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Comparative Study of Air Quality Models

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Abstract—*In mega cities and urban areas, industrial growth and vehicular emissions have caused severe concern of ambient air pollution. Situation is alarming; it can increase in near future to cope up with population expansion. Air quality models have been using for assessing impact of emission sources to ambient air pollution as well as for planning emission controls. These models use meteorology and emission inventory to trace the dispersion path of a pollutant to estimate the impact at the receptor. US-EPA's AERMOD has an improved approach for characterizing boundary layer parameters and vertical profile of atmosphere as compared to other dispersion models. The application of Gaussian Plume Model (GPM) requires knowledge of several parameters, i.e. atmospheric turbulence, emission release rate, wind speed, dispersion coefficients, effective stack height, mixing height etc. In most of the cases of Indian scenario, meteorological data is not available. Under such conditions, it is proposed to use 'Plausibility Approach Model' to obtain maximum possible impact from pollution source. Input parameters in this method are chose by considering their plausibility of occurrence; such that the model gives the maximum impact. Based on the available literature from past, this paper proposes to study AERMOD and Plausibility Approach Model, their application and comparative performances. Ground level concentrations for pollutant Total Suspended Particulate Matter (TSPM) calculated by both the models and compared.*

Keywords*: Air Quality Modeling, Plausibility Approach Model, AERMOD, Gaussian Plume Model, Ambient air pollution.*

1. INTRODUCTION

Ambient air pollution has become severe problem in India along with the rapid growth in industries and vehicular emissions. The problem is supposed to be alarming in order to cope up with the population expansion in the future (Andria et al. 2008; Banerjee 2010). Air quality modeling is an important way to assess effect of any emission source in the ambient atmosphere. This study focuses on finding concentrations at the ground level in study area of 5 km radius. Selected industry as an emission source is 'Sahakarmaharshi Shankarrao Mohite-Patil sahakari sakhar karkhana Ltd., Akluj, Dist.:- Solapur, Maharashtra. Air quality modeling has performed for this industrial source, having boilers connected to stack; using bagasse as a fuel for co-generation of electricity. For this purpose, emission, meteorological and receptor inventory was established. US-EPA's AERMOD v9.2 has used for air quality modeling and results have analyzed. Same emission, meteorological and receptor inventory is used in plausibility approach model. Results have compared in order to understand both the air quality models and their comparative performances.

2. LITERATURE SURVEY

The relevant research articles have referred from various researchers.

Sharma et al., (2004) carried out evaluation of some commonly used dispersion models to quantify their predictive capacity and performance. The study showed that despite several limitations and assumptions of Gaussian air pollution dispersion models, these models are comparatively more accurate and consistent with random nature of turbulence in atmosphere and are best suited for pollutant dispersion. **Bandyoadhyay, (2010)** has conducted 'Dispersion modeling in assessing air quality of industrial projects under Indian regulatory regime'. This study aims at providing approaches to determine pollution potential for proposed power plant operation under different conditions. In order to assess the performance of the computational work, four different cases had analyzed based on worst scenario. Results obtained through predictions had compared with National Ambient Air Quality Standards (NAAQS) of India. One specific case found to overshoot the ambient air quality adversely in respect of SO_2 and was therefore, suggested to install a FGD system with at least 80% SO_2 removal efficiency. **Tartakovsky et al., (2013)** conducted study on the 'Evaluation of AERMOD and CALPUFF for predicting ambient concentration of Total Suspended Particulate Matter emission from a quarry'; which was present in the complex terrain. The study suggests that for a wide range of meteorological and topographical conditions, AERMOD predictions were in a better agreement with the measurements than those obtained by CALPUFF. In addition, onsite meteorological data has shown to be crucial for reliable dispersion calculations in complex terrain. **Gulia et al., (2015)** have done 'Assessment of Urban Air Quality around a Heritage Site Using AERMOD: A Case Study of Amritsar City, India'. The performance of AERMOD has evaluated for prediction of NO_x, SO_2 PM_{10}. It has observed from the results that predicted pollutant concentrations are in satisfactory limits. The index of agreement (d) values estimated for NO_x, SO_2 and PM_{10} are 0.57, 0.51 and 0.50, respectively, indicating satisfactory performance of AERMOD.

Literature review reveals that, numerous experimental studies have done on finding relation between modeled and observed concentrations of different pollutants by making use of several software models such as CALPUFF, ISCST3, and AERMOD etc. Literature suggests that AERMOD is relatively more reliable and found to be most suitable to use for air quality modeling purpose. In addition, emission inventory along with accurate meteorological data is key point in obtaining and governing results of the output models. As the Indian condition is concerned, accurate and continuous, meteorological data is not available. There is great need of development of air quality model, which is suitable for such conditions.

3. OBJECTIVES OF STUDY

3.1 To establish emission, meteorological and receptor inventory

3.2 To perform air quality modeling using Plausibility Approach Model and AERMOD

3.3 To compare and analyze results of both methods critically

4. EXPERIMENTAL METHODOLOGY

4.1 AERMOD model

4.1.1 Emission inventory

Emission details includes Fuel details, Flue gas characteristics and Stack details etc. are collected through extensive stack monitoring as according to the IS 11255. Emission rate has calculated based on the results of the stack monitoring. Emission inventory is as described in table 4.1.1

4.1.2 Meteorological conditions

One of the pre-processors of AERMOD; AERMET analyzes meteorological data set and gives Wind Rose diagram and Wind Joint Frequency as an output. Wind Rose diagram represents the prevalent conditions. AERMOD processes AERMET output to understand boundary layer parameters of the atmosphere. Wind Rose diagram is as shown in Figure 4.1.1**.**

Table 4.1.1: Emission inventory

Sr. No.	Particulars	Description
1.	Attached to	Boiler
2.	Capacity	200 TPH
3.	Fuel Type	Bagasse
4.	Fuel Quantity	2170 TPD
1.	Material of construction	RCC
2.	Stack Height (above ground)	80 m
3.	Stack Diameter	4 m
4.	Flue Gas Temp.	119 ^{0}C
5.	Flue gas velocity	8.53 m/s
6.	Control Equipment preceding the stack	ESP

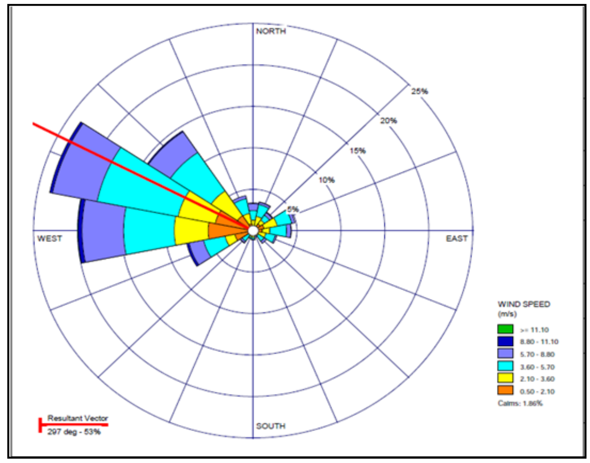

Figure 4.1.1: Wind Rose diagram plotted by AERMET

4.1.3 Receptor inventory

Receptors are chose in the surrounding area of the industry unit. Receptor distance and their orientation have considered with respect to the stack, as according to the CPCB guidelines. Receptor inventory is as shown in Table 4.1.2.

Based on this input inventory, AERMOD model obtains concentrations at the ground level. Concentrations have obtained for pollutant TSPM for the sake comparison. Concentration contours have plotted for 5 km of stretch; for receptors in the industry area with stack as a reference coordinate to understand dispersion patterns.

Table 4.1.2: Receptor Summary

Receptor	Village Name	Distance (m)	Angle (deg)
R-1	Pisewadi	1700	90
R-2	Vidyanagar	2800	90
R-3	Sumitranagar	1250	0
R-4	Sarati	5000	0
R-5	Swarupnagar	1200	30
R-6	Savta-mali nagar	2200	30
R-7	Zopadpatti	1300	180
R-8	Water supply lake	4900	180
R-9	Dattanagar	4500	150
R-10	Malewadi	3300	90

4.2 Plausibility Approach Model

Plausibility Approach Model is based on finding out concentrations of pollutants by considering plausibility of occurrence of stability and critical wind conditions. Same emission and meteorological data is used. Concentrations have found out for same receptors as that of Table 4.1.2.

First, critical wind speed is determined for each stability class at standard distances; gives maximum concentration. Based on plausibility of occurrence of each stability class, during day and night time, concentrations for 24 hours have found out and averaged out for 1 hour. Therefore, this concentration values are maximum under any condition, which shall not be occurring at any time.

5. RESULTS:

Results have obtained for all selected receptors for pollutant TSPM; by both the methods as shown below. For comparison, 1 hour and 24 hour averaging periods are used.

5.1 Plausibility Approach Model Results

Table 5.1 TSPM concentrations by plausibility approach model

Plausibility approach concentrations for 24 hr. average (µg/m3)		
Receptors	**Case-1**	**Case-2**
R-1	0.566	0.438
R-2	0.537	0.331
R-3	0.645	0.517
R-4	0.474	0.242
R-5	0.656	0.524
R-6	0.55	0.384
R-7	0.516	0.4112
R-8	0.48	0.246
R-9	0.501	0.262
R-10	0.544	0.314

Case-1 & Case-2 are nothing but two different assumptions of stability class occurrences. Case-1 is with the assumption of occurrence of stability classes as:- i) A class for 4 hours ii) B class for 4 hours iii) C class for 4 hours iv) D class for 12 hours and E & F class not occurring. Whereas, Case 2 is for real time occurrence of stability classes, for which 24-hour concentrations are maximum; computed by AERMOD. Meteorological conditions have studied for that day and used in the plausibility model. The occurrence of stability classes is as:- i) A class for 3 hours ii) B class for 3 hours iii) C class for 4 hours iv) D class for 12 hours v) E for 2 hours with no occurrence of F class.

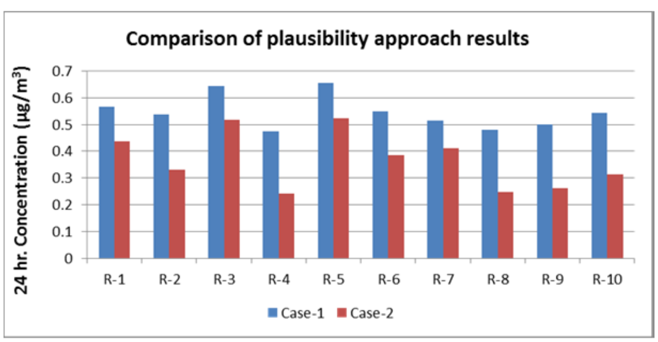

Figure 5.1 Comparison of Plausibility Approach Model results between case-1 and case-2

5.2 AERMOD Results

Table 5.2 TSPM concentrations by AERMOD

Receptor	1 hr. concentration (µg/m^3)	24 hour concentration (µg/m3)
R-1	2.98	0.42
R-2	2.23	0.405
R-3	3.15	0.2
R-4	1.26	.06
R-5	2.725	0.34
R-6	2.34	0.2
R-6	2.34	0.2
R-7	2.38	0.2
R-8	0.8	0.04
R-9	1.14	0.12
R-10	1.9	0.38

Concentration contours have plotted for TSPM pollutant by AERMOD software in order to understand dispersion pattern in the surrounding area of the industry.

Contour of same colour represents same concentration value ranges. Contours are as shown in Figure 5.2(a) & 5.2(b).

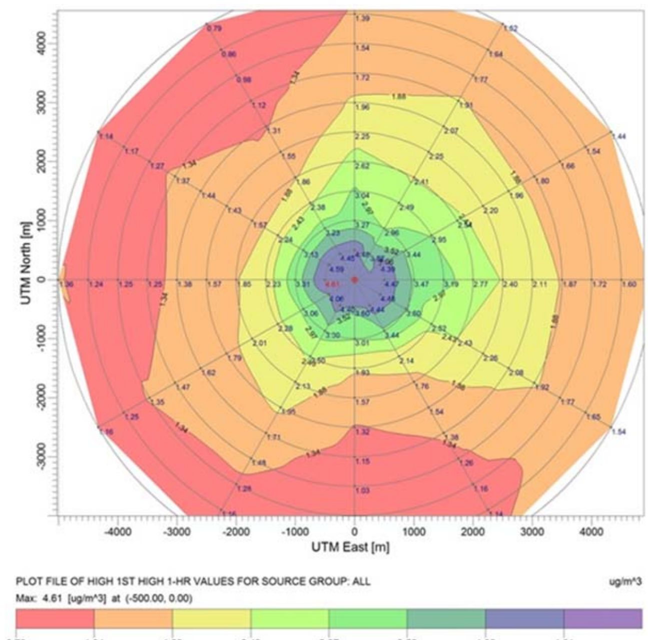

Figure 5.2(a) 1 hr. concentration contour for 5km around industry

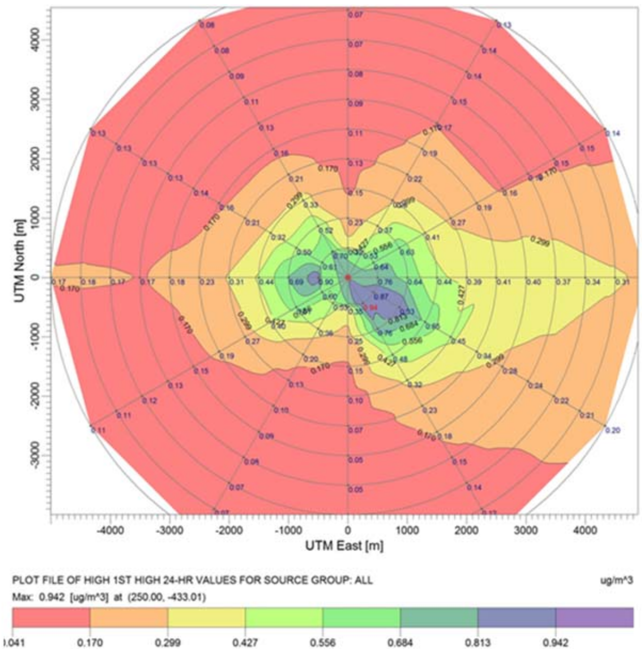

Figure 5.2(b) 24 hr. concentration contour for 5km around industry

Maximum concentration for 1 hour and 24 hour are 4.61 and 0.942 µg/m^3 obtained at coordinates of (-500, 0) and (250, -433) respectively.

5.3 Comparative Results

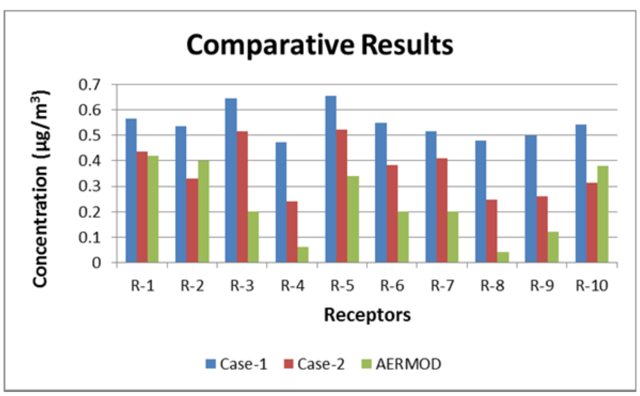

Figure 5.3 Comparison of Plausibility approach model case-1 and case-2 with AERMOD

6. CONCLUSIONS:

1. Study of Air Quality Modeling involves data requirement on a large and continuous basis for meteorology. As per as the Indian conditions are concerned, such data is not available.
2. In this study, Plausibility Approach Model was used to counterpart data unavailability. As it is based on finding maximum concentrations considering worst-case scenario, resulting concentration values are more than that of AERMOD.
3. Assumptions of stability class occurrence in Case-1 are considering worse scenario than Case-2; hence resulted in more values in Case-1 than Case-2.
4. Even though Case-2 involves same meteorological data set as that of AERMOD, Concentration values are more for Case-2 than AERMOD
5. Hence, we can conclude that, Plausibility Approach Model performs better than AERMOD for Indian conditions.
6. AERMOD has an advantage over Plausibility Approach Model, as far as plotting concentration with better visual representation is concerned.

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