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(Review Article)

A Review on the Performance of AERMOD Software for different Air Pollutant Sources under Indian Context

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Abstract

Industries are thriving in a developing country like India, and population growth, transportation congestion, and construction activity are all on the rise. As a result, a variety of air pollutants are released into the atmosphere, causing harm to individuals, plants, and property. The amount of air pollutants emitted from various sources that tend to stay in the atmosphere is influenced by the site's meteorological and topographical characteristics. As a result, it's vital to evaluate the ambient air quality, which can also be done using a variety of ambient air quality dispersion models. AERMOD is a state-of-the-art air quality dispersion software that is used all over the world. This review research explores several sources of air pollutants and their contributions to overall ambient air quality as monitored by continuous ambient air quality monitoring stations (CAAQMS). The usefulness of air quality dispersion modelling along with key features of the AERMOD software and even the types of input data needed to run the model, are also addressed. In particular, the AERMOD software's applications and performance for numerous air quality dispersion studies conducted in India have been critically examined. The role of default values as a model input (i.e. Albedo, Bowen, and Surface roughness) on the performance is a significant component explored in this review work & methods for determination is also been included. These default values differ from location to location, thus it's critical to determine out what they are before starting the AERMOD software. Adoption of these approaches can help the AERMOD model work more effectively in the Indian context.

Keywords: Air pollution, AERMOD, Dispersion modeling, Albedo, Surface roughness, Bowen ratio

1. Introduction

The primary causes of negative influence on Earth are air pollution, traffic congestion, environmental deterioration, reduced atmospheric visibility, and public health issues [1]. In developing countries like India, rapid industrialization are the primary causes of air pollution. The significance of air quality in illustrating air pollution, its management, and the initiatives that may be taken to lessen it could be emphasized. During the past decade, India's air quality has decreased dramatically. Air quality has become a serious concern in recent years. Air pollution is the most bothersome when compared to water, land, and noise pollution. It could be triggered by a real phenomenon whether by human activity. Air pollution is a major challenge in developing countries like India because it is known as the "Silent Killer." [2]

Allowable levels of air pollution have breached the norms as a result of successful economic growth targets, resulting in an urbanized skyline defined by smog and dust clouds.

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The current air quality in India is alarming; all parameters, such as SOX, NOX, PM10, and PM2.5, are exceeding the limits suggested by the Ministry of Environment, Forests, and Climate Change in its Notification No. G.S.R. 826(E), dated November 16, 2009, regarding National Ambient Air Quality Standards (NAAQS), and thereby attention must be paid to this issue. [2] Pollution through construction sector has had quite a significant role in diminishing ambient air quality over the last 30 years.

Rapid development has also resulted in the rise of so many other issues that have a detrimental effect on citizens' socioeconomic existence [1]. According to WHO estimates from 2016, 10 cities of India were listed as critically polluted amongst 20 worldwide most polluted cities. India was ranked fifth most polluting country by WHO (2019) based on PM2.5 emission concentrations, with 21 of the top 30 polluted cities in India. The WHO level was exceeded by an alarming 500 percent over the period in Indian cities. Air pollution control and abatement are crucial because it affects the flora and fauna, as well as biotic and abiotic components in the biosphere [2]. Dust and gases from demolition and building activities can degrade air quality, causing health problems and lowering quality of life [3]. As a response, the Central Pollution Control Board (CPCB) has established a continuous ambient air quality monitor to measure the status of ambient air quality in various locations of India.

2. Various Sources of Air Pollution

Air pollution is created not just by human activities, but also by catastrophic events such as forest fires, cyclones, landslides, and anaerobic digestion. This natural disaster releases large quantities of various air pollutants such as sulphur dioxide (SO2), particulate matter (PM), and nitrogen oxides (NOx) into the atmosphere. Stationary and mobile sources of air pollution can also be categorized as sources of air pollution [4]. Stationary sources of air pollution are those whose source of various air pollutants releases does not alter over time. The sources are further divided into point, fugitive, area, and volume sources. Mobile sources of air pollution, on the other hand, are those whose point of emission of air pollutants is constantly changing. Pollution control is largely dependent on the sources of air pollutants; hence it is necessary to identify the sources of air pollution in order to reduce pollution in any given area. The primary determinant of air pollution control technique is where the air pollutant is emitted [5]. For all sources of air pollution, the same air pollution control approach cannot be used. In India, a study called a source apportionment study was conducted to determine the contribution of various types of air pollutants from various types of pollution sources in six major cities. Transportation, industries, agriculture, power plants, waste treatment, biomass burning, residential, construction, and waste demolition are all sources of air pollution. Figure 1 demonstrates pollutant concentrations in six Indian megacities where source apportionment investigations were conducted and reported by the Central Pollution Control Board .[6],[7],[8],[9],[10],[11]. Figure 2 shows that cities like Delhi and Chennai contribute significantly to the total air quality in their respective cities in terms of nitrogen oxides (NOx). PM10 is a major contributing air pollutant in cities such as Bangalore, Pune, Kanpur, and Mumbai. Pollutants' contribution to total air quality is determined by a variety of factors, including the kind of fuel used, the number of cars on the road, traffic management, air pollution control measures implemented, urban planning, infrastructural facility construction projects, and so on.

3. Air Quality Dispersion Modeling

The mathematical simulation of emissions as they disperse is known as dispersion modelling. Air dispersion modelling is a technique for calculating air quality based on emissions and local atmospheric processes that lead to pollutants dispersion and movement. The dispersion in the Planetary Boundary Layer (PBL), the turbulent air layer adjacent to the earth's surface that is regulated by surface heating, friction, and overlying stratification, is the core concern in most air quality applications.

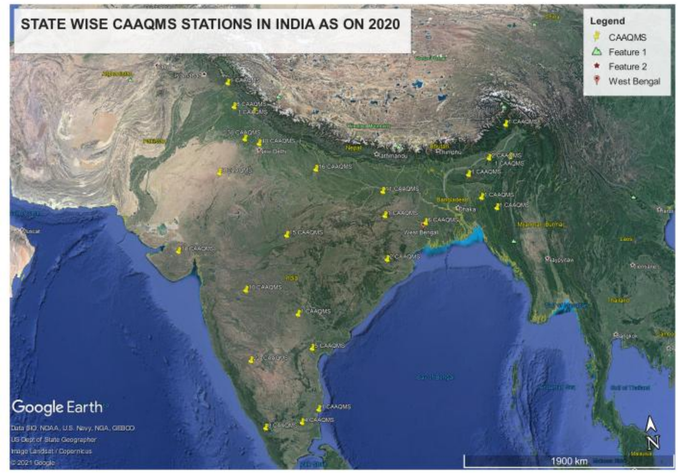

Figure 1. State – wise continuous ambient air quality stations in India

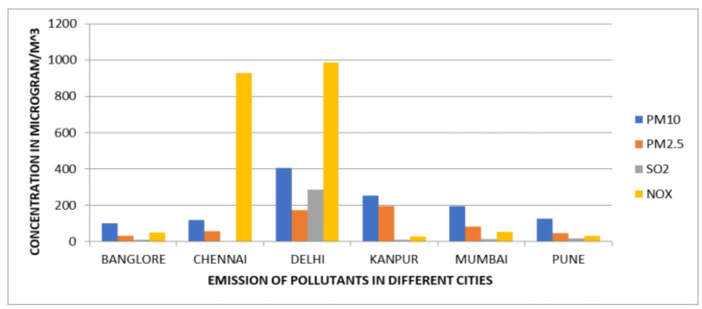

Figure 2. Various pollutant concentrations in µg/m^3 of mega cities of India

The complexity of the dispersion, which is governed by geographical and meteorological factors, is a key factor to consider in air dispersion modelling. Air pollution mitigation approaches have now been used by an integrated aspect of urban design as policymakers become far more aware of the implications. Pollutant concentrations are predicted using regulatory air quality models, which is an essential element of air quality management techniques. However, validation of the regulatory model is required before it can be implemented in a different geographical and climatic zone than the one for which it was designed [12]. As a result, before applying a model, it must be validated for local site settings, as model performance varies depending on source conditions and meteorological factors. Models of air dispersion are mathematical representations of the physics and chemistry that govern the transport, dispersion, and transformation of pollutants in the atmosphere. Models are tools for predicting ground level concentration over time and space from any point, area, volume, or line source. Different air dispersion models are employed in various scenarios and are classed as Gaussian, Statistical, and Numerical models. [13] Air dispersion models have a wide range of uses. Monitoring pollutant concentrations across time and space with the use of equipment and monitors is a challenging and expensive task. Air dispersion model application is preferred to overcome such constraints with field measurement, and many applications are listed in Figure 3.

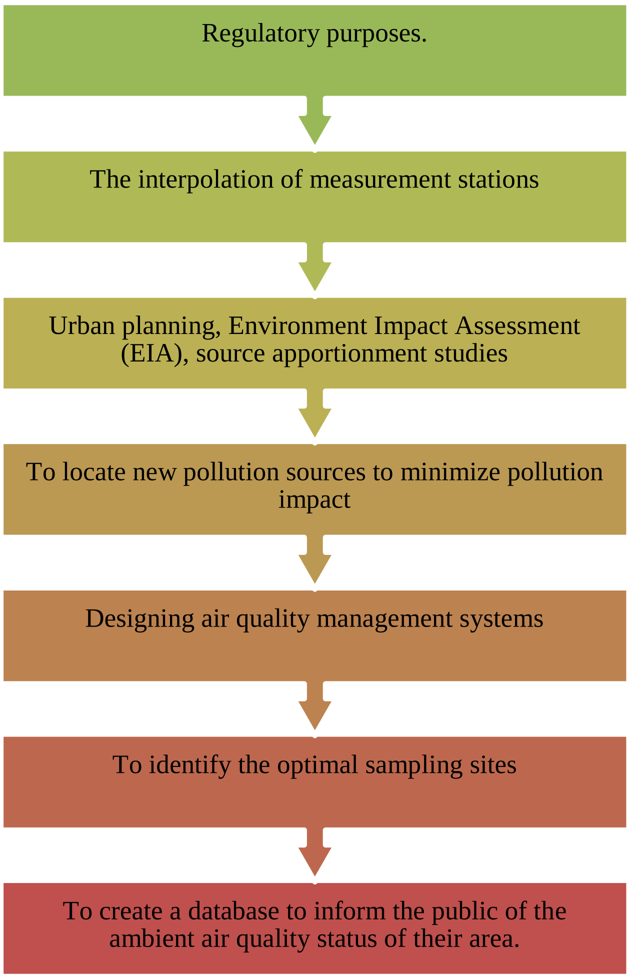

Figure 3. Applications of air dispersion modeling

4. AERMOD – A State of art Model

In its dispersion models, AERMOD software uses a Gaussian and a bi-Gaussian technique. It creates hourly, daily, and monthly centralizations of pollutants in the surrounding air, as well as yearly centralizations. The model can manage a wide range of contamination sources in a wide range of environments. Figure 4 illustrates the advantages of AERMOD software over other air dispersion tools. The ability of AERMOD to define the planetary limit layer (PBL) through both surface and boundary layer scaling is one of the major improvements it delivers. AERMOD (AERMIC Dispersion Model), AERMAP (AERMOD Terrain Pre-processor), and AERMET (AERMOD Meteorological Pre-processor) are the three key components of AERMOD software.

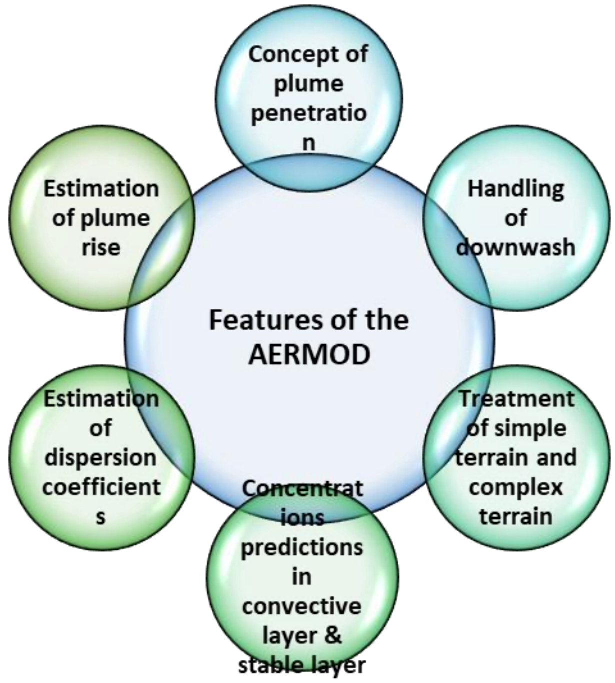

Figure 4. Features of the AERMOD software

4.1 AERMET AND AERMAP – Input data file for AERMOD:
To compute the limit layer boundary required by AERMOD, the module AERMET uses meteorological data and surface attributes. Regardless of whether the information is on-site or off-site, it should be illustrative of the meteorology in the exhibiting space. The outcomes of air quality assessments are influenced by the height of the region. The extent of the effects is determined on the type of environmental setting. In AERMOD, two types of territory are investigated i.e. Simple Terrain & Complex terrain. Simple Terrain: When the landscape heights for the surrounding region are not higher than the highest point of the stack being examined visible all around, simple terrain is used. Complex Terrain: For this situation, the landscape heights for the encompassing region, characterized as any place inside 50 km from the stack, are over the highest point of the stack being assessed.

AERMAP is the AERMOD model's computerised territorial pre-processor. It investigates and plans sophisticated landscape data for AERMOD's use. The computerised territorial information records for AERMAP must be in a local (non SDTS) USGS 1-degree or 7.5-minute DEM design. Various sellers offer advanced height territory information for the United States in a few different ways. The module AERMAP calculates a delegate landscape impact tallness for each receptor area using gridded territory information for the showing region. AERMAP supports two types of data recordings. Very first input run stream record outlines the receptor zones and determines the information and yield document names by coordinating AERMAP's actions through a series of selections. The Digital Elevation Model (DEM) data obtained from the United States Geological Survey is the second type of data required to run AERMAP (USGS). AERMAP verifies the entirety of the sources and receptors determined during arrangement handling to ensure that they exist in the space, and therefore inside the space covered by the DEM documents. If a receptor is spotted outside the space, or if the space goes beyond the space covered by the DEM information, AERMAP sends a deadly blunder message, and further processing of the information is halted. The modelling structure system is shown in Figure 5.

In order to run the model, air modelling software requires certain data as model inputs. Table 1 lists the types of input data required by the AERMOD software for point and area sources.

The determination of an interest pollutant's emission rate is a critical data input for any air dispersion software. In order to estimate the maximum ground level concentration of pollutants with the least amount of variance, emission rate prediction is vital in air quality dispersion modelling. As a result, in order to obtain better and more accurate findings, it is necessary to properly estimate the emission rate under all operating situations. There are three common approaches for estimating the emission rate from point sources. 1. Based on pollutant volumetric concentrations 2. Based on combustible fuel composition 3. Determined by the emission factors of a industry or activity. Out of the three approaches, in any case, the emission factor approach is one of the most extensively used methods. Emission factor is a term that indicates the relationship between the degree of pollutant released into the atmosphere and the activity involved with the discharge of that pollutant. The weight of the pollutant divided by a unit weight, volume, distance, or time of the activity emitting the pollutant is why these factors are commonly stated (e. g., kilogrammes of particulate emitted per metre square of area excavated). These emission parameters make it easier to estimate emissions from diverse sources of air pollution. In most situations, these parameters are simply the average of all available data of reasonable quality, and they are considered to represent long-term averages for all facilities in the source category. [14]

The General expression for emission rate calculation is as follows:

$$E = A \times EF$$

Where, E = emissions (mass of pollutant emitted)
A = activity or activity rate
EF = emission factor

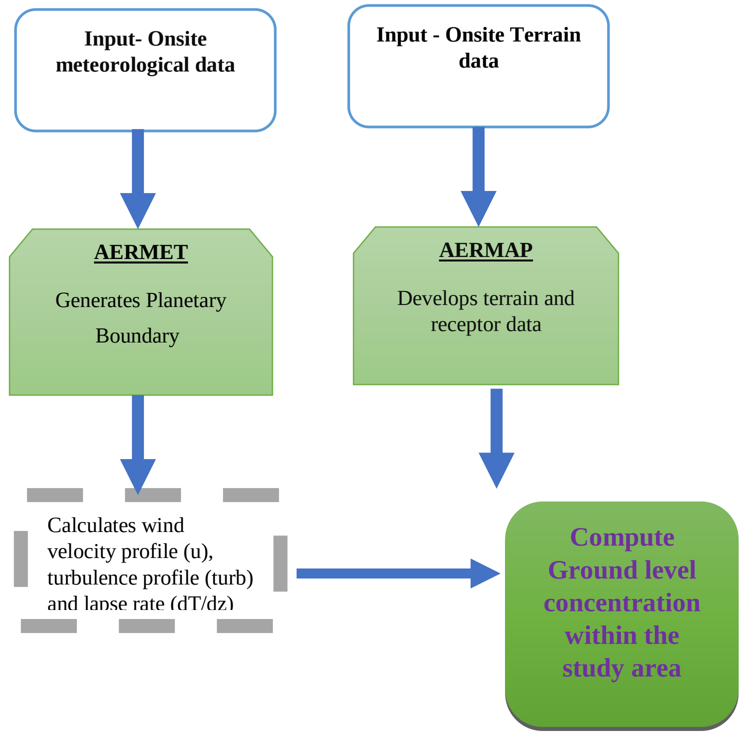

Figure 5. AERMOD Modeling structure system

5. Role of Input Data in AERMOD software

To appropriately calculate the turbulent dispersion of pollutants, the AERMET pre-processor requires three site-specific land use parameters: albedo, Bowen ratio, and surface roughness length. Heat and momentum fluxes drive the growth and structure of the atmospheric boundary layer (ABL).

Table 1. Input data required for Point & Area Source

TYPE OF AIR POLLUTION SOURCES	INPUT DATA REQUIRED		Reference
Elevated Point Source	**Emission data**	**Meteorological data**	**[16],[24]**
	Emission rate of pollutant	Wind speed	
	Stack height	Wind direction	
	Stack inside diameter	Humidity	
	Stack exit gas velocity	Cloud cover	
	Stack temperature	Hourly Precipitation	

	--	Dry bulb temperature	
	--	Solar radiation	
Area Source	Emission rate of Pollutant	Wind speed	**[24]**
	No. of vertices (Vertex Coordinates of the Polygon Area Source)	Wind direction	
	--	Humidity	
	--	Cloud cover	
	--	Hourly Precipitation	
	--	Dry bulb temperature	
	--	Solar radiation	

These surface factors, in turn, have an impact on a local scale. The following equation is used to determine the Monin Obukhov Length (L) that is output from the AERMET pre-processor.

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

Where;
g = Acceleration of gravity
Cp = Specific heat at constant pressure
ρ = Density of Air
Tref = Ambient temperature representative of the surface layer
u* = Friction velocity
H = Sensible Heat Flux
L= monin- obakhov length

Friction velocity and sensible heat flow are applied to compute the Monin – Obukhov length, as illustrated in the preceding equation. The friction velocity can be estimated using the formula below.

$$u_* = \frac{k u_{ref}}{ln\left(\frac{z_{ref}}{z_0}\right) - \psi_m\left\{\frac{z_{ref}}{L}\right\} + \psi_m\left\{\frac{z_0}{L}\right\}}$$

Where,

Ψm = stability term
Z0 = Surface roughness length

K= karman constant
Uref = Wind speed at reference height
The Monin – Obukhov length is measured using friction velocity and sensible heat flow, as shown in the previous equation. The formula below can then be used to calculate the friction velocity.

H+ λE+ G= Rn

Assuming G = 0.1 Rn & λ E = $\frac{H}{Bo}$

Hence,

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

Where,
B_o = Bowen Ration

The insolation and thermal radiation balance at the ground are used to calculate Rn, which is also known as the albedo value. And the stability class is determined by the sign of the sensible heat flux, i.e., if H > 0, the boundary layer is convective; if H 0, the boundary layer is stable. Albedo, Bowen ratio, and surface roughness length each have a significant impact in determining friction velocity and Monin Obukhov length during convective (daytime) conditionsThe albedo is the percentage of incoming solar energy that is reflected back into space. The leftover radiation heats the earth's surface after some of it is utilised to evaporate moisture from the ground and plant leaves. In the daylight, this causes a lot of turbulence and consequently dispersion in the atmosphere. Increased turbulence directly influences air pollutant concentration by increasing dispersion, and indirectly by affecting the profile of wind speed, turbulence, and other parameters with height, causing the mixing height to rise. [15] The importance of site-specific surface parameters as model input is illustrated in Figure 6, which graphically depicts how input default values might affect model output.

Albedo: Albedo is a unitless, non-dimensional quantity. It's the percentage of incident radiation reflected back by the surface. The amount of incoming solar radiation reflected and dispersed back to the atmosphere is determined by elements such as land use characteristics, moisture content of the ground surface, time of year, and geography of the location.

Table 2. Default albedo values for different land use type

Land use types	General values	Spring	Summer	Autumn	Winter
Water Surface	0.03-1.0	0.12	0.10	0.14	0.20
Deciduous Forest	0.15-0.20	0.12	0.12	0.12	0.50
Coniferous Forest	0.05-0.15	0.12	0.12	0.12	0.35

Swamp	--	0.12	0.14	0.16	0.30
Cultivated land	--	0.14	0.20	0.18	0.60
Grassland	0.16-0.26	0.18	0.18	0.20	0.60
Urban	--	0.14	0.16	0.18	0.35
Desert Shrub Land	0.25-0.30	0.30	0.28	0.28	0.4
Fresh Snow	0.75-0.95	--	--	--	--

The AERMOD software requires a site-specific Albedo value, which can be determined with a Pyranometer. It is a sensor-equipped instrument that measures incoming solar (I0) insolation when its face is facing the sun and measures irradiation (IR) from the ground when the sensor faces the ground surface. Albedo is defined as the ratio of IR to I0. NASA also offers a monthly average surface albedo value for place during a 22-year period. Table 3 shows the determination of albedo value for three seasons in India: winter (December, January, February), summer (March, April, May), and post-monsoon (September, October, November). The real default albedo value must be substituted for air dispersion modelling if the project is located in any of the following states in India. [16]. The value of albedo measured by remote sensing for cultivated land is 0.14, whereas the value for the urban area is 0.42. [17]

Bowen Ratio: The ratio of heat energy used for sensible heating to heat energy used for latent heating, which fluctuates depending on the moisture content of the surface and varies by region. When comparing to a moist surface, the proportion for a dry surface is vastly higher. The Bowen ratio for cultivated land, as calculated by remote sensing, is 0.86, while the urban area has a value of 2.712. [17]

Table 3. State Wise Albedo Value

Name of Capital	Seasons		
	Winter	**Summer**	**Post Monsoon**
Andaman & Nicobar	0.16	0.16	0.16
Arunachal Pradesh	0.16	0.21	0.15
Assam	0.12	0.10	0.12
Bihar	0.13	0.14	0.14
Chhattisgarh	0.15	0.17	0.16
Delhi	0.15	0.19	0.17
Goa	0.17	0.19	0.16
Haryana	0.17	0.17	0.16
Meghalaya	0.11	0.11	0.13
Punjab	0.15	0.16	0.12
Rajasthan	0.16	0.18	0.12
Sikkim	0.23	0.26	0.22
Tamilnadu	0.16	0.16	0.16
U.P.	0.16	0.20	0.17
West Bengal	0.15	0.17	0.16
Karnataka	0.13	0.13	0.13
Kerala	0.10	0.12	0.11
M.P.	0.13	0.15	0.14
Maharashtra	0.13	0.13	0.12

Surface Roughness: The vertical height of the atmosphere over which the log mean horizontal velocity is assumed to be zero. This influences the wind pattern, changing the friction and convective velocity scales, as well as the Monin - Obukhov length (L), as a factor of stability. The following condition generates the Monin Obukhov Length (L), which is the yield from the AERMET pre-processor. The Monin-Obukhov length is however a target for determining the proportion of stability in the environment. A positive correlation means stable circumstances, whereas a negative one indicates unstable circumstances.

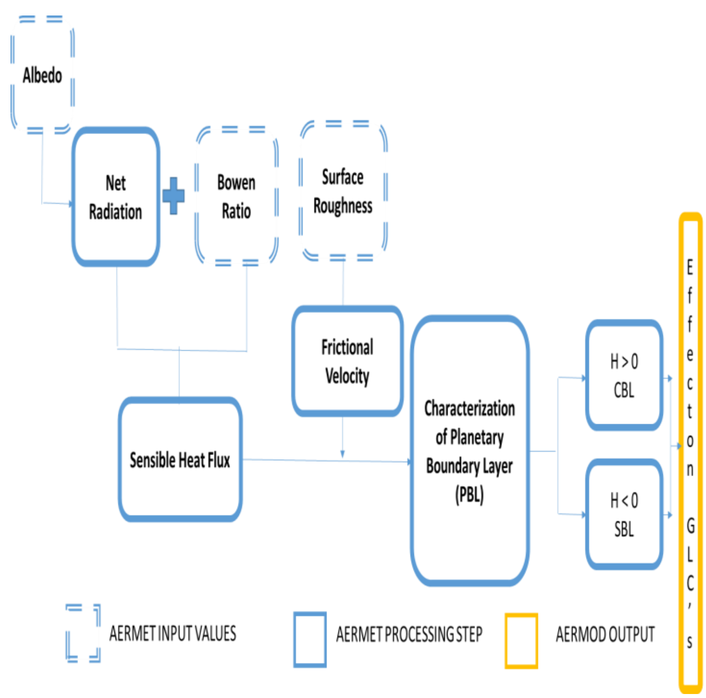

Figure 6. Effect of default values on model prediction

5.1 An approach for determination of default values for study area: An inverse distance weighted geometric mean for a default upwind distance of 1 kilometre relative to the measurement location should be used to calculate the surface roughness length. To accommodate for differences in land cover near the measurement site, surface roughness length can be changed by sector; however, sector widths should not be less than 30 degrees. A basic unweighted geometric mean (i.e., no direction or distance dependency) for a representative domain, with a default domain determined by a 10km by 10km region centred on the measurement site, should be used to calculate the Bowen ratio. The albedo should be calculated using a simple unweighted arithmetic.

6. Comparison of AERMOD Performance with other Models in India

AERMOD is state of art software that is commonly applied in assessments of air quality dispersion. In the United States and Australia, the AERMOD software is a regulatory model. According to the rules set forth by the Central Pollution Control Board, ISCST – 3 and AERMOD software can be used for air dispersion studies in India. The AMS/EPA Regulatory Model (AERMOD) is a promising model for calculating concentrations corresponding to emissions criterion pollutant NO_2, but its efficacy at various time scales has yet to be determined. The model is put to the test at numerous stations in Delhi, including residential and sensitive areas, throughout time scales of one hour, eight hours, and twenty-four hours. The AERMOD's performance has been compared to field catual data, and the various statistical analysis show that it is capable of predicting 24-hour average concentrations rather than 8-hour and 1-hour average concentrations for all source locations. The performance of AERMOD is better for larger time scales in general, as statistical study shows. [1]. For the city of Delhi, the performance of two well-known models termed AERMOD and ADMS – Urban was evaluated. The models were used to anticipate SO2 and NO2 levels from 2000 to 2004. When the results of both models were examined, it was revealed that both have a tendency to overpredict. Both models' statistical comparisons agree within a factor of two with the reported concentration. As input data, both models comprised elevated point sources, automobile traffic, and household fuel burning. Additional case studies for model performance boost model users' and developers' confidence in the models. The AERMOD has a higher susceptibility for overprediction than the ADMS. Because AERMOD relies on high-quality meteorology and surface parameterization data, it has an impact on the model's performance [18]. The state-of-the-art models, including AERMOD, ADMS-Urban, ISCST3, and CALINE4, as well as two codes, GFLSM and DFLSM (based on the Gaussian principle), were employed to predict the air quality of an urban intersection in Delhi, India, and their performance was evaluated. These models are used to forecast the concentrations of carbon monoxide (CO), nitrogen dioxide (NO2), and PM2.5 (particles smaller than 2.5 microns), all of which are key components of vehicle exhaust emissions. Standard statistical markers such as Index of Agreement (d), Factor of 2 (FAC2), Fractional Bias (FB), Normalized Mean Square Error (NMSE), Geometric Mean Bias, and Geometric Mean Variance were used to evaluate the performance of all models/codes. When compared to ISCST3 and AERMOD, ADMS – urban has performed well in predicting NO_2 concentration. The AERMOD, ISCST3, and ADMS-urban have all performed well in terms of PM2.5. When compared to CALINE4, DFLSM, and GFLSM for forecasting CO concentrations, the AERMOD, ADMS-Urban, and ISCST3 perform well. Moreover, AERMOD requires hourly surface and upper air meteorological observations that are consistent and horizontally uniform. However, observations with such a high frequency are hard to come by in most parts of India. [19] To address this constraint, the AERMOD-required planetary boundary layer and surface layer characteristics were calculated using the National Centre for Atmospheric Research's Weather Research and Forecasting (WRF) Model (version 2.1.1). (NCAR). The dispersion of respairable particulate matter (RSPM/PM10) has been simulated over Pune, India. The Pune Air Quality Management Program of the Ministry of Environment and Forests (MoEF), India, and the USEPA used data from an emissions inventory development and field-monitoring programme (13–17 April 2005) to drive and validate AERMOD. WRF is capable of generating trustworthy meteorological inputs for AERMOD, as proven by a comparison of simulated and observed temperature and wind fields. When comparing observed and generated PM10 concentrations, the model consistently underestimates values across the city. [20]. A comparison of two models, ISCST – 3 and AERMOD, for predicting SOx, NOX, and PM10 over Ranchi during the pre-monsoon season of 2010 was carried out. According to the findings, AERMOD outperformed the ISCST – 3[21]. AERMOD can be used to assess various forms of pollution sources. For the months of January and February 2020, AERMOD was used to assess particulate matter (PM10). The results from AERMOD were compared to the results of the High-Volume Air Sampler (HVAS) for field measurement of particulate matter (PM10). The findings of the AERMOD and HVAS analyses are practically identical, and the particulate matter concentration at Kerala GIDC is within the National Ambient Air Quality Standards (NAAQS), which was 100 g/m^3 [22]. The validation of CALPUFF and AERMOD for NOx concentration assessment in the near field region of the steel sector in the Bellary district of Karnataka, India. The relative performances are assessed using statistical analysis to compare monitored and predicted contaminants. The CALPUFF's superior performance than the AERMOD may be attributed to its capacity to predict in calm conditions, where the plume dispersion model fails. [23]. AERMOD has been used to predict different pollutants such as SO2, NO2, PM10, and PM2.5 in various locations of India, indicating that it has a tendency to underestimate reported values. One reason for the underprediction is that AERMOD is sensitive to various surface characteristics factors including Albedo, Bowen ratio, and surface roughness. Even though AERMOD applications for EIA for source apportionment studies have begun in India, these surface factors are not taken into account, resulting in erroneous results for policy level decisions. To make the AERMOD model more robust, it must be rigorously validated for various circumstances. [24] The AERMOD model is a commonly used software for modelling dispersion from mining activities around the world. For the AERMOD's performance evaluation, statistical analysis was used. Due to the abundance of dust sources, an opencast mine was chosen as a research location. The model appears to perform well for daily and monthly averaging time periods in Indian geo-mining circumstances, according to the results. The model does not accurately forecast dust (PM10) dispersion for smaller values, according to the findings. In comparison to the winter months, AERMOD performs better in the summer. [25]. The goal of this study was to use AERMOD to analyse the urban air quality surrounding a heritage site in Amritsar, India. The performance of AERMOD is assessed in terms of predicting nitrogen oxide (NOx), sulphur dioxide (SO2), and particulate matter with a diameter of 10 m. (PM10). The estimated index of agreement (d) values for NOx, SO2, and PM10 are 0.57, 0.51, and 0.50, respectively, showing that AERMOD performed satisfactorily. [23]

7. Effect of Input Surface Parameters on Model Performance

Surface properties such as Albedo, Bowen ratio (amount of moisture present in the surface), and Surface roughness length are required as inputs for AERMOD (height of obstacles where log mean horizontal velocity is considered practically zero). Changes in surface features have an impact on AERMOD. Because site-specific surface parameters are not available in India, the model derives their value, which may differ from the real value. As a result, ground level concentration (GLC) model predictions aren't very accurate. To improve model performance, it is required to measure actual land use parameters and to evaluate its impact on ground level concentration. Land use of the surface greatly associated with the albedo, bowen ratio & surface roughness. Changes in albedo, surface roughness, wind speed, temperature, and cloud cover significantaly affects AERMOD performance. The Bowen ratio had no effect on the AERMOD results. To test AERMOD's sensitivity to various inputs and compare AERMOD's anticipated greatest downwind concentrations from a ground-level area source (GLAS) to those predicted by ISCST3. The results show how sensitive AERMOD is to slight changes in wind speed and surface roughness. Small changes in these factors can impact the distance within which concentration limits are exceeded by several hundred metres when AERMOD is used to predict line concentrations [26]. AERMOD was the most sensitive to surface roughness for all three usual source types, according to this modelling investigation. Surface roughness lengths for specific land use types can vary from 0.0001 m for water to 1 m for urban areas, [27]. Only during convective conditions do changes in the albedo and the Bowen ratio change the concentration patterns. Changes in albedo and Bowen ratio have the same effects on concentration patterns for a short average time [28]. The impacts of changes in albedo, Bowen ratio, and surface roughness lengths on regulatory design concentrations predicted by AERMOD were investigated in combination and separately. Changes in albedo, Bowen ratio, and surface roughness length can result in 1.5, 2.6, and 160 percent changes in design concentrations, respectively [29]. The calculated concentrations by AERMOD can vary resulting from natural variations in albedo, Bowen ratio, and surface roughness length, including one of the studies. As a result, their selection should play a significant role in modelling [30]. Increases in albedo for urban land use categories from 0.16 – 0.17 to 0.2075 result in a 0.4 percent rise in GLC over four months on average. The results reveal that as the albedo value goes up, so does the ground level concentration [16]. The results suggest that surface roughness is the most sensitive attribute in urban areas. For all average times, albedo and Bowen ratio have little effect on ground level concentrations [31]. The Bowen ratio and albedo have a significantly smaller impact on plume diffusion. Surface roughness, speed, and distance that a plume can travel, as well as mechanically driving mixing height are all factors to consider. The investigation found that among the three surface parameters, surface roughness has the highest impact on emissions [32].

8. Conclusion

Based on the literature reviewed in these papers for AERMOD air quality software, it can be concluded that AERMOD is one the state of art & mostly widely adopted software not only in USA, Australia but in India also. With the help of AERMOD software any type of air pollution sources can be modelled for any period of time. Planetary boundary layer & similarity characterization features enhance its utility for air quality assessment, policy decision making and source apportionment studies. The software requires authentic & reliable data source for better performance proximate with the field measurements. AERMOD performance is evaluated for point, area, line & volume sources for major pollutants i.e. PM 10, PM 2.5, SOx, NOx of various parts of the Indian location or cities where different terrain conditions were present. AERMOD has a tendency to over predict for NOx while underpredict for SOx, PM10, PM 2.5 from various types of the sources. It can be concluded that the, AERMOD model is sensitive to the Albedo, Bowen & surface roughness parameters required as surface data as the model input. These parameters are associated with the Land use & land cover of that study location. In India model users run the AERMOD with default albedo, Bowen ratio & surface roughness in the absence of site-specific surface input parameter. This could be the reasons associated with the AERMOD software average performance in India for various pollutants. The albedo, Bowen ratio & surface roughness parameter are associated with meteorological conditions & site-specific conditions. AERMOD model is developed for western country considering their meteorological conditions & surface conditions. Hence it is clear that surface default values are developed under different condition than the India. So, while using AERMOD model for any air dispersion study it is very important to determine site specific albedo, Bowen & surface roughness values & then should run the model. The utilization of Pyranometer or remote sensing techniques would help to determine site specific albedo, Bowen ratio & surface roughness. Adoption of these practices can enhance the AERMOD model credibility in future time.

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References

1. Dhirendra Mishra and P. Goyal. Performance of AERMOD over Delhi Urban Area, different time scales, International journal of earth and atmospheric science, April-June 2015, Vol 2, Issue 2, Pages 49-57
2. Goral Parikh, S. M. Usman. A Review paper on performance of AERMOD for various Parameters, Journal of Emerging Technologies and Innovative Research, May 2020, Volume 7, Issue 5
3. R Gopi, R Saravanakumar, K S Elango, A Chandrasekar, K S Navaneethan and N Gopal., Construction Emission Management using Wind Rose Plot and AERMOD Application, IOP Conf. Series: Materials Science and Engineering, 1145 (2021) 012106 doi:10.1088/1757-899X/1145/1/012106
4. B.R. Shah and Snehal Popli, Environmental studies, Mahajan Publication, Tenth Edition, 2017
5. N.S. Varandani, Basics of Environmental studies, Books India, Publication, 2nd Edition, 2010
6. NEERI Nagpur. Air quality Assessment, Emission inventory & source apportionment: November 2010
7. Mukesh Sharma; PhD, Air Quality Assessment, Emissions Inventory and Source Apportionment Studies for Kanpur City, Indian Institute of Technology Kanpur, November 2010
8. TERI, 2010. Air quality assessment, emission inventory & source apportionment study for Bangalore city: Final report, New Delhi: Energy & resource institute. 186 pp.
9. IIT Madaras. Chemical Engineering department. Air quality monitoring, emission inventory & source apportionment study for Chennai city: Project Summary Report
10. NEERI Nagpur. Air quality monitoring, emission inventory & source apportionment study for Delhi
11. The Automotive Research Association of India, Pune, Air Quality Monitoring and Emission Source Apportionment Study for Pune, 2009-10
12. Kalpana D. Saini. Performance of AERMOD software in Indian scenario, International Journal of Advance Research and Innovative Ideas in Education, Vol-6 Issue-4 2020
13. Cimorelli, A. J., Perry, G. S., Venkatram, A., Weil, J. C., Paine R. J., Wilson R. B., Lee, R. F., Peters, W. D., and Brode R. W., 2004. AERMOD: A Dispersion Model for Industrial Source Applications. Part 1: General model formulation and boundary layer characterization, Journal of Applied meteorology Vol. 44, pp. 682-693
14. Payal Patel, M.E dissertation. Air dispersion modeling with special reference to thermal power plant. Gujarat University, 2011
15. Thomas G. Grosch and and Russell F. Lee. Sensitivity of the AERMOD air quality model to the selection of land use parameters. Transactions on Ecology and the Environment vol 29
16. Vishwa Hareshkumar Shukla, Huma Syed, N.S. Varandani, "Assessment of AERMOD performance for point source under Indian Scenario", Gujarat Technological University, May 2015
17. Dharmin Gada & Huma Syed. Determination of Bowen ratio & its effect on AERMOD model Predictions. Gujarat Technological University, April 2017
18. Manju mohan, Shweta Bhati, Pallavi Marrapu. Perfromance Evaluation of AERMOD and ADMS – Urban models in a tropical urban environment. Indian journal of air pollution control, Volume IX , No.1 , March 2009 , pp 47-62
19. M Khare, S Nagendra & S. Gulia. Performance evaluation of air quality dispersion models at urban intersection of an Indian city: a case study of Delhi city , WIT Transactions on Ecology and The Environment, Vol 157
20. Amit P. Kesarkar, Mohit Dalvi , Akshara Kaginalkar ,Ajay Ohja . Coupling of the Weather Research and Forecasting Model with AERMOD for pollutant dispersion modeling. A case study for PM10 dispersion over Pune, India, Atmospheric Environment 41 (2007) 1976–1988
21. Rahul Boadh, Satyanarayana A N V and Rama Krishna T V B P S . Evaluation and Comparison Of Air Pollution Dispersion Models AERMOD During Pre-Monsoon, Jr. of Industrial Pollution Control 37(4)(2021) pp 674-685
22. Goral Parikh, S. M. Usman. Cumulative Particulate Matter Assessment of Kerala GIDC using AERMOD, Journal of Emerging Technologies and Innovative Research Volume 7, Issue 6
23. S Gulia. Performance evaluation of CALPUFF and AERMOD dispersion models for air quality assessment of an industrial complex, Journal of scientific research & industrial research, Vol. 74, May 2015, pp. 302-305
24. Kalpana D. Saini and Minarva J Pandya. Assessment of particulate matter emission using AERMOD software: A case study of Ahmedabad Metro rail

project, Gujarat Technological University, April 2017

25. Tarun Verma, B. K. Shrivastva, Sanjay K. Sharma. Performance evaluation of AERMOD for Indian Geomining conditions, Research Journal of Mining Volume 1 (2017) Issue 2 Pages 88-99
26. William B. Faulkner , Bryan W. Shaw & Tom Grosch. 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.
27. Glen E. Long* , James F. Cordova, and Saffet Tanrikulu. An analysis of AERMOD sensitivity to input parameters in the san francisco bay area, Bay Area Air Quality Management District, San Francisco, CA
28. Pascal Moudi Igri , Derbetini Appolinaire Vondou and Franc¸ois Mkankam Kamga. 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.
29. Thomas G. Grosch & Russell F. Lee. Sensitivity of the AERMOD air quality model to the selection of land use parameters, Thomas g. Grosch, trinity consultants.
30. George Karvounis, Despina Deligiorgi and Kostaa Philippopoulos 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.
31. 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
32. Elizabeth Carper, Eri Ottersburg. Sensitivity analysis study considering the selection of appropriate land use parameters in AERMOD modeling analysis, presented at the 2004 AWMA annual conference, trinity consultants.

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