PERFORMANCE OF AERMOD SOFTWARE IN INDIAN SCENARIO

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ABSTRACT

Air quality modeling plays an important role in formulating air pollution control and management strategies by providing guidelines for better and more efficient air quality planning. In last few decades the urban air quality has been deteriorated in mega cities of India. Among air quality dispersion models, AERMOD is found one of the strong model used to evaluate the urban air quality. However, applications of these models are still limited in developing countries like India due to lack of availability of specific input data. Till now AERMOD is applied for different pollutants such as SO2, NO2, PM10, PM2.5 in various parts of India which shows that it has tendency of under-prediction to the observed values. The one of the reason behind under prediction is that AERMOD being sensitive to some of the surface characteristics parameters such as Albedo, Bowen ratio & surface roughness. Even though the applications of AERMOD has been started in India for EIA for source apportionment study & these surface parameters are not being taken into considerations which leads to erroneous result for policy level decisions. To make AERMOD model as robust model rigours validation for different scenarios shall be carried out. In this paper overview on performance of AERMOD air dispersion model for different locations, sources of air pollution & pollutants is studied to check its credibility. Moreover, the role of these surface parameters on model predictions is also discussed in this paper.

Keyword: - *AERMOD, Regulatory model, Albedo, Surface roughness, Bowen ratio, Dispersion model*

1. INTRODUCTION

Poor air quality is a cause for concern in India, particularly in mega cities and air pollutants including particulate matter (PM), sulfur dioxide (SO_2), nitrogen oxides (NO_x), carbon monoxide (CO), and ozone (O_3) often exceed the National Ambient Air Quality Standards (NAAQS) [9]. India has large geographical area with a very wide spectrum of climatic conditions, topographical conditions, land cover etc. Due to diverse topographical and climatic conditions in India it's not possible to reach specific location every time to measure the pollutant concentration. Although the measurement of air pollutants using the instruments becomes somewhat time consuming & not economical. Models are systematic tools to predict ground level concentrations over a period of time & space from any sources of pollution. The applications of air dispersion models are quite wide such as it can be used for regulatory purpose, urban planning, EIA, source apportionment studies so on & so forth for overall air quality management. AERMOD was developed at the United States Environmental Protection Agency. ISCST – 3 and AERMOD model predictions have been compared worldwide and AERMOD has been proved as more realistic model. As per AERMOD's performance and utility worldwide, India has started adoption of AERMOD model for air quality impact. In India, AERMOD has recently been added to the list of recommended models for regulatory applications (CPCB, 2008). The Performance of AERMOD and ADMS-Urban has been studied for mega city Delhi to estimate particulate matter concentration for year 2000-2004 for winter season. The estimated values indicated that ADMS-Urban showed better correlation with observed values while AERMOD predicted lower values than observed [7]. AERMOD was used for the simulation of PM_{10} over Pune city. It requires surface and upper air meteorological observations which are not easily available for most locations in India. This limitation was overcome by computing the planetary boundary layer and surface layer parameters required for AERMOD using WRF (Weather Research and Forecasting) model (version 2.1.1). WRF succeeded in generating the meteorological inputs required for AERMOD. To conclude the reliability of system to predict pollutant dispersion the sensitivity analysis of AERMOD to different WRF parameterization is required in future [1]. The validation of AERMOD model with the estimated values of PM_{10} over Madurai city has been studied. AERMOD under predicted PM_{10} by a factor 1-1.5 in the concentration [3]. Performance evaluation of AERMOD and ADMS-Urban for tropical city Delhi to estimate SO_2 and NO_2 for 2000-2004 year in seven cities has been studied. Both the models over predicted and monthly estimated concentrations were better than the 24-hr daily average concentration [6]. However, due to lack of requisite extensive input data for AERMOD. The most often used model is still ISCST3. The commercially available air quality models, e.g. AERMOD and ADMS-Urban (regulatory model in U.K.) are highly advanced and complex but user- friendly performing satisfactorily with old generation line source dispersion models such as CALINE 4, GFLSM and DFLSM. Most of the predications which have been done in Indian climatic conditions shows those AERMOD predictions are lower than the observed values. The probable reasons could be default values of original software which has been validated as per the USA conditions. And it is obvious that climatic conditions and factors affected them are totally different in India other than USA. Hence it is necessary to identify the reasons for under prediction of ARMOD software & their effect on pollution predictions. AERMOD requires LULC (land use and land cover) parameters such as Albedo, surface roughness and Bowen ratio. Looking at present scenario, most of the air quality modeling has been carried out with the help of AERMOD software with default surface characteristics. So, it is necessary to determine the albedo, surface roughness and Bowen ratio for India under different land use category and its effect on model prediction. Studies on the effect of surface parameters for different land use pattern on performance of AERMOD and its impact on ambient on ambient air concentration has been done for Capital of Gujarat state. It is important to know that Land use and Land cover (LULC) data is important for air pollution modelling to predict the accurate result in study area because most of the time study area is not under single land use category but more than one land use patterns [2] .To test the performance of AERMOD with actual value of Albedo an attempt has been done using Albedo values given by NASA In that default value of albedo is modified with NASA value considering Gandhinagar completely under Urban category [12]. Same test has been performed for Gandhinagar city & determination of Albedo is done with Pyranometer considering Urban, deciduous & cultivated LULC [2]. To increase the credibility of AERMOD in India its application for specific source and specific meteorological conditions becomes necessary.

2. AIR QUALITY IN METROPOLITIAN CITIES IN INDIA

Urban air quality in majority of the megacities in India is getting deteriorated due to some major contributors of air pollution such as increasing industrial development, urbanization, mining operations, construction activities, disposal of solid and liquid waste along with motorized road transport. The Indian cities are growing at a greater pace. In Indian metropolitan cities, the vehicles are estimated to account for 70% of CO, 50% of HC, 30–40% of NOx, 30% of SPM and 10% of SO2 of the total air pollution load of these cities, of which two-third is contributed by two wheelers alone [1]. World Health Organization (WHO) reported that 14% deaths were due to chronic obstructive pulmonary disease or acute lower respiratory infections by PM_{10}. It's increased by 6% from 2009- 2012 (WHO, 2014). Due to degrading air quality in metro cities it is essential to predict the pollutant concentration so that the data can be further used in generating the strategies to mitigate the impact of these pollutants in ambient air. The air quality in some major metro cities is shown below. (Data is taken from ENVIS, CPCB website).

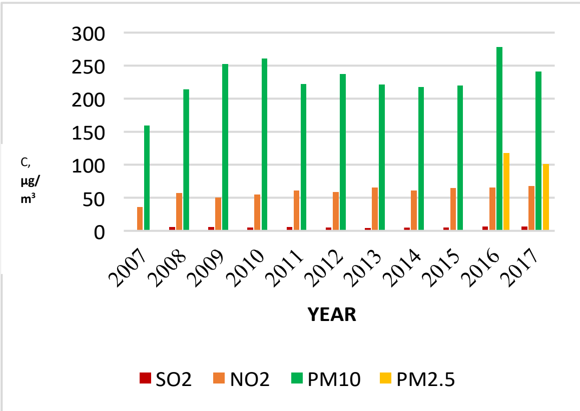

Chart -1: Air quality in Delhi

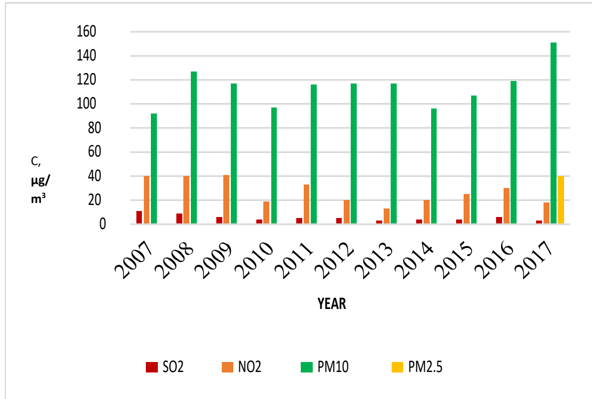

Chart -2: Air quality in Mumbai

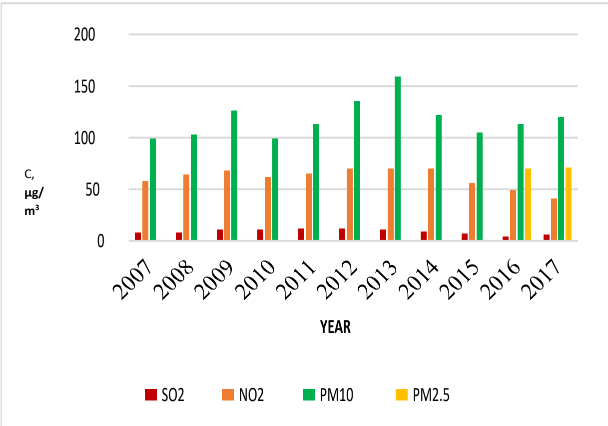

Chart -3: Air quality in Kolkata

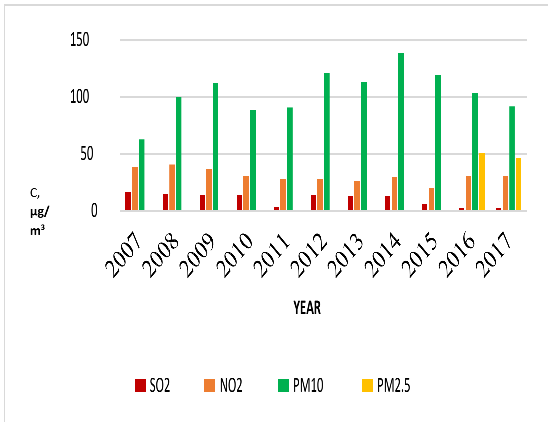

Chart -4: Air quality in Bangalore

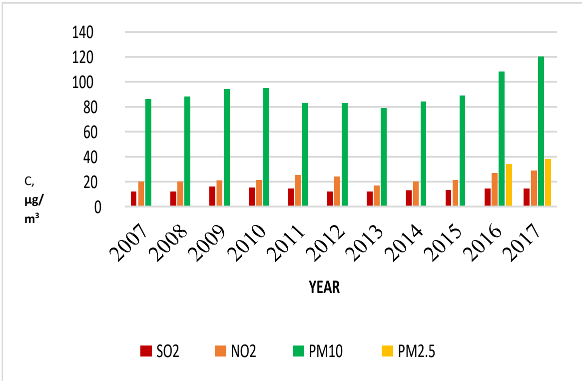

Chart -5: Air quality in Ahmedabad

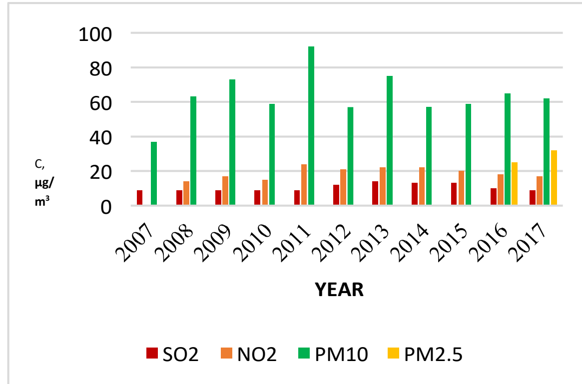

Chart -6: Air quality in Hyderabad

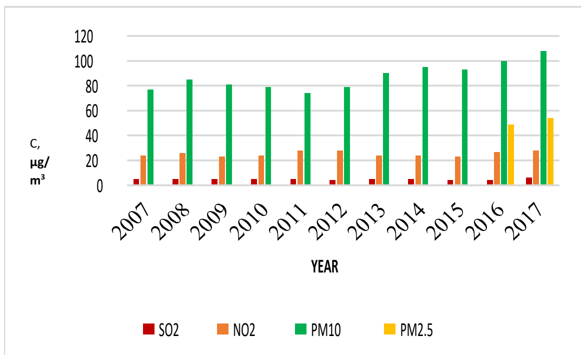

Chart -7: Air quality in Chennai

3. AIR QUALITY MODELING

Air quality modeling is a mathematical simulation of how air pollutants disperse and react in the atmosphere to affect ambient air quality based on measured inputs. These models are designed to characterize primary pollutants that are emitted directly into the atmosphere and, in some cases, secondary pollutants too based on inputs of meteorological data and source information like emission rates and stack height etc. So, in order to quantify the impacts of emission sources on ambient air quality and human health it is necessary to evaluate the impact of different emission sources by using efficient air quality prediction tools. Also for air quality management strategies prediction of pollutant concentrations with the aid of regulatory air quality models is an essential part. However, before implementation of the regulatory model validation is important for which the model is originally developed. The performance of model varies for different source scenarios and climatic conditions thus, a model must be evaluated for the local site conditions prior to it's application for predicting and forecasting pollution load. For this purpose, various dispersion models for are being used for different point, line, area and volume sources.

4. DISPERSION MODELING

Dispersion modeling is a set of mathematical equations that simulates the emission and dispersion of air pollutants in the atmosphere. In other words, it is a mathematical simulation of the physics and chemistry governing the transport, dispersion, transformation of pollutants in the atmosphere. They are the systematic tools to predict ground level concentrations over a period of time and space from any point, line, area and volume sources. The continuous growth of industries and vehicular traffic accounts for urban pollution and has given rise to a need for comprehensive monitoring accomplished by modeling of air quality. Due to high cost, time constraint and the experimental difficulties involved it is not always feasible to monitor or measure concentration of pollutant at various points in a particular area.

Table -1: Commonly used dispersion model

MODEL NAME	DESCRIPTION
AERMOD	AERMOD is the preferred U.S. EPA air dispersion model. It is a steady-state plume model that incorporates air dispersion based on planetary boundary layer turbulence structure, scaling concepts including treatment of both surface and elevated sources, and both simple and complex terrain.
ISCST – 3	ISCST – 3 is a steady-state Gaussian plume model which can be used to assess pollutant concentrations from a wide variety of sources associated with an industrial complex.

5. AERMOD- AIR DISPERSION MODEL

AERMOD uses a Gaussian and a bi-Gaussian approach in it’s dispersion model (USEPA, 2002). AERMOD is not

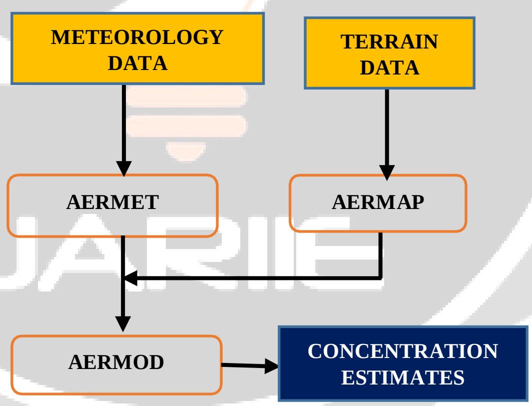

Fig -1: AERMOD software processing flow

a traditional Gaussian model. It uses different algorithms based on the dominant meteorological characteristics of the area over which the predictions are to be made. AERMOD generates daily, monthly as well as annual concentrations of pollutants in ambient air. The model is capable of handling various pollutants in a wide variety of things such as rural and urban as well as flat and complex terrain.

AERMET

1. Wind speed
2. Wind direction
3. Ambient temperature
4. Latitude
5. Longitude
6. Albedo
7. Bowen ratio
8. Roughness length

AERMAP

1. DEM formatted terrain data (xt, yt, zt)
2. Design of receptor grid; AERMAP accepts either polar, Cartesian or discrete receptors

Fig -2: Input parameters for AERMOD

6. EFFECT OF SURFACE PARAMETERS ON GLC PREDICTION IN AERMOD

AERMOD model requires some of the meteorological input data such as Albedo, Bowen Ration & Surface roughness. These values play an important role for differentiation of Convective & Stable Boundary layers. The algorithms of AERMOD software shows that based on the stability classes' model uses different equations for prediction of Ground level concentrations. In turn these values are associated with Land use & Land Cover of a particular location. The following figure shows the relation between albedo as a input value with prediction of ground level concentration [12].

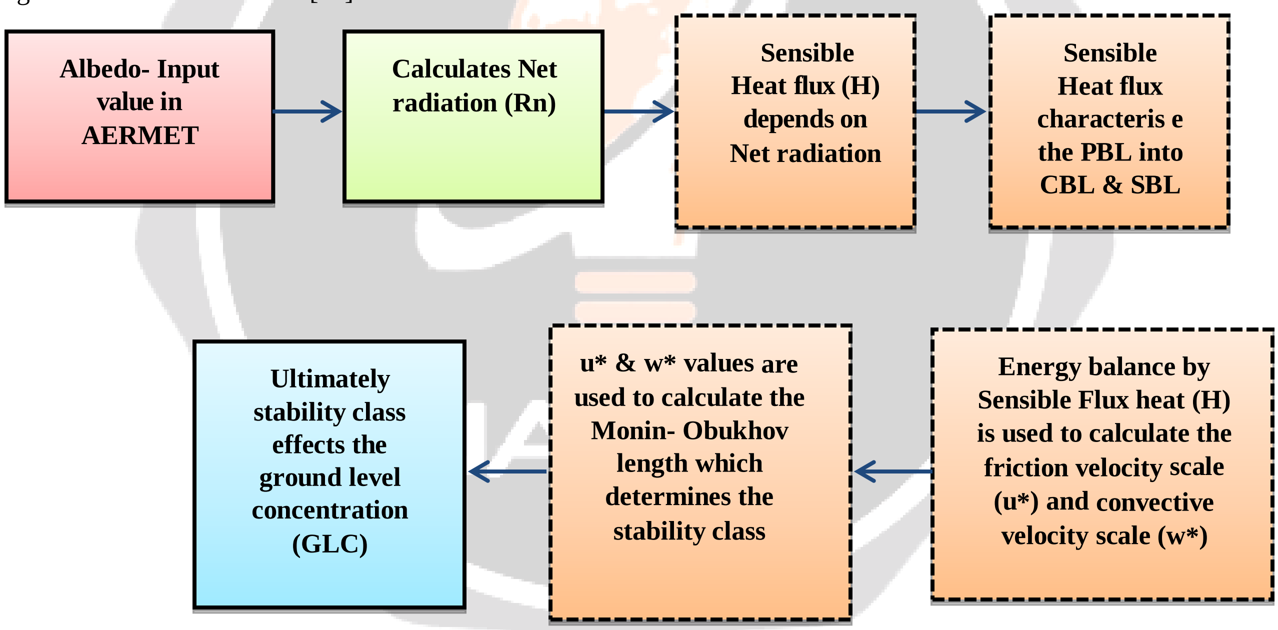

Fig. 3. Relationship between albedo and GLC

7. DISCUSSION

As per the overview of AERMOD model software in India shows that majority of the performance is evaluated for either point or volume types of sources & result shows that model predictions have tendency to under predict. The reasons for the under predictions are lack of availability of specific input data. Moreover, model is sensitive to the input data of surface characteristics such as Albedo, Bowen ratio & surface roughness. In order to test effect on ground level concentrations on albedo, value has been modified with default value of the software & the study showed that as the albedo value increases ground level concentration increases [12]. Using Pyranometer the actual average value of albedo for Gandhinagar city is obtained as 0.15 whereas in AERMOD default value of Albedo is 0.2075 [2]. Using GIS the Albedo was 0.42 for Gandhinagar city [6]. The albedo values for India under different land use category for different seasons are required to be determined [12]. Input surface parameters such as albedo, Bowen ratio & surface roughness are the function of land use & land cover & predictions over a region changes along with change in these parameters alone as well as in combinations [12]. Hence it is concluded that in order to increase the credibility of the model as robust more & more evaluation on AERMOD software must be carried out for Area, Line & Volume sources under diverse climatic conditions & for simple & complex terrain.

8. CONCLUSION

The air quality has been deteriorating at greater pace since 2007 till 2017 in all metro cities of India significantly due to rapid industrialization, urbanization & poor mobility. Looking at the air quality, the predominant pollutant is PM_{10} which is respirable type of pollutant having adverse health impacts. So the need of air quality monitoring & management is the utmost need in today's context. Air quality dispersion models are proved to be one of the tools for air quality monitoring & management. As AERMOD is regulatory model of USA & widely used model all over the world even in India. As to make AERMOD as regulatory model for India model should be validated for all types of sources & pollutants under various scenario. Climatic conditions in USA & India are totally different hence it's application in India may lead to erroneous result. To make it a robust model rigours study is required. Study shows that the AERMOD is sensitive to meteorological data as well as Land use & Land cover (LULC) data. Availability of these data are not readily available in our country. In Indian context for PM_{10} & SO_2 model results have tendency of under predictions. Reasons for under predictions are lack of specific input data which significantly affects the classification of stability conditions. So application of AERMOD for particular location under climatic conditions needs to be performed with Land use & Land cover (LULC) data in terms of Albedo, Bowen ratio & Surface roughness.

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