An Introductory Note On Atmospheric Dispersion Models

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Abstract: The air quality models are immensely helpful for assessment and prediction of air quality. The dispersion models require meteorological data and source strength to determine the pollutant concentration in atmosphere. Depending on the type of dispersion model, the data requirement and applicability varies widely.

Introduction

Degradation of air quality is a major environmental concern in developed and developing countries due to increased population and thereby increasing industrialized activities in urban area. Industries, irrespective of their type, demand electricity in a huge quantity to run their operations. Many of the renewable options for power generation, such as hydro power have a feasibility problem in India. As there are several factors such as long gestation period and relatively permanent setting contribute in disadvantages of hydroelectric power plants. Therefore, there is a inclination towards the use coal-based thermal power plant for electricity generation [1].

The air pollutants released in the environment from coal-based thermal power plants have deleterious effects on human health and ecosystem. The damaged caused by the emissions from thermal power plants is often underestimated or overlooked in order to gain economic benefits and better lifestyle [2]. However, as the demand of electricity in society in ever-increasing, the harmful consequences of the emission of air pollutants in the atmosphere can no longer be denied [3]. In last few decades, research on the effects of specific size classes of particulate matters (PM) has gained focus significantly [4]. Another major pollutant emitted from coal-based thermal power plant is Sulfur dioxide (SO_2).

The effect of SO_2 is diverse. It is one of the main precursors of acid rain. Besides, it can cause inflammation and damage of lungs. The activities such as combustion of fossil fuels and other sulfer related industrial processes are the most significant source of SO_2 in industries [5]. Apart from degradation of human health, Oxides of sulfur (SO_x) and oxides of nitrogen(NO_x) also affect plants adversely.

Environmental degradation caused by the stack emissions is in maximum when the pollutants are not dispersed and get condensed due to the stable nature of the atmosphere. Under normal conditions, the concentration of the pollutants decrease with increasing distance of the receptor points from the sources due to the advection and diffusion of the pollutants. Changes in emission rate results in changes in ambient concentration of air pollutants. These changes may vary spatially and temporally depending on the meteorological conditions and composition of local atmosphere [6]. Mathematical simulation of pollutant dispersion enables the estimation of the

pollutant concentration at a certain point of area of concern. Numerous studies have been conducted using Gaussian based air quality models to assess the air quality in different cities around the world. In spite of their ease of use and reproducibility, air quality models exhibit certain degrees of uncertainty. *Ramakrishna et al., (2004)* has shown that the Gaussian plume model predictions largely differ from the realistic value obtained from field data [7].

Emission factor

In order to quantify the total emission from a source, a relationship between the activity rate and emission is in practice for a long time (Eq. 1). The relationship is considered to be linear and a source-specific factor, namely emission factor (EF) is involved in it [8].

$$E = A \times EF \times (1 - ER/100) \quad \text{..... (Eq. 1)}$$

Where,

E = amount of the pollutant released into the atmosphere

A = the rate of a specific activity which causes the emission

EF = emission factor

ER = percentage of reduction in emission due to the air pollution control systems

Transportation of the pollutants

The movement of air pollutants from the source to the receptors is known as pollutant transport. Generally, the transport of the pollutants occurs due to the time-average flow of the wind. On the other hand, the dispersion is a result of the atmospheric turbulence in smaller scale. Besides, the pollutant concentration in atmosphere also depends on the atmospheric chemistry.The chemical reactions in troposphere play a very important role in transport and transformation of the pollutants. Besides, the deposition of the particulate pollutants due to the gravitational pull and precipitation is also an important factor in determining the pollutant concentration in the atmosphere[9].

Model development

Air quality models are organized sequence of mathematical and numerical techniques to simulate the fate of air pollutants in the atmosphere. In orderto identify and quantify the movement and transformation of primary pollutants (that are emitted directly into the atmosphere from its sources),air quality models use the meteorological data and varioussource related information as input. This source information includes emission rates, stack height, flue gas temperature etc.

In some cases the models can quantify the generation and transport of secondary pollutants (that are formed due to the chemical reactions of primary pollutants in the atmosphere) as well. *Jiménez-Guerrero et al. (2008)* assessed air quality in North-Western Mediterranean by combining the Weather Research & Forecasting model, Congestion Mitigation and Air Quality model and Dust Regional Atmospheric Model (WRF-EMICAT-CMAQ-DREAM) to examine the concentration of photochemical air pollutantswith and special focus onozone, nitrogen, nitrogen dioxide, carbon monoxide and particulate matters [10].

Although Gaussian dispersion equation based models may be used as initial screening model, there are many shortcoming in using this kind of simplistic models. Although the simplified model such as Gaussian air quality model is easy to execute and cost-effective, it may tends to exhibit significant deviation from the real observations when used for long range [11].

Lutman et al., (2004) conducted a study to compare the forecasted data from a Gaussian based air quality model with a Lagrangian based dispersion model to calculate the annual average of PM concentration. The researchers used a popular Gaussian based dispersion model, PLUME. The model was developed by UK National Radiological Protection Board (NRPB) [12]. When applied in long range the Lagrangian based model was proved to produce more realistic results than the Gaussian dispersion model. The reason behind the better performance of Lagrangian based model is its ability to use the meteorological data of higher temporal resolution.The main limitation of PLUME model was the under-estimation of the effects of wet deposition for 100 km or longer distance.

Conclusion

In order to formulate the solutions of air pollution related problems, proper quantification of ambient concentration of the pollutants is of utmost importance. Air quality models used for the prediction of pollutant levels in the atmosphere. The dispersion of the pollutants depends on the meteorological condition, source characteristics and atmospheric chemistry. The ability of consider different factor in the models varies widely depending on the underlying base theory. Therefore, the selection of the model is very much objective and should be considered carefully.

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