CHAPTER-II
LITERATURE SURVEY
2.1: Preamble

A model is a simplified picture of reality. It doesn't contain all the features of the real system but contains the features of interest for the management issue of scientific problem we wish to solve by its use. Models are widely used in science to make predictions and/or to solve problems, and are often used to identify the best solutions for the management of specific environmental problems.

Models may be:

- physical - a scaled-down representation of reality
- Mathematical - a description of the system using mathematical relationships and equations.

Dispersion modeling specially for dispersion of dust in the opencast mines is relatively a new concept in India. Website of Premier Universities related with mining studies like Indian Institute of Technology, [http://www.iitkgp.ac.in-10/12/2007], Indian School of Mines, Dhanbad [www.ismdhanbad.ac.in], Institute of Technology, BHU [www.itbhu.ac.in-12/4/2008] etc. were searched for taking stalk of the studies undertaken at these Universities of similar nature.

Use of Dispersion Model for Thermal Power Plants and other industries having point source like chimneys are common but for opencast coal mining activities, having fugitive dust generation sources, use of dispersion model was found to be limited to determination and validation of emission rates only. At Centre of Mining Environment (CME), Indian School of Mines and at Central Institute of
Mining & Fuel Research [http://cmriindia.nic.in/r&d.html-13/4/2008] few studies were taken up regarding dust dispersion modeling and they have been presented in subsequent paragraphs.

As regards use of dispersion models in countries other than India, most authentic and comprehensive work have been taken up by US, EPA and they have developed various mathematical models to represent the real situation. The details of these models available on the US, EPA website are also presented.

In order to understand details of the modeling the mechanism of dust (particulate matter) formation, its dispersion, its deposition and its re-entrainment needs a brief discussion and these concepts have been dealt in the first instance.

2.2. Particulate Matter Formation Mechanism

The range of particle sizes formed in a process is largely dependent on the types of particle formation mechanisms present. The general size range of particles can be estimated by simply recognizing which particle formation mechanisms are most important in the process being evaluated. The most important particle formation mechanisms in air pollution sources include the following:

- Physical attrition/mechanical dispersion
- Combustion particle burnout
- Homogeneous and heterogeneous nucleation
- Droplet evaporation
Several particle formation mechanisms can be present in an air pollution source. As a result, the particles created can have a wide range of sizes and chemical compositions.

**Physical attrition** occurs when two surfaces rub together. For example, the grinding of a metal rod on a grinding wheel yields small particles that break off from both surfaces. The compositions and densities of these particles are identical to the parent materials.

The tertiary stone crusher is an example of an industrial source of particulate matter that involves only physical attrition. The dust particles formed range from less than 10 µm to almost 1000 µm. However, due to the limited energy used in the crushing operation, very little of the particulate matter is less than 10 µm. Physical attrition generates primarily moderate-to-large sized particles.

In order to burn the fuel, it must be **pulverized** or **atomized** so that there is sufficient surface area exposed to oxygen and high temperature. The surface area of particles increases substantially as more and more of the material is reduced in size. Accordingly, most industrial scale combustion processes use one or more types of physical attrition in order to prepare or introduce their fuel into the furnace. For example, coal-fired boilers use **pulverizers** to reduce the chunks of coal to sizes that can be burned quickly. Oil-fired boilers use atomizers to disperse the oil as fine droplets. In both cases, the fuel particle size range is reduced to primarily the 10- to 1000-micrometer range by physical attrition.
Particle Burnout

When fuel particles are injected into the hot furnace area of the combustion process, such as fossil-fuel-fired boilers, most of the organic compounds in the fuel are vaporized and oxidized in the gas stream. Fuel particles become smaller as the volatile matter leaves and they are quickly reduced to only the incombustible matter (ash) and the slow burning char composed of organic compounds. Eventually, most of the char will also burn leaving primarily the incombustible material.

As combustion progresses, the fuel particles, which started as 10- to 1000-μm particles, are reduced to ash and char particles that are primarily in the 1 to 100 μm range. This mechanism for particle formation can be termed combustion particle burnout. Both combustion particle burnout and nucleation occur in a fossil-fuel-fired boiler. Nucleation is discussed in the next section.

Homogeneous and Heterogeneous Nucleation

Homogeneous nucleation and heterogeneous nucleation involve the conversion of vapor phase materials to a particulate form. In both cases, the vapor-containing gas streams must cool to the temperature at which nucleation can occur, which is the dew point. Each vapor phase element and compound has a different dew point. Therefore, some materials nucleate in relatively hot gas zones while others remain as vapor until the gas stream is cold.

Homogeneous nucleation is the formation of new particles composed almost entirely of the vapor phase material. The formation of particles by homogeneous nucleation involves only one compound.
Heterogeneous nucleation is the accumulation of material on the surfaces of existing particles. In the case of heterogeneous nucleation, the resulting particle consists of more than one compound.

The organic vapors begin to condense in areas downstream from the process where the gas temperatures are cooler. These particles must then be collected in the downstream air pollution control systems. Homogeneous and heterogeneous nucleation generally create particles that are very small, often between 0.1 and 1.0 μm.

Heterogeneous nucleation facilitates a phenomenon called enrichment of particles in the sub-micrometer size range. The elemental metals and metal compounds volatilized during high temperature operations (fossil fuel combustion, incineration, industrial furnaces, and metallurgical processes) nucleate preferentially as small particles or on the very small particles produced by these processes. Consequently, very small particles have more potentially toxic materials than the very large particles leaving the processes. Heterogeneous nucleation contributes to the formation of particle distributions that have quite different chemical compositions in different size ranges.

Another consequence of particle formation by heterogeneous nucleation is that a greater variety of chemical reactions may occur in the gas stream than would otherwise happen. During heterogeneous nucleation, small quantities of metals are deposited on the surfaces of many small particles. In this form, the metals are available to participate in catalytic reactions with gases or other vapor phase materials that are continuing to nucleate. Accordingly, heterogeneous nucleation increases the types of chemical reactions that can occur as the
particles travel in the gas stream from the process source and through the air pollution control device.

**Droplet Evaporation**

Some air pollution control systems use solids-containing water recycled from wet scrubbers to cool the gas streams. This practice inadvertently creates another particle formation mechanism that is very similar to fuel burnout. The water streams are atomized during injection into the hot gas streams. As these small droplets evaporate to dryness, the suspended and dissolved solids are released as small particles. The particle size range created by this mechanism has not been extensively studied. However, it probably creates particles that range in size from 0.1 to 20 μm. All of these particles must then be collected in the downstream air pollution control systems.

Thus, knowing the size range of particles is important in air pollution studies because the collection efficiency of different types of particulate control equipment is heavily dependent on particle size. Figure 2.1 summarizes the expected particle size range produced by the formation mechanisms discussed in this lesson. In most industrial processes, more than one particle formation mechanism is at work. Thus, industrially generated particles usually cover a broad size range.
2.3. Particle Size Categories

The most important characteristic of particulate matter (PM) is the particle size. This property has the greatest impact on the behavior of particulate matter in control equipment, the atmosphere, and the respiratory tract. Particles of importance in air pollution control span a broad size range from extremely small (0.01 micrometer) to more than 1,000 micrometers. As a frame of reference, a human hair has a diameter of approximately 50 micrometers. A particle size is usually expressed in terms of its aerodynamic diameter instead of its actual or physical diameter.

The chemical composition of the particulate matter is also important. Absorption and heterogeneous nucleation of vapor phase pollutants onto existing particles can create toxic particulate matter. Other characteristics besides size and chemical composition should be considered when selecting an
appropriate particulate control device for a gas stream. Other important characteristics of particulate matter in gas streams include **stickiness**, **resistivity**, and **explosiveness**.

As per research carried out by US EPA (1997), Anthropogenic sources of particulate matter in the United States of America are shown in Figure 2.2. Major sources include fugitive dust, agricultural processes, industrial processes, coal-burning electric power plants, residential fuel combustion, and highway vehicles. In Indian conditions, the scenario may not be the same, however the figures are indicative of nature. In case of Coal mine areas, especially Talcher Coalfields, where the wind velocity is very low during almost the entire year and where there is abundance of coal transportation tippers moving day and night on almost unpaved roads, the contribution of coal transportation towards dust generation would be maximum.

**Fig. 2.2: Major Sources of Particulate Matter (PM$_{10}$)**

- Combustion: 6%
- Agriculture & Forest: 14%
- Wind Erosion: 16%
- Industrial Processes: 4%
- Transportation: 2%
- Fugitive Dust: 58%

Data Source: US EPA 1998
It may be noticed that how and why the U.S. EPA, in its research efforts and regulations, has focused on progressively smaller and smaller particles.

**Particle Size and PM Regulations**

Particulate matter of all sizes is regulated as **total filterable particulate matter**. This was the first category of air pollutants that was subject to air pollution control regulations. The reason for this early attention was the tendency for the large-diameter particulate matter to settle on houses, deposit and discolor urban buildings, and reduce visibility.

Less than forty years ago, the total filterable particulate problem in many metropolitan areas was measured using "dustfall" buckets. These tests indicated the deposition of total particulate in units of tons per square mile per month!

In 1971, the U.S. Environmental Protection Agency (U.S. EPA) established the National Ambient Air Quality Standard (NAAQS) for total filterable particulate matter to reduce community exposure to this pollutant. Particulate control regulations developed by State and local agencies in response to the Particulate NAAQS have been instrumental in reducing particulate matter emissions since 1971.

During the 1970s and early 1980s, research studies indicated that the severity of adverse health effects of particles depended, in part, on their size. Particulate matter that was less than or equal to 10 micrometers (PM\textsubscript{10}) was more closely associated with adverse health effects than the larger sized particulate matter. This phenomenon is due to the ability of smaller particles to more effectively penetrate through the upper respiratory tract, which serves as the body's first line of defense. The relationship between particle size and health effects is also
due to the difference in chemical composition of small particles and their ability
to remain airborne for long time periods.

In order to focus attention on particles having the greatest impact on health, the
U.S. EPA revised their ambient air quality standards with respect to particulate
matter in 1988. The NAAQS for total filterable particulate matter was replaced
with a NAAQS for PM$_{10}$.

PM$_{10}$ limitations are now being applied to stack emissions from stationary
sources so that the ambient levels of PM$_{10}$ do not exceed the NAAQS ambient
air concentration limits.

In the mid-1980s, research began to focus increasingly on the possible adverse
health effects associated with particles that are less than 2.5 micrometers in
diameter (PM$_{2.5}$). The composition of these particles is considerably different
from larger particulate matter (even particles in the size range from 2.5 to 10
micrometers). Most particles less than 2.5 micrometers are formed by the
following mechanisms:

- Heterogeneous nucleation of vapor phase material
- Homogeneous nucleation of vapor phase material
- Atmospheric reactions of gases to form vapors that homogeneously and
  heterogeneously nucleate to form particles

These formation mechanisms combine to generate a set of particles that are
different from larger sized particulate matter in both chemical composition and
health effects. Due to the special characteristics of these small particles, EPA in
July of 1997 promulgated a new NAAQS for particulate matter less than 2.5
micrometers. The U.S. EPA developed the different sets of particulate matter,
illustrated in Figure 2.3, as part of its research into the health effects of small particulate matter.

Fig. 2.3 : Tri-Modal Distribution of Particulate Matter in the Atmosphere

Since the range of particle sizes of concern for air emission evaluation is quite broad it is beneficial to divide this range into smaller categories. Defining different size categories is useful since particles of different sizes behave differently in the atmosphere and the respiratory system.

The US, EPA has defined four terms for categorizing particles of different sizes. Table 2.1 displays the EPA terminology along with the corresponding particle sizes (US EPA, 2008).

<table>
<thead>
<tr>
<th>EPA Description</th>
<th>Particle Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>Supercoarse</td>
<td>d_{pa} &gt; 10 \mu m</td>
</tr>
<tr>
<td>Coarse</td>
<td>2.5 \mu m &lt; d_{pa} \leq 10 \mu m</td>
</tr>
<tr>
<td>Fine</td>
<td>0.1 \mu m &lt; d_{pa} \leq 2.5 \mu m</td>
</tr>
<tr>
<td>Ultrafine</td>
<td>d_{pa} \leq 0.1\mu m</td>
</tr>
</tbody>
</table>
In addition to the terminology provided in Table 2.1 the EPA also categorizes particles as follows:

- Total Suspended Particulate Matter (TSP)
- PM$_{10}$
- PM$_{2.5}$
- Particles less than 0.1
- Condensable Particulate Matter

These particle categories are important because particulate matter is regulated and tested for under these categories.

Figure 2.4 displays a typical size distribution of atmospheric particulate matter that combines the two classification schemes discussed above.

Figure 2.4: Ambient Particulate Matter Size Distribution
The website of Haz –Dust (http://www.hazdust.com/products.ph) has given a very interesting graph showing the Relative size of lung damaging particles and the danger zone which is given in Figure 2.5.

**Figure 2.5: Relative size of lung damaging particles**
2.4. Dust Emission, Dust Dispersion, Deposition & its Re-entrainment with particular reference to Mineral Industry

By far the most important aspect of air pollution in relation to quarries is the generation of dust. There may be small amounts of fumes or smoke generated from diesel equipment or processing plant which can cause a visual impact. There may also be some gases such as NO\textsubscript{2} and CO produced in the blasting process, but dust is considered most important among all.

Dust generation is \textit{unfortunately} an \textit{inevitable consequence} of minerals working. Deposited (nuisance) dust gives rise to the greatest number of complaints to quarries from local residents, and fears are commonly expressed in relation to the alleged health effects. Without appropriate mitigation, residents can potentially be affected by dust \textbf{up to 1km} from the source, although concerns about dust are most likely to be experienced near to dust sources, generally within \textbf{100 metres} depending on site characteristics \cite{Bate et al, 1991}.

Dust particles are dispersed by their suspension and entrainment in an airflow. Dispersal is affected by the \textbf{particle size, shape and density}, as well as \textbf{wind speed} and other climatic effects. Smaller dust particles remain airborne for longer, \textbf{dispersing widely} and depositing \textbf{more slowly} over a wider area. Large dust particles (greater than \textbf{30 \textmu m}), that make up the \textbf{greatest proportion} of dust emitted from mineral workings will largely deposit within \textbf{100 m} of sources. Intermediate sized particles (\textbf{10 - 30 \textmu m}) are likely to travel up to \textbf{200 - 500m}. Smaller particles (less than \textbf{10 \textmu m}) which make up a \textbf{small proportion} of the dust emitted from most mineral workings, are only deposited slowly. Concentrations \textbf{decrease rapidly} on moving away from the source, due to \textbf{dispersion} and \textbf{dilution}.
The process by which dust becomes airborne is referred to as 'dust emission'. For this to happen, energy is required to overcome the gravitational and cohesive forces binding dust particles to the surface. Potential dust emission that may be associated with mineral workings can be caused by:

- mechanical handling operations, including crushing and grading processes where in general the more powerful the machinery and the greater the volumes of material handled the greater the potential for dust emission;
- haulage, where the weight of vehicles, their speed of passage and number of wheels in contact with the ground, and the nature and condition of road surfaces or haul routes all affect the amount of dust emitted;
- blasting;
- ancillary "manufacturing" operations within quarries (batching plants, concrete plants, asphalt plants etc.);
- wind blow from paved areas, stockpiles etc.

Dust emission, dispersion patterns and impacts are difficult to predict due to the wide range of activities on site that may give rise to dust, the lack of reliable emission factors for these activities, and the influence of local meteorology and topographic features. Computer modelling can provide crude predictions of likely dispersion patterns, and various dust monitoring techniques can provide an understanding of possible levels of dust that may be deposited in and around a site.
Extent of the Problem

The amount of dust generated and emitted from a mineral working and the impact on the surrounding area varies with respect to the following factors:

- the types and quantity of mineral and the method of working;
- the types of processing activities undertaken on a site;
- the character and land use of the area surrounding the site;
- the hydrogeology of the site and the vegetation cover;
- climate/local meteorology and topography;
- dust control measures employed on the site.

The variation in potential dust impacts between different mineral types, is accounted for by a number of factors:

- **the scale of operations**: generally the more extensive the scale of operations, the more likely that dust will be a concern,
- **the nature of the mineral**: although softer minerals crumble more easily during handling and may produce a greater number of dust particles, intensive handling of hard minerals may produce large amounts of dust due to higher energy inputs,
- **the colour and opacity of the mineral**: high contrast dust from minerals, such as coal or limestone are generally more likely to be noticed on deposition,
- **length of operation**: a potential dust problem may be more acceptable if it is known that operations will soon cease or move to another part of the site,
the type of activities undertaken within a site and the location and duration of those activities, and

the chemical nature of the dust: will affect the severity of the impacts upon soils and vegetation.

Dust emission from typical activities have been summarized in Table 2.2

<table>
<thead>
<tr>
<th>Activity</th>
<th>Relevance for Mineral Types</th>
<th>Duration of Activity</th>
<th>Potential for Dust Emission</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soil handling</td>
<td>Most minerals.</td>
<td>Relatively short.</td>
<td>Significant potential. Depends on silt/clay content &amp; dryness of material and transport to mounds on the edge of site</td>
</tr>
<tr>
<td>Overburden handling</td>
<td>Most minerals, but quantities vary considerably.</td>
<td>Varies, can be intermittent over life of site.</td>
<td>Significant potential. Depends on nature of overburden during the unloading and haulage stages.</td>
</tr>
<tr>
<td>Drilling and blasting</td>
<td>Usually for hard rocks</td>
<td>Short, but can take place frequently</td>
<td>Drill rigs have significant potential unless suppression is used which localises dust generation. Properly designed/controlled blasts have limited potential.</td>
</tr>
<tr>
<td>Other extraction and handling activities</td>
<td>Most minerals.</td>
<td>Varies considerably but usually long.</td>
<td>Varies considerably depending on the equipment used.</td>
</tr>
<tr>
<td>Initial loading Activities</td>
<td>All mineral types.</td>
<td>Ongoing during extraction.</td>
<td>Can be significant but varies considerably depending on the nature of the material, whether it is wet or dry, volumes handled and equipment used.</td>
</tr>
<tr>
<td>Crushing and grading</td>
<td>Most minerals, not always at extraction</td>
<td>Varies, generally ongoing.</td>
<td>Varies depending on type of equipment and exposure to wind.</td>
</tr>
<tr>
<td>Storage of minerals on site</td>
<td>Most mineral types.</td>
<td>Usually ongoing during extraction.</td>
<td>Varies depending on the volume, wet or dry and exposure to wind.</td>
</tr>
<tr>
<td>Transport and load-out within site</td>
<td>All mineral types.</td>
<td>Usually ongoing.</td>
<td>Mainly by road but varies. Not usually significant (except near site exits).</td>
</tr>
<tr>
<td>Transport off-site</td>
<td>All mineral types.</td>
<td>Usually ongoing.</td>
<td>Mainly by road but varies. Not usually significant (except near site exits).</td>
</tr>
<tr>
<td>Soil/overburden reinstatement/ restoration works</td>
<td>Most minerals.</td>
<td>Can be relatively short - but may proceed intermittently in phases. &gt;</td>
<td>Significant potential but depends on the state of the material and transportation from edges of the site.</td>
</tr>
</tbody>
</table>
Influence of Weather

The potential for any site to emit dust is greatly influenced by weather. Pick-up due to strong winds has been considered already, but other factors are also significant. Rainfall decreases dust emissions, due to both surface wetting and increasing the rate at which airborne dust is removed from air. In contrast, strong, warm, drying winds increase the rate at which dust is lifted from an untreated surface and emitted into the air and also has the effect of spreading dust over a large area. The following meteorological phenomena are therefore important in considering the likely behaviour of dust at mineral sites:

- patterns of rainfall (usually expressed in terms of number of days experiencing greater than 2 mm of rainfall (considered sufficient to effectively suppress wind blown dust emissions));
- patterns of atmospheric turbulence;
- frequencies of wind speeds and direction.

Site Topography

The topography of a site and surrounding areas can have strong effects on localised wind patterns. The effect is most pronounced in or near to valleys or hills which can channel and direct winds. In addition, the presence of surface features, such as woodland, and buildings or structures can influence dust deposition patterns. Open, exposed sites lacking shelter and surface features are likely to be more susceptible to dust blow. At the same time, wind speeds increase with height, and large mounds which project well above ground level can thus be the subject of significant wind erosion. In contrast, activities within a quarry or void will be sheltered to some extent from external winds, restricting
the potential for dust to disperse beyond the site. The placing of dust generating activities within worked out areas of the site can therefore significantly reduce potential dust impacts off site.

2.4.1. Basics of Removal/Collection Mechanism of Dust

When sunlight streams into a quiet room, particles of many different shapes and sizes can be seen, some appear to float while others slowly settle to the floor. All of these small particles are denser than the room air, but they do not settle very fast. The solid, liquid, and fibrous particles formed in air pollution sources behave in a manner that is very similar to standard household dusts and other familiar particles. What we instinctively understand about these everyday particles can be applied in many respects to the particles from air pollution sources.

There are, however, two major differences between industrially generated particles and those in more familiar settings. The industrial particles are much smaller than most household particles. Also, some industrial particles have complex chemical compositions and include compounds and elements that are known to be toxic.

Emission testing devices and air pollution control systems apply forces to the particles in order to remove them from the gas stream. These forces are basically the "tools" that can be used for separating particles from the gas stream.

All of these collection mechanism forces are strongly dependent on particle size:

- Inertial impaction and interception
Brownian diffusion
• Gravitational settling
• Electrostatic attraction
• Thermophoresis
• Diffusiophoresis

**Inertial Impaction and Interception**

Due to inertia, a particle moving in a gas stream can strike slowly moving or stationary obstacles (targets) in its path. As the gas stream deflects around the obstacle, the particle continues toward the object and impacts it. The obstacle may be a water droplet as shown in the Figure 2.5 below.

**Fig. 2.5: Inertial Impaction**

![Diagram of Inertial Impaction](image)

Two primary factors affect the probability of an impaction occurring: (1) aerodynamic particle size and (2) the difference in velocity between the particle and the obstacle. Larger particles are collected more easily than smaller particles due to their greater inertia. Also, collection efficiency increases as the difference in velocity between the particle in the gas stream and the obstacle (or target) increases.

Inertial impaction is analogous to a small car riding down an interstate highway at 65 mph and approaching a merge lane where a slowly moving truck is entering. If the car is unable to get into the passing lane to go around the merging truck, there could be an "impaction" incident. Larger cars will have
more difficulty going around the truck than smaller cars. Also, the faster the car is going relative to the truck, the more probable is an impaction.

The efficiency of impaction is directly proportional to the impaction parameter shown in the following Equation:

\[ K_I = \frac{C_0 d_{ps}^2 v \rho_p}{18 \mu D_o} \]  

(1)

Where:

- \( K_I \) = Impaction parameter (dimensionless)
- \( C_0 \) = Cunningham slip correction factor (dimensionless)
- \( d_{ps} \) = Stokes particle diameter (micrometers)
- \( v \) = Difference in velocity (cm/sec)
- \( \rho_p \) = Particle density (gm/cm²)
- \( D_o \) = Diameter of droplet (cm)
- \( \mu \) = Gas viscosity (gm/cm·sec)

As the value of this parameter increases, the efficiency of inertial impaction increases. This parameter is related to the square of the Stokes particle diameter and the difference in velocity between the particle and the target droplet.

The Cunningham slip correction factor (also called Cunningham's correction factor) accounts for molecular slip. Molecular slip occurs when the size of the particle is of the same magnitude as the distance between gas molecules. The particle no longer moves as a continuum in the gas, but as a particle among discrete gas molecules thereby reducing the drag force. For particles in air with actual diameters of 1.0 \( \mu m \) and less, the Cunningham correction factor is significant.
Inertial impaction occurs when obstacles (e.g. water droplets) are directly in the path of the particle moving in the gas stream. Sometimes the obstacle or target is offset slightly from the direct path of the moving particle. In this instance, as the particle approaches the edge of the obstacle, the obstacle may collect the particle through a process called interception. Interception is illustrated in Figure 2.6.

**Fig. 2.6: Interception**

Inertial impaction and interception are usually highly efficient for particles larger than 10 μm. They become progressively less effective as the size decreases. Impaction is not efficient for particles less than 0.3 μm due to their low inertia.

**Brownian Diffusion**

Brownian diffusion becomes the dominant collection mechanism for particles less than 0.3 μm and is especially significant for particles in the 0.01 to 0.1 μm size range.

Very small particles in a gas stream deflect slightly when gas molecules strike them. Transfer of kinetic energy from the rapidly moving gas molecule to the small particle causes this deflection, called Brownian diffusion. These small particles are captured when they impact a target (e.g. liquid droplet) as a result of this random movement.
**Diffusivity** is a measure of the extent to which molecular collisions influence very small particles, causing them to move in a random manner across the direction of gas flow. The diffusion coefficient in the equation below represents the diffusivity of a particle at certain gas stream conditions.

\[
D_p = \frac{C_c K T}{3 \pi d_{pa} \mu} \tag{2}
\]

Where:

- \( D_p \) = Diffusion coefficient (cm\(^2\)/sec)
- \( C_c \) = Cunningham slip correction factor (dimensionless)
- \( K \) = Boltzmann constant (gm cm\(^2\)/sec\(^2\)/°K)
- \( T \) = Absolute temperature (°K)
- \( d_{pa} \) = Particle aerodynamic diameter (micrometers)
- \( \mu \) = Gas viscosity (kg/m sec)

**Gravitational Settling**

Particles in still air have two forces acting on them; (1) a gravitational force downward and (2) the air resistance (or drag) force upward. When particles begin to fall, they quickly reach a **terminal settling velocity**, which represents the constant velocity of a falling particle when the gravitational force downward is balanced by the air resistance (or drag) force upward. The terminal settling velocity can usually be expressed using Equation 3.

\[
\nu_t = g \frac{\rho_p d_{pa}^2 C_v}{18 \mu} \tag{3}
\]

Where:
\[
\begin{align*}
\nu_t &= \text{Terminal settling velocity (cm/sec)} \\
g &= \text{Gravitational acceleration (cm/sec}^2) \\
\rho_p &= \text{Density of particle (gm/cm}^3) \\
d_{ps} &= \text{Stokes particle diameter (cm)} \\
C_s &= \text{Cunningham slip correction factor (dimensionless)} \\
\mu &= \text{Viscosity of air (gm/cm-sec)}
\end{align*}
\]

Note: Equation 3 is applicable for particles less than 80 \(\mu\)m in size (aerodynamic diameter) and having a Reynolds number \(\left[ N_{Re(p)} \right]\) less than 2.0 and a low velocity.

**Electrostatic Attraction**

In air pollution control, **electrostatic precipitators** (ESPs) use electrostatic attraction for particulate collection. Electrostatic attraction of particles is accomplished by establishing a strong electrical field and creating unipolar ions. The particles passing through the electrical field are charged by the ions being driven along the electrical field lines. Several parameters dictate the effectiveness of electrostatic attraction including the particle size, gas flow rate, and resistivity.

The particles will eventually reach a maximum or saturation charge, which is a function of the particle area. The saturation charge occurs when the localized field created by the already captured ions is sufficiently strong to deflect the electrical field lines. Particles can also be charged by diffusion of ions in the gas stream. The strength of the electrical charges imposed on the particles by both mechanisms is particle size dependent.

**Thermophoresis and Diffusiophoresis**

Thermophoresis and diffusiophoresis are two relatively small forces. **Thermophoresis** is particle movement caused by thermal differences on two sides of the particle. Gas molecules at higher temperatures have greater kinetic
energy than those at lower temperatures. Therefore, when the particle collides with a gas molecule from the hotter side, the particle receives more kinetic energy than when it collides with a gas molecule from the cooler side. Accordingly, particles tend to be deflected toward the colder area.

**Diffusiophoresis** is particle movement caused by *concentration* differences on two sides of the particle. When there is a strong difference in the concentration of gas molecules on two sides of the particle, there is a difference in the number of molecular collisions, which causes an imbalance in the total kinetic energies of the gas molecules. Gas molecules in the high concentration area striking a particle transmit more kinetic energy to the particle than molecules in the lower concentration area. Therefore, particles tend to move toward the area of lower concentration.

Diffusiophoresis can be important when the evaporation or condensation of water is involved since these conditions create substantial concentration gradients. The normal differences in pollutant concentration are not sufficient to cause significant particle movement.

**Combined Effect of Collection Mechanisms**

Due to the combined action of the various collection mechanisms described previously, the performance of particulate control devices often has the Particle Size - Collection Efficiency Relationship shown in Figure 2.8.

Above 100 micrometers, particles are collected with very high efficiency by inertial impaction, electrostatic attraction, and even settling due to gravity.

Efficiency remains high throughout the range of 10 to 100 micrometers due to the inertial and/or electrostatic forces (depending on type of collector). Both inertial and electrostatic forces are approximately proportional to the square of
the particle diameter. For particles less than 10 micrometers, the limits of inertial forces and electrostatic forces begin to become apparent, and the efficiency drops. Efficiency due to these collection mechanisms reaches negligible levels between 3 and 0.3 micrometers depending on the factors such as gas velocities (inertial forces) and electrical field strengths (electrostatic attraction).

Below 0.3 micrometer, Brownian diffusion begins to become effective. Accordingly, the overall efficiency curve begins to rise in this very small size range.

The result of these various collection mechanisms is a potentially low collection efficiency for particles in the 0.1 to 0.5 micrometer range. In many control devices, none of the collection mechanisms are highly efficient for particles in this range. These particles can be classified as "difficult-to-control" due to the inherent limitations of the collection mechanisms.

This relationship, which can be seen in a number of studies of actual sources, indicates that stationary sources generating high concentrations of particles in the 0.1 to 0.5 micrometer range may be an especially challenging control problem.
The extent to which this gap in particulate control capability actually exists varies substantially among the types of particulate control systems. The gap is most noticeable in wet scrubbers and electrostatic precipitators. Fabric filters generally have a very minimal decrease in overall efficiency in this range due to the multiple collection mechanisms inherently present. Cyclonic collectors are generally inefficient for particles less than 1 to 3 micrometers. Therefore, the left side of the efficiency curve in the Figure is irrelevant.

A study in this regard at Florida State University, USA ((Winchester, 1991) revealed that once in the atmosphere, the particle may remain suspended as stable aerosol, where the normal movement of air act as to prevent their settling to the surface. Sedimentation, impaction, diffusion, coagulation and water vapor condensation control the distribution of sizes in the aerosol suspension of particles.

The very coarsest particles can settle out of air to the ground, but their settling velocity, described by the Stoke's equation, decreases as the square of particle radius. For normal density particles of 10 µm radius, they settle at about 1cm/s, a speed which may be counterbalanced by vertical air motions normally encountered. Thus, these and smaller particles may remain suspended for long periods of time.

Particles may also be removed by impaction against rough surfaces. Impaction efficiency decreases with decreasing particle size and also with decreasing wind speed. The process is essentially the same as that of striking flying insects by the wind shield of a moving automobile. The largest insects are intercepted and make the glass dirty. The smaller insects are carried by the deflected air stream around the automobile and escape.
Nature has always expected the atmosphere to contain coarse dust, but fine \textbf{sub-micrometer} particles have been a rarity until recently. The removal mechanism by rainout, washout, impaction and settling are all \textbf{effective} in keeping the atmosphere clean of dust. The human respiratory tract is also \textbf{efficient} in removing coarse particles. But these mechanisms for purifying air, in the atmosphere and in the inhaled air, are \textbf{notably less efficient} for \textbf{fine particles}.

Today the addition of particulate pollutants to the atmosphere is primarily in the fine particle sizes. These remain airborne for \textbf{unusually long time}, are transported over unusually \textbf{long distances}, and may be inhaled much more deeply into the lungs than the respiratory tract was evolved to expect. Fine particles, of sizes comparable to the \textbf{wavelength of light}, also are more efficient optical scatters than are coarse particles and intensity of haze has consequently risen sharply in many location. It is perhaps fortunate that the fine particle pollutants are more visible then if they were coarse, for visibility is an \textbf{early warning} of possibly injurious levels of particulate pollutants in the atmosphere. By understanding more of their properties and effects, we may better be able to control them.

\textbf{Mechanism of Dry Deposition}

Although deposition occurs as the result of a complex of individual process, it is useful to speak of a generalized deposition velocity, $V_d$, equivalent to a gravitational falling speed, which is the ratio of flux, $F$, to the ground and concentration, $C$, in air:

\[ V_d = \frac{F}{C} \]
Particles coarser than D=20 μm diameter settle primarily by gravitational settling according to Stoke's Law, where $V_d$ varies directly as $d^2$ and is about 1 cm/s at 20 μm. Additional removal may occur by inertial impaction near rough surfaces in turbulent eddies.

Sedimentation is a result of earth's gravitational field. The rate at which a particle descends, or terminal velocity, is determined by the balance of the gravitational force and the aerodynamic drag on the particle. Approximate terminal velocity for some particle radius is given in Table 2.3.

Table 2.3: Terminal Velocity for some particle radius

<table>
<thead>
<tr>
<th>Particle radius (μm)</th>
<th>Terminal Velocity (cm/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>0.3</td>
</tr>
<tr>
<td>10</td>
<td>1.2</td>
</tr>
<tr>
<td>50</td>
<td>30</td>
</tr>
<tr>
<td>100</td>
<td>120</td>
</tr>
</tbody>
</table>

Particle Re-Entrainment

In both urban and rural environment, Particulate Matter is suspended or re-entrained into the atmosphere by the action of both man and nature. In urban areas, typical man made sources include dust thrown up by construction activity and vehicular traffic. In rural areas, farming activity may introduce significant quantities of dust into the atmosphere, as well as the vehicle movements on unpaved roads. In both environment the common natural process of dust suspension is by wind action. The mechanisms involved have been described by Bagnold (Bagnold, 1959). Large particles (diameter greater than about 80 μm) undergo creep (rolling) and saltation (bouncing) at normal wind speeds.
These, in turn, collide with other particles, causing creep and saltation of large particles and suspension of small particles. Only small particles become suspended, and only by being dislodged by larger particles, since the aerodynamic drag forces on them are insufficient by themselves to cause suspension.

2.5 Characterization of Airborne Particles

In a relevant study (Jones et.al, 2002) airborne particulate matter were collected from within, and proximal to, an opencast coal mine in south Wales over a three year period under the project work to collect and characterise, then determine the possible toxicology of airborne particles in the south Wales region. High-resolution Field Emission SEM has shown that the coal mine dusts consist largely of an assemblage of mineral grains and vehicle exhaust particles. SEM-EDX has shown that the mineralogical make-up of the PM$_{10}$ is complex, heterogeneous, and constantly changing. These findings are supported by analytical TEM-EPXMA. However, patterns can be determined relating the mineralogical composition of the airborne particles to collection locations and mining activities within the opencast. At the study site, quartz, which has known health effects, never exceeded 30% of the total collection mass, and average levels were much less. Vehicle exhaust emissions was the largest source in terms of particle numbers. The mass of airborne particulate matter within the pit averaged approximately twice that of outside the pit: importantly however, this higher mass was due to relatively large and non-respirable mineral grains. This study demonstrates that the physico-chemical and mineralogical characterisation of airborne particles from mining
and quarrying is essential to quantify the respirable fraction, and to identify potentially hazardous components within the PM$_{10}$.

In another study ((John et. al, 2003) it was established that there are different types of dust – relatively heavier dust, and respirable dust. Heavy dust is down to 50 \textmu m. Dust suppression works well with this. This type of dust falls at 200 mm/sec, so it is not likely to get to the border of the Mine Site. Water Jets will form a crust and, as long as that crust is not broken, will provide adequate dust control. The dust is readily seen as a cloud with the naked eye. Respirable Dust is of a size which can be breathed into the lungs, is anything below 10 \textmu m, and may stay in the air for half an hour or more. This type travels across Mine Site boundaries as a visible dust cloud, and settles on leaf surfaces. When a cross wind comes the fine dust is kicked into the air again for another 30 minutes or so. It requires water spray droplets, ideally as a mist. The mist will agglomerate dust at the size of the water droplet (the smaller the better). Once the clump of dust falls to the ground, or leaf surface it will dry out, and once again become a potential source of fugitive windblown dust. Ideally this type of dust needs a water spray dosed with a binding agent.

\textbf{Rate of Dust Pollution & Toxicity}

In a Study of dust pollution caused by traffic in Aligarh city the dust pollution caused by vehicles in Aligarh city was estimated (Lone \emph{et.al}, 2005). The dust pollution was found to be maximum on Kanpur road (46.44 gm/m$^2$/month) followed by Agra road (38.94 gm/m$^2$/month) and Delhi road (34.52 gm/m$^2$/month). The least dust pollution was recorded on Anoopshahar road (20.10 gm/m$^2$/month). The average dust fall rate per unit area was estimated to be about 35 gm/m$^2$/month in Aligarh city.
In a study at Pt Ravishankar Shukla University, Raipur, Chattisgarh named "Load of heavy metals in the airborne dust particulates of an urban city of central India" dust fall samples from different sites were collected and some selected toxic metals in them were determined by AAS. Total annual flux of 11.7, 541.4, 2751.0, 14.2, 9.8, 90.9, 17.6 and 17.7 kg/km²/yr were measured for Cr, Mn, Fe, Ni, Cu, Zn, Sb, and Pb respectively. The results of analysis show the existence of toxic metal concentration in the order Fe>Mn>Zn>Pb>Sb>Ni>Cr>Cu in Raipur city. These large levels of metal pollutants have also been correlated with some meteorological parameters like temperature, relative humidity and wind velocity, and strong positive correlations were observed.

In a study at NIOSH Pittsburgh Research Laboratory on "Characteristics of fugitive dust generated from unpaved mine haulage roads" (Organiscak et. al, 2004) it was observed that Fugitive dust is generated along unpaved mine roads from intermittent equipment traffic. Typically, the majority of such traffic consists of trucks hauling either mine product or waste from the surface mine pit and/or the processing plant. Fugitive dust generated along these unpaved mine roads includes particles of all sizes that become airborne. The potential hazards include the deleterious effects to human health of inhaled dust, traffic visibility hazards, and environmental impacts on the localized area by the larger-sized visible airborne dust. Two field surveys were recently conducted to quantify fugitive dust generation and dispersion from truck traffic on unpaved and untreated mine haulage roads. For these surveys, airborne dust sampling was conducted at multiple sampling locations away from an unpaved haulage road at a limestone quarry/plant and at a coal mine preparation plant to
measure the size characteristics, concentrations, and dispersive behavior of the dust cloud generated from truck traffic. Results show that at least 80% of the airborne dust generated by haul trucks was larger than 10 μm. Airborne respirable, thoracic, and total dust concentrations all decreased and approached background concentrations 30.5 m (100 ft) from the road. This report describes the average and instantaneous peak dust levels that were measured up to 30.5 m (100 ft) from the haulage road.

Brown Haze-observed over Asian Region

In a report recently published in Science Daily namely "Pollution Amplifies Greenhouse Gas Warming Trends To Jeopardize Asian Water Supplies" (www.sciencedaily.com-2008) Scientists have concluded that the global warming trend caused by the buildup of greenhouse gases is a major contributor to the melting of Himalayan and other tropical glaciers. Now a new analysis of pollution-filled "brown clouds" over south Asia by researchers at Scripps Institution of Oceanography at UC San Diego offers hope that the region may be able to arrest some of the alarming retreat of such glaciers by reducing its air pollution.

The team led by Scripps atmospheric chemistry Professor V. Ramanathan describes findings that atmospheric brown clouds enhanced solar heating of the lower atmosphere by about 50 percent in a paper to be released in the Aug. 2 edition of the journal Nature.

The combined heating effect of greenhouse gases and the brown clouds, which contain soot, trace metals and other particles from a growing cadre of urban, industrial and agricultural sources, is enough to account for the retreat of Himalayan glaciers observed in the past half century, the researchers
concluded. The glaciers supply water to major Asian rivers including the Yangtze, Ganges and Indus. These rivers in turn comprise the chief water supply for billions of people in China, India and other south Asian countries.

"The rapid melting of these glaciers, the third-largest ice mass on the planet, if it becomes widespread and continues for several more decades, will have unprecedented downstream effects on southern and eastern Asia," the Nature article concluded.

"The main cause of climate change is the buildup of greenhouse gases from the burning of fossil fuels," said Achim Steiner, United Nations under-secretary general and executive director of the UN Environment Programme (UNEP), which helped support the research. "But brown clouds, whose environmental and economic impacts are beginning to be unraveled by scientists, are complicating and in some cases aggravating their effects.

"The new findings should spur the international community to ever greater action, in particular at the next crucial climate change convention meeting in Indonesia this December. For it is likely that in curbing greenhouse gases we can tackle the twin challenges of climate change and brown clouds and in doing so, reap wider benefits from reduced air pollution to improved agricultural yields," Steiner added.

The scientists based their conclusions in large part on data gathered by a fleet of unmanned aircraft during a landmark field campaign conducted in March 2006 in the skies over the Maldives, an island nation in the Indian Ocean south of India. The Maldives Autonomous unmanned aerial vehicle Campaign (MAC) took place during the region's dry season when polluted air masses travel south from the continent to the Indian Ocean. The air typically contains particles
released from industrial and vehicle emissions as well as through biomass burning.

Such polluted air has been demonstrated to have a **dual effect** of **warming** the atmosphere as particles absorb sunlight and of cooling the earth's surface as the particles curb the amount of sunlight that reaches the ground. The net effect of the two forces remains uncertain but other research by Ramanathan has suggested that the surface dimming might serve to mask global warming, leading scientists and the public to under appreciate the full magnitude of anthropogenic climate change.

The aircraft, flying in stacked formations, made nearly simultaneous measurements of the brown clouds from different altitudes, creating a profile of soot concentrations and light absorption that was unprecedented in its level of vertical detail.

The researchers validated the data from the aircraft with ground-based measurements taken at a station at the Maldivian island Hanimadhoo.

When the researchers fed both greenhouse gas and brown cloud data into computer climate models, the simulations yielded an estimate that the region's atmosphere has warmed **0.25°C** (0.5 degrees F) **per decade** since **1950** at altitudes ranging from **2 to 5 kilometers** (6,500 to 16,500 feet) above sea level. At those heights are found many of the **glaciers in the Himalayas**. The amount of heating corresponds to observed levels of glacial retreat.

"In order to understand the processes that can throw the climate out of balance, Ramanathan and colleagues, for the first time ever, used small and inexpensive unmanned aircraft and their miniaturized instruments as a creative means of simultaneously sampling of clouds, aerosols and radiative fluxes in polluted..."
environments, from within and from all sides of the clouds," said Jay Fein, program director in the National Science Foundation (NSF)\'s Division of Atmospheric Sciences. "These measurements, combined with routine environmental observations and a state-of-the science model, led to these remarkable results."

The analysis revealed that the effect of the brown cloud was necessary to explain temperature changes that have been observed in the region over the last half-century. It also indicated that south Asia\'s warming trend is more pronounced at higher altitudes than closer to sea level.

"The conventional thinking is that brown clouds have masked as much as 50 percent of the global warming by greenhouse gases through the so-called global dimming," said Ramanathan, who is lead author of the Nature paper. "While this is true globally, this study reveals that over southern and eastern Asia, the soot particles in the brown clouds are intensifying the atmospheric warming trend caused by greenhouse gases by as much as 50 percent."

2.6. Use of Dispersion Model in Indian Mining Condition

From the foregoing discussion it is clear that only scientists of Central Institute of Mining & Fuel Research and Indian School of Mines have taken up similar work for validation of two dispersion models in Indian Mining condition. They have used PAL2 Model and FDM model and concluded that FDM is more suitable for Indian mining condition (Cahulya et. al, 2003; Cahulya et. al, 2001; CMRI, 1998). Therefore in the present research study FDM Model has been applied in detail for Orissa coal mining condition and thus it is an extension over the previous work done by CIMFR.
2.7. Use of Dispersion Models outside India

As regards use of dispersion models in countries other than India, most authentic and comprehensive work have been taken up by US, EPA and they have developed various mathematical models to represent the real situation. In addition Models used at Newzeland and Australia are also described.

Air quality models use mathematical and numerical techniques to simulate the physical and chemical processes that affect air pollutants as they disperse and react in the atmosphere. Based on inputs of meteorological data and source information like emission rates and stack height, these models are designed to characterize primary pollutants that are emitted directly into the atmosphere and, in some cases, secondary pollutants that are formed as a result of complex chemical reactions within the atmosphere. These models are important to our air quality management system because they are widely used by agencies tasked with controlling air pollution to both identify source contributions to air quality problems and assist in the design of effective strategies to reduce harmful air pollutants. For example, air quality models can be used during the permitting process to verify that a new source will not exceed ambient air quality standards or, if necessary, determine appropriate additional control requirements. In addition, air quality 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.

The most commonly used air quality models include the following:
Dispersion Modeling - These models are typically used in the permitting process to estimate the concentration of pollutants at specified ground-level receptors surrounding an emissions source.

Photochemical Modeling - These models are typically used in regulatory or policy assessments to simulate the impacts from all sources by estimating pollutant concentrations and deposition of both inert and chemically reactive pollutants over large spatial scales.

Receptor Modeling - These models are observational techniques which use the chemical and physical characteristics of gases and particles measured at source and receptor to both identify the presence of and to quantify source contributions to receptor concentrations.

Dispersion modeling uses mathematical formulations to characterize the atmospheric processes that disperse a pollutant emitted by a source. Based on emissions and meteorological inputs, a dispersion model can be used to predict concentrations at selected downwind receptor locations. These air quality models are used to determine compliance with National Ambient Air Quality Standards (NAAQS), and other regulatory requirements such as New Source Review (NSR) and Prevention of Significant Deterioration (PSD) regulations. These models are addressed in Appendix A of EPA's Guideline on Air Quality Models (also published as Appendix W of 40 CFR Part 51), which was originally published in April 1978 to provide consistency and equity in the use of modeling within the U.S. air quality management system. These guidelines are periodically revised to ensure that new model developments or expanded regulatory requirements are incorporated. This site provides links for dispersion models and other related tools and information.
Good Practice Guide for Atmospheric Dispersion Modelling

Ministry of Environment, Govt. of New Zealand (http://www.mfe.govt.nz, 2008) has provided a guideline for use of dispersion modeling. The purpose of this guide is to provide good-practice protocols for modelling the dispersion of discharges to air from industrial complexes in New Zealand. Guidance is provided for all modellers, from relative newcomers to experts. The guideline provides recommendations which direct modellers towards adopting a best practice approach. The recommendations are somewhat prescriptive, but allow flexibility. They are consistent with current practice in Australia and the USA, with some adaptation for New Zealand-specific conditions. The practitioner should always justify the methods used, whichever modelling approach is taken.

For convenience, dispersion model types are divided broadly into steady-state Gaussian-plume models and 'advanced' models. This is a differentiation on roughly historical grounds: plume models have been in common use for decades, while advanced models are beginning to be used more widely for regulatory applications. From a practical standpoint, the greatest difference between model types is in the requirements of meteorological information and computer resources. However, some 'steady-state' models are highly sophisticated and not necessarily 'Gaussian', so the distinction can be blurred. Although the guide encourages modellers to move towards advanced models - because in principle they are more realistic - it does discuss the advantages and limitations of all model types. The use of an 'advanced' model need not be the best option.
This guide provides useful guidance for the modeller by discussing specific models currently in use in New Zealand. The list includes AUSPLUME, FDM, ISCST3, AERMOD, CTDMPLUS, CALPUFF and TAPM. Model configuration, data requirements, model applicability, physical and chemical formulations and the interpretation of results are discussed for these models.

Much of the guide is devoted to practical advice and provides recommendations on the aspects of dispersion modelling essential to a realistic assessment using a dispersion model. These aspects are the choice of input parameters, the specification of emissions and meteorology, and the analysis of results.

A chapter on model configuration discusses model domain size and receptor distribution, dispersion parameters, stability class specification, the use of turbulence measurements, settings for plume rise and inversion penetration, land-use variations and averaging times. It also describes how the different models simulate emissions from different source types, and provides guidance on emission factor databases and on accounting for time-varying emissions. It further describes how the models simulate the interaction between pollutant plumes from different sources within an industrial complex, in terms of building wake effects and enhanced plume buoyancy.

The simulation of terrain effects on pollutant dispersion is examined in detail, including a description of methods used by the main models.

There is some discussion on atmospheric chemistry - a common requirement is the determination of NO₂ concentrations, given emissions of NOₓ. A couple of
empirical methods for this are described, although the guide does not favour one over the other.

A complete chapter of this guide is devoted to the meteorological aspects of dispersion modelling. The complex terrain of New Zealand, and the coastal location of most settlements, can lead to highly complicated meteorological features in the vicinity of many pollutant sources. These include land-sea breezes, slope-valley flows and internal boundary layers (with associated fumigation effects), which may cause complex patterns of pollution dispersion.

A fundamental difference between steady-state and advanced models is in their meteorological data requirements. The development of single-site meteorological data for steady-state dispersion models is discussed, including screening data sets, the treatment of calms, missing data, and the derivation of parameters such as stability class and mixing height. The development of three-dimensional time-dependent meteorological data sets for advanced dispersion models using prognostic and diagnostic models is also discussed in detail. The advantages and limitations of all approaches are examined.

Guidance on the analysis of model results is given, to ensure that results are realistic and credible. This includes model validation, assessment of uncertainties and sensitivity tests. Advice is given on the presentation of statistical summaries, tables, graphs and contour plots at the reporting stage. There is also guidance on the incorporation of background concentrations and the assessment of environmental and health effects.
The good practice guide focuses mainly on discharges from industrial sources, but there is some discussion on other specialised applications, such as airshed modelling, dispersion from roadways, regional and long-range transport, accidental releases, steam effects and visibility. Many of the recommendations regarding industrial discharges apply equally to these other cases.

The guide attempts to be forward thinking by acknowledging that dispersion modelling requirements (that is, new applications) and the models themselves are changing, and by providing guidance on the use of the latest, state-of-the-science dispersion models.

In Australia dispersion model namely “AUSPLUME” an air modelling software for industry [http://www.epa.vic.gov.au, 2009] is the EPA approved air dispersion model for modelling emissions of wastes to air. AUSPLUME must be used in accordance with the requirements set out in the State Environment Protection Policy (Air Quality Management) Schedule C.

AUSPLUME Version 6.0 is the current EPA approved regulatory model in Australia.

The AUSPLUME package includes:

1. the AUSPLUME Windows-based software
2. two meteorological data files
3. sample input and output files
4. sample background files.

AUSPLUME runs under Windows 95/98/NT/2000/XP.
2.8. Concluding Remarks

From perusal of the above mentioned paragraphs it is clear that dust dispersion modeling is an statutory requirement in most of the advance counties like USA, Australia, Newzeland etc, however in Indian condition very limited dust modeling exercise have been conducted. From literature review it has been found that only three studies have been conducted by CMRI Scientists in Indian Mining condition.

It is also to be noted that out of the three US EPA models namely FDM, ISCST & PAL-2, suitable for fugitive dust modeling under coal mining conditions, FDM has been found to be most appropriate and accurate through the above three studies conducted by CMRI, Scientists. Hence, FDM model has been selected as appropriate Model for the present study.

Further, the emission rate equations derived by CMRI through a study instituted by Indian Ministry of Environment & Forest have been used as input for the model because the Emission Factors given in USEPA web site (AP-42) are not fully appropriate for Indian Mining Conditions considering the quite different geo-mining and altogether different climatological conditions prevailing in Indian conditions.