900 302.5 1  1200.0  426.0   1.0472    -999.0 0.7000   0   0.00
12 6 214 260.0000    0.9900 303.0 1  1400.0  426.0   0.8559    -999.0 0.7000   0   0.00
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12 6 220 260.0000    0.9900 302.6 5  0000.0  280.7   0.2221      46.6 0.7000   0   0.00
12 6 221 260.0000    0.9900 302.4 5   000.0  247.8   0.3309      88.9 0.7000   0   0.00
12 6 222 260.0000    0.9900 302.8 5   000.0  214.9   0.2051      34.0 0.7000   0   0.00
12 6 223 260.0000    0.9900 302.7 5   000.0  182.0   0.3305      88.2 0.7000   0   0.00
12 6 224 260.0000    0.9900 301.9 5   000.0  182.0   0.0000       0.0 0.7000   0   0.00
12 6 3 1 266.0000    1.1200 302.4 5   000.0  387.9   1.4210    4010.6 0.7000   0   0.00
```

Figure 2. Typical meteorological file.

3.2 Modeling Process

The model was arranged to generate the pollutant ground level concentration ensuing from all the five stacks at all the grids enclosed by the receptor location. The model was then run by adding the steady state concentration contributions from every source at each receptor point in turn. The calculations were based on maximum 8 hour average concentrations, month wise from June 2012 to May 2013. It was implicit that the quantity of pollutant produced by every source was preserved, that is the model implicit that there would be no loss of pollutant between source and receptor. Other assumptions of the ISCST model include the emission conditions are steady state; emission inventories are not time dependent; emission sources will not interfere with each other; loss of pollutant due to atmospheric reactions, absorption are not considered; and the influence of different structures situated in the surrounding area of pollutant releasing sources has insignificant impact[2]. The typical ISCST3 program[13] used to calculate the Ground level concentration is shown below:

3.3 Typical ISCST3 Input File

The typical input file for the Nitrogen Oxides (NOx) is represented in the Figure 3.

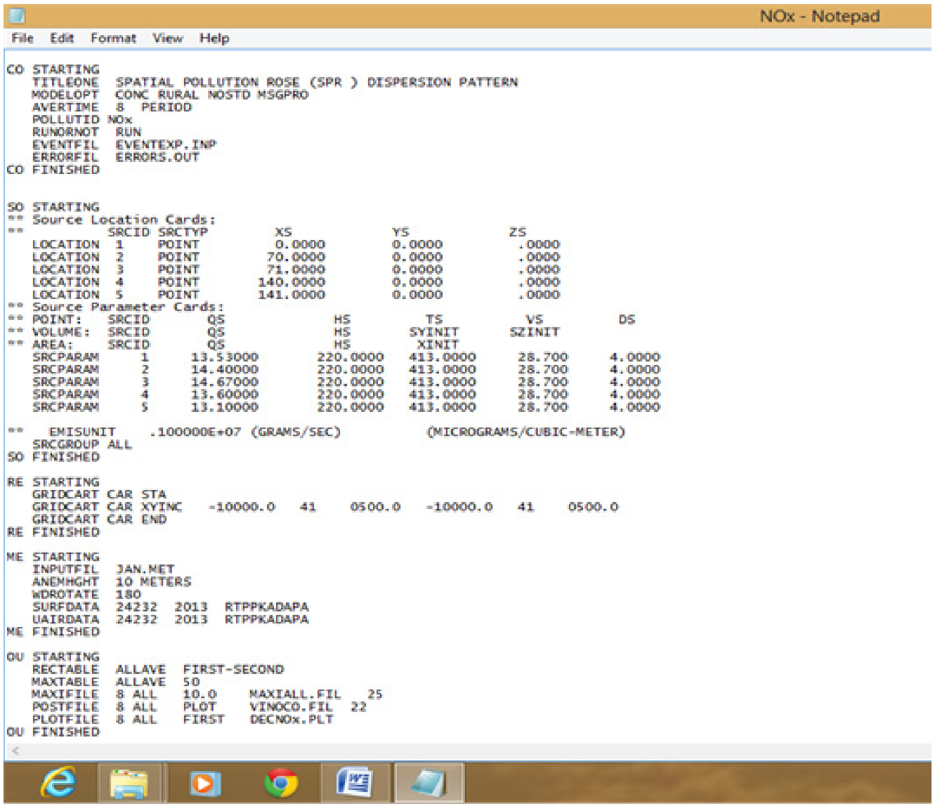
3.4 Model Output

The ISCST3 model output is provided with coordinates and respective concentrations. The Study area is 10,000 m^2, each receptor grid cart is 500 m^2, and total numbers of receptor points are 41×41 = 1681. Ground level concentrations of every receptor point are obtained from the model output file, which are represented in Figure 4.

4. Spatial Distributions of Pollutant Concentration Levels

The isopleths given in Figures 5(a) to 16(b) were plotted using Golden Software Surfer version 8. In ISCST3 model these concentration contours are more significant in finding the spatial allocation of nitrogen oxides (NOx) over the Modeled region[5]. Certainly the contours of concentration could be used for the following determinations:

- It is feasible to decide the spatial and temporal areas for which the CPCB/WHO standard value of pollutant concentration level is reached or exceeded.
- By regulating the pollutant emission rates from definite sources, it is likely to use the ISCST model to find out those sources that have the maximum effect



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   POLLUTID NOx
   RUNORNOT  RUN
   EVENTFIL  EVENTEXP.INP
   ERRORFIL  ERRORS.OUT
CO FINISHED


SO STARTING
** Source Location Cards:
**          SRCID SRCTYP        XS              YS              ZS
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   LOCATION  3     POINT       71.0000          0.0000          .0000
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** Source Parameter Cards:
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** VOLUME:  SRCID        QS              HS       SYINIT      SZINIT
** AREA:    SRCID        QS              HS        XINIT
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   SRCPARAM     4     13.60000        220.0000   413.0000     28.700      4.0000
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**   EMISUNIT    .100000E+07 (GRAMS/SEC)          (MICROGRAMS/CUBIC-METER)
   SRCGROUP ALL
SO FINISHED

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   GRIDCART CAR XYINC   -10000.0   41    0500.0   -10000.0   41    0500.0
   GRIDCART CAR END
RE FINISHED

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   ANEMHGHT  10 METERS
   WDROTATE  180
   SURFDATA  24232  2013  RTPPKADAPA
   UAIRDATA  24232  2013  RTPPKADAPA
ME FINISHED

OU STARTING
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   MAXTABLE  ALLAVE  50
   MAXIFILE  8 ALL   10.0    MAXIALL.FIL   25
   POSTFILE  8 ALL   PLOT    VINOCO.FIL  22
   PLOTFILE  8 ALL   FIRST   DECNOx.PLT
OU FINISHED
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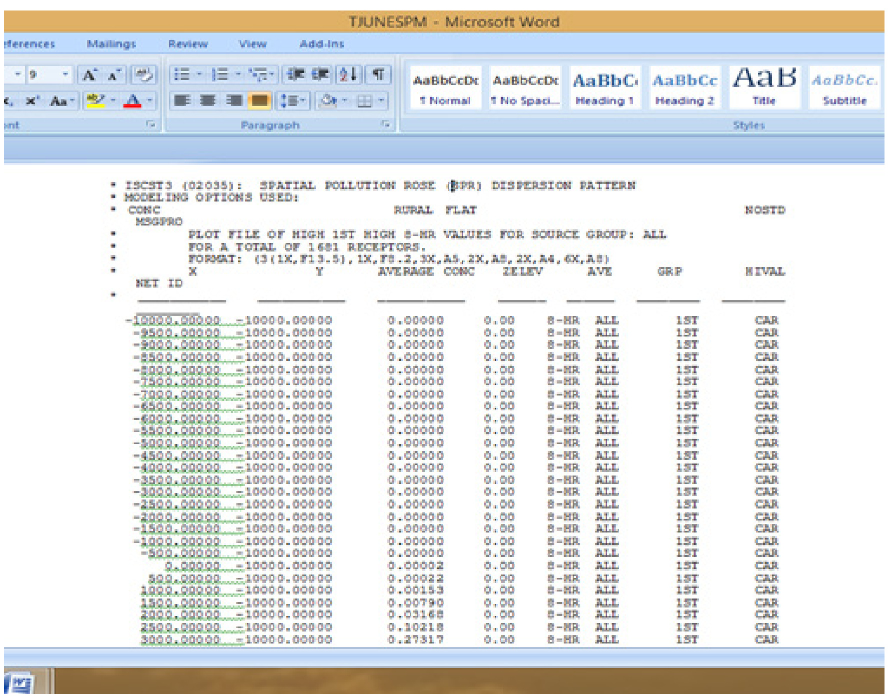
Figure 3. Input file for NO_x.



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   MSGPRO
*          PLOT FILE OF HIGH 1ST HIGH 8-HR VALUES FOR SOURCE GROUP: ALL
*          FOR A TOTAL OF 1681 RECEPTORS.
*          FORMAT: (3(1X,F13.5),1X,F8.2,3X,A5,2X,A8,2X,A4,6X,A8)
*          X              Y         AVERAGE CONC    ZELEV      AVE       GRP        HIVAL
   NET ID
*
   ___________   ___________   ___________   ______   ______   ______   ______

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   -7000.00000 -10000.00000     0.00000      0.00    8-HR  ALL        1ST       CAR
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    2500.00000 -10000.00000     0.10218      0.00    8-HR  ALL        1ST       CAR
    3000.00000 -10000.00000     0.27317      0.00    8-HR  ALL        1ST       CAR
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Figure 4. Model output.

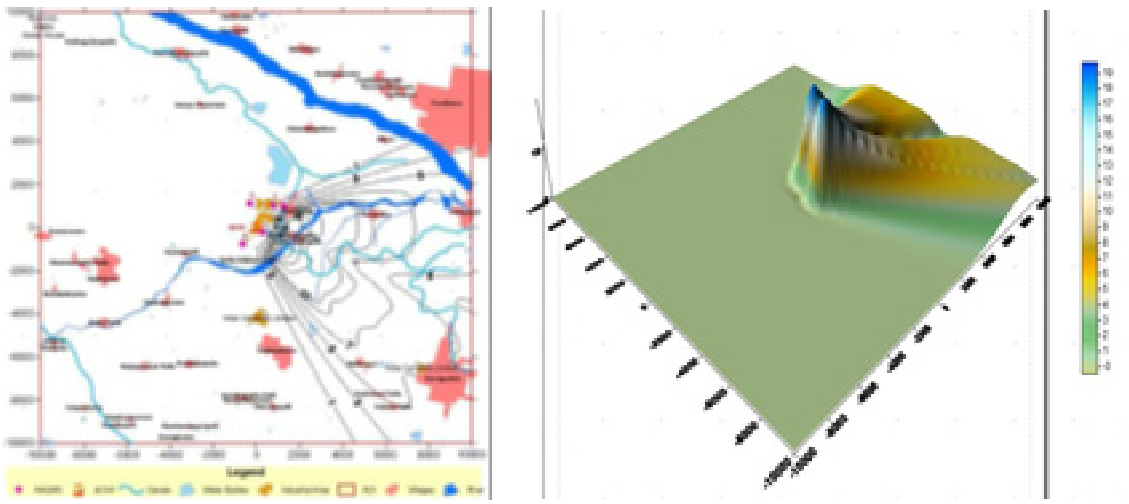
in terms of air quality troubles in the highly sensitive locations of a region.

- It is feasible to study the best possible means of regulating pollutant emissions from the all major sources.
- The model can be applied to recommend the power project of the maximum emissions that could be tolerated without beyond the WHO standards when steady state meteorological conditions are predicted.
- The model can be employed to understand future scenarios that comprise the impacts of growing energy consumption per-capita, of increasing populations and if new power plant establishments, in addition to their most favorable setting[2].

5. Validation of ISCST3

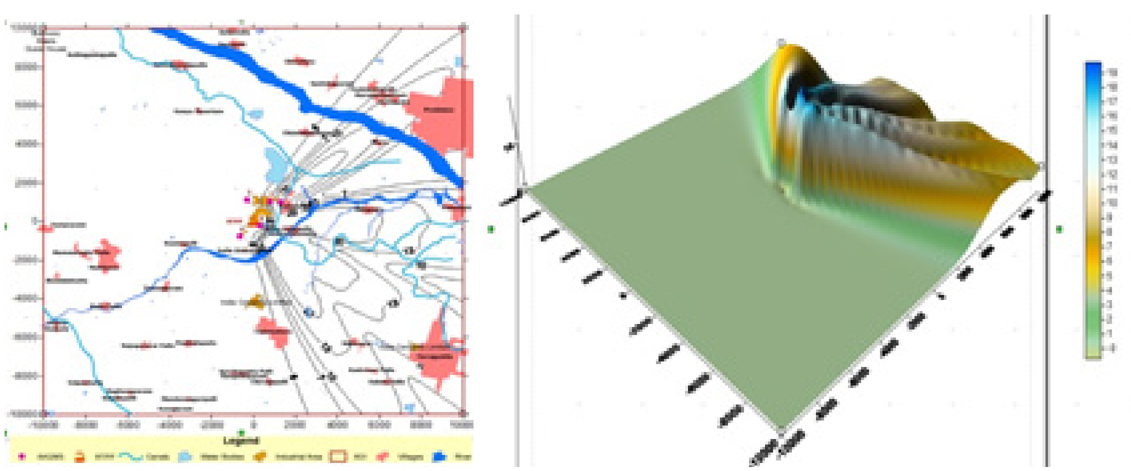
Andhra Pradesh State Pollution Control Board (APPCB) established four Ambient Air Quality Monitoring Stations around the emission source point of the Rayalaseema Thermal Power Project. The coordinates of the monitoring stations are identified from the grid map; details were specified in the Table 1.

Modeled output values are collected from the output files of the ISCST3 model; these values are not included with the background concentrations of the RTPP site. With reference to Environmental Impact Assessment report of RTPP site, a background concentration of NO_X is 17 $\mu g/m^3$ [10]. Predicted (P) values can be produced by



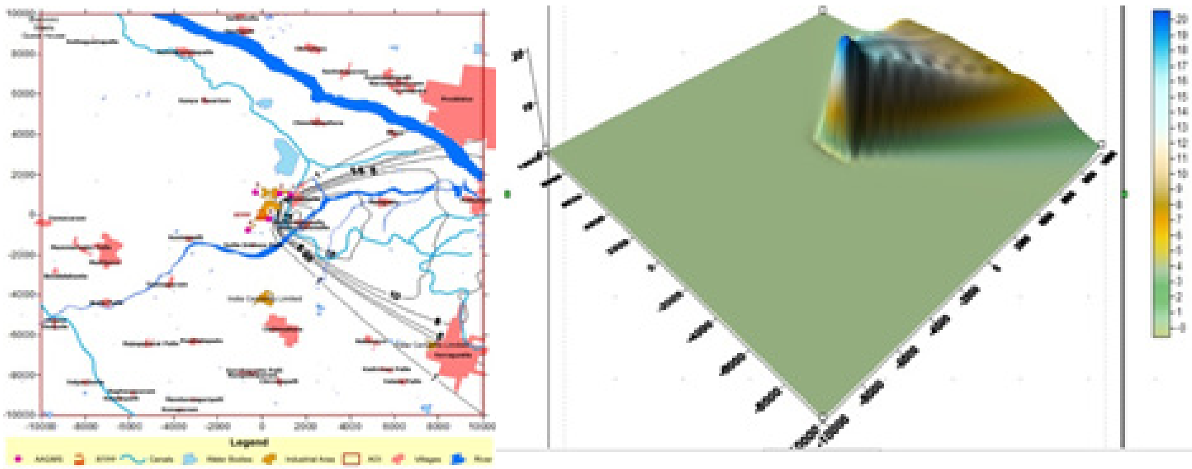
(a) (b)

Figure 5. (a) Isopleths of NO_X in the vicinity of RTPP June 2012. (b) 3-Dimensional view of NO_X dispersion in the vicinity of RTPP June 2012.



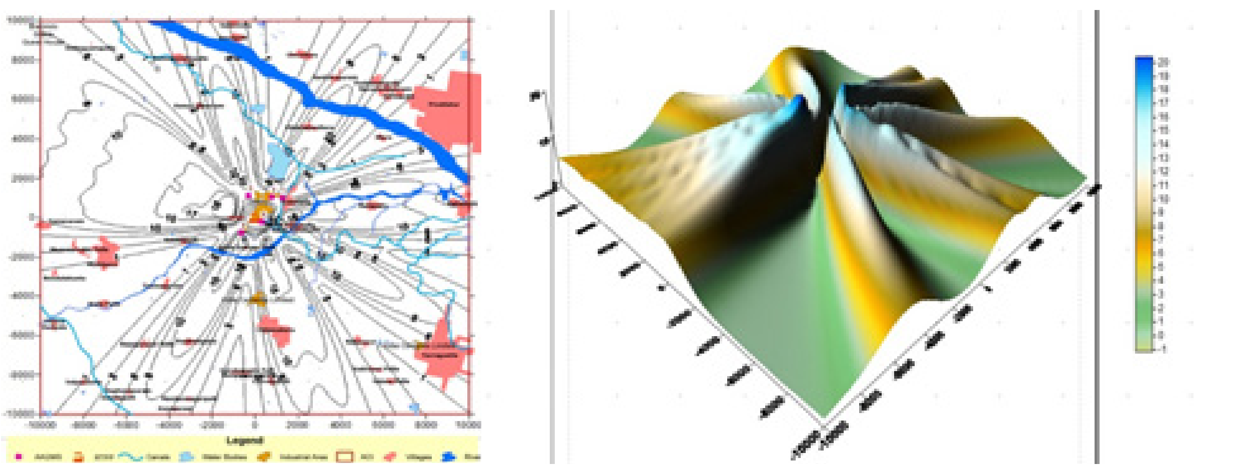
(a) (b)

Figure 6. (a) Isopleths of NO_X in the vicinity of RTPP July 2012. (b) 3-Dimensional view of NO_X dispersion in the vicinity of RTPP July 2012.



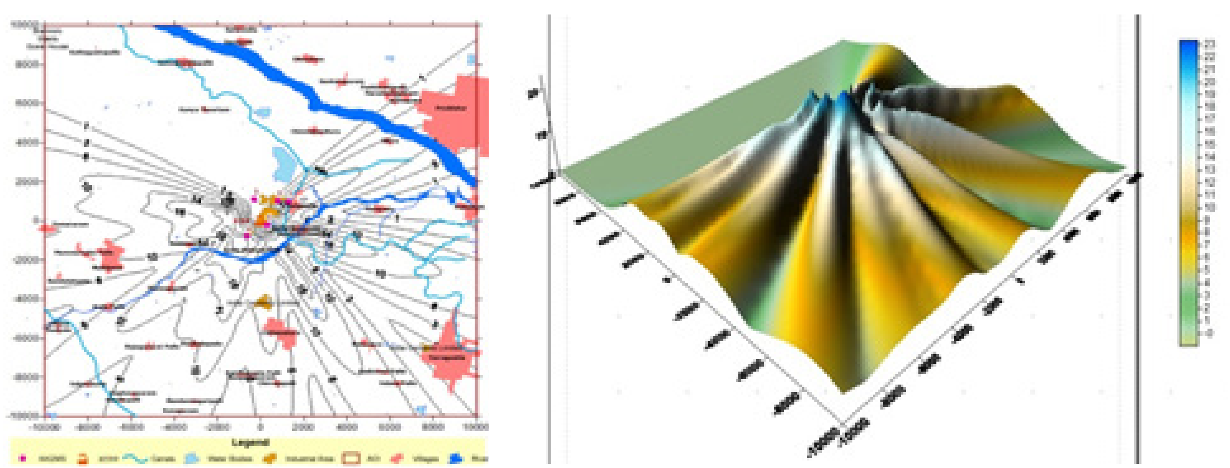
(a) (b)

Figure 7. (a) Isopleths of NO_X in the vicinity of RTPP August 2012. (b) 3-Dimensional view of NO_X dispersion in the vicinity of RTPP August 2012.



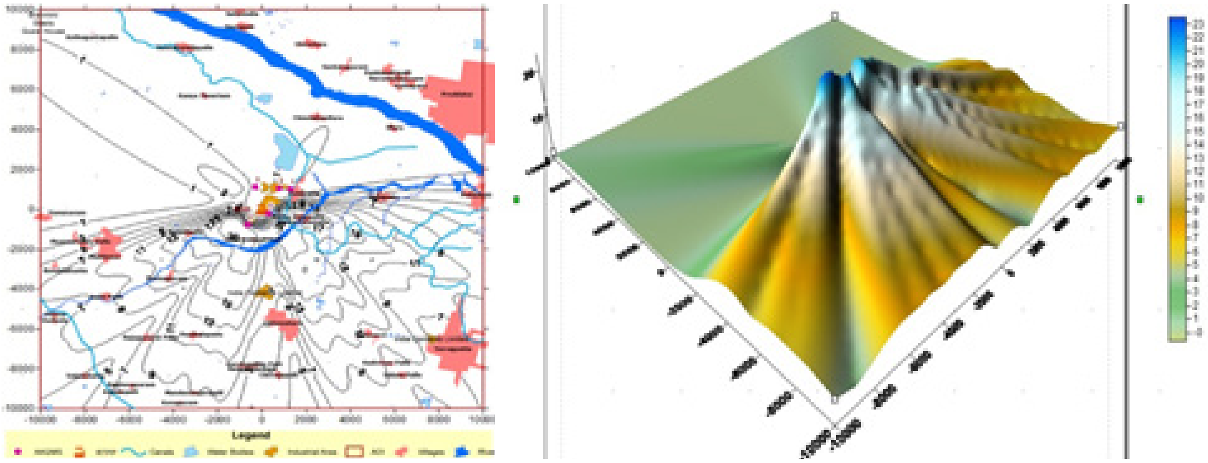
(a) (b)

Figure 8. (a) Isopleths of NO_X in the vicinity of RTPP September 2012. (b) 3-Dimensional view of NO_X dispersion in the vicinity of RTPP September 2012.



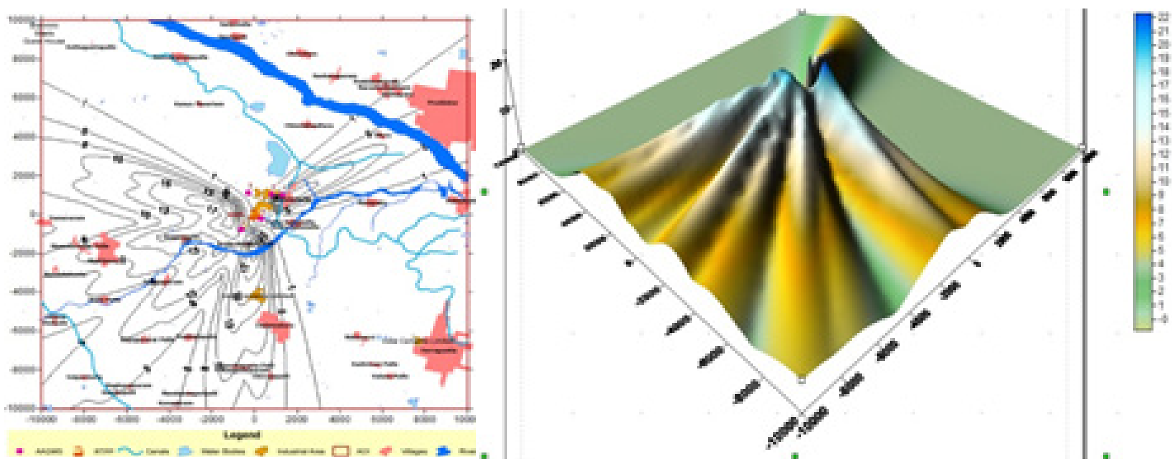
(a) (b)

Figure 9. (a) Isopleths of NO_X in the vicinity of RTPP October 2012. (b) 3-Dimensional view of NO_X dispersion in the vicinity of RTPP October 2012.



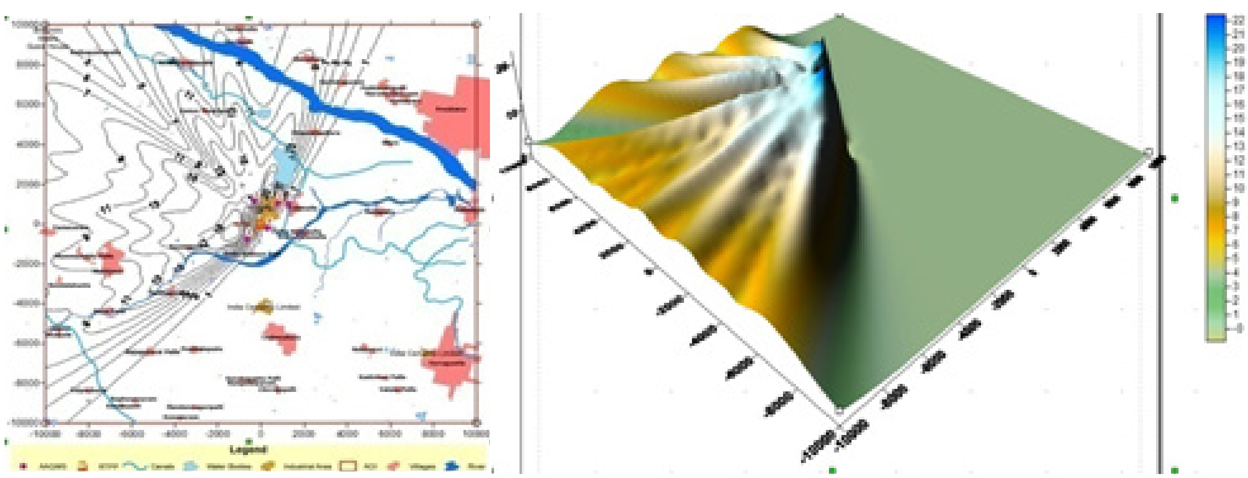
(a) (b)

Figure 10. (a) Isopleths of NO_X in the vicinity of RTPP November 2012. (b) 3-Dimensional view of NO_X dispersion in the vicinity of RTPP November 2012.



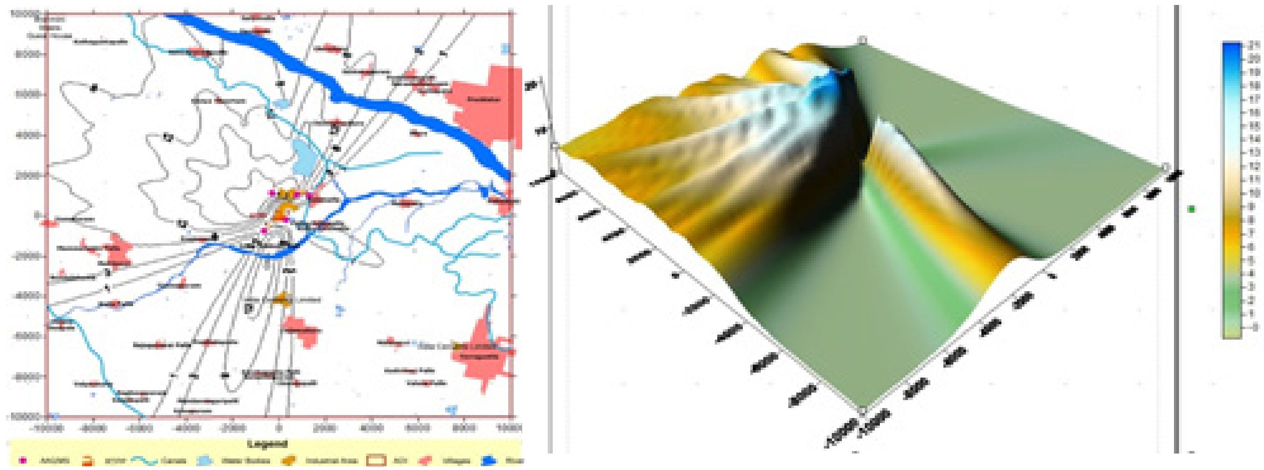
(a) (b)

Figure 11. (a) Isopleths of NO_X in the vicinity of RTPP December 2012. (b) 3-Dimensional view of NO_X dispersion in the vicinity of RTPP December 2012.



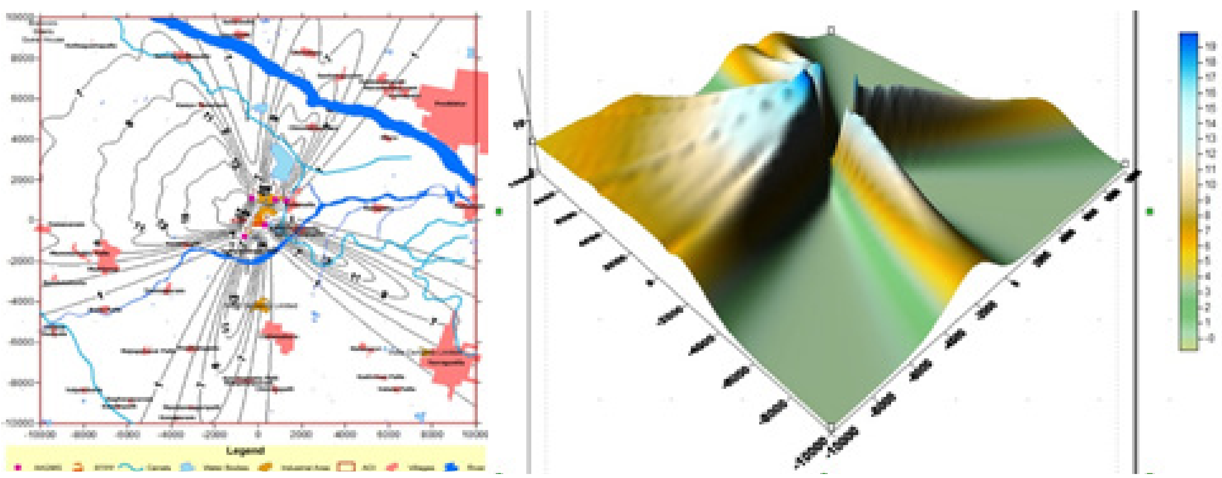
(a) (b)

Figure 12. (a) Isopleths of NO_X in the vicinity of RTPP January 2013. (b) 3-Dimensional view of NO_X dispersion in the vicinity of RTPP January 2013.



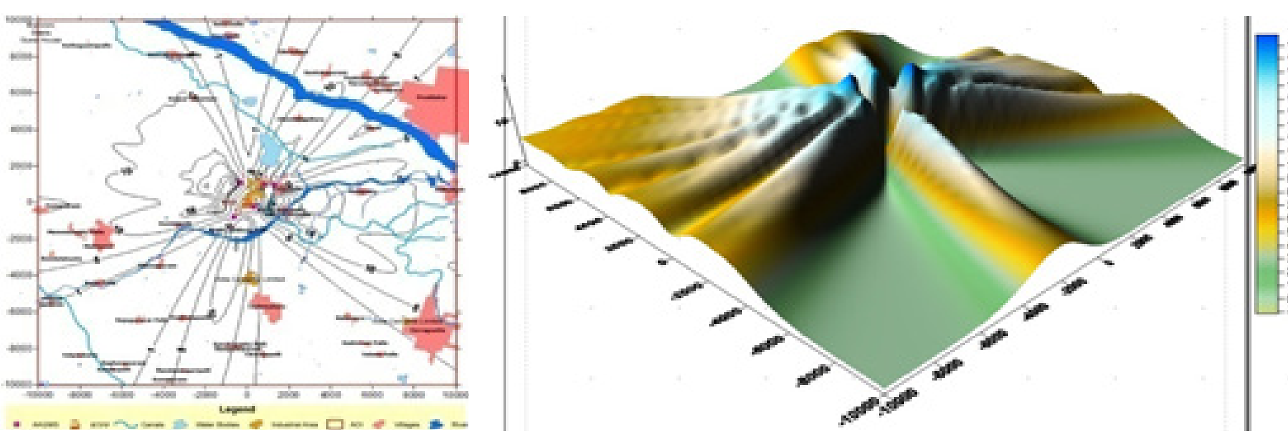
(a) (b)

Figure 13. (a) Isopleths of NO_X in the vicinity of RTPP February 2013. (b) 3-Dimensional view of NO_X dispersion in the vicinity of RTPP February 2013.



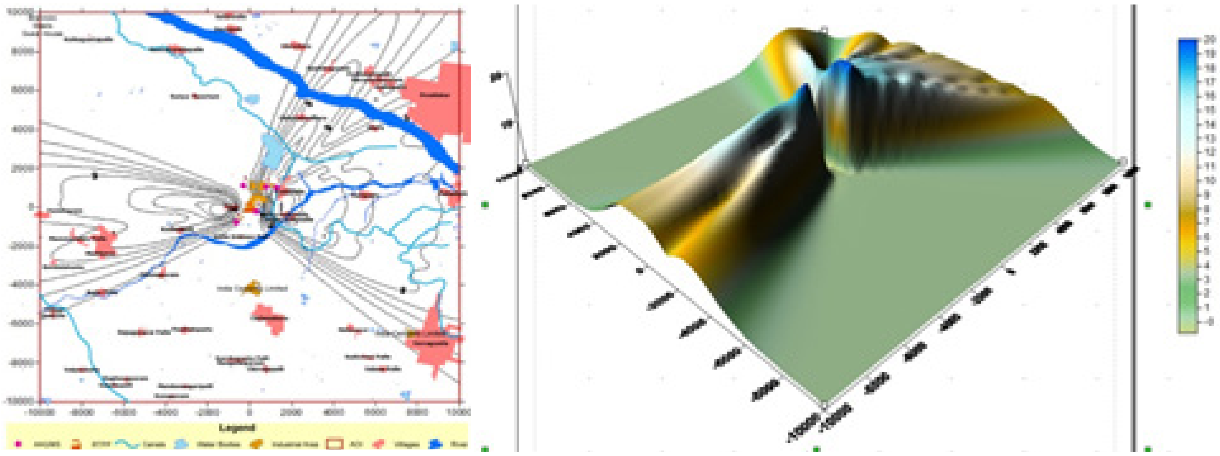
(a) (b)

Figure 14. (a) Isopleths of NO_X in the vicinity of RTPP March 2013. (b) 3-Dimensional view of NO_X dispersion in the vicinity of RTPP March 2013.



(a) (b)

Figure 15. (a) Isopleths of NO_X in the vicinity of RTPP April 2013. (b) 3-Dimensional view of NO_X dispersion in the vicinity of RTPP April 2013.



(a) (b)

Figure 16. (a) Isopleths of NO_X in the vicinity of RTPP May 2013. (b) 3-Dimensional view of NO_X dispersion in the vicinity of RTPP May 2013.

Table 1. Details of source and monitoring stations in the study area

Source/Monitoring Station	Location	Latitude	Longitude	Coordinates X	Coordinates Y
Source point	----	14.7022	78.4564	0	0
AAQMS-1	Kalamala police station	14.7114	78.4690	1500	1000
AAQMS-2	Project hostel	14.7119	78.4642	1000	1000
AAQMS-3	Project guest house	14.7125	78.4542	-1000	1000
AAQMS-4	Weigh bridge	14.6954	78.4510	-1000	-1000
AAQMS-5	TXR Office	14.7005	78.4598	500	-500

Table 2. Predicted and measured concentrations of NO_X

Month and year	Receptor points									
	AAQMS-1 (Kalamala Village Police Station)		AAQMS-2 (Project Hostel)		AAQMS-3 (Project Guest House)		AAQMS-4 (Weigh Bridge)		AAQMS-5 (TXR Office)	
	P	M	P	M	P	M	P	M	P	O
June-2012	22	--	18	21	17	20	17	22	17	25
July-2012	34	--	34	28	17	26	17	21	18	26
August-2012	21	--	18	21	17	22	17	22	17	21
September-2012	21	24	33	33	37	28	24	25	17	25
October-2012	31	37	23	25	19	21	41	37	17	25
November-2012	18	20	18	25	21	25	41	39	30	21
December-2012	31	33	23	24	21	22	35	35	17	22
January-2013	17	20	19	21	34	37	33	37	17	23
February-2013	18	20	26	23	35	35	17	20	17	21
March-2013	18	21	26	26	35	34	17	21	17	21
April-2013	22	28	34	29	35	40	19	22	17	25
May-2013	34	38	34	32	17	20	19	26	17	37

Table 3. Statistical performance measures of ISCST3 model

Parameter	Monitoring station	R^2	Inference
NO_X	AAQMS-1	0.96	Strong positive correlation
	AAQMS-2	0.77	Strong positive correlation
	AAQMS-3	0.76	Strong positive correlation
	AAQMS-4	0.94	Strong positive correlation
	AAQMS-5	0.05	Weak correlation

adding the background concentrations to the modeled output concentrations[11]. APPCB provided the Measured (M) values from monitoring stations for the period of June-2012 to May-2013. Predicted and measured concentrations of NOX are presented in the Table 2.

The coefficient of determination, R^2, is calculated for predicting concentrations from ISCST3 and measured values from all the Ambient Air Quality Monitoring Stations[6]. For the best curve fit R^2must be 1. Table 3 provides statistical performance measure of ISCST3 model.

6. Conclusions

This work represents the replication of nitrogen oxide dispersion from Rayalaseema Thermal Power Plant, and assessment between the predicted and measured concentrations at the RTPP site. Both measured and predicted data incorporated monthly NO_X concentrations from June 2012 to May 2013. For all Ambient Air Quality Monitoring Stations, the predicted NO_X concentrations were found to agree quantitatively well with the measured data. Our result represented the ISCST3 model can be operated for the dispersion of NO_X concentration prediction with reasonable precision. This model can be operated for the prediction of other primary pollutants from any Thermal Power Plant to its vicinity.

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