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Review Paper

Air pollution Modeling for Human Exposure Predictions: A Review

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Abstract

The aim of this study is to provide a comprehensive review with regards to recent developments, major research, computational methods and air quality models applications. The development of models for air pollution assessment has been identified as an important area for future research. Air pollution due to massive use of motor vehicles in urban areas of India is one of the most serious and fast growing problem to solve. These motor vehicles emit significant quantities of CO2, CO, hydrocarbons, oxides of nitrogen, SPM and other toxic substances in the atmosphere which adversely affect the environmental and the health. The objective of this study is to understand the chemistry of air pollution with its precise estimation through modeling. The behavior and relation between emission and deposition of pollutants can explain with the help of air quality models. Modeling is a set of different scientific methods that are helpful to analyze nature and behavior of pollutants in the atmosphere. On the basis of source of pollutants air quality models are classified as point, area or line source models. Various Gaussian based line source models are commonly used in India to assess the impact of vehicular pollution along the roads or highways. Sources of air pollution, chemistry of pollutants and computational methods for dispersion modeling are discussed and reviewed with respect to various literature and corresponding methods. The paper includes comparative study of various air quality models and study of complex phenomenon of air pollution. Recent modified air quality models and their future scope are also discussed in the paper which help for scientists who work in the same field.

Keywords: Air pollution, air quality models, pollutants, computational methods.

Introduction

The problem of air pollution because of continuous development and increase of population in the urban areas has become so remarkable that there is a urgency for timely information about changes in the pollution level. The transport and diffusion of pollutants in the atmosphere depend on nature as well as meteorological and emission conditions of pollutants. Respiratory difficulties, heart disease, loss of agricultural products and damage to aquatic and terrestrial ecosystems are main adverse effects of air pollution. Photochemical reactions taking place within the atmosphere are responsible for emission of many of pollutants that cause serious health hazards to human. Main traffic related pollutants like CO reduces oxygen carrying capacity of blood, benzene pollutants cause cancer and SO2 and particulates can cause respiratory diseases (UNEP, 2009). Air quality dispersion models act as a valuable tool to predict the quality of air against the National Ambient Air Quality Standards and are useful in the air pollution management. Modeling of air pollution is based on various models like Gaussian modes, box models, narrow plume models and complex computational fluid dynamic models. Gaussian models are based on a set of empirical equations that is mainly applied to coal burning electricity producing plants and to exhaust from automobiles in the cities[1,2].

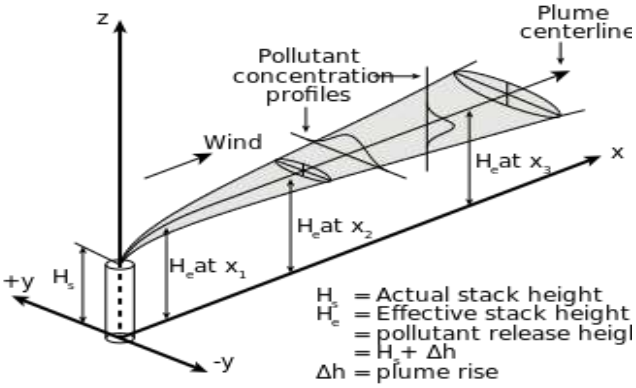

Figure-1
Visualization of a buoyant Gaussian air pollutant dispersion plume

The standard algorithm used in the Gaussian plume model (O.G. Sutton, 1932) is as follows:

$$C(x,y,z)=\frac{Q}{2*\pi*u*\sigma y*\sigma z}*\exp\frac{-y^2}{2*\sigma y^2})*(\exp(\frac{-(z-h)^2}{2*\sigma z^2})+\exp(\frac{-(z+h)^2}{2*\sigma z^2}))$$

Where, i. C(x,y,z,)is the concentration of the emission (in microgram per cubic meter) at any point x meters downwind of the source, y meters laterally from the centre line of the plume and z meter above ground level. ii. Q is the quantity or mass of

the emission in grams per unit of time (second). iii. u is the wind speed (in meters per second). iv. H is the height of the source above ground level(in meters). v. σ_y and σ_z are the standard deviations of a statistically normal plume in the lateral and vertical dimensions respectively.

Gaussian plume models have following features: They, i. do not require significant computer resources, they can be run on any desktop PC. ii. are easy to use and comparatively small number of input variables are required. iii. are widely used, easy to study the results which can easily be compared with others. iv. can give significant results for short level sources.

Some common types of models are:
Dispersion models[3]: which use equations to represent the path that pollutants travel in the air in order to calculate the downwind air concentrations

Receptor models[4]: which use properties of air pollutants to identify and quantify the sources of air pollutants,

Meteorological models[5]: which use equations that represent the behavior of atmosphere in order to predict the meteorological conditions at specific area.

Physical models: small used in wind tunnels to simulate actual conditions and

Statistical models: where statistics are used to relate emissions and the resulting concentrations.

Results and Discussion

The modern science of air pollution modeling introduced in the year 1920 when the dispersion of toxic chemicals released in the battlefield under different conditions was trying to estimate by military scientists in England[6]. Fossil fuel power generation is continuously expanding in India with the growth of population and industrialization. Combustion of fossil fuels thus produces air pollutants considerably. To address this issue, Ministry of Environment and Forests (MEF), Government of India decided to put forward dispersion models to evaluate the adverse effect of power plant operations on the ambient air quality in terms of concentration level of different pollutants. A dispersion model is a computational method for predicting concentrations downwind of a pollutant source on the basis of knowledge of the emissions properties, surface structure, wind speed, stability, local topography. AIRVIRO, a regional scale dispersion model, developed by the Swedish scientists was used to analyze the impact of emission of oxides of nitrogen from automobiles to the air quality in Singapore[7]. Jiang et al[8] described an approach to analyze air quality assessment of a power plant in Hongkong Shenzhen area. Borrego et al[9] studied dispersion modeling for the assessment of air pollution in Lisbon city. The Transport Emission Model for line sources (TREM) and the Local Scale Dispersion Model (VADIS) were described by them[10,11]. The Central Pollution Control Board (CPCB) of India put forward general guidelines for EIA studies that are listed in EIA Notification 2006[12,13] to obtain environmental clearance.

The major elements of an AQM are depicted schematically in the following figure:

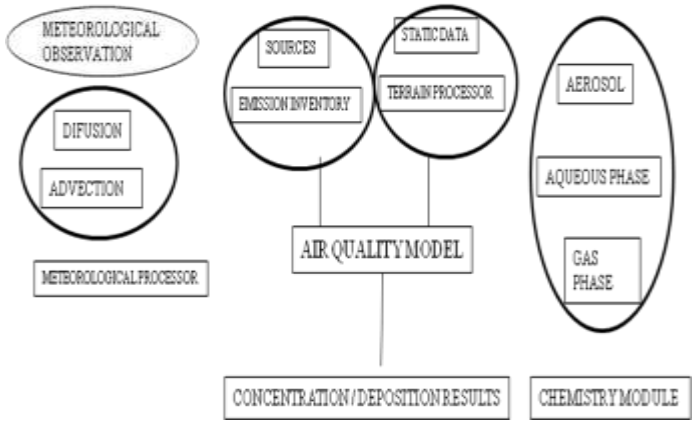

Figure-2
Major elements of air quality model

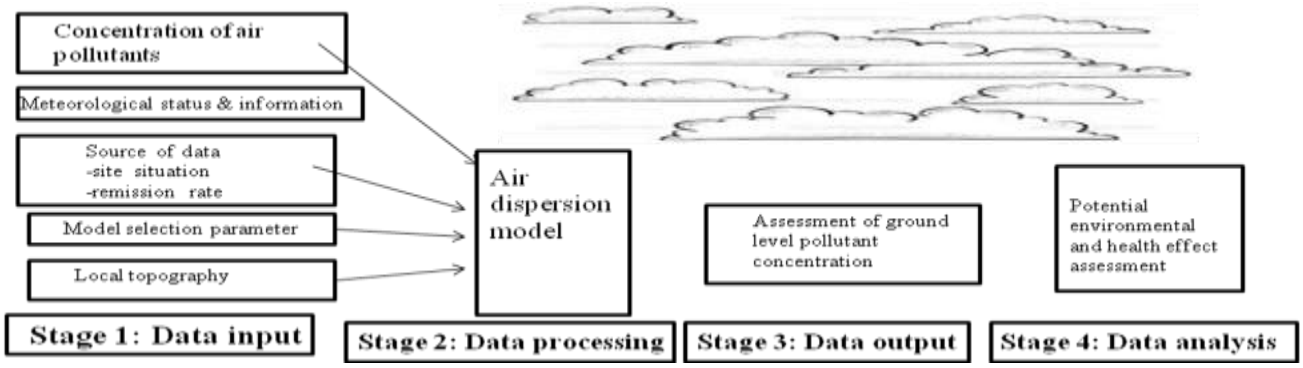

Figure-3
Shows the four stages of modeling[14]

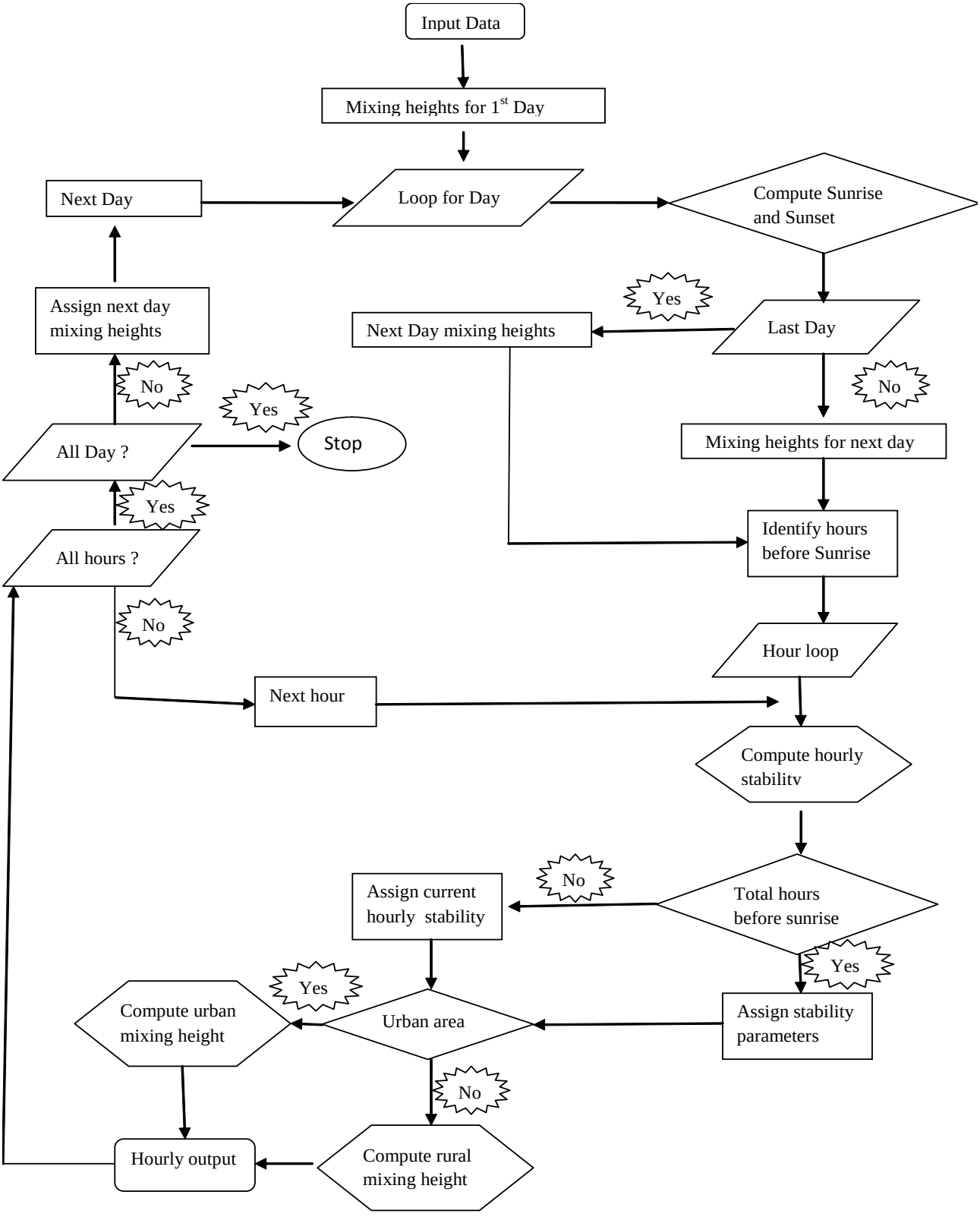

Figure-4
Flow chart showing air pollution processing module[15]

An air dispersion model has five main stages: input data collection, processing of dispersion model, output data, interpretation of dispersion modeling results and preparation of the assessment report.

Stages of modeling and processing of basic environmental data and details of it are shown in figure 3 and 4 as flow charts.

The pollution control regulation can be represented by a predictive model to gain ambient standards. Therefore an air quality management system is to prepare for monitoring the ambient air quality. There are two general types of dispersion models, Gaussian plume models such as AUSPLUME, ISCST3, AERMOD and CTDMPLUS and advanced models such as CALPUFF and TAPM. A numbers of air pollution modeling software are available such as AUSPLUME, it is very easy to apply and quick to run, AERMOD, it is used to define variation of turbulence with height and dispersion coefficients as a continuum, CTDMPLUS, it is developed for tall point sources in complex terrain areas, CALPUFF, (a puff model) is used in regulating long range transport of pollutants[16] and TAPM, which is developed to stimulate three dimensional meteorology and pollution dispersion[17]. There are still many open points to the improvement of the meteorological models and of the emission inventory. It is keeping in mind that the models of intermediate algorithms are of great interest.

Conclusion

Gaussian models, narrow plume models, box models, trajectory models and gradient transport models are the basic models of air pollution modeling. A three dimensional axis system is set up within the crosswind, downwind and vertical direction. By Gaussian distribution, pollutant concentrations crosswind and vertically are analyzed. Uniform mixing throughout the volume of a three dimensional box is described by box models. Pollutant concentrations upwind are described by narrow plume hypothesis based models[18-21].

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