

## Air Dispersion Modelling to Assess Ambient Air Quality Impact Due to Carbon Industry

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**Abstract:** Industrial activities are sources of high emission rates of particulate matter,  $SO_2$  and other pollutants. The existence of many such industrial plants close to a populated area can have a severe effect on human health. The effects can be even worse when these emissions are added to existing background concentration levels. This paper deals with the assessment of the  $SO_2$  pollution caused by industrial activities close to the villages of Patalganga in Raigad district. An atmospheric dispersion model AERMOD 8.8.9 was used. An emission sources inventory was prepared for the carbon manufacturing industry. Villages within a boundary of 5 km were selected as key receptors. Meteorological data for one year was processed using AERMET processor. The model was run for pollutant  $SO_2$  with different scenarios.

The model outputs were compared with NAAQS, 2009 norms. Model runs were made for yearly, seasonal and daily averaged emission scenarios. All the GLCs at receptor locations (villages) was found below norms. Daily averaged model runs are useful in understanding the plume spread and analysis of hot spots from the stack emissions. Seasonal averaged model run outputs were compared with respect to sensitive receptors selected in all four directions of the industry. It was observed from the seasonal model runs that the pollutant concentrations varied at receptors with the seasonal changes in meteorology. All GLC values for  $SO_2$  at key receptor locations are below NAAQS, 2009 norms. It was concluded that the said industry is safe to operate in this area.

**Keywords:** Pollutant, Dispersion, Impact, Modelling,  $SO_2$  and Air Mode Model.

### 1. INTRODUCTION

Carbon manufacturing plant is located at Patalganga industrial region of Raigad district. Carbon is the largest manufacturer and supplier of high quality Carbon Black additives globally Carbon provides a complete portfolio of products across ASTM grades and specialty blacks to meet the specific end requirements across Rubber, Plastics, Coatings, Inks and other niche industries globally. The global manufacturing presence, with significant production capacities and supply capability, ensures regular and uninterrupted availability of consistent quality products for the customers. Customers include leading brands and companies across Tires, Rubbers, Plastics, Inks and Paints industries globally.

This paper describes the air dispersion modeling analysis for  $SO_2$  from the Patalganga Carbon Industries Plant only and the consequent comparison with the National Ambient Air Quality Standards, 2009 by CPCB and air emission standards by MPCB under consent to operate. The air emission impact analysis was completed using AERMOD 8.2., to verify whether the plant's air emissions create a significant air quality impact on nearby villages (Tribal Village).

### 2. MATERIALS AND METHODS

#### 2.1. Methodology: Air Dispersion Modeling Using AERMOD

The AERMOD modeling system consists of one main program (AERMOD) and two pre-processors (AERMET and AERMAP). The major purpose of AERMET is to calculate boundary layer parameters for use by AERMOD. The major purpose of AERMAP is to calculate terrain heights and receptor grids for AERMOD. Both AERMET and AERMAP require observational data to parameterize the growth and structure of the atmospheric boundary layer. AERMOD uses terrain, boundary layer and source data to model pollutant transport and dispersion for calculating temporally averaged air pollution concentrations.

Dispersion modelling requires three different models 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 for AERMOD: 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

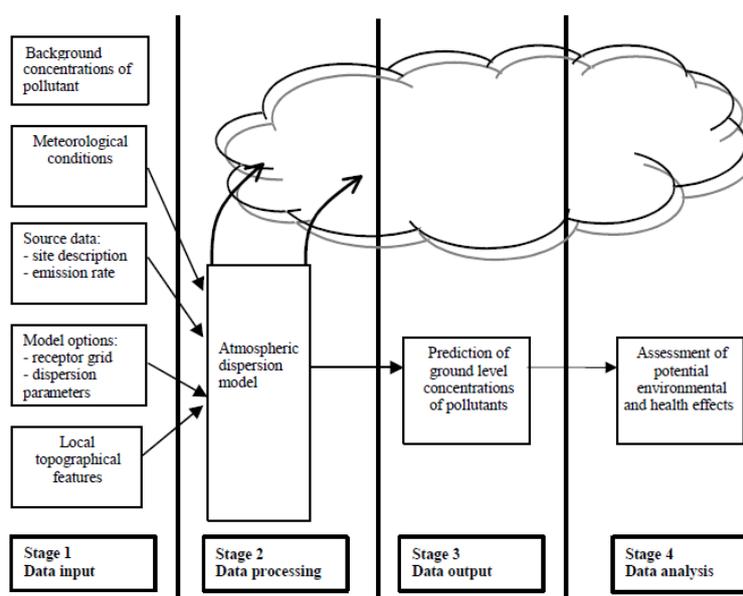
Model inputs: DEM data [x, y, z]; design of receptor grid (pol., cart., disc.)

Model outputs for AERMOD: [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)

Figure 01 explains the schematic of various processes involved in doing dispersion modeling.



**Fig1.** Schematic of various processes involved dispersion modeling.

### 2.2. Meteorological Data for AERMOD

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 flux 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:**

Cloud covers (tenths)

Ceiling height (m)

Dry bulb temperature (OC)

Global horizontal radiation (whm-2d-1)

Relative humidity (%)

Precipitation amount (hundredths of inches)

Station pressure (mb)

Wind direction (deg)

Wind speed (m/s)

### **Upper air data**

There are two modes of estimating upper air data

**Standard AERMET:** It process using specified upper air data.

**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

### **2.3. Meteorological Conditions as Model Inputs**

AERMET, one of the pre-processors of AERMOD was used to calculate the hourly boundary layer parameters e.g. Monin-obukhov length, convective velocity scale, temperature scale, mixing height and surface heat flux. The parameters (Surface heat flux, Monin-obukuv length and etc.) calculated by AERMET are important in the evolution of the boundary layer which, in turn, influences the dispersion of pollutants.

The above-mentioned meteorological data was used to run AERMOD. Both the Climatology Research Group's database and the Eskom database were used to get surface characteristics, cloud cover, upper air temperature sounding and near surface measurement of wind speed within the study area. Longitudinal and latitudinal coordinates as well as the time zone and wind speed threshold were used as input to AERMET. AERMET produced two files for input into AERMOD. The surface file contained observed and calculated surface observations.

#### *2.3.1. Elevation Data as Model Input*

AERMAP was used as a pre-processor in order to load the elevation data sets, and then AERMOD analysed the data. AERMAP required the use of gridded data to calculate terrain height scale for the receptor locations. The terrain data required by AERMAP was obtained from SRTM and land cover data was obtained from NLC 2001 AERMOD simulated a horizontal plume under stable conditions and also an elevation-following plume in order to account for varying elevation in the area.

## **3. RESULTS AND DISCUSSION**

With MET data processed through AERMET processor and providing input for sources and receptors along with terrain features, dispersion model was prepared using AERMOD 8.8.9. The model was run for various pollutants for one year MET data as well as one winter month MET data to check worst case scenario. The MODEL was not run for monsoon month considering the heavy rainfall in the study area, which will provide scrubbing action for the pollutants.

The MODEL was run for SO<sub>2</sub>. The results in terms of concentration contours were represented in this chapter along with its interpretation. Output also includes pollutant concentration at key receptors locations (Villages) as well as nearby locations within a boundary of 5 km. The receptors concentrations were obtained as 24 hr average (daily) and Annual average, based upon NAAQS, 2009 norms. Results were compared with NAAQS, 2009 to check any violation of norms by the industry.

The Model was run with SO<sub>2</sub> pollutant and MET data

Annual Average- One year MET data

24 Hr Average- One year MET data

24 Hr Average-One Month MET data- January

### 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 modelled.

### For each hour modelled

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

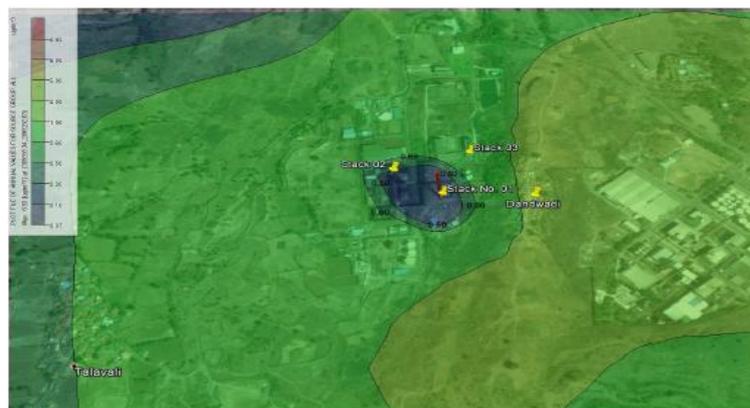
The plume is reflected at the surface with no deposition or reaction with the

Surface

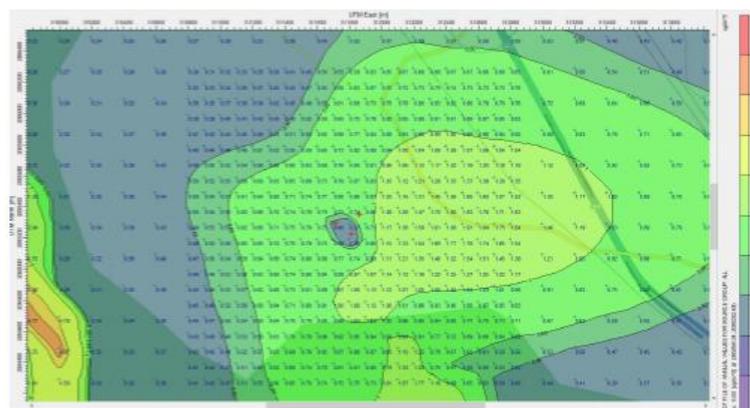
The dispersion in the crosswind (y) and vertical (z direction) take form of

Gaussian distributions about the plume centerline.

Final output concentration contours are as shown in following figures.



**Fig1.** SO<sub>2</sub> Concentration Contours Annual Average (one year MET data)



**Fig2.** Surface Characteristics SO<sub>2</sub> Concentration Contours Annual Average (one year MET data)

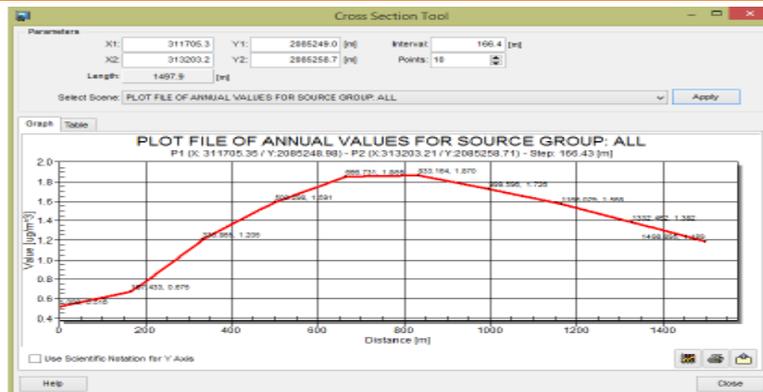


Fig3. SO2 Concentration Annual Average variation over a distance of 1400 m from the sources

Table1. Summary of AERMOD SO<sub>2</sub> Outputs for Yearly Averaged Model Runs for January 2012

S.No.	Name of the Receptor Village	Highest GLC – Ground level concentration in (µg/m <sup>3</sup> ) Annual average
1	Dandwadi,	2.00
2	Talaveli,	0.6
3	Lohop,	1.00
4	Vadgaon,	0.5
5	Washivali,	0.2
6	Vanivali	0.5
7	Vayal	0.2

Results in this section were obtained for SO<sub>2</sub> annual average. SO<sub>2</sub> concentration contours are obtained as output from AERMOD as shown in Figure 1 & Figure 2, concentration variation is shown in different colors. SO<sub>2</sub> concentrations at key receptor villages are as shown in table 1. Figure No.2 shows SO<sub>2</sub> concentrations at each receptor points as per receptor grid. All GLC values within 5 km boundary are below NAAQS norms for ambient air quality. Figure No.3 is application of AERMOD which helps us to understand variation in pollutant concentration with distance. This is done by using cross section tool. Figure No.3 shows, change in SO<sub>2</sub> concentration up to 1400 m from the emission sources.



Fig4. SO2 Concentration Contours 24 Hr Average (one year MET data)

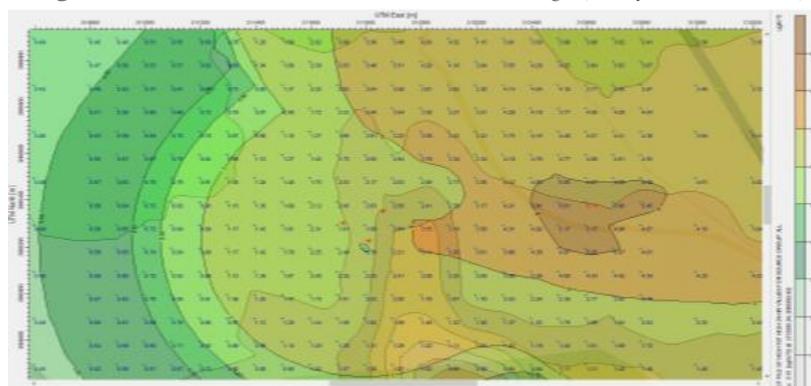


Fig5. SO2 Concentration Contours 24 Hr Average (one year MET data)

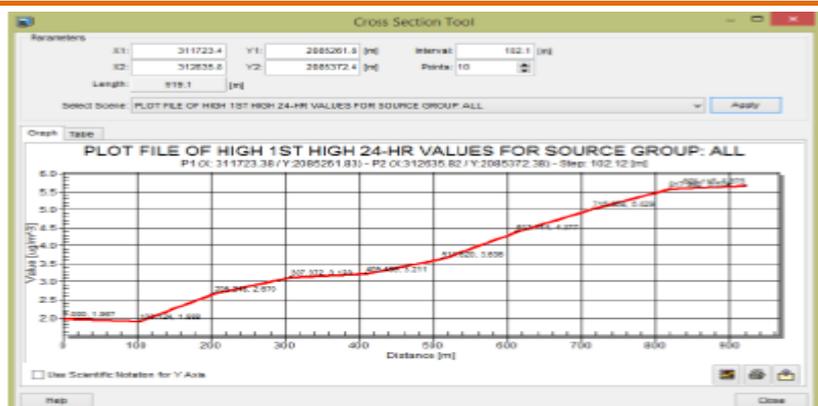


Fig6. SO2 Concentration 24 Hr Average variation over a distance of 900 m from the sources

Table2. Summary of AERMOD SO<sub>2</sub> Outputs for Daily Averaged (24 Hr) Model Runs for 2012

S.No.	Name of the receptor village	Highest GLC – Ground level concentration in (µg/m <sup>3</sup> ) 24 Hr. Average Daily average
1	Dandwadi,	5.00
2	Talaveli,	3.00
3	Lohop,	3.00
4	Vadgaon,	3.00
5	Washivali,	ND (Not Detected)
6	Vanivali	3.00
7	Vayal	ND (Not Detected)

Results in this section were obtained for SO<sub>2</sub> - 24 hr average. SO<sub>2</sub> concentration contours are obtained as output from AERMOD as shown in figure 4 & 5, concentration variation is shown in different colors. SO<sub>2</sub> concentrations at key receptor villages are as shown in Table no. 4. SO<sub>2</sub> concentrations at each receptor points is as per receptor grid marked in Figure No. 5. All GLC values within 5 km boundary are below NAAQS norms for ambient air quality. Figure No. 6 is application of AERMOD which helps us to understand variation in pollutant concentration with distance. This is done by using cross section tool. Figure No.6



Fig7. SO2 Concentration Contours 24 Hr Average (one winter Month MET data- January)

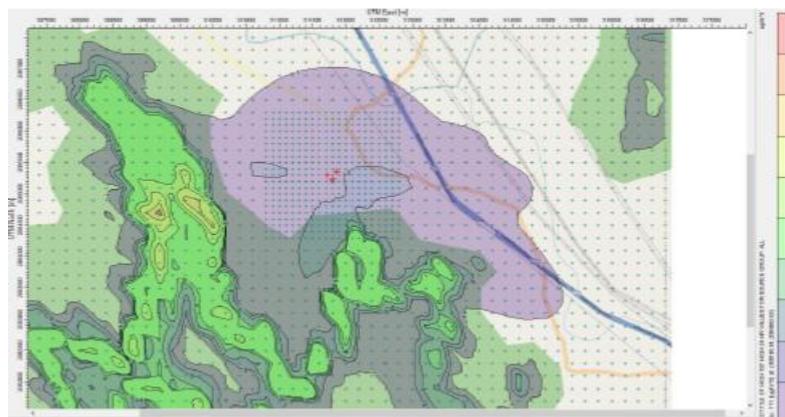


Fig8. SO2 Concentration Contours 24 Hr Average (one winter Month MET data- January)

**Table 3.** Summary of AERMOD SO<sub>2</sub> Outputs for Daily Averaged (24 Hr) Model Runs for January 2012

S.No.	Name of the receptor village	Highest GLC – Ground level concentration in (µg/m <sup>3</sup> ) 24 Hr. Average Daily averaged for January 2012
1	Dandwadi,	5.00
2	Talaveli,	3.00
3	Lohop,	3.00
4	Vadgaon,	ND (Not Detected)
5	Washivali,	ND (Not Detected)
6	Vanivali	3.00
7	Vayal	ND (Not Detected)

AERMOD was run for one month (January) meteorological data, to verify GLCs during winter season, to check effect of clam wind conditions (stable atmospheric conditions). Results in this section were obtained for SO<sub>2</sub> - 24 hr average for January month. SO<sub>2</sub> concentration contours are obtained as output from AERMOD as shown in figure 7 & figure 8, concentration variation is shown in different colors. SO<sub>2</sub> concentrations at key receptor villages are as shown in Table no. 3. All GLC values within 5 km boundary are below NAAQS 2009 norms for ambient air quality.

#### 4. CONCLUSION

From the data collected and analyzed by using AERMOD 8.8.9, the following conclusion appears to be justified.

After literature survey it was found that “AERMOD 8.8.9” is generally used for dispersion modelling for non-reactive pollutants like SO<sub>2</sub> from similar industries.

Meteorological parameters like wind, rain, temperature, solar radiation, terrain etc. plays significant role in dispersion of these kind of pollutants.

GLCs are comparatively low during rainy season due to scrubbing of pollutants gases in rains.

GLCs during winter are comparatively high due to stable atmospheric conditions.

Terrain of the area plays important role in the dispersion of the pollutants. In urban areas, multi-storey buildings leads to building down wash effect.

AERMOD 8.8.9 model output suggest that pollutants concentration in ambient air are within acceptance limits as per NAAQS 2009 norms within 5 km boundary.

Some locations show higher concentrations of pollutants in ambient air quality, but those areas are not inhabited.

The industry under study is safe to operate in this area and also it can go for expansion of the manufacturing facility.

#### REFERENCES

- A.Yegnan, D.G. Williamson, A.J. Graettinger,” Uncertainty analysis in air dispersion modeling,” *Environmental Modelling & Software* 17 (2002) 639–649.
- Akshay Bhargava (Principal, Kalol institute and technology research centre, kalol.), And Payalpatel (2011),” Environment Engineering Department, L.D College, Ahmedabad. Air Dispersion models for different Applications – Special references to Thermal power Plant”, National Conference on Recent Trends in Engineering & Technology.
- Arthur S. Rood,” Performance evaluation of AERMOD, CALPUFF, and legacy air dispersion models using the Winter Validation Tracer Study dataset,” *Atmospheric Environment* 89 (2014) 707-720.
- Bajwaa, K. S., Aryaa, S. P. and Aneja, V.P. (2012), “Modeling Studies of Ammonia Dispersion and Dry Deposition at Some Hog Farms in North Carolina”, *Journal of the Air & Waste Management Association*, 58(9), 1198-1207.
- Bhanarkar, A. D., Goyal, S. K., Sivacoumar, R. and Chalapati Rao, C. V. (2005), “Assessment of contribution of SO<sub>2</sub> and NO<sub>2</sub> from different sources in Jamshedpur Region, India”, *Atmospheric Environment*, 39, 7745-7760.

- Daly, A. and Zannetti, P. (2007), "Air Pollution Modeling—An Overview: Chapter 2", Arab School for Science and Technology (ASST) and Enviro Comp Institute Fremont, CA (USA).
- G. Praveen Kumar, S. Palanivelraja," Dispersion Modelling of SO<sub>2</sub> Emission from a Coal Fired Thermal Power Plant in Dadri", Uttar Pradesh International Journal of Engineering and Advanced Technology (IJEAT)ISSN: 2249 – 8958, Volume-3 Issue-6, August 2014.
- Jieyun Ma, Honghong Yi, Xiaolong Tang, Yan Zhang, Ying Xiang, Li Pu," Application of AERMOD on near future air quality simulation under the latest national emission control policy of China," Journal of Environmental Sciences 2013, 25(8) 1608–1617.
- Koppolu, L., Schulte, D.D., Lin. S., Rinkol, M.J., Billesbach, D. P. and Verma, S. B. (2002), "Comparison of AERMOD and STINK for Dispersion Modeling of Odorous Compounds", Paper No. 024015. ASAE Annual International Meeting, Chicago, Illinois.
- L.S. Hadlocona, L.Y. Zhaoa, G. Bohrerb, W. Kennyb, S.R. Garrityb, J. Wangc, B. Wyslouzild & J.Upadhyaya," Modeling of particulate matter dispersion from apoultry facility using AERMOD", Journal of the Air & Waste Management Association 23 January 2015.
- Laura Capelli a, Selena Sironi , Renato Del Rosso , Jean-Michel Guillot," Measuring odours in the environment vs. dispersion modeling," A review Atmospheric Environment 79 (2013) 731-743.
- M. J. Assael, K. E. Kakosimos, A.S. Katsarou," Application and evaluation of AERMOD on the assessment of particulate matter pollution caused by industrial activities in the Greater Thessaloniki Area," Environmental Technology Manuscript ID: TENT-2010-0073.
- Mark D. Gibson , Soumita Kundu , Mysore Satish," Dispersion model evaluation of PM<sub>2.5</sub>, NO<sub>x</sub> and SO<sub>2</sub> from point andmajor line sources in Nova Scotia, Canada using AERMOD Gaussian plume air dispersion model", Atmospheric Pollution Research 4 (2013) 157-167.
- Mutahharah M. Mokhtara, Mimi H. Hassima,b, Rozainee M. Taiba," Health risk assessment of emissions from acoal-fired power plant using AERMOD modeling", Process Safety and Environmental Protection 9 2 ( 2 0 1 4 ) 476–485.
- Patrick T. O'Shaughnessy, Ralph Altmaier," Use of AERMOD to determine a hydrogen sulfide emission factor for swine operations by inverse modeling," Atmospheric Environment 45 (2011) 4617-4625.
- Rosmeika1, Arief SabdoYuwono and Dyah Wulandani (2014)," Case Study on Air Pollutant Emission from Boiler Stack of Biodiesel Plant using Atmospheric Dispersion Modelling Ind. J. Sci. Res. and Tech. 2014 2(3):11-17.
- Sarath K. Guttikunda, Puja Jawahar," Application of SIM-air modeling tools to assess air quality in Indian cities." Atmospheric Environment 62 (2012) 551-561.
- Schulte, D.D., Modi, M.R., Henry, C.G., Stowel, R. R., Billesbach, D. P., Hoff, S. J. and Jacobson, L. D. (2007), "Modeling Odor Dispersion From a Swine Facility Using AERMOD", Agricultural and Biosystems Engineering, University of Nebraska; Black & Veatch; Iowa State University; University of Minnesota.
- Seangkiatiyuth, K., Surapipith, V., Tantrakarnapa, K. and Lothongkum, A. W. (2011), "Application of the AERMOD modeling system for environmental impact assessment of NO<sub>2</sub> emissions from a cement complex", Journal of Environmental Sciences, 23(6), 931–940.
- Sharan T.V.B.P.S. Rama Krishna, M.K. Reddy, R.C. Reddy, R.N. Singh," Impact of an industrial complex on the ambient air quality: Case study using a dispersion model", Atmospheric Environment 39 (2005) 5395–5407.
- Theobald, M. R., Lofstrom, P., Walker, J., Andersen, V. H., Pedersen, P., Vallejo, A. and Sutton, A. M. (2012), "An inter comparison of models used to simulate the short-range atmospheric dispersion of agricultural ammonia emissions", Environmental Modeling & Software, 37, 90-102.
- URL-01: Engineering Tool Box, Dry bulb temperature <<http://www.engineeringtoolbox>
- URL-02: Hyper Physics, relative humidity <<http://hyperphysics.phy-astr.gsu.edu/hbase/kinetic/rehum.html> (accessed on 27.08.2013).
- US EPA. (2004), "User's guide for the AERMOD meteorological pre-processor AERMET", EPA-454/B-03-002.

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