CHAPTER 1

INTRODUCTION

1.1 AN OVERVIEW

Air pollution may be defined as any atmospheric condition in which substances are present at concentrations higher than their normal ambient levels to produce a measurable effect on men, animals, vegetation or materials. Air pollution caused by effluents from a single or small group of stacks is a local problem. The concentrations effluents generally occur at distances ranging from immediate vicinity of the stack to those on the order of several kilometers.

The concentration of air pollutants depend not only on the quantities that are emitted from air pollution sources but also on the ability of the atmosphere to either absorb or disperse these emissions. The air pollution concentrations vary spatially and temporally causing the air pollution pattern to change with different locations and time due to changes in meteorological and topographical condition (CPCB 2003a).

1.2 NEED FOR THE STUDY

Prediction of likely impact on the air environment due to discharge from point source is a pre requisite for environment impact assessment studies and evaluation of project for granting permission or rejection (CPCB 1998). Modelling of stack gas dispersion is also essential for selecting the ambient
air sampling locations, implementing strategies for air pollution control, stipulating the discharge limits, fixing stack heights and environmental planning of zone/region.

In major metropolitan cities of India, air pollution has become a serious problem as a result of industrialization and urbanization. Dispersion of pollutants in the atmosphere and their concentrations at different distances from the emission source depend on emission source parameters, meteorological parameters and geographical conditions of the region of interest. Air pollution caused by effluents from a single or small group of stacks is a local problem. The combined effect of a large number of stack effluents spread over a large area produces increased concentration of pollutants at a greater distance from the source of emissions. In order to ensure that the industrial activity is not causing any serious environmental degradation, the assessment of the impact of emission on the environment both in urban and rural areas, either during daytime or nighttime is imperative.

1.3 AIR AND ITS IMPORTANCE

A clean environment is the basic need for the existence of life. The life support system on this planet consists of air, water, land, flora and fauna. Normally these are mutually interconnected and interdependent. Man’s capacity to become master of his surroundings and his quest to enhance the quality of life has caused immense harm to human beings and environment. In his eagerness to urbanize and industrialize, man has not only destroyed the plant cover built up meticulously by nature over million of years, but also polluted air, water, and land. As a result the development has become synonymous with deforestation and desertification and progress with pollution.
Of course, pollution is not a new phenomenon. It is as old as civilization itself. It was conceived the day Adam dawned on the planet of earth. The first episode of air pollution probably occurred when early humans, tried to make a fire in a poorly ventilated cave.

Over the past 100 years, air pollution assumed menacing proportions due to rapid increase in population and industrialization. The consequence is that air pollution affected the health and well being of people, caused wide spread damage to vegetation, crops, wildlife, materials, buildings and climate, and resulted in depletion of the scarce natural resources needed for long term economic development. Therefore, there is an urgent need to manage air quality to maintain an acceptable balance between the positive effects of activities, which however cause pollution, and the negative effects of poor quality.

1.4 ATMOSPHERIC DISPERSION MODELS

1.4.1 Evolutionary development

During the beginning of 20th century, the earlier air quality models were postulated to describe pollutant dispersion in the atmosphere and based on the theories of the German physiologist, Adolph Fick. Sutton (1932) proposed a model, which was widely used for the prediction of atmospheric dispersion. In the 1950’s, the state urban air pollution caused by automobiles in Los Angeles drew considerable attention. After the passing of Clean Air Act in 1963 in USA and its further amendments in 1970, there was considerable impetus to the effects on air quality modelling.
1.4.2 Various generic models

Generally air pollution can be classified into four generic classes as follows:

1. Closed form analytical model
2. Numerical model
   (a) Eulerian grid model
   (b) Lagrangian (trajectory model)
   (c) Hybrid Lagrangian - Eulerian model
   (d) Random walk model
   (e) Box model
3. Statistical model
4. Physical model

The first two groups represent deterministic modelling and the other two groups represent statistical modelling. Both analytical and numerical models calculate the concentration of pollutant from an emission inventory and other independent, mostly meteorological variables according to the solution of various equations which represent the relevant physical processes. In most cases, they use solution of diffusion equation derived from the mass conservation principle, Fickian theorem, and first – order closure (k theory) approximation.

In contrast to deterministic model, the statistical model calculates concentration by statistical methods from meteorological and other parameters after the statistical relationship has been obtained empirically from measured concentrations. The physical model is one in which nature of atmospheric dispersion is simulated on a smaller scale in the laboratory (e.g.) in a wind tunnel. Deterministic models, where quantitative results are
obtained and it is based on a cause – effect relationship between the emission of pollutants and Ambient Air Quality Standards (AAQS) concentration. Further, it is a suitable prediction tool for long term planning decisions. The statistical models are very useful for short term forecast of concentrations and the physical models are of use if specific purposes are being considered e.g. influences of topography on the mean airflow.

1.4.3 Closed form analytical model

The diffusion equation may be solved only by means of numerical methods. However, under a set of simplified assumptions, the analytical closed form solution of the equation can be obtained. The first formulation for the steady state concentration down wind form a continuous point source was presented by Sutton (1932) and further developed by Pasquill (1961) and Gifford (1975), and the solution commonly known as Gaussian plume model. The concentrations distribution perpendicular to the plume axis is assumed Gaussian. The plume travels with a uniform wind velocity down wind from the source.

1.4.4 Numerical models

Numerical models are time dependant, so all variables can be functions of time and the concentration is calculated depending on time. Such models are capable of handling a variety of problems, including unsteady state conditions and steady state conditions. The numerical methods can be used to solve a variety of problems; ranging from micro level prediction up to the long range transport (LRT) of air pollutants, and also they are adaptable to photo reactive pollutants.
In spite of its advantages, numerical models have common limitation such as,

1) It is valid only if the size of the plume or puff of pollutants is greater than the size of the dominant turbulent eddies.

2) It is not valid for the convective boundary layer under strong instability.

1.4.5 Eulerian grid model

This model considers the emission, transport, diffusion, transformation and deposition of pollutants at multiple levels within a fixed coordinate system. The region of interest is subdivided into two or three dimensional array of grid cells and the polluted air is simulated as it passes from cell to cell. The diffusion equation is solved numerically, to yield the desired time independent concentration distribution.

The advantages and disadvantages of this model are listed below:

Advantages

1) All the various items in diffusion equation can be accommodated.

2) Sophisticated three dimensional treatment of air pollution problem is possible.

3) The non-linear chemistry (example: formation of photochemical smog) can be included.
Disadvantages

1) Huge computational time and storage.
2) Requirements of large amount of input data.

1.4.6 Lagrangian trajectory model

This model considers a parcel or column of air that ingests pollutant emissions as it passes over the various sources. The horizontal extent of the moving column has been assumed as small as one m$^2$ or as large as km$^2$, the size of urban complex of emissions. The concentrations calculated by this model normally depend on vertical dimensions which may be specified as the distance from the ground level to an inversion base, or some other related to the vertical mixing. When the mixing depth changes, the cell volume increases and the concentration decreases. In other words, the concentration is taken to be independent of inversion height and to depend only on emissions.

The advantages and disadvantages of this model are listed below:

Advantages

1) It is applicable for urban, regional, and long distance
2) Computational cost is relatively low.

Disadvantages

1) It is unable to account wind shear.
2) Difficult to incorporate non-linear chemistry.
3) Horizontal and vertical diffusion neglected.
1.4.7 Hybrid Eulerian – Lagrangian model

This model uses the most desirable features of both Eulerian and Lagrangian approaches. In this method, the mass of pollutants is separated into discrete particles follow a Lagrangian trajectory under the influence of the prevailing wind and a velocity representing turbulent diffusion. Each particle is treated on an Eulerian grid, and the concentrations are computed by counting the total number of parcels in a given cell. The model has been developed to simulate the time dependant distributions of air pollutants under such conditions as,

1) Space and time varying wind fields (wind shear).
2) Calm conditions.
3) Space and time variable diffusion parameters.

However, this model has the following disadvantages

1) Large numbers of particles are required to yield accurate averaging statistics for estimating the concentrations.
2) This method requires long execution time, which limits practical applications.

1.4.8 Random walk particle trajectory model

In this model, the dispersion is described in terms of pollutants, each representing a specified mass of pollutant. Particles are released in numbers proportional to the strength of a given source, and they move under the influence of the mean wind and the atmospheric turbulence. Random movements of the particles simulate the effect of turbulence.
The advantages and disadvantages of this model are listed below:

**Advantages**

1) This model can be applied to any scale of dispersion simulation and provides great generality and flexibility for handling complex and time varying emissions.

2) Diffusion calculations are related directly to basic turbulent characteristics.

3) It is most suitable for sea breeze or complex terrain.

**Disadvantages**

1) Large number of particles must be generated to yield significant averaging statistics for estimating the concentration.

2) Requirement of large volume of input data and Computational cost.

**1.4.9 Box Type Models**

The region of interest is divided into grid of boxes. The dimensions of each box may be related to topography or to the space resolution of the data available and emissions from chimneys and ground level, sources into each box are assumed to be instantaneously mixed. The major advantage of the model is that this model can be used for urban diffusion modelling with reliable results. Box Models lack spatial resolution but in situations in which the wind fields are complex, they may describe the concentration field at a level of detail that is appropriate for the uncertainties involved.