UNIT II

1. List the types of plume behavior

Plume refers to the path and extent in the atmosphere of the gaseous effluents released from a source usually a stack (chimney)

The behavior of a plume emitted from any stack depends on localized air stability. The Geometric forms of stack plumes are a function of the vertical temperature and wind profiles, vice versa, by looking at the plume one can state stability condition and dispersive capacity of atmosphere.

The behavior and dispersion of a plume entirely depend on the environmental lapse rate (ELR).influencing the flume behavior are the diurnal (seasonal) variations in the atmospheric stability and the long term variations which occur with change in seasons Effluents from town stacks are often injected to an effective height of several 100m aboveground because of the cumulative effects of buoyancy and velocity on plume rise other factors.

Six types of plume behavior are shown in the figure below; the spread of the plume is directly related to the vertical temperature gradient as shown in the figure.

1)Looping

2)Coning

3)Fanning

4)Lofting

5)Fumigation

6)Trapping

LOOPING:

It is a type of plume which has a wavy character. It occurs in a highly unstable atmosphere because of rapid mixing. The high degree of turbulence helps in dispersing the plume rapidly but high concentrations may occur close to the stack if the plume touches the ground.

CONING:

It is a type of plume which is shaped like a CONE. This takes place in a near neutral atmosphere, when the wind velocity is greater than 32 km/hr. However the plume reaches the ground at greater distances than with loping.

FANNING:

It is a type of plume emitted under extreme inversion conditions. the plume under these condition will spread horizontally, but little if at all vertically. Therefore the prediction of ground level concentration (SLC) is difficult here

.LOFTING:

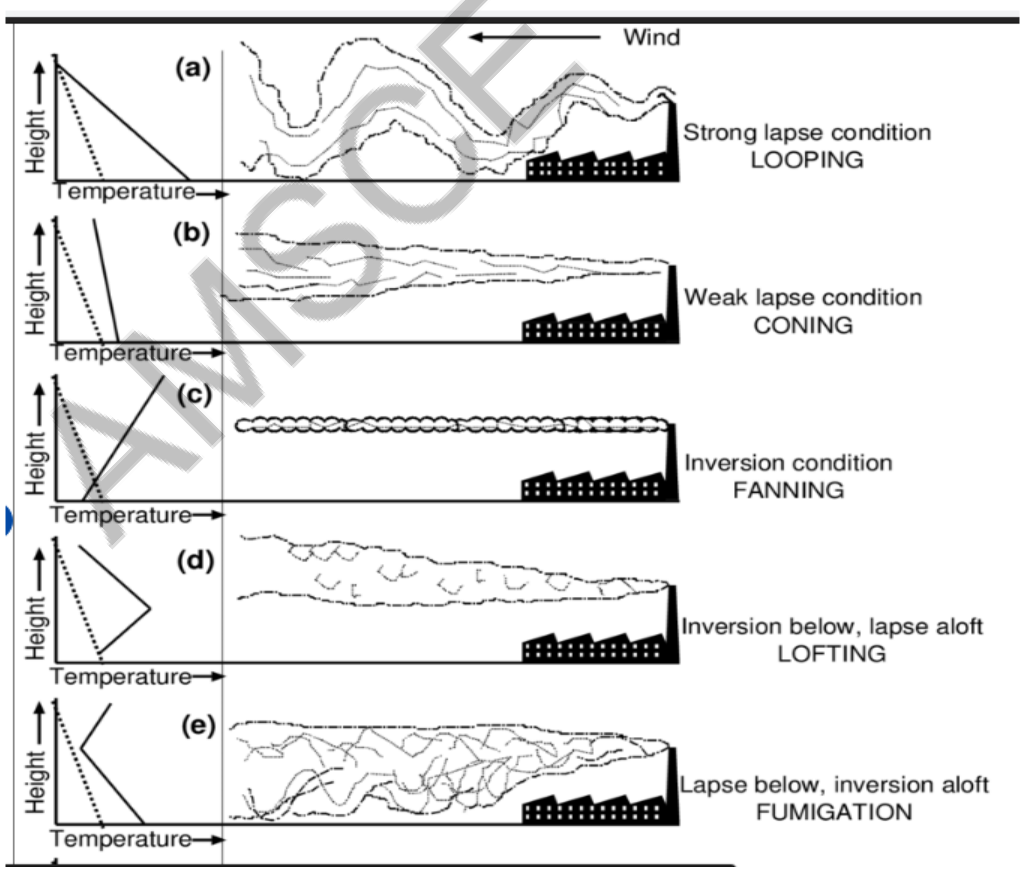
Lofting occurs when there is a strong lapse rate above a surface inversion. Under this condition, diffusion is rapid upwards, but downward diffusion does not penetrate the inversion layer under these conditions, emission will not reach surface.

FUMIGATION:

It is a phenomenon in which pollutants that are emitted into the atmosphere are brought rapidly to the ground level when the air destabilizes.

TRAPPING:

This refers to conditions where the plume is caught between inversions and can only diffuse within a limited vertical height. The lofting plume is most favorable air to minimizing air pollution. The fumigation and trapping plumes are very critical from the points of ground level pollutant concentrations



2. Explain dispersion models with applications

There are five types of air pollution dispersion models, as well as some hybrids of the five types

- **Box model** — The box model is the simplest of the model types. It assumes the airshed (i.e., a given volume of atmospheric air in a geographical region) is in the shape of a box. It also assumes that the air pollutants inside the box are homogeneously distributed and uses that assumption to estimate the average pollutant concentrations anywhere within the airshed. Although useful, this model is very limited in its ability to accurately predict dispersion of air pollutants over an airshed because the assumption of homogeneous pollutant distribution is much too simple.
- **Gaussian model** — The Gaussian model is perhaps the oldest and perhaps the most commonly used model type. It assumes that the air pollutant dispersion has a Gaussian distribution, meaning that the pollutant distribution has a normal probability distribution. Gaussian models are most often used for predicting the dispersion of continuous, buoyant air pollution plumes originating from ground-level or elevated sources. Gaussian models may also be used for predicting the dispersion of non-continuous air pollution plumes (called *puff models*). The primary algorithm used in Gaussian modeling is the *Generalized Dispersion Equation For A Continuous Point-Source Plume*.
- **Lagrangian model** — a Lagrangian dispersion model mathematically follows pollution plume parcels (also called particles) as the parcels move in the atmosphere and they model the motion of the parcels as a random walk process. The Lagrangian model then calculates the air pollution dispersion by computing the statistics of the trajectories of a large number of the pollution plume parcels. A Lagrangian model uses a moving frame of reference as the parcels move from their initial location. It is said that an observer of a Lagrangian model follows along with the plume.
- **Eulerian model** — an Eulerian dispersion model is similar to a Lagrangian model in that it also tracks the movement of a large number of pollution plume parcels as they move from their initial location. The most important difference between the two models is that the Eulerian model uses a fixed three-dimensional Cartesian grid as a frame of reference rather than a moving frame of reference. It is said that an observer of an Eulerian model watches the plume go by.

- **Dense gas model** — Dense gas models are models that simulate the dispersion of dense gas pollution plumes (i.e., pollution plumes that are heavier than air). The three most commonly used dense gas models are:
    - The DEGADIS model developed by Dr. Jerry Havens and Dr. Tom Spicer at the University of Arkansas under commission by the US Coast Guard and US EPA.[7]
    - The SLAB model developed by the Lawrence Livermore National Laboratory funded by the US Department of Energy, the US Air Force and the American Petroleum Institute.
    - The HEGADAS model developed by Shell Oil's research division.

3. Explain the atmospheric stability with lapse rate.

In the atmosphere, rising or sinking air will only cool or warm at one of two rates - the dry adiabatic lapse rate or the moist adiabatic lapse rate. The first, the dry adiabatic lapse rate, is the rate an unsaturated parcel of air warms or cools when moving vertically through the atmosphere. The dry adiabatic lapse rate is approximately a 5.5 degree Fahrenheit change in temperature for every 1000 feet of vertical movement. The moist adiabatic lapse rate, on the other hand, is the rate at which a saturated parcel of air warms or cools when it moves vertically. This lapse rate is approximately 3.3 degrees Fahrenheit for every 1000 feet of vertical movement.

The actual stability of an air parcel is determined by the orientation of the environmental lapse rate in comparison with either the dry or moist adiabatic lapse rates. The environmental lapse rate is simply what it says- the rate of change of the temperature of the environment (atmosphere) with changing altitude. It is important to relaize that because the atmosphere (environment), on average, is not rising or sinking, the environmental lapse rate can look much different than the dry or moist adiabatic lapse rates. In fact, it is those differences that allow us to determine whether a particular part of the atmosphere is stable or unstable.

The atmosphere is considered to be unstable if a rising parcel cools more slowly than the environmental lapse rate. This causes the air parcel to remain warmer and less dense than its surroundings and, therefore, continue to accelerate upward.

The atmosphere is considered to be stable if a rising parcel cools faster than the environmental lapse rate. This causes the air parcel to be cooler and more dense than its surroundings and, therefore, lose its buoyancy. Vertical motions tend to be restricted when the atmosphere is in stable equilibrium.

A temperature inversion occurs when the temperature increases with height. The environmental profile associated with a temperature inversion is the most stable type of environment. The inversion is at the top, where temperature increases with height.

When the environment is unstable, air mixes readily in the vertical. This vertical mixing can have a profound effect on various atmospheric phenomena as diverse as air quality, wind speed and cloud type. Vertical mixing in an unstable environment helps bring cleaner air from above down to the surface, while transporting polluted air aloft. Also, stronger winds from above (where there is little friction) can be transported (mixed) toward the ground when the atmosphere is unstable. This is why it is often breezy on a sunny afternoon, and often quite calm in the morning, when vertical mixing is restricted

The atmospheric motions that occur in a stable environment are fundamentally different than those found in an unstable environment. The most profound difference between these two types of environments is the inhibition of vertical mixing in the stable environment. The lack of vertical mixing leads to a "stratified" atmosphere, where many atmospheric variables are separated into layers instead of being well-mixed. The stratification of the atmosphere when stable leads to, for instance, pollution episodes and drastic changes in wind speed and direction over short vertical distance

Relationships between pressure and temperature lead to a simple linear relation between temperature and altitude for rising or sinking air. This is known as the Dry Adiabatic Lapse Rate (DALR), and is equal to 9.8°K km-1. Air lifted up will cool at this rate due to reduction in pressure, air sinking will warm at this rate due to pressure increases. This was demonstrated in the pressure vessel (Lecture 2). The word ‘adiabatic’ is derived from the Greek word for ‘impassable’, and it refers to a system which does not lose or gain energy. Thus, rising air is said to cool or warm adiabatically when its temperature changes are due entirely to pressure changes. In reality, some degree of energy exchange will always take place, but these are generally small on short timescales.

When condensation or evaporation occur in the air, however, lapse rates of rising or falling air differ from this value. As we have seen in Lecture 1, latent heat is released by condensation and consumed by evaporation (2,500 J g-1). This alters the adiabatic lapse rate: because energy is released by condensation, rising air will cool more slowly if condensation is occurring. Thus, there is a smaller change in temperature with height than would be the case for unsaturated air. The modified lapse rate is termed the Saturated Adiabatic Lapse Rate (SALR). The varying amounts of water vapour that can be held in air at different temperatures means that the SALR is non linear. The SALR is lowest at high temperatures, because of much higher saturation mixing ratios: i.e: greater amounts of energy are released at the vapour/droplet transition, therefore temperature changes with altitude are reduced. At low temperatures, the SALR is more similar to DALR: smaller amounts of moisture are available for condensation, so the modification of the lapse rate is less.

Adiabatic Lapse Rates are commonly different to the real vertical change in temperature, known as the Environmental Lapse Rate (ELR). The ELR is influenced by patterns of heating, cooling and mixing, and the past history of an air mass. Actual vertical temperature gradients in the atmosphere are thus highly variable, and can even show an increase in temperature with height, a situation known as a temperature inversion

The stability of air masses depends on the relative values of the ELR and the appropriate Adiabatic Lapse Rate.

Stability

Air is stable if the ELR less than the ALR. If, for any reason, a parcel of air is uplifted, it will cool to lower temperatures than its new surroundings along the ALR. Hence the air parcel will be denser than its surroundings and will tend to fall back to its original level. This situation is encouraged by a small ELR or a temperature inversion.

The lapse rate is considered positive when the temperature decreases with elevation, zero when the temperature is constant with elevation, and negative when the temperature increases with elevation (temperature inversion). The lapse rate of nonrising air—commonly referred to as the normal, or environmental, lapse rate—is highly variable, being affected by radiation, convection, and condensation; it averages about 6.5 °C per kilometre (18.8 °F per mile) in the lower atmosphere (troposphere). It differs from the adiabatic lapse rate, which involves temperature changes due to the rising or sinking of an air parcel. Adiabatic lapse rates are usually differentiated as dry or moist.

The dry adiabatic lapse rate for air depends only on the specific heat capacity of air at constant pressure and the acceleration due to gravity. The dry adiabatic lapse rate for the Earth's atmosphere equals 9.8 °C per kilometre (28.3 °F per mile); thus, the temperature of an air parcel that ascends or descends 5 km (3 miles) would fall or rise 49 °C (85 °F), respectively.

When an air parcel that is saturated with water vapour rises, some of the vapour will condense and release latent heat. This process causes the parcel to cool more slowly than it would if it were not saturated. The moist adiabatic lapse rate varies considerably because the amount of water vapour in the air is highly variable. The greater the amount of vapour, the smaller the adiabatic lapse rate. As an air parcel rises and cools, it may eventually lose its moisture through condensation; its lapse rate then increases and approaches the dry adiabatic value.

The difference between the normal lapse rate in the atmosphere and the dry and moist adiabatic lapse rates determines the vertical stability of the atmosphere—that is, the tendency of an air particle to return to its original position or to accelerate away from its original position after being given a slight vertical displacement. For this reason, the lapse rate is of prime importance to meteorologists in forecasting certain types of cloud formations, the incidence of thunderstorms, and the intensity of atmospheric turbulence.

4. Explain the meteorological factors affecting air pollution and its effects on air pollution.

- Wind, speed and direction
- Temperature
- Atmospheric stability
- Mixing height
- Rainfall and precipitation
- Humidity
- Solar radiation
- Visibility

Wind, speed and direction:

- It changes the concentration of pollutant near ground level.
- The pollutant gets diluted with high volume of atmospheric air.
- Gustiness determines the dilution of the pollutant with air.
- In plane area the wind speed decides the movement of pollutant.
- In hilly areas hills deflect the air flow.
- Wind speed can be measured by anemometer.

Atmospheric Stability and inversion:

- It is defined as the measure of atmospheric tendency to encourage the vertical motion.
- The degree of atmospheric stability is determined by temperature differences between the air parcel and the air surrounding in it.
- The rate at which the atmospheric temperature decreases with increase in altitude is known as lapse rate.
- When the negative lapse rate occurs, a dense cold air at the ground level is covered by warm air at higher level. This is inversion.
- Due to the temperature inversion the atmosphere is stable and mixing of air with pollutant takes place.

Mixing height:

- It is the height above the earth surface to which pollutant will extend through the atmospheric turbulence.

Precipitation and Rainfall:

- It exerts two fold cleansing action on the pollutant.
- Rainfall accelerates the deposition of particulate matter on the ground.

Humidity:

- The moisture content of the atmosphere affects the corrosive action of air pollutant and represents the potentiality for fog formation.

Solar Radiation:

- It includes the chemical reaction between atmospheric air components and pollutants in air.
- The reaction depends upon the location.

5. What are the effects of meteorology on air pollution.

- Solar radiation and temperature affects the quantity of pollutant by their influence on amount of space heating required.
- Sunshine is the reason for photochemical production of oxidant forming smog.
- The wind velocity, turbulence and stability affects the transport, dilution and dispersion of pollutant.
- The rainfall has a scavenging effect in washing out the particles in atmosphere.
- The humidity affects the pollutant concentration.

6. List the factors affecting dispersion of pollutant.

- Source characters.
- Emission rate of pollutant.
- Stack height.
- Exit velocity of gas.
- Exit temperature of the gas.
- Stack diameter.
- Meteorological conditions.
- Wind velocity.
- Wind direction.
- Ambient temperature.
- Atmospheric stability.