AIR DISPERSION MODELS FOR DIFFERENT APPLICATIONS - SPECIAL REFERENCE TO THERMAL POWER PLANT

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ABSTRACT:
The air pollution has assumed greater and alarming proportion in urban , industrial & pockets where cluster of air polluting industries are in existence .Various air pollutants , namely , Carbon Monoxide (co), sulphur dioxide (SO2), oxides of nitrogen (Nox),suspended particulate matter, Respirable suspended particulate matter(PM10, PM2.5, PM1.0), Hydrogen Sulphide(H2s), Methane, Hydrocarbons(HC), Benzene, Aldehydes, 1-3 Butadiene, PAH, Mercaptans, Carbon disulphide(CS2) , Fluorine based gases and so on so forth are emitted out from these sources.

These pollutants are caused on account of vehicular emissions, industrial, Mining, Commercial and Household fuel burning. These pollutants when released in the atmosphere are subjected to transportation, dispersion, transformation, fall out and wash out and finally reach the ground level at a particular distance. Emissions from stacks are subjected to plume rise which again is dependent on force of buoyancy and momentum. The higher is the plume rise or stack, the lesser will be Ground level Concentration.

The relationship between the source of emissions and its magnitude with the ground level concentrations at different receptor points is governed by air dispersion models which takes into account the source strength , plume rise, Atmospheric Stability, mixing height, wind velocity, terrain and other meteorological conditions.

Various air dispersion models have been developed world over for different applications under different scenarios. Applications of such models have been made mandatory within the framework of environmental impact assessment (EIA) notification, 1994, as amended from time to time. It has therefore assumed greater importance for the academicians, consultants and regulatory authorities. An attempt has been made in the present paper to discuss majority of such models with a view to select a particular model that can be used for a particular area or application.

AIR DISPERSION MODEL:-

Air dispersion models are system tools to predict ground level concentrations over a period of time and space from any point, multiple point, line and area sources. It requires input data in the form of source strength for each pollutant from a given source along with meteorological parameters, topography, terrain features, stack details and so on so forth.

A dispersion model is a set of mathematical equations that simulates the release and dispersion of air pollutants in the atmosphere. Atmospheric dispersion model is also a mathematical simulation of the physics and chemistry governing the transport, dispersion and transformation of pollutants in the atmosphere .It also determine as to how air pollutant dispersed in to atmosphere. It is performed with computer programs, called dispersion model, that solve the mathematical equations and algorithms which simulate the pollutant dispersion.

APPLICATIONS OF AIR DISPERSION MODELS:

The application of air dispersion models are quite wide in as much as that it is effectively used for urban planning, industrial estate planning, industrial zoning, sitting of industrial project and overall special planning from environmental point of view. It can also be used to forecast the critical air pollution levels in certain areas and during certain periods. It also helps in managing the air pollution control strategies.

Models can also be used to predict future pollutant concentrations from multiple sources after the implementation of a new regulatory program, in order to estimate the effectiveness of the program in reducing harmful exposures to humans and the environment.

Modeling can be used to analyze actual or potential accidents that release contaminants to the atmosphere. Use for determining appropriate stack heights, For managing existing emissions ,Purpose of designing ambient air monitoring networks ,identifying the main contributors to existing air pollution problems, estimating the influence of geophysical factors on dispersion, assessing the risks of and planning for the management of rare events such as accidental hazardous substance releases. Other applications are as under.

- assessing compliance of emissions with air quality guidelines, criteria and standards
- planning new facilities
- determining appropriate stack heights
- managing existing emissions
- designing ambient air monitoring networks
- identifying the main contributors to existing air pollution problems
- evaluating policy and mitigation strategies (e.g. the effect of emission standards)

- forecasting pollution episodes
- assessing the risks of and planning for the management of rare events such as accidental hazardous substance releases
- estimating the influence of geophysical factors on dispersion (e.g. terrain elevation, presence of water bodies and land use)
- running 'numerical laboratories' for scientific research involving experiments that would otherwise be too costly in the real world (e.g. tracking accidental hazardous substance releases,)
- saving cost and time over monitoring − modelling costs are a fraction of monitoring costs and a simulation of annual or multi-year periods may only take a few weeks to assess.

TYPES OF AIR DISPERSION MODELS:-

Various air dispersion models have been or are being used under different scenarios. Broadly these models can be classified under following categories.

1. Gaussian models
2. Statistical models
3. Numerical models

Gaussian models are used for predicting the dispersion of continuous, buoyant air pollution plumes originating from ground-level or elevated sources. Models may also be used for predicting the dispersion of non-continuous air pollution plumes (called *puff models*).

A statistical model is a formalization of relationships between variables in the form of mathematical equations. A statistical model describes how one or more random variables are related to one or more random variables. In mathematical terms, a statistical model is frequently thought of as a pair (Y,P) where Y is the set of possible observations and P the set of possible probability distributions on Y.

A Numerical model expressed in mathematical formulas and solved approximately on a computer. Numerical models are mathematical models that use some sort of numerical time-stepping procedure to obtain the models behavior over time. The mathematical solution is represented by a generated table and/or graph.

Usually in practice, Gaussian models are being use widely all over the world. However there are different types of Gaussian models which are being used presently in different parts of the world under different conditions.

COMMON FEATURES OF GAUSSIAN-PLUME MODELS:-

- Characteristics of steady-state Gaussian models that make them convenient tools include the fact that they:

- do not require significant computer resources − they can be run on almost any desktop PC and can usually process a complete year of meteorological data in a matter of minutes
- are easy to use – they come with user-friendly graphical user interfaces (GUIs) and a relatively small number of input variables are required
- are widely used – well developed knowledge due to many users and results can easily be compared between different studies
- have simple meteorological data requirements – an input data set can be developed from standard meteorological recordings.
- have conservative results for short (<100 m) or low-level sources − overseas validation shows these models are more likely to over- rather than under-predict ground-level concentrations, which offers some degree of safety in the regulatory environment when assessing discharges from short or low-level sources.

AIR DISPERSION MODELS CURRENTLY IN USE:-

There are several air dispersion models currently in use and are based on Gaussian approach. These models have different applications. The details of such models are given here under with a view to select them for a particular field application.

1. **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.

2. **ISC3 (ISC): ISC3** 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. This model can account for the following: settling and dry deposition of particles; downwash; point, area, line, and volume sources; plume rise as a function of downwind distance; separation of point sources; and limited terrain adjustment.

3. **SCIPUFF: SCIPUFF** is a time-dependent Gaussian puff model developed by Titan's ARAP Group that employs second-order closure turbulence modeling techniques to relate the dispersion rate to velocity fluctuation statistics. BREEZE developers created a Graphical User Interface (GUI) that include a GIS, user-friendly data entry forms, parameter range checks, 3D visualization, reporting, and more.

4. **CAL3QHCR: CAL3QHCR** is a more refined version based on CAL3QHC that requires local meteorological data.

5. **SLAB**: A model for denser-than-air gaseous plume releases that utilizes the one-dimensional equations of momentum, conservation of mass and energy, and the equation of state. SLAB handles point source ground-level releases, elevated jet releases, releases from volume sources and releases from the evaporation of volatile liquid spill pools.

6. **OBODM**: A model for evaluating the air quality impacts of the open burning and detonation (OB/OD) of obsolete munitions and solid propellants. It uses dispersion and deposition algorithms taken from existing models for instantaneous and quasi-continuous sources to predict the transport and dispersion of pollutants released by the open burning and detonation operations.

7. **FARM (Italy):** The **Flexible Air quality Regional Model (FARM)** is an atmospheric dispersion model designed for the analysis of episodes and scenarios, evaluation of the effects of regional emission control policies and pollution forecasts in complex situations. It accommodates point and area sources, and includes photochemistry and plume depletion by wet and dry deposition.
The Simulation of Air pollution From Emissions II (SAFE AIR II) was developed at the Department of Physics, University of Genoa, Italy to simulate the dispersion of air pollutants above complex terrain at local and regional scales. It can handle point, line, area and volume sources and continuous plumes as well as puffs. It includes first-order chemical reactions and plume depletion by wet and dry deposition, but it does not include any photochemistry.

8. **STACKS (The Netherlands)**: A Gaussian plume dispersion model for point and area buoyant plumes to be used over flat terrain on a local scale. It includes building effects, NO_2 chemistry and plume depletion by deposition. It is used for environmental impact studies and evaluation of emission reduction strategies.

9. **CAR-International: CAR-International** (The Netherlands) - Calculation of Air pollution from Road traffic (CAR-International) is an atmospheric dispersion model developed by the Netherlands Organisation for Applied Scientific Research. It is used for simulating the dispersion of vehicular emissions from roadway traffic.

10. **LOTOS-EUROS : LOTOS-EUROS** (The Netherlands) - The LOng Term Ozone Simulation - EURopean Operational Smog (LOTOS-EUROS) model was developed by the Netherlands National Institute for Public Health and the Environment (RIVM) in The Netherlands. It is designed for modeling the dispersion of pollutants (such as: photo-oxidants, aerosols, heavy metals) over all of Europe. It includes simple reaction chemistry as well as wet and dry deposition.

11. **EK100W (Poland) :** A Gaussian plume model used for air quality impact assessments of pollutants from industrial point sources as well as for urban air quality studies on a local scale. It includes wet and dry deposition. The effects of complex terrain are not included.

12. **POLGRAPH (Portugal) :**This model was developed at the University of Aveiro, Portugal by Professor Carlos Borrego. It was designed for evaluating the impact of industrial pollutant releases and for air quality assessments. It is a Gaussian plume dispersion model for continuous, elevated point sources to be used on a local scale over flat or gently rolling terrain.

13. **INPUFF-U (Romania) :**This model was developed by the National Institute of Meteorology and Hydrology in Bucharest, Romania. It is a Gaussian puff model for calculating the dispersion of radionuclides from passive emission plumes on a local to urban scale. It can simulate accidental or continuous releases from stationary or mobile point sources. It includes wet and dry deposition. Building effects, buoyancy effects, chemical reactions and effects of complex terrain are not included.

14. **MODIM (Slovak Republic) :** A model for calculating the dispersion of continuous, neutral or buoyant plumes on a local to regional scale. It integrates a Gaussian plume model for single or multiple point and area sources with a numerical model for line sources, street networks and street canyons. It is intended for regulatory and planning purposes.

AIR DISPERSION MODELS USED IN POWER PLANTS:-

- Air dispersion models used in thermal power plants are primarily Gaussian approach models which takes in to account tall stacks with huge volume of gases. Some of the models those have been used in various parts of the world for thermal power plant are given here under.

- Gaussian approach model, namely, **ISC4VIEW**.............has been applied for a power plant located at 16 km west from the city of Targu Jiu at an altitude of 250 m at the thermal power plant of rovinari..Of gorj country..

- This power plant is coal based with a capacity of 330mw for 4 units . having a stack height of 250..mts.of having dia 8 .The predicted results have been shown within the acceptable guidelines formed by Romanian legislations.

- The **ISCST3 & AERMOD** dispersion models were applied for a power plant caylrhan which is located at the central Anatolia, 120 km north west of Ankara & 3 km from caylrhan town (Turkey) thermal power plant. To estimate a ground level concentrations of SO2 , NOx & PM10.

- The ground level concentrations predicted by two models were compared with the results of ambient air pollution measurements for November 2004. Predictions of both **ISCST3** and **AERMOD** were underestimating the ground level SO2 concentrations. However, **AERMOD** predictions are better than **ISCST3** predictions. The results of both models had good correlation with the results of NOx measurements. It has been shown that the contribution of the power plant to SO2, NOx and PM10 pollution in the area studied is minimal.

- Model **ADMS 4** has been applied for 3 power plants located at Pakistan by Mahboob Ali & Makshoof Athar having 3 different stack height in the range of 22-40 m with different dia varying from o.8 - 1.0 m.

- Results of the dispersion modeling indicate that, using selected sets of meteorological parameters, **ADMS** predicted the peak concentrations within the plume relatively well. On the other hand, considering that atmospheric conditions vary diurnally, assuming an average set of meteorological parameters over simplifies the required meteorology for accurate plume and concentration predictions. The sensitivity analysis was conducted using peak concentrations. The resulting data demonstrated that the model was most influenced by variations in wind speed, mixing height, and atmospheric stability. Further analysis considered combinations of minimum, mean, and maximum wind speed and mixing height.

- For all cases, using minimum wind speed and maximum mixing height resulted in acceptable model performance. However, a consistent improvement was not observed in all combinations. Increasing the mixing height allows more volume for pollutant dilution, thus resulting in lower concentrations. In contrast, decreasing the wind speed resulted in higher concentrations. It appears that the present paper has been written under the guidance of Proffesor (Dr. combination of these extreme values presents an average meteorological scenario and therefore results in acceptable predictions.

- Gaussian model has been applied for power plant located at ahmedabad. Medha S.Naik presented paper at Indian institute of tropical meteorology, pune 411008, india on 30 november 1991.

- Gaussian air dispersion model was attempted by MEDHA S. NAIK, Indian institute of tropical meteorology, pune, india in the year 1993 for a thermal power plant at Ahmedabad.

- This power plant is coal based with a capacity of 381 mw. Having stack height in the range of 30-90 m. They have different dia varying from 1.46- 1.9 m.

- To estimate probable air quality, the meteorological data for 3 consecutive days in the middle of each month of 1983 is used. The concentration of sulphur dioxide is computed at a distance of every 500 m in 16 directions up to the city limit.

- **IIT points source model (IITPS)** by Dr.P.Goyal & Siddhartha , centre for atmospheric sciences, Indian institute of technology , Delhi , india in the year 1998-1999 for Badarpur thermal power station Delhi.

- The following conclusions were drawn by the author by using IITPS model.

- The hourly concentrations of SPM, computed from **IITPS** model are low in night hours and considerably higher in day hours.

- The 24-hourly averaged concentrations of SPM in winter season, though has worse meteorological scenario, does not exceed the National Ambient Air Quality Standards i.e. 500 |ig m~3.

- The seasonal evaluation of BTPS indicates that SPM levels are maximum in winter and decreased progressively towards pre-monsoon, post-monsoon and monsoon. The most affected areas outside BTPS are Okhla and Tajpur, which are located downwind of BTPS for predominant wind direction.

- Monitored SPM concentrations, at three of the six monitoring stations exceed the National Ambient Air Quality Standards of particulate matter, a result which may be due to the combined impact of concentration contributions made by BTPS and the other sources e.g. industries and vehicular traffic, present in the near vicinity of the BTPS. The present results may be used in future to assess the additional impact of new sources.

CONCLUSION

The Gaussian model can be classified as widely used model for majority of the application including thermal power plants for predicting the ground level concentrations Of air pollutants over a period of time and space.

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