STUDY OF IMPACT OF SURFACE CHARACTERSTICS ON AMBIENT AIR CONCENTRATION BY USING AERMOD: A REVIEW

Arasi Dobariya[1], Prof.Dr.N.S.Varandani[2], Prof. Huma Syed[3]

[1]*M.E. Student, Department of environmental engineering, L.D College of Engineering, Gujarat*
[2]*Principal Research Scientist, Environment & Energy efficiency research wing, GERMI - Gandhinagar, Gujarat*
[3]*Asso. Prof of Environmental Engineering, L.D. College of Engineering, Gujarat*

ABSTRACT

In India, AERMOD has been added to the list of recommended model for a regulatory application like Environment Impact Assessment and Source apportionment studies by CPCB in 2008. AERMOD is also recommended model in USA and Australia since 2005 for air quality modeling purpose. It is an updated version of ISCST-3 (Industrial Source Complex Short Term-3). AERMOD is one of the popular Gaussian type air dispersion model which is based on Planetary Boundary Layer (PBL) and Similarity relationship theory. AERMOD requires as input surface characteristics like Albedo(amount of incident radiation reflected back to the surface), Bowen ratio (amount of moisture present in the surface) and Surface roughness length (height of obstacles where log mean horizontal velocity is considered practically zero). AERMOD is sensitive to change in surface characteristics. In India, absence of availability of site specific surface parameters, model calculates value of such parameters itself, which may be differ from actual value. Thus model prediction results for ground level concentration (GLC) are not much accurate. To improve model performance it is required to measure actual land use parameters and to evaluate its impact on ground level concentration. This paper shows how surface characteristics affect the ground level concentration(GLC).

Keyword - *AERMOD, Albedo, Bowen ratio, Surface roughness length*

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1. INTRODUCTION

Air pollution modeling is a numerical tool used to describe the causal relationship between emissions, meteorology, atmospheric concentrations, deposition, and other factors. Air pollution measurements give important, quantitative information about ambient concentrations and deposition, but they can only describe air quality at specific locations and times, without giving clear guidance on the identification of the causes of the air quality problem. Air pollution modeling, instead, can give a more complete deterministic description of the air quality problem, including an analysis of factors and causes (emission sources, meteorological processes, and physical and chemical changes), and some guidance on the implementation of mitigation measures. Air pollution models are the only method that quantifies the deterministic relationship between emissions and concentrations /depositions, including the consequences of past and future scenarios and the determination of the effectiveness of abatement strategies. This makes air pollution models indispensable in regulatory, research, and forensic applications. Air dispersion models can be used for regulatory purpose, urban planning, Environment Impact Assessment (EIA), source apportionment studies so on so forth for overall air quality management. Various air dispersion models are used under different scenario and are broadly classified as Gaussian, Statistical and Numerical type of models.

In 1991, the American Meteorological Society (AMS) and the U.S. Environmental Protection Agency (EPA initiated a formal collaboration with the designed goal of introducing current planetary boundary layer (PBL) concepts into regulatory dispersion models. In most air quality applications one is concerned with dispersion in the PBL, the turbulent air layer next to the earth's surface that is controlled by the surface heating and friction and the overlying stratification. The PBL typically ranges from a few hundred meters in depth at night to 1 - 2 km during the day. AERMOD is such an updated version of industrial source complex – 3(ISCST -3) having improved algorithms for plume rise and bouncy, computation of vertical profiles of wind, turbulence and temperature. AERMOD is a steady-state plume dispersion model for assessment of pollutant concentrations from a variety of sources, which is based on planetary boundary layer (PBL) concepts.

2. MODEL DESCRIPTION

AERMOD uses a Gaussian and a bi-Gaussian approach in its dispersion model (US EPA, 2002). AERMOD is not a traditional Gaussian model. AERMOD generates daily, monthly as well as annual concentrations of pollutants in ambient air. The model handles a variety of pollutant sources in a wide variety of settings such as rural and urban as well as flat and complex terrain. AERMOD is differ from ISCST in that it uses current planetary boundary layer (PBL) theory to determine the dispersion parameters σy and σz instead of depending on Pasquill– Gifford–Turner stability curves (US EPA, 2002). AERMOD uses different algorithms based on the dominant meteorological characteristics of the area over which the predictions are to be made. AERMAP is a terrain pre-processor designed to simplify and standardize the input of terrain data for the AERMOD. The major purpose of AERMET is to calculate boundary layer parameters for use by AERMOD. AERMET input interims of hourly wind speed, wind direction, dry bulb temperature along with surface characteristics in the form of Albedo , Surface Roughness and Bowen ration which are associated with land use land cover (LULC).AERMOD models a system with three separate components as shown in **Figure no.1**

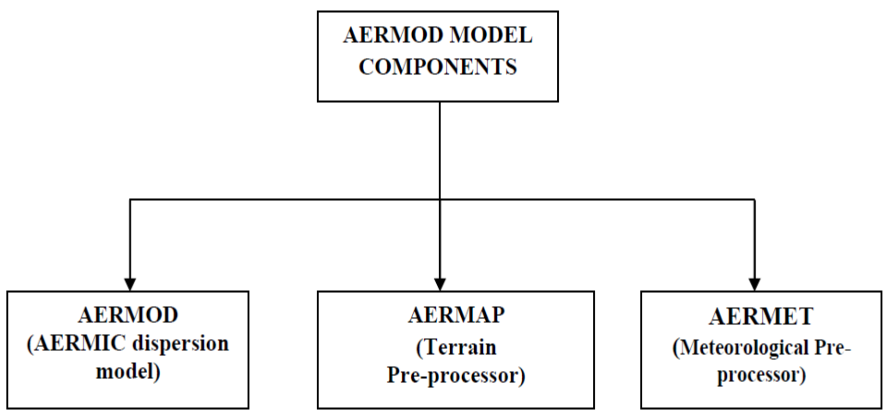

Fig -1: Components of AERMOD model

2.1 ROLE OF SURFACE PARAMETERS IN AERMOD

AERMET pre processor required three site specific land use parameters, albedo, Bowen ratio, and surface roughness length to properly calculate the turbulent dispersion of pollutants. To properly characterize the PBL, one first needs a good estimate of the surface sensible heat flux (*H*) which depends on the net radiation (*Rn*) and surface characteristics such as the available surface moisture (described in the form of the Bowen ratio (*Bo*)).

The energy balance in PBL can be written as follows;

$$H+\lambda E+G= R_n \quad (1)$$

where *H* is the sensible heat flux, λ*E* is the latent heat flux, *G* is the soil heat flux, and *Rn* is the net radiation. To arrive at an estimate of *H* simple parameterizations are made for the soil and latent heat flux terms; that is, G=0.1 *Rn* and λ*E* =*H* /*Bo*, respectively. Substituting these and , respectively. Substituting these expressions into eq. **(1)** the expression for surface heat flux becomes

$$H = \frac{0.9R_n}{\left(1 + {}^{1}/_{B_0}\right)} \quad (2)$$

Monin Obukhov Length (L) which is output from the AERMET pre – processor is calculated by following equation. Monin- Obukhov length is also an objective to measure of stability in the atmosphere. A positive value indicates stable conditions, while a negative value indicates unstable conditions.

$$L = -\frac{\rho C_p T_{ref} u^3{}_*}{kgH} \quad (3)$$

Where,
G = Acceleration of gravity
Cp = Specific heat at constant pressure
P = Density of Air
T_{ref} = Ambient temperature representative of the surface layer
u_* = Friction velocity
H = Sensible Heat Flux
As shown in above equation it can be stated that friction velocity and sensible heat flux are used to derive the Monin – Obukhov length. Friction velocity can be calculated with following expression:

$$u_* = \frac{ku_{ref}}{ln\left({}^{Z_{ref}}/_{Z_0}\right) - \psi_m\left\{{}^{Z_{ref}}/_{L}\right\} + \psi_m\left\{{}^{Z_0}/_{L}\right\}} \quad (4)$$

Where,

Ψm = stability term

Z_0 = Surface roughness length

K= karman constant

L= monin- obakhov length

Uref = Wind speed at reference height

From above model formulation it can be stated that during day time (convective) conditions, surface characteristics (albedo, bowen ratio, surface roughness length) play a significant role in determining the friction velocity & monin-obukhov length. Monin- Obukhov length is also an objective measurement of stability in the atmosphere. A positive value indicates stable conditions, while a negative value indicates unstable conditions. Ultimately, Atmospheric stability condition is affect the ground level concentration

2.2 EFFECT OF SURFACE PARAMETERS ON GLC PREDICTION IN AERMOD

The following line diagram shows how the Albedo, Bowen Ratio and Surface roughness affects the GLC

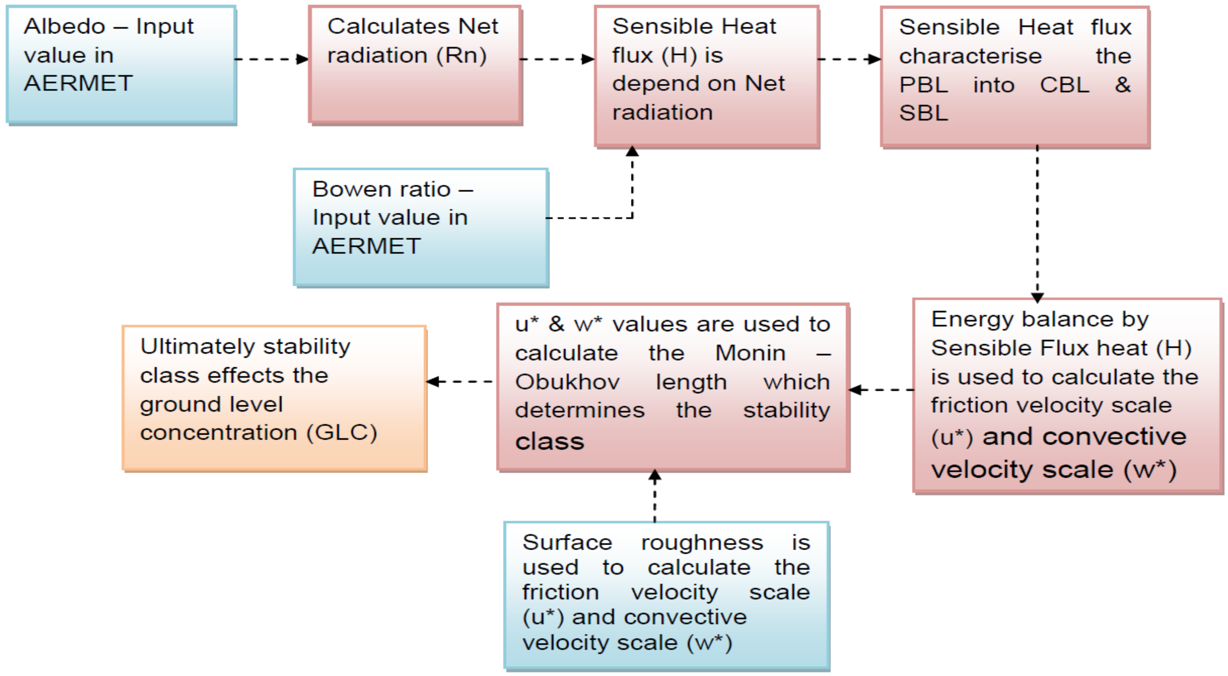

Fig -2: **how the Albedo, Bowen Ratio and Surface roughness affects the GLC**

3. LITERATURE REVIEW

AERMOD was sensitive to changes in albedo, surface roughness, wind speed, temperature, and cloud cover. Bowen ratio did not affect the results from AERMOD. To determine the sensitivity of AERMOD to various inputs and compare the highest downwind concentrations from a ground-level area source (GLAS) predicted by AERMOD to those predicted by ISCST3. Concentrations predicted using ISCST3 were sensitive to changes in wind speed, temperature, solar radiation (as it affects stability class), and mixing heights below 160 m. Surface roughness also affected downwind concentrations predicted by ISCST3. Results demonstrate AERMOD's sensitivity to small changes in wind speed and surface roughness. When AERMOD is used to determine property line concentrations, small changes in these variables may affect the distance within which concentration limits are exceeded by several hundred meters[1]. This modeling analysis showed that for all three typical source types, AERMOD was the most sensitive to surface roughness. Surface roughness lengths for specific land use types can vary from 0.0001 m for water to 1 m for urban areas, a span much larger than the factor of 4 used in this study. Of special concern was the nonlinear response AERMOD displayed as a function of surface roughness change and source type[2]. Results reveal variations in concentration patterns depending on the roughness length, albedo and the Bowen ratio. Changes in the albedo as well as the Bowen ratio only alter the concentration patterns during convective conditions. For a short averaging time, changes in albedo and Bowen ratio have the same effects on the concentration patterns [3].The effects of changes in albedo, Bowen ratio, and surface roughness lengths, in combination and individually, on regulatory design concentrations predicted by AERMOD were studied. Changes in albedo, Bowen ratio, and surface roughness length can result in changes in design concentrations of factors of 1.5, 2.6, and 160, respectively[4]. This study shows that estimated concentrations by AERMOD can vary due to normal variation in albedo, bowen ratio and surface roughness length. Therefore, their selection should be an important part in modeling [5]. Increase in albedo for urban land use category from 0.16 – 0.17 to 0.2075 results into increase in GLC by 0.4 % average for four months. Results shown that as the albedo values increases ground level concentration increases[6]. The results show that for urban area, the most sensitive parameter is surface roughness. There is negligible effect on ground level concentrations with respect to albedo and Bowen ratio for all averaging times[7]. Albedo and Bowen ratio have much lower impact on plume dispersion. Surface roughness speed and distance of plume can travel and mechanically driving mixing height. The result of the analysis conclude that all 3 surface characteristics, Surface roughness has the greatest impact on emission impacts[8].

4. CONCLUSIONS

From research it is concluded that surface characteristics play a significant role in prediction of ground level concentration in AERMOD model. Surface roughness has the greatest impact on prediction other than albedo and surface roughness. Increase in albedo value increase in ground level concentration and increase in surface roughness value decrease in ground level concentration. So, it is required to measure actual land use parameters and to evaluate its impact on ground level concentration.

5. REFERENCES

[1]. Sensitivity of two dispersion models (AERMOD and ISCST – 3) to input parameters for a rural ground level area – source. , journal of air & waste management association, 2008) 58 : 1288 – 1296.
[2]. An analysis of AERMOD sensitivity to input parameters in the san francisco bay area, glen e. long*, james f. cordova, and saffet tanrikulu bay area air quality management district, san francisco.
[3]. Case study of pollutants concentration sensitivity to meteorological fields and land use parameter over douala (Cameroon) using AERMOD dispersion model ", atmosphere (2011)2: 715 – 741.
[4]. Sensitivity of the AERMOD air quality model to the selection of land use parameters, thomas g. grosch, trinity consultants.
[5]. On the sensitivity of AERMOD to surface parameters under various anemological conditions, proceedings of the 11th international conference on harmonisation within atmospheric dispersion modelling for regulatory .
[6]. Vishwa hareshkumar shukla, master of engineering in environmental management "ASSESSMENT OF AERMOD PERFOMANCE FOR POINT SOURCE UNDER INDIAN SCENARIO", Gujarat technological university, May- 2015.
[7]. Kanwar siddharth bhardwaj, master of science in civil engineering "EXAMINATION OF SENSITIVITY OF LAND USE PARAMETERS AND POPULATION ON THE PERFORMANCE OF THE AERMOD MODEL FOR AN URBAN AREA", the university of toledo, December 2005
[8]. Sensitivity analysis study considering the selection of appropriate land use parameters in AERMOD modeling analysis, presented at the 2004 awma annual conference, trinity consultants.
[9]. https://www3.epa.gov/scram001/7thconf/aermod/aermod_mfd.pdf