2.1 Meteorology

The study of earth’s atmosphere is termed as Meteorology. A close interaction between air pollutants and atmosphere are of great significance in transport, diffusion and natural cleansing of pollutants in the atmosphere [1]. With emission of pollutants the air borne cycle is initiated followed by their transport and diffusion in the atmosphere. This process will be completed by their deposition on soil, vegetation, water surfaces and on other objects and the pollutants will be finally washed out in the atmosphere by rain [2]. In some cases, the pollutants get reintroduced into the atmosphere by wind. Topographical and Meteorological conditions influence restricted dispersion of air pollutants, causing them to concentrate at harmful levels. In highly industrialized and traffic prone areas, the concentration of pollutants exceeding safer limit may adversely affect men, material and vegetation. Thus, information is very essential in locating the industry and planning control measures for air pollution [3]. The ambient air quality is influenced not only by the rate at which pollutants are released but also by physical situations like meteorological conditions, wind speeds and direction, temperature, humidity etc. which actually influence the concentration of pollutants by dispersion or diffusion [4].

2.2 The Earth’s Atmosphere

The atmosphere is an insulating blanket protecting our earth. It is composed of various gases and water vapour and in its upper most regions it is charged with subatomic particles. Atmosphere
consists of 78% nitrogen, 21% oxygen and traces of argon, CO$_2$, neon, helium, methane etc. Atmosphere is the only layer supporting life, hence this layer is of great significance in the field of air pollution [5]. The atmosphere stores and distributes contaminants which have been released into it, and it is this function which is of interest in air pollution. The behavior of atmosphere determines whether the pollution released into it will remain around us or shall be blown away. The atmosphere is a mixture of gases surrounding the earth in several layers of varying thickness and density [6].

Fig. 2.1: Temperature profile of earth’s atmosphere [1].

The layer nearest to the earth is called troposphere, which extends from the earth’s surface to about 10-12 km. In general, the atmosphere is not heated by the sun’s rays, rather is heated from below by the warm earth. Temperature, therefore, decrease with altitude in this layer along with the decrease in density and pressure of gases. The lower troposphere up to 2 km is of most interest in air pollution meteorology. About 80% of the mass of atmosphere is contained in the troposphere [3]

The next layer, the stratosphere, is characterized by the increasing temperature. Near top of this layer is a layer of ozone, which absorbs ultraviolet (UV) solar radiation and
gets heated. UV radiation, in fact, dissociate the ozone into an oxygen atom (O) and a molecule of oxygen (O$_2$), and their reunion again in ozone, releases energy in the form of heat. This makes the stratosphere a warm area and a shield to prevent the entry of harmful UV radiation and cosmic rays into the lower atmosphere near the ground level.

The layer above the stratosphere is called mesosphere, in which the temperature decreases with altitude falling up to 110ºC at the top. Above this, is a layer where ionization of the gases is a major phenomenon, thus, increasing the temperature again. This layer is called thermosphere or Ionosphere

Only lower troposphere is routinely involved in the determination of weather, and hence in air pollution. The other layers are of least significance in determining the fate of air pollution.

### 2.3 Meteorological factors influencing Air Pollution

The degree to which air pollutants discharged from various sources and concentrate in a particular area depends largely on meteorological conditions. The application of dispersion theory and knowledge of local weather conditions are necessary to determine the required stack height for emission and to evaluate the intensity of air pollution. In a specific area the total discharge of the pollutants into the atmosphere remains constant on all the days. However, the degree of air pollution vary widely because of differences in meteorological conditions. The Meteorological factors influencing air pollution classified as Primary and Secondary parameters. They are detailed below.

The Primary parameters are
Heat, temperature, environmental lapse rate and atmospheric stability.

Wind direction, wind speed and mixing height.

The secondary parameters are

Precipitation, Humidity and Solar radiation.

Low pressure and high pressure.

2.4 Effects of meteorological parameters on transport and diffusion of Air Pollutants

The air pollution cycle can be considered to be consisted of three phases, i.e., release of air pollutants at the source, their transport and diffusion in the atmosphere and reception of air pollutants by people, plants, animals and other objects. The most concern in transport and diffusion of pollutants are the wind and atmospheric stability.

Heat

One of the atmospheric critical variable is heat. Sun radiates energy and earth receives if in the form of short wave radiation ($0.5\mu m$), is in the form of visible light. After striking the earth, it loses energy and reradiates to the atmosphere as long wavelength radiation ($10-18\mu m$), in the form of non visible radiation.

Wind Effects

The wind is a result of unequal distribution of atmospheric temperature and pressure on earth’s surface and affected by the earth’s rotation. The direction of wind is always from high pressure to low, but the coriolis force deflects air currents out of these
expected patterns. The horizontal motion of air plays a significant role in air pollution. The speed of the wind determines that how the pollution is diluted and blown away and the direction of the wind decides the direction in which dilution take place. The concentration of pollutants in the air decreases with the increase in the speed of wind.

**Pressure**

The difference in surface roughness, radiation and wind energy combine to development high and low pressure systems. The low pressure is associated with cloudy skies, gusty winds, formation fronts leading to atmospheric instability. Due to unstable atmosphere with minimum dispersion the air pollution will be less.

**Fronts**

Air of different properties does not mix up. The colder air tends to over slide less dense air. In case of warm fronts, warm air being lighter rises over the cold air, and a wide band of precipitation results. The precipitation is normally heavy in the beginning but decreases as warm air progresses.

**Humidity**

It is a measure of water vapor in atmosphere. The amount of moisture in air depends on temperature. Topography also influence humidity. Humidity acts as a catalyst in the reaction of air pollutants like SO$_2$, NO$_2$ and particulates, Moisture indicates the potentiality for fog formation in relation to the degree of air pollution.

**Rainfall and precipitation**

Precipitation has a twofold cleansing action on the air pollutants. It helps to remove gaseous pollutants that are soluble in water. It also acts as a scrubbing agent for the
removal of gaseous pollutants, air borne radio-active wastes and particulates matter their by accelerating the process of deposition of pollutants on the ground. Precipitation in the form of fog does not allow the pollutants to disperse easily and brings the pollutants downwards forming a thick blanket sinking onto the ground.

2.5 Atmospheric stability

Atmospheric stability is governed by vertical motions of air. Atmosphere can be called unstable when there is an appreciable vertical turbulence in air. The unstable atmosphere facilitates dispersion of pollutants vertically in the air. Reduction in the vertical turbulence produces stable atmosphere. The vertical turbulence of air is the result of solar heating of the ground which produces convection currents of the air.

Temperature lapse rates and temperature inversion

The rate of change of temperature in atmosphere with height is called temperature lapse rate. The temperature of atmosphere decreases by about 1.8°C. When the reverse or negative lapse rate occur, cold stratum of air at the ground level gets covered by lighter and warmer air at the higher level, then one say inversion is caused. Inversion condition is responsible for creating strongly stable atmosphere that is considered to be highly unfavorable for the dispersion of pollutants. Because of inversion, vertical air movement is stopped and pollution is concentrated below the inversion layer. During temperature inversion, the atmosphere is stable and very little turbulence takes place. Due to this, pollutants in the air do not disperse. During winter season, inversion is frequent the concentration of smoke and other contaminants leads to increase in the concentration of pollutants by preventing sun’s rays from warming the ground and surrounding air. Inversion commonly associated with fog.
Adiabatic Lapse Rate

On the basis of temperature gradients, the lapse is classified into different categories. The dry adiabatic lapse rate is characterized by a temperature decrease at the rate of 1°C per 100 meter. The Lapse rate of a parcel of dry air as it moves upward in a hydrostatically stable environment and expands slowly to lower environmental pressure without exchange of heat, is known as the adiabatic lapse rate. The decrease of temperature at more than 1°C per 100 meter is called super adiabatic lapse rate and the temperature decrease with a rate less than 1°C per 100 meter is sub adiabatic lapse rate. Under the condition of adiabatic lapse rate, a smoke plume can rise into the atmosphere by virtue of being low dense until it reaches air of similar density. During summer, rapid heating of the earth by the sun warms air near the surface, then the lapse rate become super adiabatic and that makes atmosphere to be unstable. Under these conditions pollutants get dispersed rapidly.

Mixing height

An important primary meteorological parameter is the ‘mixing height’. It is defined as, the height above earth’s surface to which related pollutants will extend due to atmospheric turbulence. Mixing height is related to these factors wind direction, wind speed and wind turbulence.

2.6 Thermodynamics and Air pollution

Laws of thermodynamics find its application in almost all fields of air pollution, from source of origin to control. In depth study of the role of thermodynamics is useful not only in controlling the emissions of pollutants into atmosphere by various sources [5].
Thermodynamics of gaseous Pollutants monitored during the study period explained as follows [5].

**Thermodynamics of formation of oxides Sulphur (SO\(_X\))**

Major source of sulphur are burning of fossil fuel its combustion processes release significant quantities of oxides of sulphur. Coal contains 0.5 to 4% of sulphur like wise residual fuel also contain 1-4% of sulphur. The reaction for the formation of sulphur dioxide from sulphur in fossil fuels is

\[
S + O_2 \rightarrow \text{SO}_2
\]

The reaction is highly exothermic with a heat release of about 30000kj/mole at 25 °C in addition to \(\text{SO}_2\), traces of \(\text{SO}_3\) also formed in the combustion reaction. In the combustion of fossil fuels \(\text{SO}_2\) can act both as a reducing agent and an oxidizing agent at normal atmospheric conditions [5].

Important thermodynamic relations are

\[
\text{SO}_2 + \frac{1}{2} \text{O}_2 \rightarrow \text{catalyst} \rightarrow \text{SO}_3
\]

In the presence of humidity, \(\text{SO}_2\) forms acid mists as given in the following reaction.

\[
2\text{SO}_2 + 2 \text{H}_2\text{O} + \text{O}_2 \rightarrow \text{catalyst} \rightarrow 2\text{H}_2\text{SO}_4
\]

\[
\text{SO}_3 + \text{H}_2\text{O} \rightarrow \text{H}_2\text{SO}_4
\]

Salts such as sulphates and chlorides of iron and manganese are the noted catalysts for these reactions. The acid mists are corrosive and reduce visibility and are responsible for the formation of acid rains. \(\text{SO}_2\) is the main oxide of sulphur formed in the combustion and the conversion of \(\text{SO}_2\) to \(\text{SO}_3\) in the atmosphere is a slow process. \(\text{SO}_2\) gets easily converted to \(\text{SO}_3\) in the presence of particulates and humidity. This
leads to an increase in sulphate aerosol formation that is dangerous to man and material [5]

**Thermodynamics of formation of Nitrogen oxides (NO\textsubscript{X})**

Vehicular emission is one main source of nitrogen oxides. Atmospheric nitrogen is another source of nitrogen. It is the element primarily responsible for the formation of photo chemical smog. Nitrogen combines with oxygen in the presence of known catalyst during combustion and forms oxides of nitrogen. These reactions lead to the formation of chemical compounds which may not affect humans and plants. In particular, major cities with high automobile, high population density and industrial emissions in large scale experiences the effects induced by the nitrogen oxides. The stable gaseous oxides of nitrogen include nitrogen dioxide (NO\textsubscript{2}), nitric oxide (NO), nitrogen trioxide oxide (N\textsubscript{2}O\textsubscript{3}) and nitrogen pentoxide (N\textsubscript{2}O\textsubscript{5}). Among the oxides of nitrogen, nitrogen dioxide is present in significant amount in the atmosphere.

The main chemical reactions in the formation of nitrogen oxides are

\[
\frac{1}{2} \text{N}_2 + \frac{1}{2} \text{O}_2 \rightarrow \text{NO}
\]

\[
\text{NO} + \frac{1}{2} \text{O}_2 \rightarrow \text{NO}_2
\]

The two main reactions of concern in air pollution are

\[
\text{N}_2 + \text{O}_2 \rightarrow 2\text{NO}
\]

\[
\text{NO} + \frac{1}{2} \text{O}_2 \rightarrow \text{NO}_2
\]
References


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6  World Health Organization (WHO), 2003.