AIR POLLUTION AND CONTROL ENGINEERING

UNIT I INTRODUCTION

Structure and composition of Atmosphere – Definition, Scope and Scales of Air Pollution– Sources and classification of air pollutants and their effect on human health, vegetation, animals, property, aesthetic value and visibility- Ambient Air Quality and Emission standards –Ambient and stack sampling and Analysis of Particulate and Gaseous Pollutants.

Structure and composition of atmosphere

Atmosphere, **composition** and **structure**. Earth's **atmosphere** is composed of about 78% nitrogen, 21% oxygen, and 0.93% argon. The remainder, less than 0.1%, contains such trace gases as water vapor, carbon dioxide, and ozone.

Definition of Air pollutants: Substances introduces into the air, natural or manmade, in concentrations detrimental to human, plant or animal life, or to property.

Major Classification of Air Pollutants:

1] Primary – Secondary

2] Natural – Manmade

3] Criteria Air Pollutants

4] Physical - chemical - biological

Primary pollutants and secondary pollutants: Primary pollutants are substances that are directly emitted into the atmosphere from sources. Primary pollutants are those that are emitted directly from identifiable sources. Secondary air pollutants are those that are produced in the air by the interaction of two or more primary air pollutant.

Primary Air pollutants:-

(i) Fine (less than 100µ) and coarse (more than 100µ) suspended particulate matter

(ii) Oxides of sulfur

(iii) Oxides of nitrogen

(iv) Carbon monoxide

(v) Halogens

(vi) Organic compounds

(vii) Radioactive compounds

Secondary Air pollutants:-

(i) Ozone

(ii) PAN (peroxi aceyl nitrate)

(iii) Photochemical smog

(iv) Acid mists

Air pollutants arise from both manmade and natural processes. The ambient air quality may be defined by the concentration of a set of pollutants which may be present in the ambient air we breathe in. These pollutants may be called **criteria pollutants**.

Natural Contaminants: Pollen is important natural contaminant because of its peculiar properties of irritation and allergy sometimes leading to bronchitis, asthma and dermatitis. Pollen grains are the male gametophytes of gymnosperms and angiosperms and they are discharged into the atmosphere from plants etc. The air transported pollen grains range mainly between 10 and 50 microns. Manmade refers to any pollutant produced to influence or action of humans.

Aerosols: Aerosols refer to the dispersion of solid or liquid particles of microscopic size in the air. It can also be defined as a colloidal system in which the dispersion medium is gas and the dispersed phase is solid or liquid. The term aerosol is applicable until it is in suspension and after settlement due to its own weight or by addition with other particles (agglomeration) it is no longer an air pollutant. The diameter of the aerosol may range from 0.01 (or less) micron to 100 micron.

The various aerosols are as follows:-

(i) **Dust:** Dust is produced by the crushing, grinding and natural sources like windstorms. Generally the dust particles are over 20 micron in diameter. They do not flocculate but settle under gravity, but smaller particles like 5 micron form stable suspensions.

(ii) **Smoke:** Smoke is made up of finely divided particles produced by incomplete combustion. Generally it consists of carbon particles of size less than 1.0 micron.

(iii) **Mists:** Mist is a light dispersion of minute water droplets suspended in the atmosphere ranging from 40 to 400 micron in size.

(iv) **Fog:** Fog is made up of dispersion of water or ice near the earth’s surface reducing visibility to less than 500 m. In natural fog the size of particles range from 1.0 to 40 micron.

(v) **Fumes:** Fumes are solid particles generated by condensation from the gaseous state after volatilization from melted substances. Fumes flocculate and sometimes coalesce. Gases:

Following are the **main air pollutant gases**

(i) **Sulphur dioxide:** It is a major air pollutant gas produced by the combustion of fuels like coal.

The main source of electricity production is by burning of fossil fuels in India and the whole world. The sulphur content of the coal varies from 1 to 4% and fortunately the Indian coal is low in sulphur content. SO2 is also produced in the metallurgical operations.

(ii) **Oxides of nitrogen:** Oxides of nitrogen are produced either in the production of nitric acid or in the automobile exhausts and as the effluent of power plants. Out of the seven oxides of Nitrogen (N2O, NO, NO2, NO3, N2O3, N2O4, N2O5) only nitric oxide and nitrogen dioxide are classified as the main pollutants. All the oxides of nitrogen are collectively known as NOX.

(iii) **Carbon monoxide:** It is produced because of the incomplete combustion of coal and other petroleum products. It is produced in the exhaust of automobiles. In the pollution check of vehicles mainly CO and unburnt hydrocarbons are measured.

(iv) **Hydrogen sulphide:** Hydrogen Sulphide is an obnoxious (bad smelling) gas. It is produced mainly by the anaerobic (in absence of air) decomposition of organic matter. Other air polluting sulfur compounds are methyl mercaptan (CH3SH) and dimethyl sulphide (CH3-S-CH3) etc.

(v) **Hydrogen fluoride:** It is an important pollutant even in very low concentrations. It is produced in the manufacturing of phosphate fertilizers.

(vi) **Chlorine and hydrogen chloride:** It is mixed in the air either from the leakages from water treatment plants or other industries where it is produced or used. Hydrogen chloride is also evolved in various industrial chemical processes. The main effect of chlorine is respiratory irritation which may be fatal.

(vii) **Ozone:** It is a desirable gas in the upper layers of atmosphere as it absorbs the UV radiation of sunlight. But near the earth surface it is a poisonous gas. It makes poisonous chemicals by photochemical reactions.

(viii) **Aldehydes:** They are produced by the incomplete oxidation of motor fuels and lubricating oil. They may also be formed because of photochemical reactions. Formaldehydes are irritating to the eyes.

Classification according to chemical composition: (Organic – inorganic)

1. Sulfur-containing compounds.
2. Nitrogen-containing compounds.
3. Carbon-containing compounds.
4. Halogen-containing compounds.
5. Toxic substances (any of about).
6. Radiative compounds.

Classification according to physical state:

1. Gaseous.
2. Liquid (aqueous).
3. Solid.

Criteria air pollutants are six major pollutants defined by EPA (Environmental Protection Agency) for which ambient air standards have been set to protect human health and welfare.

These include :

1. Ozone, O_3.
2. Carbon monoxide, CO.
3. Sulfur dioxide, SO_2.
4. Nitrogen oxides, NO_x.
5. Lead, Pb.
6. Particulates, PM10.

Pollutant	**Description**	**Sources**	**Health Effects**	**Welfare Effects**
Carbon Monoxide (CO)	Colorless, odorless gas	Motor vehicle exhaust, indoor sources include kerosene or wood burning stoves.	Headaches reduced mental alertness, heart attack, cardiovascular diseases, impaired fetal development, and death.	Contribute to the formation of smog.
Sulfur Dioxide (SO2)	Colorless gas that dissolves in water vapor to form acid, and interact with other gases and particles in the air.	Coal-fired power plants, petroleum refineries, manufacture of sulfuric acid and smelting of ores containing sulfur.	Eye irritation, wheezing, chest tightness, shortness of breath, lung damage.	Contribute to the formation of acid rain, visibility impairment, plant and water damage, aesthetic damage.
Nitrogen Dioxide (NO2)	Reddish brown, highly reactive gas.	Motor vehicles, electric utilities, and other industrial, commercial, and residential sources that burn fuels.	Susceptibility to respiratory infections, irritation of the lung and respiratory symptoms (e.g., cough, chest pain, difficulty breathing).	Contribute to the formation of smog, acid rain, water quality deterioration, global

				warming, and visibility impairment.
Ozone (O3)	Gaseous pollutant when it is formed in the troposphere.	Vehicle exhaust and certain other fumes. Formed from other air pollutants in the presence of sunlight.	Eye and throat irritation, coughing, respiratory tract problems, asthma, lung damage.	Plant and ecosystem damage
Lead (Pb)	Metallic element	Metal refineries, lead smelters, battery manufacturers, iron and steel producers.	Anemia, high blood pressure, brain and kidney damage, neurological disorders, cancer,	Affects animals and plants, affects aquatic ecosystems.
Particulate Matter (PM)	Very small particles of soot, dust, or other matter, including tiny droplets of liquids.	Diesel engines, power plants, industries, windblown dust, wood stoves.	Eye irritation, asthma, bronchitis, lung damage, cancer, heavy metal poisoning, cardiovascular effects	Visibility impairment, atmospheric deposition, aesthetic damage.

Chapter 7

Meteorology and Air Pollution

The earth's atmosphere is about 100 miles deep.

That thickness and volume sometimes are suggested to be enough to dilute all of the chemicals and particles thrown into it.

However, 95% of this air mass is within 12 miles of the earth's surface.

This 12-mile depth contains the air we breathe as well as the pollutants we emit.

This layer, called the troposphere, is where we have our weather and air pollution problems.

Weather patterns determine how air contaminants are dispersed and move through the troposphere, and thus determine the concentration of a particular pollutant that is breathed or the amount deposited on vegetation.

An air pollution problem involves three parts:

- The pollution source
- The movement or dispersion of the pollutant
- The recipient

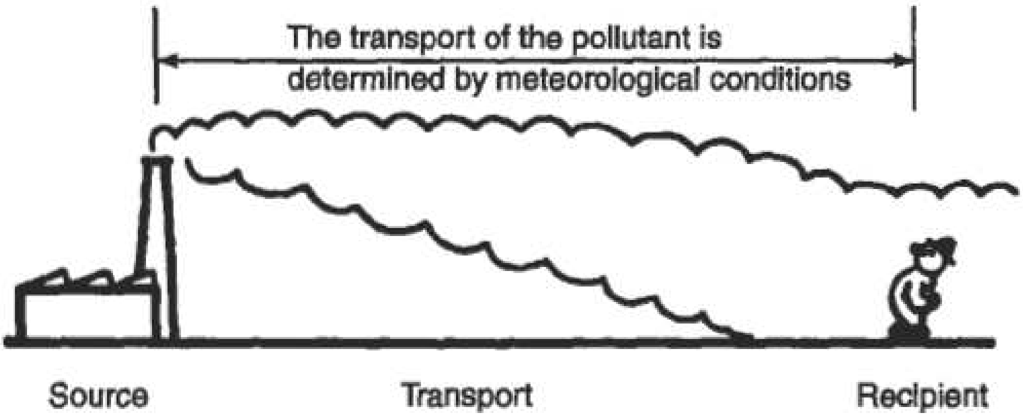


Figure 1. Meteorology of air pollutants.

This chapter concerns itself with the transport mechanism: how the pollutants travel through the atmosphere.

The environmental engineer should be conversant enough with some basic meteorology to be able to predict the dispersion of air pollutants.

BASIC METEOROLOGY

Pollutants circulate the same way the air in the troposphere circulates.

Air movement is caused by solar radiation and the irregular shape of the earth and its surface, which causes unequal absorption of heat by the earth's surface and atmosphere.

This differential heating and unequal absorption creates a dynamic system.

The dynamic thermal system of the earth's atmosphere also yields differences in barometric pressure, associated with low-pressure systems with both hot and cold weather fronts.

Air movement around low-pressure fronts in the Northern Hemisphere is counterclockwise and vertical winds are upward, where condensation and precipitation take place.

High-pressure systems bring sunny and calm weather – stable atmospheric conditions - with winds (in the Northern Hemisphere) spiraling clockwise and downward.

Low- and high-pressure systems, commonly called cyclones and anticyclones, are illustrated in Fig. 2.

Anticyclones are weather patterns of high stability, in which dispersion of pollutants is poor, and are often precursors to air pollution episodes.

The high-pressure area indicates a region of stable air, where pollutants build up and do not disperse.

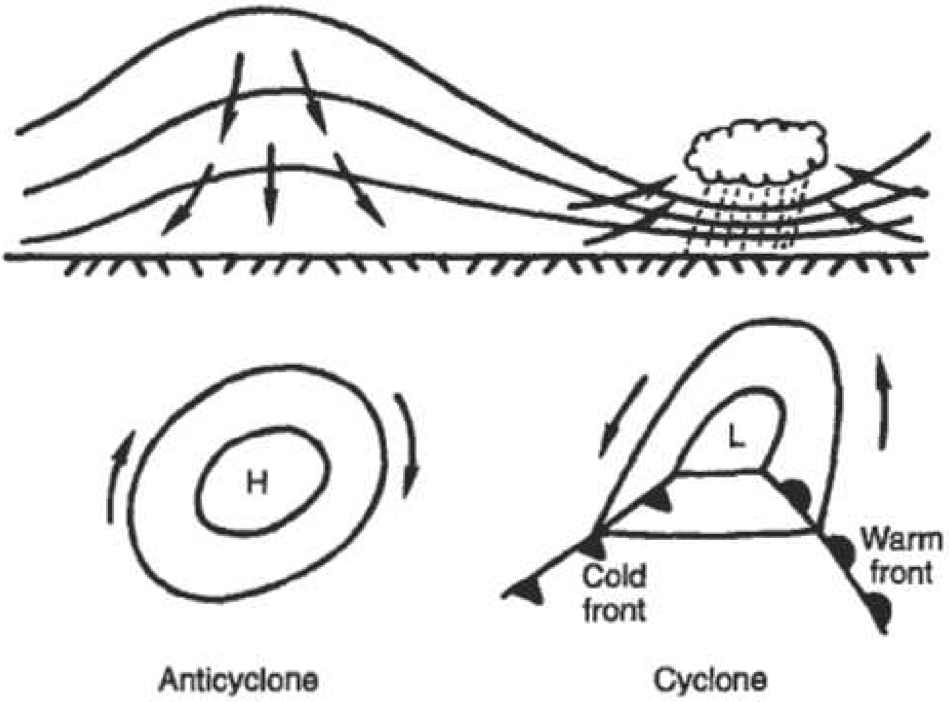


Figure 2. Anticyclone and cyclone.

Air quality management involves both control of air pollution sources and effective dispersion of pollutants in the atmosphere.

HORIZONTAL DISPERSION OF POLLUTANTS

The earth receives light energy at high frequency from the sun and converts this to heat energy at low frequency, which is then radiated back into space.

Heat is transferred from the earth's surface by radiation, conduction, and convection.

Radiation is direct transfer of energy and has little effect on the atmosphere.

Conduction is the transfer of heat by physical contact (the atmosphere is a poor conductor since the air molecules are relatively far apart).

Convection is transfer of heat by movement of warm air masses.

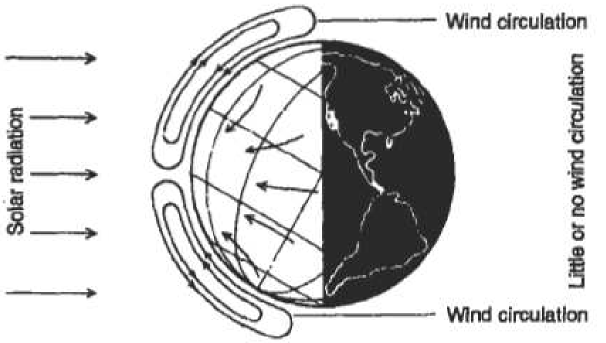
Solar radiation warms the earth and thus the air above it. This heating is most effective at the equator and least at the poles.

The warmer, less dense air rises at the equator and cools, becomes more dense, and sinks at the poles.

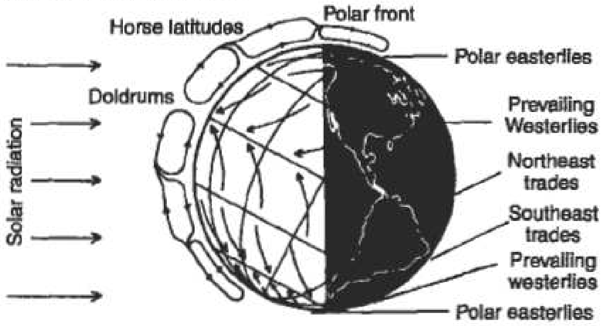
If the earth did not rotate then the surface wind pattern would be from the poles to the equator.

However, the rotation of the earth continually presents new surfaces to be warmed, so that a horizontal air pressure gradient exists as well as the vertical pressure gradient.

The resulting motion of the air creates a pattern of winds around the globe, as shown by Fig. 18-3.



A. If the earth did not turn, the air would circulate in a fixed pattern



B. The earth turns, creating variable wind patterns

Figure 3. Global wind patterns.

Seasonal and local temperature, pressure and cloud conditions, and local topography complicate the picture.

Land masses heat and cool faster than water so that shoreline winds blow out to sea at night and inland during the day.

Valley winds result from cooling of air high on mountain slopes.

In cities, brick and concrete buildings absorb heat during the day and radiate it at night, creating a heat island (Fig. 4), which sets up a self-contained circulation called a haze hood from which pollutants cannot escape.

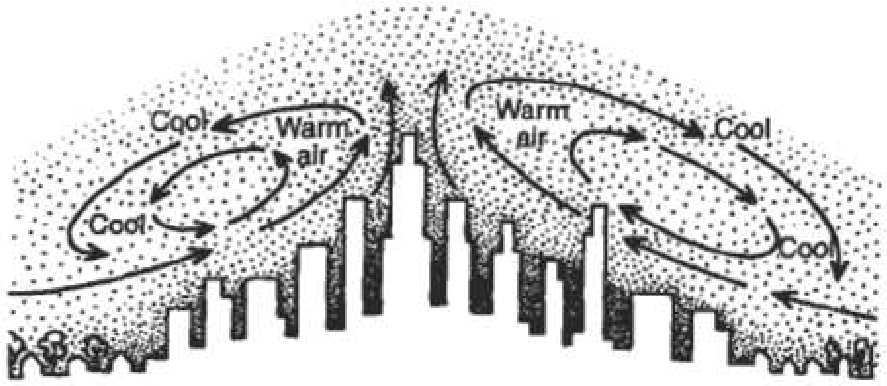


Figure 4. Heat island formed over a city.

Horizontal wind motion is measured as wind velocity. Wind velocity data are plotted as a wind rose, a graphic picture of wind velocities and the direction from which the wind came. The wind rose in Fig. 5 shows that the prevailing winds were from the southwest.

Figure 5. Typical wind rose.

The three features of a wind rose are:

1. The orientation of each segment, which shows the direction from which the wind came
2. The width of each segment, which is proportional to the wind speed
3. The length of each segment, which is proportional to the percent of time that wind at that particular speed was coming from that particular direction.

Air pollution enforcement engineers sometimes use a pollution rose, a variation of a wind rose in which winds are plotted only on days when the air contamination level exceeds a given amount.

Figure 6 shows pollution roses at three points plotted only for days when the SO_2 level exceeded 250 µg/m3.

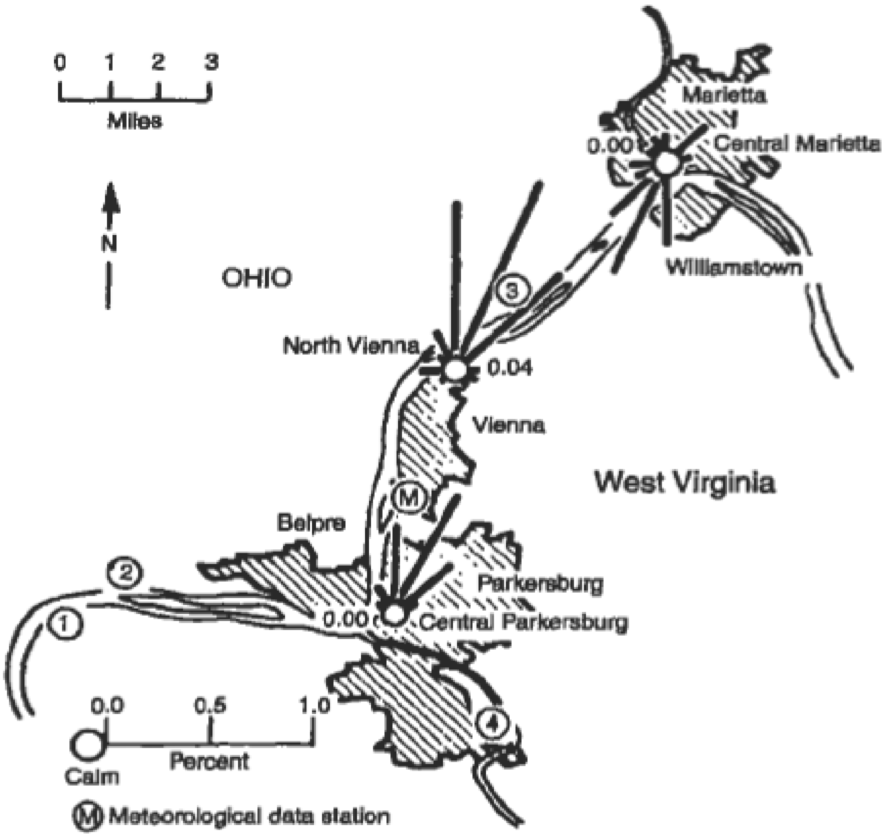


Figure 6. Pollution roses for SO2 concentrations greater than 250 pg/m3. The four chemical plants are the suspected sources, but the roses clearly point to Plant 3, identifying it as the primary culprit.

Note that because the roses indicate the directions from which the wind is coming the apparent primary pollution source is plant 3.

Wind is probably the most important meteorological factor in the movement and dispersion of air pollutants, or, in simple terms, pollutants move predominantly downwind.

VERTICAL DISPERSION OF POLLUTANTS

As a parcel of air in the earth's atmosphere rises through the atmosphere, it experiences decreasing pressure and thus expands.

This expansion lowers the temperature of the air parcel, and therefore the air cools as it rises.

The rate at which dry air cools as it rises is called the dry adiabatic lapse rate and is independent of the ambient air temperature.

The term "adiabatic" means that there is no heat exchange between the rising parcel of air under consideration and the surrounding air.

The dry adiabatic lapse rate may be calculated from basic physical principles.

$$dT/dz|_{\text{dry-adiabatic}} = -9.8°\text{C/km},$$

where T = temperature and z = altitude.

The actual measured rate at which air cools as it rises is called the ambient or prevailing lapse rate.

The relationships between the ambient lapse rate and the dry adiabatic lapse rate essentially determine the stability of the air and the speed with which pollutants will disperse.

These relationships are shown in Fig. 7.

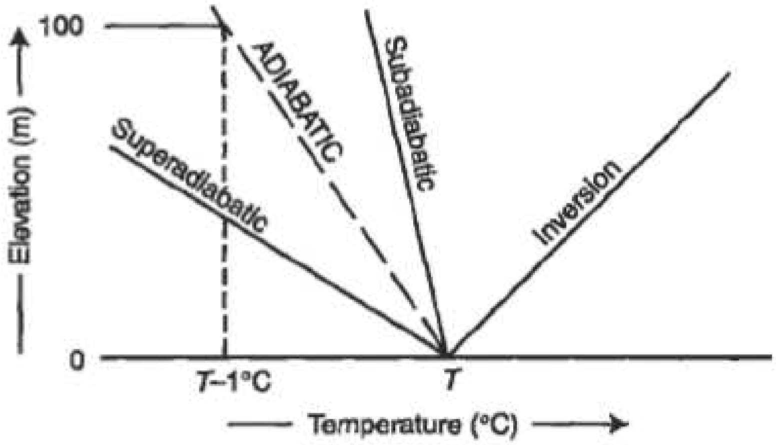


Figure 7. Ambient lapse rates and the dry adiabatic lapse rate.

When the ambient lapse rate is exactly the same as the dry adiabatic lapse rate, the atmosphere has neutral stability.

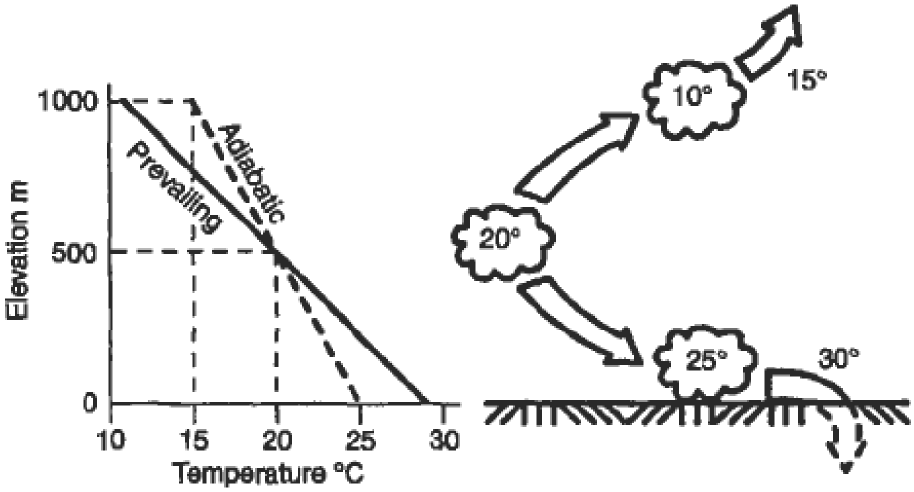
Superadiabatic conditions prevail when the air temperature drops more than 9.8^{o}C/Km (l^{o}C/100m).

Subadiabatic conditions prevail when the air temperature drops at a rate less than 9.8^{o}C/Km.

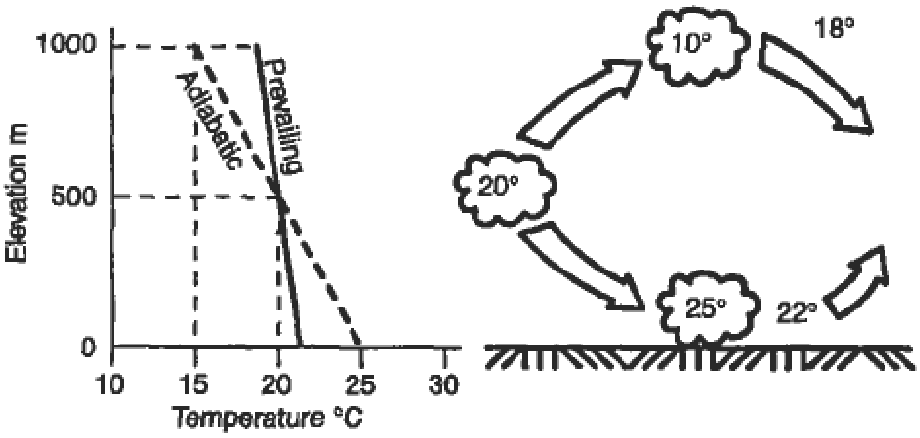
A special case of subadiabatic conditions is the temperature inversion, when the air temperature actually increases with altitude and a layer of warm air exists over a layer of cold air.

Superadiabatic atmospheric conditions are unstable and favor dispersion; subadiabatic conditions are stable and result in poor dispersion; inversions are extremely stable and trap pollutants, inhibiting dispersion.

These conditions may be illustrated by the following example, illustrated in Fig. 8:



A. Super-adiabatic conditions (unstable)



B. Sub-adiabatic conditions (stable)

Figure 8. Stability and vertical air movement.

The air temperature at an elevation of 500 m is 20°C, and the atmosphere is superadiabatic, the ground level temperature is 30°C and the temperature at an elevation of 1 km is 10°C.

The (superadiabatic) ambient lapse rate is -20°C/km.

If a parcel of air at 500 m moves up adiabatically to 1 km, what will be its temperature? According to the dry adiabatic lapse rate of - 9.8^{o}C/Km the air parcel would cool by 4.9 ^{o}C to about 15°C.

However, the temperature at 1 km is not 15°C but 10°C. Our air parcel is 5°C warmer than the surrounding air and will continue to rise.

In short, under subadiabatic conditions, a rising parcel of air keeps right on going up. Similarly, if our parcel were displaced downward to, say, 250m, its temperature would increase by 2.5 ^{o}C to 22.5 ^{o}C.

The ambient temperature at 250 m, however, is 25 ^{o}C, so that our parcel of air is now cooler than the surrounding air and keeps on sinking.

There is no tendency to stabilize; conditions favor instability.

Now let us suppose that the ground level temperature is 22 ^{o}C, and the temperature at an elevation of 1 km is 15°C.

The (subadiabatic) ambient lapse rate is now -7 ^{o}C/Km.

If our parcel of air at 500 m moves up adiabatically to 1 km, its temperature would again drop by 4.9 ^{o}C to about 15°C, the same as the temperature of the surrounding air at 1 km.

Our air parcel would cease rising, since it would be at the same density as the surrounding air.

If the parcel were to sink to 250 m, its temperature would again be 22.5 ^{o}C, and the ambient temperature would be a little more than 20°C.

The air parcel is slightly warmer than the surrounding air and tends to rise back to where it was. In other words, its vertical motion is damped, and it tends to become stabilized, subadiabatic conditions favor stability and limit vertical mixing.

Figure 9 is an actual temperature sounding for Los Angeles. Note the beginning of an inversion at about 1000 ft that puts an effective cap on the city and holds in the air pollution.

This type of inversion is called a subsidence inversion, caused by a large mass of warm air subsiding over a city.

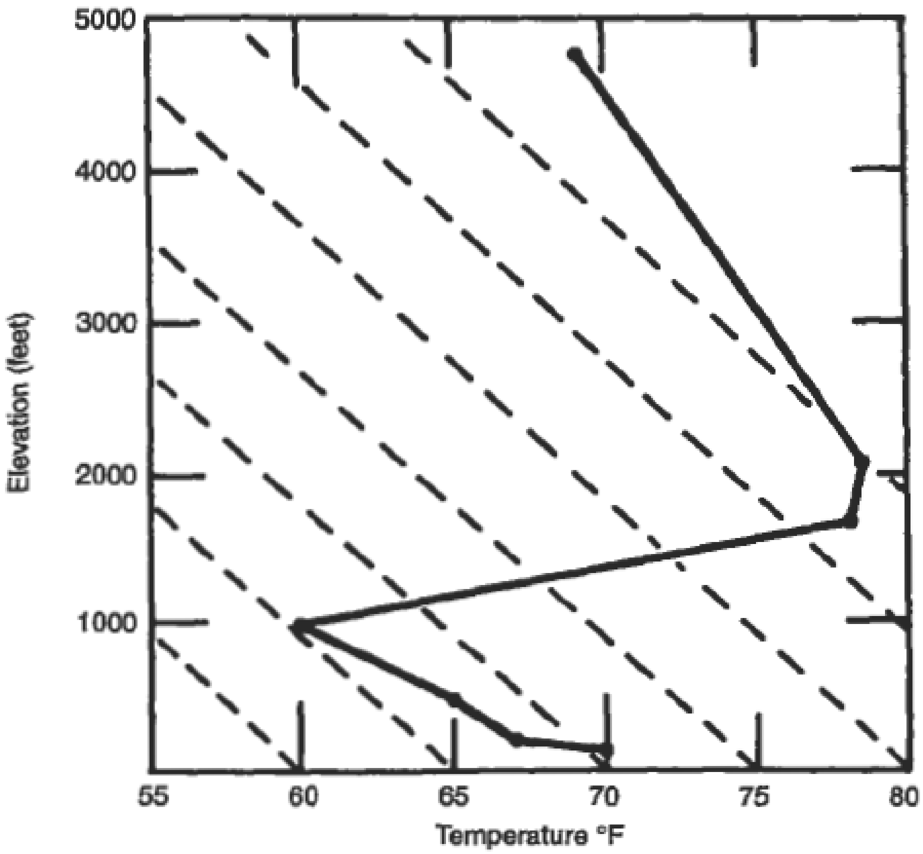


Figure 9. Temperature sounding for Los Angeles, 4 PM, October 1962. The dotted lines show the dry adiabatic lapse rate.

A more common type is the radiation inversion, caused by radiation of heat from the earth at night. As heat is radiated, the earth and the air closest to it cool, and this cold air is trapped under the warm air above it (Fig. 10).

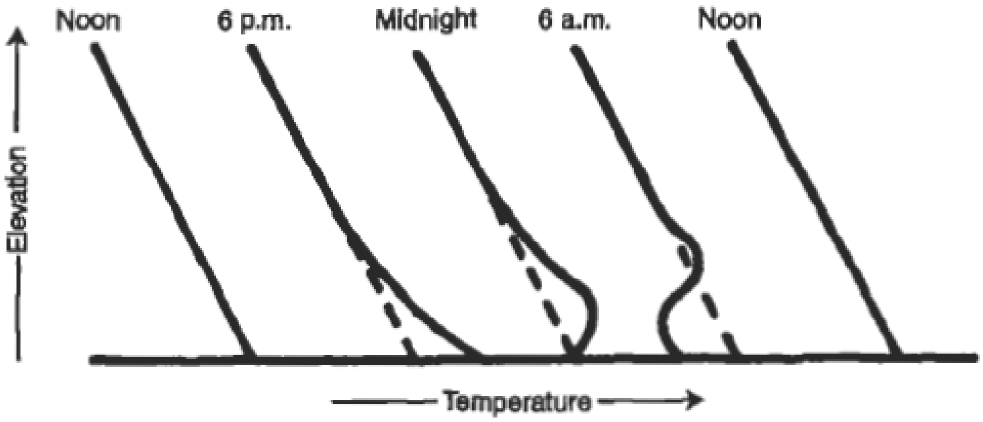


Figure 10. Typical ambient lapse rates during a sunny day and clear night.

Pollution emitted during the night is caught under the "inversion lid."

Atmospheric stability may often be recognized by the shapes of plumes emitted from smokestacks as seen in Figs. 11 and 12.

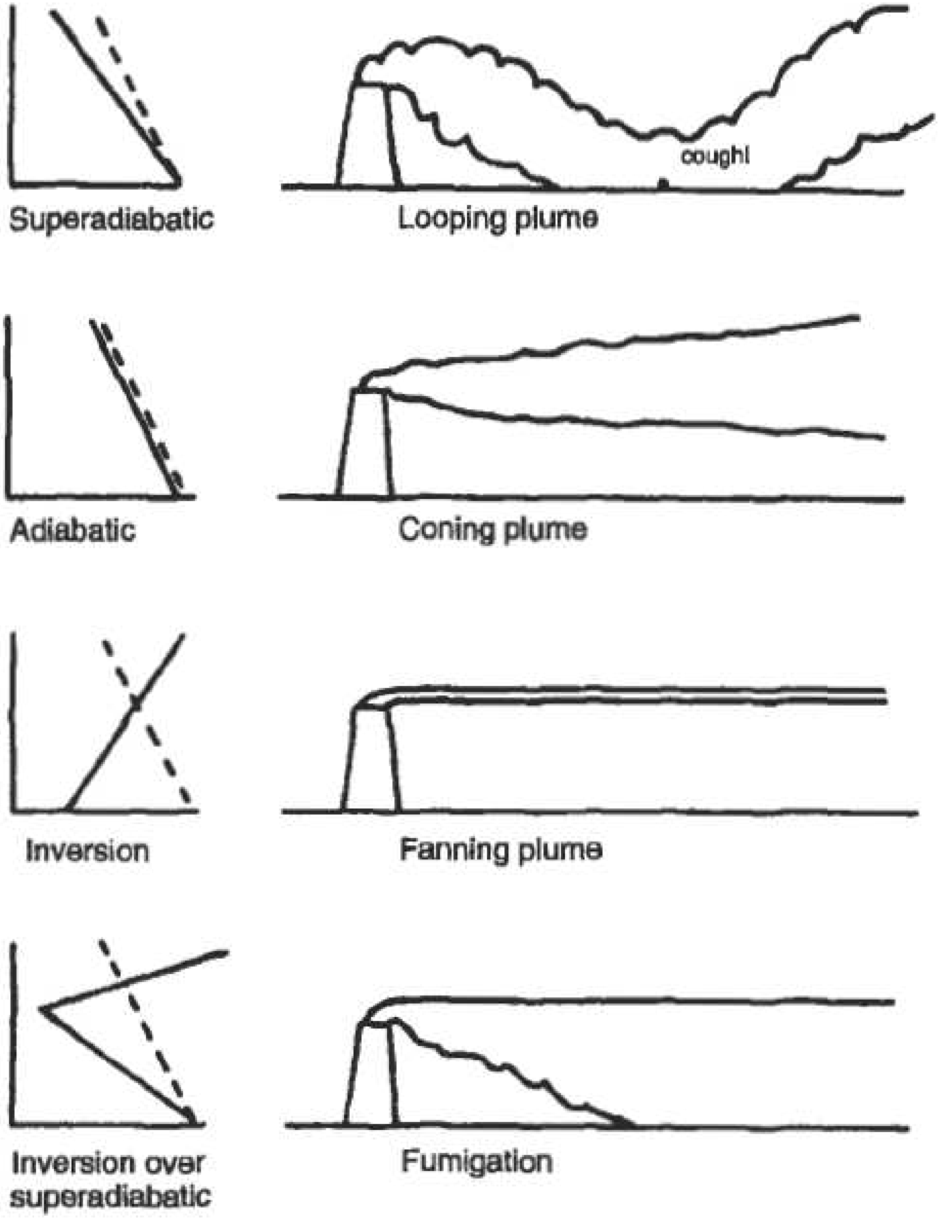


Figure 11. Plume shapes and atmospheric stability.

Figure 12. Iron oxide dust looping plume from a steel mill

Neutral stability conditions usually result in coning plumes, while unstable (superadiabatic) conditions result in a highly dispersive looping plume.

Under stable (subadiabatic) conditions, the funning plume tends to spread out in a single flat layer.

One potentially serious condition is called fumigation, in which pollutants are caught under an inversion and are mixed owing to strong lapse rate.

A looping plume also produces high ground-level concentrations as the plume touches the ground.

Assuming adiabatic conditions in a plume allows estimation of how far it will rise or sink, and what type of plume it will be during any given atmospheric temperature condition, as illustrated by Example 1.

EXAMPLE 1.

A stack l00 m tall emits a plume whose temperature is 20°C. The temperature at the ground is 19°C. The ambient lapse rate is -4.5 °C /km up to an altitude of 200 m. Above this the ambient lapse rate is +20°C /km. Assuming perfectly adiabatic conditions, how high will the plume rise and what type of plume will it be?
Figure 13 shows the various lapse rates and temperatures.

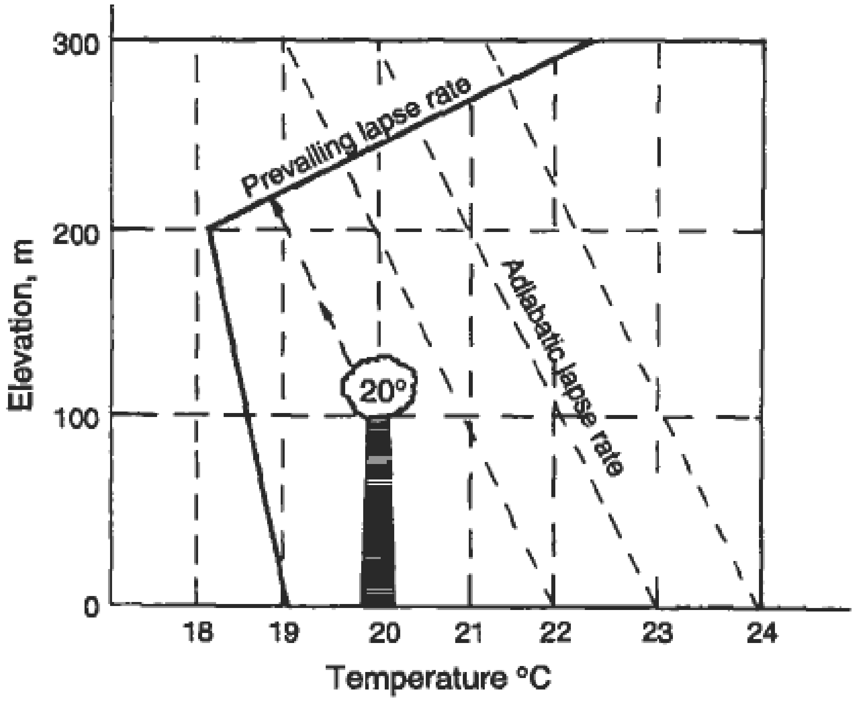


Figure 13. Atmospheric conditions in Example 1.

The plume is assumed to cool at the dry adiabatic lapse rate 10°C km. The ambient lapse rate below 200 m is subadiabatic, the surrounding air is cooler than the plume, so it rises, and cools as it rises.

At 225 m, the plume has cooled to 18.7°C, but the ambient air is at this temperature also, and the plume ceases to rise.

Below 225 m, the plume would have been slightly coning. It would not have penetrated 225 m.

Effect of Water in the Atmosphere

The dry adiabatic lapse rate is characteristic of dry air.

Water in the air will condense or evaporate, and in doing so will release or absorb heat, respectively, making calculations of the lapse rate and atmospheric stability complicated.

In general, as a parcel of air rises, the water vapor in that parcel will condense and heat will be released.

The rising air will therefore cool more slowly as it rises; the wet adiabatic lapse rate will in general be less negative than the dry adiabatic lapse rate.

The wet adiabatic lapse rate has been observed to vary between -6.5 and -3.5°C /Km.

Water in the atmosphere affects air quality in other ways as well.

Fogs are formed when moist air cools and the moisture condenses.

Aerosols provide the condensation nuclei, so that fogs tend to occur more frequently in urban areas.

Serious air pollution episodes are almost always accompanied by fog (remember that the roots of the word “smog” are “smoke” and “fog”).

The tiny water droplets in fog participate in the conversion of SO_3 to H_2SO_4.

Fog sits in valleys and stabilizes inversions by preventing the sun from warming the valley floor, thus often prolonging air pollution episodes.

ATMOSPHERIC DISPERSION

Dispersion is the process by which contaminants move through the air and a plume spreads over a large area, thus reducing the concentration of the pollutants it contains.

The plume spreads both horizontally and vertically.

If it is a gaseous plume, the motion of the molecules follows the laws of gaseous diffusion.

The most commonly used model for the dispersion of gaseous air pollutants is the Gaussian model developed by Pasquill, in which gases dispersed in the atmosphere are assumed to exhibit ideal gas behavior.

The principles on which the model is based are:

- The predominant force in pollution transport is the wind; pollutants move predominantly downwind.

- The greatest concentration of pollutant molecules is along the plume center line.
- Molecules diffuse spontaneously from regions of higher concentration to regions of lower concentration.

- The pollutant is emitted continuously, and the emission and dispersion process is steady state.

Figure 14 shows the fundamental features of the Gaussian dispersion model, with the geometric arrangement of source, wind, and plume.

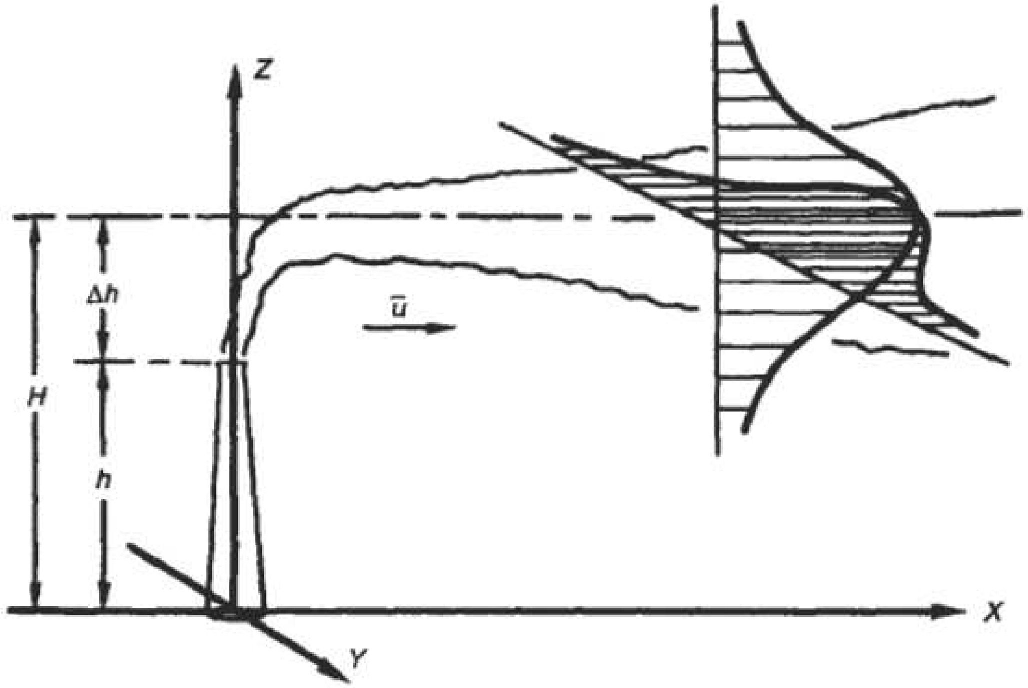


Figure 14. Gaussian dispersion model.

We can construct a Cartesian coordinate system with the emission source at the origin and the wind direction along the x axis. Lateral and vertical dispersions are along the y and z axes, respectively.

As the plume moves downwind, it spreads both laterally and vertically away from the plume centerline as the gas molecules move from higher to lower concentrations.

Cross sections of the pollutant concentration along both the y and the z axes thus have the shape of Gaussian curves, as shown in Fig. 14.

Since stack gases are generally emitted at temperatures higher than ambient, the buoyant plume will rise some distance before beginning to travel downwind.

The sum of this vertical travel distance and the geometric stack height is H, the effective stack height.

The source of the pollutant plume is, in effect, a source elevated above the ground at elevation

$$Z=H$$

and the downwind concentration emanating from this elevated source may be written

$$C(x, y, z) = \frac{Q}{2\pi u \sigma_y \sigma_z} \exp\left(-\frac{y^2}{2\sigma_y^2}\right)\left(\exp\left(-\frac{(z+H)^2}{2\sigma_z^2}\right) + \exp\left(-\frac{(z-H)^2}{2\sigma_z^2}\right)\right)$$

where

C(x, y, z) is the concentration at some point in space with coordinates x, y, z,

Q = the emission rate of the pollution source (in g/s),

u = the average wind speed in (m/s) ,

σ_y = the standard deviation of the plume in the y direction (m), and

$\sigma_{z,}$ = the standard deviation of the plume in the z direction (m).

The units of concentration are grams per cubic meter (g/m^3). Since pollution concentrations are usually measured at ground level, that is, for z = 0, the Eq. usually reduces to

$$C(x, y, 0) = \frac{Q}{\pi u \sigma_y \sigma_z} \exp\left(-\frac{y^2}{2\sigma_y^2}\right)\left(\exp\left(-\frac{(H)^2}{2\sigma_z^2}\right)\right)$$

This equation takes into account the reflection of gaseous pollutants from the surface of the ground.

We are usually interested in the greatest value of the ground level concentration in any direction, and this is the concentration along the plume centerline; that is, for y = 0.

In this case, the Eq. reduces to

$$C(x,0,0) = \frac{Q}{\pi u \sigma_y \sigma_z} \exp\left(\frac{-H^2}{2\sigma_z^2}\right)$$

Finally, for a source of emission at ground level, H = 0, and the ground level concentration of pollutant downwind along the plume centerline is given by

$$C(x,0,0) = \frac{Q}{\pi u \sigma_y \sigma_z}$$

For a release above ground level the maximum downwind ground level concentration occurs along the plume centerline when the following condition is satisfied:

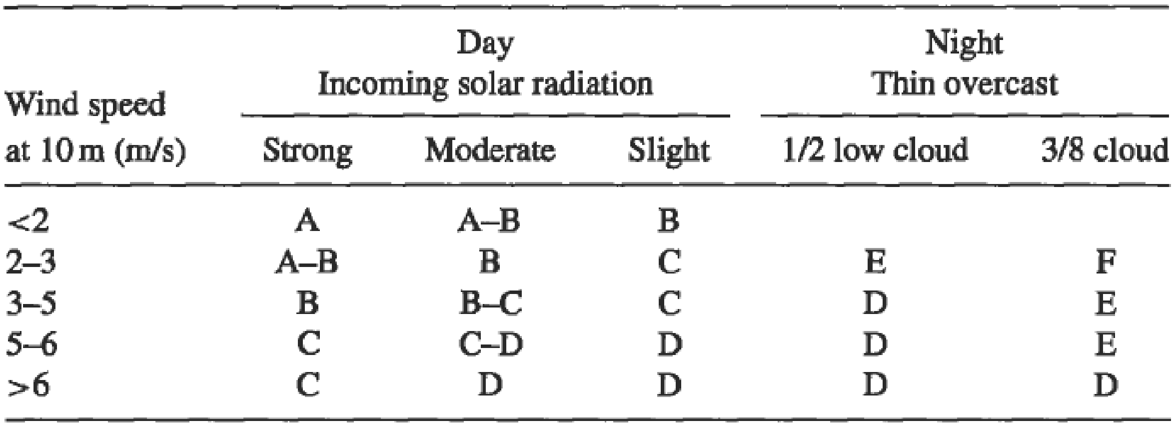
$$\sigma_z = \frac{H}{\sqrt{2}}.$$

The standard deviations σ_y, and σ_z, are measures of the plume spread in the crosswind (lateral) and vertical directions, respectively.

They depend on atmospheric stability and on distance from the source.

Atmospheric stability is classified in categories A through F, called stability classes. Table 1 shows the relationship between stability class, wind speed, and sunshine conditions.

Table 1. Atmospheric Stability under Various Conditions



Wind speed	Day Incoming solar radiation			Night Thin overcast	
at 10 m (m/s)	Strong	Moderate	Slight	1/2 low cloud	3/8 cloud
<2	A	A–B	B		
2–3	A–B	B	C	E	F
3–5	B	B–C	C	D	E
5–6	C	C–D	D	D	E
>6	C	D	D	D	D

Class A is the least stable; Class F is the most stable.

In terms of ambient lapse rates, Classes A, B, and C are associated with superadiabatic conditions; Class D with neutral conditions; and Classes E and F with subadiabatic conditions. A seventh, Class G, indicates conditions of extremely severe temperature inversion, but in considering frequency of occurrence is usually combined with Class F.

Urban and suburban populated areas rarely achieve stability greater than Class D, because of the heat island effect; stability classes E and F are found in rural and unpopulated areas.

Values for the lateral and vertical dispersion constants, σ_y, and σ_z, are given in Figs. 15 and 16.

Use of the figures is illustrated in the following Examples:

EXAMPLE 2

An oil pipeline leak results in emission of l00g/h of H_2S. On a very sunny summer day, with a wind speed of 3.0 m/s, what will be the concentration of H_2S 1.5 km directly downwind from the leak?

From Table 1, we may assume Class B stability. Then, from Fig. 15, at x = 1.5 km, σ_y is approximately 210m and, from Fig. 16, σ_z is approximately 160m, and

$$Q = 100 \text{ g/h} = 0.0278 \text{ g/s}.$$

Applying the Eq., we have

$$C(x, 0, 0) = \frac{Q}{\pi u \sigma_y \sigma_z}$$

$$C(1500, 0, 0) = \frac{0.0278 \text{ g/s}}{\pi (3.0 \text{ m/s})(210 \text{ m})(160 \text{ m})} = 8.77 \times 10^{-8} \text{ g/m}^3 = 0.088 \,\mu\text{g/m}^3$$

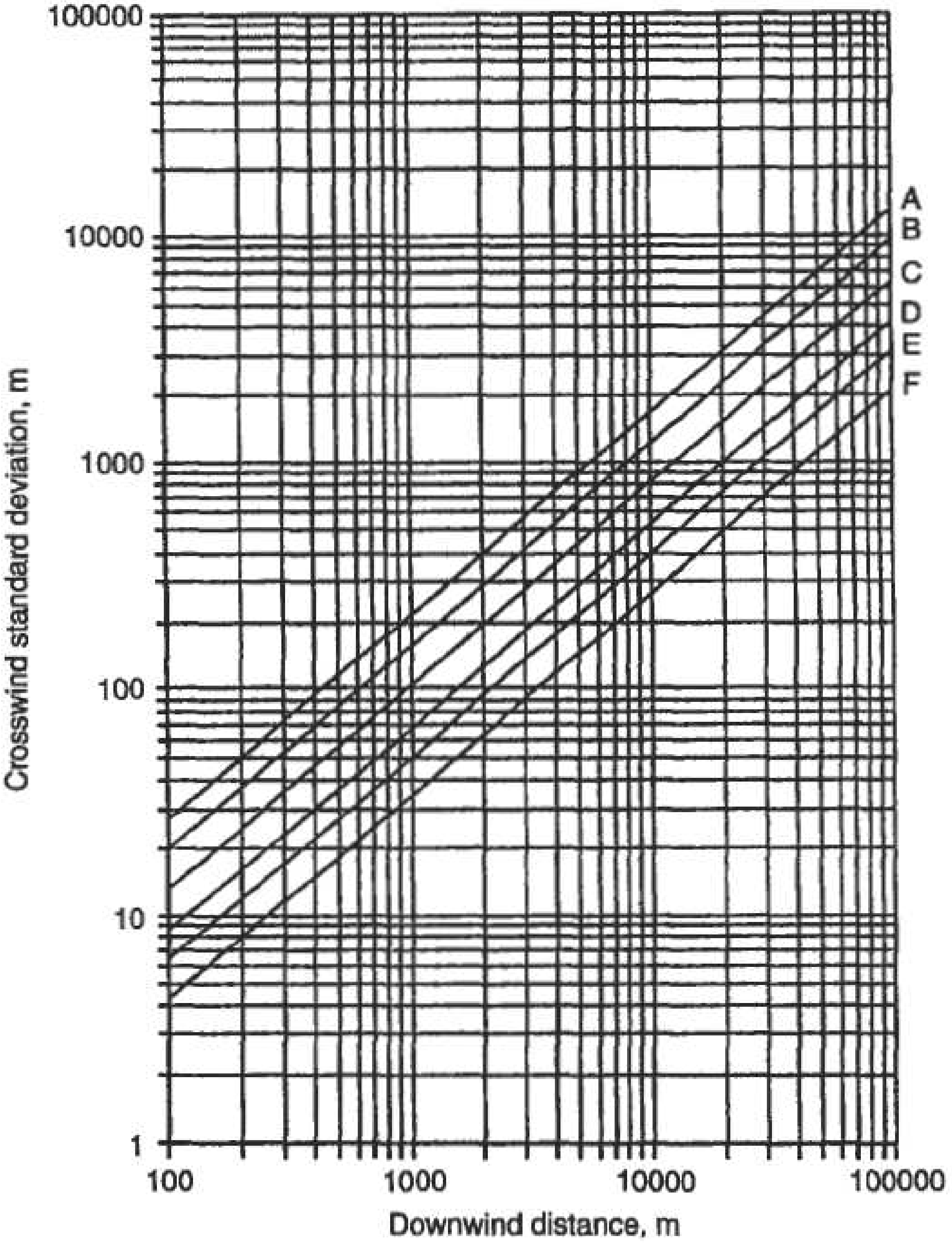


Figure 15. Standard deviation or dispersion coefficient, σ_y, in the crosswind direction as a function of downwind distance (Wark and Warner 1986).

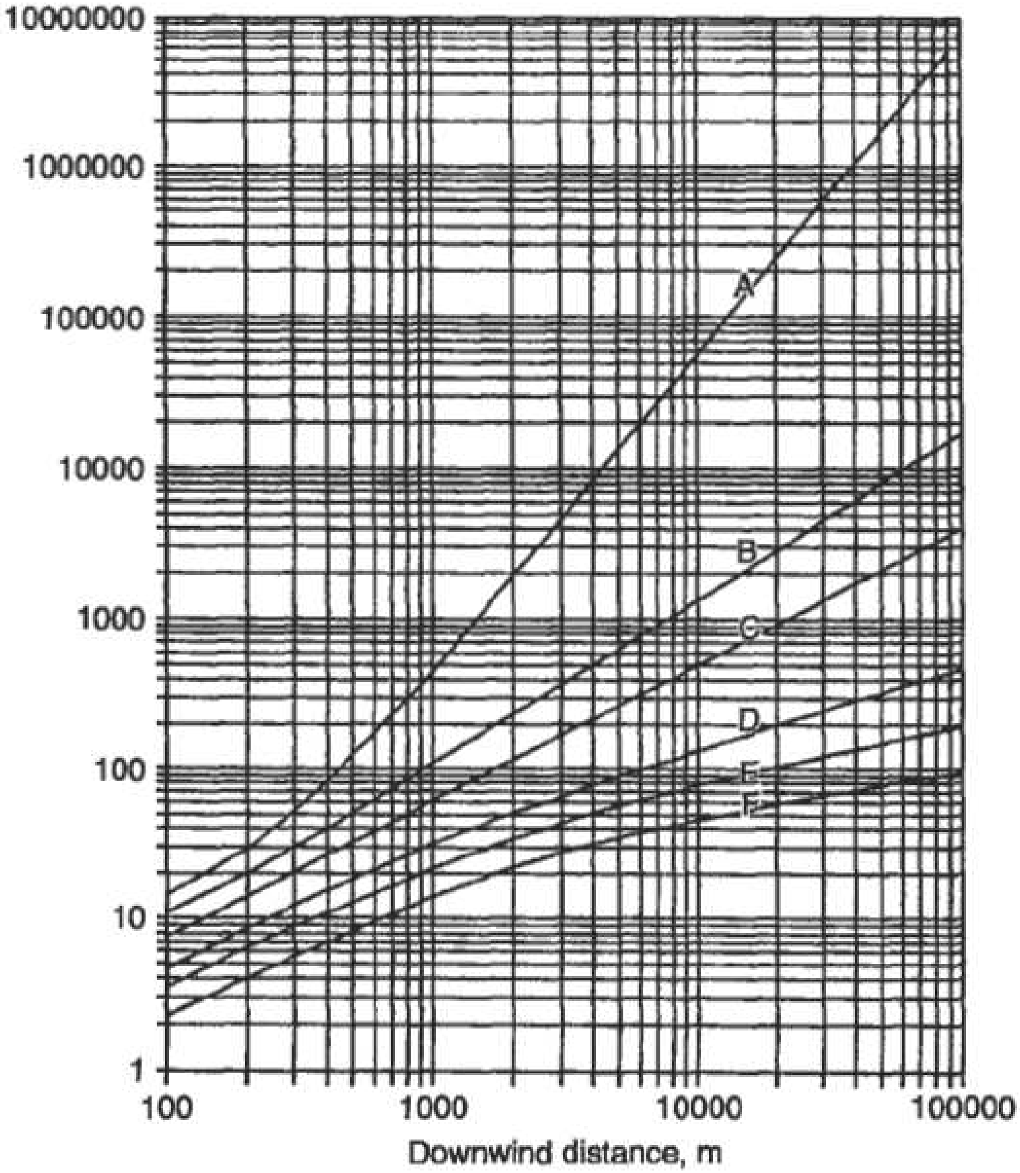


Figure 16. Standard deviation or dispersion coefficient, σ_z, in the vertical direction as a function of downwind distance (Wark and Warner 1986).

EXAMPLE 3

A coal-burning electric generating plant emits 1.1 kg/min of SO_2 from a stack with an effective height of 60m. On a thinly overcast evening, with a wind speed of 5.0 m/s , what will be the ground level concentration of SO_2 500 m directly downwind from the stack?

From Table 1, we may assume Class D stability. Then, from Fig. 15, at x = 0.5 km, σ_y is approximately 35 m and σ_z, is approximately 19 m, and

$$Q = 1.10 \text{ kg/min} = 18 \text{ g/s}.$$

In this problem, the release is elevated, and H = 60 m.

Applying the Eq., we have

$$C(x,0,0) = \frac{Q}{\pi u \sigma_y \sigma_z} \exp\left(\frac{-H^2}{2\sigma_z^2}\right)$$

$$C(0.5,0,0) = \frac{18 \text{ g/s}}{\pi (5 \text{ m/s})(35 \text{ m})(19 \text{ m})} \exp\left(\frac{-(60)^2}{2(19)^2}\right) = 11.8 \times 10^{-6} \text{ g/m}^3,$$

Variation of Wind Speed With Elevation

The model used so far assumes that the wind is uniform and unidirectional, and that its velocity can be estimated accurately.

These assumptions are not realistic:

Wind direction shifts and wind speed varies with time as well as with elevation.

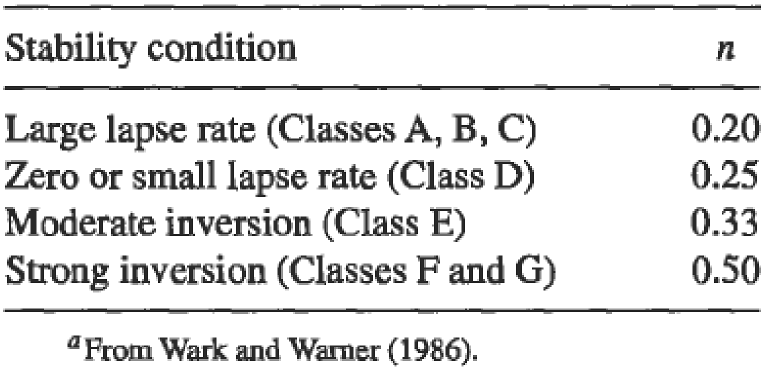
The variation of wind speed with elevation can be approximated by a parabolic wind velocity profile.

That is, the wind speed u at an elevation h may be calculated from the measured wind speed u_o at a given elevation h_o using the relationship

$$u = u_0 \left(\frac{h}{h_0}\right)^n$$

The exponent n, called the stability parameter, is an empirically determined function of the atmospheric stability, and is given in Table 2.

Table 2. Relationship between the Stability Parameter and Atmospheric stability [a]



Stability condition	n
Large lapse rate (Classes A, B, C)	0.20
Zero or small lapse rate (Class D)	0.25
Moderate inversion (Class E)	0.33
Strong inversion (Classes F and G)	0.50

[a] From Wark and Warner (1986).

Wind is often measured in weather stations at an elevation of 10 m above ground level.

Effective Stack Height

The effective stack height is the height above ground at which the plume begins to travel downwind the effective release point of the pollutant and the origin of its dispersion.

A number of empirical models exist for calculating the plume rise h - the height above the stack to which the plume rises before dispersing downwind.

Three equations that give a reasonably accurate estimate of plume rise have been developed by Carson and Moses (1969) for different stability conditions.

For superadiabatic conditions

$$\Delta h = 3.47\frac{V_s d}{u} + 5.15\frac{Q_h^{0.5}}{u};$$

for neutral stability

$$\Delta h = 0.35\frac{V_s d}{u} + 2.64\frac{Q_h^{0.5}}{u}$$

and for subadiabatic conditions

$$\Delta h = -1.04\frac{V_s d}{u} + 2.24\frac{Q_h^{0.5}}{u}$$

where

V, = stack gas exit speed (in m/s) ,

d = stack diameter (in m), and

Q_h = heat emission rate from the stack (in kJ/s).

As before, length is in meters and time is in seconds, and the heat emission rate is measured in kilojoules per second.

EXAMPLE 4

A power plant has a stack with a diameter of 2 m and emits gases with a stack exit velocity of 15 m/s and a heat emission rate of 4,800 kJ/S. The wind speed is 5 m/s . Stability is neutral. Estimate the plume rise. If the stack has a geometric height of 40 m, what is the effective stack height?

$$\Delta h = 0.35\frac{(15)(2)}{5} + 2.64\frac{\sqrt{4800}}{5} = 38.7\,\mathrm{m}$$

$$H = h_g + h$$

$$H = 40\,\mathrm{m} + 38.7\,\mathrm{m} = 78.7\,\mathrm{m}.$$

The accuracy of plume rise and dispersion analysis is not very good.

Un calibrated models predict ambient concentrations to within an order of magnitude at best.

To ensure reasonable validity and reliability, the model should be calibrated with measured ground level concentrations.

The model discussed applies only to a continuous, steady point source of emission.

Discrete discontinuous emissions or puffs, larger areas that act as sources, like parking lots, and line sources, like highways, are modeled using variants of the Gaussian approach, but the actual representation used in each case is quite different.

Computer Models for Assessing Atmospheric Dispersion

A number of computer models that run on a desktop PC exist for assessing atmospheric dispersion of pollutants.

These are essentially codifications of the Gaussian dispersion equations that solve the equations many times and output an isopleth plot.

Some models are:

DEPOSlTION 2.0 (U.S. Nuclear Regulatory Commission NUREG/GR-0006, 1993)
CAP88-PC (US. Department of Energy, ER 8.2, GTN, 1992)
RISKIND (Yuan et al. 1993)
HAZCON (Sandia National Laboratories 1991)
TRANSAT (Sandia National Laboratories 1991)
HOTSPOT (Lawrence Livermore National Laboratory, 1996)
MACCS 2 (Sandia National Laboratories, 1993)

CLEANSING THE ATMOSPHERE

Processes by which the atmosphere cleans itself do exist, and include the effect of gravity, contact with the earth’s surface, and removal by precipitation.

Gravity

Particles in the air, if they are larger than about a millimeter in diameter, are observed to settle out under the influence of gravity; the carbon particles from elevated diesel truck exhaust are a very good example of such settling.

However, most particles of air pollutants are small enough that their settling velocity is a function of atmospheric turbulence, viscosity, and friction, as well as of gravitational acceleration, and settling can be exceedingly slow.

Particles smaller than 20 µ,m in diameter will seldom settle out by gravity alone.

Gases are removed by gravitational settling only if they are adsorbed onto particles or if they condense into particulate matter.

Sulfur trioxide, for example, condenses with water and other airborne particulates to form sulfate particles.

Particles small enough to stay in the air for appreciable periods of time are dispersed in the air, but in a slightly different way than gaseous pollutants are dispersed.

The dispersion equation must be modified by considering the settling velocity of these small particles.

For particles between 1 and 100 µm in diameter, the settling velocity follows Stokes' law

$$V_t = gd^2 \frac{\rho}{18\mu}$$

where
V_t = settling or terminal velocity,
g = acceleration due to gravity,
d = particle diameter,
ρ = particle density, and
µ = viscosity of air.

The settling velocity modifies the Gaussian dispersion equation, to give the analogous equation

$$C(x, y, 0) = \frac{Q}{2\pi u \sigma_y \sigma_z} \exp\left(\frac{-y^2}{2\sigma_y^2}\right) \exp\left(-\frac{(H - (V_t x/u))^2}{2\sigma_z^2}\right)$$

for dispersion of small particles, The factor of in the 0.5 in the first term arises because falling particles are not reflected at the ground surface.

The rate, ω, at which particulate matter is being deposited on the ground, is related to the ambient concentration as shown in

$$\omega = V_t C(x, y, 0) = \frac{Q}{2\pi u \sigma_y \sigma_z} \exp\left(\frac{-y^2}{2\sigma_y^2}\right) \exp\left(-\frac{(H - (V_t x/u))^2}{2\sigma_z^2}\right)$$

where ω = the deposition rate (in g/s-m^2).

EXAMPLE 5

Using the data of Example 3, and assuming that the emission consists of particles 10 µm in diameter and having a density of 1 g/cm^3, calculate (1) the ambient ground level concentration at 200 m downwind along the plume centerline, and (2) the deposition rate at that point. The viscosity of the air is 0.0185 g/m-s at 25°C.

The settling velocity is

$$V_t = (9.8\,\mathrm{m/s^2})(10^{-5}\,\mathrm{m})^2 \frac{(1\,\mathrm{g/cm^3})}{(10^{-6}\,\mathrm{m^3/cm^3})(18)(0.0185\,\mathrm{g/m\text{–}s})} = 0.0029\,\mathrm{m/s},$$

From example 3

$$Q = 18\,\mathrm{g/s}$$

$$C(0.2, 0, 0) = \frac{18\,\mathrm{g/s}}{2\pi(5\,\mathrm{m/s})(35\,\mathrm{m})(19\,\mathrm{m})} \times \exp\left\{-\frac{1}{2}\left[\frac{60\,\mathrm{m} - \left(\frac{(.0029\,\mathrm{m/s})(200\,\mathrm{m})}{5\,\mathrm{m/s}}\right)}{19\,\mathrm{m}}\right]^2\right\}$$

$$= 6.03 \times 10^{-6}\,\mathrm{g/m^3}$$

The deposition rate is then

$$\omega = (0.0029\,\mathrm{m/s})(6.03 \times 10^{-6}\,\mathrm{g/m^3\text{–}s})$$

$$= 1.75 \times 10^{-8}\,\mathrm{g/m^2\text{–}s}$$

Surface Sink Absorption

Many atmospheric gases are absorbed by the features of the earth’s surface, including stone, soil, vegetation, bodies of water, and other materials.

Soluble gases like SO_2 dissolve readily in surface waters, and such dissolution can result in measurable acidification.

Precipitation

Precipitation removes contaminants from the air by two methods.

Ruinout is an “incloud” process in which very small pollutant particles become nuclei for the formation of rain droplets that grow and eventually fall as precipitation.

Washout is a “belowcloud” process in which rain falls through the pollutant particles and molecules, which are entrained by the impinging rain droplets or which actually dissolve in the rainwater.

The relative importance of these removal mechanisms was illustrated by a study of SO_2 emissions in Great Britain, where the surface sink accounted for 60% of the $S0_2$, 15% was removed by precipitation, and 25% blew away from Great Britain, heading northwest toward Norway and Sweden.

CONCLUSION

Polluted air results from both emissions into the air and meteorological conditions that control the dispersion of those emissions.

Pollutants are moved predominantly by wind, so that very light wind results in poor dispersion. Other conditions conducive to poor dispersion are:

- Little lateral wind movement across the prevailing wind direction,
- Stable meteorological conditions, resulting in limited vertical air movement,
- Large differences between day and night air temperatures, and the trapping of cold air in valleys, resulting in stable conditions,

- Fog, which promotes the formation of secondary pollutants and hinders the sun from warming the ground and breaking inversions, and

- High-pressure areas resulting in downward vertical air movement and absence of rain for washing the atmosphere.

Air pollution episodes can now be predicted, to some extent, on the basis of meteorological data. The EPA and many state and local air pollution control agencies are implementing early warning systems, and acting to curtail emissions and provide emergency services in the event of a predicted episode.

UNIT 1

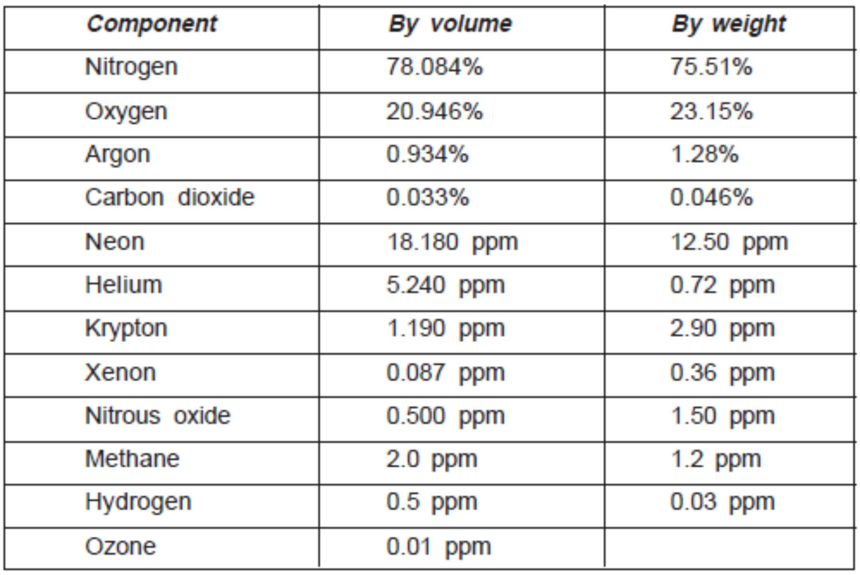
10CV765 APC

Definition of Air pollution: It is the presence of substances in air in sufficient concentration and for sufficient time, so as to be, or threaten to be injurious to human, plant or animal life, or to property, or which reasonably interferes with the comfortable enjoyment of life and property.

The air Act of Govt. of India (amendment 1987) defines air pollution as “air pollution means any solid, liquid or gaseous substances present in the atmosphere in such concentrations that may tend to be injurious to human beings or other living creatures or plants or property or enjoyment”.

Perkins (1974) defined air pollution as “air pollution means the presence in the outdoor atmosphere of one or more contaminants such as dust, fumes, gas, mist, odor, smoke or vapor in quantities or characteristics and of duration such as to be injurious to human, plant or animal life or to property or which unreasonably interferes with the comfortable enjoyment of life and property.”

Atmosphere can be defined as the thin blanket of air surrounding the earth. The clean dry air has following average composition:-



Component	*By volume*	*By weight*
Nitrogen	78.084%	75.51%
Oxygen	20.946%	23.15%
Argon	0.934%	1.28%
Carbon dioxide	0.033%	0.046%
Neon	18.180 ppm	12.50 ppm
Helium	5.240 ppm	0.72 ppm
Krypton	1.190 ppm	2.90 ppm
Xenon	0.087 ppm	0.36 ppm
Nitrous oxide	0.500 ppm	1.50 ppm
Methane	2.0 ppm	1.2 ppm
Hydrogen	0.5 ppm	0.03 ppm
Ozone	0.01 ppm	

Definition of Air pollutants: Substances introduces into the air, natural or manmade, in concentrations detrimental to human, plant or animal life, or to property.

Major Classification of Air Pollutants:

1] Primary – Secondary
2] Natural – Manmade
3] Criteria Air Pollutants
4] Physical - chemical - biological

Primary pollutants and secondary pollutants: Primary pollutants are substances that are directly emitted into the atmosphere from sources. Primary pollutants are those that are emitted directly from identifiable sources. Secondary air pollutants are those that are produced in the air by the interaction of two or more primary air pollutant.

Primary Air pollutants:-

(i) Fine (less than 100μ) and coarse (more than 100μ) suspended particulate matter
(ii) Oxides of sulfur
(iii) Oxides of nitrogen
(iv) Carbon monoxide
(v) Halogens
(vi) Organic compounds
(vii) Radioactive compounds

Secondary Air pollutants:-
(i) Ozone
(ii) PAN (peroxi aceyl nitrate)
(iii) Photochemical smog
(iv) Acid mists

Air pollutants arise from both manmade and natural processes. The ambient air quality may be defined by the concentration of a set of pollutants which may be present in the ambient air we breathe in. These pollutants may be called **criteria pollutants**.

Natural Contaminants: Pollen is important natural contaminant because of its peculiar properties of irritation and allergy sometimes leading to bronchitis, asthma and dermatitis. Pollen grains are the male gametophytes of gymnosperms and angiosperms and they are discharged into the atmosphere from plants etc. The air transported pollen grains range mainly between 10 and 50 microns. Manmade refers to any pollutant produced to influence or action of humans.

Aerosols: Aerosols refer to the dispersion of solid or liquid particles of microscopic size in the air. It can also be defined as a colloidal system in which the dispersion medium is gas and the dispersed phase is solid or liquid. The term aerosol is applicable until it is in suspension and after settlement due to its own weight or by addition with other particles (agglomeration) it is no longer an air pollutant. The diameter of the aerosol may range from 0.01 (or less) micron to 100 micron.

The various aerosols are as follows:-

(i) **Dust:** Dust is produced by the crushing, grinding and natural sources like windstorms. Generally the dust particles are over 20 micron in diameter. They do not flocculate but settle under gravity, but smaller particles like 5 micron form stable suspensions.

(ii) **Smoke:** Smoke is made up of finely divided particles produced by incomplete combustion. Generally it consists of carbon particles of size less than 1.0 micron.

(iii) **Mists:** Mist is a light dispersion of minute water droplets suspended in the atmosphere ranging from 40 to 400 micron in size.

(iv) **Fog:** Fog is made up of dispersion of water or ice near the earth’s surface reducing visibility to less than 500 m. In natural fog the size of particles range from 1.0 to 40 micron.

(v) **Fumes:** Fumes are solid particles generated by condensation from the gaseous state after volatilization from melted substances. Fumes flocculate and sometimes coalesce. Gases:

Following are the **main air pollutant gases**

(i) **Sulphur dioxide:** It is a major air pollutant gas produced by the combustion of fuels like coal. The main source of electricity production is by burning of fossil fuels in India and the whole world. The sulphur content of the coal varies from 1 to 4% and fortunately the Indian coal is low in sulphur content. SO2 is also produced in the metallurgical operations.

(ii) **Oxides of nitrogen:** Oxides of nitrogen are produced either in the production of nitric acid or in the automobile exhausts and as the effluent of power plants. Out of the seven oxides of Nitrogen (N_2O, NO, NO_2, NO_3, N_2O_3, N_2O_4, N_2O_5) only nitric oxide and nitrogen dioxide are classified as the main pollutants. All the oxides of nitrogen are collectively known as NO_X.

(iii) **Carbon monoxide:** It is produced because of the incomplete combustion of coal and other petroleum products. It is produced in the exhaust of automobiles. In the pollution check of vehicles mainly CO and unburnt hydrocarbons are measured.

(iv) **Hydrogen sulphide:** Hydrogen Sulphide is an obnoxious (bad smelling) gas. It is produced mainly by the anaerobic (in absence of air) decomposition of organic matter. Other air polluting sulfur compounds are methyl mercaptan (CH_3SH) and dimethyl sulphide (CH_3-S-CH_3) etc.

(v) **Hydrogen fluoride:** It is an important pollutant even in very low concentrations. It is produced in the manufacturing of phosphate fertilizers.

(vi) **Chlorine and hydrogen chloride:** It is mixed in the air either from the leakages from water treatment plants or other industries where it is produced or used. Hydrogen chloride is also evolved in various industrial chemical processes. The main effect of chlorine is respiratory irritation which may be fatal.

(vii) **Ozone:** It is a desirable gas in the upper layers of atmosphere as it absorbs the UV radiation of sunlight. But near the earth surface it is a poisonous gas. It makes poisonous chemicals by photochemical reactions.

(viii) **Aldehydes:** They are produced by the incomplete oxidation of motor fuels and lubricating oil. They may also be formed because of photochemical reactions. Formaldehydes are irritating to the eyes.

Classification according to chemical composition: (Organic – inorganic)

1. Sulfur-containing compounds.
2. Nitrogen-containing compounds.
3. Carbon-containing compounds.
4. Halogen-containing compounds.
5. Toxic substances (any of about).
6. Radiative compounds.

Classification according to physical state:

1. Gaseous.
2. Liquid (aqueous).
3. Solid.

Criteria air pollutants are six major pollutants defined by EPA (Environmental Protection Agency) for which ambient air standards have been set to protect human health and welfare. These include :

1. Ozone, O_3.
2. Carbon monoxide, CO.
3. Sulfur dioxide, SO_2.
4. Nitrogen oxides, NO_x.
5. Lead, Pb.
6. Particulates, PM10.

Pollutant	Description	Sources	Health Effects	Welfare Effects
Carbon Monoxide (CO)	Colorless, odorless gas	Motor vehicle exhaust, indoor sources include kerosene or wood burning stoves.	Headaches reduced mental alertness, heart attack, cardiovascular diseases, impaired fetal development, and death.	Contribute to the formation of smog.
Sulfur Dioxide (SO2)	Colorless gas that dissolves in water vapor to form acid, and interact with other gases and particles in the air.	Coal-fired power plants, petroleum refineries, manufacture of sulfuric acid and smelting of ores containing sulfur.	Eye irritation, wheezing, chest tightness, shortness of breath, lung damage.	Contribute to the formation of acid rain, visibility impairment, plant and water damage, aesthetic damage.
Nitrogen Dioxide (NO2)	Reddish brown, highly reactive gas.	Motor vehicles, electric utilities, and other industrial, commercial, and residential sources that burn fuels.	Susceptibility to respiratory infections, irritation of the lung and respiratory symptoms (e.g., cough, chest pain, difficulty breathing).	Contribute to the formation of smog, acid rain, water quality deterioration, global warming, and visibility impairment.
Ozone (O3)	Gaseous pollutant when it is formed in the troposphere.	Vehicle exhaust and certain other fumes. Formed from other air pollutants in the presence of sunlight.	Eye and throat irritation, coughing, respiratory tract problems, asthma, lung damage.	Plant and ecosystem damage.
Lead (Pb)	Metallic element	Metal refineries, lead smelters, battery manufacturers, iron and steel producers.	Anemia, high blood pressure, brain and kidney damage, neurological disorders, cancer, lowered IQ.	Affects animals and plants, affects aquatic ecosystems.
Particulate Matter (PM)	Very small particles of soot, dust, or other matter, including tiny droplets of liquids.	Diesel engines, power plants, industries, windblown dust, wood stoves.	Eye irritation, asthma, bronchitis, lung damage, cancer, heavy metal poisoning, cardiovascular effects.	Visibility impairment, atmospheric deposition, aesthetic damage.

Emission Sources

Major Classification of Air Pollution Sources:

1] Based on Origin: Natural and Manmade

While man-made air pollution does present health hazards, natural sources of air pollution can be equally dangerous at times. These sources include dust picked up by wind erosion, the emission of methane by livestock, and smoke from wildfires. Volcanic eruptions are perhaps the largest single source of air pollution, natural or man-made, that humans have ever dealt with. These can produce clouds of abrasive volcanic ash and other harmful substances such as chlorine and sulfur.

2] Based on Position: Stationary and Mobile

The sources of air pollution may be classified as stationary point sources (generally industrial in origin), diffuse or area sources and mobile sources (mainly cars and trucks).

3] Based on Aix of Release: Horizontal axis (Roadways traffic)
Vertical Axis release (Industrial Stacks)
4] Based on Intensity/frequency of release: Continuous release (Industrial Stacks)
Instantaneous release (Roadways traffic)

Stationary Sources

The stationary industrial sources are usually classified by process type or sub-type. Thus an oil refining plant also includes large industrial boilers as a sub-type. Small and medium scale plants such as garment or food processing plants may include industrial boilers, a common source of air pollution. The quality and type of fuel used for energy production are important determinants of the air pollution potential of a plant. Each type of plant or activity generally emits more than one pollutant, and the pollutant emission rate depends on the fuel type and quality, the design of the plant (and whether fitted with air pollution control devices or not), and the activity rate or output of the plant.

(i) Point source (power plant stacks)
(ii) Area source (forest fires, open burning)
(iii) Line Source (highway vehicle exhausts)

Mobile Sources Refer mainly to emissions from cars, trucks, minibuses and buses. The fuel source may be petrol or diesel, and emissions include exhaust emissions and fugitive emissions. Vehicle (mobile) source emissions depend on a number of factors, including vehicle size, fuel type, speed and vehicle technology. Total vehicle emissions depend on the vehicle population on the road at a given time.

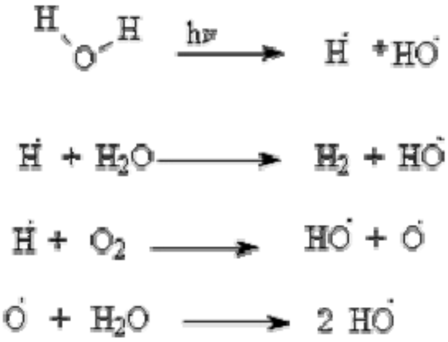
Chemical Reactions in the Atmosphere

Substances in the top layer of the geosphere, known as the lithosphere, tend to become more reduced over time. Biomass (CH_2O) for example is slowly transformed to substances which have no oxygen atoms through a sequence of steps, then to compounds with successively larger carbon to hydrogen ratios and finally to products with a form of pure carbon. However, atmospheric chemical reactions have the opposite effect on substances, causing an atom to become more oxidized over time in the atmosphere. Atmospheric gases that are found in their reduced states are oxidized stepwise to form ionic substances that are washed out of the atmosphere in rainfall. Example, dissolution of atmospheric hydrogen sulfide by rain to form sulfate molecule.

$$H_2S + H_2O\ (\text{rain}) \rightarrow SO_4^{2-}$$

Chemical reactions in the atmosphere can occur as gas phase collisions between molecules, on the surfaces of solid particles or in aqueous solution (in water droplets); predominantly acid-base reactions. Particles spend short residence time in the atmosphere. Due to this, reactions that occur on particle surfaces are of minor importance in most cases. Gas phase reactions dominate the chemical changes that occur to substances in the atmosphere.

The most important single species in atmospheric chemistry is the hydroxyl radical (HO·). This radical is formed by several reactions. However, the primary process is one where an O-H bond of the water molecule is broken to form a hydrogen atom (H·) and a hydroxyl radical (HO·). The hydrogen atom can then react with another water molecule to form hydrogen and a second hydroxyl radical, or with an oxygen molecule (O2) to form a second hydroxyl radical and an oxygen atom. The new oxygen atom can then react with another water molecule to form two new hydroxyl radicals.



Molecules in the atmosphere are continually moving and colliding with one another, as described by the kinetic-molecular theory. The atmosphere is also continually illuminated during daylight hours. As a result, absorption of light energy by atmospheric molecules can cause photochemical reactions, reactions that would not occur at normal atmospheric temperatures in the absence of light. Such reactions play an important role in determining the composition of the atmosphere itself and the fate of many chemical species that contribute to air pollution.

Nitrogen dioxide, NO2, is one of the most photochemically active species in the atmosphere. The NO2 molecule is an example of a free radical because it contains an unpaired electron, represented by a next to its formula. When an NO2 molecule absorbs a photon of light with energy, the molecule is raised to a higher energy level; it becomes an electronically excited molecule, designated by an asterisk (*).

$$\cdot \mathrm{NO_2(g)} \xrightarrow{h\nu} \cdot \mathrm{NO_2^*}$$

The excited molecule may quickly re-emit a photon of light, or the energy may break an N-O bond to form a nitrogen monoxide (NO) molecule and an oxygen atom (O). Both NO and O are free radicals, because they have one or more unpaired electrons each denoted by a dot.

$$\cdot NO_2^*(g) \xrightarrow{h\nu} \cdot NO(g) + \cdot O\cdot(g)$$

Photodissociation is another mechanism of formation of radicals, in which a molecule absorbs an ultraviolet photon and produces two free radicals as products. Molecular oxygen can photodissociate to form two oxygen atoms.

$$O_2(g) \xrightarrow{h\nu} \cdot O\cdot(g) + \cdot O\cdot(g)$$

Some free radicals, such as an oxygen atom, react with another atom or molecule almost immediately. Others, such as an NO2 molecule, are not quite so reactive and are stable enough to exist for a somewhat longer time. Most radicals are highly reactive and short-lived.

Fate of air pollutants in the atmosphere

1] NO_x, Hydrocarbons, Ozone, Mist: - Formation of photochemical smog

2] SO_2, NO_x: - Formation of Acid Mist / Rain

3] SO_2, CO, Mist: - Formation of coal induced smog

4] [O], NOx, OH^- - Formation of Ozone

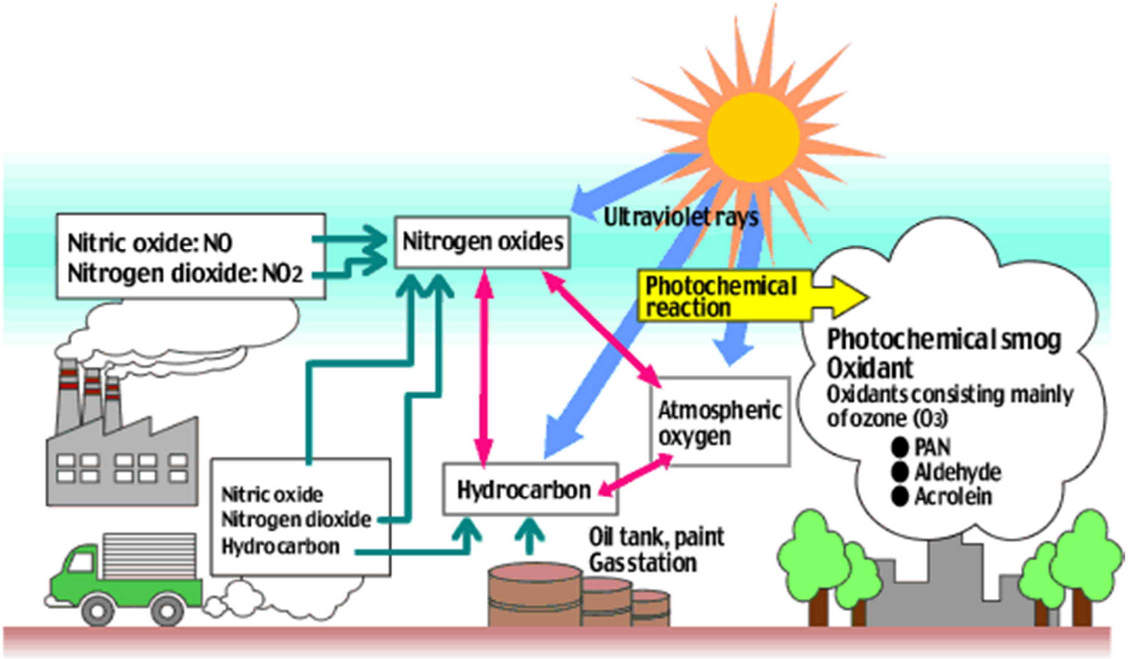
PHOTO CHEMICAL SMOG

Photochemical smog was first described in the 1950s. It is the chemical reaction of sunlight, nitrogen oxides and volatile organic compounds in the atmosphere, which leaves airborne

particles and ground-level ozone. This noxious mixture of air pollutants can includes Aldehydes, Nitrogen oxides, such as nitrogen dioxide, Peroxyacyl nitrates

Tropospheric ozone, Volatile organic compounds etc. All of these chemicals are usually highly reactive and oxidizing. Photochemical smog is considered to be a problem of modern industrialization. It is present in all modern cities, but it is more common in cities with sunny, warm, dry climates and a large number of motor vehicles. Because it travels with the wind, it can affect sparsely populated areas as well.

VOCs + NOx + sunlight → photochemical smog



To begin the chemical process of photochemical smog development the following conditions must occur:

- Sunlight.
- The production of oxides of nitrogen (NOx).
- The production of volatile organic compounds (VOCs).
- Temperatures greater than 18 degrees Celsius.

Nitrogen oxide is an essential ingredient of photochemical smog that is produced during the high temperatures associated with combustion of vehicle’s engines. Nitrogen oxide is an essential ingredient of photochemical smog that is produced during the high temperatures associated with combustion of vehicle’s engines.

Formation

Sunlight can break down nitrogen dioxide back into nitrogen oxide.

$$NO_2 + \text{sunlight} \text{ »»» } NO + O$$

The atomic oxygen formed in the above reaction then reacts with one of the abundant oxygen molecules producing ozone.

$$O + O_2 \text{ »»» } O_3$$

Nitrogen dioxide can also react with radicals produced from volatile organic compounds in a series of reactions to form toxic products such as peroxyacetyl nitrates.

$$NO_2 + R \text{ »»» products such as PAN}$$

Note the symbol R represents a hydrocarbon (a molecule composed of carbon, hydrogen and other atoms) which is primarily created from volatile organic compounds.

Steps

1) Nitrogen oxides generate oxygen atoms

2) Oxygen atoms form hydroxyl radicals

3) Hydroxyl radicals generate hydrocarbon radicals

4) Hydrocarbon radicals form hydrocarbon peroxides

5) Hydrocarbon peroxides form aldehydes

6) Aldehydes form aldehyde peroxides

7) Aldehyde peroxides form peroxy-acyl-nitrates

Health effects

It can cause eye and nose irritation and it dries out the protective membranes of the nose and throat and interferes with the body's ability to fight infection, increasing susceptibility to illness.

COAL INDUCED SMOG

Introduction to Smog

Smog is a recent compound word from "smoke" and "fog", and was coined by Harold Antoine des Voeux, a doctor, in 1905. Smog refers to locally high concentrations of acids, dry acid-forming compounds, particulates, or other pollutants in stagnant, stable air. Smog’s form when emissions are prevented from dispersing by stable or sinking air masses. They were very prevalent in European and North American cities during first part of 20th Century. London smog’s were infamous in the 19th and early 20th centuries and formed every autumn and winter due to sulphur emissions from coal burning industries and domestic fires. The most severe London smog was on 4-10th December 1952, when cold, high-pressure conditions trapped coal smoke in foggy air. The output of smoke was increased by the cold weather, due to the large numbers of domestic fires. Sooty smoke produced peak daily concentrations of black smoke of 5000 mgs/m3 (WHO 24 hr. max limit of 100-150), and daily average SO2 levels of 3000-4000 mg/m3 (WHO 24 hr. max limit of 100-150). Sulphuric acid droplets resulted in pH estimated as 1.4 to 1.9: as acidic as car battery acid.

$$H_2SO_{4(g)} + H_2O \rightarrow H_2SO_{4(aq)}$$
$$SO_{2(g)} + H_2O_{(l)} \rightarrow H_2SO_{3(aq)}$$

Chemistry

These are produced by high outputs of SO2, which are converted to acids on contact with atmospheric moisture. Usually, sulphurous smog’s also contain elevated concentrations of suspended soot.

Impacts

Visibility was reduced to 5m at times, and London buses had to be guided through the street by men with lanterns during daylight hours. The smog lasted for 5 days, eventually extending over a 50km radius. Approx. 4,000 excess deaths occurred as a result of inhaling pollution, mainly old and sick and those with chest problems. Respiratory diseases alone accounted for 59 per cent of the increase in deaths registered in the week ending 13 December and 76 per cent in the following week. Bronchitis and emphysema were the two conditions that stood out in the coroner's records as showing the greatest increase. Cardiovascular disease accounted for 22 per cent of the increased number of deaths in the first week and 16 per cent in the week ending 20 December. The disaster ultimately led to the introduction of the Clean Air Acts.

ACID MIST/ RAIN

Definition

Normal Rain water p^H is slightly acidic due to certain concentration of CO_2 dissolved as rainwater trickles down atmosphere,

$$CO_2+H_2O \rightarrow HCO^{3-}+H^+$$

Acid rain is defined as any type of precipitation with a p^H that is unusually low or lower than 5.7. Acid rain was first found in Manchester, England. In 1852, Robert Angus Smith found the relationship between acid rain and atmospheric pollution. Though acid rain was discovered in 1852, it wasn't until the late 1960s that scientists began widely observing and studying the phenomenon.

Causes

The principal natural phenomena that contribute acid-producing gases to the atmosphere are emissions from volcanoes and those from biological processes that occur on the land, in wetlands, and in the oceans. The major biological source of sulfur containing compounds is dimethyl sulfide.

The principal cause of acid rain is sulfuric and nitrogen compounds from human sources, such as electricity generation, factories and motor vehicles. Coal power plants are one of the most polluting. The gases can be carried hundreds of kilometres in the atmosphere before they are converted to acids and deposited. Factories used to have short funnels to let out smoke, but this caused many problems, so now, factories have longer smoke funnels. The problem with this is those pollutants get carried far off, where it creates more destruction.

Sulfur dioxide contributes to about seventy percent of acid rain while nitrogen oxides provide the remaining thirty percent. The sources of sulfur in the atmosphere include coal combustion, smelting, organic decay, and ocean spray. Approximately ninety percent of atmospheric sulfur results from human activities.

In the atmosphere, sulfur dioxide combines with water vapor to form hydrogen sulfite gas:

$$SO_2 + H_2O+1/2O_2 \rightarrow H_2SO_4$$

Next, hydrogen sulfite reacts with oxygen to form sulfuric acid, a major component of acid rain:

$$H_2SO_3 + 1/2O_2 \rightarrow H_2SO_4$$

The sources of nitrogen oxides include the combustion of oil, coal and natural gas, forest fires, bacterial action in soil, volcanic gases, and lighting-induced atmospheric reactions.

In the atmosphere, nitrogen monoxide reacts with oxygen gas to form nitrogen dioxide gas:

$$NO + 1/2O_2 \rightarrow NO_2$$

Then, nitrogen dioxide reacts with water vapor in the atmosphere to form hydrogen nitrite and hydrogen nitrate:

$$2NO_2 + H_2O \rightarrow HNO_2 + HNO_3$$

Henceforth, acid rain is a mixture of HNO_3, H_2SO_4 + HCl. however conditions needed to favor formation of these are sunlight, temperature, humidity, hydrocarbons, NO_X, SO_2.

Effects

Both the lower p^H and higher aluminum concentrations in surface water that occur as a result of acid rain can cause damage to fish and other aquatic animals. At p^H lower than 5 most fish eggs will not hatch and lower p^H can kill adult fish. As lakes become more acidic biodiversity is reduced. Soil biology can be seriously damaged by acid rain. Some tropical microbes can quickly consume acids but other microbes are unable to tolerate low p^H and are killed.

Acid rain can slow the growth of forests, cause leaves and needles to turn brown and fall off and die. In extreme cases trees or whole areas of forest can die. The death of trees is not usually a direct result of acid rain; often it weakens trees and makes them more susceptible to other threats. Some scientists have suggested direct links to human health, but none have been proven. However, fine particles, a large fraction of which are formed from the same gases as acid rain (sulfur dioxide and nitrogen dioxide), have been shown to cause illness and premature deaths such as cancer and other deadly diseases

Toxic metals released into the environment by acid rain may enter water supplies or accumulate in fish and crops. Acid deposition also destroys statues, headstones, buildings, and fountains. Limestone structures are especially susceptible because they dissolve easily in acidic solutions.

Acid rain can also cause damage to certain building materials and historical monuments. Acid rain can cause weathering on ancient and valuable statues and has caused considerable damage. This is because the sulfuric acid in the rain chemically reacts with the calcium compounds in the stones (limestone, sandstone, marble and granite) to create gypsum, which then flakes off. Acid rain also causes an increased rate of oxidation for iron.

Control

- Design more efficient automobile engines in order to reduce nitrogen oxide emissions.
- Increase efficiency of power plants that burn coal in order to reduce waste that contains sulfur dioxide and nitrogen oxide.
- Increase penalties on industries that do not meet air pollution guidelines.

- Increase tax incentives to industries that do meet guidelines.
- Use alternative energy sources, Increase funding for alternative energy sources; for example, give tax incentives to buyers of hybrid cars.
- Provide tax incentives to companies that use alternative energy sources.
- Add $CaCO_3$ (calcium carbonate) to lakes suffering from acid deposition; calcium carbonate acts as a buffer, resisting a change in p^H and lessening the negative effects of acid rain.

OZONE DEPLETION

Definition

Ozone layer is an umbrella 24 km [15 miles] from earth surface, an essential component of the stratosphere that absorbs short wavelength ultraviolet radiation from the sun, heating the gases of the stratosphere in the process. World ozone day is celebrated on Sept, 16 of every year.

Stratospheric ozone is measured in Dobson units [DU] named after G.M.B Dobson who pioneered the study; [I Dobson unit = 0.01 mm thickness of stratospheric ozone], Average ozone thickness in stratosphere is 300 DU, & when it falls below 200 DU, it’s considered as Ozone hole. It is thinnest around equator and thickest near poles.

Stratospheric ozone depletion is the term applied to the loss of stratospheric ozone molecules (O_3) and the disruption of Oxygen-Ozone concentration equilibrium in stratosphere [i.e., when chlorine atoms upset the natural O_2/O_3 equilibrium in the stratosphere]. Oxygen molecules interact with the intense solar radiation present at this elevation to form oxygen atoms. The oxygen atoms thus generated react with other oxygen molecules to form ozone (O_3).

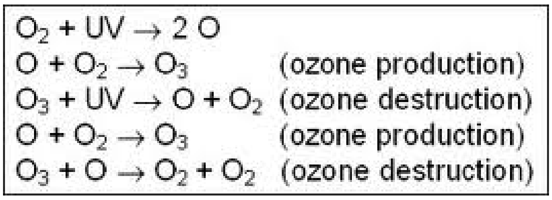
Causes

Ozone depletion is caused by the release of chlorofluorocarbons (CFC's) and other ozone-depleting substances (ODS), which were used widely as refrigerants, insulating foams, and solvents. The discussion below focuses on CFCs, but is relevant to all ODS [NO, NO_2 (aircraft exhaust), Br^-, UV rays, [O] Atomic oxygen etc].

Although CFCs are heavier than air, they are eventually carried into the stratosphere in a process that can take as long as 2 to 5 years. When CFCs reach the stratosphere, the ultraviolet radiation from the sun causes them to break apart and release chlorine atoms which react with ozone, starting chemical cycles of ozone destruction that deplete the ozone layer. One chlorine atom can break apart more than 100,000 ozone molecules.

Other chemicals that damage the ozone layer include methyl bromide (used as a pesticide), halons (used in fire extinguishers), and methyl chloroform (used as a solvent in industrial processes). As methyl bromide and halons are broken apart, they release bromine atoms, which are 40 times more destructive to ozone molecules than chlorine atoms.

Chapman's Reaction



$O_2 + UV \rightarrow 2\,O$

$O + O_2 \rightarrow O_3$ (ozone production)

$O_3 + UV \rightarrow O + O_2$ (ozone destruction)

$O + O_2 \rightarrow O_3$ (ozone production)

$O_3 + O \rightarrow O_2 + O_2$ (ozone destruction)

Ozone Depletion by CFC's

All above reactions occur in the presence of UV rays, while the 2nd set of reactions governs the oxygen-ozone equilibrium due to its spontaneity.

Effects

Effect of ozone hole include cataract, genetic mutation, constriction of blood vessels, reduced crop yield, leukemia, breast cancer, damage to crop, aqua culture, etc.,

The higher energy UV radiation absorbed by ozone is generally accepted to be a contributory factor to skin cancer. In addition, increased surface UV leads to increased tropospheric ozone, which is a health risk to humans such as Snow Blindness [photo keratosis], i.e., inflammation of cornea (outer coating of eyeball). The most common forms of skin cancer in humans, basal and squamous cell carcinomas have been strongly linked to UVB exposure. Another form of skin cancer, malignant melanoma, is much less common but far more dangerous, being lethal in about 15% - 20% of the cases diagnosed. In India there is no standard for Ozone. However WHO standard is 100 ppm for 8 hrs. – avg.

Control Measures

The Montreal Protocol, an international agreement signed by 139 nations, banning the production of CFCs by the year 2000. We can't make enough ozone to replace what's been destroyed, but provided that we stop producing ozone-depleting substances, natural ozone production reactions should return the ozone layer to normal levels by about 2050. It is very important that the world comply with the Montreal Protocol; delays in ending production could result in additional damage and prolong the ozone layer's recovery. Control mechanism stresses on replacement of the banned chemical by ammonia, steam, helium etc.

10CV765 / AIR POLLUTION AND CONTROL / R.G.

Unit – 2

Effects of air pollution On Human Health

Exposure to air pollution is associated with numerous effects on human health, including pulmonary, cardiac, vascular, and neurological impairments. The health effects vary greatly from person to person. High-risk groups such as the elderly, infants, pregnant women, and sufferers from chronic heart and lung diseases are more susceptible to air pollution. Children are at greater risk because they are generally more active outdoors and their lungs are still developing.

Exposure to air pollution can cause both acute (short-term) and chronic (long-term) health effects. Acute effects are usually immediate and often reversible when exposure to the pollutant ends. Some acute health effects include eye irritation, headaches, and nausea. Chronic effects are usually not immediate and tend not to be reversible when exposure to the pollutant ends. Some chronic health effects include decreased lung capacity and lung cancer resulting from long-term exposure to toxic air pollutants.

The scientific techniques for assessing health impacts of air pollution include air pollutant monitoring, exposure assessment, dosimetry, toxicology, and epidemiology. Although in humans pollutants can affect the skin, eyes and other body systems, they affect primarily the respiratory system. Air is breathed in through the nose, which acts as the primary filtering system of the body. The small hairs and the warm, humid conditions in the nose effectively remove the larger pollutant particles. Both gaseous and particulate air pollutants can have negative effects on the lungs. Solid particles can settle on the walls of the trachea, bronchi, and bronchioles. Most of these particles are removed from the lungs through the cleansing (sweeping) action of "cilia", small hair like outgrowths of cells, located on the walls of the lungs

Gaseous air pollutants may also affect the function of the lungs by slowing the action of the cilia. Continuous breathing of polluted air can slow the normal cleansing action of the lungs and result in more particles reaching the lower portions of the lung.

The table summarizes the sources, health and welfare effects for the Criteria Pollutants.

Pollutant	Description	Sources	Health Effects	Welfare Effects
Carbon Monoxide (CO)	Colorless, odorless gas	Motor vehicle exhaust, indoor sources include kerosene or wood burning stoves.	Headaches reduced mental alertness, heart attack, cardiovascular diseases, impaired fetal development, and death.	Contribute to the formation of smog.
Sulfur Dioxide (SO2)	Colorless gas that dissolves in water vapor to form acid, and interact with other gases and particles in the air.	Coal-fired power plants, petroleum refineries, manufacture of sulfuric acid and smelting of ores containing sulfur.	Eye irritation, wheezing, chest tightness, shortness of breath, lung damage.	Contribute to the formation of acid rain, visibility impairment, plant and water damage, aesthetic damage.
Nitrogen Dioxide (NO2)	Reddish brown, highly reactive gas.	Motor vehicles, electric utilities, and other industrial, commercial, and residential sources that burn fuels.	Susceptibility to respiratory infections, irritation of the lung and respiratory symptoms (e.g., cough, chest pain, difficulty breathing).	Contribute to the formation of smog, acid rain, water quality deterioration, global warming, and visibility impairment.
Ozone (O3)	Gaseous pollutant when it is formed in the troposphere.	Vehicle exhaust and certain other fumes. Formed from other air	Eye and throat irritation, coughing, respiratory tract problems, asthma, lung	Plant and ecosystem damage.

		pollutants in the presence of sunlight.	damage.	
Lead (Pb)	Metallic element	Metal refineries, lead smelters, battery manufacturers, iron and steel producers.	Anemia, high blood pressure, brain and kidney damage, neurological disorders, cancer, lowered IQ.	Affects animals and plants, affects aquatic ecosystems.
Particulate Matter (PM)	Very small particles of soot, dust, or other matter, including tiny droplets of liquids.	Diesel engines, power plants, industries, windblown dust, wood stoves.	Eye irritation, asthma, bronchitis, lung damage, cancer, heavy metal poisoning, cardiovascular effects.	Visibility impairment, atmospheric deposition, aesthetic damage.

Effects of air pollution On Plants

The effects of pollution on plants include mottled foliage, "burning" at leaf tips or margins, twig dieback, stunted growth, premature leaf drop, delayed maturity, abortion or early drop of blossoms, and reduced yield or quality.

In general, the visible injury to plants is of three types: (1) collapse of leaf tissue with the development of necrotic patterns, (2) yellowing or other color changes, and (3) alterations in growth or premature loss of foliage. Injury from air pollution can be confused with the symptoms caused by fungi, bacteria, viruses, nematodes, insects, nutritional deficiencies and toxicities, and the adverse effects of temperature, wind, and water.

Factors that govern the extent of damage and the region where air pollution is a problem are (1) type and concentration of pollutants, (2) distance from the source, (3) length of exposure, and (4) meteorological conditions.

Effects of air pollution On Materials

(i) Abrasion (loss of material by wind with coarser particles).
(ii) Corrosion (acidic effect of rain water).
(iii) Deposition and removal (adhering substances like SPM and removal of material by rusting.
(iv) Direct chemical attack (effect of gases like SO_2).
(v) Indirect chemical attack (action of acid or its fumes on stones like marble, corrosion of reinforcement due to diffusion of gases in RCC).

MAJOR ENVIRONMENTAL AIR POLLUTION EPISODES

London Smog

Introduction to Smog

Smog is a recent compound word from "smoke" and "fog", and was coined by Harold Antoine des Voeux, a doctor, in 1905. Smog refers to locally high concentrations of acids, dry acid-forming compounds, particulates, or other pollutants in stagnant, stable air. Smog’s form when emissions are prevented from dispersing by stable or sinking air masses.

Introduction to London Smog

They were very prevalent in European and North American cities during first part of 20th Century. London smog’s were infamous in the 19th and early 20th centuries and formed every autumn and winter due to sulphur emissions from coal burning industries and domestic fires. The most severe London smog was on 4-10th December 1952, when cold, high-pressure conditions trapped coal smoke in foggy air. The output of smoke was increased by the cold weather, due to the large numbers of domestic fires. Sooty smoke produced peak daily concentrations of black smoke of 5000 mgs/m3 (WHO 24 hr max limit of 100-150), and daily average SO_2 levels of 3000-4000 mg/m3 (WHO 24 hr max limit of 100-150). Sulphuric acid droplets resulted in pH estimated as 1.4 to 1.9: as acidic as car battery acid.

Chemistry

$$H_2SO_{4(g)} + H_2O \rightarrow H_2SO_{4(aq)}$$
$$SO_{2(g)} + H_2O_{(l)} \rightarrow H_2SO_{3(aq)}$$

These are produced by high outputs of SO2, which are converted to acids on contact with atmospheric moisture. Usually, sulphurous smog's also contain elevated concentrations of suspended soot.

Impacts

Visibility was reduced to 5m at times, and London buses had to be guided through the street by men with lanterns during daylight hours. The smog lasted for 5 days, eventually extending over a 50km radius. Approx. 4,000 excess deaths occurred as a result of inhaling pollution, mainly old and sick and those with chest problems. Respiratory diseases alone accounted for 59 per cent of the increase in deaths registered in the week ending 13 December and 76 per cent in the following week. Bronchitis and emphysema were the two conditions that stood out in the coroner's records as showing the greatest increase. Cardiovascular disease accounted for 22 per cent of the increased number of deaths in the first week and 16 per cent in the week ending 20 December. The disaster ultimately led to the introduction of the Clean Air Acts.

Bhopal Gas Tragedy

INTRODUCTION

The Bhopal gas tragedy was a gas leak incident in India and, considered one of the world's worst industrial disasters. It occurred on the night of 2nd and dawn of 3rd December 1984 at the Union Carbide India Limited (UCIL) pesticide plant in Bhopal, Madhya Pradesh, India. UCIL was the Indian subsidiary of Union Carbide Corporation. The plant manufactured Sevin Carbide, among other pesticides. MIC was one of the chemicals processed for the prime reactions.

ACCIDENT

Even before the December 1984 incident, numerous incidents had fore-warned of an oncoming disaster. During the incident, most of the safety systems were not functioning. Many valves and lines were in poor condition. Tank 610 contained 42 tons of MIC, much more than what safety rules allowed. During the nights of 2–3 December, a large amount of water is claimed to have entered tank 610. A runaway reaction started, which was accelerated by contaminants, high temperatures and other factors. The reaction generated a major increase in the temperature inside the tank to over 200 °C (400 °F). This forced the emergency venting of pressure from the MIC holding tank, releasing a large volume of toxic gases. The reaction was sped up by the presence of iron from corroding non-stainless steel pipelines. Workers cleaned pipelines with water and claim they were not told to isolate the tank with a pipe slip-blind plate. Owing of this, and the poor maintenance, the workers consider that water might have accidentally entered the tank.

IMPACT

A leak of methyl iso-cyanate gas and other chemicals from the plant resulted in the exposure of hundreds of thousands of people. The official immediate death toll was 2,259 and the government of Madhya Pradesh has confirmed a total of 3,787 deaths related to the gas release. Others estimate 8,000 died within two weeks and another 8,000 or more have since died from gas-related diseases. When panic was at its peak at major hospitals of the city, the patients could be graded symptomatically into four categories: (i) Minor eye ailments, throat irritation and cough, (ii) Severe conjunctivitis, keratitis, acute bronchitis and drowsiness, (iii) Severe pulmonary oedema leading to cardio-respiratory distress, and (iv) Convulsions, followed by cardio-respiratory arrest. Intense fatigue and muscular weakness was another common feature. Civil and criminal cases are pending in the United States District Court, Manhattan and the District Court of Bhopal, India, involving UCC, UCIL employees.

Passing of THE ENVIRONMENTAL PROTECTION ACT, 1986 and PUBLIC LIABILITY INSURANCE ACT, 1986

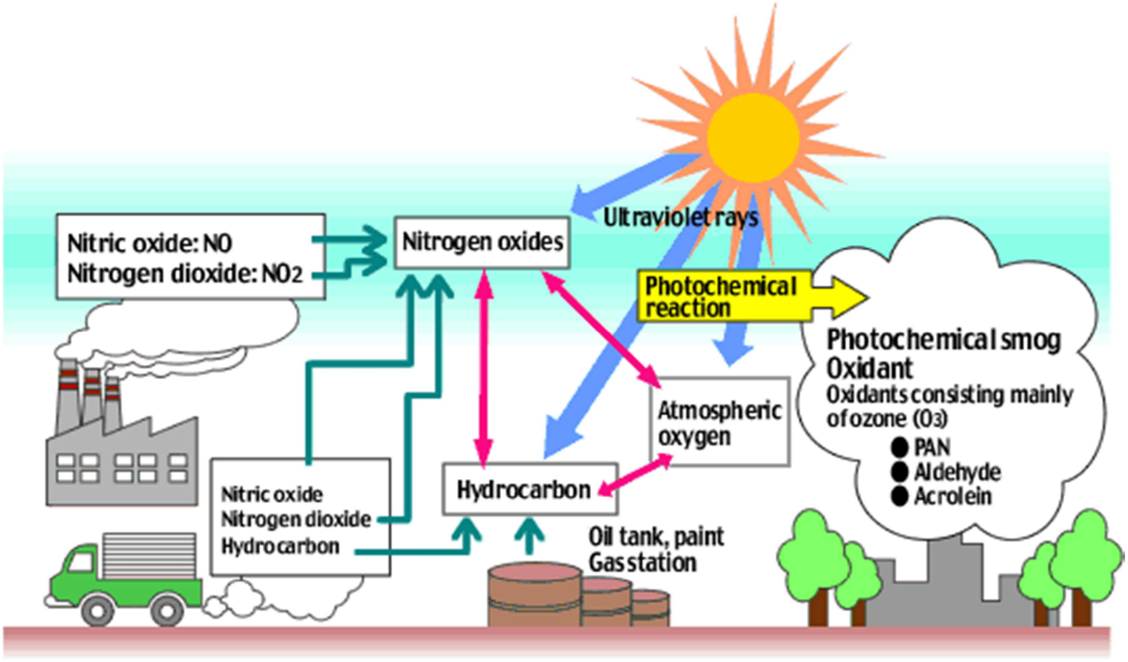
Los Angeles Smog

INTRODUCTION

Photochemical smog was first described in the 1950s. It is the chemical reaction of sunlight, nitrogen oxides and volatile organic compounds in the atmosphere, which leaves airborne particles and ground-level ozone. This noxious mixture of air pollutants can includes Aldehydes, Nitrogen oxides, such as nitrogen dioxide, Peroxyacyl nitrates Tropospheric ozone, Volatile organic compounds etc. All of these chemicals are usually highly reactive and oxidizing.

Photochemical smog is considered to be a problem of modern industrialization. It is present in all modern cities, but it is more common in cities with sunny, warm, dry climates and a large number of motor vehicles. Because it travels with the wind, it can affect sparsely populated areas as well.

VOCs + NOx + sunlight → photochemical smog



To begin the chemical process of photochemical smog development the following conditions must occur:

- Sunlight.
- The production of oxides of nitrogen (NOx).
- The production of volatile organic compounds (VOCs).
- Temperatures greater than 18 degrees Celsius.

Nitrogen oxide is an essential ingredient of photochemical smog that is produced during the high temperatures associated with combustion of vehicle’s engines. Nitrogen oxide is an essential ingredient of photochemical smog that is produced during the high temperatures associated with combustion of vehicle’s engines.

Formation

Sunlight can break down nitrogen dioxide back into nitrogen oxide.

$$NO_2 + \text{sunlight} »»» NO + O$$

The atomic oxygen formed in the above reaction then reacts with one of the abundant oxygen molecules producing ozone.

$$O + O_2 »»» O_3$$

Nitrogen dioxide can also react with radicals produced from volatile organic compounds in a series of reactions to form toxic products such as peroxyacetyl nitrates.

$$NO_2 + R »»» \text{products such as PAN}$$

Note the symbol R represents a hydrocarbon (a molecule composed of carbon, hydrogen and other atoms) which is primarily created from volatile organic compounds.

Steps

1) Nitrogen oxides generate oxygen atoms

2) Oxygen atoms form hydroxyl radicals

3) Hydroxyl radicals generate hydrocarbon radicals

4) Hydrocarbon radicals form hydrocarbon peroxides

5) Hydrocarbon peroxides form aldehydes

6) Aldehydes form aldehyde peroxides

7) Aldehyde peroxides form peroxy-acyl-nitrates

Health effects

It can cause eye and nose irritation and it dries out the protective membranes of the nose and throat and interferes with the body's ability to fight infection, increasing susceptibility to illness.

Chapter 3

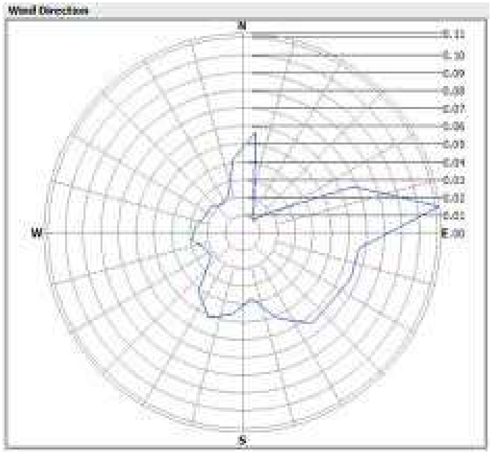
Air Pollution and Meteorology

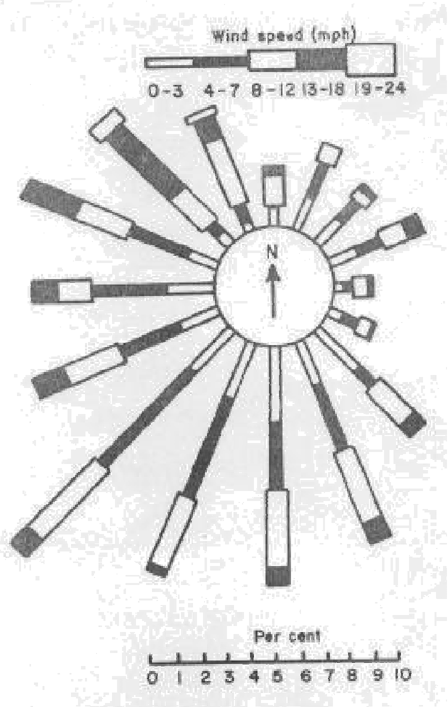
The science of meteorology has great bearing on air pollution. An air pollution problem involves three parts: the source, the movement of the pollutant and the recipient. All meteorological phenomena are a result of interaction of the elemental properties of the atmosphere, heat, pressure, wind and moisture.

Wind

Wind is simply air in motion. On global or macroscale wind patterns are set up due to unequal heating of earth surface by solar radiation at the equator and the polar regions, rotation of the earth and the difference between conductive capacities of land and ocean masses. Secondary or mesoscale circulation patterns develop because of the regional or local topography. Mountain ranges, cloud cover, waterbodies, deserts, forestation, etc., influence wind patterns on scales of a few hundred kilometers. Accordingly a pattern of wind is setup, some seasonal and some permanent. Microscale phenomenon occurs over areas of less than 10 km extent. Standard wind patterns may deviate markedly due to varying frictional effects of the earth surface, such as, rural open land, irregular topography and urban development, effect of radiant heat from deserts and cities, effect of lakes, etc. The movement of air at the mesoscale and microscale levels is of concern in control of air pollution. A study of air movement over relatively small geographical regions can help in understanding the movement of pollutants.

It is obviously important in predicting pollutant dispersion to know the direction of wind. The wind direction and speed data may be collected every hour in a month and classified according to speed and direction. It is then summarized in the form of a polar diagram called *wind rose.* Figure shows a hypothetical wind rose. The position of the spokes show the direction from which the wind was blowing, the length of various segments of the spokes show the percent of time the wind was of the designated speed. Thus from the diagram, most often (12% of time) the wind was from SE; the strongest wind (9-11 m/s) was from NW and NNW.

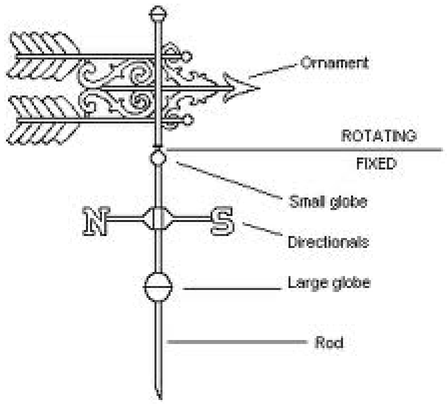


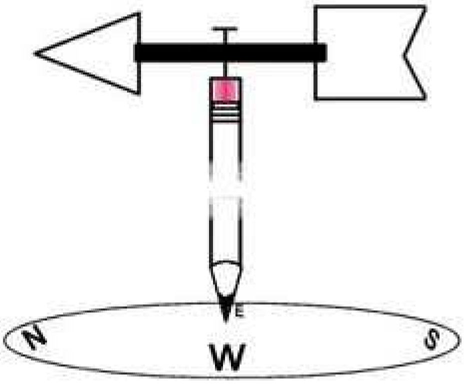


Importance of wind rose in air pollution studies

A wind rose is a graphic tool used by meteorologists to give a succinct view of how wind speed and direction are typically distributed at a particular location. It assists in city planning and siting of industries.

An anemometer is a device for measuring wind speed, and is a common weather station instrument. Anemometers can be divided into two classes: those that measure the wind's speed, and those that measure the wind's pressure; but as there is a close connection between the pressure and the speed, an anemometer designed for one will give information about both. A simple type of anemometer, consistS of four hemispherical cups each mounted on one end of four horizontal arms, which in turn were mounted at equal angles to each other on a vertical shaft. The air flow past the cups in any horizontal direction turned the cups in a manner that was proportional to the wind speed. Therefore, counting the turns of the cups over a set time period produced the average wind speed for a wide range of speeds. On an anemometer with four cups it is easy to see that since the cups are arranged symmetrically on the end of the arms, the wind always has the hollow of one cup presented to it and is blowing on the back of the cup on the opposite end of the cross.



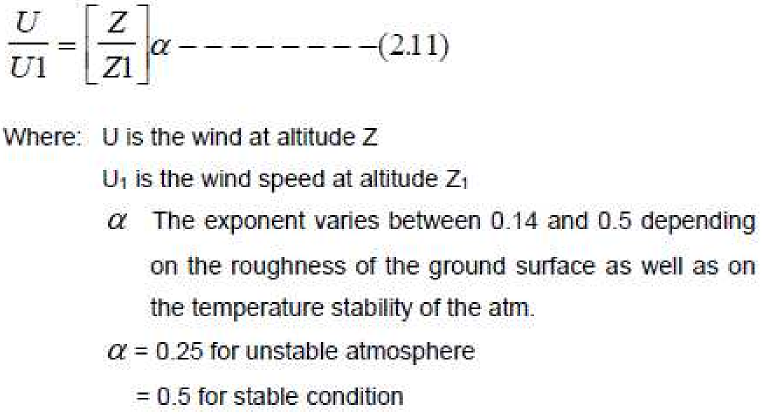


A weather vane (or weathercock) is an instrument for showing the direction of the wind . They are typically used as an architectural ornament to the highest point of a building. Although partly functional, weather vanes are generally decorative, often featuring the traditional cockerel design with letters indicating the points of the compass. Other common motifs include ships, arrows and horses.

The design of a wind vane is such that the weight is evenly distributed on each side of the surface, but the surface area is unequally divided, so that the pointer can move freely on its axis. The side with the larger surface area is blown away from the wind direction, so that the smaller side, with the pointer, is pivoted to face the wind direction. Most wind vanes have directional markers beneath the arrow, aligned with the geographic directions.

Wind vanes, especially those with fanciful shapes, do not always show the real direction of a very gentle wind. This is because the figures do not achieve the necessary design balance: an unequal surface area but balanced in weight. To obtain an accurate reading, the wind vane must be located well above the ground and away from buildings, trees, and other objects which interfere with the true wind direction. Changing wind direction can be meaningful when coordinated with other apparent sky conditions, enabling the user to make simple short range forecasts. From the street level the size of many weathercocks is deceptive.

The mean wind speed variation with altitude is the planetary boundary layer can be represented by a simple empirical power.



$$\frac{U}{U1} = \left[\frac{Z}{Z1}\right]\alpha \text{---------}(2.11)$$

Where: U is the wind at altitude Z

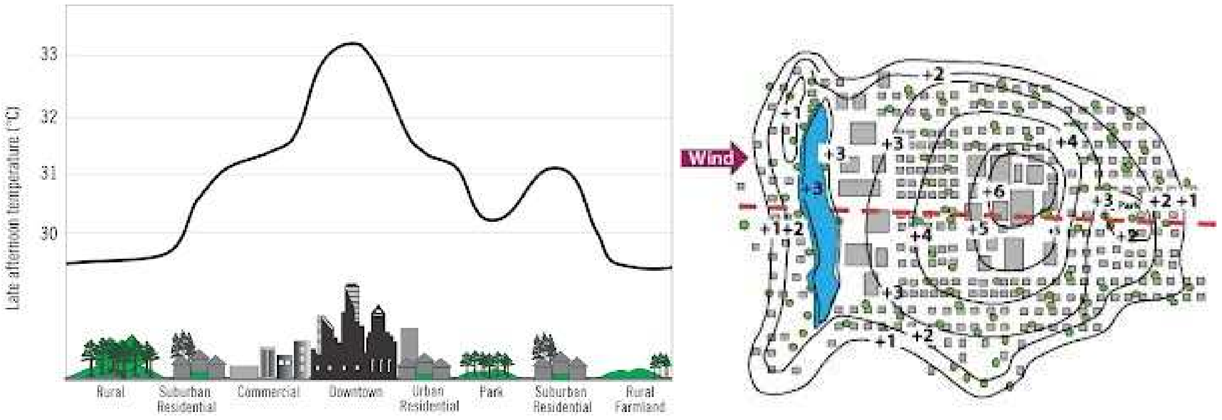
U_1 is the wind speed at altitude Z_1

α The exponent varies between 0.14 and 0.5 depending on the roughness of the ground surface as well as on the temperature stability of the atm.

α = 0.25 for unstable atmosphere

= 0.5 for stable condition

Urban Heat Islands



Urbanization negatively impacts the environment mainly by the production of pollution, the modification of the physical and chemical properties of the atmosphere, and the covering of the soil surface. Considered to be a cumulative effect of all these impacts is the UHI, defined as the rise in temperature of any man-made area, resulting in a well-defined, distinct "warm island" among the "cool sea" represented by the lower temperature of the area’s nearby natural landscape.

Though heat islands may form on any rural or urban area, and at any spatial scale, cities are favoured, since their surfaces are prone to release large quantities of heat. Nonetheless, the UHI negatively impacts not only residents of urban-related environs, but also humans and their associated ecosystems located far away from cities. In fact, UHIs have been indirectly related to climate change due to their contribution to the greenhouse effect, and therefore, to global warming.

It is well-known that the progressive replacement of natural surfaces by builtsurfaces, through urbanization, constitutes the main cause of UHI formation. Natural surfaces are often composed of vegetation and moisture-trapping soils. Therefore, they utilize a relatively large proportion of the absorbed radiation in the evapotranspiration process and release water vapour that contributes to cool the air in their vicinity. In contrast, built surfaces are composed of a high percentage of non-reflective and water-resistant construction materials. As consequence, they tend to absorb a significant proportion of the incident radiation, which is released as heat.

Vegetation intercepts radiation and produces shade that also contributes to reduce urban heat release. The decrease and fragmentation of large vegetated areas such as parks, not only reduces these benefits, but also inhibits atmospheric cooling due to horizontal air circulation generated by the temperature gradient between vegetated and urbanized areas (i.e. advection), which is known as the park cool island effect. On the other hand, the narrow arrangement of buildings along the city's streets form urban canyons that inhibit the escape of the reflected radiation from most of the three-dimensional urban surface to space. This radiation is ultimately absorbed by the building walls (i.e. reduced sky view factor), thus enhancing the urban heat release. Additional factors such as the scattered and emitted radiation from atmospheric pollutants to the urban area, the production of waste heat from air conditioning and refrigeration systems, as well from industrial processes and motorized vehicular traffic (i.e. anthropogenic heat), and the obstruction of rural air flows by the windward face of the built-up surfaces, have been recognized as additional causes of the UHI effect

As it would be expected, the characteristic inclination towards warming of urban surfaces is exacerbated during hot days and heat waves, which reinforces the air temperature increase, particularly in ill-ventilated outdoor spaces or inner spaces of residential and commercial buildings with poor thermal isolation. This increases the overall energy consumption for cooling (i.e. refrigeration and air-conditioning), hence increasing the energy production by power plants, which leads to higher emissions of heat-trapping greenhouse gases such as carbon dioxide, as well as other pollutants such as sulfur dioxide, carbon monoxide and particulate matter. Furthermore, the increased energy demand means more costs to citizens and goverments, which in large metropolitan areas may induce significant economic impacts. On the other hand, UHIs promote high air temperatures that contribute to formation of ozone precursors, which combined photochemically produce ground level ozone.

A direct relationship has been found between UHI intensity peaks and heat-related illness and fatalities, due to the incidence of thermal discomfort on the human cardiovascular and respiratory systems. Heatstroke, heat exhaustion, heat syncope,and heat cramps, are some of the main stress events, while a wide number of diseases may become worse, particularly in the elderly and children. In a similar way, respiratory and lung diseases have shown to be related to high ozone levels induced by heat events. Other meteorological impacts of the UHI are associated with reductions in snowfall frecuencies and intensities, as well as reductions in the diurnal and seasonal range of freezing temperatures. Lastly, high temperatures may produce physiological and phenological disturbances on ornamental plants and urban forests.

There are two main UHI reduction strategies: first, to increase surface reflectivity (i.e. high albedo), in order to reduce radiation absorption of urban surfaces, and second, to increase vegetation cover, mainly in the form of urban forests and parks, in order to maximize the multiple vegetation benefits in controlling the temperature rises. Reflective surfaces simply results from light colored or white paint on the surface of a given construction material or from cover the construction material surface with a white membrane. Both techniques have been mainly applied on roofs and pavements. Cool roofs are specially important in commercial and residential buildings, where significant energy demand for cooling can be saved by reducing heat gain to the building. Cool pavements have mainly based on the use of whitened asphalt roads, a very warm material.

Urban Dust Domes

Urban dust domes are a meteorological phenomenon in which soot, dust, and chemical emissions become trapped in the air above urban spaces. This trapping is a product of local air circulations. Calm surface winds are drawn to urban centers, they then rise above the city and descend slowly on the periphery of the developed core. This cycle is often a cause of smog

through photochemical reactions that occur when strong concentrations of the pollutants in this cycle are exposed to solar radiation. These are one result of urban heat islands: pollutants concentrate in a dust dome because convection lifts pollutants into the air, where they remain because of somewhat stable air masses produced by the urban heat island.

Atmospheric Stability

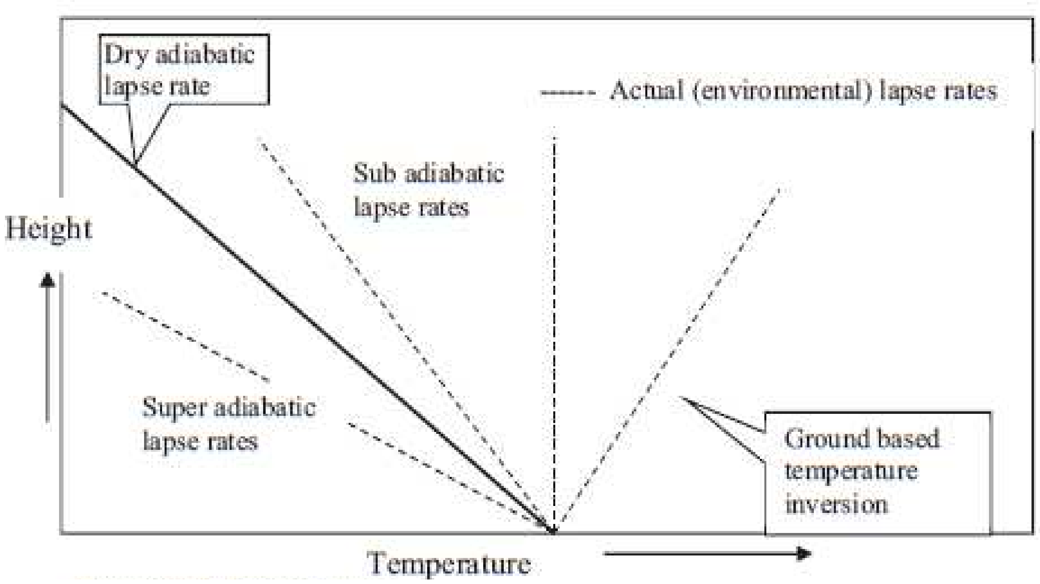
The ability of the atmosphere to disperse the pollutants emitted in to it depends to a large extent on the degree of stability. A comparison of the adiabatic lapse rate with the environmental lapse rate gives an idea of stability of the atmosphere. When the environmental lapse rate and the dry adiabatic lapse rate are exactly the same, a raising parcel of air will have the same pressure and temperature and the density of the surroundings and would experience no buoyant force. Such atmosphere is said to be neutrally stable where a displaced mass of air neither tends to return to its original position nor tends to continue its displacement

Lapse rate

As a parcel of air rises in the earth's atmosphere it experiences lower and lower pressure from the surrounding air molecules, and thus it expands. This expansion lowers its temperature. Ideally, if it does not absorb heat from its surroundings and it does not contain any moisture, it cools at a rate of 1ºC/100 m rise. This is known as *dry adiabatic lapse rate.*

If the parcel moves down it warms up at the same rate. For a particular place at a particular time, the existing temperature can be determined by sending up a balloon equipped with a thermometer. The balloon moves through the air, and not with it. The temperature profile of the air, which the balloon measures, is called the *ambient lapse rate, environmental lapse rate,* or the *prevailing lapse rate.*

A super-adiabatic lapse rate also called a strong lapse rate occurs when the atmosphere temperature drops more than 1ºC/100m. A sub-adiabatic rate also called weak lapse rate, is characterized by drop of less than 1ºC/100 m. A special case of weak lapse rate is the inversion, a condition which has warmer layer above colder air.



During super-adiabatic lapse rate the atmospheric conditions are unstable. If a parcel of air at 500m elevation, at 20ºC is pushed upward to 1000m, its temperature will come down to 15ºC (according to adiabatic lapse rate). The prevailing temperature is however 10ºC at 1000m. The parcel of air will be surrounded by colder air and therefore will keep moving up.

Similarly if the parcel is displaced downwards, it will become colder than its surroundings and therefore will move down. Super-adiabatic conditions are thus unstable, characterized by a great deal of vertical air movement and turbulence. The sub-adiabatic condition shown in is by contrast a very stable system. Consider again a parcel of air at 500 m elevation at 20ºC. If the parcel is displaced to 1000 m it will cool by 5ºC to 15ºC. But the surrounding air would be warmer. It will therefore fall back to its point of origin. Similarly if a parcel of air at 500 m is pushed down, it will become warmer than its surrounding and therefore will rise back to its original position. Thus such systems are characterized by very limited vertical mixing.

Inversion

An inversion is an extreme sub-adiabatic condition, and thus the vertical air movement within the inversion is almost nill. The two most common kind of inversion are *subsidence inversion* and *radiation inversion.* The base of the subsidence inversion lies some distance above earth's surface. This type of inversion is formed due to adiabatic compression and warming of sinking air mass to a lower altitude in the region of a high pressure center. In the case of radiation inversion, the surface layers of the atmosphere during the day receive heat by conduction, convection and radiation from the earth's surface and are warmed. This results in a temperature profile in the lower atmosphere, which is represented by a negative temperature gradient. On a clear night, the ground surface radiates heat and quickly cools. The air layer adjacent to the earth surface are cooled to a temperature below that of the layers of air at higher elevations. This type of the inversion is strongest just before daylight when it may extend to 500 m. It breaks up as the morning sun heats the ground.

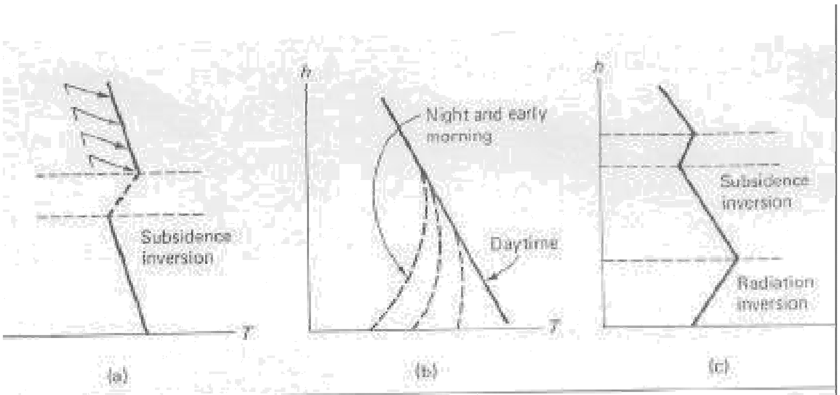


FIGURE 4 ILLUSTRATIONS OF SUBSIDENCE AND RADIATION INVERSIONS.

Maximum mixing depth

The dispersion of pollutants in the lower atmosphere is greatly aided by the convective and turbulent mixing that takes place. The vertical extent to which this mixing takes place depends on the environmental lapse rate which varies diurnally, from season to season and is also affected by topographical features. The depth of the convective mixing layer in which vertical movement of pollutants is possible, is called the maximum mixing depth (MMD). Figure illustrates these MMDs for different lapse rate profiles.

These profiles are usually measured at night or early in the morning. An air parcel at a temperature (maximum surface temperature for the month) warmer than the existing ground level temperature rises and cools according to adiabatic lapse rate. The level where its temperature becomes equal to the surrounding air gives the MMD value. Urban air pollution episodes are known to occur when MMD is 1500 m or less.

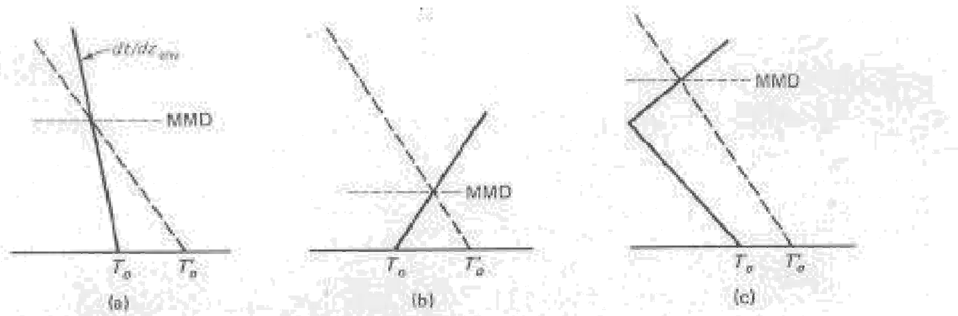
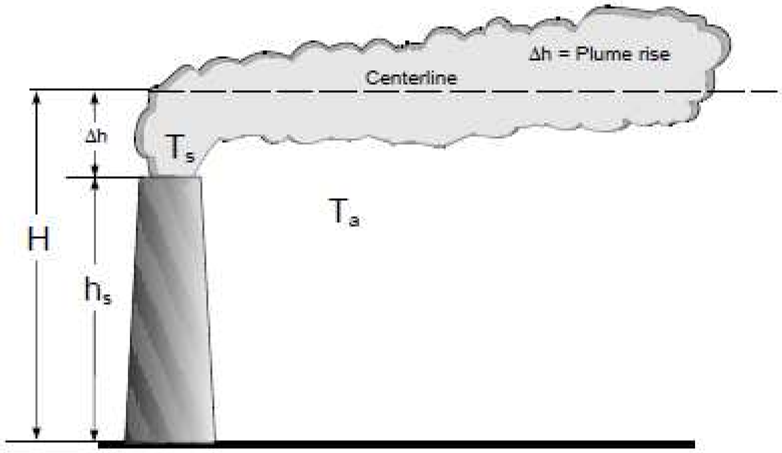


FIGURE 5 MAXIMUM MIXING DEPTH (MMD) UNDER VARIOUS ATMOSPHERIC CONDITIONS, (ADIABATIC PROFILE -------, ENVIRONMENTAL PROFILE———).

Plume Dispersion

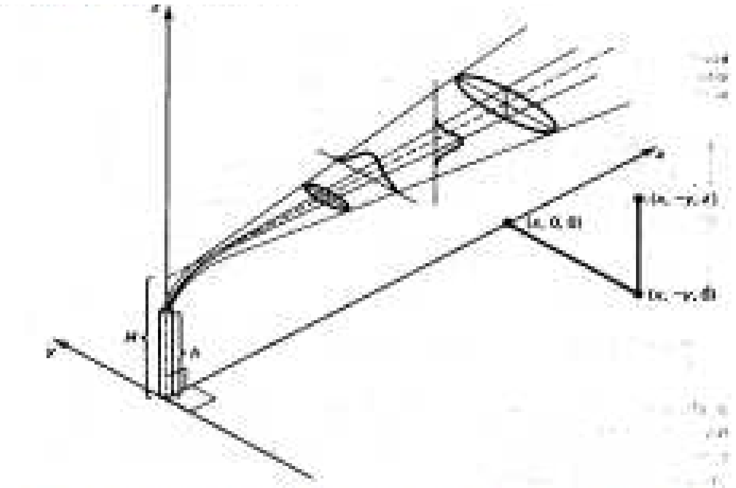
Gases that are emitted from stacks are often pushed out by fans. As the turbulent exhaust gases exit the stack they mix with ambient air. This mixing of ambient air into the plume is called entrainment. As the plume entrains air into it, the plume diameter grows as it travels downwind. These gases have momentum as they enter the atmosphere. Often these gases are heated and are warmer than the outdoor air. In these cases the emitted gases are less dense than the outside air and are therefore buoyant. A combination of the gases' momentum and buoyancy causes the gases to rise. This is referred to as plume rise and allows air pollutants emitted in this gas stream to be lofted higher in the atmosphere. Since the plume is higher in the atmosphere and at a further distance from the ground, the plume will disperse more before it reaches ground level.



The final height of the plume, referred to as the effective stack height (H), is the sum of the physical stack height (hs) and the plume rise (Δh). Plume rise is actually calculated as the distance to the imaginary centerline of the plume rather than to the upper or lower edge of the plume (Figure 6-1). Plume rise depends on the stack's physical characteristics and on the effluent's (stack gas) characteristics. The difference in temperature between the stack gas (Ts) and ambient air (Ta) determines the plume density which affects plume rise. Also, the velocity of the stack gases which is a function of the stack diameter and the volumetric flow rate of the exhaust gases determines the plume's momentum.

The Gaussian plume model

The present tendency is to interpret dispersion data in terms of the Gaussian model. The standard deviations are related to the eddy diffusivities.



Plume dispersion coordinate sysem, showing Gaussian distributions in the horizontal and vertical directions (Turner, 1970)

Ground level concentration

In this case Z=0

$$[\rho A](x, y, 0, H) = \frac{Q}{\pi \delta y\, \delta Z u^{-}} \exp.\left(\frac{-1}{2}\left(\frac{y}{\delta y}\right)^{2}\right).\exp\left[\frac{-1}{2}\left(\frac{H}{\delta Z}\right)\right]$$

Dispersion characteristics of stack plumes

Dispersion is the process of spreading out pollution emission over a large area and thus reducing their concentration. Wind speed and environmental lapse rates directly influence the dispersion pattern.

Coning

A *coning* plume, shown in, occurs under essentially neutral stability, when environmental lapse rate is equal to adiabatic lapse rate, and moderate to strong winds occur. The plume enlarges in the shape of a cone. A major part of pollution may be carried fairly far downwind before reaching ground.

Looping

Under super-adiabatic condition, both upward and downward movement of the plume is possible. Large eddies of a strong wind cause a *looping* pattern. Although the large eddies tend to disperse pollutants over a wide region, high ground level concentrations may occur close to the stack.

Fanning

A *fanning* plume occurs in the presence of a negative lapse rate when vertical dispersion is restricted. The pollutants disperse at the stack height, horizontally in the from of a fanning plume.

Fumigation

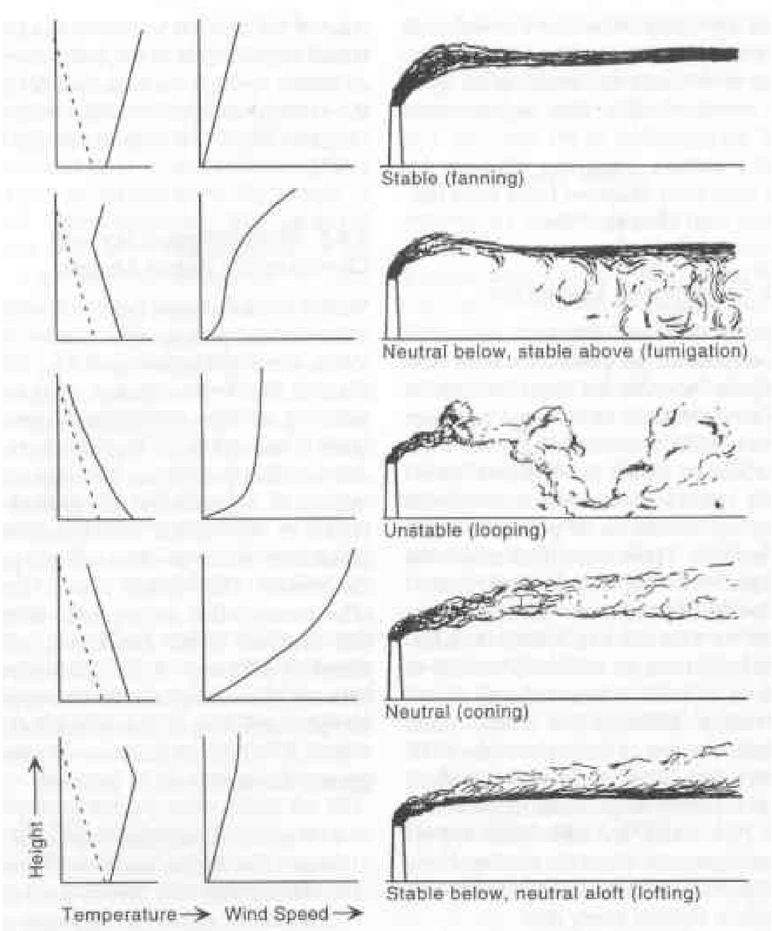
When the emission from the stack is under an inversion layer, the movement of the pollutants in the upward direction is restricted. The pollutants move downwards. The resulting *fumigation* can lead to a high ground level concentration downwind of the stack.

Lofting

When the stack is sufficiently high and the emission is above an inversion layer, mixing in the upward direction is uninhibited, but downward motion is restricted. Such *lofting* plumes do not result in any significant concentration at ground level. However, the pollutants are carried hundreds of kilometers from the source.

Trapping

It occurs when the plume effluent is caught between two inversion layers. The diffusion of the effluent is severely restricted to the unstable layer between the two unstable layers.



Unit – 4

10CV765 APC

Industrial Plant Location and Planning

General factors considered while siting an industrial location include water supply, raw material supply, proximity to nearest railway station, land availability, power supply etc. Hence it's most evident that air pollution and its control are most ignored.

Following are the factors to be considered while deciding industrial installation, keeping in mind air pollution and its impacts.

1] Existing levels of air contaminates

This involves a pre-operational survey, to know the existing level of contaminants under prevailing meteorological conditions, and if not and even if any existing industries. This gives idea if existing pollution levels is high or low. It also gives idea if upcoming industry will aggravate the pollution levels and by how much. It gives idea at what levels must the pollution be released based on existing levels.

2] Potential effects on the surrounding area

The effect of air pollution shall vary from area to area depending on its environment and build forms. Any industrial emission near a city shall endanger more lives than that closer to a forest or un-habituated place.

3] Meteorological factors and the climate

Role of wind direction, wind speed, stability conditions is pivotal to air pollution. Areas having more inversions should be avoided.

4] Availability of clean air

Some industries need clean air for production or in their processes. Polluted air shall make it costlier towards clean-up process and may also impair its regular operations.

5] Topographical features

Industries situated in valleys are more prone to severe impacts during depression, when compared to flat terrains. As inversions or depressions in a valley system shall result in more deposition, less dispersion, no circulation of pollutants.

6] City planning and zoning. (Explanation provided in further sections)

City Planning

Urban Planning is a process of guiding the use and development of land with the aim of making the city a better place to live and work. Particularly important today as more than one-half of the world's population now resides in urban places. Cities, towns and other urban forms are therefore the sites for most of mankind's activities. Yet in most cities and towns, land and access to basic resources and services are usually scarce and unevenly distributed. Planning is 'a general activity…the making of an orderly sequence of action that will lead to the achievement of a stated goal or goals' (Hall 2002). It involves written statements supplemented as appropriate by statistical projections, quantified evaluations and diagrams. Planning involves an attempt to (re)shape prevailing social and economic dynamics to achieve particular developmental ends. The process has different names e.g. town & country planning, town planning, city planning, physical planning etc.it may be thought as a rational (highly technical) and systemic process of forethought set in motion by the need to resolve urban and regional problems, and yet it may be interpreted as a highly political and economistic process.

What do urban planners do?

Determine the best uses of land and resources for homes, businesses, and recreation.
Devise ways to renovate slums, expand cities, modernize transportation systems, and distribute public facilities such as schools and parks.
Urban planners design new communities and develop programs to revitalize and expand existing cities.
Regional planners work on a much larger scale, studying the problems of states, multistate regions, and sometimes entire countries.

Impact of bad planning w.r.t. air pollution

More traffic jams
Irregular dispersions and dissipation air pollutants
More cases of casualty's w.r.t acute and chronic effects.
Blocking of regular wind-paths and thereby hampering free circulation of air.

Lack of proper planning results in failure of remedial measures, and is aggravated by increased costs of control equipment. The main aspect of planning hence must resort to industrial zoning. Cumulative zoning in the past has resulted in less availability of land for industries. This system has now been modified as permissive systems. However this system has now been modified as permissive system. However this system has also resulted in the crowding of industrial zones with other uses besides industries. The next system over this is called excusive zonings system. This type of planning provided for compatible uses for each zones, excluding all other uses. In this system suitable industrial zones are provided and thus there is no air pollution problem.

Zoning criteria for industries:

1] Functional requirement: this includes the inter industry linkages, railways siding, grouping, land traffic generation utilities etc. these aspects are covered under govt. policies.

2] Performance characteristics: this includes the traffic congestion, obnoxious and hazardous character of the industries, industrial nuisance etc. The nuisance includes dust, heat, smoke, fire, odor etc. It is necessary to place obnoxious industries away from neat industries. If planning is done in early stages, its impact analysis can be done for effective execution.

While classifying industries on basis of differential zoning, the following aspects might be followed.

There are 3 categories of industries.

Group 1.] These are smaller industries with a variety of products and with close relations to cities. Their emissions have very little impact on the natural environment. These industries can hence be located on the fringes of the cities.

Group 2] These include cottage and small scale industries requiring less land but indulge in creative and artistic productions. These can be located within cities. As they have no or little adverse effects on the cities.

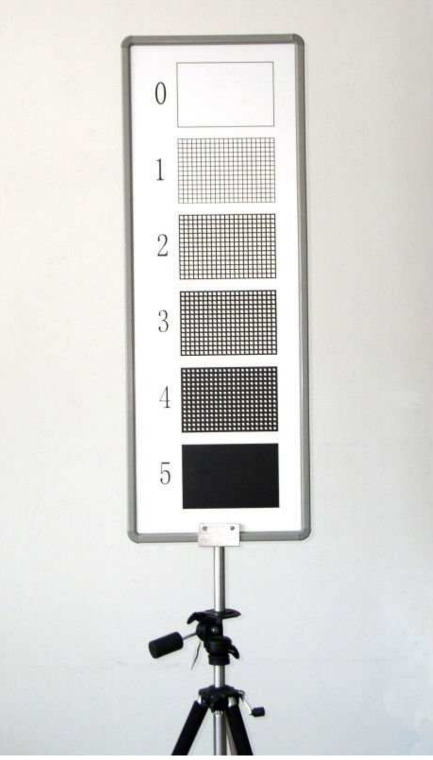
Group 3] These include big industries with relatively less number of unit process and having remote relevance to the central residential areas of the cities. These have profound effect on the cities and hence should be located as far as possible from the residential vicinities.

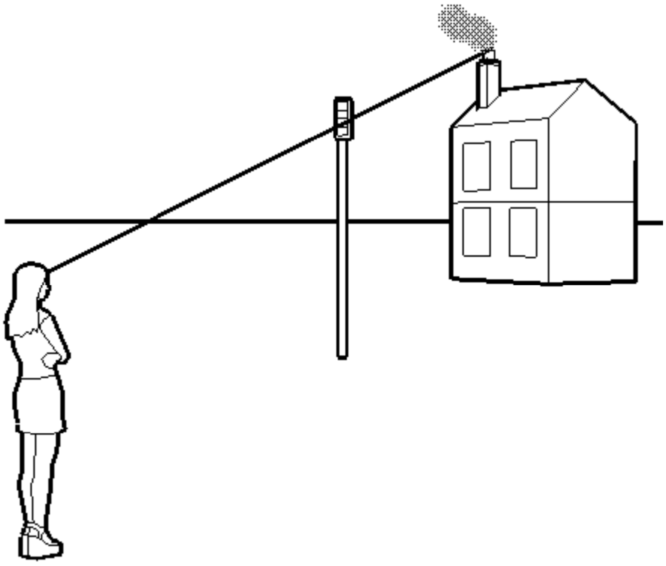
The buffer zone for light industries is about half kilometer, for that of heavy industries it is 0.6 to 1.5 km. for explosive industries it is more than 2 km.

10CV765 / AIR POLLUTION AND CONTROL / R.G.

Unit – 5

MEASUREMENT OF SMOKE DENSITY





Dark smoke is partially burned particles of fuel, the result of incomplete combustion. It can be dangerous because small particles are absorbed into the lungs. **White smoke** is mainly tiny water droplets, generated when vapour released during combustion condenses in cool air. Generally, dark smoke is clearly visible against a light sky but difficult to see at night or against a dark background, white smoke is visible in darkness when illuminated but will be more difficult to see against a light sky background. Smoke is commonly measured in terms of its apparent density in relation to a scale of known greyness.

The most widely-used scale is that developed by Professor Maximilian Ringelmann of La Station d'Essais de Machines in Paris in 1888. It has a 5 levels of density inferred from a grid of black lines on a white surface which, if viewed from a distance, merge into known shades of grey. There is no definitive chart, rather, Prof. Ringelmann provides a specification; where smoke Level '0' is represented by white, levels '1' to '4' by 10mm square grids drawn with 1mm, 2.3mm, 3.7mm and 5.5 mm wide lines and level '5' by all black. It should be remembered that the data obtained has definite limitations. The apparent darkness of a smoke depends upon the concentration of the particulate matter in the effluent, the size of the particulate, the depth of the smoke column being viewed, and natural lighting conditions such as the direction of the sun relative to the observer while the accuracy of the chart itself depends on the whiteness of the paper and blackness of the ink used.

USING THE CHARTS

The large chart on page 4 should be printed with black ink onto very white card and mounted vertically on a board. It is preferably fixed to a pole or held by an assistant at a sufficient distance (typically c20m) for the lines to appear to merge into uniform grey rectangles and to be seen in line with the top of the chimney. The addition of a white (No. 0) square can provide a useful indication that both the chart and chimney are equally illuminated. If a larger chart is needed, the shaded rectangles can be made up into larger ones as mosaics. The observer glances from the smoke, as it issues from the stack, to the chart and notes the number most nearly corresponding with the shade of the smoke. A clear stack is recorded as No. 0, and 100 percent black smoke as No. 5. There is very little value in making a single observation. A series of observations should be made, preferably by two or more observers, over an extended period, at regular intervals.

The Miniature Charts are not the official Ringelmann chart, but a handy interpretation of it, intended to be held at arm's length.

SAMPLING

Selection of sampling procedure:

There are two types of sampling – continuous and time averaged in –situ samplings. Continuous sampling is carried out by automatic sensors, optical or electrochemical, and spectroscopic methods which produce continuous records of concentration values. The specific time-averaged concentration data can then be obtained from continuous records. Time-averaged data can also be obtained by sampling for a short time – i.e. by sampling a known volume of air for the required averaging time. Samples are then analyzed by established physical, chemical, and biological methods for the concentration values which are the effective average over the period of sampling.

Sampling locations

Sampling locations are in general governed by factors like objectives, method of sampling and resources available. If the objective is to study health hazards and material damages, then locations should be kept close to the objects where the effects are being studied and should be kept at breathing level in the population centres, hospitals, schools, etc. For vegetation, it should be at foliage level. For background concentration, sampling location should be away from the sources of pollution. It can also be done by gridding the entire area to get statistically recommended values. The number of locations however depends upon the variability of concentration over the area under survey. A spot checking may be done to decide the location besides considering practical factors.

Period of sampling, frequency and duration:

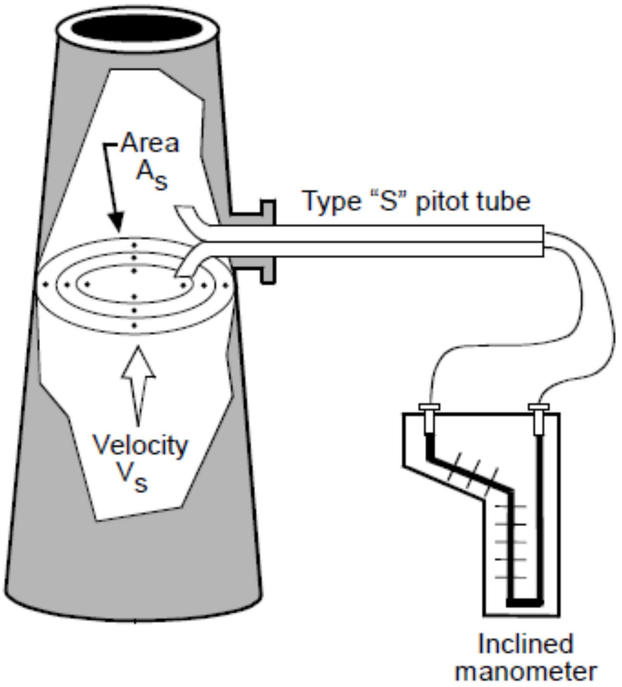
Period, frequency and duration of sampling should be appropriate to the objectives of the study. It should be such that the measurable quantities are trapped in the sample at the end of the sampling. It is preferable to observe sampling period consistent with the averaging times for which air quality standards of the given pollutants are specified.

SOURCE SAMPLING METHODOLOGY

Stationary source emissions occur primarily as either a gas or solid. The ability to collect a representative sample of particulate or gaseous pollutants largely determines the success of the measurement. Since no single method of measurement can accurately analyze every form of pollutant emitted from an exhaust stack, it is important to understand the properties of particulate and gaseous pollutants and the methods used to measure them.

Distributed Sampling Points.

A representative sample of the effluent is taken by first measuring the velocity, as shown in Figure, then extracting gas from an array of sampling points distributed over equal areas of the cross section of the stack or duct. If only gaseous pollutants are to be sampled, less sampling points are required since the stack gases are considered sufficiently mixed.

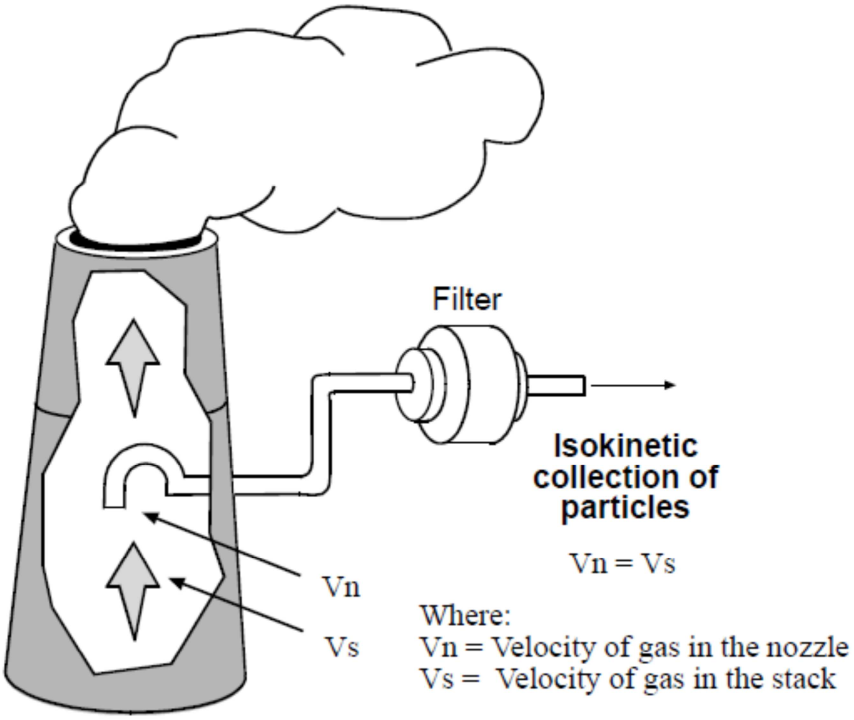


Sampling Distributed Over Time.

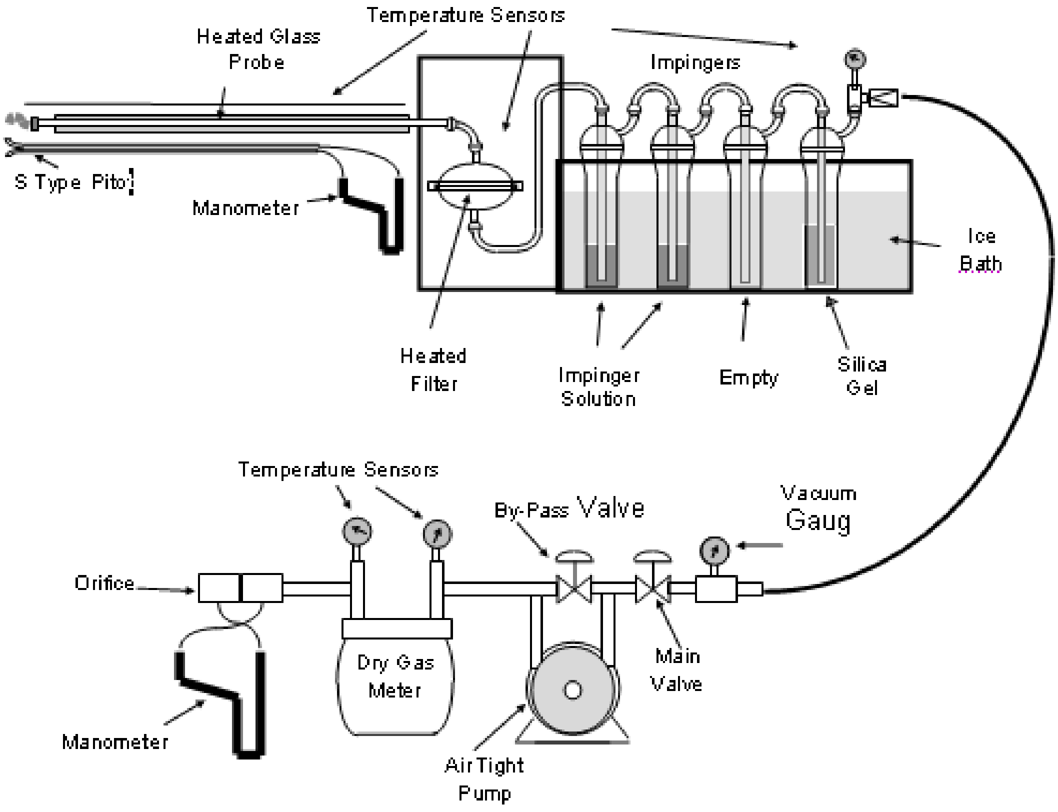
Each point should be sampled for an equal period of time, with the total sampling time or run usually lasting about an hour. Typically, three runs are performed after which their results are then averaged.

Isokinetic Sampling.

When sampling for particles it is essential that the sample be extracted at the same rate at which the gas is flowing through the stack or duct. The stack gas velocity is measured at each individual sample point and the sample extraction rate is adjusted to withdraw the sample at the same rate as the sampled points velocity. This kind of sampling is called *isokinetic* sampling and is meant to ensure that a representative sample, equal in concentration to the stack, is extracted from the gas stream (see Figure). If the sample is isokinetic, the distribution of particles sizes (from small to large) entering the probe will be exactly the same as that in the stack gas itself.



SAMPLING TRAIN



SAMPLING TRAIN

Separation of Gas Constituents.

A known quantity of the stack gas is then drawn from the stack or duct through a *sampling train*, or a leak-proof series of equipment components configured to capture pollutants. Capturing water vapor and gaseous pollutants is best achieved by condensation—or bubbling the sample gas through chilled *impingers* (sealed glass vessels), some which may contain liquid *reagents* to absorb gases. Solids are captured on filter paper, which is heated and connected to the probe with inter-connecting glassware. The first component of the sampling train is a heated probe, or a hollow glass tube that is inserted into the stack or duct. The last component—a pump—draws gases through the other pieces of equipment (the probe, filters and impingers). The volume of sampled gas is measured by a gas meter and is finally exhausted into the atmosphere through the orifice, which is used for sample train flow adjustments at the by-pass valve.

Sample Recovery and Analysis.

Filters are pre-weighed and reagent volumes pre-measured prior to use. After each run, the content of each sampling train component is carefully recovered to a sealed vessel, then weighed, measured, or otherwise evaluated under laboratory conditions.

Data Recording.

Throughout each run, appropriate measurement data are recorded. On a point-by-point basis, the sampling time, sample train vacuum, differential pressures across the gas temperature, orifice meters, and dry gas meter readings are recorded. Averages of these values, along with the total sample gas volume, are then used to calculate the test results.

Calculation of Results.

The concentration of a pollutant in the sampled gas is calculated as the proportion of captured pollutant’s mass to the volume of gas sampled. These results are corrected to a standard temperature and pressure and expressed on a dry basis. This standardized measure allows the results of a test performed under specific conditions to be comparable to a regulatory standard or other test results.

AIR POLLUTION CONTROL PROCEDURES FOR INDUSTRIES

The control of stationary source emissions can be accomplished through the application of a sound control strategy. The control strategy required for an industrial environmental impact is a four step process: (1) elimination of the problem source or operation, (2) modification of the source operation, (3) relocation of the source, and (4) selection and application of the appropriate control technology.

Exhaust stacks do not reduce emissions from a stationary source; rather they reduce the local effects of the pollution by elevating the exhaust stream to a point where it can be more effectively dispersed. High exhaust stacks were an inexpensive solution in the absence of expensive control technology.

Compliance with emission standards may require the use of control technology, but many industrial operations have reduced emissions by changing operational methods. Some of these changes include pretreating process materials, fuel or material substitution, and changes in the manufacturing process. Another way to comply with emission standards is to substitute cleaner fuels during the refining process. Natural gas and low-sulfur fuel oil are just two examples of fuels that emit less pollution during combustion. However, cleaner fuels can be more expensive and can increase national reliance on foreign fuel sources. Reduction in emissions from stationary sources can also be accomplished through increased attention to plant maintenance.

Use of CONTROL EQUIPMENTS (Control Technology)

A final way to reduce emissions from stationary sources is through the use of advanced, addon control technology. Control devices can destroy or recover gaseous compounds or particulate matter for proper disposal or re-use. The pollution control operations used to destroy or capture gases include combustion, adsorption, absorption, and condensation. Control devices that implement these processes include thermal incinerators, catalytic incinerators, flares, boilers, process heaters, carbon absorbers, spray towers, and surface condensers.

The most important process parameters for selecting air pollution control equipment are the exhaust gas characteristics obtained from emissions tests and process or site characteristics.

Exhaust Gas Characteristics

- Total exhaust gas flow rate
- Exhaust gas temperature
- Required control efficiency
- Particle size distribution
- Particle resistivity
- Composition of emissions
- Corrosiveness of exhaust gas over operating range
- Moisture content
- Stack pressure
- Exhaust gas combustibility and flammability properties

Process or Site Characteristics

- Reuse/recycling of collected emissions
- Availability of space
- Availability of additional electrical power
- Availability of water
- Availability of wastewater treatment facilities
- Frequency of startup and shutdowns
- Environmental conditions
- Anticipated changes in control regulations
- Anticipated changes in raw materials
- Plant type – stationary or mobile

Technologies used to control particulate matter focus on removing particles from the effluent gas stream. Many factors (such as particle size and chemical characteristics) determine the appropriate particulate control device for a process.

Devices most commonly used to control particulate matter include

electrostatic precipitators,
fabric filters,
venture scrubbers,
cyclone collectors,
settling chambers.

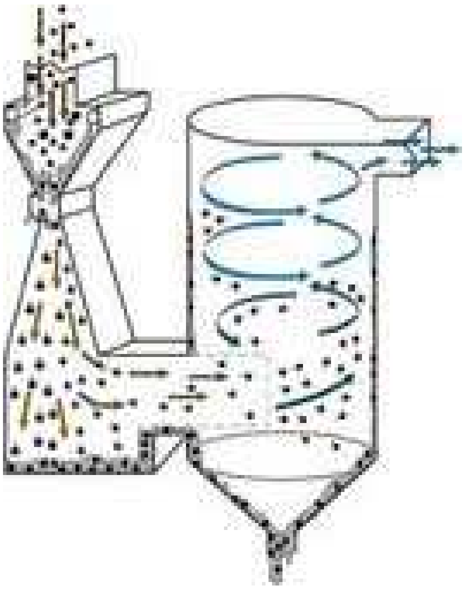
The following section provides a more detailed discussion of each type of control technology used for both particulate and gaseous emissions

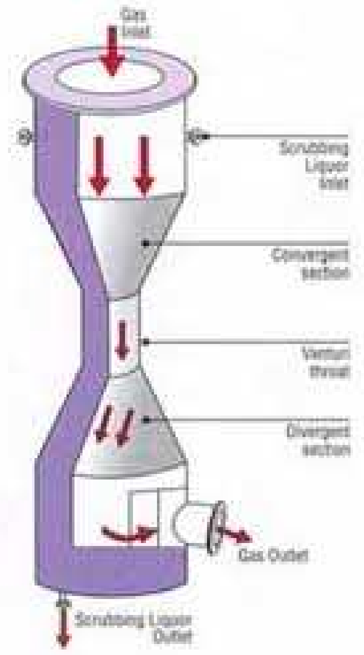
CONTROL DEVICES FOR PARTICULATE EMISSIONS

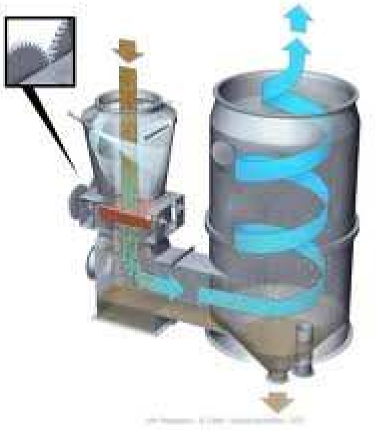
Particulate matter is any finely divided liquid or solid substance. Examples of particulate matter include smoke, dust, or some forms of fine mist and is entrained in effluent gas streams or suspended in ambient air. Any particulate less than 10 micrometers (µm) in diameter is defined as PM10 and is regulated as a criteria pollutant. The purpose of such regulation is to control smaller, respirable particles that can bypass the body's respiratory filters and penetrate deeply into the lungs, which could cause harm to human health. Toxic substances, such as sulfates, sulfites, nitrates, heavy metals, and polycyclic organic matter are predominantly carried by particles in this size range. Therefore, control devices used today, to prevent particles from reaching the ambient air, focus on capturing particulate matter $\leq$10µm in diameter. Several factors must be considered when selecting an appropriate particulate control device. Typically, particles must be captured from an effluent gas stream; therefore, characteristics of the particles and the gas stream will determine the appropriate control device. Characteristics that must be considered include the particle size and resistivity, exhaust flow rate, temperature, moisture content, and various chemical properties of the exhaust stream such as explosiveness, acidity, alkalinity, and flammability.

VENTURI SCRUBBERS

Venturi scrubbers use a liquid stream to remove solid particles. A venturi scrubber accelerates the waste gas stream to atomize the scrubbing liquid and to improve gas-liquid contact. In a venturi scrubber, a "throat" section is built into the duct that forces the gas stream to accelerate as the duct narrows and then expands. As the gas enters the venture throat, both gas velocity and turbulence increase. Depending on the scrubber design, the scrubbing liquid is sprayed into the gas stream before the gas encounters the venturi throat, or in the throat, or upwards against the gas flow in the throat. The scrubbing liquid is then atomized into small droplets by the turbulence in the throat and droplet-particle interaction is increased. Some designs use supplemental hydraulically or pneumatically atomized sprays to augment droplet creation. However, the disadvantage of these designs is that clean liquid feed is required to avoid clogging. After the throat section, the mixture decelerates, and further impacts occur causing the droplets to agglomerate. Once the particles are captured by the liquid, the wetted PM and excess liquid droplets are then separated from the gas stream by an entrainment section, which usually consists of a cyclonic separator and/or a mist eliminator. Particle collection efficiencies of venturi scrubbers range from 70 to greater than 99 percent, depending on the application. Typically, venturi scrubbers are applied where it is necessary to obtain high collection efficiencies for fine PM. Thus, they are applicable to controlling emission sources with high concentrations of submicron PM.







Advantages of Venturi Scrubbers

- Capable of handling flammable and explosive dusts
- Can handle mists in process exhausts
- Relatively low maintenance
- Simple in design and easy to install
- Collection efficiency can be varied
- Provides cooling for hot gases
- Neutralizes corrosive gases and dusts

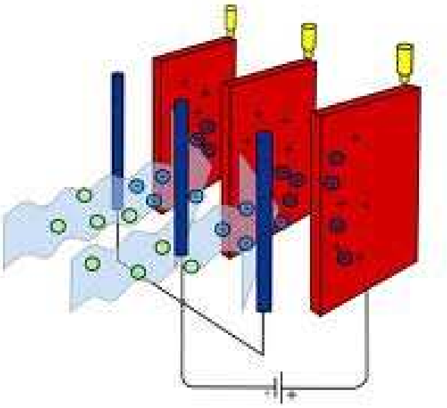
Disadvantages of Scrubbers

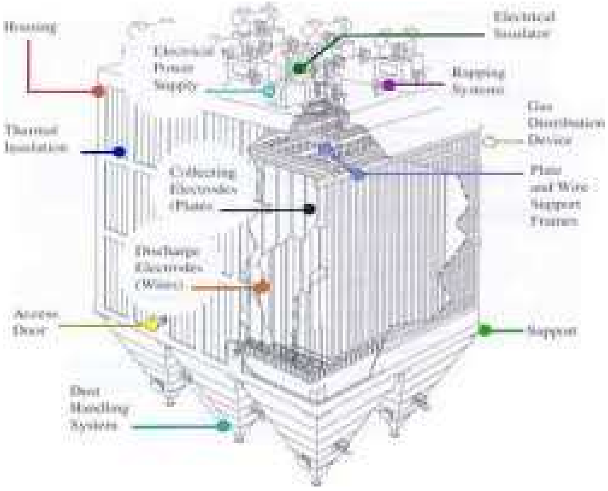
- Effluent liquid can create water pollution problems
- Waste product collected wet
- High potential for corrosion problems
- Requires protection against freezing
- Final exhaust gas requires reheating to avoid visible plume
- Collected PM may be contaminated, and not recyclable
- Disposal of waste sludge may be very expensive

ELECTROSTATIC PRECIPITATORS.

An ESP is a PM control device that uses electrical forces to move particles entrained within an exhaust stream onto collection surfaces. The entrained particles are given an electrical charge when they pass through a corona, a region where gaseous ions flow. Electrodes in the center of the flow lane are maintained at high voltage and generate the electrical field that forces the particles to the collector plates. The high voltage electrodes are long wires or rigid “masts” suspended from a frame in the upper part of the ESP that run through the axis of each tube. Rigid electrodes are generally supported by both an upper and lower frame. The power supplies for the ESP convert the industrial AC voltage to pulsating DC voltage in the range of 20,000 to 100,000 volts as needed. The voltage applied to the electrodes causes the gas between the electrodes to break down electrically, an action known as a “corona.” The electrodes are usually given a negative polarity because a negative corona supports a higher voltage than does a positive corona before sparking occurs. The ions generated in the corona follow electric field lines from the electrode to the collecting pipe. Therefore, each electrode-pipe combination establishes a charging zone through which the particles must pass.

As larger particles (>10μm diameter) absorb many times more ions than small particles (>1μm diameter), the electrical forces are much stronger on the large particles. When the collection plates are filled to capacity, the particulate is removed from the plates by “rapping,” which is a mechanical means to dislodge the particulate. The collected particulate material slides downward into a hopper located below the unit. The collection efficiency of an ESP is quite reliably about 99 percent for particles less than 10 micrometers. ESPs, in general, are very expensive to operate and are not very well suited for use in industrial processes because they are too sensitive to fluctuations in the gas stream. The Electrostatic Precipitator (ESP) separates particles from the gas stream by electrically charging the particles.





FABRIC FILTER

In a fabric filter, flue gas is passed through a tightly woven or felted fabric, causing PM in the flue gas to be collected on the fabric by sieving and other mechanisms. Fabric filters may be in the form of sheets, cartridges, or bags, with a number of the individual fabric filter units housed together in a group. Bags are the most common type of fabric filter. The dust cake that forms on the filter from the collected PM can significantly increase collection efficiency. Fabric filters are frequently referred to as baghouses because the fabric is usually configured in cylindrical bags. Bags may be 6 to 9m (20 to 30 ft) long and 12.7 to 30.5 centimeters (cm) (5 to 12 inches) in diameter. Groups of bags are placed in isolable compartments to allow cleaning of the bags or replacement of some of the bags without shutting down the entire fabric filter). Operating conditions are important determinants of the choice of fabric. Some fabrics (i.e., polyolefins, nylons, acrylics, polyesters) are useful only at relatively low temperatures of 95° to 150ºC (200° to 300ºF). For high temperature flue gas streams, more thermally stable fabrics such as fiberglass, Teflon, or Nomex must be used.

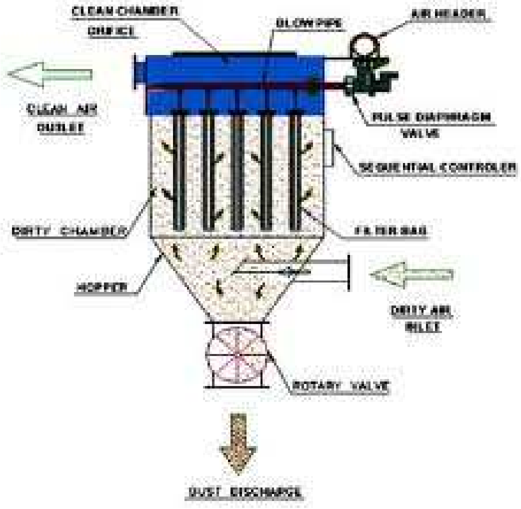
The practical application of fabric filters requires the use of a large fabric area in order to avoid an unacceptable pressure drop across the fabric. Baghouse size for a particular unit is determined by the choice of air-to-cloth ratio, or the ratio of volumetric airflow to cloth area. The selection of air-to-cloth ratio depends on the particulate loading and characteristics, and the cleaning method used. A high particulate loading will require the use of a larger baghouse in order to avoid forming too heavy a dust cake.

Determinants of baghouse performance include the fabric chosen, the cleaning frequency and methods, and the particulate characteristics. Fabrics can be chosen which will intercept a greater

fraction of particulate. In order to accomplish this, some fabrics are coated with a membrane of very fine openings for enhanced removal of submicron particulate. However, such fabrics tend to be more expensive. Cleaning intensity and frequency are important variables in determining removal efficiency because the dust cake can affect the fine particulate removal capability of a fabric. Cleaning procedures, which may be too frequent or too intense, will also lower the removal efficiency of the fabric filter. On the other hand, if removal is too infrequent or too ineffective, then the baghouse pressure drop will become too high.

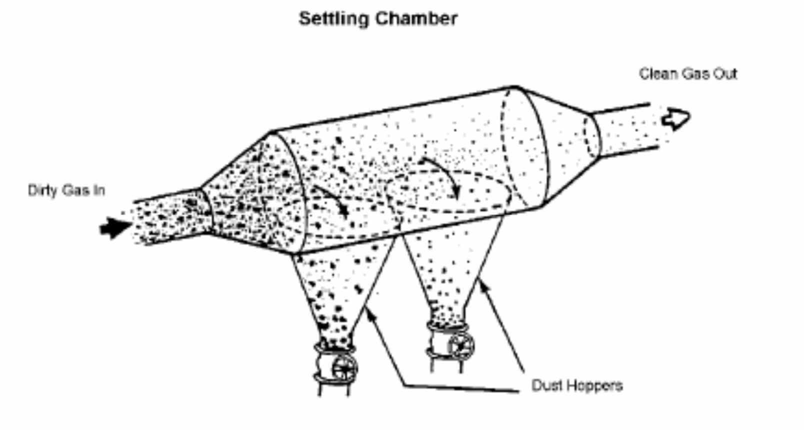
Mechanical shaking of the bags has been a popular cleaning method for many years because of its simplicity as well as its effectiveness. In a typical operation, dusty gas enters an inlet pipe to the shaker. Very large particles are removed from the stream when they strike the baffle plate in the inlet duct and fall into the hopper. The particulate-laden gas is drawn from beneath a cell plate in the floor and into the filter bags. The gas proceeds from the inside of the bags to the outside and through the outlet pipe. The particles are collected on the inside surface of the bags and a filter cake accumulates. In mechanical shaking units, the tops of bags are attached to a shaker bar, which is moved briskly (usually in a horizontal direction) to clean the bags. The shaker bars are operated by mechanical motors or by hand, in applications where cleaning is not required frequently. Reverse-air cleaning is another popular fabric filter cleaning method that has been used extensively and improved over the years. It is a gentler but sometimes less effective cleaning mechanism than mechanical shaking. Most reverse-air fabric filters operate in a manner similar to shaker-cleaned fabric filters. Typically, the bags are open on bottom, closed on top, and the gas flows from the inside to the outside of the bags with dust being captured on the inside. However, some reverse-air designs collect dust on the outside of the bags. In either design, forcing clean air through the filters in the opposite direction of the dusty gas flow performs reverse-air cleaning. The change in direction of the gas flow causes the bag to flex and crack the filter cake. In internal cake collection, the bags are allowed to collapse to some extent during reverse-air cleaning. The bags are usually prevented from collapsing entirely by some kind of support, such as rings that are sewn into the bags. The support enables the dust cake to fall off the bags and into the hopper. Cake release is also aided by the reverse flow of the gas because felted fabrics retain dust more than woven fabrics. Therefore, they are more difficult to clean. For this reason, felts are usually not used in reverse-air systems.

Fabric filters in general provide high collection efficiencies on both coarse and fine (submicron) particulates. Typical new equipment design efficiencies are between 99% and 99.9%.



SETTLING CHAMBERS

This type of technology is a part of the group of air pollution controls collectively referred to as "precleaners." They are referred to as precleaners because they are often used to reduce the inlet loading of particulate matter (PM) to downstream collection devices by removing larger, abrasive particles. Settling chambers are also referred to as gravity settling chambers, gravity collectors, expansion chambers, and outfall chambers. This is because settling chambers are quite effective in removing only large particles; therefore, they can be frequently used in combination with other control devices. Settling Chambers rely on simple gravitation to remove particles from a gas stream.



Settling chambers, which rely on gravitational settling as a collection mechanism are the simplest and oldest mechanical collectors. Settling chambers are generally built in the form of long, horizontal, rectangular chambers with an inlet at one end and an exit at the side or top of the opposite end. Flow within the chamber must be uniform and without any macroscopic mixing. Uniform flow is can be improved by flow straighteners at the inlet to the chamber. Hoppers are used to collect the settled-out material, though drag scrapers and screw conveyers have also been employed. The dust removal system must be sealed to prevent air from leaking into the chamber which increases turbulence, causes dust reentrainment, and prevents dust from being properly discharged from the device. There are two primary types of settling chambers: the expansion chamber and the multiple-tray chamber. In the expansion chamber, the velocity of the gas stream is significantly reduced as the gas expands in a large chamber. The reduction in velocity allows larger particles to settle out of the gas stream.

A multiple-tray settling chamber is an expansion chamber with a number of thin trays closely spaced within the chamber, which causes the gas to flow horizontally between them. While the gas velocity is increased slightly in a multiple-tray chamber, when compared to a simple expansion chamber, the collection efficiency generally improves because the particles have a much shorter distance to fall before they are collected. Multiple-traysettling chambers have lower volume requirements than expansion-type settling chambers for the collection of small particles (<15μm). Settling chambers are most effective when collecting large or dense particles, but often fail when the chamber becomes plugged with collected dust.

The most common failure of settling chambers is when chambers become plugged with collected dust. In expansion settling chambers the plugging can result from hopper bridging or hopper discharge seal failure. Multiple-tray settling chambers may experience plugging of the individual gas passages. Such failures can be prevented or minimized by use of hopper level indicators or by continuous monitoring of the dust discharge. Scheduled internal inspection can determine areas of air leakage and condensation, both of which may cause hopper bridging. Normal instrumentation for a settling chamber generally includes only an indicator of differential static pressure. An increase in static pressure drop can indicate plugging

Advantages of Settling Chambers

- Low capital cost
- Very low energy cost
- No moving parts
- Few maintenance requirements
- Low operating costs
- Excellent reliability
- Low pressure drop through device
- Device not subject to abrasion due to low gas velocity
- Provide incidental cooling of gas stream
- Dry collection and disposal

Disadvantages of Settling Chambers

- Relatively low PM collection efficiencies
- Unable to handle sticky or tacky materials
- Large physical size
- Trays in multiple-tray settling chamber may warp

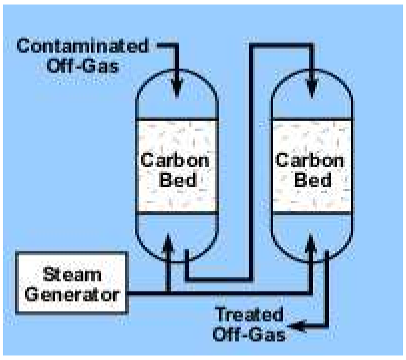
Control of gaseous pollutants from stationary sources - Adsorption

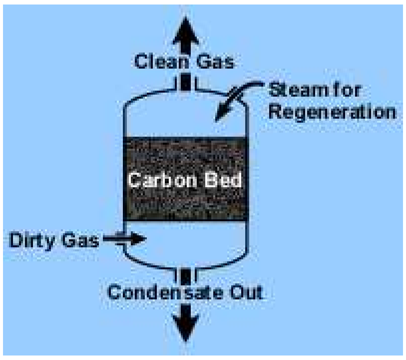
When a gas or vapor is brought into contact with a solid, part of it is taken up by the solid. The molecules that disappear from the gas either enter the inside of the solid, or remain on the outside attached to the surface. The former phenomenon is termed absorption (or dissolution) and the latter adsorption. Adsorption is the binding of molecules or particles to a surface. In this phenomenon molecules from a gas or liquid will be attached in a physical way to a surface. The binding to the surface is usually weak and reversible. The most common industrial adsorbents are activated carbon, silica gel, and alumina, because they have enormous surface areas per unit weight.

Activated carbon is the universal standard for purification and removal of trace organic contaminants from liquid and vapor streams. Carbon adsorption uses activated carbon to control and/or recover gaseous pollutant emissions. In carbon adsorption, the gas is attracted and adheres to the porous surface of the activated carbon. Removal efficiencies of 95 percent to 99 percent can be achieved by using this process. Carbon adsorption is used in cases where the recovered organics are valuable. For example, carbon adsorption is often used to recover perchloroethylene, a compound used in the dry cleaning process.

Carbon adsorption systems are either regenerative or non-regenerative. A regenerative system usually contains more than one carbon bed. As one bed actively removes pollutants, another bed

is being regenerated for future use. Steam is used to purge captured pollutants from the bed to a pollutant recovery device. By "regenerating" the carbon bed, the same activated carbon particles can be used again and again. Regenerative systems are used when concentration of the pollutant in the gas stream is relatively high. Non-regenerative systems have thinner beds of activated carbon. In a non-regenerative adsorber, the spent carbon is disposed of when it becomes saturated with the pollutant. Because of the solid waste problem generated by this type of system, non-regenerative carbon adsorbers are usually used when the pollutant concentration is extremely low.

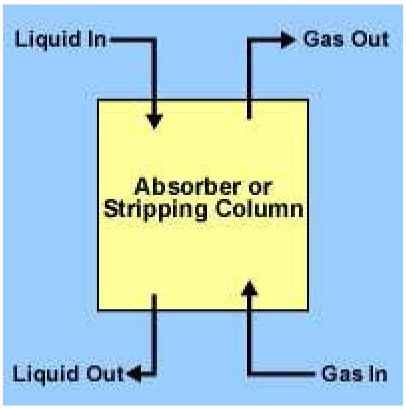




Regenerative Carbon Adsorption System Non-Regenerative Carbon Adsorption System

Control of gaseous pollutants from stationary sources – Absorption

The removal of one or more selected components from a gas mixture by absorption is probably the most important operation in the control of gaseous pollutant emissions. Absorption is a process in which a gaseous pollutant is dissolved in a liquid. Water is the most commonly used absorbent liquid. As the gas stream passes through the liquid, the liquid absorbs the gas, in much the same way that sugar is absorbed in a glass of water when stirred. Absorption is commonly used to recover products or to purify gas streams that have high concentrations of organic compounds. Absorption equipment is designed to get as much mixing between the gas and liquid as possible. Absorbers are often referred to as scrubbers, and there are various types of absorption equipment. The principal types of gas absorption equipment include spray towers, packed columns, spray chambers, and venture scrubbers. The packed column is by far the most commonly used for the absorption of gaseous pollutants. The packed column absorber has a column filled with an inert (non-reactive) substance, such as plastic or ceramic, which increases the liquid surface area for the liquid/gas interface. The inert material helps to maximize the absorption capability of the column. In addition, the introduction of the gas and liquid at opposite ends of the column causes mixing to be more efficient because of the counter-current flow through the column. In general, absorbers can achieve removal efficiencies greater than 95 percent. One potential problem with absorption is the generation of waste-water, which converts an air pollution problem to a water pollution problem.



Typical packed column diagram

Unit–6 -- 10CV765 -- APC
AUTOMOBILE POLLUTION

The addition of chemicals released from automobile emissions constituting NO_X, HC's, CO, SPM, SO_2, Pb resulting in deterioration of ambient air is termed as automobile pollution. Five of these are also criteria air pollutants.

SOURCE, EFFECT AND CONTROL OF AUTOMOBILE POLLUTANTS

1] **SO2**.

The formation of Sulphur di Oxide in exhaust gases is caused by the oxidation of the sulphur in the fuel during the combustion process. In the atmosphere however, SO2 combines with moisture to form H2SO4, which then falls as acid rain, and has been linked to environmental damage.The major health concerns associated with exposure to high concentrations of SO2 include effects on breathing (decreased lung function), respiratory illness, alterations in pulmonary defences, and aggravation of existing cardiovascular disease. Children, the elderly, and people with asthma, cardiovascular disease or chronic lung disease (such as bronchitis or emphysema), are most susceptible to adverse health effects associated with exposure to SO2.

2] **Pb**.

Exposure to lead mainly occurs through inhalation of air and ingestion of lead in food, paint, water, soil, or dust. Lead accumulates in the body in blood, bone, and soft tissue. Because it is not readily excreted, lead can also affect the kidneys, liver, nervous system, and other organs. Excessive exposure to lead may cause anemia, kidney disease, reproductive disorders, and neurological impairments such as seizures, mental retardation, and/or behavioral disorders. Even at low doses, lead exposure is associated with changes in fundamental enzymatic, energy transfer, and other processes in the body. Fetuses and children are especially susceptible to low doses of lead, often suffering central nervous system damage or slowed growth. Lead may also contribute to osteoporosis in post-menopausal women.

3] **SPM**.

The composition and properties of particulates varies greatly and is therefore difficult to define. Furthermore, there is not a quantitative relationship between the smoke opacity and the particulate emission. Particle emissions from engines can originate from:

a) agglomeration of very small particles of partly burned fuel;
b) partly burned lub oil;
c) ash content of fuel oil and cylinder lub oil; or
d) sulphates and water.

The smaller particles that are likely responsible for adverse health effects because of their ability to reach the lower regions of the respiratory tract. Major concerns for human health from exposure to PM-10 include: effects on breathing and respiratory systems, damage to lung tissue, cancer, and premature death. The elderly, children, and people with chronic lung disease, influenza, or asthma, are especially sensitive to the effects of particulate matter. Acidic PM-10 can also damage human-made materials and is a major cause of reduced visibility.

The most effect method of reducing particulate emissions is to use lighter distillate fuels however, this leads to added expense. Additional reductions in particulate emissions can be achieved by increasing the fuel injection pressure to ensure that optimum air-fuel mixing is achieved, however, as fuel injection pressure increases, the reliability of the equipment decreases. Much research has also been conducted on cyclone separators, which are effective for particle sizes greater than 0.5μm while electrostatic precipitators are more effective, capable of reduction emissions by up to 99%. Unfortunately, precipitators are expensive, prone to clog and are large in size.

4] **Unburnt Hydrocarbons**.

The emission of unburned hydrocarbons (HC) generally results from fuel, which is unburned as a result of insufficient temperature. This often occurs near the cylinder wall (wall quenching) where the temperature of the air/fuel mixture is significantly less than in the centre of the cylinder. Bulk quenching can also occur as a result of insufficient pressure or temperature within the cylinder itself. Still further, HC production may also be a result of poorly designed fuel injection systems, injector needle bounce, excessive nozzle cavity volumes or fuel jets reaching a quench layer.

Volatile Organic Compounds or VOCs are organic chemicals that easily vaporize at room temperature. VOCs include a very wide range of individual substances, such as hydrocarbons (for example benzene and toluene), halocarbons and oxygenates.

Hydrocarbon VOCs are usually grouped into methane and other non-methane VOCs. Methane is an important component of VOCs, its environmental impact principally related to its contribution to global warming and to the production of ground level or lower atmosphere ozone. Most methane is released to the atmosphere via the leakage of natural gas from distribution systems. Benzene, a non-methane hydrocarbon, is a colourless, clear liquid. It is fairly stable but highly volatile, readily evaporating at room temperature. Since 80% of man-made emissions come from petrol-fuelled vehicles, levels of benzene are higher in urban areas than rural areas. Benzene concentrations are highest along urban roadsides. Evaporation of solvents, used for example in paints, cause a release of hydrocarbons, oxygenates and halocarbons to the atmosphere.

Some VOCs are extremely harmful, including the carcinogens benzene, polycyclic aromatic hydrocarbons (PAHs) and 1,3 butadiene. Benzene may increase susceptibility to

leukaemia, if exposure is maintained over a period of time. There are several hundred different forms of PAH, and sources can be both natural and man-made processes. PAHs can cause cancer. Sources of 1,3 butadiene include the manufacturing of synthetic rubbers, petrol driven vehicles and cigarette smoke. There is an apparent correlation between butadiene exposure and a higher risk of cancer.

HC reduction would most likely only be possible using primary and further secondary oxidation catalysts.

5] **NOx**.

NOx is formed during the combustion process within the burning fuel sprays and is deemed one of the most harmful to the environment and contributes to acidification, formation of ozone, nutrient enrichment and to smog formation, which has become a considerable problem in most major cities world-wide.

The amount of NOx produced is a function the maximum temperature in the cylinder, oxygen concentrations, and residence time. At cylinder temperatures, nitrogen from the intake air and fuel becomes active with the oxygen in the air forming oxides of nitrogen. Increasing the temperature of combustion increases the amount of NOx by as much as 3 fold for every 100$_o$C increase. NO is formed first in the cylinder followed by the formation of NO_2 and N_2O, typically at concentrations of 5% and 1%; respectively. NO_2 is soluble and washed out by rain which increases the acidity level of the soil.

Nitrogen dioxide can irritate the lungs and lower resistance to respiratory infections such as influenza. The effects of short-term exposure are still unclear, but continued or frequent exposure to concentrations that are typically much higher than those normally found in the ambient air may cause increased incidence of acute respiratory illness in children. Nitrogen oxides contribute to ozone formation and can have adverse effects on both terrestrial and aquatic ecosystems. Nitrogen oxides in the air contribute to acid rain and eutrophication. (Eutrophication occurs when a body of water suffers an increase in nutrients that leads to a reduction in the amount of oxygen in the water, producing an environment that is destructive to fish and other animal life.)

The best way to reduce NOx generation, is to reduce peak cylinder temperatures.

6] **CO**.

CO is formed due to the incomplete combustion of organic material where the oxidation process does not have enough time or reactant concentration to occur completely. In engines, the formation of CO is determined by the air/fuel mixture in the combustion chamber and as diesels have a consistently high air to fuel ratio, formation of this toxic gas is minimal. Nevertheless, insufficient combustion can occur if the fuel droplets in a

diesel engine are too large or if insufficient turbulence or swirl is created in the combustion chamber.

Carbon monoxide enters the bloodstream and reduces oxygen delivery to the body's organs and tissues. The health threat from exposure to CO is most serious for those who suffer from cardiovascular disease. Healthy individuals are also affected, but only at higher levels of exposure. Exposure to elevated CO levels is associated with visual impairment, reduced work capacity, reduced manual dexterity, poor learning ability, and difficulty in performing complex tasks.

The intensity and frequency of the afore-mentioned impacts essentially depends on several other factors such as age of the vehicle, type of fuel used, condition of engine, type of engine, maintenance and operation mode of vehicle etc.

PETROL ENGINE vs. DIESEL ENGINE

Petrol engine	**Diesel engine**
High CO, HC's concentration in emissions	Lesser HC's concentration i.e., 1/10 CO that of petrol
Less smoke	Major problem odor and smoke, at least 80% SPM than in petrol exhaust
Less SO2, NOX,PM	More NO_X, SO_2, PM/SPM

Inference: The major pollutants in diesel exhaust emissions are a direct result of the diesel combustion process itself. Diesel engines have higher compression ratio than petrol. First air is compressed, then fuel injected, then ignition but in petrol, air fuel mixed first, compressed and the n ignited. HC's concentration is less, because blowby is negligible as only air is present in compression stroke & evaporative emissions. Hydrocarbons are as well low because diesel uses a closed injection fuel system.

SMOKE

When compared to diesel emissions, petrol emissions are more toxic w.r.t. human; while diesel emissions contribute towards environmental impacts. Yet smoke emission from diesel cannot be ignored.

Maximum smoke is produced when vehicle runs at 60% of total power. It is measured in Ringlemann's Scale.

Effects of smoke: Irritation of eye membrane, ear membrane and respiratory tract, soiling of clothes, disfiguring of buildings.

Control means: High A/F ratio, Smokeless fuel – Vehicle maintenance - Lean mixture.

2 STROKE ENGINE vs. 4 STROKE ENGINE

When compared to 4 stroke, 2 stroke engine produces more pollution [HC's, CO, SPM, Smoke] as it burns an oil gasoline mixture, but 2 stroke engine is more powerful, lighter, less expensive. On the contrary, 4 stroke engine gives more mileage, produces less HC's and VOC's [volatile organic carbon] as there is no short circuit of raw fuel.

TYPES OF EMISSIONS

1. Tailpipe emissions: This is what most people think of when they think of vehicle air pollution; the products of burning fuel in the vehicle's engine, emitted from the vehicle's exhaust system. The major pollutants emitted include:

Hydrocarbons: This class is made up of unburned or partially burned fuel, and is a major contributor to urban smog, as well as being toxic. They can cause liver damage and even cancer.

Nitrogen oxides (NOx): These are generated when nitrogen in the air reacts with oxygen under the high temperature and pressure conditions inside the engine. NOx emissions contribute to both smog and acid rain.

Carbon monoxide (CO): A product of incomplete combustion, carbon monoxide reduces the blood's ability to carry oxygen and is dangerous to people with heart disease.

Carbon dioxide (CO_2): Emissions of carbon dioxide are considered to pollute because it is a significant greenhouse gas and increasing its levels in the atmosphere contributes to global climate change.

Exhaust emissions contain 100% CO, 100% NO_X, 100% Pb and 60-65% HC's

2. Blowby/Crankcase emissions: 20% unburnt HC's mainly due to leakage of oil vapor around Worn-out piston rings.

3. Evaporative emissions: These are produced from the evaporation of fuel, and are a large contributor to urban smog, since these heavier molecules stay closer to ground level. Fuel tends to evaporate in these ways:

Gas tank venting: the heating of the vehicle as the temperature rises from the night-time temperature to the hottest temperatures of the day mean that gasoline in the tank evaporates, increasing the pressure inside the tank above atmospheric pressure. This pressure must be relieved, and before emissions control it was simply vented into the atmosphere.

Running losses include the escape of gasoline vapors from the hot engine. **Refueling losses** include these can cause a lot of hydrocarbon vapor emission. The empty space inside a vehicle's tank is filled with hydrocarbon gases, and as the tank is filled, these gases are forced out into the atmosphere. In addition, there is loss from further evaporation and fuel spillage.

Bird view of emission of net pollution

65 % from Exhaust + 15 % from Blowby + 20 % Evaporative = 100%

Bird view of Hydrocarbon emissions [mainly as Benzopyrene]

60 % from Exhaust + 20 % from Blowby + 20 % Evaporative = 100%

Evaporative emissions: 20% HC’S via gas tank venting, refueling & running losses.

Operation w.r.t Emissions

Mode of Operation	Unburnt HC’s [ppm]	CO [% by volume]	NO_X [ppm]	A/F RATIO
IDLE	750	5.2	30	11:1-12:1
CRUISING	300	0.8	1500	11:1-13:1
ACCELERATION	400	5.2	3000	13:1-15:1
DECELERATION	4000	4.2	60	11:1-12.5:1

Comparative study

When A/F ratio is high, then less CO, HC’s but high NOx
When Vehicle decelerates high HC’s [hydrocarbon]
When vehicle is idle [engine not switched off during signals] high CO, low NO_X, moderate HC’s.
When vehicle accelerates low HC’S , high CO, high CO, and high NOx
When vehicle cruises high NOx, low CO, moderate HC’s and high CO_2.

Drawbacks

Pb is released from exhaust as lead halides which are a cumulative toxin, a chief environmental pollutant capable of affecting neural development resulting in lower IQ.

Also lead acts as poison for catalytic converter. This resulted in advent of unleaded petrol. The alternative used was MTBE. But it has been found to be non-bio-degradable and possible ground contamination. This resulted in the use of ethanol as anti-knocking agent to boost octane rating. But ethanol causes fuel to absorb moisture from air, over long time it leads to rusting, corrosion in fuel line. Also it is poorly soluble and enhances possibility of bacterial contamination.

TEL now banned in road sector continues to be used in aviation fuel as additive called as AVGAS. The catch is despite using unleaded petrol; the emissions consist of benzene which causes cancer, anemia and blood cancer. The other option w.r.t knocking phenomenon is utilize branched chain alkanes, which results pre ignition, loss of power, lower octane rating.

Catalytic converters

The air fuel ratio must be so high that all CO formed is converted to CO_2, but if ratio is less [lack of O_2], it facilitates formation of CO, Unburnt HC's, NO_X. Also due to higher temperature [2000-2500 ^{0}C], high pressure formation of Nitric oxide takes place.

If a car burns fuel with perfect efficiency, its only exhaust products would be CO_2 and H_2O. Unfortunately not every molecule burns to completion. Catalytic converter consists of an array of tubes, each coated with porous ceramics. Embedded in this coating are tiny particles of platinum and rhodium which serve as catalyst. Previously V_2O_5, Vanadium Pentoxide served the purpose.

$$HC+CO+NO_X \rightarrow H_2O+CO_2+N_2$$

Nowadays Rhodium, Platinum, Palladium serve the role as 3-way catalyst, once the exhaust heats the converter above 300^{0}C, unwanted molecules bind temporarily to catalyst and are converted. 95% of HC's, CO, NO_X is removed by converter but the presence of Pb in fuel as lead Halide gets coated over surface inactivating them. Catalytic converters have no moving parts, but its limitations include poisoning by lead, deterioration with time and pressure loss.

Indirect Control measures

Car pool system, eco-friendly fuels, hybrid vehicles, use of bio fuels, use of alternate energy such as solar driven, use of unleaded petrol, complying to rules and regulation, frequent periodical emission testing, stringent norms and enforcement on violation,

Minimizing the use of vehicles by walking for small distances, pooling of the vehicles, switching off the vehicles on red lights, maintaining the vehicles in proper order, adopting efficient ways of driving, ban on overloading, better design and maintenance of roads collectively can reduce automobile air pollution.

Direct Control measures

The amount of SO2 formed is a function of the sulphur content of the fuel used and therefore the only effective method of reducing SOx is by reducing the sulphur content of the fuel. Unfortunately, low-sulphur fuels are more expensive to purchase (10 to 20% greater cost, when switching from 3.5% to 1% sulphur) and there is a practical lower sulphur limit desired as desulphurisation of fuel lowers the lubricity of the fuel which can lead to increase wear on fuel pumps and injectors.

proper operation and maintenance of vehicles

Using catalytic converter for HC's, CO, NOx, C_6H_6

Increasing air-fuel ratio for HC's, CO and Benzene

Recycling exhaust gas for NO_x, [15-25%]

In case of SPM, ensure proper maintenance and operation process, such has change air filter regularly, change engine oil as per manufacturer's specification, use moderate acceleration and avoid slowing of engine atop gear.

The industry may be compelled to manufacture the vehicles in such a way, i.e. enforcing the Euro standards, that they produce minimum pollutants.

To maintain the vehicle by its proper servicing (tuning of engine) in such a way that the exhaust emissions are under control.

Control on the quality of fuel. Use unleaded petrol. Sometimes Kerosene is mixed with petrol or diesel (as it is cheaper) than the emissions are more pollutant and are of different nature.

Unit – 7

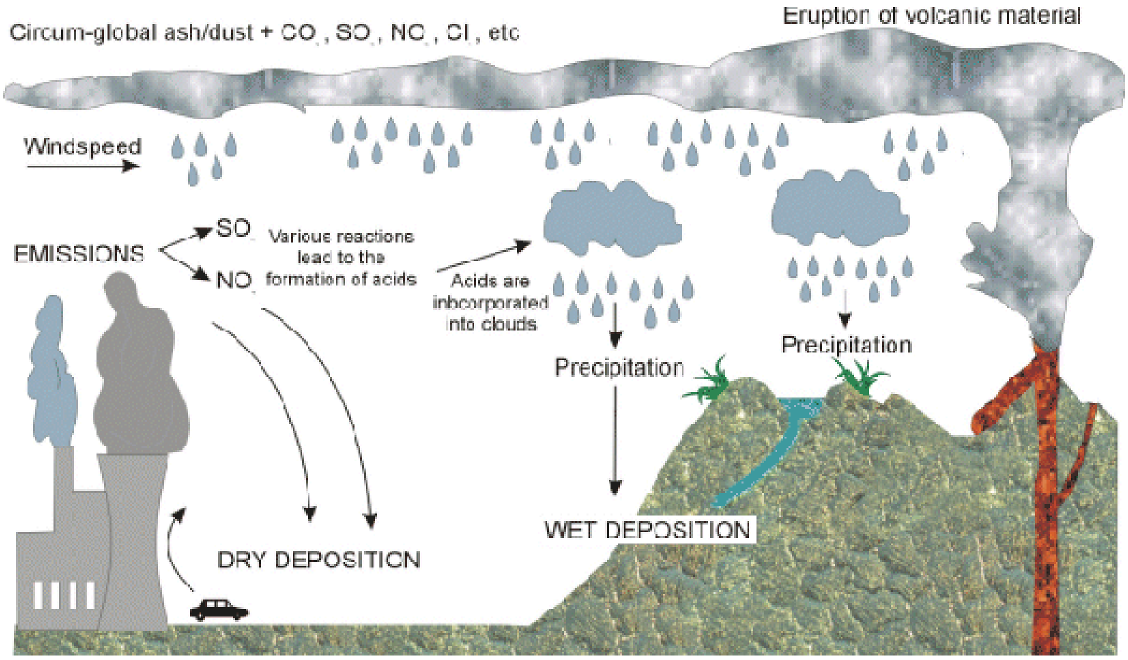
ACID RAIN

Definition

Normal Rain water p^H is slightly acidic due to certain concentration of CO_2 dissolved as rainwater trickles down atmosphere, i.e. $CO_2+H_2O \rightarrow HCO^{3-}+H^+$

Acid rain is defined as any type of precipitation with a p^H that is unusually low or lower than 5.7. Acid rain was first found in Manchester, England. In 1852, Robert Angus Smith found the relationship between acid rain and atmospheric pollution. Though acid rain was discovered in 1852, it wasn't until the late 1960s that scientists began widely observing and studying the phenomenon.

Causes



The principal natural phenomena that contribute acid-producing gases to the atmosphere are emissions from volcanoes and those from biological processes that occur on the land, in wetlands, and in the oceans. The major biological source of sulfur containing compounds is dimethyl sulfide.

The principal cause of acid rain is sulfuric and nitrogen compounds from human sources, such as electricity generation, factories and motor vehicles. Coal power plants are one of the most polluting. The gases can be carried hundreds of kilometres in the atmosphere before they are converted to acids and deposited. Factories used to have short funnels to let out smoke, but this caused many problems, so now, factories have longer smoke funnels. The problem with this is those pollutants get carried far off, where it creates more destruction.

Sulfur dioxide contributes to about seventy percent of acid rain while nitrogen oxides provide the remaining thirty percent. The sources of sulfur in the atmosphere include coal combustion, smelting, organic decay, and ocean spray. Approximately ninety percent of atmospheric sulfur results from human activities.

In the atmosphere, sulfur dioxide combines with water vapor to form hydrogen sulfite gas: $SO_2 + H_2O+1/2O_2 \rightarrow H_2SO_4$

Next, hydrogen sulfite reacts with oxygen to form sulfuric acid, a major component of acid rain: $H_2SO_3 + 1/2O_2 \rightarrow H_2SO_4$

The sources of nitrogen oxides include the combustion of oil, coal and natural gas, forest fires, bacterial action in soil, volcanic gases, and lighting-induced atmospheric reactions.

In the atmosphere, nitrogen monoxide reacts with oxygen gas to form nitrogen dioxide gas: $NO + 1/2O_2 \rightarrow NO_2$

Then, nitrogen dioxide reacts with water vapor in the atmosphere to form hydrogen nitrite and hydrogen nitrate: $2NO_2 + H_2O \rightarrow HNO_2 + HNO_3$

Henceforth, acid rain is a mixture of HNO_3, H_2SO_4 + HCl. however conditions needed to favor formation of these are sunlight, temperature, humidity, hydrocarbons, NO_X, SO_2.

Effects

Both the lower p^H and higher aluminum concentrations in surface water that occur as a result of acid rain can cause damage to fish and other aquatic animals. At p^H lower than 5 most fish eggs will not hatch and lower p^H can kill adult fish. As lakes become more acidic biodiversity is reduced. Soil biology can be seriously damaged by acid rain. Some tropical microbes can quickly consume acids but other microbes are unable to tolerate low p^H and are killed.

Acid rain can slow the growth of forests, cause leaves and needles to turn brown and fall off and die. In extreme cases trees or whole areas of forest can die. The death of trees is not usually a direct result of acid rain; often it weakens trees and makes them more susceptible to other threats.

Some scientists have suggested direct links to human health, but none have been proven. However, fine particles, a large fraction of which are formed from the same gases as acid

rain (sulfur dioxide and nitrogen dioxide), have been shown to cause illness and premature deaths such as cancer and other deadly diseases

Toxic metals released into the environment by acid rain may enter water supplies or accumulate in fish and crops. Acid deposition also destroys statues, headstones, buildings, and fountains. Limestone structures are especially susceptible because they dissolve easily in acidic solutions.

Acid rain can also cause damage to certain building materials and historical monuments. Acid rain can cause weathering on ancient and valuable statues and has caused considerable damage. This is because the sulfuric acid in the rain chemically reacts with the calcium compounds in the stones (limestone, sandstone, marble and granite) to create gypsum, which then flakes off. Acid rain also causes an increased rate of oxidation for iron.

Control

- Design more efficient automobile engines in order to reduce nitrogen oxide emissions.
- Increase efficiency of power plants that burn coal in order to reduce waste that contains sulfur dioxide and nitrogen oxide.
- Increase penalties on industries that do not meet air pollution guidelines.
- Increase tax incentives to industries that do meet guidelines.
- Use alternative energy sources, Increase funding for alternative energy sources; for example, give tax incentives to buyers of hybrid cars.
- Provide tax incentives to companies that use alternative energy sources.
- Add $CaCO_3$ (calcium carbonate) to lakes suffering from acid deposition; calcium carbonate acts as a buffer, resisting a change in p^H and lessening the negative effects of acid rain.

OZONE DEPLETION

Definition

Ozone layer is an umbrella 24 km [15 miles] from earth surface, an essential component of the stratosphere that absorbs short wavelength ultraviolet radiation from the sun, heating the gases of the stratosphere in the process. World ozone day is celebrated on Sept, 16 of every year.

Stratospheric ozone is measured in Dobson units [DU] named after G.M.B Dobson who pioneered the study; [I Dobson unit = 0.01 mm thickness of stratospheric ozone], Average ozone thickness in stratosphere is 300 DU, & when it falls below 200 DU, it’s considered as Ozone hole. It is thinnest around equator and thickest near poles.

Stratospheric ozone depletion is the term applied to the loss of stratospheric ozone molecules (O_3) and the disruption of Oxygen-Ozone concentration equilibrium in stratosphere [i.e., when chlorine atoms upset the natural O_2/O_3 equilibrium in the stratosphere]. Oxygen molecules interact with the intense solar radiation present at this elevation to form oxygen atoms. The oxygen atoms thus generated react with other oxygen molecules to form ozone (O_3).

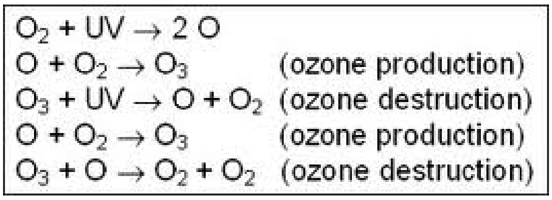
Causes

Ozone depletion is caused by the release of chlorofluorocarbons (CFC's) and other ozone-depleting substances (ODS), which were used widely as refrigerants, insulating foams, and solvents. The discussion below focuses on CFCs, but is relevant to all ODS [NO, NO_2 (aircraft exhaust), Br^-, UV rays, [O] Atomic oxygen etc].

Although CFCs are heavier than air, they are eventually carried into the stratosphere in a process that can take as long as 2 to 5 years. When CFCs reach the stratosphere, the ultraviolet radiation from the sun causes them to break apart and release chlorine atoms which react with ozone, starting chemical cycles of ozone destruction that deplete the ozone layer. One chlorine atom can break apart more than 100,000 ozone molecules.

Other chemicals that damage the ozone layer include methyl bromide (used as a pesticide), halons (used in fire extinguishers), and methyl chloroform (used as a solvent in industrial processes). As methyl bromide and halons are broken apart, they release bromine atoms, which are 40 times more destructive to ozone molecules than chlorine atoms.

Chapman's Reaction



$O_2 + UV \rightarrow 2\,O$

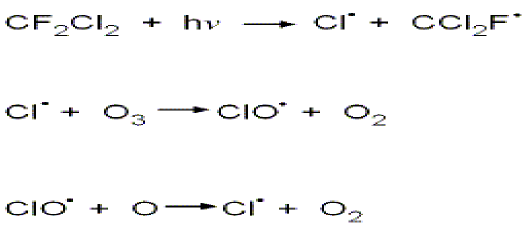
$O + O_2 \rightarrow O_3$ (ozone production)

$O_3 + UV \rightarrow O + O_2$ (ozone destruction)

$O + O_2 \rightarrow O_3$ (ozone production)

$O_3 + O \rightarrow O_2 + O_2$ (ozone destruction)

Ozone Depletion by CFC's



$$CF_2Cl_2 + h\nu \longrightarrow Cl^{\cdot} + CCl_2F^{\cdot}$$

$$Cl^{\cdot} + O_3 \longrightarrow ClO^{\cdot} + O_2$$

$$ClO^{\cdot} + O \longrightarrow Cl^{\cdot} + O_2$$

All above reactions occur in the presence of UV rays, while the 2nd set of reactions governs the oxygen-ozone equilibrium due to its spontaneity.

Effects

Effect of ozone hole include cataract, genetic mutation, constriction of blood vessels, reduced crop yield, leukemia, breast cancer, damage to crop, aqua culture, etc.,

The higher energy UV radiation absorbed by ozone is generally accepted to be a contributory factor to skin cancer. In addition, increased surface UV leads to increased tropospheric ozone, which is a health risk to humans such as Snow Blindness [photo keratosis], i.e., inflammation of cornea (outer coating of eyeball). The most common forms of skin cancer in humans, basal and squamous cell carcinomas have been strongly linked to UVB exposure. Another form of skin cancer, malignant melanoma, is much less common but far more dangerous, being lethal in about 15% - 20% of the cases diagnosed. In India there is no standard for Ozone. However WHO standard is 100 ppm for 8 hrs – avg.

Control Measures

The Montreal Protocol, an international agreement signed by 139 nations, banning the production of CFCs by the year 2000. We can't make enough ozone to replace what's been destroyed, but provided that we stop producing ozone-depleting substances, natural ozone production reactions should return the ozone layer to normal levels by about 2050. It is very important that the world comply with the Montreal Protocol; delays in ending production could result in additional damage and prolong the ozone layer's recovery. Control mechanism stresses on replacement of the banned chemical by ammonia, steam, helium etc.

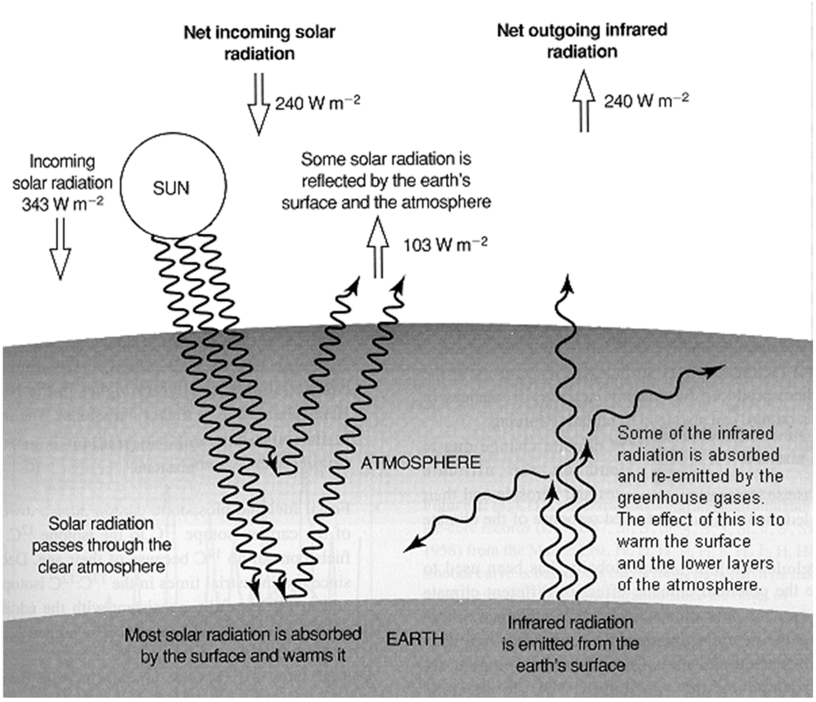
GREEN HOUSE EFFECT

Introduction

Objects that absorb all radiation upon them are called "blackbody" absorbers. The earth is close to being a black body absorber. Gases, on the other hand, are selective in their absorption characteristics. While many gases do not absorb radiation at all some selectively absorb only at certain wavelengths. Those gases that are "selective absorbers" of solar energy are the gases we know as "Greenhouse Gases."

Definition

The greenhouse effect is a phenomenon that ought to create a condition in the upper atmosphere, causing a trapping of excess heat and leading to increased surface temperatures.



Mechanism

The Earth receives energy from the Sun in the form of radiation. The Earth reflects about 30% of the incident solar flux; the remaining 70% is absorbed, warming the land, atmosphere and oceans. The visible solar radiation heats the surface, not the atmosphere, whereas most of the infrared radiation escaping to space is emitted from the upper atmosphere, not the surface. The infrared photons emitted by the surface are mostly absorbed by the atmosphere and do not escape directly to space. Hence earth's greenhouse effect is a natural phenomenon that helps regulates the temperature of our planet. Simply put, the sun heats the earth and some of this heat, rather than escaping back to space, is trapped in the atmosphere by clouds and greenhouse gases, such as water vapor and carbon di oxide. If all these greenhouse gases were to suddenly disappear, our planet would be 60° F colder and uninhabitable.

GREENHOUSE GASSES – SOURCES & SINKS

On Earth, the major natural greenhouse gases are water vapor, which causes about 36–70% of the greenhouse effect (not including clouds); carbon dioxide (CO_2), which causes 9–26%; methane (CH_4), which causes 4–9%; and ozone, which causes 3–7%.

Carbon Dioxide

Sources: Released by the combustion of fossil fuels (oil, coal, and natural gas), flaring of natural gas, changes in land use (deforestation, burning and clearing land for agricultural purposes), and manufacturing of cement.
Sinks: Photosynthesis and deposition to the ocean.
Significance: Accounts for about half of all warming potential caused by human activity.

Methane

Sources: Landfills, wetlands and bogs, domestic livestock, coal mining, wet rice growing, natural gas pipeline leaks, biomass burning, and termites.
Sinks: Chemical reactions in the atmosphere.
Significance: Molecule for molecule, methane traps heat 20-30 times more efficiently than CO_2. Within 50 years it could become the most significant greenhouse gas.

Nitrous Oxide [296 times potential than CO_2]

Sources: Burning of coal and wood, as well as soil microbes' digestion.
Sinks: Chemical reactions in the atmosphere.
Significance: Long-lasting gas that eventually reaches the stratosphere where it participates in ozone destruction.

Ozone

Sources: Not emitted directly, ozone is formed in the atmosphere through photochemical reactions involving nitrogen oxides and hydrocarbons in the presence of sunlight.
Sinks: Deposition to the surface, chemical reactions in the atmosphere.
Significance: In the troposphere ozone is a pollutant. In the stratosphere it absorbs hazardous ultraviolet radiation.

Chlorofluorocarbons (CFCs)

Sources: Used for many years in refrigerators, automobile air conditioners, solvents, aerosol propellants and insulation.
Sinks: Degradation occurs in the upper atmosphere at the expenses of the ozone layer. One CFC molecule can initiate the destruction of as many as 100,000 ozone molecules.
Significance: The most powerful of greenhouse gases — in the atmosphere one molecule of CFC has about 20,000 times the heat trapping power on a molecule of CO_2.

GLOBAL WARMING - CLIMATE CHANGE

Definition

Global warming is the increase in the average temperature of the Earth's near-surface air and oceans in recent decades and its projected continuation.

Impacts

- Consequences may include changes in agricultural yields, glacier retreat, reduced summer stream flows, species extinctions and increases in the ranges of disease vectors.

- The melting of Arctic ice and increased regional precipitation can add freshwater to the oceans, and potentially affect ocean currents in the North Atlantic.

- Forest fires could become more frequent.

- Due to the warming; insect outbreaks will increasingly disturb large areas of forest.

- Many Arctic animals, such as polar bears, seals, walruses, and seabirds, rely on the sea's biological productivity and on the presence of sea ice, both of which are highly dependent on climatic conditions.

- Changes in sea surface temperatures or currents could have a strong effect on Arctic marine fish stocks, which are an important food source for the world and play a vital role in the region's economy.

- Additional anticipated effects include 18% to 35% of a sample of 1,103 animal and plant species to be extinct by 2050, based on future climate projections.

Control

The world's primary international agreement on combating global warming is the Kyoto Protocol, an amendment to the United Nations Framework Convention on Climate Change (UNFCCC), negotiated in 1997. The Protocol now covers more than 160 countries globally and over 55% of global greenhouse gas (GHG) emissions.

How to Combat Global Warming

Use Compact Fluorescent Bulbs
Use Recycled Paper
Use Solar-heated Water
Take Shorter Showers
Buy Products Locally
Buy a Hybrid Car, Bio-fuel driven
Carpool When You Can
Plant a Tree
Replace Old Appliances
Unplug Un-Used Electronics
Insulate Your Home

Change Your Air Filter
Check Your Water Heater
Change the AC Filter
Install a Low-Flow Showerhead
Buy Minimally Packaged Goods
Buy a Fuel Efficient Car,
Reduce Garbage
Buy Organic Food
Use a Push Mower
Air Dry Your Clothes
Switch to Double Pane Windows

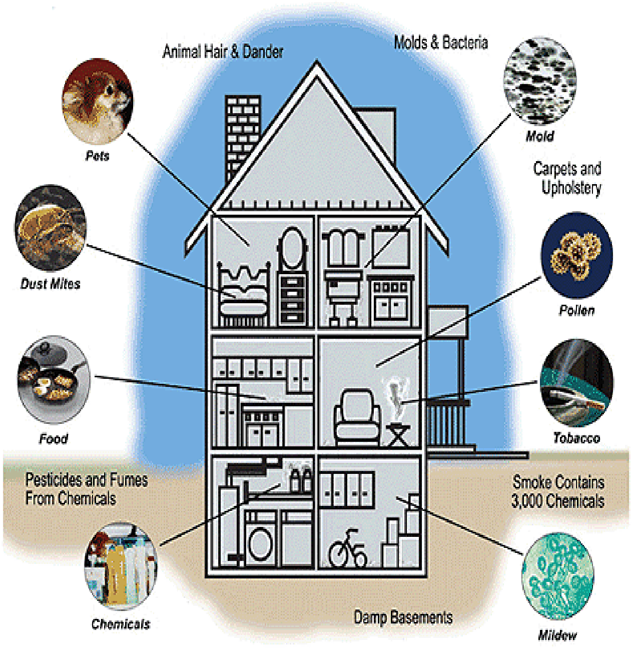
Bring Cloth Bags to the Market & Turn off Your Computer Whenever Possible

INDOOR AIR POLLUTION

Introduction

The indoor environment represents an important microenvironment in which people spend a large part of their time each day.

Source



The major sources of indoor air pollution worldwide include combustion of solid fuels indoors, tobacco smoking, outdoor air pollutants, emissions from construction materials and furnishings, and improper maintenance of ventilation and air conditioning systems.

About half of the world's population, largely in developing countries, relies on traditional fuels such as biomass (wood, agricultural residues and animal dung), charcoal and coal as the primary source of domestic energy.

Use of solid fuels in open or poorly ventilated stoves for cooking and heating exposes an estimated three billion people to high concentrations of PM and gases that are some 10–20 times higher than levels commonly found in international health guidelines (including the WHO air quality guidelines). Although relatively clean sources of household energy predominate in developed countries, improvements in energy efficiency have led to homes being relatively airtight, reducing ventilation and raising indoor pollutant levels. In such circumstances even minor sources of pollution, such as gas cookers, new furnishings, damp conditions, household products or naturally occurring radon gas, can lead to significant exposures and recognized health effects.

In developing countries, the most significant issue for indoor air quality is exposure to pollutants released during combustion of solid fuels, including biomass (wood, dung and crop residues) or coal (mainly in China), used for cooking and heating. The majorities of households using such fuels are located in poor rural communities and use inefficient devices such as earthen or metal stoves in kitchens that are often poorly ventilated, resulting in very high exposures.

Sources Outside Building

Contaminated outdoor air
pollen, dust, fungal spores
industrial pollutants
general vehicle exhaust

Emissions from nearby sources
exhaust from vehicles on nearby roads or in parking lots, or garages
loading docks
odors from dumpsters
re-entrained (drawn back into the building) exhaust from the building itself or from neighboring buildings
unsanitary debris near the outdoor air intake

Soil gas-Radon
leakage from underground fuel tanks
contaminants from previous uses of the site (e.g., landfills)
pesticides

Equipment-HVAC system
dust or dirt in ductwork or other components
microbiological growth in drip pans, humidifiers, ductwork, coils
improper use of biocides, sealants, and/or cleaning compounds
improper venting of combustion products
refrigerant leakage

Non-HVAC equipment
emissions from office equipment (volatile organic compounds, ozone)
supplies (solvents, toners, ammonia)
emissions from shops, labs, cleaning processes
elevator motors and other mechanical systems

Human Activities

Personal activities
Smoking, cooking
body odor
cosmetic odors

Housekeeping activities
cleaning materials and procedures
emissions from stored supplies or trash
use of deodorizers and fragrances
airborne dust or dirt (e.g., circulated by sweeping and vacuuming)

Maintenance activities
microorganisms in mist from improperly maintained cooling towers
airborne dust or dirt
volatile organic compounds from use of paint, caulk, adhesives, and other products
pesticides from pest control activities
emissions from stored supplies
Building Components and Furnishings
Locations that produce or collect dust or fibers
textured surfaces such as carpeting, curtains, and other textiles
open shelving
old or deteriorated furnishings
materials containing damaged asbestos

Impact

Indoor air quality (IAQ) is a term which refers to the air quality within and around buildings and structures, especially as it relates to the health and comfort of building occupants. IAQ can be affected by gases (including carbon monoxide, radon, volatile organic compounds), particulates, microbial contaminants (mould, bacteria) or any mass or energy stressor that can induce adverse health conditions.

Sick Building Syndrome, a phenomenon where building occupants experience acute health and comfort effects linked to time spent in the building. Most of the complainants report relief soon after leaving the building. The causes of contributing factors to sick building syndrome are inadequate ventilation & chemical contamination from indoor and outdoor sources. Concentrations of indoor pollutants are often two to five times higher than outdoor concentrations. These pollutants can build up rapidly indoors to levels much higher than those usually found outdoors. This is especially true if large amounts of a pollutant are released indoors. Moreover, "tighter" construction in newer homes can prevent pollutants from escaping to the outdoors.

Radon (Rn) gas, a carcinogen, is exuded from the Earth in certain locations and trapped inside houses.

Building materials including carpeting and plywood emit formaldehyde (H2CO) gas.

Paint and solvents give off volatile organic compounds (VOCs) as they dry. Lead paint can degenerate into dust and be inhaled.

Intentional air pollution is introduced with the use of air fresheners, incense, and other scented items.

Controlled wood fires in stoves and fireplaces can add significant amounts of smoke particulates into the air, inside and out.

Indoor pollution fatalities may be caused by using pesticides and other chemical sprays indoors without proper ventilation.

Carbon monoxide (CO) poisoning and fatalities are often caused by faulty vents and chimneys, or by the burning of charcoal indoors. Chronic carbon monoxide poisoning can result even from poorly adjusted pilot lights.

Clothing emits tetrachloroethylene, or other dry cleaning fluids, for days after dry cleaning.

Though its use has now been banned in many countries, the extensive use of asbestos in industrial and domestic environments in the past has left a potentially very dangerous material in many localities. Asbestosis is a chronic inflammatory medical condition affecting the tissue of the lungs. Sufferers have severe dyspnea (shortness of breath) and are at an increased risk regarding several different types of lung cancer.

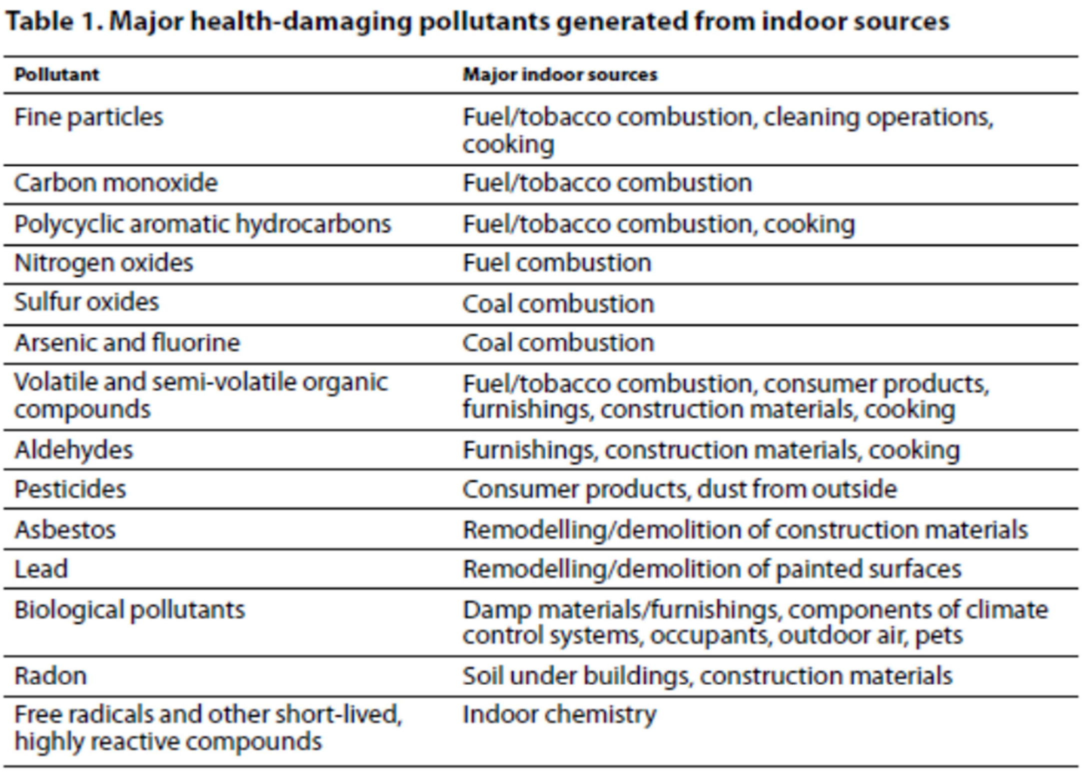


Table 1. Major health-damaging pollutants generated from indoor sources

Pollutant	Major indoor sources
Fine particles	Fuel/tobacco combustion, cleaning operations, cooking
Carbon monoxide	Fuel/tobacco combustion
Polycyclic aromatic hydrocarbons	Fuel/tobacco combustion, cooking
Nitrogen oxides	Fuel combustion
Sulfur oxides	Coal combustion
Arsenic and fluorine	Coal combustion
Volatile and semi-volatile organic compounds	Fuel/tobacco combustion, consumer products, furnishings, construction materials, cooking
Aldehydes	Furnishings, construction materials, cooking
Pesticides	Consumer products, dust from outside
Asbestos	Remodelling/demolition of construction materials
Lead	Remodelling/demolition of painted surfaces
Biological pollutants	Damp materials/furnishings, components of climate control systems, occupants, outdoor air, pets
Radon	Soil under buildings, construction materials
Free radicals and other short-lived, highly reactive compounds	Indoor chemistry

Biological sources of air pollution are also found indoors, as gases and airborne particulates. Pets produce dander, people produce dust from minute skin flakes and decomposed hair, dust mites in bedding, carpeting and furniture produce enzymes and micrometre-sized fecal droppings, inhabitants emit methane, mold forms in walls and generates mycotoxins and spores, air conditioning systems can incubate Legionnaires' disease and mold, and houseplants, soil and surrounding gardens can produce pollen, dust, and mold.

The presence of many biological agents in the indoor environment is due to dampness and inadequate ventilation. Excess moisture on almost all indoor materials leads to growth of microbes, which subsequently emit spores, cells, fragments and volatile organic compounds into indoor air. Moreover, dampness initiates chemical or biological degradation of materials, which also pollutes indoor air.

Recent studies estimate that exposure to indoor air pollutants associated with household solid fuel use may be responsible for nearly 1.6 million excess deaths and about 3% of the global burden of disease.

Factors governing the indoor air quality problem

Air exchange rate
Indoor rate of removal of pollutants
Outdoor concentration of air pollutant
Infiltration and exfiltration rate.

When there isn't an effective air exchange rate, which is the rate at which outdoor air replaces indoor air, indoor pollutant levels can increase. Air exchange rate is managed through natural and/or mechanical ventilation.

Natural ventilation occurs when air moves through opened doors and windows by wind or temperature differences. Mechanical ventilation occurs when devices such as fans or air handling systems distribute or move air. A proper air exchange rate it is vital for maintaining healthy indoor air.

Control

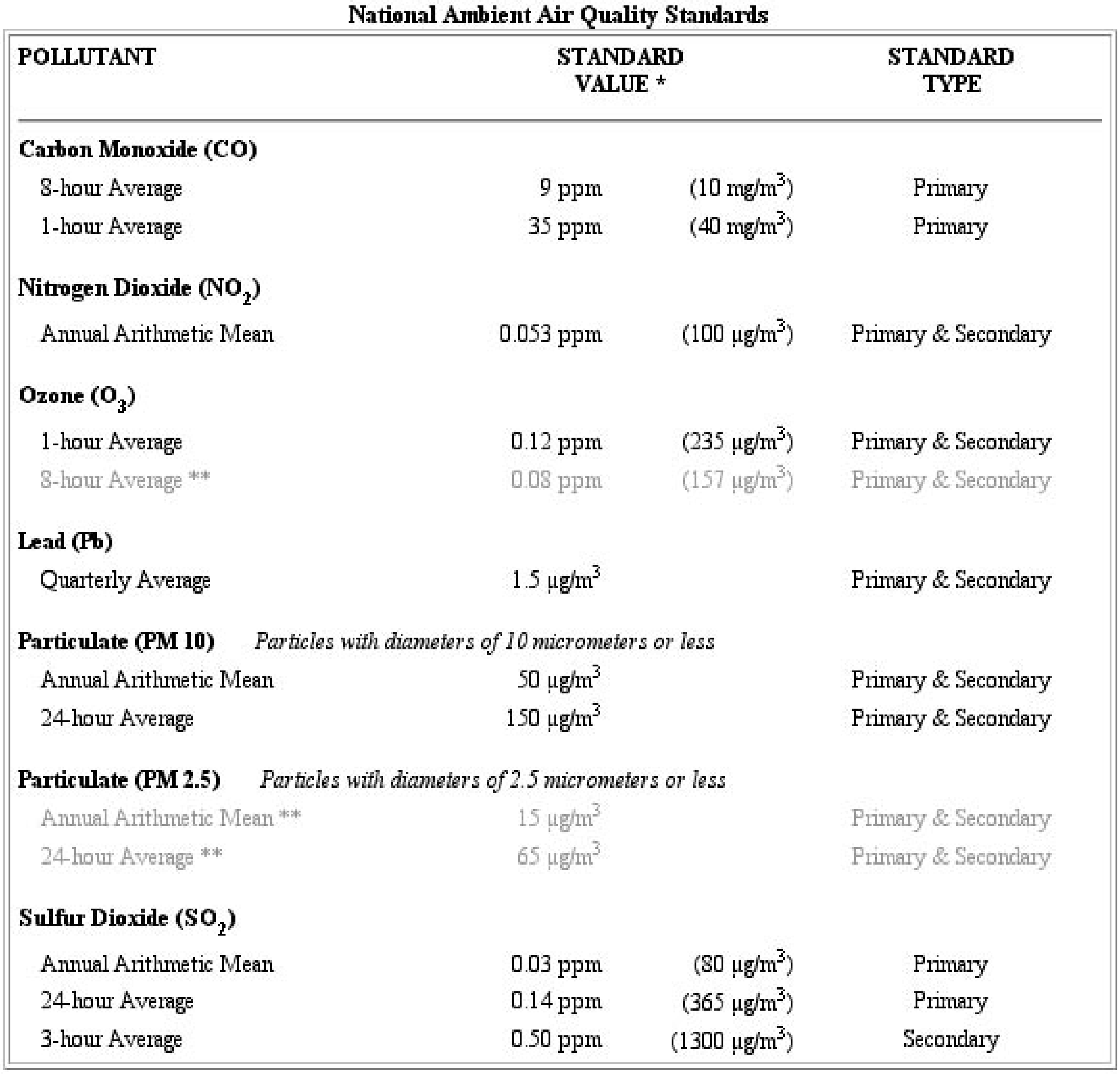
Source control, filtration and the use of ventilation to dilute contaminants are the primary methods for improving indoor air quality in most buildings.

Often seen outdoors, indoor plants are the best, natural and economical purifiers available to combat indoor air pollution.

Properly utilize and maintain air filters and cleaners

Unit – 8 (Standards and legislation)

Air Quality and Emission Standards



National Ambient Air Quality Standards

POLLUTANT	STANDARD VALUE *		STANDARD TYPE
Carbon Monoxide (CO)			
8-hour Average	9 ppm	(10 mg/m^3)	Primary
1-hour Average	35 ppm	(40 mg/m^3)	Primary
Nitrogen Dioxide (NO_2)			
Annual Arithmetic Mean	0.053 ppm	(100 μg/m^3)	Primary & Secondary
Ozone (O_3)			
1-hour Average	0.12 ppm	(235 μg/m^3)	Primary & Secondary
8-hour Average **	0.08 ppm	(157 μg/m^3)	Primary & Secondary
Lead (Pb)			
Quarterly Average	1.5 μg/m^3		Primary & Secondary
Particulate (PM 10) *Particles with diameters of 10 micrometers or less*			
Annual Arithmetic Mean	50 μg/m^3		Primary & Secondary
24-hour Average	150 μg/m^3		Primary & Secondary
Particulate (PM 2.5) *Particles with diameters of 2.5 micrometers or less*			
Annual Arithmetic Mean **	15 μg/m^3		Primary & Secondary
24-hour Average **	65 μg/m^3		Primary & Secondary
Sulfur Dioxide (SO_2)			
Annual Arithmetic Mean	0.03 ppm	(80 μg/m^3)	Primary
24-hour Average	0.14 ppm	(365 μg/m^3)	Primary
3-hour Average	0.50 ppm	(1300 μg/m^3)	Secondary

EMISSION STANDARD

Emission standards are requirements that set specific limits to the amount of pollutants that can be released into the environment. Many emissions standards focus on regulating pollutants released by automobiles (motor cars) and other powered vehicles but they can also regulate emissions from industry, power plants, small equipment such as lawn mowers and diesel generators. Frequent policy alternatives to emissions standards are technology standards (which mandate Standards generally regulate the emissions of nitrogen oxides (NOx), sulfur oxides, particulate matter (PM) or soot, carbon monoxide (CO), or volatile hydrocarbons (see carbon dioxide equivalent).

LEGISLATION AND REGULATION

Short title, extent and commencement.

THE AIR (PREVENTION AND CONTROL OF POLLUTION) ACT, 1981

(1) This Act may be called the Air (Prevention and Control of Pollution) Act, 1981.

(2) It extends to the whole of India, with effect from 16 May 1981.

(3) It shall come into force on such date as the Central Government may, by notification in the Official Gazette, appoint.

Definitions.

In this Act, unless the context otherwise requires,-

(a) "air pollutant" means any solid, liquid or gaseous substance 2[(including noise)] present in the atmosphere in such concentration as may be or tend to be injurious to human beings or other living creatures or plants or property or environment;

(b) "air pollution" means the presence in the atmosphere of any air

(c) "approved appliances" means any equipment or gadget used for the bringing of any combustible material or for generating or consuming any fume, gas of particulate matter and approved by the State Board for the purpose of this Act;

(d) "approved fuel" means any fuel approved by the State Board for the purposes of this Act;

(e) "automobile" means any vehicle powered either by internal combustion engine or by any method of generating power to drive such vehicle by burning fuel;

(h) "chimney" includes any structure with an opening or outlet from or through which any air pollutant may be emitted,

(i) "control equipment" means any apparatus, device, equipment or system to control the quality and manner of emission of any air pollutant and includes any device used for securing the efficient operation of any industrial plant;

(j) "emission" means any solid or liquid or gaseous substance coming out of any chimney, duct or flue or any other outlet;

(k) "industrial plant" means any plant used for any industrial or trade purposes and emitting any air pollutant into the atmosphere;

4[(m) "occupier", in relation to any factory or premises, means the person who has control over the affairs of the factory or the premises, and includes, in relation to any substance, the person in possession of the substance;]

Powers and functions of boards

Functions of Central Board.

(1) Subject to the provisions of this Act, and without prejudice to the performance, of its functions under the Water (Prevention and Control of Pollution) Act, IL974 (6 of 1974), the main functions of the Central Board shall be to improve the quality of air and to prevent, control or abate air pollution in the country.

(2) In particular and without prejudice to the generality of the foregoing functions, the Central Board may-

(a) advise the Central Government on any matter concerning the improvement of the quality of air and the prevention, control or abatement of air pollution;

(b) plan and cause to be executed a nation-wide programme for the prevention, control or abatement of air pollution;

(c) co-ordinate the activities of the State and resolve disputes among them;

(d) provide technical assistance and guidance to the State Boards, carry out and sponsor investigations and research relating to problems of air pollution and prevention, control or abatement of air pollution;

(e) plan and organise the training of persons engaged or to be engaged in programmes for the prevention, control or abatement of air pollution on such terms and conditions as the Central Board may specify;

(f) organise through mass media a comprehensive programme regarding the prevention, control or abatement of air pollution;

(g) collect, compile and publish technical and statistical data relating to air pollution and the measures devised for its effective prevention, control or abatement and prepare manuals, codes or guides relating to prevention, control or abatement of air pollution;

(h) lay down standards for the quality of air.,

(i) collect and disseminate information in respect of matters relating to air pollution;

(j) perform such other functions as may be prescribed.

(3) The Central Board may establish or recognise a laboratory or laboratories to enable the Central Board to perform its functions under this section efficiently.

FUNCTIONS OF STATE BOARDS.

(1) subject to the provisions of this Act, and without prejudice to the performance of its functions, if any, under the Water (Prevention and Control of Pollution) Act, 1974 (Act 6 of 1974), the functions of a State Board shall be-

(a) to plan a comprehensive programme for the prevention, control or abatement of air pollution and to secure the execution thereof-,

(b) to advise the State Government on any matter concerning the prevention, control or abatement of air pollution;

(c) to collect and disseminate information relating to air pollution;

(d) to collaborate with the Central Board in organising the training of persons engaged or to be engaged in programmes relating to prevention, control or abatement of air pollution and to organise mass-education programme relating thereto;

(e) to inspect, at all reasonable times, any control equipment, industrial plant or manufacturing process and to give, by order, such directions to such persons as it may consider necessary to take steps for the prevention, control or abatement of air pollution;

(f) to inspect air pollution control areas at such intervals as it may think necessary, assess the quality of air therein and take steps for the prevention, control or abatement of air pollution in such areas;

(g) to lay down, in consultation with the Central Board and having regard to the standards for the quality of air laid down by the Central Board, standards for emission of air pollutants into the atmosphere from industrial plants and automobiles or for the discharge of any air pollutant into the atmosphere from any other source whatsoever not being a ship or an aircraft:

(h) to advise the State Government with respect to the suitability of any premises or location for carrying on any industry which is likely to cause air pollution;

(i) to Perform such other functions as may be prescribed or as may, from time to time, be entrusted to it by the Central Board or the State Government;

(j) to do such other things and to perform such other acts as it may think necessary for the proper discharge of its functions and generally for the purpose of carrying into effect the purposes of this Act.

(2) A State Board may establish or recognise a laboratory or laboratories to enable the State Board to perform its functions under this section efficiently.

Powers under the Act

Power to declare air pollution control areas

Power to give instructions for ensuring standards for emission from automobiles.

Power of Board to make application to court for restraining person from causing air pollution.

Restrictions on use of certain industrial plants.

Power to obtain information.

Power of entry and inspection.

PENALTIES AND PROCEDURE

Penalties for certain acts. Whoever-

(a) destroys, pulls down, removes, injures or defaces any pillar, post or stake fixed in the ground or any notice or other matter put up, incsribed or placed, by or under the authority of the Board, or

(b) obstructs any person acting under the orders or directions of the Board from exercising his powers and performing his functions under this Act, or

(c) damages any works or property belonging to the Board, or

(d) fails to furnish to the Board or any officer or other employee of the Board any information required by the Board or such officer or other employee for the purpose of this Act, or

(e) fails to intimate the occurrence of the emission of air pollutants into the atmosphere in excess of the standards laid down by the State Board or the apprehension of such occurrence, to the State Board and other prescribed authorities or agencies as required under sub-section (1) of section 23, or

(f) in giving any information which he is required to give under this Act, makes a statement which is false in any material particular, or

(g) for the purpose of obtaining any consent under section 21, makes a statement which is false in any material particular shall be punishable with imprisonment for a term which may extend to three months or with fine which may extend to 29[ten thousand rupees] or with both.

Penalty for contravention of provisions of the Act.

Whoever contravenes any of the provisions of this Act or any order or direction issued thereunder, for which no penalty has been elsewhere provided in this Act, shall be punishable with imprisonment for a term which may extend to three months or with fine which may extend to ten thousand rupees or with both, and in the case of continuing contravention, with an additional fine which may extend to five thousand, rupees for every day during which such contravention continues after conviction for the first such contravention.)

40. Offences by companies.

(1) Where an offence under this Act has been committed by a company, every person who, at the time the offence was committed, was directly in charge of, and was responsible to, the company for the conduct of the business of the company, as well as the company, shall be deemed to be guilty of the offence and shall be liable to be proceeded against and punished accordingly:

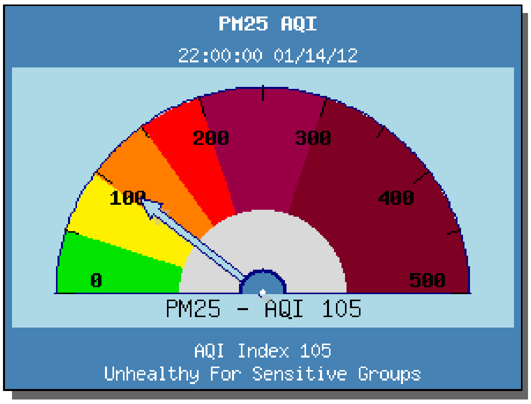
Provided that nothing contained in this sub-section shall render any such person liable to any punishment provided in this Act, if he proves that the offence was committed without his knowledge or that he exercised all due diligence to prevent the commission of such offence.

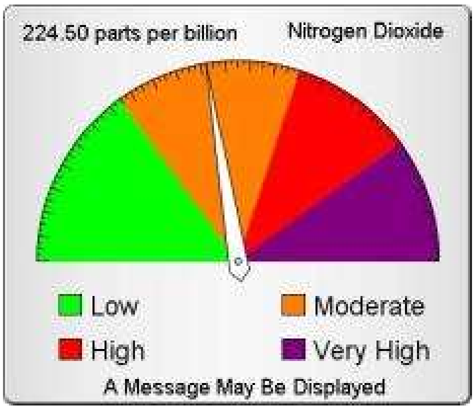
AIR POLLUTION INDEX

The Air Pollution Index (API) is a simple and generalized way to describe the air quality in. It is calculated from several sets of air pollution data. The API level is based on the level of 5 atmospheric pollutants, namely sulfur dioxide (SO_2), nitrogen dioxide (NO_2), suspended particulates (PM_{10}), carbon monoxide (CO), and ozone (O_3) measured at the monitoring stations. An air quality index (AQI) is a number used by government agencies to communicate to the public how polluted the air is currently or how polluted it is forecast to become. As the AQI increases, an increasingly large percentage of the population is likely to experience increasingly severe adverse health effects. Different countries have their own air quality indices which are not all consistent. Different countries also use different names for their indices such as Air Quality Health Index, Air Pollution Index and Pollutant Standards Index.

Air quality is defined as a measure of the condition of air relative to the requirements of one or more biotic species or to any human need or purpose.[1] To compute the AQI requires an air pollutant concentration from a monitor or model. The function used to convert from air pollutant concentration to AQI varies by pollutant, and is different in different countries. Air quality index values are divided into ranges, and each range is assigned a descriptor and a color code. Standardized public health advisories are associated with each AQI range.

PSI	Descriptor	General Health Effects
0 - 50		None
51 - 100	Moderate	Few or none for the general population
101 - 200	Unhealthy	Mild aggravation of symptoms among susceptible persons i.e. those with underlying conditions such as chronic heart or lung ailments; transient symptoms of irritation e.g. eye irritation, sneezing or coughing in some of the healthy population.
201 - 300	Very Unhealthy	Moderate aggravation of symptoms and decreased tolerance in persons with heart or lung disease; more widespread symptoms of transient irritation in the healthy population.
301 - 400	Hazardous	Early onset of certain diseases in addition to significant aggravation of symptoms in susceptible persons; and decreased exercise tolerance in healthy persons.
Above 400	Hazardous	PSI levels above 400 may be life-threatening to ill and elderly persons. Healthy people may experience adverse symptoms that affect normal activity.





UNIT 1

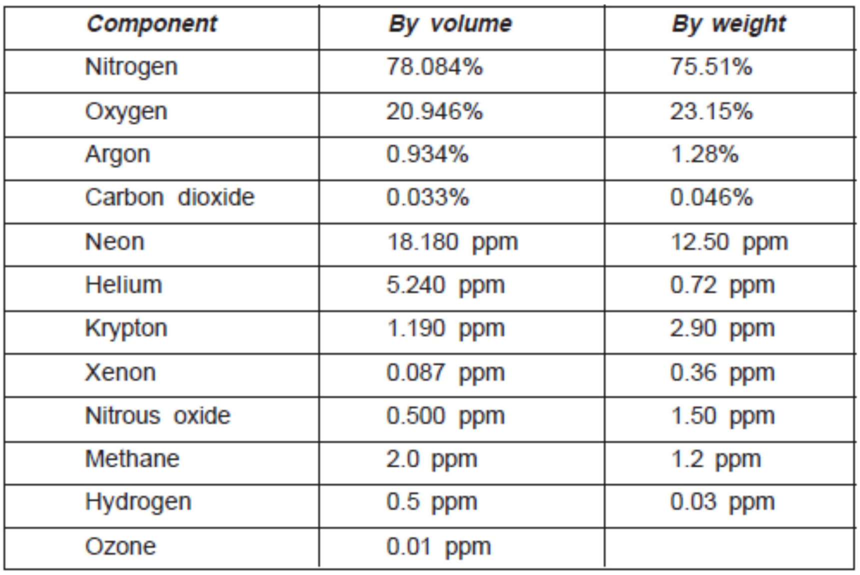
10CV765 APC

Definition of Air pollution: It is the presence of substances in air in sufficient concentration and for sufficient time, so as to be, or threaten to be injurious to human, plant or animal life, or to property, or which reasonably interferes with the comfortable enjoyment of life and property.

The air Act of Govt. of India (amendment 1987) defines air pollution as “air pollution means any solid, liquid or gaseous substances present in the atmosphere in such concentrations that may tend to be injurious to human beings or other living creatures or plants or property or enjoyment”.

Perkins (1974) defined air pollution as “air pollution means the presence in the outdoor atmosphere of one or more contaminants such as dust, fumes, gas, mist, odor, smoke or vapor in quantities or characteristics and of duration such as to be injurious to human, plant or animal life or to property or which unreasonably interferes with the comfortable enjoyment of life and property.”

Atmosphere can be defined as the thin blanket of air surrounding the earth. The clean dry air has following average composition:-



Component	By volume	By weight
Nitrogen	78.084%	75.51%
Oxygen	20.946%	23.15%
Argon	0.934%	1.28%
Carbon dioxide	0.033%	0.046%
Neon	18.180 ppm	12.50 ppm
Helium	5.240 ppm	0.72 ppm
Krypton	1.190 ppm	2.90 ppm
Xenon	0.087 ppm	0.36 ppm
Nitrous oxide	0.500 ppm	1.50 ppm
Methane	2.0 ppm	1.2 ppm
Hydrogen	0.5 ppm	0.03 ppm
Ozone	0.01 ppm	

Definition of Air pollutants: Substances introduces into the air, natural or manmade, in concentrations detrimental to human, plant or animal life, or to property.

Major Classification of Air Pollutants:

1] Primary – Secondary
2] Natural – Manmade
3] Criteria Air Pollutants
4] Physical - chemical - biological

Primary pollutants and secondary pollutants: Primary pollutants are substances that are directly emitted into the atmosphere from sources. Primary pollutants are those that are emitted directly from identifiable sources. Secondary air pollutants are those that are produced in the air by the interaction of two or more primary air pollutant.

Primary Air pollutants:-

(i) Fine (less than 100μ) and coarse (more than 100μ) suspended particulate matter
(ii) Oxides of sulfur
(iii) Oxides of nitrogen
(iv) Carbon monoxide
(v) Halogens
(vi) Organic compounds
(vii) Radioactive compounds

Secondary Air pollutants:-
(i) Ozone
(ii) PAN (peroxi aceyl nitrate)
(iii) Photochemical smog
(iv) Acid mists

Air pollutants arise from both manmade and natural processes. The ambient air quality may be defined by the concentration of a set of pollutants which may be present in the ambient air we breathe in. These pollutants may be called **criteria pollutants**.

Natural Contaminants: Pollen is important natural contaminant because of its peculiar properties of irritation and allergy sometimes leading to bronchitis, asthma and dermatitis. Pollen grains are the male gametophytes of gymnosperms and angiosperms and they are discharged into the atmosphere from plants etc. The air transported pollen grains range mainly between 10 and 50 microns. Manmade refers to any pollutant produced to influence or action of humans.

Aerosols: Aerosols refer to the dispersion of solid or liquid particles of microscopic size in the air. It can also be defined as a colloidal system in which the dispersion medium is gas and the dispersed phase is solid or liquid. The term aerosol is applicable until it is in suspension and after settlement due to its own weight or by addition with other particles (agglomeration) it is no longer an air pollutant. The diameter of the aerosol may range from 0.01 (or less) micron to 100 micron.

The various aerosols are as follows:-

(i) **Dust:** Dust is produced by the crushing, grinding and natural sources like windstorms. Generally the dust particles are over 20 micron in diameter. They do not flocculate but settle under gravity, but smaller particles like 5 micron form stable suspensions.

(ii) **Smoke:** Smoke is made up of finely divided particles produced by incomplete combustion. Generally it consists of carbon particles of size less than 1.0 micron.

(iii) **Mists:** Mist is a light dispersion of minute water droplets suspended in the atmosphere ranging from 40 to 400 micron in size.

(iv) **Fog:** Fog is made up of dispersion of water or ice near the earth’s surface reducing visibility to less than 500 m. In natural fog the size of particles range from 1.0 to 40 micron.

(v) **Fumes:** Fumes are solid particles generated by condensation from the gaseous state after volatilization from melted substances. Fumes flocculate and sometimes coalesce. Gases:

Following are the **main air pollutant gases**

(i) **Sulphur dioxide:** It is a major air pollutant gas produced by the combustion of fuels like coal. The main source of electricity production is by burning of fossil fuels in India and the whole world. The sulphur content of the coal varies from 1 to 4% and fortunately the Indian coal is low in sulphur content. SO2 is also produced in the metallurgical operations.

(ii) **Oxides of nitrogen:** Oxides of nitrogen are produced either in the production of nitric acid or in the automobile exhausts and as the effluent of power plants. Out of the seven oxides of Nitrogen (N_2O, NO, NO_2, NO_3, N_2O_3, N_2O_4, N_2O_5) only nitric oxide and nitrogen dioxide are classified as the main pollutants. All the oxides of nitrogen are collectively known as NO_X.

(iii) **Carbon monoxide:** It is produced because of the incomplete combustion of coal and other petroleum products. It is produced in the exhaust of automobiles. In the pollution check of vehicles mainly CO and unburnt hydrocarbons are measured.

(iv) **Hydrogen sulphide:** Hydrogen Sulphide is an obnoxious (bad smelling) gas. It is produced mainly by the anaerobic (in absence of air) decomposition of organic matter. Other air polluting sulfur compounds are methyl mercaptan (CH_3SH) and dimethyl sulphide (CH_3-S-CH_3) etc.

(v) **Hydrogen fluoride:** It is an important pollutant even in very low concentrations. It is produced in the manufacturing of phosphate fertilizers.

(vi) **Chlorine and hydrogen chloride:** It is mixed in the air either from the leakages from water treatment plants or other industries where it is produced or used. Hydrogen chloride is also evolved in various industrial chemical processes. The main effect of chlorine is respiratory irritation which may be fatal.

(vii) **Ozone:** It is a desirable gas in the upper layers of atmosphere as it absorbs the UV radiation of sunlight. But near the earth surface it is a poisonous gas. It makes poisonous chemicals by photochemical reactions.

(viii) **Aldehydes:** They are produced by the incomplete oxidation of motor fuels and lubricating oil. They may also be formed because of photochemical reactions. Formaldehydes are irritating to the eyes.

Classification according to chemical composition: (Organic – inorganic)

1. Sulfur-containing compounds.
2. Nitrogen-containing compounds.
3. Carbon-containing compounds.
4. Halogen-containing compounds.
5. Toxic substances (any of about).
6. Radiative compounds.

Classification according to physical state:

1. Gaseous.
2. Liquid (aqueous).
3. Solid.

Criteria air pollutants are six major pollutants defined by EPA (Environmental Protection Agency) for which ambient air standards have been set to protect human health and welfare. These include :

1. Ozone, O_3.
2. Carbon monoxide, CO.
3. Sulfur dioxide, SO_2.
4. Nitrogen oxides, NO_x.
5. Lead, Pb.
6. Particulates, PM_{10}.

Pollutant	Description	Sources	Health Effects	Welfare Effects
Carbon Monoxide (CO)	Colorless, odorless gas	Motor vehicle exhaust, indoor sources include kerosene or wood burning stoves.	Headaches reduced mental alertness, heart attack, cardiovascular diseases, impaired fetal development, and death.	Contribute to the formation of smog.
Sulfur Dioxide (SO2)	Colorless gas that dissolves in water vapor to form acid, and interact with other gases and particles in the air.	Coal-fired power plants, petroleum refineries, manufacture of sulfuric acid and smelting of ores containing sulfur.	Eye irritation, wheezing, chest tightness, shortness of breath, lung damage.	Contribute to the formation of acid rain, visibility impairment, plant and water damage, aesthetic damage.
Nitrogen Dioxide (NO2)	Reddish brown, highly reactive gas.	Motor vehicles, electric utilities, and other industrial, commercial, and residential sources that burn fuels.	Susceptibility to respiratory infections, irritation of the lung and respiratory symptoms (e.g., cough, chest pain, difficulty breathing).	Contribute to the formation of smog, acid rain, water quality deterioration, global warming, and visibility impairment.
Ozone (O3)	Gaseous pollutant when it is formed in the troposphere.	Vehicle exhaust and certain other fumes. Formed from other air pollutants in the presence of sunlight.	Eye and throat irritation, coughing, respiratory tract problems, asthma, lung damage.	Plant and ecosystem damage.
Lead (Pb)	Metallic element	Metal refineries, lead smelters, battery manufacturers, iron and steel producers.	Anemia, high blood pressure, brain and kidney damage, neurological disorders, cancer, lowered IQ.	Affects animals and plants, affects aquatic ecosystems.
Particulate Matter (PM)	Very small particles of soot, dust, or other matter, including tiny droplets of liquids.	Diesel engines, power plants, industries, windblown dust, wood stoves.	Eye irritation, asthma, bronchitis, lung damage, cancer, heavy metal poisoning, cardiovascular effects.	Visibility impairment, atmospheric deposition, aesthetic damage.

Emission Sources

Major Classification of Air Pollution Sources:

1] Based on Origin: Natural and Manmade

While man-made air pollution does present health hazards, natural sources of air pollution can be equally dangerous at times. These sources include dust picked up by wind erosion, the emission of methane by livestock, and smoke from wildfires. Volcanic eruptions are perhaps the largest single source of air pollution, natural or man-made, that humans have ever dealt with. These can produce clouds of abrasive volcanic ash and other harmful substances such as chlorine and sulfur.

2] Based on Position: Stationary and Mobile

The sources of air pollution may be classified as stationary point sources (generally industrial in origin), diffuse or area sources and mobile sources (mainly cars and trucks).

3] Based on Aix of Release: Horizontal axis (Roadways traffic)
Vertical Axis release (Industrial Stacks)
4] Based on Intensity/frequency of release: Continuous release (Industrial Stacks)
Instantaneous release (Roadways traffic)

Stationary Sources

The stationary industrial sources are usually classified by process type or sub-type. Thus an oil refining plant also includes large industrial boilers as a sub-type. Small and medium scale plants such as garment or food processing plants may include industrial boilers, a common source of air pollution. The quality and type of fuel used for energy production are important determinants of the air pollution potential of a plant. Each type of plant or activity generally emits more than one pollutant, and the pollutant emission rate depends on the fuel type and quality, the design of the plant (and whether fitted with air pollution control devices or not), and the activity rate or output of the plant.

(i) Point source (power plant stacks)
(ii) Area source (forest fires, open burning)
(iii) Line Source (highway vehicle exhausts)

Mobile Sources Refer mainly to emissions from cars, trucks, minibuses and buses. The fuel source may be petrol or diesel, and emissions include exhaust emissions and fugitive emissions. Vehicle (mobile) source emissions depend on a number of factors, including vehicle size, fuel type, speed and vehicle technology. Total vehicle emissions depend on the vehicle population on the road at a given time.

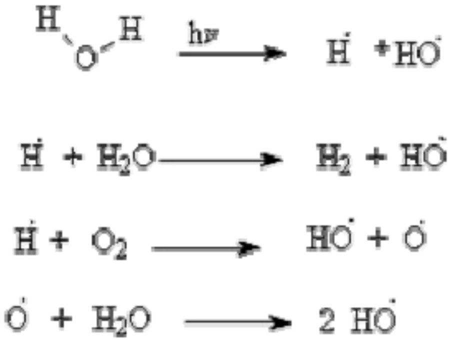
Chemical Reactions in the Atmosphere

Substances in the top layer of the geosphere, known as the lithosphere, tend to become more reduced over time. Biomass (CH_2O) for example is slowly transformed to substances which have no oxygen atoms through a sequence of steps, then to compounds with successively larger carbon to hydrogen ratios and finally to products with a form of pure carbon. However, atmospheric chemical reactions have the opposite effect on substances, causing an atom to become more oxidized over time in the atmosphere. Atmospheric gases that are found in their reduced states are oxidized stepwise to form ionic substances that are washed out of the atmosphere in rainfall. Example, dissolution of atmospheric hydrogen sulfide by rain to form sulfate molecule.

$$H_2S + H_2O\ (\text{rain}) \rightarrow SO_4^{2-}$$

Chemical reactions in the atmosphere can occur as gas phase collisions between molecules, on the surfaces of solid particles or in aqueous solution (in water droplets); predominantly acid-base reactions. Particles spend short residence time in the atmosphere. Due to this, reactions that occur on particle surfaces are of minor importance in most cases. Gas phase reactions dominate the chemical changes that occur to substances in the atmosphere.

The most important single species in atmospheric chemistry is the hydroxyl radical (HO·). This radical is formed by several reactions. However, the primary process is one where an O-H bond of the water molecule is broken to form a hydrogen atom (H·) and a hydroxyl radical (HO·). The hydrogen atom can then react with another water molecule to form hydrogen and a second hydroxyl radical, or with an oxygen molecule (O2) to form a second hydroxyl radical and an oxygen atom. The new oxygen atom can then react with another water molecule to form two new hydroxyl radicals.



Molecules in the atmosphere are continually moving and colliding with one another, as described by the kinetic-molecular theory. The atmosphere is also continually illuminated during daylight hours. As a result, absorption of light energy by atmospheric molecules can cause photochemical reactions, reactions that would not occur at normal atmospheric temperatures in the absence of light. Such reactions play an important role in determining the composition of the atmosphere itself and the fate of many chemical species that contribute to air pollution.

Nitrogen dioxide, NO2, is one of the most photochemically active species in the atmosphere. The NO2 molecule is an example of a free radical because it contains an unpaired electron, represented by a next to its formula. When an NO2 molecule absorbs a photon of light with energy, the molecule is raised to a higher energy level; it becomes an electronically excited molecule, designated by an asterisk (*).

$$\cdot\mathrm{NO_2(g)} \xrightarrow{h\nu} \cdot\mathrm{NO_2^*}$$

The excited molecule may quickly re-emit a photon of light, or the energy may break an N-O bond to form a nitrogen monoxide (NO) molecule and an oxygen atom (O). Both NO and O are free radicals, because they have one or more unpaired electrons each denoted by a dot.

$$\cdot\mathrm{NO}_2^*(\mathrm{g}) \xrightarrow{h\nu} \cdot\mathrm{NO}(\mathrm{g}) + \cdot\mathrm{O}\cdot(\mathrm{g})$$

Photodissociation is another mechanism of formation of radicals, in which a molecule absorbs an ultraviolet photon and produces two free radicals as products. Molecular oxygen can photodissociate to form two oxygen atoms.

$$\mathrm{O}_2(\mathrm{g}) \xrightarrow{h\nu} \cdot\mathrm{O}\cdot(\mathrm{g}) + \cdot\mathrm{O}\cdot(\mathrm{g})$$

Some free radicals, such as an oxygen atom, react with another atom or molecule almost immediately. Others, such as an NO2 molecule, are not quite so reactive and are stable enough to exist for a somewhat longer time. Most radicals are highly reactive and short-lived.

Fate of air pollutants in the atmosphere

1] NO_x, Hydrocarbons, Ozone, Mist: - Formation of photochemical smog

2] SO_2, NO_x: - Formation of Acid Mist / Rain

3] SO_2, CO, Mist: - Formation of coal induced smog

4] [O], NOx, OH^- - Formation of Ozone

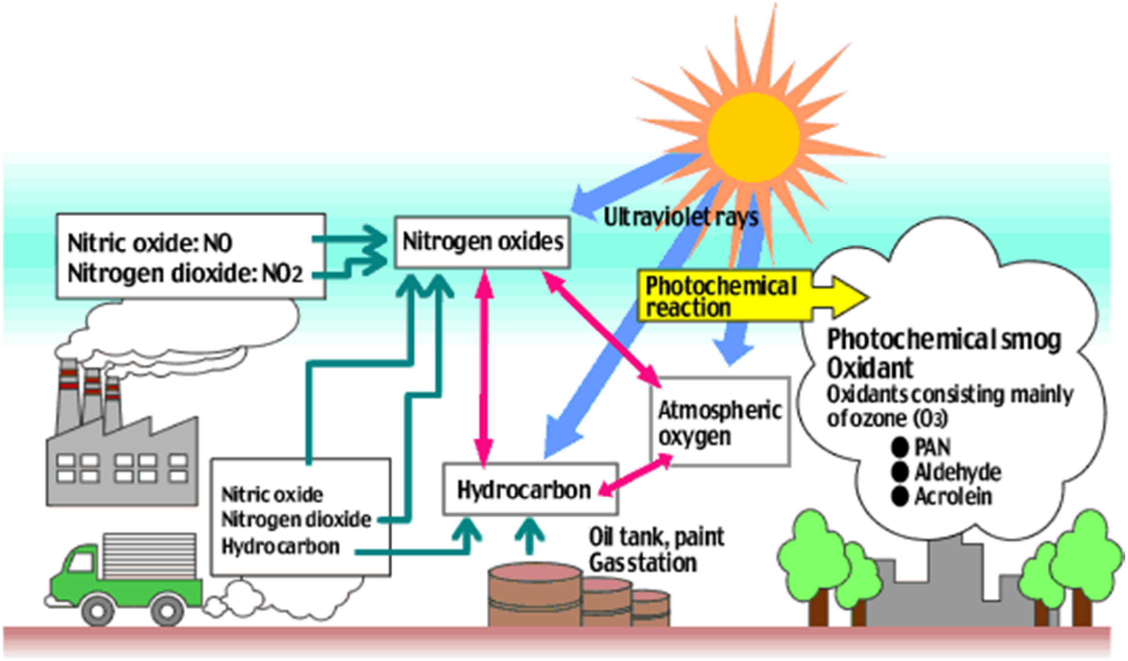
PHOTO CHEMICAL SMOG

Photochemical smog was first described in the 1950s. It is the chemical reaction of sunlight, nitrogen oxides and volatile organic compounds in the atmosphere, which leaves airborne

particles and ground-level ozone. This noxious mixture of air pollutants can includes Aldehydes, Nitrogen oxides, such as nitrogen dioxide, Peroxyacyl nitrates

Tropospheric ozone, Volatile organic compounds etc. All of these chemicals are usually highly reactive and oxidizing. Photochemical smog is considered to be a problem of modern industrialization. It is present in all modern cities, but it is more common in cities with sunny, warm, dry climates and a large number of motor vehicles. Because it travels with the wind, it can affect sparsely populated areas as well.

VOCs + NOx + sunlight → photochemical smog



To begin the chemical process of photochemical smog development the following conditions must occur:

- Sunlight.
- The production of oxides of nitrogen (NOx).
- The production of volatile organic compounds (VOCs).
- Temperatures greater than 18 degrees Celsius.

Nitrogen oxide is an essential ingredient of photochemical smog that is produced during the high temperatures associated with combustion of vehicle’s engines. Nitrogen oxide is an essential ingredient of photochemical smog that is produced during the high temperatures associated with combustion of vehicle’s engines.

Formation

Sunlight can break down nitrogen dioxide back into nitrogen oxide.

$$NO_2 + \text{sunlight} \text{ »»» } NO + O$$

The atomic oxygen formed in the above reaction then reacts with one of the abundant oxygen molecules producing ozone.

$$O + O_2 \text{ »»» } O_3$$

Nitrogen dioxide can also react with radicals produced from volatile organic compounds in a series of reactions to form toxic products such as peroxyacyl nitrates.

$$NO_2 + R \text{ »»» products such as PAN}$$

Note the symbol R represents a hydrocarbon (a molecule composed of carbon, hydrogen and other atoms) which is primarily created from volatile organic compounds.

Steps

1) Nitrogen oxides generate oxygen atoms

2) Oxygen atoms form hydroxyl radicals

3) Hydroxyl radicals generate hydrocarbon radicals

4) Hydrocarbon radicals form hydrocarbon peroxides

5) Hydrocarbon peroxides form aldehydes

6) Aldehydes form aldehyde peroxides

7) Aldehyde peroxides form peroxy-acyl-nitrates

Health effects

It can cause eye and nose irritation and it dries out the protective membranes of the nose and throat and interferes with the body's ability to fight infection, increasing susceptibility to illness.

COAL INDUCED SMOG

Introduction to Smog

Smog is a recent compound word from "smoke" and "fog", and was coined by Harold Antoine des Voeux, a doctor, in 1905. Smog refers to locally high concentrations of acids, dry acid-forming compounds, particulates, or other pollutants in stagnant, stable air. Smog’s form when emissions are prevented from dispersing by stable or sinking air masses. They were very prevalent in European and North American cities during first part of 20th Century. London smog’s were infamous in the 19th and early 20th centuries and formed every autumn and winter due to sulphur emissions from coal burning industries and domestic fires. The most severe London smog was on 4-10th December 1952, when cold, high-pressure conditions trapped coal smoke in foggy air. The output of smoke was increased by the cold weather, due to the large numbers of domestic fires. Sooty smoke produced peak daily concentrations of black smoke of 5000 mgs/m3 (WHO 24 hr. max limit of 100-150), and daily average SO2 levels of 3000-4000 mg/m3 (WHO 24 hr. max limit of 100-150). Sulphuric acid droplets resulted in pH estimated as 1.4 to 1.9: as acidic as car battery acid.

$$H_2SO_{4(g)} + H_2O \rightarrow H_2SO_{4(aq)}$$
$$SO_{2(g)} + H_2O_{(l)} \rightarrow H_2SO_{3(aq)}$$

Chemistry

These are produced by high outputs of SO2, which are converted to acids on contact with atmospheric moisture. Usually, sulphurous smog’s also contain elevated concentrations of suspended soot.

Impacts

Visibility was reduced to 5m at times, and London buses had to be guided through the street by men with lanterns during daylight hours. The smog lasted for 5 days, eventually extending over a 50km radius. Approx. 4,000 excess deaths occurred as a result of inhaling pollution, mainly old and sick and those with chest problems. Respiratory diseases alone accounted for 59 per cent of the increase in deaths registered in the week ending 13 December and 76 per cent in the following week. Bronchitis and emphysema were the two conditions that stood out in the coroner's records as showing the greatest increase. Cardiovascular disease accounted for 22 per cent of the increased number of deaths in the first week and 16 per cent in the week ending 20 December. The disaster ultimately led to the introduction of the Clean Air Acts.

ACID MIST/ RAIN

Definition

Normal Rain water p^H is slightly acidic due to certain concentration of CO_2 dissolved as rainwater trickles down atmosphere,

$$CO_2+H_2O\rightarrow HCO^{3-}+H^+$$

Acid rain is defined as any type of precipitation with a p^H that is unusually low or lower than 5.7. Acid rain was first found in Manchester, England. In 1852, Robert Angus Smith found the relationship between acid rain and atmospheric pollution. Though acid rain was discovered in 1852, it wasn't until the late 1960s that scientists began widely observing and studying the phenomenon.

Causes

The principal natural phenomena that contribute acid-producing gases to the atmosphere are emissions from volcanoes and those from biological processes that occur on the land, in wetlands, and in the oceans. The major biological source of sulfur containing compounds is dimethyl sulfide.

The principal cause of acid rain is sulfuric and nitrogen compounds from human sources, such as electricity generation, factories and motor vehicles. Coal power plants are one of the most polluting. The gases can be carried hundreds of kilometres in the atmosphere before they are converted to acids and deposited. Factories used to have short funnels to let out smoke, but this caused many problems, so now, factories have longer smoke funnels. The problem with this is those pollutants get carried far off, where it creates more destruction.

Sulfur dioxide contributes to about seventy percent of acid rain while nitrogen oxides provide the remaining thirty percent. The sources of sulfur in the atmosphere include coal combustion, smelting, organic decay, and ocean spray. Approximately ninety percent of atmospheric sulfur results from human activities.

In the atmosphere, sulfur dioxide combines with water vapor to form hydrogen sulfite gas:

$$SO_2 + H_2O+1/2O_2 \rightarrow H_2SO_4$$

Next, hydrogen sulfite reacts with oxygen to form sulfuric acid, a major component of acid rain:

$$H_2SO_3 + 1/2O_2 \rightarrow H_2SO_4$$

The sources of nitrogen oxides include the combustion of oil, coal and natural gas, forest fires, bacterial action in soil, volcanic gases, and lighting-induced atmospheric reactions.

In the atmosphere, nitrogen monoxide reacts with oxygen gas to form nitrogen dioxide gas:

$$NO + 1/2O_2 \rightarrow NO_2$$

Then, nitrogen dioxide reacts with water vapor in the atmosphere to form hydrogen nitrite and hydrogen nitrate:

$$2NO_2 + H_2O \rightarrow HNO_2 + HNO_3$$

Henceforth, acid rain is a mixture of HNO_3, H_2SO_4 + HCl. however conditions needed to favor formation of these are sunlight, temperature, humidity, hydrocarbons, NO_X, SO_2.

Effects

Both the lower p^H and higher aluminum concentrations in surface water that occur as a result of acid rain can cause damage to fish and other aquatic animals. At p^H lower than 5 most fish eggs will not hatch and lower p^H can kill adult fish. As lakes become more acidic biodiversity is reduced. Soil biology can be seriously damaged by acid rain. Some tropical microbes can quickly consume acids but other microbes are unable to tolerate low p^H and are killed.

Acid rain can slow the growth of forests, cause leaves and needles to turn brown and fall off and die. In extreme cases trees or whole areas of forest can die. The death of trees is not usually a direct result of acid rain; often it weakens trees and makes them more susceptible to other threats. Some scientists have suggested direct links to human health, but none have been proven. However, fine particles, a large fraction of which are formed from the same gases as acid rain (sulfur dioxide and nitrogen dioxide), have been shown to cause illness and premature deaths such as cancer and other deadly diseases

Toxic metals released into the environment by acid rain may enter water supplies or accumulate in fish and crops. Acid deposition also destroys statues, headstones, buildings, and fountains. Limestone structures are especially susceptible because they dissolve easily in acidic solutions.

Acid rain can also cause damage to certain building materials and historical monuments. Acid rain can cause weathering on ancient and valuable statues and has caused considerable damage. This is because the sulfuric acid in the rain chemically reacts with the calcium compounds in the stones (limestone, sandstone, marble and granite) to create gypsum, which then flakes off. Acid rain also causes an increased rate of oxidation for iron.

Control

- Design more efficient automobile engines in order to reduce nitrogen oxide emissions.
- Increase efficiency of power plants that burn coal in order to reduce waste that contains sulfur dioxide and nitrogen oxide.
- Increase penalties on industries that do not meet air pollution guidelines.

- Increase tax incentives to industries that do meet guidelines.
- Use alternative energy sources, Increase funding for alternative energy sources; for example, give tax incentives to buyers of hybrid cars.
- Provide tax incentives to companies that use alternative energy sources.
- Add $CaCO_3$ (calcium carbonate) to lakes suffering from acid deposition; calcium carbonate acts as a buffer, resisting a change in p^H and lessening the negative effects of acid rain.

OZONE DEPLETION

Definition

Ozone layer is an umbrella 24 km [15 miles] from earth surface, an essential component of the stratosphere that absorbs short wavelength ultraviolet radiation from the sun, heating the gases of the stratosphere in the process. World ozone day is celebrated on Sept, 16 of every year.

Stratospheric ozone is measured in Dobson units [DU] named after G.M.B Dobson who pioneered the study; [I Dobson unit = 0.01 mm thickness of stratospheric ozone], Average ozone thickness in stratosphere is 300 DU, & when it falls below 200 DU, it’s considered as Ozone hole. It is thinnest around equator and thickest near poles.

Stratospheric ozone depletion is the term applied to the loss of stratospheric ozone molecules (O_3) and the disruption of Oxygen-Ozone concentration equilibrium in stratosphere [i.e., when chlorine atoms upset the natural O_2/O_3 equilibrium in the stratosphere]. Oxygen molecules interact with the intense solar radiation present at this elevation to form oxygen atoms. The oxygen atoms thus generated react with other oxygen molecules to form ozone (O_3).

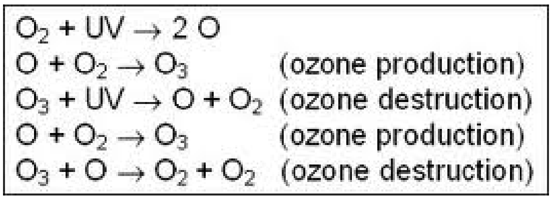
Causes

Ozone depletion is caused by the release of chlorofluorocarbons (CFC's) and other ozone-depleting substances (ODS), which were used widely as refrigerants, insulating foams, and solvents. The discussion below focuses on CFCs, but is relevant to all ODS [NO, NO_2 (aircraft exhaust), Br^-, UV rays, [O] Atomic oxygen etc].

Although CFCs are heavier than air, they are eventually carried into the stratosphere in a process that can take as long as 2 to 5 years. When CFCs reach the stratosphere, the ultraviolet radiation from the sun causes them to break apart and release chlorine atoms which react with ozone, starting chemical cycles of ozone destruction that deplete the ozone layer. One chlorine atom can break apart more than 100,000 ozone molecules.

Other chemicals that damage the ozone layer include methyl bromide (used as a pesticide), halons (used in fire extinguishers), and methyl chloroform (used as a solvent in industrial processes). As methyl bromide and halons are broken apart, they release bromine atoms, which are 40 times more destructive to ozone molecules than chlorine atoms.

Chapman's Reaction



$O_2 + UV \rightarrow 2\ O$

$O + O_2 \rightarrow O_3$ (ozone production)

$O_3 + UV \rightarrow O + O_2$ (ozone destruction)

$O + O_2 \rightarrow O_3$ (ozone production)

$O_3 + O \rightarrow O_2 + O_2$ (ozone destruction)

Ozone Depletion by CFC's

All above reactions occur in the presence of UV rays, while the 2nd set of reactions governs the oxygen-ozone equilibrium due to its spontaneity.

Effects

Effect of ozone hole include cataract, genetic mutation, constriction of blood vessels, reduced crop yield, leukemia, breast cancer, damage to crop, aqua culture, etc.,

The higher energy UV radiation absorbed by ozone is generally accepted to be a contributory factor to skin cancer. In addition, increased surface UV leads to increased tropospheric ozone, which is a health risk to humans such as Snow Blindness [photo keratosis], i.e., inflammation of cornea (outer coating of eyeball). The most common forms of skin cancer in humans, basal and squamous cell carcinomas have been strongly linked to UVB exposure. Another form of skin cancer, malignant melanoma, is much less common but far more dangerous, being lethal in about 15% - 20% of the cases diagnosed. In India there is no standard for Ozone. However WHO standard is 100 ppm for 8 hrs. – avg.

Control Measures

The Montreal Protocol, an international agreement signed by 139 nations, banning the production of CFCs by the year 2000. We can't make enough ozone to replace what's been destroyed, but provided that we stop producing ozone-depleting substances, natural ozone production reactions should return the ozone layer to normal levels by about 2050. It is very important that the world comply with the Montreal Protocol; delays in ending production could result in additional damage and prolong the ozone layer's recovery. Control mechanism stresses on replacement of the banned chemical by ammonia, steam, helium etc.

10CV765 / AIR POLLUTION AND CONTROL / R.G.

Unit – 2

Effects of air pollution On Human Health

Exposure to air pollution is associated with numerous effects on human health, including pulmonary, cardiac, vascular, and neurological impairments. The health effects vary greatly from person to person. High-risk groups such as the elderly, infants, pregnant women, and sufferers from chronic heart and lung diseases are more susceptible to air pollution. Children are at greater risk because they are generally more active outdoors and their lungs are still developing.

Exposure to air pollution can cause both acute (short-term) and chronic (long-term) health effects. Acute effects are usually immediate and often reversible when exposure to the pollutant ends. Some acute health effects include eye irritation, headaches, and nausea. Chronic effects are usually not immediate and tend not to be reversible when exposure to the pollutant ends. Some chronic health effects include decreased lung capacity and lung cancer resulting from long-term exposure to toxic air pollutants.

The scientific techniques for assessing health impacts of air pollution include air pollutant monitoring, exposure assessment, dosimetry, toxicology, and epidemiology. Although in humans pollutants can affect the skin, eyes and other body systems, they affect primarily the respiratory system. Air is breathed in through the nose, which acts as the primary filtering system of the body. The small hairs and the warm, humid conditions in the nose effectively remove the larger pollutant particles. Both gaseous and particulate air pollutants can have negative effects on the lungs. Solid particles can settle on the walls of the trachea, bronchi, and bronchioles. Most of these particles are removed from the lungs through the cleansing (sweeping) action of "cilia", small hair like outgrowths of cells, located on the walls of the lungs

Gaseous air pollutants may also affect the function of the lungs by slowing the action of the cilia. Continuous breathing of polluted air can slow the normal cleansing action of the lungs and result in more particles reaching the lower portions of the lung.

The table summarizes the sources, health and welfare effects for the Criteria Pollutants.

Pollutant	Description	Sources	Health Effects	Welfare Effects
Carbon Monoxide (CO)	Colorless, odorless gas	Motor vehicle exhaust, indoor sources include kerosene or wood burning stoves.	Headaches reduced mental alertness, heart attack, cardiovascular diseases, impaired fetal development, and death.	Contribute to the formation of smog.
Sulfur Dioxide (SO_2)	Colorless gas that dissolves in water vapor to form acid, and interact with other gases and particles in the air.	Coal-fired power plants, petroleum refineries, manufacture of sulfuric acid and smelting of ores containing sulfur.	Eye irritation, wheezing, chest tightness, shortness of breath, lung damage.	Contribute to the formation of acid rain, visibility impairment, plant and water damage, aesthetic damage.
Nitrogen Dioxide (NO_2)	Reddish brown, highly reactive gas.	Motor vehicles, electric utilities, and other industrial, commercial, and residential sources that burn fuels.	Susceptibility to respiratory infections, irritation of the lung and respiratory symptoms (e.g., cough, chest pain, difficulty breathing).	Contribute to the formation of smog, acid rain, water quality deterioration, global warming, and visibility impairment.
Ozone (O_3)	Gaseous pollutant when it is formed in the troposphere.	Vehicle exhaust and certain other fumes. Formed from other air	Eye and throat irritation, coughing, respiratory tract problems, asthma, lung	Plant and ecosystem damage.

		pollutants in the presence of sunlight.	damage.	
Lead (Pb)	Metallic element	Metal refineries, lead smelters, battery manufacturers, iron and steel producers.	Anemia, high blood pressure, brain and kidney damage, neurological disorders, cancer, lowered IQ.	Affects animals and plants, affects aquatic ecosystems.
Particulate Matter (PM)	Very small particles of soot, dust, or other matter, including tiny droplets of liquids.	Diesel engines, power plants, industries, windblown dust, wood stoves.	Eye irritation, asthma, bronchitis, lung damage, cancer, heavy metal poisoning, cardiovascular effects.	Visibility impairment, atmospheric deposition, aesthetic damage.

Effects of air pollution On Plants

The effects of pollution on plants include mottled foliage, “burning” at leaf tips or margins, twig dieback, stunted growth, premature leaf drop, delayed maturity, abortion or early drop of blossoms, and reduced yield or quality.

In general, the visible injury to plants is of three types: (1) collapse of leaf tissue with the development of necrotic patterns, (2) yellowing or other color changes, and (3) alterations in growth or premature loss of foliage. Injury from air pollution can be confused with the symptoms caused by fungi, bacteria, viruses, nematodes, insects, nutritional deficiencies and toxicities, and the adverse effects of temperature, wind, and water.

Factors that govern the extent of damage and the region where air pollution is a problem are (1) type and concentration of pollutants, (2) distance from the source, (3) length of exposure, and (4) meteorological conditions.

Effects of air pollution On Materials

(i) Abrasion (loss of material by wind with coarser particles).

(ii) Corrosion (acidic effect of rain water).

(iii) Deposition and removal (adhering substances like SPM and removal of material by rusting.

(iv) Direct chemical attack (effect of gases like SO2).

(v) Indirect chemical attack (action of acid or its fumes on stones like marble, corrosion of reinforcement due to diffusion of gases in RCC).

MAJOR ENVIRONMENTAL AIR POLLUTION EPISODES

London Smog

Introduction to Smog

Smog is a recent compound word from "smoke" and "fog", and was coined by Harold Antoine des Voeux, a doctor, in 1905. Smog refers to locally high concentrations of acids, dry acid-forming compounds, particulates, or other pollutants in stagnant, stable air. Smog’s form when emissions are prevented from dispersing by stable or sinking air masses.

Introduction to London Smog

They were very prevalent in European and North American cities during first part of 20th Century. London smog’s were infamous in the 19th and early 20th centuries and formed every autumn and winter due to sulphur emissions from coal burning industries and domestic fires. The most severe London smog was on 4-10th December 1952, when cold, high-pressure conditions trapped coal smoke in foggy air. The output of smoke was increased by the cold weather, due to the large numbers of domestic fires. Sooty smoke produced peak daily concentrations of black smoke of 5000 mgs/m3 (WHO 24 hr max limit of 100-150), and daily average SO2 levels of 3000-4000 mg/m3 (WHO 24 hr max limit of 100-150). Sulphuric acid droplets resulted in pH estimated as 1.4 to 1.9: as acidic as car battery acid.

Chemistry

$$H_2SO_{4(g)} + H_2O \rightarrow H_2SO_{4(aq)}$$
$$SO_{2(g)} + H_2O_{(l)} \rightarrow H_2SO_{3(aq)}$$

These are produced by high outputs of SO2, which are converted to acids on contact with atmospheric moisture. Usually, sulphurous smog’s also contain elevated concentrations of suspended soot.

Impacts

Visibility was reduced to 5m at times, and London buses had to be guided through the street by men with lanterns during daylight hours. The smog lasted for 5 days, eventually extending over a 50km radius. Approx. 4,000 excess deaths occurred as a result of inhaling pollution, mainly old and sick and those with chest problems. Respiratory diseases alone accounted for 59 per cent of the increase in deaths registered in the week ending 13 December and 76 per cent in the following week. Bronchitis and emphysema were the two conditions that stood out in the coroner’s records as showing the greatest increase. Cardiovascular disease accounted for 22 per cent of the increased number of deaths in the first week and 16 per cent in the week ending 20 December. The disaster ultimately led to the introduction of the Clean Air Acts.

Bhopal Gas Tragedy

INTRODUCTION

The Bhopal gas tragedy was a gas leak incident in India and, considered one of the world's worst industrial disasters. It occurred on the night of 2nd and dawn of 3rd December 1984 at the Union Carbide India Limited (UCIL) pesticide plant in Bhopal, Madhya Pradesh, India. UCIL was the Indian subsidiary of Union Carbide Corporation. The plant manufactured Sevin Carbide, among other pesticides. MIC was one of the chemicals processed for the prime reactions.

ACCIDENT

Even before the December 1984 incident, numerous incidents had fore-warned of an oncoming disaster. During the incident, most of the safety systems were not functioning. Many valves and lines were in poor condition. Tank 610 contained 42 tons of MIC, much more than what safety rules allowed. During the nights of 2–3 December, a large amount of water is claimed to have entered tank 610. A runaway reaction started, which was accelerated by contaminants, high temperatures and other factors. The reaction generated a major increase in the temperature inside the tank to over 200 °C (400 °F). This forced the emergency venting of pressure from the MIC holding tank, releasing a large volume of toxic gases. The reaction was sped up by the presence of iron from corroding non-stainless steel pipelines. Workers cleaned pipelines with water and claim they were not told to isolate the tank with a pipe slip-blind plate. Owing of this, and the poor maintenance, the workers consider that water might have accidentally entered the tank.

IMPACT

A leak of methyl iso-cyanate gas and other chemicals from the plant resulted in the exposure of hundreds of thousands of people. The official immediate death toll was 2,259 and the government of Madhya Pradesh has confirmed a total of 3,787 deaths related to the gas release. Others estimate 8,000 died within two weeks and another 8,000 or more have since died from gas-related diseases. When panic was at its peak at major hospitals of the city, the patients could be graded symptomatically into four categories: (i) Minor eye ailments, throat irritation and cough, (ii) Severe conjunctivitis, keratitis, acute bronchitis and drowsiness, (iii) Severe pulmonary oedema leading to cardio-respiratory distress, and (iv) Convulsions, followed by cardio-respiratory arrest. Intense fatigue and muscular weakness was another common feature. Civil and criminal cases are pending in the United States District Court, Manhattan and the District Court of Bhopal, India, involving UCC, UCIL employees.

Passing of THE ENVIRONMENTAL PROTECTION ACT, 1986 and PUBLIC LIABILITY INSURANCE ACT, 1986

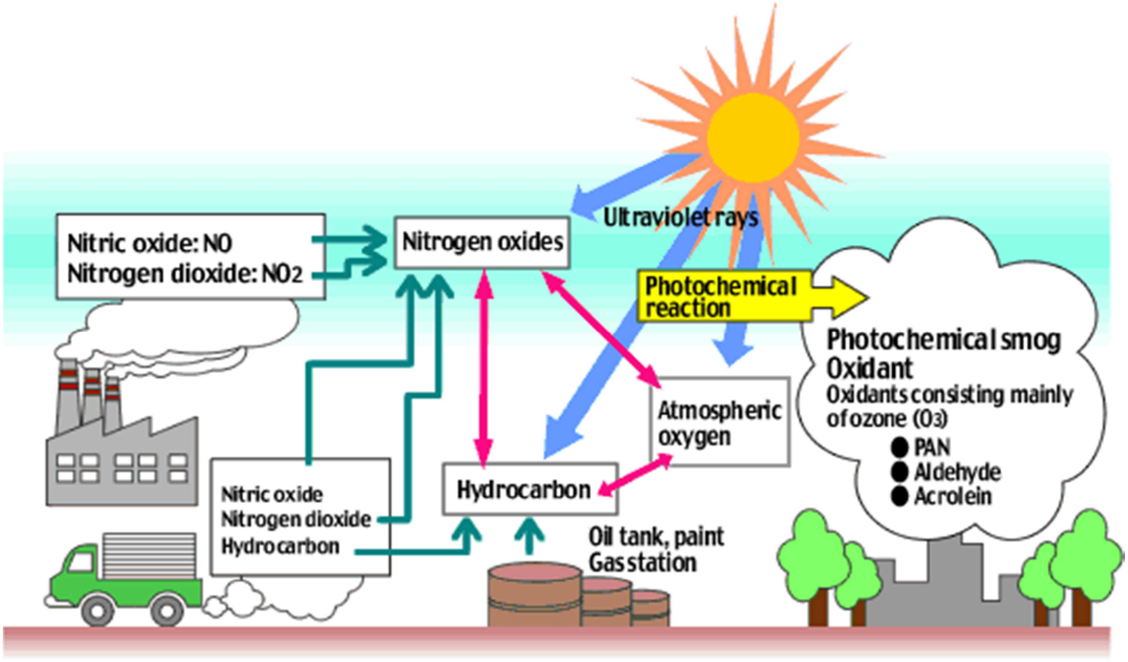
Los Angeles Smog

INTRODUCTION

Photochemical smog was first described in the 1950s. It is the chemical reaction of sunlight, nitrogen oxides and volatile organic compounds in the atmosphere, which leaves airborne particles and ground-level ozone. This noxious mixture of air pollutants can includes Aldehydes, Nitrogen oxides, such as nitrogen dioxide, Peroxyacyl nitrates Tropospheric ozone, Volatile organic compounds etc. All of these chemicals are usually highly reactive and oxidizing.

Photochemical smog is considered to be a problem of modern industrialization. It is present in all modern cities, but it is more common in cities with sunny, warm, dry climates and a large number of motor vehicles. Because it travels with the wind, it can affect sparsely populated areas as well.

VOCs + NOx + sunlight → photochemical smog



To begin the chemical process of photochemical smog development the following conditions must occur:

- Sunlight.
- The production of oxides of nitrogen (NOx).
- The production of volatile organic compounds (VOCs).
- Temperatures greater than 18 degrees Celsius.

Nitrogen oxide is an essential ingredient of photochemical smog that is produced during the high temperatures associated with combustion of vehicle’s engines. Nitrogen oxide is an essential ingredient of photochemical smog that is produced during the high temperatures associated with combustion of vehicle’s engines.

Formation

Sunlight can break down nitrogen dioxide back into nitrogen oxide.

$$NO_2 + \text{sunlight} \text{ »»» } NO + O$$

The atomic oxygen formed in the above reaction then reacts with one of the abundant oxygen molecules producing ozone.

$$O + O_2 \text{ »»» } O_3$$

Nitrogen dioxide can also react with radicals produced from volatile organic compounds in a series of reactions to form toxic products such as peroxyacetyl nitrates.

$$NO_2 + R \text{ »»» products such as PAN}$$

Note the symbol R represents a hydrocarbon (a molecule composed of carbon, hydrogen and other atoms) which is primarily created from volatile organic compounds.

Steps

1) Nitrogen oxides generate oxygen atoms

2) Oxygen atoms form hydroxyl radicals

3) Hydroxyl radicals generate hydrocarbon radicals

4) Hydrocarbon radicals form hydrocarbon peroxides

5) Hydrocarbon peroxides form aldehydes

6) Aldehydes form aldehyde peroxides

7) Aldehyde peroxides form peroxy-acyl-nitrates

Health effects

It can cause eye and nose irritation and it dries out the protective membranes of the nose and throat and interferes with the body's ability to fight infection, increasing susceptibility to illness.

Chapter 3

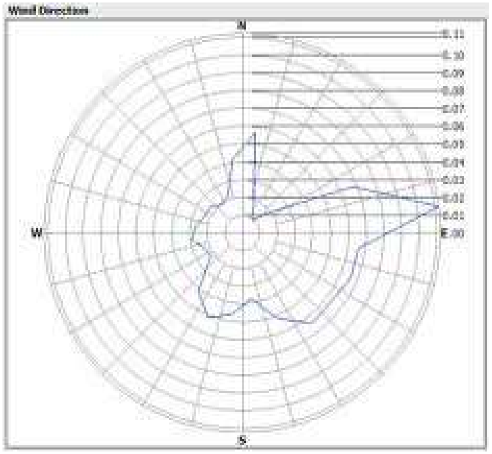
Air Pollution and Meteorology

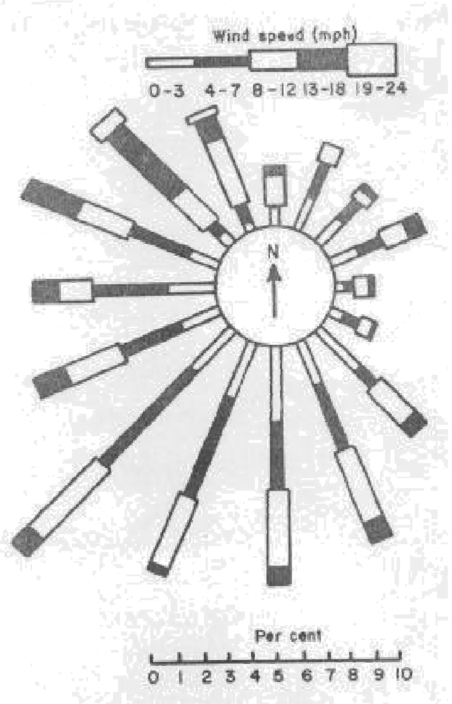
The science of meteorology has great bearing on air pollution. An air pollution problem involves three parts: the source, the movement of the pollutant and the recipient. All meteorological phenomena are a result of interaction of the elemental properties of the atmosphere, heat, pressure, wind and moisture.

Wind

Wind is simply air in motion. On global or macroscale wind patterns are set up due to unequal heating of earth surface by solar radiation at the equator and the polar regions, rotation of the earth and the difference between conductive capacities of land and ocean masses. Secondary or mesoscale circulation patterns develop because of the regional or local topography. Mountain ranges, cloud cover, waterbodies, deserts, forestation, etc., influence wind patterns on scales of a few hundred kilometers. Accordingly a pattern of wind is setup, some seasonal and some permanent. Microscale phenomenon occurs over areas of less than 10 km extent. Standard wind patterns may deviate markedly due to varying frictional effects of the earth surface, such as, rural open land, irregular topography and urban development, effect of radiant heat from deserts and cities, effect of lakes, etc. The movement of air at the mesoscale and microscale levels is of concern in control of air pollution. A study of air movement over relatively small geographical regions can help in understanding the movement of pollutants.

It is obviously important in predicting pollutant dispersion to know the direction of wind. The wind direction and speed data may be collected every hour in a month and classified according to speed and direction. It is then summarized in the form of a polar diagram called *wind rose.* Figure shows a hypothetical wind rose. The position of the spokes show the direction from which the wind was blowing, the length of various segments of the spokes show the percent of time the wind was of the designated speed. Thus from the diagram, most often (12% of time) the wind was from SE; the strongest wind (9-11 m/s) was from NW and NNW.

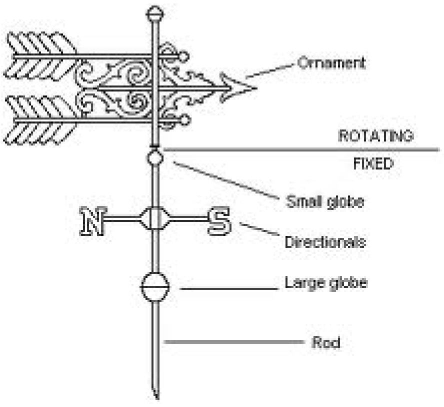


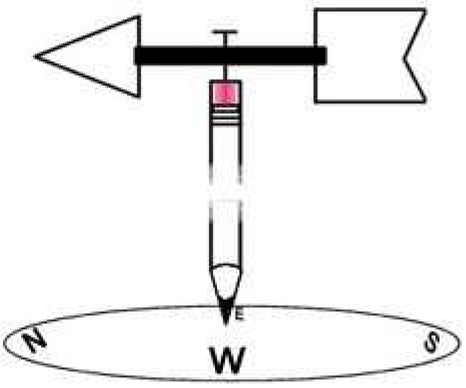


<u>Importance of wind rose in air pollution studies</u>

A wind rose is a graphic tool used by meteorologists to give a succinct view of how wind speed and direction are typically distributed at a particular location. It assists in city planning and siting of industries.

An anemometer is a device for measuring wind speed, and is a common weather station instrument. Anemometers can be divided into two classes: those that measure the wind's speed, and those that measure the wind's pressure; but as there is a close connection between the pressure and the speed, an anemometer designed for one will give information about both. A simple type of anemometer, consistS of four hemispherical cups each mounted on one end of four horizontal arms, which in turn were mounted at equal angles to each other on a vertical shaft. The air flow past the cups in any horizontal direction turned the cups in a manner that was proportional to the wind speed. Therefore, counting the turns of the cups over a set time period produced the average wind speed for a wide range of speeds. On an anemometer with four cups it is easy to see that since the cups are arranged symmetrically on the end of the arms, the wind always has the hollow of one cup presented to it and is blowing on the back of the cup on the opposite end of the cross.





A weather vane (or weathercock) is an instrument for showing the direction of the wind . They are typically used as an architectural ornament to the highest point of a building. Although partly functional, weather vanes are generally decorative, often featuring the traditional cockerel design with letters indicating the points of the compass. Other common motifs include ships, arrows and horses.

The design of a wind vane is such that the weight is evenly distributed on each side of the surface, but the surface area is unequally divided, so that the pointer can move freely on its axis. The side with the larger surface area is blown away from the wind direction, so that the smaller side, with the pointer, is pivoted to face the wind direction. Most wind vanes have directional markers beneath the arrow, aligned with the geographic directions.

Wind vanes, especially those with fanciful shapes, do not always show the real direction of a very gentle wind. This is because the figures do not achieve the necessary design balance: an unequal surface area but balanced in weight. To obtain an accurate reading, the wind vane must be located well above the ground and away from buildings, trees, and other objects which interfere with the true wind direction. Changing wind direction can be meaningful when coordinated with other apparent sky conditions, enabling the user to make simple short range forecasts. From the street level the size of many weathercocks is deceptive.

The mean wind speed variation with altitude is the planetary boundary layer can be represented by a simple empirical power.

$$\frac{U}{U1} = \left[\frac{Z}{Z1}\right]\alpha \text{ --------- }(2.11)$$

Where: U is the wind at altitude Z

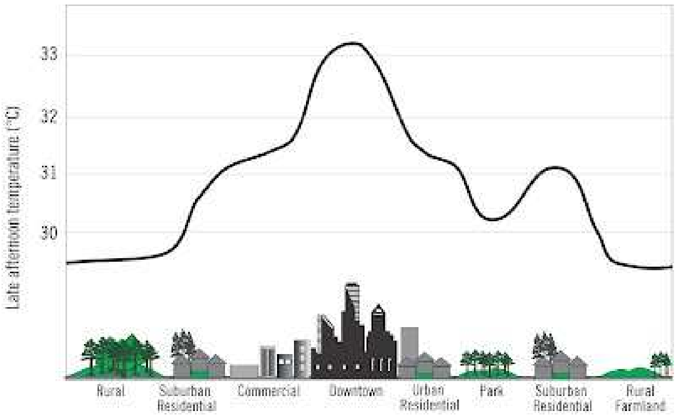
U_1 is the wind speed at altitude Z_1

α The exponent varies between 0.14 and 0.5 depending on the roughness of the ground surface as well as on the temperature stability of the atm.

α = 0.25 for unstable atmosphere

= 0.5 for stable condition

Urban Heat Islands



Urbanization negatively impacts the environment mainly by the production of pollution, the modification of the physical and chemical properties of the atmosphere, and the covering of the soil surface. Considered to be a cumulative effect of all these impacts is the UHI, defined as the rise in temperature of any man-made area, resulting in a well-defined, distinct "warm island" among the "cool sea" represented by the lower temperature of the area’s nearby natural landscape.

Though heat islands may form on any rural or urban area, and at any spatial scale, cities are favoured, since their surfaces are prone to release large quantities of heat. Nonetheless, the UHI negatively impacts not only residents of urban-related environs, but also humans and their associated ecosystems located far away from cities. In fact, UHIs have been indirectly related to climate change due to their contribution to the greenhouse effect, and therefore, to global warming.

It is well-known that the progressive replacement of natural surfaces by builtsurfaces, through urbanization, constitutes the main cause of UHI formation. Natural surfaces are often composed of vegetation and moisture-trapping soils. Therefore, they utilize a relatively large proportion of the absorbed radiation in the evapotranspiration process and release water vapour that contributes to cool the air in their vicinity. In contrast, built surfaces are composed of a high percentage of non-reflective and water-resistant construction materials. As consequence, they tend to absorb a significant proportion of the incident radiation, which is released as heat.

Vegetation intercepts radiation and produces shade that also contributes to reduce urban heat release. The decrease and fragmentation of large vegetated areas such as parks, not only reduces these benefits, but also inhibits atmospheric cooling due to horizontal air circulation generated by the temperature gradient between vegetated and urbanized areas (i.e. advection), which is known as the park cool island effect. On the other hand, the narrow arrangement of buildings along the city's streets form urban canyons that inhibit the escape of the reflected radiation from most of the three-dimensional urban surface to space. This radiation is ultimately absorbed by the building walls (i.e. reduced sky view factor), thus enhancing the urban heat release. Additional factors such as the scattered and emitted radiation from atmospheric pollutants to the urban area, the production of waste heat from air conditioning and refrigeration systems, as well from industrial processes and motorized vehicular traffic (i.e. anthropogenic heat), and the obstruction of rural air flows by the windward face of the built-up surfaces, have been recognized as additional causes of the UHI effect

As it would be expected, the characteristic inclination towards warming of urban surfaces is exacerbated during hot days and heat waves, which reinforces the air temperature increase, particularly in ill-ventilated outdoor spaces or inner spaces of residential and commercial buildings with poor thermal isolation. This increases the overall energy consumption for cooling (i.e. refrigeration and air-conditioning), hence increasing the energy production by power plants, which leads to higher emissions of heat-trapping greenhouse gases such as carbon dioxide, as well as other pollutants such as sulfur dioxide, carbon monoxide and particulate matter. Furthermore, the increased energy demand means more costs to citizens and goverments, which in large metropolitan areas may induce significant economic impacts. On the other hand, UHIs promote high air temperatures that contribute to formation of ozone precursors, which combined photochemically produce ground level ozone.

A direct relationship has been found between UHI intensity peaks and heat-related illness and fatalities, due to the incidence of thermal discomfort on the human cardiovascular and respiratory systems. Heatstroke, heat exhaustion, heat syncope,and heat cramps, are some of the main stress events, while a wide number of diseases may become worse, particularly in the elderly and children. In a similar way, respiratory and lung diseases have shown to be related to high ozone levels induced by heat events. Other meteorological impacts of the UHI are associated with reductions in snowfall frecuencies and intensities, as well as reductions in the diurnal and seasonal range of freezing temperatures. Lastly, high temperatures may produce physiological and phenological disturbances on ornamental plants and urban forests.

There are two main UHI reduction strategies: first, to increase surface reflectivity (i.e. high albedo), in order to reduce radiation absorption of urban surfaces, and second, to increase vegetation cover, mainly in the form of urban forests and parks, in order to maximize the multiple vegetation benefits in controlling the temperature rises. Reflective surfaces simply results from light colored or white paint on the surface of a given construction material or from cover the construction material surface with a white membrane. Both techniques have been mainly applied on roofs and pavements. Cool roofs are specially important in commercial and residential buildings, where significant energy demand for cooling can be saved by reducing heat gain to the building. Cool pavements have mainly based on the use of whitened asphalt roads, a very warm material.

Urban Dust Domes

Urban dust domes are a meteorological phenomenon in which soot, dust, and chemical emissions become trapped in the air above urban spaces. This trapping is a product of local air circulations. Calm surface winds are drawn to urban centers, they then rise above the city and descend slowly on the periphery of the developed core. This cycle is often a cause of smog

through photochemical reactions that occur when strong concentrations of the pollutants in this cycle are exposed to solar radiation. These are one result of urban heat islands: pollutants concentrate in a dust dome because convection lifts pollutants into the air, where they remain because of somewhat stable air masses produced by the urban heat island.

Atmospheric Stability

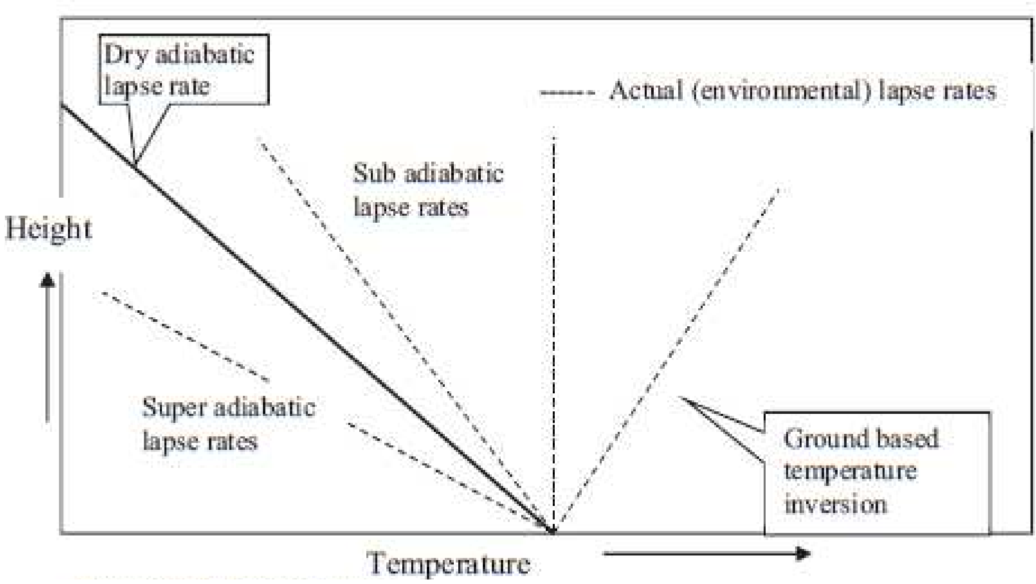
The ability of the atmosphere to disperse the pollutants emitted in to it depends to a large extent on the degree of stability. A comparison of the adiabatic lapse rate with the environmental lapse rate gives an idea of stability of the atmosphere. When the environmental lapse rate and the dry adiabatic lapse rate are exactly the same, a raising parcel of air will have the same pressure and temperature and the density of the surroundings and would experience no buoyant force. Such atmosphere is said to be neutrally stable where a displaced mass of air neither tends to return to its original position nor tends to continue its displacement

Lapse rate

As a parcel of air rises in the earth's atmosphere it experiences lower and lower pressure from the surrounding air molecules, and thus it expands. This expansion lowers its temperature. Ideally, if it does not absorb heat from its surroundings and it does not contain any moisture, it cools at a rate of 1ºC/100 m rise. This is known as *dry adiabatic lapse rate.*

If the parcel moves down it warms up at the same rate. For a particular place at a particular time, the existing temperature can be determined by sending up a balloon equipped with a thermometer. The balloon moves through the air, and not with it. The temperature profile of the air, which the balloon measures, is called the *ambient lapse rate, environmental lapse rate,* or the *prevailing lapse rate.*

A super-adiabatic lapse rate also called a strong lapse rate occurs when the atmosphere temperature drops more than 1ºC/100m. A sub-adiabatic rate also called weak lapse rate, is characterized by drop of less than 1ºC/100 m. A special case of weak lapse rate is the inversion, a condition which has warmer layer above colder air.



During super-adiabatic lapse rate the atmospheric conditions are unstable. If a parcel of air at 500m elevation, at 20ºC is pushed upward to 1000m, its temperature will come down to 15ºC (according to adiabatic lapse rate). The prevailing temperature is however 10ºC at 1000m. The parcel of air will be surrounded by colder air and therefore will keep moving up.

Similarly if the parcel is displaced downwards, it will become colder than its surroundings and therefore will move down. Super-adiabatic conditions are thus unstable, characterized by a great deal of vertical air movement and turbulence. The sub-adiabatic condition shown in is by contrast a very stable system. Consider again a parcel of air at 500 m elevation at 20ºC. If the parcel is displaced to 1000 m it will cool by 5ºC to 15ºC. But the surrounding air would be warmer. It will therefore fall back to its point of origin. Similarly if a parcel of air at 500 m is pushed down, it will become warmer than its surrounding and therefore will rise back to its original position. Thus such systems are characterized by very limited vertical mixing.

Inversion

An inversion is an extreme sub-adiabatic condition, and thus the vertical air movement within the inversion is almost nill. The two most common kind of inversion are *subsidence inversion* and *radiation inversion.* The base of the subsidence inversion lies some distance above earth's surface. This type of inversion is formed due to adiabatic compression and warming of sinking air mass to a lower altitude in the region of a high pressure center. In the case of radiation inversion, the surface layers of the atmosphere during the day receive heat by conduction, convection and radiation from the earth's surface and are warmed. This results in a temperature profile in the lower atmosphere, which is represented by a negative temperature gradient. On a clear night, the ground surface radiates heat and quickly cools. The air layer adjacent to the earth surface are cooled to a temperature below that of the layers of air at higher elevations. This type of the inversion is strongest just before daylight when it may extend to 500 m. It breaks up as the morning sun heats the ground.

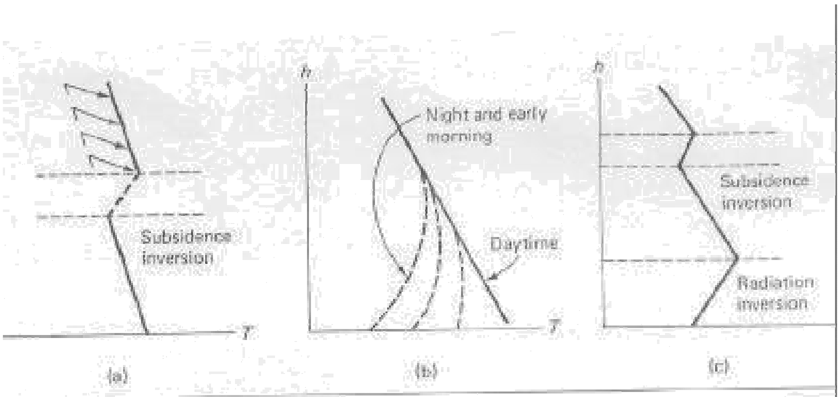


FIGURE 4 ILLUSTRATIONS OF SUBSIDENCE AND RADIATION INVERSIONS.

Maximum mixing depth

The dispersion of pollutants in the lower atmosphere is greatly aided by the convective and turbulent mixing that takes place. The vertical extent to which this mixing takes place depends on the environmental lapse rate which varies diurnally, from season to season and is also affected by topographical features. The depth of the convective mixing layer in which vertical movement of pollutants is possible, is called the maximum mixing depth (MMD). Figure illustrates these MMDs for different lapse rate profiles.

These profiles are usually measured at night or early in the morning. An air parcel at a temperature (maximum surface temperature for the month) warmer than the existing ground level temperature rises and cools according to adiabatic lapse rate. The level where its temperature becomes equal to the surrounding air gives the MMD value. Urban air pollution episodes are known to occur when MMD is 1500 m or less.

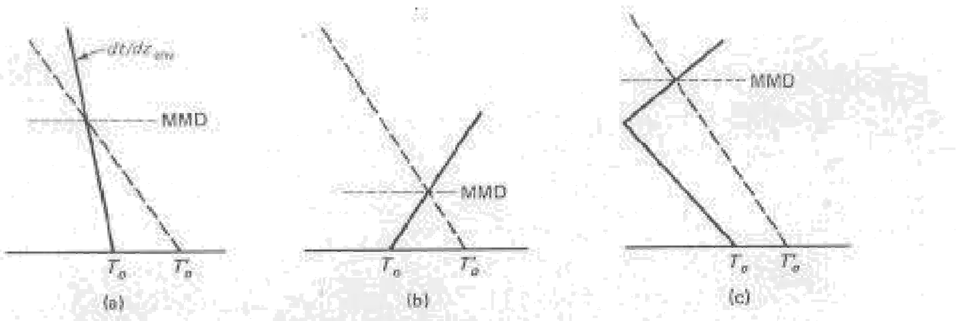
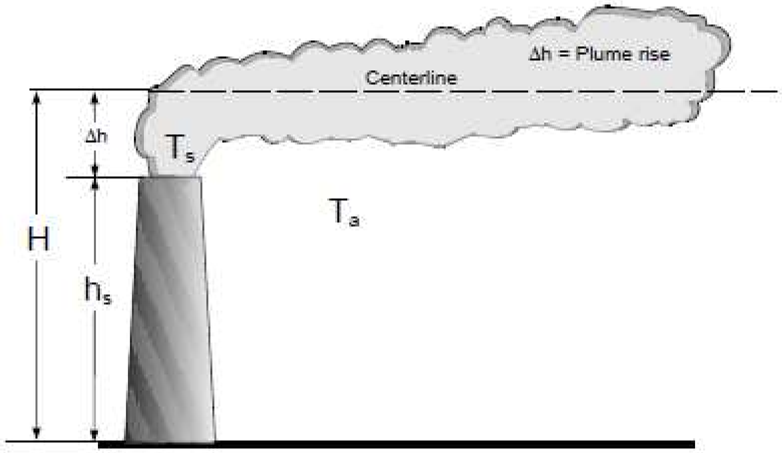


FIGURE 5 MAXIMUM MIXING DEPTH (MMD) UNDER VARIOUS ATMOSPHERIC CONDITIONS, (ADIABATIC PROFILE -------, ENVIRONMENTAL PROFILE———).

Plume Dispersion

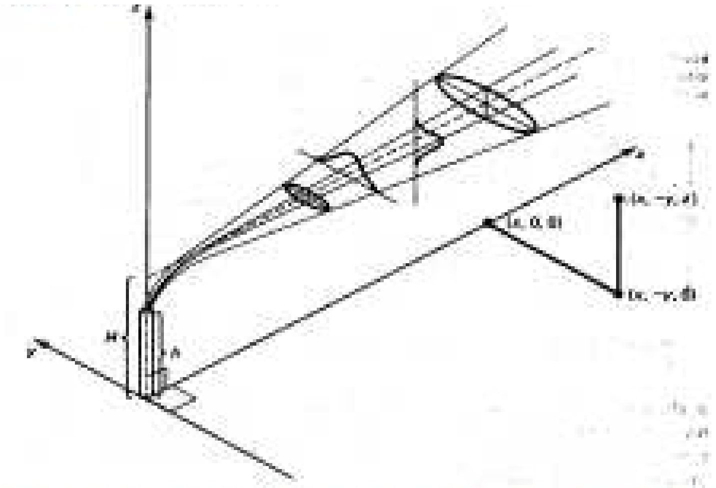
Gases that are emitted from stacks are often pushed out by fans. As the turbulent exhaust gases exit the stack they mix with ambient air. This mixing of ambient air into the plume is called entrainment. As the plume entrains air into it, the plume diameter grows as it travels downwind. These gases have momentum as they enter the atmosphere. Often these gases are heated and are warmer than the outdoor air. In these cases the emitted gases are less dense than the outside air and are therefore buoyant. A combination of the gases' momentum and buoyancy causes the gases to rise. This is referred to as plume rise and allows air pollutants emitted in this gas stream to be lofted higher in the atmosphere. Since the plume is higher in the atmosphere and at a further distance from the ground, the plume will disperse more before it reaches ground level.



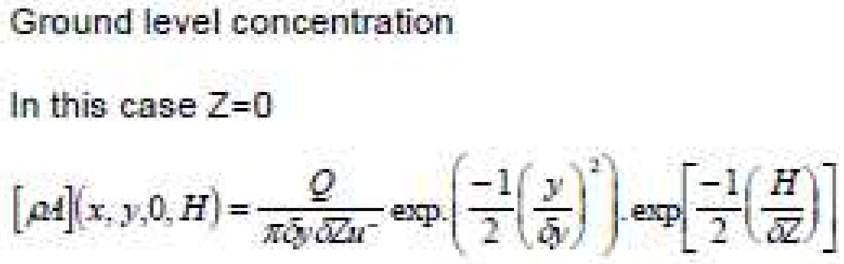
The final height of the plume, referred to as the effective stack height (H), is the sum of the physical stack height (hs) and the plume rise (Δh). Plume rise is actually calculated as the distance to the imaginary centerline of the plume rather than to the upper or lower edge of the plume (Figure 6-1). Plume rise depends on the stack's physical characteristics and on the effluent's (stack gas) characteristics. The difference in temperature between the stack gas (Ts) and ambient air (Ta) determines the plume density which affects plume rise. Also, the velocity of the stack gases which is a function of the stack diameter and the volumetric flow rate of the exhaust gases determines the plume's momentum.

The Gaussian plume model

The present tendency is to interpret dispersion data in terms of the Gaussian model. The standard deviations are related to the eddy diffusivities.



Plume dispersion coordinate sysem, showing Gaussian distributions in the horizontal and vertical directions (Turner, 1970)



Ground level concentration

In this case Z=0

$$[\rho A](x, y, 0, H) = \frac{Q}{\pi \delta y \, \delta Z u^{-}} \exp.\left(\frac{-1}{2}\left(\frac{y}{\delta y}\right)^{2}\right).\exp\left[\frac{-1}{2}\left(\frac{H}{\delta Z}\right)\right]$$

Dispersion characteristics of stack plumes

Dispersion is the process of spreading out pollution emission over a large area and thus reducing their concentration. Wind speed and environmental lapse rates directly influence the dispersion pattern.

Coning

A *coning* plume, shown in, occurs under essentially neutral stability, when environmental lapse rate is equal to adiabatic lapse rate, and moderate to strong winds occur. The plume enlarges in the shape of a cone. A major part of pollution may be carried fairly far downwind before reaching ground.

Looping

Under super-adiabatic condition, both upward and downward movement of the plume is possible. Large eddies of a strong wind cause a *looping* pattern. Although the large eddies tend to disperse pollutants over a wide region, high ground level concentrations may occur close to the stack.

Fanning

A *fanning* plume occurs in the presence of a negative lapse rate when vertical dispersion is restricted. The pollutants disperse at the stack height, horizontally in the from of a fanning plume.

Fumigation

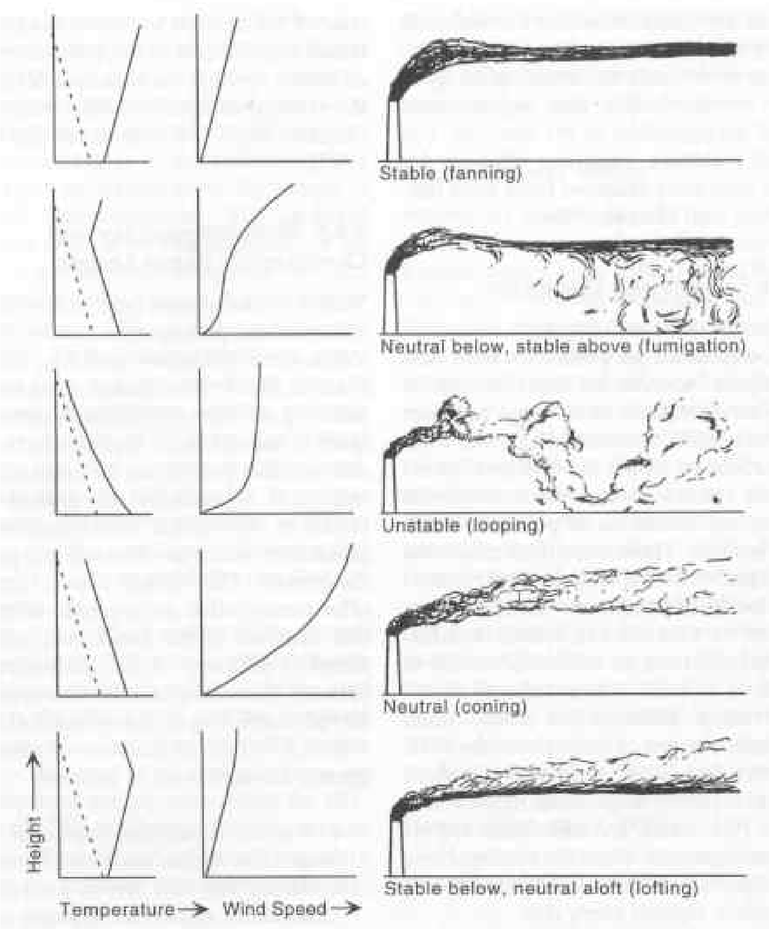
When the emission from the stack is under an inversion layer, the movement of the pollutants in the upward direction is restricted. The pollutants move downwards. The resulting *fumigation* can lead to a high ground level concentration downwind of the stack.

Lofting

When the stack is sufficiently high and the emission is above an inversion layer, mixing in the upward direction is uninhibited, but downward motion is restricted. Such *lofting* plumes do not result in any significant concentration at ground level. However, the pollutants are carried hundreds of kilometers from the source.

Trapping

It occurs when the plume effluent is caught between two inversion layers. The diffusion of the effluent is severely restricted to the unstable layer between the two unstable layers.



Unit – 4

10CV765 APC

Industrial Plant Location and Planning

General factors considered while siting an industrial location include water supply, raw material supply, proximity to nearest railway station, land availability, power supply etc. Hence it’s most evident that air pollution and its control are most ignored.

Following are the factors to be considered while deciding industrial installation, keeping in mind air pollution and its impacts.

1] Existing levels of air contaminates

This involves a pre-operational survey, to know the existing level of contaminants under prevailing meteorological conditions, and if not and even if any existing industries. This gives idea if existing pollution levels is high or low. It also gives idea if upcoming industry will aggravate the pollution levels and by how much. It gives idea at what levels must the pollution be released based on existing levels.

2] Potential effects on the surrounding area

The effect of air pollution shall vary from area to area depending on its environment and build forms. Any industrial emission near a city shall endanger more lives than that closer to a forest or un-habituated place.

3] Meteorological factors and the climate

Role of wind direction, wind speed, stability conditions is pivotal to air pollution. Areas having more inversions should be avoided.

4] Availability of clean air

Some industries need clean air for production or in their processes. Polluted air shall make it costlier towards clean-up process and may also impair its regular operations.

5] Topographical features

Industries situated in valleys are more prone to severe impacts during depression, when compared to flat terrains. As inversions or depressions in a valley system shall result in more deposition, less dispersion, no circulation of pollutants.

6] City planning and zoning. (Explanation provided in further sections)

City Planning

Urban Planning is a process of guiding the use and development of land with the aim of making the city a better place to live and work. Particularly important today as more than one-half of the world's population now resides in urban places. Cities, towns and other urban forms are therefore the sites for most of mankind's activities. Yet in most cities and towns, land and access to basic resources and services are usually scarce and unevenly distributed. Planning is 'a general activity…the making of an orderly sequence of action that will lead to the achievement of a stated goal or goals' (Hall 2002). It involves written statements supplemented as appropriate by statistical projections, quantified evaluations and diagrams. Planning involves an attempt to (re)shape prevailing social and economic dynamics to achieve particular developmental ends. The process has different names e.g. town & country planning, town planning, city planning, physical planning etc.it may be thought as a rational (highly technical) and systemic process of forethought set in motion by the need to resolve urban and regional problems, and yet it may be interpreted as a highly political and economistic process.

What do urban planners do?

Determine the best uses of land and resources for homes, businesses, and recreation.
Devise ways to renovate slums, expand cities, modernize transportation systems, and distribute public facilities such as schools and parks.
Urban planners design new communities and develop programs to revitalize and expand existing cities.
Regional planners work on a much larger scale, studying the problems of states, multistate regions, and sometimes entire countries.

Impact of bad planning w.r.t. air pollution

More traffic jams
Irregular dispersions and dissipation air pollutants
More cases of casualty's w.r.t acute and chronic effects.
Blocking of regular wind-paths and thereby hampering free circulation of air.

Lack of proper planning results in failure of remedial measures, and is aggravated by increased costs of control equipment. The main aspect of planning hence must resort to industrial zoning. Cumulative zoning in the past has resulted in less availability of land for industries. This system has now been modified as permissive systems. However this system has now been modified as permissive system. However this system has also resulted in the crowding of industrial zones with other uses besides industries. The next system over this is called excusive zonings system. This type of planning provided for compatible uses for each zones, excluding all other uses. In this system suitable industrial zones are provided and thus there is no air pollution problem.

Zoning criteria for industries:

1] Functional requirement: this includes the inter industry linkages, railways siding, grouping, land traffic generation utilities etc. these aspects are covered under govt. policies.

2] Performance characteristics: this includes the traffic congestion, obnoxious and hazardous character of the industries, industrial nuisance etc. The nuisance includes dust, heat, smoke, fire, odor etc. It is necessary to place obnoxious industries away from neat industries. If planning is done in early stages, its impact analysis can be done for effective execution.

While classifying industries on basis of differential zoning, the following aspects might be followed.

There are 3 categories of industries.

Group 1.] These are smaller industries with a variety of products and with close relations to cities. Their emissions have very little impact on the natural environment. These industries can hence be located on the fringes of the cities.

Group 2] These include cottage and small scale industries requiring less land but indulge in creative and artistic productions. These can be located within cities. As they have no or little adverse effects on the cities.

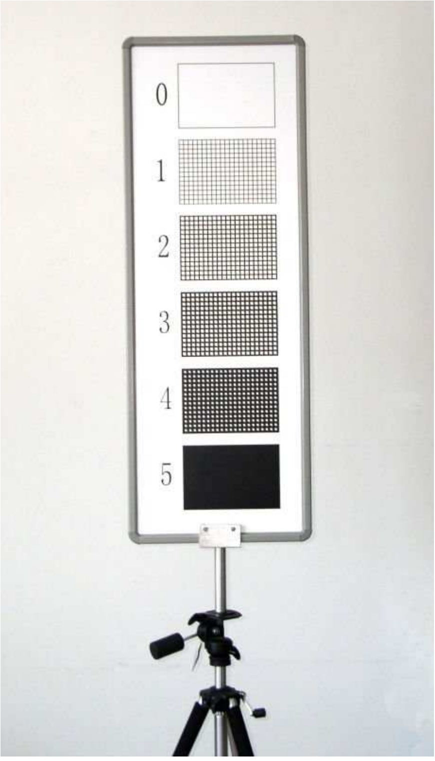
Group 3] These include big industries with relatively less number of unit process and having remote relevance to the central residential areas of the cities. These have profound effect on the cities and hence should be located as far as possible from the residential vicinities.

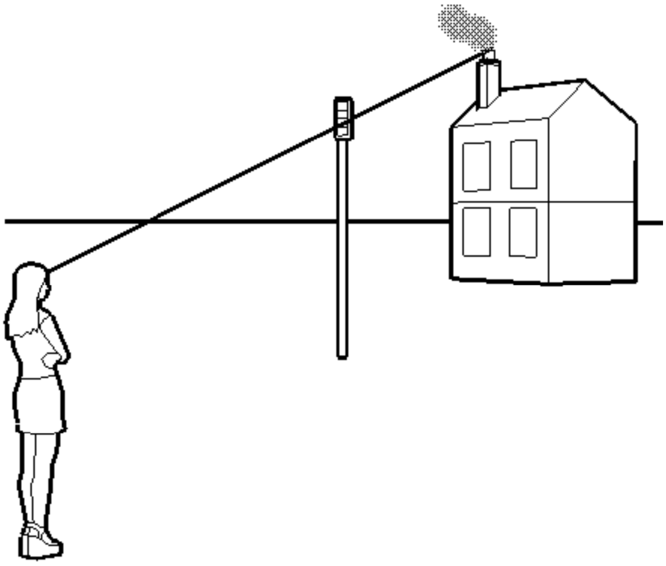
The buffer zone for light industries is about half kilometer, for that of heavy industries it is 0.6 to 1.5 km. for explosive industries it is more than 2 km.

10CV765 / AIR POLLUTION AND CONTROL / R.G.

Unit – 5

MEASUREMENT OF SMOKE DENSITY





Dark smoke is partially burned particles of fuel, the result of incomplete combustion. It can be dangerous because small particles are absorbed into the lungs. **White smoke** is mainly tiny water droplets, generated when vapour released during combustion condenses in cool air. Generally, dark smoke is clearly visible against a light sky but difficult to see at night or against a dark background, white smoke is visible in darkness when illuminated but will be more difficult to see against a light sky background. Smoke is commonly measured in terms of its apparent density in relation to a scale of known greyness.

The most widely-used scale is that developed by Professor Maximilian Ringelmann of La Station d'Essais de Machines in Paris in 1888. It has a 5 levels of density inferred from a grid of black lines on a white surface which, if viewed from a distance, merge into known shades of grey. There is no definitive chart, rather, Prof. Ringelmann provides a specification; where smoke Level '0' is represented by white, levels '1' to '4' by 10mm square grids drawn with 1mm, 2.3mm, 3.7mm and 5.5 mm wide lines and level '5' by all black. It should be remembered that the data obtained has definite limitations. The apparent darkness of a smoke depends upon the concentration of the particulate matter in the effluent, the size of the particulate, the depth of the smoke column being viewed, and natural lighting conditions such as the direction of the sun relative to the observer while the accuracy of the chart itself depends on the whiteness of the paper and blackness of the ink used.

USING THE CHARTS

The large chart on page 4 should be printed with black ink onto very white card and mounted vertically on a board. It is preferably fixed to a pole or held by an assistant at a sufficient distance (typically c20m) for the lines to appear to merge into uniform grey rectangles and to be seen in line with the top of the chimney. The addition of a white (No. 0) square can provide a useful indication that both the chart and chimney are equally illuminated. If a larger chart is needed, the shaded rectangles can be made up into larger ones as mosaics. The observer glances from the smoke, as it issues from the stack, to the chart and notes the number most nearly corresponding with the shade of the smoke. A clear stack is recorded as No. 0, and 100 percent black smoke as No. 5. There is very little value in making a single observation. A series of observations should be made, preferably by two or more observers, over an extended period, at regular intervals.

The Miniature Charts are not the official Ringelmann chart, but a handy interpretation of it, intended to be held at arm's length.

SAMPLING

Selection of sampling procedure:

There are two types of sampling – continuous and time averaged in –situ samplings. Continuous sampling is carried out by automatic sensors, optical or electrochemical, and spectroscopic methods which produce continuous records of concentration values. The specific time-averaged concentration data can then be obtained from continuous records. Time-averaged data can also be obtained by sampling for a short time – i.e. by sampling a known volume of air for the required averaging time. Samples are then analyzed by established physical, chemical, and biological methods for the concentration values which are the effective average over the period of sampling.

Sampling locations

Sampling locations are in general governed by factors like objectives, method of sampling and resources available. If the objective is to study health hazards and material damages, then locations should be kept close to the objects where the effects are being studied and should be kept at breathing level in the population centres, hospitals, schools, etc. For vegetation, it should be at foliage level. For background concentration, sampling location should be away from the sources of pollution. It can also be done by gridding the entire area to get statistically recommended values. The number of locations however depends upon the variability of concentration over the area under survey. A spot checking may be done to decide the location besides considering practical factors.

Period of sampling, frequency and duration:

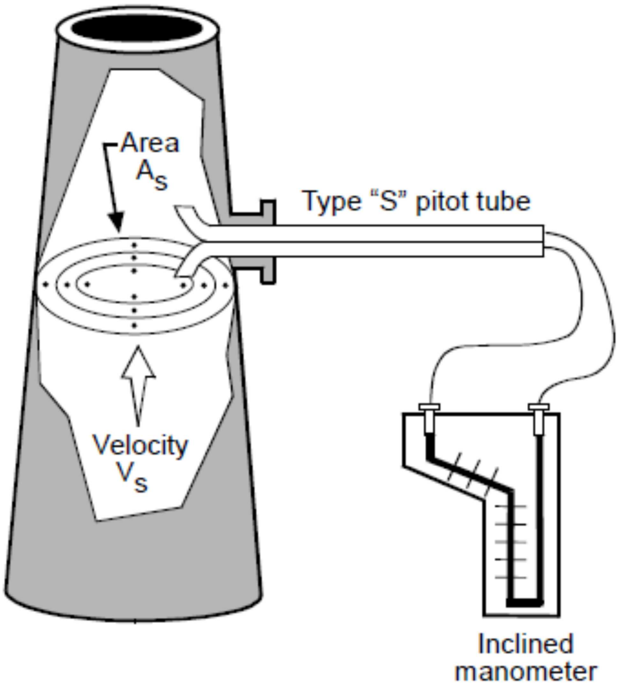
Period, frequency and duration of sampling should be appropriate to the objectives of the study. It should be such that the measurable quantities are trapped in the sample at the end of the sampling. It is preferable to observe sampling period consistent with the averaging times for which air quality standards of the given pollutants are specified.

SOURCE SAMPLING METHODOLOGY

Stationary source emissions occur primarily as either a gas or solid. The ability to collect a representative sample of particulate or gaseous pollutants largely determines the success of the measurement. Since no single method of measurement can accurately analyze every form of pollutant emitted from an exhaust stack, it is important to understand the properties of particulate and gaseous pollutants and the methods used to measure them.

Distributed Sampling Points.

A representative sample of the effluent is taken by first measuring the velocity, as shown in Figure, then extracting gas from an array of sampling points distributed over equal areas of the cross section of the stack or duct. If only gaseous pollutants are to be sampled, less sampling points are required since the stack gases are considered sufficiently mixed.

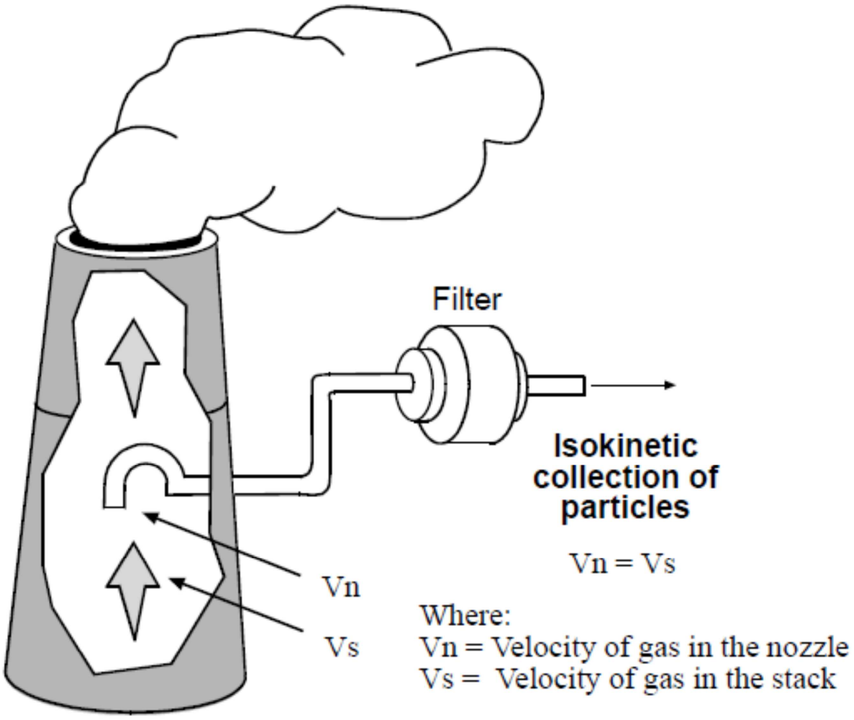


Sampling Distributed Over Time.

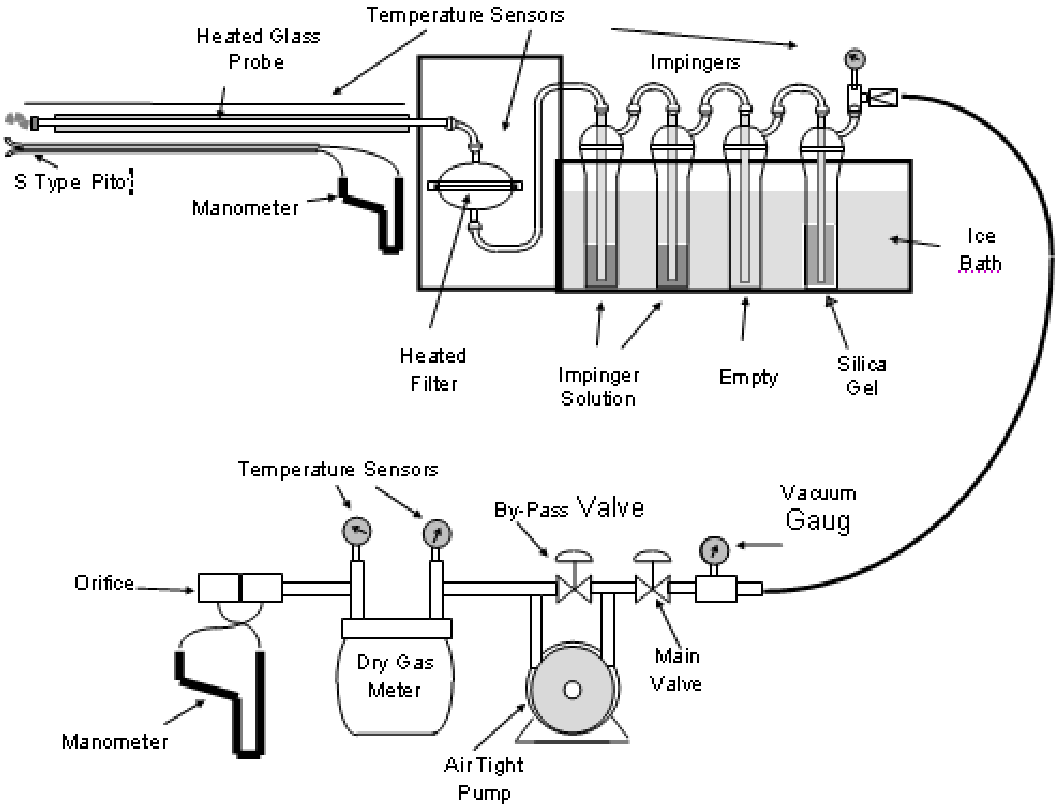
Each point should be sampled for an equal period of time, with the total sampling time or run usually lasting about an hour. Typically, three runs are performed after which their results are then averaged.

Isokinetic Sampling.

When sampling for particles it is essential that the sample be extracted at the same rate at which the gas is flowing through the stack or duct. The stack gas velocity is measured at each individual sample point and the sample extraction rate is adjusted to withdraw the sample at the same rate as the sampled points velocity. This kind of sampling is called *isokinetic* sampling and is meant to ensure that a representative sample, equal in concentration to the stack, is extracted from the gas stream (see Figure). If the sample is isokinetic, the distribution of particles sizes (from small to large) entering the probe will be exactly the same as that in the stack gas itself.



SAMPLING TRAIN



SAMPLING TRAIN

Separation of Gas Constituents.

A known quantity of the stack gas is then drawn from the stack or duct through a *sampling train*, or a leak-proof series of equipment components configured to capture pollutants. Capturing water vapor and gaseous pollutants is best achieved by condensation—or bubbling the sample gas through chilled *impingers* (sealed glass vessels), some which may contain liquid *reagents* to absorb gases. Solids are captured on filter paper, which is heated and connected to the probe with inter-connecting glassware. The first component of the sampling train is a heated probe, or a hollow glass tube that is inserted into the stack or duct. The last component—a pump—draws gases through the other pieces of equipment (the probe, filters and impingers). The volume of sampled gas is measured by a gas meter and is finally exhausted into the atmosphere through the orifice, which is used for sample train flow adjustments at the by-pass valve.

Sample Recovery and Analysis.

Filters are pre-weighed and reagent volumes pre-measured prior to use. After each run, the content of each sampling train component is carefully recovered to a sealed vessel, then weighed, measured, or otherwise evaluated under laboratory conditions.

Data Recording.

Throughout each run, appropriate measurement data are recorded. On a point-by-point basis, the sampling time, sample train vacuum, differential pressures across the gas temperature, orifice meters, and dry gas meter readings are recorded. Averages of these values, along with the total sample gas volume, are then used to calculate the test results.

Calculation of Results.

The concentration of a pollutant in the sampled gas is calculated as the proportion of captured pollutant’s mass to the volume of gas sampled. These results are corrected to a standard temperature and pressure and expressed on a dry basis. This standardized measure allows the results of a test performed under specific conditions to be comparable to a regulatory standard or other test results.

AIR POLLUTION CONTROL PROCEDURES FOR INDUSTRIES

The control of stationary source emissions can be accomplished through the application of a sound control strategy. The control strategy required for an industrial environmental impact is a four step process: (1) elimination of the problem source or operation, (2) modification of the source operation, (3) relocation of the source, and (4) selection and application of the appropriate control technology.

Exhaust stacks do not reduce emissions from a stationary source; rather they reduce the local effects of the pollution by elevating the exhaust stream to a point where it can be more effectively dispersed. High exhaust stacks were an inexpensive solution in the absence of expensive control technology.

Compliance with emission standards may require the use of control technology, but many industrial operations have reduced emissions by changing operational methods. Some of these changes include pretreating process materials, fuel or material substitution, and changes in the manufacturing process. Another way to comply with emission standards is to substitute cleaner fuels during the refining process. Natural gas and low-sulfur fuel oil are just two examples of fuels that emit less pollution during combustion. However, cleaner fuels can be more expensive and can increase national reliance on foreign fuel sources. Reduction in emissions from stationary sources can also be accomplished through increased attention to plant maintenance.

Use of CONTROL EQUIPMENTS (Control Technology)

A final way to reduce emissions from stationary sources is through the use of advanced, addon control technology. Control devices can destroy or recover gaseous compounds or particulate matter for proper disposal or re-use. The pollution control operations used to destroy or capture gases include combustion, adsorption, absorption, and condensation. Control devices that implement these processes include thermal incinerators, catalytic incinerators, flares, boilers, process heaters, carbon absorbers, spray towers, and surface condensers.

The most important process parameters for selecting air pollution control equipment are the exhaust gas characteristics obtained from emissions tests and process or site characteristics.

Exhaust Gas Characteristics

- Total exhaust gas flow rate
- Exhaust gas temperature
- Required control efficiency
- Particle size distribution
- Particle resistivity
- Composition of emissions
- Corrosiveness of exhaust gas over operating range
- Moisture content
- Stack pressure
- Exhaust gas combustibility and flammability properties

Process or Site Characteristics

- Reuse/recycling of collected emissions
- Availability of space
- Availability of additional electrical power
- Availability of water
- Availability of wastewater treatment facilities
- Frequency of startup and shutdowns
- Environmental conditions
- Anticipated changes in control regulations
- Anticipated changes in raw materials
- Plant type – stationary or mobile

Technologies used to control particulate matter focus on removing particles from the effluent gas stream. Many factors (such as particle size and chemical characteristics) determine the appropriate particulate control device for a process.

Devices most commonly used to control particulate matter include

electrostatic precipitators,
fabric filters,
venture scrubbers,
cyclone collectors,
settling chambers.

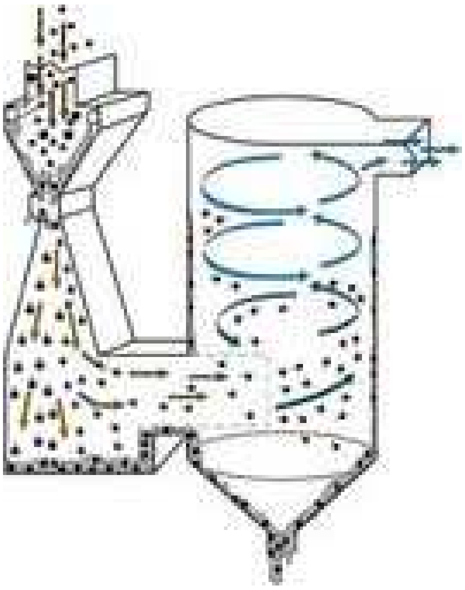
The following section provides a more detailed discussion of each type of control technology used for both particulate and gaseous emissions

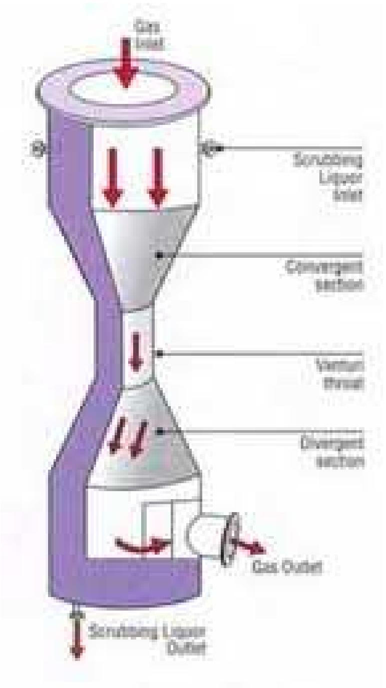
CONTROL DEVICES FOR PARTICULATE EMISSIONS

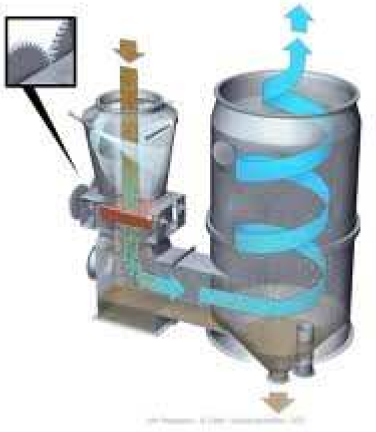
Particulate matter is any finely divided liquid or solid substance. Examples of particulate matter include smoke, dust, or some forms of fine mist and is entrained in effluent gas streams or suspended in ambient air. Any particulate less than 10 micrometers (µm) in diameter is defined as PM10 and is regulated as a criteria pollutant. The purpose of such regulation is to control smaller, respirable particles that can bypass the body's respiratory filters and penetrate deeply into the lungs, which could cause harm to human health. Toxic substances, such as sulfates, sulfites, nitrates, heavy metals, and polycyclic organic matter are predominantly carried by particles in this size range. Therefore, control devices used today, to prevent particles from reaching the ambient air, focus on capturing particulate matter ≤10µm in diameter. Several factors must be considered when selecting an appropriate particulate control device. Typically, particles must be captured from an effluent gas stream; therefore, characteristics of the particles and the gas stream will determine the appropriate control device. Characteristics that must be considered include the particle size and resistivity, exhaust flow rate, temperature, moisture content, and various chemical properties of the exhaust stream such as explosiveness, acidity, alkalinity, and flammability.

VENTURI SCRUBBERS

Venturi scrubbers use a liquid stream to remove solid particles. A venturi scrubber accelerates the waste gas stream to atomize the scrubbing liquid and to improve gas-liquid contact. In a venturi scrubber, a "throat" section is built into the duct that forces the gas stream to accelerate as the duct narrows and then expands. As the gas enters the venture throat, both gas velocity and turbulence increase. Depending on the scrubber design, the scrubbing liquid is sprayed into the gas stream before the gas encounters the venturi throat, or in the throat, or upwards against the gas flow in the throat. The scrubbing liquid is then atomized into small droplets by the turbulence in the throat and droplet-particle interaction is increased. Some designs use supplemental hydraulically or pneumatically atomized sprays to augment droplet creation. However, the disadvantage of these designs is that clean liquid feed is required to avoid clogging. After the throat section, the mixture decelerates, and further impacts occur causing the droplets to agglomerate. Once the particles are captured by the liquid, the wetted PM and excess liquid droplets are then separated from the gas stream by an entrainment section, which usually consists of a cyclonic separator and/or a mist eliminator. Particle collection efficiencies of venturi scrubbers range from 70 to greater than 99 percent, depending on the application. Typically, venturi scrubbers are applied where it is necessary to obtain high collection efficiencies for fine PM. Thus, they are applicable to controlling emission sources with high concentrations of submicron PM.







Advantages of Venturi Scrubbers

- Capable of handling flammable and explosive dusts
- Can handle mists in process exhausts
- Relatively low maintenance
- Simple in design and easy to install
- Collection efficiency can be varied
- Provides cooling for hot gases
- Neutralizes corrosive gases and dusts

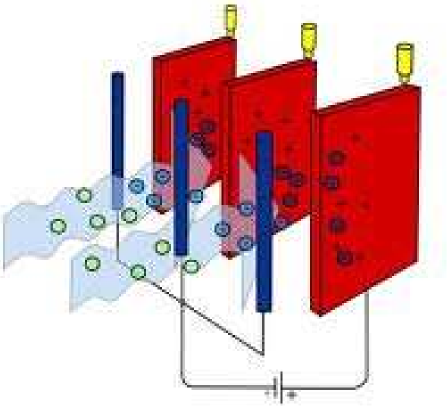
Disadvantages of Scrubbers

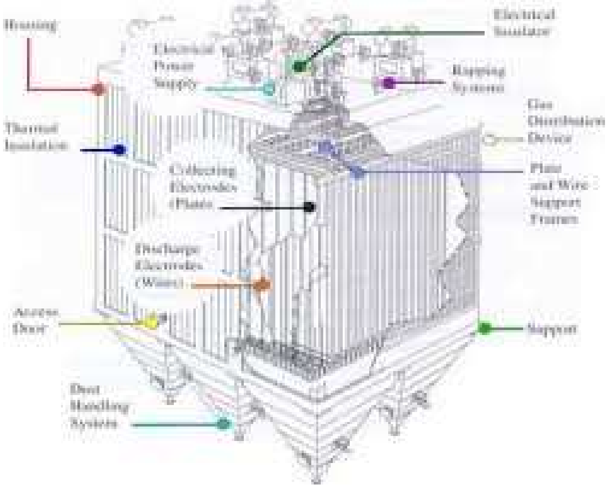
- Effluent liquid can create water pollution problems
- Waste product collected wet
- High potential for corrosion problems
- Requires protection against freezing
- Final exhaust gas requires reheating to avoid visible plume
- Collected PM may be contaminated, and not recyclable
- Disposal of waste sludge may be very expensive

ELECTROSTATIC PRECIPITATORS.

An ESP is a PM control device that uses electrical forces to move particles entrained within an exhaust stream onto collection surfaces. The entrained particles are given an electrical charge when they pass through a corona, a region where gaseous ions flow. Electrodes in the center of the flow lane are maintained at high voltage and generate the electrical field that forces the particles to the collector plates. The high voltage electrodes are long wires or rigid “masts” suspended from a frame in the upper part of the ESP that run through the axis of each tube. Rigid electrodes are generally supported by both an upper and lower frame. The power supplies for the ESP convert the industrial AC voltage to pulsating DC voltage in the range of 20,000 to 100,000 volts as needed. The voltage applied to the electrodes causes the gas between the electrodes to break down electrically, an action known as a “corona.” The electrodes are usually given a negative polarity because a negative corona supports a higher voltage than does a positive corona before sparking occurs. The ions generated in the corona follow electric field lines from the electrode to the collecting pipe. Therefore, each electrode-pipe combination establishes a charging zone through which the particles must pass.

As larger particles (>10μm diameter) absorb many times more ions than small particles (>1μm diameter), the electrical forces are much stronger on the large particles. When the collection plates are filled to capacity, the particulate is removed from the plates by "rapping," which is a mechanical means to dislodge the particulate. The collected particulate material slides downward into a hopper located below the unit. The collection efficiency of an ESP is quite reliably about 99 percent for particles less than 10 micrometers. ESPs, in general, are very expensive to operate and are not very well suited for use in industrial processes because they are too sensitive to fluctuations in the gas stream. The Electrostatic Precipitator (ESP) separates particles from the gas stream by electrically charging the particles.





FABRIC FILTER

In a fabric filter, flue gas is passed through a tightly woven or felted fabric, causing PM in the flue gas to be collected on the fabric by sieving and other mechanisms. Fabric filters may be in the form of sheets, cartridges, or bags, with a number of the individual fabric filter units housed together in a group. Bags are the most common type of fabric filter. The dust cake that forms on the filter from the collected PM can significantly increase collection efficiency. Fabric filters are frequently referred to as baghouses because the fabric is usually configured in cylindrical bags. Bags may be 6 to 9m (20 to 30 ft) long and 12.7 to 30.5 centimeters (cm) (5 to 12 inches) in diameter. Groups of bags are placed in isolable compartments to allow cleaning of the bags or replacement of some of the bags without shutting down the entire fabric filter). Operating conditions are important determinants of the choice of fabric. Some fabrics (i.e., polyolefins, nylons, acrylics, polyesters) are useful only at relatively low temperatures of 95° to 150ºC (200° to 300ºF). For high temperature flue gas streams, more thermally stable fabrics such as fiberglass, Teflon, or Nomex must be used.

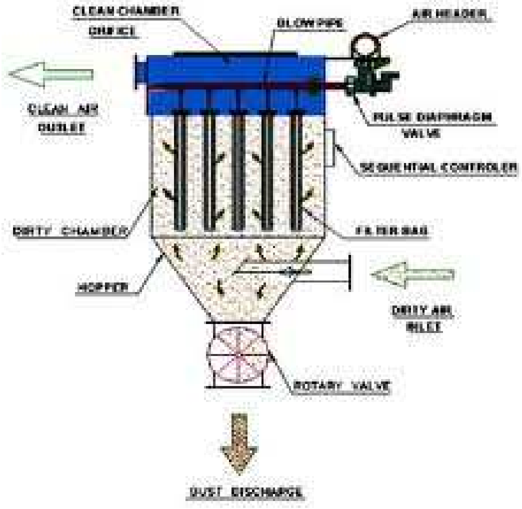
The practical application of fabric filters requires the use of a large fabric area in order to avoid an unacceptable pressure drop across the fabric. Baghouse size for a particular unit is determined by the choice of air-to-cloth ratio, or the ratio of volumetric airflow to cloth area. The selection of air-to-cloth ratio depends on the particulate loading and characteristics, and the cleaning method used. A high particulate loading will require the use of a larger baghouse in order to avoid forming too heavy a dust cake.

Determinants of baghouse performance include the fabric chosen, the cleaning frequency and methods, and the particulate characteristics. Fabrics can be chosen which will intercept a greater

fraction of particulate. In order to accomplish this, some fabrics are coated with a membrane of very fine openings for enhanced removal of submicron particulate. However, such fabrics tend to be more expensive. Cleaning intensity and frequency are important variables in determining removal efficiency because the dust cake can affect the fine particulate removal capability of a fabric. Cleaning procedures, which may be too frequent or too intense, will also lower the removal efficiency of the fabric filter. On the other hand, if removal is too infrequent or too ineffective, then the baghouse pressure drop will become too high.

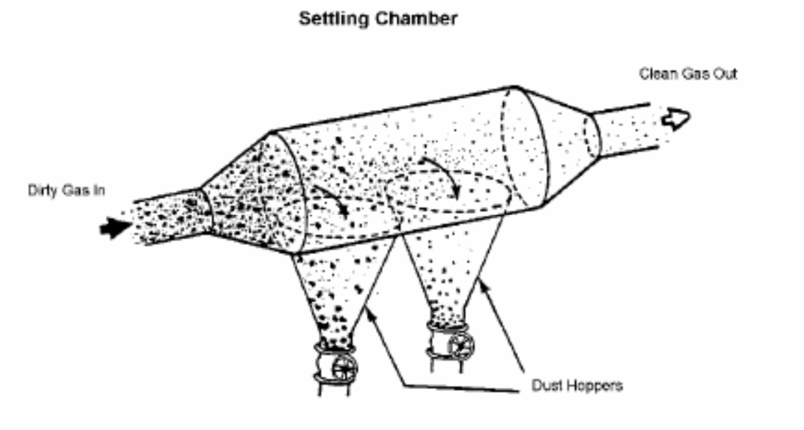
Mechanical shaking of the bags has been a popular cleaning method for many years because of its simplicity as well as its effectiveness. In a typical operation, dusty gas enters an inlet pipe to the shaker. Very large particles are removed from the stream when they strike the baffle plate in the inlet duct and fall into the hopper. The particulate-laden gas is drawn from beneath a cell plate in the floor and into the filter bags. The gas proceeds from the inside of the bags to the outside and through the outlet pipe. The particles are collected on the inside surface of the bags and a filter cake accumulates. In mechanical shaking units, the tops of bags are attached to a shaker bar, which is moved briskly (usually in a horizontal direction) to clean the bags. The shaker bars are operated by mechanical motors or by hand, in applications where cleaning is not required frequently. Reverse-air cleaning is another popular fabric filter cleaning method that has been used extensively and improved over the years. It is a gentler but sometimes less effective cleaning mechanism than mechanical shaking. Most reverse-air fabric filters operate in a manner similar to shaker-cleaned fabric filters. Typically, the bags are open on bottom, closed on top, and the gas flows from the inside to the outside of the bags with dust being captured on the inside. However, some reverse-air designs collect dust on the outside of the bags. In either design, forcing clean air through the filters in the opposite direction of the dusty gas flow performs reverse-air cleaning. The change in direction of the gas flow causes the bag to flex and crack the filter cake. In internal cake collection, the bags are allowed to collapse to some extent during reverse-air cleaning. The bags are usually prevented from collapsing entirely by some kind of support, such as rings that are sewn into the bags. The support enables the dust cake to fall off the bags and into the hopper. Cake release is also aided by the reverse flow of the gas because felted fabrics retain dust more than woven fabrics. Therefore, they are more difficult to clean. For this reason, felts are usually not used in reverse-air systems.

Fabric filters in general provide high collection efficiencies on both coarse and fine (submicron) particulates. Typical new equipment design efficiencies are between 99% and 99.9%.



SETTLING CHAMBERS

This type of technology is a part of the group of air pollution controls collectively referred to as "precleaners." They are referred to as precleaners because they are often used to reduce the inlet loading of particulate matter (PM) to downstream collection devices by removing larger, abrasive particles. Settling chambers are also referred to as gravity settling chambers, gravity collectors, expansion chambers, and outfall chambers. This is because settling chambers are quite effective in removing only large particles; therefore, they can be frequently used in combination with other control devices. Settling Chambers rely on simple gravitation to remove particles from a gas stream.



Settling chambers, which rely on gravitational settling as a collection mechanism are the simplest and oldest mechanical collectors. Settling chambers are generally built in the form of long, horizontal, rectangular chambers with an inlet at one end and an exit at the side or top of the opposite end. Flow within the chamber must be uniform and without any macroscopic mixing. Uniform flow is can be improved by flow straighteners at the inlet to the chamber. Hoppers are used to collect the settled-out material, though drag scrapers and screw conveyers have also been employed. The dust removal system must be sealed to prevent air from leaking into the chamber which increases turbulence, causes dust reentrainment, and prevents dust from being properly discharged from the device. There are two primary types of settling chambers: the expansion chamber and the multiple-tray chamber. In the expansion chamber, the velocity of the gas stream is significantly reduced as the gas expands in a large chamber. The reduction in velocity allows larger particles to settle out of the gas stream.

A multiple-tray settling chamber is an expansion chamber with a number of thin trays closely spaced within the chamber, which causes the gas to flow horizontally between them. While the gas velocity is increased slightly in a multiple-tray chamber, when compared to a simple expansion chamber, the collection efficiency generally improves because the particles have a much shorter distance to fall before they are collected. Multiple-traysettling chambers have lower volume requirements than expansion-type settling chambers for the collection of small particles (<15μm). Settling chambers are most effective when collecting large or dense particles, but often fail when the chamber becomes plugged with collected dust.

The most common failure of settling chambers is when chambers become plugged with collected dust. In expansion settling chambers the plugging can result from hopper bridging or hopper discharge seal failure. Multiple-tray settling chambers may experience plugging of the individual gas passages. Such failures can be prevented or minimized by use of hopper level indicators or by continuous monitoring of the dust discharge. Scheduled internal inspection can determine areas of air leakage and condensation, both of which may cause hopper bridging. Normal instrumentation for a settling chamber generally includes only an indicator of differential static pressure. An increase in static pressure drop can indicate plugging

Advantages of Settling Chambers

- Low capital cost
- Very low energy cost
- No moving parts
- Few maintenance requirements
- Low operating costs
- Excellent reliability
- Low pressure drop through device
- Device not subject to abrasion due to low gas velocity
- Provide incidental cooling of gas stream
- Dry collection and disposal

Disadvantages of Settling Chambers

- Relatively low PM collection efficiencies
- Unable to handle sticky or tacky materials
- Large physical size
- Trays in multiple-tray settling chamber may warp

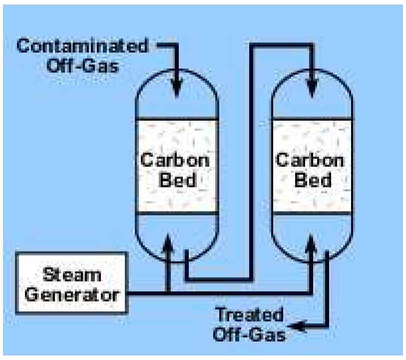
Control of gaseous pollutants from stationary sources - Adsorption

When a gas or vapor is brought into contact with a solid, part of it is taken up by the solid. The molecules that disappear from the gas either enter the inside of the solid, or remain on the outside attached to the surface. The former phenomenon is termed absorption (or dissolution) and the latter adsorption. Adsorption is the binding of molecules or particles to a surface. In this phenomenon molecules from a gas or liquid will be attached in a physical way to a surface. The binding to the surface is usually weak and reversible. The most common industrial adsorbents are activated carbon, silica gel, and alumina, because they have enormous surface areas per unit weight.

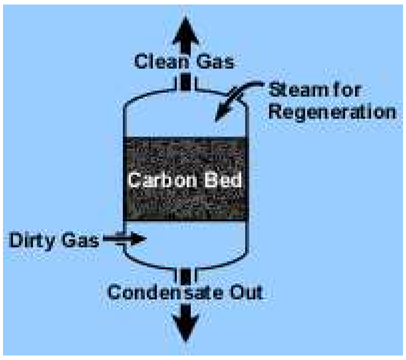
Activated carbon is the universal standard for purification and removal of trace organic contaminants from liquid and vapor streams. Carbon adsorption uses activated carbon to control and/or recover gaseous pollutant emissions. In carbon adsorption, the gas is attracted and adheres to the porous surface of the activated carbon. Removal efficiencies of 95 percent to 99 percent can be achieved by using this process. Carbon adsorption is used in cases where the recovered organics are valuable. For example, carbon adsorption is often used to recover perchloroethylene, a compound used in the dry cleaning process.

Carbon adsorption systems are either regenerative or non-regenerative. A regenerative system usually contains more than one carbon bed. As one bed actively removes pollutants, another bed

is being regenerated for future use. Steam is used to purge captured pollutants from the bed to a pollutant recovery device. By "regenerating" the carbon bed, the same activated carbon particles can be used again and again. Regenerative systems are used when concentration of the pollutant in the gas stream is relatively high. Non-regenerative systems have thinner beds of activated carbon. In a non-regenerative adsorber, the spent carbon is disposed of when it becomes saturated with the pollutant. Because of the solid waste problem generated by this type of system, non-regenerative carbon adsorbers are usually used when the pollutant concentration is extremely low.



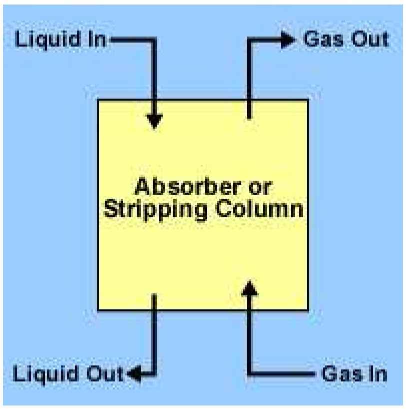
Regenerative Carbon Adsorption System



Non-Regenerative Carbon Adsorption System

Control of gaseous pollutants from stationary sources – Absorption

The removal of one or more selected components from a gas mixture by absorption is probably the most important operation in the control of gaseous pollutant emissions. Absorption is a process in which a gaseous pollutant is dissolved in a liquid. Water is the most commonly used absorbent liquid. As the gas stream passes through the liquid, the liquid absorbs the gas, in much the same way that sugar is absorbed in a glass of water when stirred. Absorption is commonly used to recover products or to purify gas streams that have high concentrations of organic compounds. Absorption equipment is designed to get as much mixing between the gas and liquid as possible. Absorbers are often referred to as scrubbers, and there are various types of absorption equipment. The principal types of gas absorption equipment include spray towers, packed columns, spray chambers, and venture scrubbers. The packed column is by far the most commonly used for the absorption of gaseous pollutants. The packed column absorber has a column filled with an inert (non-reactive) substance, such as plastic or ceramic, which increases the liquid surface area for the liquid/gas interface. The inert material helps to maximize the absorption capability of the column. In addition, the introduction of the gas and liquid at opposite ends of the column causes mixing to be more efficient because of the counter-current flow through the column. In general, absorbers can achieve removal efficiencies greater than 95 percent. One potential problem with absorption is the generation of waste-water, which converts an air pollution problem to a water pollution problem.



Typical packed column diagram

Unit–6 -- 10CV765 -- APC

AUTOMOBILE POLLUTION

The addition of chemicals released from automobile emissions constituting NO_X, HC's, CO, SPM, SO_2, Pb resulting in deterioration of ambient air is termed as automobile pollution. Five of these are also criteria air pollutants.

SOURCE, EFFECT AND CONTROL OF AUTOMOBILE POLLUTANTS

1] **SO2**.

The formation of Sulphur di Oxide in exhaust gases is caused by the oxidation of the sulphur in the fuel during the combustion process. In the atmosphere however, SO2 combines with moisture to form H2SO4, which then falls as acid rain, and has been linked to environmental damage.The major health concerns associated with exposure to high concentrations of SO2 include effects on breathing (decreased lung function), respiratory illness, alterations in pulmonary defences, and aggravation of existing cardiovascular disease. Children, the elderly, and people with asthma, cardiovascular disease or chronic lung disease (such as bronchitis or emphysema), are most susceptible to adverse health effects associated with exposure to SO2.

2] **Pb**.

Exposure to lead mainly occurs through inhalation of air and ingestion of lead in food, paint, water, soil, or dust. Lead accumulates in the body in blood, bone, and soft tissue. Because it is not readily excreted, lead can also affect the kidneys, liver, nervous system, and other organs. Excessive exposure to lead may cause anemia, kidney disease, reproductive disorders, and neurological impairments such as seizures, mental retardation, and/or behavioral disorders. Even at low doses, lead exposure is associated with changes in fundamental enzymatic, energy transfer, and other processes in the body. Fetuses and children are especially susceptible to low doses of lead, often suffering central nervous system damage or slowed growth. Lead may also contribute to osteoporosis in post-menopausal women.

3] **SPM**.

The composition and properties of particulates varies greatly and is therefore difficult to define. Furthermore, there is not a quantitative relationship between the smoke opacity and the particulate emission. Particle emissions from engines can originate from:

a) agglomeration of very small particles of partly burned fuel;
b) partly burned lub oil;
c) ash content of fuel oil and cylinder lub oil; or
d) sulphates and water.

The smaller particles that are likely responsible for adverse health effects because of their ability to reach the lower regions of the respiratory tract. Major concerns for human health from exposure to PM-10 include: effects on breathing and respiratory systems, damage to lung tissue, cancer, and premature death. The elderly, children, and people with chronic lung disease, influenza, or asthma, are especially sensitive to the effects of particulate matter. Acidic PM-10 can also damage human-made materials and is a major cause of reduced visibility.

The most effect method of reducing particulate emissions is to use lighter distillate fuels however, this leads to added expense. Additional reductions in particulate emissions can be achieved by increasing the fuel injection pressure to ensure that optimum air-fuel mixing is achieved, however, as fuel injection pressure increases, the reliability of the equipment decreases. Much research has also been conducted on cyclone separators, which are effective for particle sizes greater than 0.5μm while electrostatic precipitators are more effective, capable of reduction emissions by up to 99%. Unfortunately, precipitators are expensive, prone to clog and are large in size.

4] **Unburnt Hydrocarbons**.

The emission of unburned hydrocarbons (HC) generally results from fuel, which is unburned as a result of insufficient temperature. This often occurs near the cylinder wall (wall quenching) where the temperature of the air/fuel mixture is significantly less than in the centre of the cylinder. Bulk quenching can also occur as a result of insufficient pressure or temperature within the cylinder itself. Still further, HC production may also be a result of poorly designed fuel injection systems, injector needle bounce, excessive nozzle cavity volumes or fuel jets reaching a quench layer.

Volatile Organic Compounds or VOCs are organic chemicals that easily vaporize at room temperature. VOCs include a very wide range of individual substances, such as hydrocarbons (for example benzene and toluene), halocarbons and oxygenates.

Hydrocarbon VOCs are usually grouped into methane and other non-methane VOCs. Methane is an important component of VOCs, its environmental impact principally related to its contribution to global warming and to the production of ground level or lower atmosphere ozone. Most methane is released to the atmosphere via the leakage of natural gas from distribution systems. Benzene, a non-methane hydrocarbon, is a colourless, clear liquid. It is fairly stable but highly volatile, readily evaporating at room temperature. Since 80% of man-made emissions come from petrol-fuelled vehicles, levels of benzene are higher in urban areas than rural areas. Benzene concentrations are highest along urban roadsides. Evaporation of solvents, used for example in paints, cause a release of hydrocarbons, oxygenates and halocarbons to the atmosphere.

Some VOCs are extremely harmful, including the carcinogens benzene, polycyclic aromatic hydrocarbons (PAHs) and 1,3 butadiene. Benzene may increase susceptibility to

leukaemia, if exposure is maintained over a period of time. There are several hundred different forms of PAH, and sources can be both natural and man-made processes. PAHs can cause cancer. Sources of 1,3 butadiene include the manufacturing of synthetic rubbers, petrol driven vehicles and cigarette smoke. There is an apparent correlation between butadiene exposure and a higher risk of cancer.

HC reduction would most likely only be possible using primary and further secondary oxidation catalysts.

5] **NOx**.

NOx is formed during the combustion process within the burning fuel sprays and is deemed one of the most harmful to the environment and contributes to acidification, formation of ozone, nutrient enrichment and to smog formation, which has become a considerable problem in most major cities world-wide.

The amount of NOx produced is a function the maximum temperature in the cylinder, oxygen concentrations, and residence time. At cylinder temperatures, nitrogen from the intake air and fuel becomes active with the oxygen in the air forming oxides of nitrogen. Increasing the temperature of combustion increases the amount of NOx by as much as 3 fold for every 100_oC increase. NO is formed first in the cylinder followed by the formation of NO_2 and N_2O, typically at concentrations of 5% and 1%; respectively. NO_2 is soluble and washed out by rain which increases the acidity level of the soil.

Nitrogen dioxide can irritate the lungs and lower resistance to respiratory infections such as influenza. The effects of short-term exposure are still unclear, but continued or frequent exposure to concentrations that are typically much higher than those normally found in the ambient air may cause increased incidence of acute respiratory illness in children. Nitrogen oxides contribute to ozone formation and can have adverse effects on both terrestrial and aquatic ecosystems. Nitrogen oxides in the air contribute to acid rain and eutrophication. (Eutrophication occurs when a body of water suffers an increase in nutrients that leads to a reduction in the amount of oxygen in the water, producing an environment that is destructive to fish and other animal life.)

The best way to reduce NOx generation, is to reduce peak cylinder temperatures.

6] **CO**.

CO is formed due to the incomplete combustion of organic material where the oxidation process does not have enough time or reactant concentration to occur completely. In engines, the formation of CO is determined by the air/fuel mixture in the combustion chamber and as diesels have a consistently high air to fuel ratio, formation of this toxic gas is minimal. Nevertheless, insufficient combustion can occur if the fuel droplets in a

diesel engine are too large or if insufficient turbulence or swirl is created in the combustion chamber.

Carbon monoxide enters the bloodstream and reduces oxygen delivery to the body's organs and tissues. The health threat from exposure to CO is most serious for those who suffer from cardiovascular disease. Healthy individuals are also affected, but only at higher levels of exposure. Exposure to elevated CO levels is associated with visual impairment, reduced work capacity, reduced manual dexterity, poor learning ability, and difficulty in performing complex tasks.

The intensity and frequency of the afore-mentioned impacts essentially depends on several other factors such as age of the vehicle, type of fuel used, condition of engine, type of engine, maintenance and operation mode of vehicle etc.

PETROL ENGINE vs. DIESEL ENGINE

Petrol engine	**Diesel engine**
High CO, HC’s concentration in emissions	Lesser HC’s concentration i.e., 1/10 CO that of petrol
Less smoke	Major problem odor and smoke, at least 80% SPM than in petrol exhaust
Less SO2, NOX,PM	More NO_X, SO_2, PM/SPM

Inference: The major pollutants in diesel exhaust emissions are a direct result of the diesel combustion process itself. Diesel engines have higher compression ratio than petrol. First air is compressed, then fuel injected, then ignition but in petrol, air fuel mixed first, compressed and the n ignited. HC’s concentration is less, because blowby is negligible as only air is present in compression stroke & evaporative emissions. Hydrocarbons are as well low because diesel uses a closed injection fuel system.

SMOKE

When compared to diesel emissions, petrol emissions are more toxic w.r.t. human; while diesel emissions contribute towards environmental impacts. Yet smoke emission from diesel cannot be ignored.

Maximum smoke is produced when vehicle runs at 60% of total power. It is measured in Ringlemann’s Scale.

Effects of smoke: Irritation of eye membrane, ear membrane and respiratory tract, soiling of clothes, disfiguring of buildings.

Control means: High A/F ratio, Smokeless fuel – Vehicle maintenance - Lean mixture.

2 STROKE ENGINE vs. 4 STROKE ENGINE

When compared to 4 stroke, 2 stroke engine produces more pollution [HC's, CO, SPM, Smoke] as it burns an oil gasoline mixture, but 2 stroke engine is more powerful, lighter, less expensive. On the contrary, 4 stroke engine gives more mileage, produces less HC's and VOC's [volatile organic carbon] as there is no short circuit of raw fuel.

TYPES OF EMISSIONS

1. Tailpipe emissions: This is what most people think of when they think of vehicle air pollution; the products of burning fuel in the vehicle's engine, emitted from the vehicle's exhaust system. The major pollutants emitted include:

Hydrocarbons: This class is made up of unburned or partially burned fuel, and is a major contributor to urban smog, as well as being toxic. They can cause liver damage and even cancer.

Nitrogen oxides (NOx): These are generated when nitrogen in the air reacts with oxygen under the high temperature and pressure conditions inside the engine. NOx emissions contribute to both smog and acid rain.

Carbon monoxide (CO): A product of incomplete combustion, carbon monoxide reduces the blood's ability to carry oxygen and is dangerous to people with heart disease.

Carbon dioxide (CO_2): Emissions of carbon dioxide are considered to pollute because it is a significant greenhouse gas and increasing its levels in the atmosphere contributes to global climate change.

Exhaust emissions contain 100% CO, 100% NO_X, 100% Pb and 60-65% HC's

2. Blowby/Crankcase emissions: 20% unburnt HC's mainly due to leakage of oil vapor around Worn-out piston rings.

3. Evaporative emissions: These are produced from the evaporation of fuel, and are a large contributor to urban smog, since these heavier molecules stay closer to ground level. Fuel tends to evaporate in these ways:

Gas tank venting: the heating of the vehicle as the temperature rises from the night-time temperature to the hottest temperatures of the day mean that gasoline in the tank evaporates, increasing the pressure inside the tank above atmospheric pressure. This pressure must be relieved, and before emissions control it was simply vented into the atmosphere.

Running losses include the escape of gasoline vapors from the hot engine. **Refueling losses** include these can cause a lot of hydrocarbon vapor emission. The empty space inside a vehicle's tank is filled with hydrocarbon gases, and as the tank is filled, these gases are forced out into the atmosphere. In addition, there is loss from further evaporation and fuel spillage.

Bird view of emission of net pollution

65 % from Exhaust + 15 % from Blowby + 20 % Evaporative = 100%

Bird view of Hydrocarbon emissions [mainly as Benzopyrene]

60 % from Exhaust + 20 % from Blowby + 20 % Evaporative = 100%

Evaporative emissions: 20% HC'S via gas tank venting, refueling & running losses.

Operation w.r.t Emissions

Mode of Operation	Unburnt HC's [ppm]	CO [% by volume]	NO_X [ppm]	A/F RATIO
IDLE	750	5.2	30	11:1-12:1
CRUISING	300	0.8	1500	11:1-13:1
ACCELERATION	400	5.2	3000	13:1-15:1
DECELERATION	4000	4.2	60	11:1-12.5:1

Comparative study

When A/F ratio is high, then less CO, HC's but high NOx
When Vehicle decelerates high HC's [hydrocarbon]
When vehicle is idle [engine not switched off during signals] high CO, low NO_X, moderate HC's.
When vehicle accelerates low HC'S , high CO, high CO, and high NOx
When vehicle cruises high NOx, low CO, moderate HC's and high CO_2.

Drawbacks

Pb is released from exhaust as lead halides which are a cumulative toxin, a chief environmental pollutant capable of affecting neural development resulting in lower IQ.

Also lead acts as poison for catalytic converter. This resulted in advent of unleaded petrol. The alternative used was MTBE. But it has been found to be non-bio-degradable and possible ground contamination. This resulted in the use of ethanol as anti-knocking agent to boost octane rating. But ethanol causes fuel to absorb moisture from air, over long time it leads to rusting, corrosion in fuel line. Also it is poorly soluble and enhances possibility of bacterial contamination.

TEL now banned in road sector continues to be used in aviation fuel as additive called as AVGAS. The catch is despite using unleaded petrol; the emissions consist of benzene which causes cancer, anemia and blood cancer. The other option w.r.t knocking phenomenon is utilize branched chain alkanes, which results pre ignition, loss of power, lower octane rating.

Catalytic converters

The air fuel ratio must be so high that all CO formed is converted to CO_2, but if ratio is less [lack of O_2], it facilitates formation of CO, Unburnt HC's, NO_X. Also due to higher temperature [2000-2500 ^{0}C], high pressure formation of Nitric oxide takes place.

If a car burns fuel with perfect efficiency, its only exhaust products would be CO_2 and H_2O. Unfortunately not every molecule burns to completion. Catalytic converter consists of an array of tubes, each coated with porous ceramics. Embedded in this coating are tiny particles of platinum and rhodium which serve as catalyst. Previously V_2O_5, Vanadium Pentoxide served the purpose.

$$HC+CO+NO_X \rightarrow H_2O+CO_2+N_2$$

Nowadays Rhodium, Platinum, Palladium serve the role as 3-way catalyst, once the exhaust heats the converter above 300^{0}C, unwanted molecules bind temporarily to catalyst and are converted. 95% of HC's, CO, NO_X is removed by converter but the presence of Pb in fuel as lead Halide gets coated over surface inactivating them. Catalytic converters have no moving parts, but its limitations include poisoning by lead, deterioration with time and pressure loss.

Indirect Control measures

Car pool system, eco-friendly fuels, hybrid vehicles, use of bio fuels, use of alternate energy such as solar driven, use of unleaded petrol, complying to rules and regulation, frequent periodical emission testing, stringent norms and enforcement on violation,

Minimizing the use of vehicles by walking for small distances, pooling of the vehicles, switching off the vehicles on red lights, maintaining the vehicles in proper order, adopting efficient ways of driving, ban on overloading, better design and maintenance of roads collectively can reduce automobile air pollution.

Direct Control measures

The amount of SO2 formed is a function of the sulphur content of the fuel used and therefore the only effective method of reducing SOx is by reducing the sulphur content of the fuel. Unfortunately, low-sulphur fuels are more expensive to purchase (10 to 20% greater cost, when switching from 3.5% to 1% sulphur) and there is a practical lower sulphur limit desired as desulphurisation of fuel lowers the lubricity of the fuel which can lead to increase wear on fuel pumps and injectors.

proper operation and maintenance of vehicles

Using catalytic converter for HC's, CO, NOx, C_6H_6

Increasing air-fuel ratio for HC's, CO and Benzene

Recycling exhaust gas for NO_x, [15-25%]

In case of SPM, ensure proper maintenance and operation process, such has change air filter regularly, change engine oil as per manufacturer's specification, use moderate acceleration and avoid slowing of engine atop gear.

The industry may be compelled to manufacture the vehicles in such a way, i.e. enforcing the Euro standards, that they produce minimum pollutants.

To maintain the vehicle by its proper servicing (tuning of engine) in such a way that the exhaust emissions are under control.

Control on the quality of fuel. Use unleaded petrol. Sometimes Kerosene is mixed with petrol or diesel (as it is cheaper) than the emissions are more pollutant and are of different nature.

Unit – 7

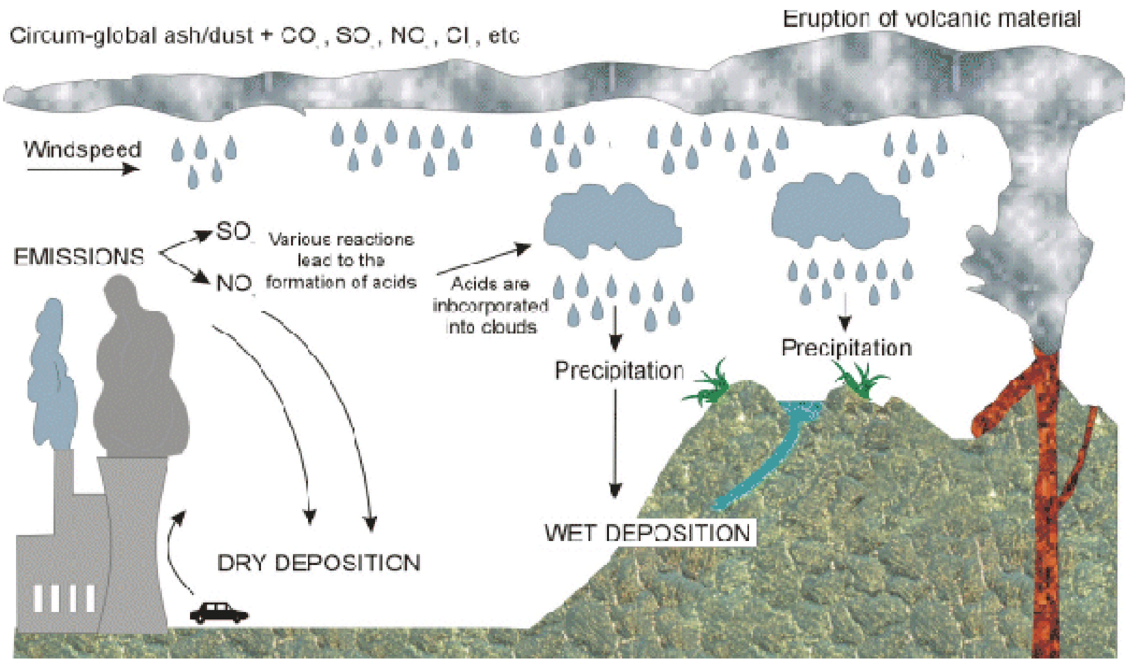
ACID RAIN

Definition

Normal Rain water p^H is slightly acidic due to certain concentration of CO_2 dissolved as rainwater trickles down atmosphere, i.e. $CO_2+H_2O \rightarrow HCO^{3-}+H^+$

Acid rain is defined as any type of precipitation with a p^H that is unusually low or lower than 5.7. Acid rain was first found in Manchester, England. In 1852, Robert Angus Smith found the relationship between acid rain and atmospheric pollution. Though acid rain was discovered in 1852, it wasn't until the late 1960s that scientists began widely observing and studying the phenomenon.

Causes



The principal natural phenomena that contribute acid-producing gases to the atmosphere are emissions from volcanoes and those from biological processes that occur on the land, in wetlands, and in the oceans. The major biological source of sulfur containing compounds is dimethyl sulfide.

The principal cause of acid rain is sulfuric and nitrogen compounds from human sources, such as electricity generation, factories and motor vehicles. Coal power plants are one of the most polluting. The gases can be carried hundreds of kilometres in the atmosphere before they are converted to acids and deposited. Factories used to have short funnels to let out smoke, but this caused many problems, so now, factories have longer smoke funnels. The problem with this is those pollutants get carried far off, where it creates more destruction.

Sulfur dioxide contributes to about seventy percent of acid rain while nitrogen oxides provide the remaining thirty percent. The sources of sulfur in the atmosphere include coal combustion, smelting, organic decay, and ocean spray. Approximately ninety percent of atmospheric sulfur results from human activities.

In the atmosphere, sulfur dioxide combines with water vapor to form hydrogen sulfite gas: $SO_2 + H_2O + 1/2O_2 \rightarrow H_2SO_4$

Next, hydrogen sulfite reacts with oxygen to form sulfuric acid, a major component of acid rain: $H_2SO_3 + 1/2O_2 \rightarrow H_2SO_4$

The sources of nitrogen oxides include the combustion of oil, coal and natural gas, forest fires, bacterial action in soil, volcanic gases, and lighting-induced atmospheric reactions.

In the atmosphere, nitrogen monoxide reacts with oxygen gas to form nitrogen dioxide gas: $NO + 1/2O_2 \rightarrow NO_2$

Then, nitrogen dioxide reacts with water vapor in the atmosphere to form hydrogen nitrite and hydrogen nitrate: $2NO_2 + H_2O \rightarrow HNO_2 + HNO_3$

Henceforth, acid rain is a mixture of HNO_3, H_2SO_4 + HCl. however conditions needed to favor formation of these are sunlight, temperature, humidity, hydrocarbons, NO_X, SO_2.

Effects

Both the lower p^H and higher aluminum concentrations in surface water that occur as a result of acid rain can cause damage to fish and other aquatic animals. At p^H lower than 5 most fish eggs will not hatch and lower p^H can kill adult fish. As lakes become more acidic biodiversity is reduced. Soil biology can be seriously damaged by acid rain. Some tropical microbes can quickly consume acids but other microbes are unable to tolerate low p^H and are killed.

Acid rain can slow the growth of forests, cause leaves and needles to turn brown and fall off and die. In extreme cases trees or whole areas of forest can die. The death of trees is not usually a direct result of acid rain; often it weakens trees and makes them more susceptible to other threats.

Some scientists have suggested direct links to human health, but none have been proven. However, fine particles, a large fraction of which are formed from the same gases as acid

rain (sulfur dioxide and nitrogen dioxide), have been shown to cause illness and premature deaths such as cancer and other deadly diseases

Toxic metals released into the environment by acid rain may enter water supplies or accumulate in fish and crops. Acid deposition also destroys statues, headstones, buildings, and fountains. Limestone structures are especially susceptible because they dissolve easily in acidic solutions.

Acid rain can also cause damage to certain building materials and historical monuments. Acid rain can cause weathering on ancient and valuable statues and has caused considerable damage. This is because the sulfuric acid in the rain chemically reacts with the calcium compounds in the stones (limestone, sandstone, marble and granite) to create gypsum, which then flakes off. Acid rain also causes an increased rate of oxidation for iron.

Control

- Design more efficient automobile engines in order to reduce nitrogen oxide emissions.
- Increase efficiency of power plants that burn coal in order to reduce waste that contains sulfur dioxide and nitrogen oxide.
- Increase penalties on industries that do not meet air pollution guidelines.
- Increase tax incentives to industries that do meet guidelines.
- Use alternative energy sources, Increase funding for alternative energy sources; for example, give tax incentives to buyers of hybrid cars.
- Provide tax incentives to companies that use alternative energy sources.
- Add $CaCO_3$ (calcium carbonate) to lakes suffering from acid deposition; calcium carbonate acts as a buffer, resisting a change in p^H and lessening the negative effects of acid rain.

OZONE DEPLETION

Definition

Ozone layer is an umbrella 24 km [15 miles] from earth surface, an essential component of the stratosphere that absorbs short wavelength ultraviolet radiation from the sun, heating the gases of the stratosphere in the process. World ozone day is celebrated on Sept, 16 of every year.

Stratospheric ozone is measured in Dobson units [DU] named after G.M.B Dobson who pioneered the study; [I Dobson unit = 0.01 mm thickness of stratospheric ozone], Average ozone thickness in stratosphere is 300 DU, & when it falls below 200 DU, it’s considered as Ozone hole. It is thinnest around equator and thickest near poles.

Stratospheric ozone depletion is the term applied to the loss of stratospheric ozone molecules (O_3) and the disruption of Oxygen-Ozone concentration equilibrium in stratosphere [i.e., when chlorine atoms upset the natural O_2/O_3 equilibrium in the stratosphere]. Oxygen molecules interact with the intense solar radiation present at this elevation to form oxygen atoms. The oxygen atoms thus generated react with other oxygen molecules to form ozone (O_3).

Causes

Ozone depletion is caused by the release of chlorofluorocarbons (CFC's) and other ozone-depleting substances (ODS), which were used widely as refrigerants, insulating foams, and solvents. The discussion below focuses on CFCs, but is relevant to all ODS [NO, NO_2 (aircraft exhaust), Br^-, UV rays, [O] Atomic oxygen etc].

Although CFCs are heavier than air, they are eventually carried into the stratosphere in a process that can take as long as 2 to 5 years. When CFCs reach the stratosphere, the ultraviolet radiation from the sun causes them to break apart and release chlorine atoms which react with ozone, starting chemical cycles of ozone destruction that deplete the ozone layer. One chlorine atom can break apart more than 100,000 ozone molecules.

Other chemicals that damage the ozone layer include methyl bromide (used as a pesticide), halons (used in fire extinguishers), and methyl chloroform (used as a solvent in industrial processes). As methyl bromide and halons are broken apart, they release bromine atoms, which are 40 times more destructive to ozone molecules than chlorine atoms.

Chapman's Reaction

$$\boxed{\begin{array}{ll} O_2 + UV \rightarrow 2\,O & \\ O + O_2 \rightarrow O_3 & \text{(ozone production)} \\ O_3 + UV \rightarrow O + O_2 & \text{(ozone destruction)} \\ O + O_2 \rightarrow O_3 & \text{(ozone production)} \\ O_3 + O \rightarrow O_2 + O_2 & \text{(ozone destruction)} \end{array}}$$

Ozone Depletion by CFC's

$$CF_2Cl_2 + h\nu \longrightarrow Cl^\cdot + CCl_2F^\cdot$$

$$Cl^\cdot + O_3 \longrightarrow ClO^\cdot + O_2$$

$$ClO^\cdot + O \longrightarrow Cl^\cdot + O_2$$

All above reactions occur in the presence of UV rays, while the 2nd set of reactions governs the oxygen-ozone equilibrium due to its spontaneity.

Effects

Effect of ozone hole include cataract, genetic mutation, constriction of blood vessels, reduced crop yield, leukemia, breast cancer, damage to crop, aqua culture, etc.,

The higher energy UV radiation absorbed by ozone is generally accepted to be a contributory factor to skin cancer. In addition, increased surface UV leads to increased tropospheric ozone, which is a health risk to humans such as Snow Blindness [photo keratosis], i.e., inflammation of cornea (outer coating of eyeball). The most common forms of skin cancer in humans, basal and squamous cell carcinomas have been strongly linked to UVB exposure. Another form of skin cancer, malignant melanoma, is much less common but far more dangerous, being lethal in about 15% - 20% of the cases diagnosed. In India there is no standard for Ozone. However WHO standard is 100 ppm for 8 hrs – avg.

Control Measures

The Montreal Protocol, an international agreement signed by 139 nations, banning the production of CFCs by the year 2000. We can't make enough ozone to replace what's been destroyed, but provided that we stop producing ozone-depleting substances, natural ozone production reactions should return the ozone layer to normal levels by about 2050. It is very important that the world comply with the Montreal Protocol; delays in ending production could result in additional damage and prolong the ozone layer's recovery. Control mechanism stresses on replacement of the banned chemical by ammonia, steam, helium etc.

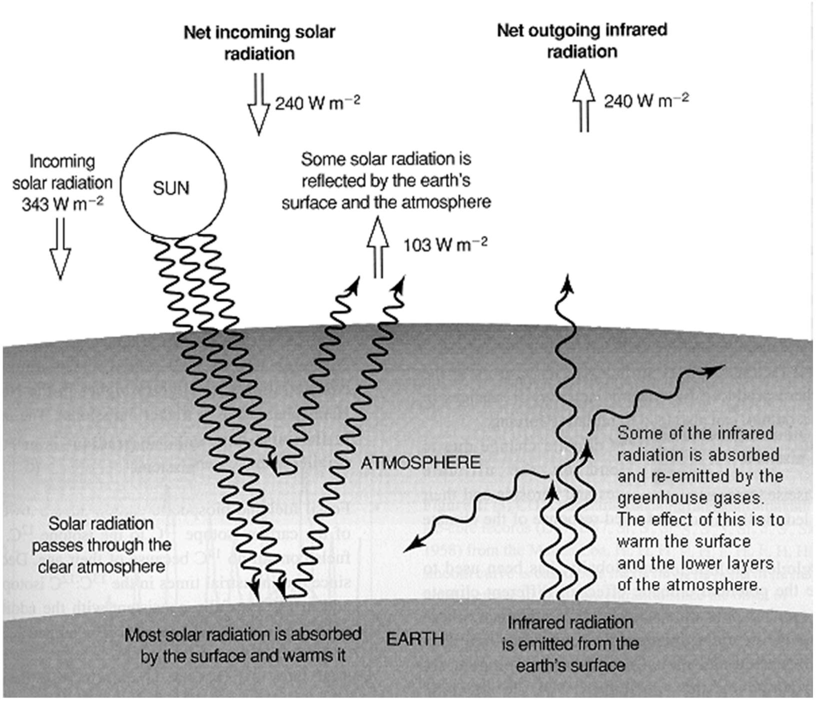
GREEN HOUSE EFFECT

Introduction

Objects that absorb all radiation upon them are called "blackbody" absorbers. The earth is close to being a black body absorber. Gases, on the other hand, are selective in their absorption characteristics. While many gases do not absorb radiation at all some selectively absorb only at certain wavelengths. Those gases that are "selective absorbers" of solar energy are the gases we know as "Greenhouse Gases."

Definition

The greenhouse effect is a phenomenon that ought to create a condition in the upper atmosphere, causing a trapping of excess heat and leading to increased surface temperatures.



Mechanism

The Earth receives energy from the Sun in the form of radiation. The Earth reflects about 30% of the incident solar flux; the remaining 70% is absorbed, warming the land, atmosphere and oceans. The visible solar radiation heats the surface, not the atmosphere, whereas most of the infrared radiation escaping to space is emitted from the upper atmosphere, not the surface. The infrared photons emitted by the surface are mostly absorbed by the atmosphere and do not escape directly to space. Hence earth's greenhouse effect is a natural phenomenon that helps regulates the temperature of our planet. Simply put, the sun heats the earth and some of this heat, rather than escaping back to space, is trapped in the atmosphere by clouds and greenhouse gases, such as water vapor and carbon di oxide. If all these greenhouse gases were to suddenly disappear, our planet would be 60° F colder and uninhabitable.

GREENHOUSE GASSES – SOURCES & SINKS

On Earth, the major natural greenhouse gases are water vapor, which causes about 36–70% of the greenhouse effect (not including clouds); carbon dioxide (CO_2), which causes 9–26%; methane (CH_4), which causes 4–9%; and ozone, which causes 3–7%.

Carbon Dioxide

Sources: Released by the combustion of fossil fuels (oil, coal, and natural gas), flaring of natural gas, changes in land use (deforestation, burning and clearing land for agricultural purposes), and manufacturing of cement.
Sinks: Photosynthesis and deposition to the ocean.
Significance: Accounts for about half of all warming potential caused by human activity.

Methane

Sources: Landfills, wetlands and bogs, domestic livestock, coal mining, wet rice growing, natural gas pipeline leaks, biomass burning, and termites.
Sinks: Chemical reactions in the atmosphere.
Significance: Molecule for molecule, methane traps heat 20-30 times more efficiently than CO_2. Within 50 years it could become the most significant greenhouse gas.

Nitrous Oxide [296 times potential than CO_2]

Sources: Burning of coal and wood, as well as soil microbes' digestion.
Sinks: Chemical reactions in the atmosphere.
Significance: Long-lasting gas that eventually reaches the stratosphere where it participates in ozone destruction.

Ozone

Sources: Not emitted directly, ozone is formed in the atmosphere through photochemical reactions involving nitrogen oxides and hydrocarbons in the presence of sunlight.
Sinks: Deposition to the surface, chemical reactions in the atmosphere.
Significance: In the troposphere ozone is a pollutant. In the stratosphere it absorbs hazardous ultraviolet radiation.

Chlorofluorocarbons (CFCs)

Sources: Used for many years in refrigerators, automobile air conditioners, solvents, aerosol propellants and insulation.
Sinks: Degradation occurs in the upper atmosphere at the expenses of the ozone layer. One CFC molecule can initiate the destruction of as many as 100,000 ozone molecules.
Significance: The most powerful of greenhouse gases — in the atmosphere one molecule of CFC has about 20,000 times the heat trapping power on a molecule of CO_2.

GLOBAL WARMING - CLIMATE CHANGE

Definition

Global warming is the increase in the average temperature of the Earth's near-surface air and oceans in recent decades and its projected continuation.

Impacts

- Consequences may include changes in agricultural yields, glacier retreat, reduced summer stream flows, species extinctions and increases in the ranges of disease vectors.

- The melting of Arctic ice and increased regional precipitation can add freshwater to the oceans, and potentially affect ocean currents in the North Atlantic.

- Forest fires could become more frequent.

- Due to the warming; insect outbreaks will increasingly disturb large areas of forest.

- Many Arctic animals, such as polar bears, seals, walruses, and seabirds, rely on the sea's biological productivity and on the presence of sea ice, both of which are highly dependent on climatic conditions.

- Changes in sea surface temperatures or currents could have a strong effect on Arctic marine fish stocks, which are an important food source for the world and play a vital role in the region's economy.

- Additional anticipated effects include 18% to 35% of a sample of 1,103 animal and plant species to be extinct by 2050, based on future climate projections.

Control

The world's primary international agreement on combating global warming is the Kyoto Protocol, an amendment to the United Nations Framework Convention on Climate Change (UNFCCC), negotiated in 1997. The Protocol now covers more than 160 countries globally and over 55% of global greenhouse gas (GHG) emissions.

How to Combat Global Warming

Use Compact Fluorescent Bulbs
Use Recycled Paper
Use Solar-heated Water
Take Shorter Showers
Buy Products Locally
Buy a Hybrid Car, Bio-fuel driven
Carpool When You Can
Plant a Tree
Replace Old Appliances
Unplug Un-Used Electronics
Insulate Your Home

Change Your Air Filter
Check Your Water Heater
Change the AC Filter
Install a Low-Flow Showerhead
Buy Minimally Packaged Goods
Buy a Fuel Efficient Car,
Reduce Garbage
Buy Organic Food
Use a Push Mower
Air Dry Your Clothes
Switch to Double Pane Windows

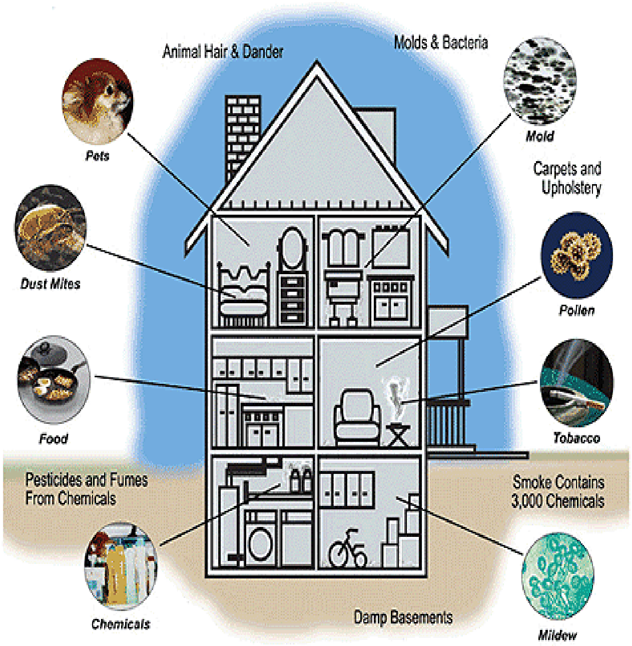
Bring Cloth Bags to the Market & Turn off Your Computer Whenever Possible

INDOOR AIR POLLUTION

Introduction

The indoor environment represents an important microenvironment in which people spend a large part of their time each day.

Source



The major sources of indoor air pollution worldwide include combustion of solid fuels indoors, tobacco smoking, outdoor air pollutants, emissions from construction materials and furnishings, and improper maintenance of ventilation and air conditioning systems.

About half of the world's population, largely in developing countries, relies on traditional fuels such as biomass (wood, agricultural residues and animal dung), charcoal and coal as the primary source of domestic energy.

Use of solid fuels in open or poorly ventilated stoves for cooking and heating exposes an estimated three billion people to high concentrations of PM and gases that are some 10–20 times higher than levels commonly found in international health guidelines (including the WHO air quality guidelines). Although relatively clean sources of household energy predominate in developed countries, improvements in energy efficiency have led to homes being relatively airtight, reducing ventilation and raising indoor pollutant levels. In such circumstances even minor sources of pollution, such as gas cookers, new furnishings, damp conditions, household products or naturally occurring radon gas, can lead to significant exposures and recognized health effects.

In developing countries, the most significant issue for indoor air quality is exposure to pollutants released during combustion of solid fuels, including biomass (wood, dung and crop residues) or coal (mainly in China), used for cooking and heating. The majorities of households using such fuels are located in poor rural communities and use inefficient devices such as earthen or metal stoves in kitchens that are often poorly ventilated, resulting in very high exposures.

Sources Outside Building

Contaminated outdoor air
pollen, dust, fungal spores
industrial pollutants
general vehicle exhaust

Emissions from nearby sources
exhaust from vehicles on nearby roads or in parking lots, or garages
loading docks
odors from dumpsters
re-entrained (drawn back into the building) exhaust from the building itself or from neighboring buildings
unsanitary debris near the outdoor air intake

Soil gas-Radon
leakage from underground fuel tanks
contaminants from previous uses of the site (e.g., landfills)
pesticides

Equipment-HVAC system
dust or dirt in ductwork or other components
microbiological growth in drip pans, humidifiers, ductwork, coils
improper use of biocides, sealants, and/or cleaning compounds
improper venting of combustion products
refrigerant leakage

Non-HVAC equipment
emissions from office equipment (volatile organic compounds, ozone)
supplies (solvents, toners, ammonia)
emissions from shops, labs, cleaning processes
elevator motors and other mechanical systems

Human Activities

Personal activities
Smoking, cooking
body odor
cosmetic odors

Housekeeping activities
cleaning materials and procedures
emissions from stored supplies or trash
use of deodorizers and fragrances
airborne dust or dirt (e.g., circulated by sweeping and vacuuming)

Maintenance activities
microorganisms in mist from improperly maintained cooling towers
airborne dust or dirt
volatile organic compounds from use of paint, caulk, adhesives, and other products
pesticides from pest control activities
emissions from stored supplies
Building Components and Furnishings
Locations that produce or collect dust or fibers
textured surfaces such as carpeting, curtains, and other textiles
open shelving
old or deteriorated furnishings
materials containing damaged asbestos

Impact

Indoor air quality (IAQ) is a term which refers to the air quality within and around buildings and structures, especially as it relates to the health and comfort of building occupants. IAQ can be affected by gases (including carbon monoxide, radon, volatile organic compounds), particulates, microbial contaminants (mould, bacteria) or any mass or energy stressor that can induce adverse health conditions.

Sick Building Syndrome, a phenomenon where building occupants experience acute health and comfort effects linked to time spent in the building. Most of the complainants report relief soon after leaving the building. The causes of contributing factors to sick building syndrome are inadequate ventilation & chemical contamination from indoor and outdoor sources. Concentrations of indoor pollutants are often two to five times higher than outdoor concentrations. These pollutants can build up rapidly indoors to levels much higher than those usually found outdoors. This is especially true if large amounts of a pollutant are released indoors. Moreover, "tighter" construction in newer homes can prevent pollutants from escaping to the outdoors.

Radon (Rn) gas, a carcinogen, is exuded from the Earth in certain locations and trapped inside houses.

Building materials including carpeting and plywood emit formaldehyde (H_2CO) gas.

Paint and solvents give off volatile organic compounds (VOCs) as they dry. Lead paint can degenerate into dust and be inhaled.

Intentional air pollution is introduced with the use of air fresheners, incense, and other scented items.

Controlled wood fires in stoves and fireplaces can add significant amounts of smoke particulates into the air, inside and out.

Indoor pollution fatalities may be caused by using pesticides and other chemical sprays indoors without proper ventilation.

Carbon monoxide (CO) poisoning and fatalities are often caused by faulty vents and chimneys, or by the burning of charcoal indoors. Chronic carbon monoxide poisoning can result even from poorly adjusted pilot lights.

Clothing emits tetrachloroethylene, or other dry cleaning fluids, for days after dry cleaning.

Though its use has now been banned in many countries, the extensive use of asbestos in industrial and domestic environments in the past has left a potentially very dangerous material in many localities. Asbestosis is a chronic inflammatory medical condition affecting the tissue of the lungs. Sufferers have severe dyspnea (shortness of breath) and are at an increased risk regarding several different types of lung cancer.

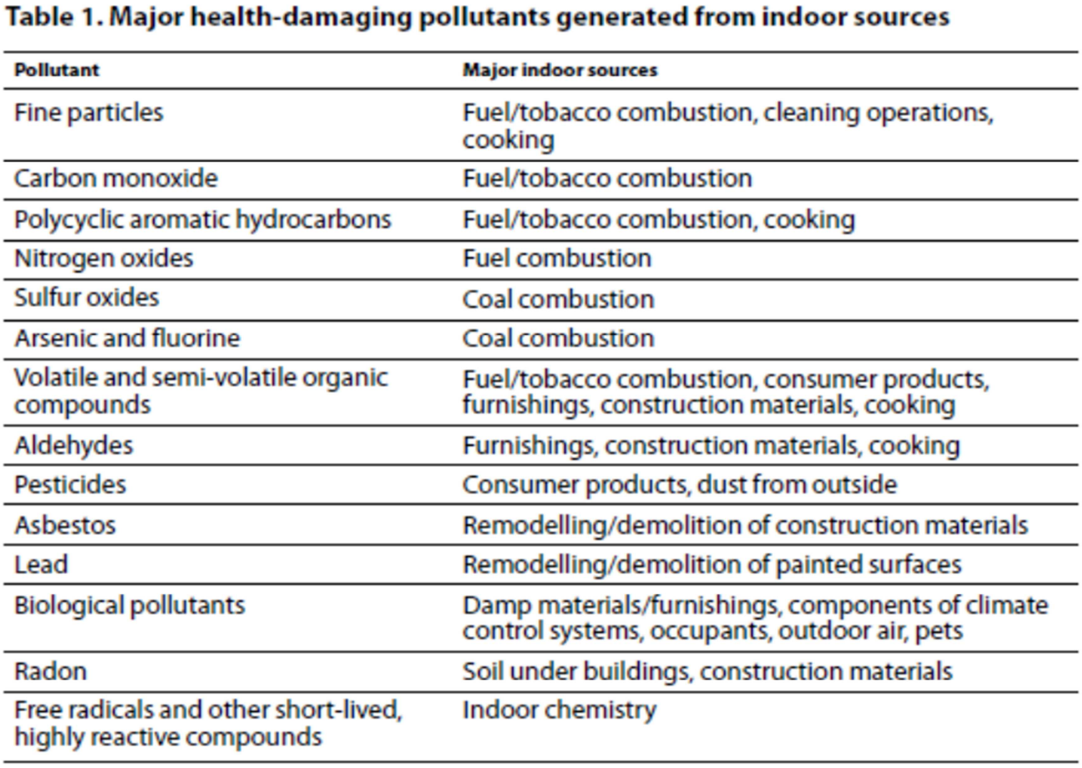


Table 1. Major health-damaging pollutants generated from indoor sources

Pollutant	Major indoor sources
Fine particles	Fuel/tobacco combustion, cleaning operations, cooking
Carbon monoxide	Fuel/tobacco combustion
Polycyclic aromatic hydrocarbons	Fuel/tobacco combustion, cooking
Nitrogen oxides	Fuel combustion
Sulfur oxides	Coal combustion
Arsenic and fluorine	Coal combustion
Volatile and semi-volatile organic compounds	Fuel/tobacco combustion, consumer products, furnishings, construction materials, cooking
Aldehydes	Furnishings, construction materials, cooking
Pesticides	Consumer products, dust from outside
Asbestos	Remodelling/demolition of construction materials
Lead	Remodelling/demolition of painted surfaces
Biological pollutants	Damp materials/furnishings, components of climate control systems, occupants, outdoor air, pets
Radon	Soil under buildings, construction materials
Free radicals and other short-lived, highly reactive compounds	Indoor chemistry

Biological sources of air pollution are also found indoors, as gases and airborne particulates. Pets produce dander, people produce dust from minute skin flakes and decomposed hair, dust mites in bedding, carpeting and furniture produce enzymes and micrometre-sized fecal droppings, inhabitants emit methane, mold forms in walls and generates mycotoxins and spores, air conditioning systems can incubate Legionnaires' disease and mold, and houseplants, soil and surrounding gardens can produce pollen, dust, and mold.

The presence of many biological agents in the indoor environment is due to dampness and inadequate ventilation. Excess moisture on almost all indoor materials leads to growth of microbes, which subsequently emit spores, cells, fragments and volatile organic compounds into indoor air. Moreover, dampness initiates chemical or biological degradation of materials, which also pollutes indoor air.

Recent studies estimate that exposure to indoor air pollutants associated with household solid fuel use may be responsible for nearly 1.6 million excess deaths and about 3% of the global burden of disease.

Factors governing the indoor air quality problem

Air exchange rate
Indoor rate of removal of pollutants
Outdoor concentration of air pollutant
Infiltration and exfiltration rate.

When there isn't an effective air exchange rate, which is the rate at which outdoor air replaces indoor air, indoor pollutant levels can increase. Air exchange rate is managed through natural and/or mechanical ventilation.

Natural ventilation occurs when air moves through opened doors and windows by wind or temperature differences. Mechanical ventilation occurs when devices such as fans or air handling systems distribute or move air. A proper air exchange rate it is vital for maintaining healthy indoor air.

Control

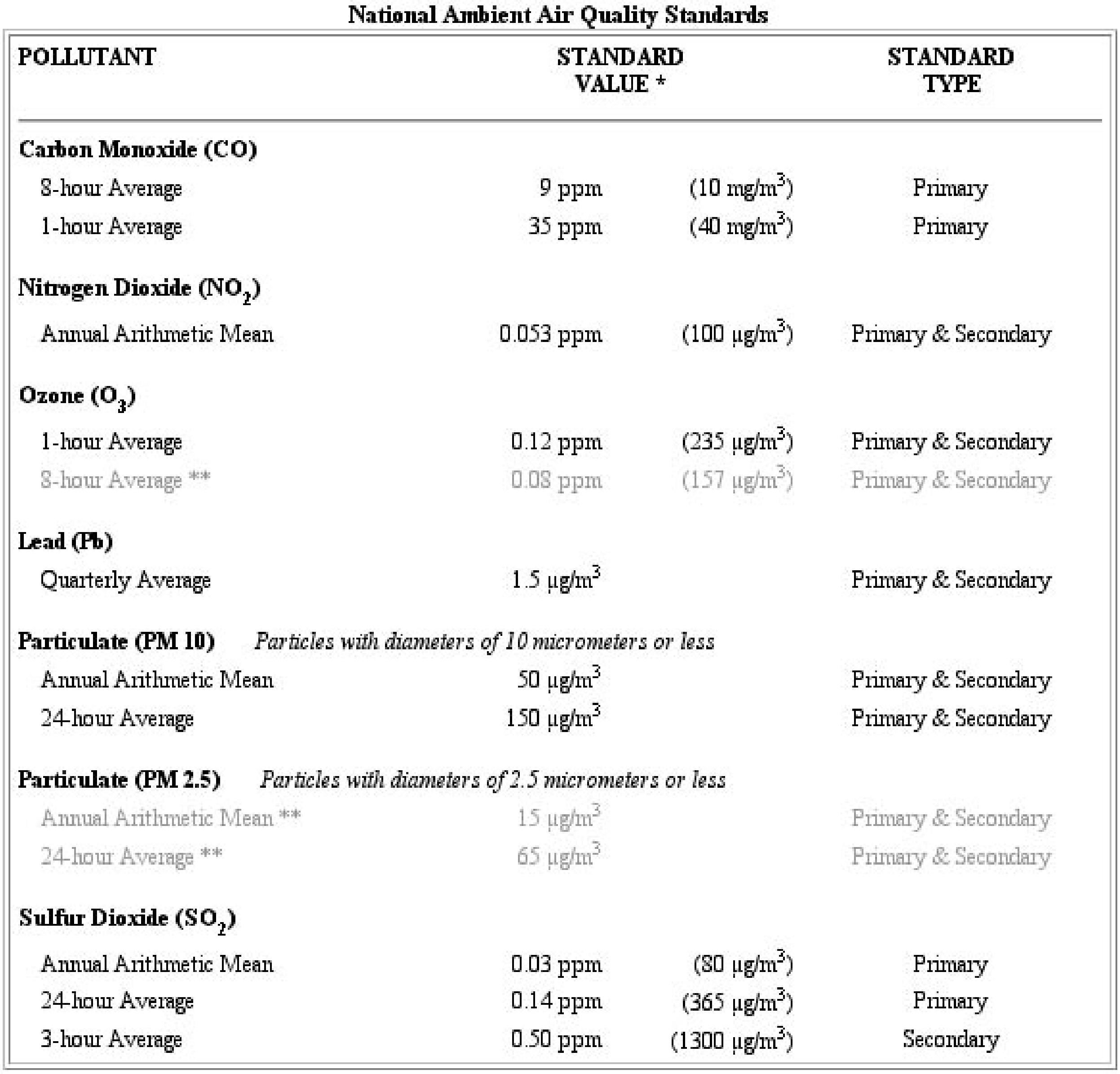
Source control, filtration and the use of ventilation to dilute contaminants are the primary methods for improving indoor air quality in most buildings.

Often seen outdoors, indoor plants are the best, natural and economical purifiers available to combat indoor air pollution.

Properly utilize and maintain air filters and cleaners

Unit – 8 (Standards and legislation)

Air Quality and Emission Standards



National Ambient Air Quality Standards

POLLUTANT	STANDARD VALUE *		STANDARD TYPE
Carbon Monoxide (CO)			
8-hour Average	9 ppm	(10 mg/m^3)	Primary
1-hour Average	35 ppm	(40 mg/m^3)	Primary
Nitrogen Dioxide (NO_2)			
Annual Arithmetic Mean	0.053 ppm	(100 µg/m^3)	Primary & Secondary
Ozone (O_3)			
1-hour Average	0.12 ppm	(235 µg/m^3)	Primary & Secondary
8-hour Average **	0.08 ppm	(157 µg/m^3)	Primary & Secondary
Lead (Pb)			
Quarterly Average	1.5 µg/m^3		Primary & Secondary
Particulate (PM 10) *Particles with diameters of 10 micrometers or less*			
Annual Arithmetic Mean	50 µg/m^3		Primary & Secondary
24-hour Average	150 µg/m^3		Primary & Secondary
Particulate (PM 2.5) *Particles with diameters of 2.5 micrometers or less*			
Annual Arithmetic Mean **	15 µg/m^3		Primary & Secondary
24-hour Average **	65 µg/m^3		Primary & Secondary
Sulfur Dioxide (SO_2)			
Annual Arithmetic Mean	0.03 ppm	(80 µg/m^3)	Primary
24-hour Average	0.14 ppm	(365 µg/m^3)	Primary
3-hour Average	0.50 ppm	(1300 µg/m^3)	Secondary

EMISSION STANDARD

Emission standards are requirements that set specific limits to the amount of pollutants that can be released into the environment. Many emissions standards focus on regulating pollutants released by automobiles (motor cars) and other powered vehicles but they can also regulate emissions from industry, power plants, small equipment such as lawn mowers and diesel generators. Frequent policy alternatives to emissions standards are technology standards (which mandate Standards generally regulate the emissions of nitrogen oxides (NOx), sulfur oxides, particulate matter (PM) or soot, carbon monoxide (CO), or volatile hydrocarbons (see carbon dioxide equivalent).

LEGISLATION AND REGULATION

Short title, extent and commencement.

THE AIR (PREVENTION AND CONTROL OF POLLUTION) ACT, 1981

(1) This Act may be called the Air (Prevention and Control of Pollution) Act, 1981.

(2) It extends to the whole of India, with effect from 16 May 1981.

(3) It shall come into force on such date as the Central Government may, by notification in the Official Gazette, appoint.

Definitions.

In this Act, unless the context otherwise requires,-

(a) "air pollutant" means any solid, liquid or gaseous substance 2[(including noise)] present in the atmosphere in such concentration as may be or tend to be injurious to human beings or other living creatures or plants or property or environment;

(b) "air pollution" means the presence in the atmosphere of any air

(c) "approved appliances" means any equipment or gadget used for the bringing of any combustible material or for generating or consuming any fume, gas of particulate matter and approved by the State Board for the purpose of this Act;

(d) "approved fuel" means any fuel approved by the State Board for the purposes of this Act;

(e) "automobile" means any vehicle powered either by internal combustion engine or by any method of generating power to drive such vehicle by burning fuel;

(h) "chimney" includes any structure with an opening or outlet from or through which any air pollutant may be emitted,

(i) "control equipment" means any apparatus, device, equipment or system to control the quality and manner of emission of any air pollutant and includes any device used for securing the efficient operation of any industrial plant;

(j) "emission" means any solid or liquid or gaseous substance coming out of any chimney, duct or flue or any other outlet;

(k) "industrial plant" means any plant used for any industrial or trade purposes and emitting any air pollutant into the atmosphere;

4[(m) "occupier", in relation to any factory or premises, means the person who has control over the affairs of the factory or the premises, and includes, in relation to any substance, the person in possession of the substance;]

Powers and functions of boards

Functions of Central Board.

(1) Subject to the provisions of this Act, and without prejudice to the performance, of its functions under the Water (Prevention and Control of Pollution) Act, IL974 (6 of 1974), the main functions of the Central Board shall be to improve the quality of air and to prevent, control or abate air pollution in the country.

(2) In particular and without prejudice to the generality of the foregoing functions, the Central Board may-

(a) advise the Central Government on any matter concerning the improvement of the quality of air and the prevention, control or abatement of air pollution;

(b) plan and cause to be executed a nation-wide programme for the prevention, control or abatement of air pollution;

(c) co-ordinate the activities of the State and resolve disputes among them;

(d) provide technical assistance and guidance to the State Boards, carry out and sponsor investigations and research relating to problems of air pollution and prevention, control or abatement of air pollution;

(e) plan and organise the training of persons engaged or to be engaged in programmes for the prevention, control or abatement of air pollution on such terms and conditions as the Central Board may specify;

(f) organise through mass media a comprehensive programme regarding the prevention, control or abatement of air pollution;

(g) collect, compile and publish technical and statistical data relating to air pollution and the measures devised for its effective prevention, control or abatement and prepare manuals, codes or guides relating to prevention, control or abatement of air pollution;

(h) lay down standards for the quality of air.,

(i) collect and disseminate information in respect of matters relating to air pollution;

(j) perform such other functions as may be prescribed.

(3) The Central Board may establish or recognise a laboratory or laboratories to enable the Central Board to perform its functions under this section efficiently.

FUNCTIONS OF STATE BOARDS.

(1) subject to the provisions of this Act, and without prejudice to the performance of its functions, if any, under the Water (Prevention and Control of Pollution) Act, 1974 (Act 6 of 1974), the functions of a State Board shall be-

(a) to plan a comprehensive programme for the prevention, control or abatement of air pollution and to secure the execution thereof-,

(b) to advise the State Government on any matter concerning the prevention, control or abatement of air pollution;

(c) to collect and disseminate information relating to air pollution;

(d) to collaborate with the Central Board in organising the training of persons engaged or to be engaged in programmes relating to prevention, control or abatement of air pollution and to organise mass-education programme relating thereto;

(e) to inspect, at all reasonable times, any control equipment, industrial plant or manufacturing process and to give, by order, such directions to such persons as it may consider necessary to take steps for the prevention, control or abatement of air pollution;

(f) to inspect air pollution control areas at such intervals as it may think necessary, assess the quality of air therein and take steps for the prevention, control or abatement of air pollution in such areas;

(g) to lay down, in consultation with the Central Board and having regard to the standards for the quality of air laid down by the Central Board, standards for emission of air pollutants into the atmosphere from industrial plants and automobiles or for the discharge of any air pollutant into the atmosphere from any other source whatsoever not being a ship or an aircraft:

(h) to advise the State Government with respect to the suitability of any premises or location for carrying on any industry which is likely to cause air pollution;

(i) to Perform such other functions as may be prescribed or as may, from time to time, be entrusted to it by the Central Board or the State Government;

(j) to do such other things and to perform such other acts as it may think necessary for the proper discharge of its functions and generally for the purpose of carrying into effect the purposes of this Act.

(2) A State Board may establish or recognise a laboratory or laboratories to enable the State Board to perform its functions under this section efficiently.

Powers under the Act

Power to declare air pollution control areas

Power to give instructions for ensuring standards for emission from automobiles.

Power of Board to make application to court for restraining person from causing air pollution.

Restrictions on use of certain industrial plants.

Power to obtain information.

Power of entry and inspection.

PENALTIES AND PROCEDURE

Penalties for certain acts. Whoever-

(a) destroys, pulls down, removes, injures or defaces any pillar, post or stake fixed in the ground or any notice or other matter put up, incsribed or placed, by or under the authority of the Board, or

(b) obstructs any person acting under the orders or directions of the Board from exercising his powers and performing his functions under this Act, or

(c) damages any works or property belonging to the Board, or

(d) fails to furnish to the Board or any officer or other employee of the Board any information required by the Board or such officer or other employee for the purpose of this Act, or

(e) fails to intimate the occurrence of the emission of air pollutants into the atmosphere in excess of the standards laid down by the State Board or the apprehension of such occurrence, to the State Board and other prescribed authorities or agencies as required under sub-section (1) of section 23, or

(f) in giving any information which he is required to give under this Act, makes a statement which is false in any material particular, or

(g) for the purpose of obtaining any consent under section 21, makes a statement which is false in any material particular shall be punishable with imprisonment for a term which may extend to three months or with fine which may extend to 29[ten thousand rupees] or with both.

Penalty for contravention of provisions of the Act.

Whoever contravenes any of the provisions of this Act or any order or direction issued thereunder, for which no penalty has been elsewhere provided in this Act, shall be punishable with imprisonment for a term which may extend to three months or with fine which may extend to ten thousand rupees or with both, and in the case of continuing contravention, with an additional fine which may extend to five thousand, rupees for every day during which such contravention continues after conviction for the first such contravention.)

40. Offences by companies.

(1) Where an offence under this Act has been committed by a company, every person who, at the time the offence was committed, was directly in charge of, and was responsible to, the company for the conduct of the business of the company, as well as the company, shall be deemed to be guilty of the offence and shall be liable to be proceeded against and punished accordingly:

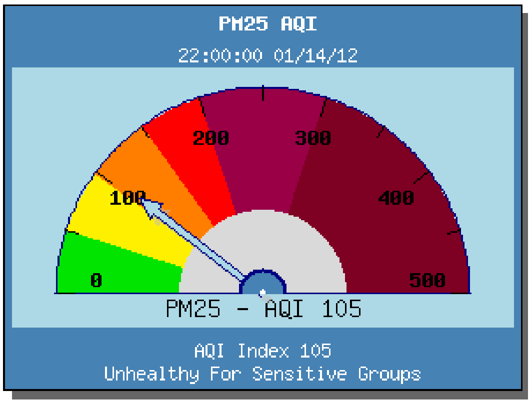
Provided that nothing contained in this sub-section shall render any such person liable to any punishment provided in this Act, if he proves that the offence was committed without his knowledge or that he exercised all due diligence to prevent the commission of such offence.

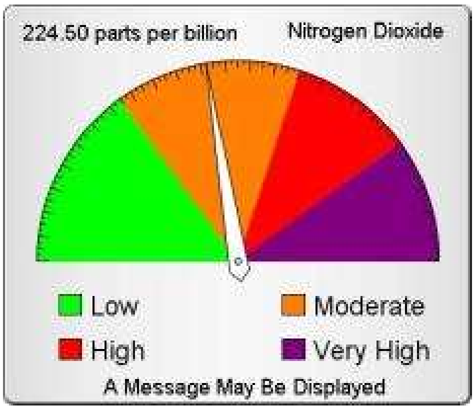
AIR POLLUTION INDEX

The Air Pollution Index (API) is a simple and generalized way to describe the air quality in. It is calculated from several sets of air pollution data. The API level is based on the level of 5 atmospheric pollutants, namely sulfur dioxide (SO2), nitrogen dioxide (NO2), suspended particulates (PM10), carbon monoxide (CO), and ozone (O3) measured at the monitoring stations. An air quality index (AQI) is a number used by government agencies to communicate to the public how polluted the air is currently or how polluted it is forecast to become. As the AQI increases, an increasingly large percentage of the population is likely to experience increasingly severe adverse health effects. Different countries have their own air quality indices which are not all consistent. Different countries also use different names for their indices such as Air Quality Health Index, Air Pollution Index and Pollutant Standards Index.

Air quality is defined as a measure of the condition of air relative to the requirements of one or more biotic species or to any human need or purpose.[1] To compute the AQI requires an air pollutant concentration from a monitor or model. The function used to convert from air pollutant concentration to AQI varies by pollutant, and is different in different countries. Air quality index values are divided into ranges, and each range is assigned a descriptor and a color code. Standardized public health advisories are associated with each AQI range.

PSI	Descriptor	General Health Effects
0 - 50		None
51 - 100	Moderate	Few or none for the general population
101 - 200	Unhealthy	Mild aggravation of symptoms among susceptible persons i.e. those with underlying conditions such as chronic heart or lung ailments; transient symptoms of irritation e.g. eye irritation, sneezing or coughing in some of the healthy population.
201 - 300	Very Unhealthy	Moderate aggravation of symptoms and decreased tolerance in persons with heart or lung disease; more widespread symptoms of transient irritation in the healthy population.
301 - 400	Hazardous	Early onset of certain diseases in addition to significant aggravation of symptoms in susceptible persons; and decreased exercise tolerance in healthy persons.
Above 400	Hazardous	PSI levels above 400 may be life-threatening to ill and elderly persons. Healthy people may experience adverse symptoms that affect normal activity.





UNIT 1

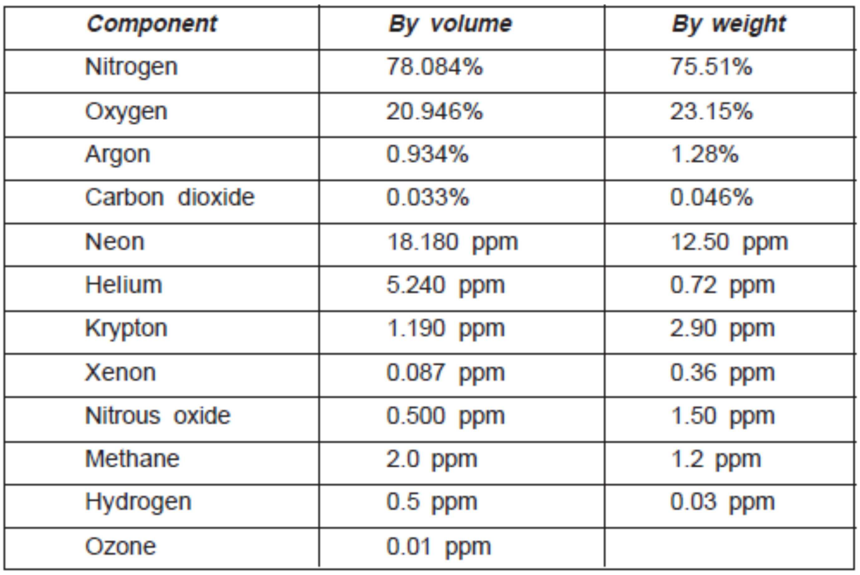
10CV765 APC

Definition of Air pollution: It is the presence of substances in air in sufficient concentration and for sufficient time, so as to be, or threaten to be injurious to human, plant or animal life, or to property, or which reasonably interferes with the comfortable enjoyment of life and property.

The air Act of Govt. of India (amendment 1987) defines air pollution as “air pollution means any solid, liquid or gaseous substances present in the atmosphere in such concentrations that may tend to be injurious to human beings or other living creatures or plants or property or enjoyment”.

Perkins (1974) defined air pollution as “air pollution means the presence in the outdoor atmosphere of one or more contaminants such as dust, fumes, gas, mist, odor, smoke or vapor in quantities or characteristics and of duration such as to be injurious to human, plant or animal life or to property or which unreasonably interferes with the comfortable enjoyment of life and property.”

Atmosphere can be defined as the thin blanket of air surrounding the earth. The clean dry air has following average composition:-



Component	*By volume*	*By weight*
Nitrogen	78.084%	75.51%
Oxygen	20.946%	23.15%
Argon	0.934%	1.28%
Carbon dioxide	0.033%	0.046%
Neon	18.180 ppm	12.50 ppm
Helium	5.240 ppm	0.72 ppm
Krypton	1.190 ppm	2.90 ppm
Xenon	0.087 ppm	0.36 ppm
Nitrous oxide	0.500 ppm	1.50 ppm
Methane	2.0 ppm	1.2 ppm
Hydrogen	0.5 ppm	0.03 ppm
Ozone	0.01 ppm	

Definition of Air pollutants: Substances introduces into the air, natural or manmade, in concentrations detrimental to human, plant or animal life, or to property.

Major Classification of Air Pollutants:

1] Primary – Secondary
2] Natural – Manmade
3] Criteria Air Pollutants
4] Physical - chemical - biological

Primary pollutants and secondary pollutants: Primary pollutants are substances that are directly emitted into the atmosphere from sources. Primary pollutants are those that are emitted directly from identifiable sources. Secondary air pollutants are those that are produced in the air by the interaction of two or more primary air pollutant.

Primary Air pollutants:-

(i) Fine (less than 100μ) and coarse (more than 100μ) suspended particulate matter
(ii) Oxides of sulfur
(iii) Oxides of nitrogen
(iv) Carbon monoxide
(v) Halogens
(vi) Organic compounds
(vii) Radioactive compounds

Secondary Air pollutants:-
(i) Ozone
(ii) PAN (peroxi aceyl nitrate)
(iii) Photochemical smog
(iv) Acid mists

Air pollutants arise from both manmade and natural processes. The ambient air quality may be defined by the concentration of a set of pollutants which may be present in the ambient air we breathe in. These pollutants may be called **criteria pollutants**.

Natural Contaminants: Pollen is important natural contaminant because of its peculiar properties of irritation and allergy sometimes leading to bronchitis, asthma and dermatitis. Pollen grains are the male gametophytes of gymnosperms and angiosperms and they are discharged into the atmosphere from plants etc. The air transported pollen grains range mainly between 10 and 50 microns. Manmade refers to any pollutant produced to influence or action of humans.

Aerosols: Aerosols refer to the dispersion of solid or liquid particles of microscopic size in the air. It can also be defined as a colloidal system in which the dispersion medium is gas and the dispersed phase is solid or liquid. The term aerosol is applicable until it is in suspension and after settlement due to its own weight or by addition with other particles (agglomeration) it is no longer an air pollutant. The diameter of the aerosol may range from 0.01 (or less) micron to 100 micron.

The various aerosols are as follows:-

(i) **Dust:** Dust is produced by the crushing, grinding and natural sources like windstorms. Generally the dust particles are over 20 micron in diameter. They do not flocculate but settle under gravity, but smaller particles like 5 micron form stable suspensions.

(ii) **Smoke:** Smoke is made up of finely divided particles produced by incomplete combustion. Generally it consists of carbon particles of size less than 1.0 micron.

(iii) **Mists:** Mist is a light dispersion of minute water droplets suspended in the atmosphere ranging from 40 to 400 micron in size.

(iv) **Fog:** Fog is made up of dispersion of water or ice near the earth’s surface reducing visibility to less than 500 m. In natural fog the size of particles range from 1.0 to 40 micron.

(v) **Fumes:** Fumes are solid particles generated by condensation from the gaseous state after volatilization from melted substances. Fumes flocculate and sometimes coalesce. Gases:

Following are the **main air pollutant gases**

(i) **Sulphur dioxide:** It is a major air pollutant gas produced by the combustion of fuels like coal. The main source of electricity production is by burning of fossil fuels in India and the whole world. The sulphur content of the coal varies from 1 to 4% and fortunately the Indian coal is low in sulphur content. SO2 is also produced in the metallurgical operations.

(ii) **Oxides of nitrogen:** Oxides of nitrogen are produced either in the production of nitric acid or in the automobile exhausts and as the effluent of power plants. Out of the seven oxides of Nitrogen (N_2O, NO, NO_2, NO_3, N_2O_3, N_2O_4, N_2O_5) only nitric oxide and nitrogen dioxide are classified as the main pollutants. All the oxides of nitrogen are collectively known as NO_X.

(iii) **Carbon monoxide:** It is produced because of the incomplete combustion of coal and other petroleum products. It is produced in the exhaust of automobiles. In the pollution check of vehicles mainly CO and unburnt hydrocarbons are measured.

(iv) **Hydrogen sulphide:** Hydrogen Sulphide is an obnoxious (bad smelling) gas. It is produced mainly by the anaerobic (in absence of air) decomposition of organic matter. Other air polluting sulfur compounds are methyl mercaptan (CH_3SH) and dimethyl sulphide (CH_3-S-CH_3) etc.

(v) **Hydrogen fluoride:** It is an important pollutant even in very low concentrations. It is produced in the manufacturing of phosphate fertilizers.

(vi) **Chlorine and hydrogen chloride:** It is mixed in the air either from the leakages from water treatment plants or other industries where it is produced or used. Hydrogen chloride is also evolved in various industrial chemical processes. The main effect of chlorine is respiratory irritation which may be fatal.

(vii) **Ozone:** It is a desirable gas in the upper layers of atmosphere as it absorbs the UV radiation of sunlight. But near the earth surface it is a poisonous gas. It makes poisonous chemicals by photochemical reactions.

(viii) **Aldehydes:** They are produced by the incomplete oxidation of motor fuels and lubricating oil. They may also be formed because of photochemical reactions. Formaldehydes are irritating to the eyes.

Classification according to chemical composition: (Organic – inorganic)

1. Sulfur-containing compounds.
2. Nitrogen-containing compounds.
3. Carbon-containing compounds.
4. Halogen-containing compounds.
5. Toxic substances (any of about).
6. Radiative compounds.

Classification according to physical state:

1. Gaseous.
2. Liquid (aqueous).
3. Solid.

Criteria air pollutants are six major pollutants defined by EPA (Environmental Protection Agency) for which ambient air standards have been set to protect human health and welfare. These include :

1. Ozone, O_3.
2. Carbon monoxide, CO.
3. Sulfur dioxide, SO_2.
4. Nitrogen oxides, NO_x.
5. Lead, Pb.
6. Particulates, PM_{10}.

Pollutant	Description	Sources	Health Effects	Welfare Effects
Carbon Monoxide (CO)	Colorless, odorless gas	Motor vehicle exhaust, indoor sources include kerosene or wood burning stoves.	Headaches reduced mental alertness, heart attack, cardiovascular diseases, impaired fetal development, and death.	Contribute to the formation of smog.
Sulfur Dioxide (SO2)	Colorless gas that dissolves in water vapor to form acid, and interact with other gases and particles in the air.	Coal-fired power plants, petroleum refineries, manufacture of sulfuric acid and smelting of ores containing sulfur.	Eye irritation, wheezing, chest tightness, shortness of breath, lung damage.	Contribute to the formation of acid rain, visibility impairment, plant and water damage, aesthetic damage.
Nitrogen Dioxide (NO2)	Reddish brown, highly reactive gas.	Motor vehicles, electric utilities, and other industrial, commercial, and residential sources that burn fuels.	Susceptibility to respiratory infections, irritation of the lung and respiratory symptoms (e.g., cough, chest pain, difficulty breathing).	Contribute to the formation of smog, acid rain, water quality deterioration, global warming, and visibility impairment.
Ozone (O3)	Gaseous pollutant when it is formed in the troposphere.	Vehicle exhaust and certain other fumes. Formed from other air pollutants in the presence of sunlight.	Eye and throat irritation, coughing, respiratory tract problems, asthma, lung damage.	Plant and ecosystem damage.
Lead (Pb)	Metallic element	Metal refineries, lead smelters, battery manufacturers, iron and steel producers.	Anemia, high blood pressure, brain and kidney damage, neurological disorders, cancer, lowered IQ.	Affects animals and plants, affects aquatic ecosystems.
Particulate Matter (PM)	Very small particles of soot, dust, or other matter, including tiny droplets of liquids.	Diesel engines, power plants, industries, windblown dust, wood stoves.	Eye irritation, asthma, bronchitis, lung damage, cancer, heavy metal poisoning, cardiovascular effects.	Visibility impairment, atmospheric deposition, aesthetic damage.

Emission Sources

Major Classification of Air Pollution Sources:

1] Based on Origin: Natural and Manmade

While man-made air pollution does present health hazards, natural sources of air pollution can be equally dangerous at times. These sources include dust picked up by wind erosion, the emission of methane by livestock, and smoke from wildfires. Volcanic eruptions are perhaps the largest single source of air pollution, natural or man-made, that humans have ever dealt with. These can produce clouds of abrasive volcanic ash and other harmful substances such as chlorine and sulfur.

2] Based on Position: Stationary and Mobile

The sources of air pollution may be classified as stationary point sources (generally industrial in origin), diffuse or area sources and mobile sources (mainly cars and trucks).

3] Based on Aix of Release: Horizontal axis (Roadways traffic)
Vertical Axis release (Industrial Stacks)
4] Based on Intensity/frequency of release: Continuous release (Industrial Stacks)
Instantaneous release (Roadways traffic)

Stationary Sources

The stationary industrial sources are usually classified by process type or sub-type. Thus an oil refining plant also includes large industrial boilers as a sub-type. Small and medium scale plants such as garment or food processing plants may include industrial boilers, a common source of air pollution. The quality and type of fuel used for energy production are important determinants of the air pollution potential of a plant. Each type of plant or activity generally emits more than one pollutant, and the pollutant emission rate depends on the fuel type and quality, the design of the plant (and whether fitted with air pollution control devices or not), and the activity rate or output of the plant.

(i) Point source (power plant stacks)
(ii) Area source (forest fires, open burning)
(iii) Line Source (highway vehicle exhausts)

Mobile Sources Refer mainly to emissions from cars, trucks, minibuses and buses. The fuel source may be petrol or diesel, and emissions include exhaust emissions and fugitive emissions. Vehicle (mobile) source emissions depend on a number of factors, including vehicle size, fuel type, speed and vehicle technology. Total vehicle emissions depend on the vehicle population on the road at a given time.

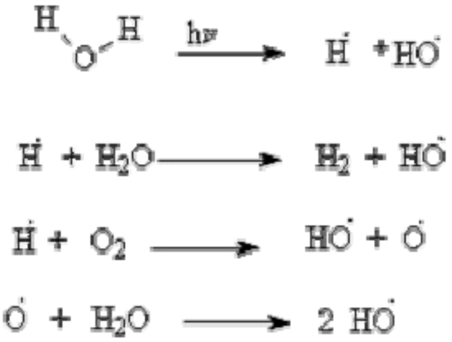
Chemical Reactions in the Atmosphere

Substances in the top layer of the geosphere, known as the lithosphere, tend to become more reduced over time. Biomass (CH_2O) for example is slowly transformed to substances which have no oxygen atoms through a sequence of steps, then to compounds with successively larger carbon to hydrogen ratios and finally to products with a form of pure carbon. However, atmospheric chemical reactions have the opposite effect on substances, causing an atom to become more oxidized over time in the atmosphere. Atmospheric gases that are found in their reduced states are oxidized stepwise to form ionic substances that are washed out of the atmosphere in rainfall. Example, dissolution of atmospheric hydrogen sulfide by rain to form sulfate molecule.

$$H_2S + H_2O\ (\text{rain}) \rightarrow SO_4^{2-}$$

Chemical reactions in the atmosphere can occur as gas phase collisions between molecules, on the surfaces of solid particles or in aqueous solution (in water droplets); predominantly acid-base reactions. Particles spend short residence time in the atmosphere. Due to this, reactions that occur on particle surfaces are of minor importance in most cases. Gas phase reactions dominate the chemical changes that occur to substances in the atmosphere.

The most important single species in atmospheric chemistry is the hydroxyl radical (HO·). This radical is formed by several reactions. However, the primary process is one where an O-H bond of the water molecule is broken to form a hydrogen atom (H·) and a hydroxyl radical (HO·). The hydrogen atom can then react with another water molecule to form hydrogen and a second hydroxyl radical, or with an oxygen molecule (O2) to form a second hydroxyl radical and an oxygen atom. The new oxygen atom can then react with another water molecule to form two new hydroxyl radicals.



Molecules in the atmosphere are continually moving and colliding with one another, as described by the kinetic-molecular theory. The atmosphere is also continually illuminated during daylight hours. As a result, absorption of light energy by atmospheric molecules can cause photochemical reactions, reactions that would not occur at normal atmospheric temperatures in the absence of light. Such reactions play an important role in determining the composition of the atmosphere itself and the fate of many chemical species that contribute to air pollution.

Nitrogen dioxide, NO2, is one of the most photochemically active species in the atmosphere. The NO2 molecule is an example of a free radical because it contains an unpaired electron, represented by a next to its formula. When an NO2 molecule absorbs a photon of light with energy, the molecule is raised to a higher energy level; it becomes an electronically excited molecule, designated by an asterisk (*).

$$\cdot\mathrm{NO_2(g)} \xrightarrow{h\nu} \cdot\mathrm{NO_2^*}$$

The excited molecule may quickly re-emit a photon of light, or the energy may break an N-O bond to form a nitrogen monoxide (NO) molecule and an oxygen atom (O). Both NO and O are free radicals, because they have one or more unpaired electrons each denoted by a dot.

$$\cdot NO_2^*(g) \xrightarrow{h\nu} \cdot NO(g) + \cdot O \cdot (g)$$

Photodissociation is another mechanism of formation of radicals, in which a molecule absorbs an ultraviolet photon and produces two free radicals as products. Molecular oxygen can photodissociate to form two oxygen atoms.

$$O_2(g) \xrightarrow{h\nu} \cdot O \cdot (g) + \cdot O \cdot (g)$$

Some free radicals, such as an oxygen atom, react with another atom or molecule almost immediately. Others, such as an NO2 molecule, are not quite so reactive and are stable enough to exist for a somewhat longer time. Most radicals are highly reactive and short-lived.

Fate of air pollutants in the atmosphere

1] NO_x, Hydrocarbons, Ozone, Mist: - Formation of photochemical smog

2] SO_2, NO_x: - Formation of Acid Mist / Rain

3] SO_2, CO, Mist: - Formation of coal induced smog

4] [O], NOx, OH^- - Formation of Ozone

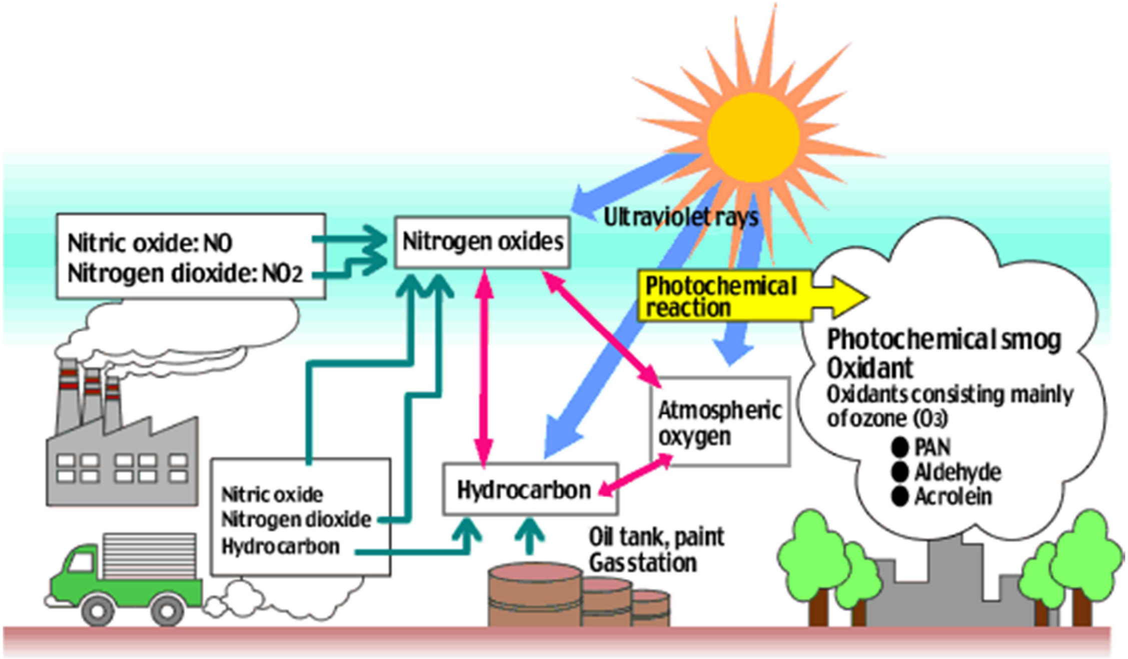
PHOTO CHEMICAL SMOG

Photochemical smog was first described in the 1950s. It is the chemical reaction of sunlight, nitrogen oxides and volatile organic compounds in the atmosphere, which leaves airborne

particles and ground-level ozone. This noxious mixture of air pollutants can includes Aldehydes, Nitrogen oxides, such as nitrogen dioxide, Peroxyacyl nitrates

Tropospheric ozone, Volatile organic compounds etc. All of these chemicals are usually highly reactive and oxidizing. Photochemical smog is considered to be a problem of modern industrialization. It is present in all modern cities, but it is more common in cities with sunny, warm, dry climates and a large number of motor vehicles. Because it travels with the wind, it can affect sparsely populated areas as well.

$$\text{VOCs} + \text{NOx} + \text{sunlight} \rightarrow \text{photochemical smog}$$



To begin the chemical process of photochemical smog development the following conditions must occur:

- Sunlight.
- The production of oxides of nitrogen (NOx).
- The production of volatile organic compounds (VOCs).
- Temperatures greater than 18 degrees Celsius.

Nitrogen oxide is an essential ingredient of photochemical smog that is produced during the high temperatures associated with combustion of vehicle’s engines. Nitrogen oxide is an essential ingredient of photochemical smog that is produced during the high temperatures associated with combustion of vehicle’s engines.

Formation

Sunlight can break down nitrogen dioxide back into nitrogen oxide.

$$NO2 + \text{sunlight} \text{ »»» } NO + O$$

The atomic oxygen formed in the above reaction then reacts with one of the abundant oxygen molecules producing ozone.

$$O + O2 \text{ »»» } O3$$

Nitrogen dioxide can also react with radicals produced from volatile organic compounds in a series of reactions to form toxic products such as peroxyacetyl nitrates.

$$NO2 + R \text{ »»» products such as PAN}$$

Note the symbol R represents a hydrocarbon (a molecule composed of carbon, hydrogen and other atoms) which is primarily created from volatile organic compounds.

Steps

1) Nitrogen oxides generate oxygen atoms

2) Oxygen atoms form hydroxyl radicals

3) Hydroxyl radicals generate hydrocarbon radicals

4) Hydrocarbon radicals form hydrocarbon peroxides

5) Hydrocarbon peroxides form aldehydes

6) Aldehydes form aldehyde peroxides

7) Aldehyde peroxides form peroxy-acyl-nitrates

Health effects

It can cause eye and nose irritation and it dries out the protective membranes of the nose and throat and interferes with the body's ability to fight infection, increasing susceptibility to illness.

COAL INDUCED SMOG

Introduction to Smog

Smog is a recent compound word from "smoke" and "fog", and was coined by Harold Antoine des Voeux, a doctor, in 1905. Smog refers to locally high concentrations of acids, dry acid-forming compounds, particulates, or other pollutants in stagnant, stable air. Smog’s form when emissions are prevented from dispersing by stable or sinking air masses. They were very prevalent in European and North American cities during first part of 20th Century. London smog’s were infamous in the 19th and early 20th centuries and formed every autumn and winter due to sulphur emissions from coal burning industries and domestic fires. The most severe London smog was on 4-10th December 1952, when cold, high-pressure conditions trapped coal smoke in foggy air. The output of smoke was increased by the cold weather, due to the large numbers of domestic fires. Sooty smoke produced peak daily concentrations of black smoke of 5000 mgs/m3 (WHO 24 hr. max limit of 100-150), and daily average SO2 levels of 3000-4000 mg/m3 (WHO 24 hr. max limit of 100-150). Sulphuric acid droplets resulted in pH estimated as 1.4 to 1.9: as acidic as car battery acid.

$$H_2SO_{4(g)} + H_2O \rightarrow H_2SO_{4(aq)}$$

$$SO_{2(g)} + H_2O_{(l)} \rightarrow H_2SO_{3(aq)}$$

Chemistry

These are produced by high outputs of SO2, which are converted to acids on contact with atmospheric moisture. Usually, sulphurous smog’s also contain elevated concentrations of suspended soot.

Impacts

Visibility was reduced to 5m at times, and London buses had to be guided through the street by men with lanterns during daylight hours. The smog lasted for 5 days, eventually extending over a 50km radius. Approx. 4,000 excess deaths occurred as a result of inhaling pollution, mainly old and sick and those with chest problems. Respiratory diseases alone accounted for 59 per cent of the increase in deaths registered in the week ending 13 December and 76 per cent in the following week. Bronchitis and emphysema were the two conditions that stood out in the coroner’s records as showing the greatest increase. Cardiovascular disease accounted for 22 per cent of the increased number of deaths in the first week and 16 per cent in the week ending 20 December. The disaster ultimately led to the introduction of the Clean Air Acts.

ACID MIST/ RAIN

Definition

Normal Rain water p^H is slightly acidic due to certain concentration of CO_2 dissolved as rainwater trickles down atmosphere,

$$CO_2+H_2O\rightarrow HCO^{3-}+H^+$$

Acid rain is defined as any type of precipitation with a p^H that is unusually low or lower than 5.7. Acid rain was first found in Manchester, England. In 1852, Robert Angus Smith found the relationship between acid rain and atmospheric pollution. Though acid rain was discovered in 1852, it wasn't until the late 1960s that scientists began widely observing and studying the phenomenon.

Causes

The principal natural phenomena that contribute acid-producing gases to the atmosphere are emissions from volcanoes and those from biological processes that occur on the land, in wetlands, and in the oceans. The major biological source of sulfur containing compounds is dimethyl sulfide.

The principal cause of acid rain is sulfuric and nitrogen compounds from human sources, such as electricity generation, factories and motor vehicles. Coal power plants are one of the most polluting. The gases can be carried hundreds of kilometres in the atmosphere before they are converted to acids and deposited. Factories used to have short funnels to let out smoke, but this caused many problems, so now, factories have longer smoke funnels. The problem with this is those pollutants get carried far off, where it creates more destruction.

Sulfur dioxide contributes to about seventy percent of acid rain while nitrogen oxides provide the remaining thirty percent. The sources of sulfur in the atmosphere include coal combustion, smelting, organic decay, and ocean spray. Approximately ninety percent of atmospheric sulfur results from human activities.

In the atmosphere, sulfur dioxide combines with water vapor to form hydrogen sulfite gas:

$$SO_2 + H_2O+1/2O_2 \rightarrow H_2SO_4$$

Next, hydrogen sulfite reacts with oxygen to form sulfuric acid, a major component of acid rain:

$$H_2SO_3 + 1/2O_2 \rightarrow H_2SO_4$$

The sources of nitrogen oxides include the combustion of oil, coal and natural gas, forest fires, bacterial action in soil, volcanic gases, and lighting-induced atmospheric reactions.

In the atmosphere, nitrogen monoxide reacts with oxygen gas to form nitrogen dioxide gas:

$$NO + 1/2O_2 \rightarrow NO_2$$

Then, nitrogen dioxide reacts with water vapor in the atmosphere to form hydrogen nitrite and hydrogen nitrate:

$$2NO_2 + H_2O \rightarrow HNO_2 + HNO_3$$

Henceforth, acid rain is a mixture of HNO_3, H_2SO_4 + HCl. however conditions needed to favor formation of these are sunlight, temperature, humidity, hydrocarbons, NO_X, SO_2.

Effects

Both the lower p^H and higher aluminum concentrations in surface water that occur as a result of acid rain can cause damage to fish and other aquatic animals. At p^H lower than 5 most fish eggs will not hatch and lower p^H can kill adult fish. As lakes become more acidic biodiversity is reduced. Soil biology can be seriously damaged by acid rain. Some tropical microbes can quickly consume acids but other microbes are unable to tolerate low p^H and are killed.

Acid rain can slow the growth of forests, cause leaves and needles to turn brown and fall off and die. In extreme cases trees or whole areas of forest can die. The death of trees is not usually a direct result of acid rain; often it weakens trees and makes them more susceptible to other threats. Some scientists have suggested direct links to human health, but none have been proven. However, fine particles, a large fraction of which are formed from the same gases as acid rain (sulfur dioxide and nitrogen dioxide), have been shown to cause illness and premature deaths such as cancer and other deadly diseases

Toxic metals released into the environment by acid rain may enter water supplies or accumulate in fish and crops. Acid deposition also destroys statues, headstones, buildings, and fountains. Limestone structures are especially susceptible because they dissolve easily in acidic solutions.

Acid rain can also cause damage to certain building materials and historical monuments. Acid rain can cause weathering on ancient and valuable statues and has caused considerable damage. This is because the sulfuric acid in the rain chemically reacts with the calcium compounds in the stones (limestone, sandstone, marble and granite) to create gypsum, which then flakes off. Acid rain also causes an increased rate of oxidation for iron.

Control

- Design more efficient automobile engines in order to reduce nitrogen oxide emissions.
- Increase efficiency of power plants that burn coal in order to reduce waste that contains sulfur dioxide and nitrogen oxide.
- Increase penalties on industries that do not meet air pollution guidelines.

- Increase tax incentives to industries that do meet guidelines.
- Use alternative energy sources, Increase funding for alternative energy sources; for example, give tax incentives to buyers of hybrid cars.
- Provide tax incentives to companies that use alternative energy sources.
- Add $CaCO_3$ (calcium carbonate) to lakes suffering from acid deposition; calcium carbonate acts as a buffer, resisting a change in p^H and lessening the negative effects of acid rain.

OZONE DEPLETION

Definition

Ozone layer is an umbrella 24 km [15 miles] from earth surface, an essential component of the stratosphere that absorbs short wavelength ultraviolet radiation from the sun, heating the gases of the stratosphere in the process. World ozone day is celebrated on Sept, 16 of every year.

Stratospheric ozone is measured in Dobson units [DU] named after G.M.B Dobson who pioneered the study; [I Dobson unit = 0.01 mm thickness of stratospheric ozone], Average ozone thickness in stratosphere is 300 DU, & when it falls below 200 DU, it’s considered as Ozone hole. It is thinnest around equator and thickest near poles.

Stratospheric ozone depletion is the term applied to the loss of stratospheric ozone molecules (O_3) and the disruption of Oxygen-Ozone concentration equilibrium in stratosphere [i.e., when chlorine atoms upset the natural O_2/O_3 equilibrium in the stratosphere]. Oxygen molecules interact with the intense solar radiation present at this elevation to form oxygen atoms. The oxygen atoms thus generated react with other oxygen molecules to form ozone (O_3).

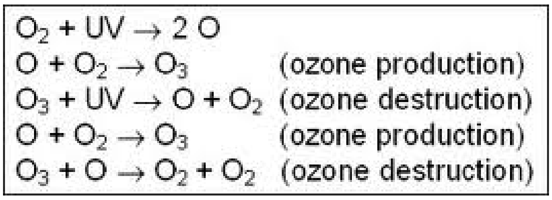
Causes

Ozone depletion is caused by the release of chlorofluorocarbons (CFC's) and other ozone-depleting substances (ODS), which were used widely as refrigerants, insulating foams, and solvents. The discussion below focuses on CFCs, but is relevant to all ODS [NO, NO_2 (aircraft exhaust), Br^-, UV rays, [O] Atomic oxygen etc].

Although CFCs are heavier than air, they are eventually carried into the stratosphere in a process that can take as long as 2 to 5 years. When CFCs reach the stratosphere, the ultraviolet radiation from the sun causes them to break apart and release chlorine atoms which react with ozone, starting chemical cycles of ozone destruction that deplete the ozone layer. One chlorine atom can break apart more than 100,000 ozone molecules.

Other chemicals that damage the ozone layer include methyl bromide (used as a pesticide), halons (used in fire extinguishers), and methyl chloroform (used as a solvent in industrial processes). As methyl bromide and halons are broken apart, they release bromine atoms, which are 40 times more destructive to ozone molecules than chlorine atoms.

Chapman's Reaction



$O_2 + UV \rightarrow 2\ O$

$O + O_2 \rightarrow O_3$ (ozone production)

$O_3 + UV \rightarrow O + O_2$ (ozone destruction)

$O + O_2 \rightarrow O_3$ (ozone production)

$O_3 + O \rightarrow O_2 + O_2$ (ozone destruction)

Ozone Depletion by CFC's

All above reactions occur in the presence of UV rays, while the 2nd set of reactions governs the oxygen-ozone equilibrium due to its spontaneity.

Effects

Effect of ozone hole include cataract, genetic mutation, constriction of blood vessels, reduced crop yield, leukemia, breast cancer, damage to crop, aqua culture, etc.,

The higher energy UV radiation absorbed by ozone is generally accepted to be a contributory factor to skin cancer. In addition, increased surface UV leads to increased tropospheric ozone, which is a health risk to humans such as Snow Blindness [photo keratosis], i.e., inflammation of cornea (outer coating of eyeball). The most common forms of skin cancer in humans, basal and squamous cell carcinomas have been strongly linked to UVB exposure. Another form of skin cancer, malignant melanoma, is much less common but far more dangerous, being lethal in about 15% - 20% of the cases diagnosed. In India there is no standard for Ozone. However WHO standard is 100 ppm for 8 hrs. – avg.

Control Measures

The Montreal Protocol, an international agreement signed by 139 nations, banning the production of CFCs by the year 2000. We can't make enough ozone to replace what's been destroyed, but provided that we stop producing ozone-depleting substances, natural ozone production reactions should return the ozone layer to normal levels by about 2050. It is very important that the world comply with the Montreal Protocol; delays in ending production could result in additional damage and prolong the ozone layer's recovery. Control mechanism stresses on replacement of the banned chemical by ammonia, steam, helium etc.

10CV765 / AIR POLLUTION AND CONTROL / R.G.

Unit – 2

Effects of air pollution On Human Health

Exposure to air pollution is associated with numerous effects on human health, including pulmonary, cardiac, vascular, and neurological impairments. The health effects vary greatly from person to person. High-risk groups such as the elderly, infants, pregnant women, and sufferers from chronic heart and lung diseases are more susceptible to air pollution. Children are at greater risk because they are generally more active outdoors and their lungs are still developing.

Exposure to air pollution can cause both acute (short-term) and chronic (long-term) health effects. Acute effects are usually immediate and often reversible when exposure to the pollutant ends. Some acute health effects include eye irritation, headaches, and nausea. Chronic effects are usually not immediate and tend not to be reversible when exposure to the pollutant ends. Some chronic health effects include decreased lung capacity and lung cancer resulting from long-term exposure to toxic air pollutants.

The scientific techniques for assessing health impacts of air pollution include air pollutant monitoring, exposure assessment, dosimetry, toxicology, and epidemiology. Although in humans pollutants can affect the skin, eyes and other body systems, they affect primarily the respiratory system. Air is breathed in through the nose, which acts as the primary filtering system of the body. The small hairs and the warm, humid conditions in the nose effectively remove the larger pollutant particles. Both gaseous and particulate air pollutants can have negative effects on the lungs. Solid particles can settle on the walls of the trachea, bronchi, and bronchioles. Most of these particles are removed from the lungs through the cleansing (sweeping) action of "cilia", small hair like outgrowths of cells, located on the walls of the lungs

Gaseous air pollutants may also affect the function of the lungs by slowing the action of the cilia. Continuous breathing of polluted air can slow the normal cleansing action of the lungs and result in more particles reaching the lower portions of the lung.

The table summarizes the sources, health and welfare effects for the Criteria Pollutants.

Pollutant	Description	Sources	Health Effects	Welfare Effects
Carbon Monoxide (CO)	Colorless, odorless gas	Motor vehicle exhaust, indoor sources include kerosene or wood burning stoves.	Headaches reduced mental alertness, heart attack, cardiovascular diseases, impaired fetal development, and death.	Contribute to the formation of smog.
Sulfur Dioxide (SO2)	Colorless gas that dissolves in water vapor to form acid, and interact with other gases and particles in the air.	Coal-fired power plants, petroleum refineries, manufacture of sulfuric acid and smelting of ores containing sulfur.	Eye irritation, wheezing, chest tightness, shortness of breath, lung damage.	Contribute to the formation of acid rain, visibility impairment, plant and water damage, aesthetic damage.
Nitrogen Dioxide (NO2)	Reddish brown, highly reactive gas.	Motor vehicles, electric utilities, and other industrial, commercial, and residential sources that burn fuels.	Susceptibility to respiratory infections, irritation of the lung and respiratory symptoms (e.g., cough, chest pain, difficulty breathing).	Contribute to the formation of smog, acid rain, water quality deterioration, global warming, and visibility impairment.
Ozone (O3)	Gaseous pollutant when it is formed in the troposphere.	Vehicle exhaust and certain other fumes. Formed from other air	Eye and throat irritation, coughing, respiratory tract problems, asthma, lung	Plant and ecosystem damage.

		pollutants in the presence of sunlight.	damage.	
Lead (Pb)	Metallic element	Metal refineries, lead smelters, battery manufacturers, iron and steel producers.	Anemia, high blood pressure, brain and kidney damage, neurological disorders, cancer, lowered IQ.	Affects animals and plants, affects aquatic ecosystems.
Particulate Matter (PM)	Very small particles of soot, dust, or other matter, including tiny droplets of liquids.	Diesel engines, power plants, industries, windblown dust, wood stoves.	Eye irritation, asthma, bronchitis, lung damage, cancer, heavy metal poisoning, cardiovascular effects.	Visibility impairment, atmospheric deposition, aesthetic damage.

Effects of air pollution On Plants

The effects of pollution on plants include mottled foliage, “burning” at leaf tips or margins, twig dieback, stunted growth, premature leaf drop, delayed maturity, abortion or early drop of blossoms, and reduced yield or quality.

In general, the visible injury to plants is of three types: (1) collapse of leaf tissue with the development of necrotic patterns, (2) yellowing or other color changes, and (3) alterations in growth or premature loss of foliage. Injury from air pollution can be confused with the symptoms caused by fungi, bacteria, viruses, nematodes, insects, nutritional deficiencies and toxicities, and the adverse effects of temperature, wind, and water.

Factors that govern the extent of damage and the region where air pollution is a problem are (1) type and concentration of pollutants, (2) distance from the source, (3) length of exposure, and (4) meteorological conditions.

Effects of air pollution On Materials

(i) Abrasion (loss of material by wind with coarser particles).

(ii) Corrosion (acidic effect of rain water).

(iii) Deposition and removal (adhering substances like SPM and removal of material by rusting.

(iv) Direct chemical attack (effect of gases like SO2).

(v) Indirect chemical attack (action of acid or its fumes on stones like marble, corrosion of reinforcement due to diffusion of gases in RCC).

MAJOR ENVIRONMENTAL AIR POLLUTION EPISODES

London Smog

Introduction to Smog

Smog is a recent compound word from "smoke" and "fog", and was coined by Harold Antoine des Voeux, a doctor, in 1905. Smog refers to locally high concentrations of acids, dry acid-forming compounds, particulates, or other pollutants in stagnant, stable air. Smog’s form when emissions are prevented from dispersing by stable or sinking air masses.

Introduction to London Smog

They were very prevalent in European and North American cities during first part of 20th Century. London smog’s were infamous in the 19th and early 20th centuries and formed every autumn and winter due to sulphur emissions from coal burning industries and domestic fires. The most severe London smog was on 4-10th December 1952, when cold, high-pressure conditions trapped coal smoke in foggy air. The output of smoke was increased by the cold weather, due to the large numbers of domestic fires. Sooty smoke produced peak daily concentrations of black smoke of 5000 mgs/m3 (WHO 24 hr max limit of 100-150), and daily average SO2 levels of 3000-4000 mg/m3 (WHO 24 hr max limit of 100-150). Sulphuric acid droplets resulted in pH estimated as 1.4 to 1.9: as acidic as car battery acid.

Chemistry

$$H_2SO_{4(g)} + H_2O \rightarrow H_2SO_{4(aq)}$$
$$SO_{2(g)} + H_2O_{(l)} \rightarrow H_2SO_{3(aq)}$$

These are produced by high outputs of SO2, which are converted to acids on contact with atmospheric moisture. Usually, sulphurous smog's also contain elevated concentrations of suspended soot.

Impacts

Visibility was reduced to 5m at times, and London buses had to be guided through the street by men with lanterns during daylight hours. The smog lasted for 5 days, eventually extending over a 50km radius. Approx. 4,000 excess deaths occurred as a result of inhaling pollution, mainly old and sick and those with chest problems. Respiratory diseases alone accounted for 59 per cent of the increase in deaths registered in the week ending 13 December and 76 per cent in the following week. Bronchitis and emphysema were the two conditions that stood out in the coroner's records as showing the greatest increase. Cardiovascular disease accounted for 22 per cent of the increased number of deaths in the first week and 16 per cent in the week ending 20 December. The disaster ultimately led to the introduction of the Clean Air Acts.

Bhopal Gas Tragedy

INTRODUCTION

The Bhopal gas tragedy was a gas leak incident in India and, considered one of the world's worst industrial disasters. It occurred on the night of 2nd and dawn of 3rd December 1984 at the Union Carbide India Limited (UCIL) pesticide plant in Bhopal, Madhya Pradesh, India. UCIL was the Indian subsidiary of Union Carbide Corporation. The plant manufactured Sevin Carbide, among other pesticides. MIC was one of the chemicals processed for the prime reactions.

ACCIDENT

Even before the December 1984 incident, numerous incidents had fore-warned of an oncoming disaster. During the incident, most of the safety systems were not functioning. Many valves and lines were in poor condition. Tank 610 contained 42 tons of MIC, much more than what safety rules allowed. During the nights of 2–3 December, a large amount of water is claimed to have entered tank 610. A runaway reaction started, which was accelerated by contaminants, high temperatures and other factors. The reaction generated a major increase in the temperature inside the tank to over 200 °C (400 °F). This forced the emergency venting of pressure from the MIC holding tank, releasing a large volume of toxic gases. The reaction was sped up by the presence of iron from corroding non-stainless steel pipelines. Workers cleaned pipelines with water and claim they were not told to isolate the tank with a pipe slip-blind plate. Owing of this, and the poor maintenance, the workers consider that water might have accidentally entered the tank.

IMPACT

A leak of methyl iso-cyanate gas and other chemicals from the plant resulted in the exposure of hundreds of thousands of people. The official immediate death toll was 2,259 and the government of Madhya Pradesh has confirmed a total of 3,787 deaths related to the gas release. Others estimate 8,000 died within two weeks and another 8,000 or more have since died from gas-related diseases. When panic was at its peak at major hospitals of the city, the patients could be graded symptomatically into four categories: (i) Minor eye ailments, throat irritation and cough, (ii) Severe conjunctivitis, keratitis, acute bronchitis and drowsiness, (iii) Severe pulmonary oedema leading to cardio-respiratory distress, and (iv) Convulsions, followed by cardio-respiratory arrest. Intense fatigue and muscular weakness was another common feature. Civil and criminal cases are pending in the United States District Court, Manhattan and the District Court of Bhopal, India, involving UCC, UCIL employees.

Passing of THE ENVIRONMENTAL PROTECTION ACT, 1986 and PUBLIC LIABILITY INSURANCE ACT, 1986

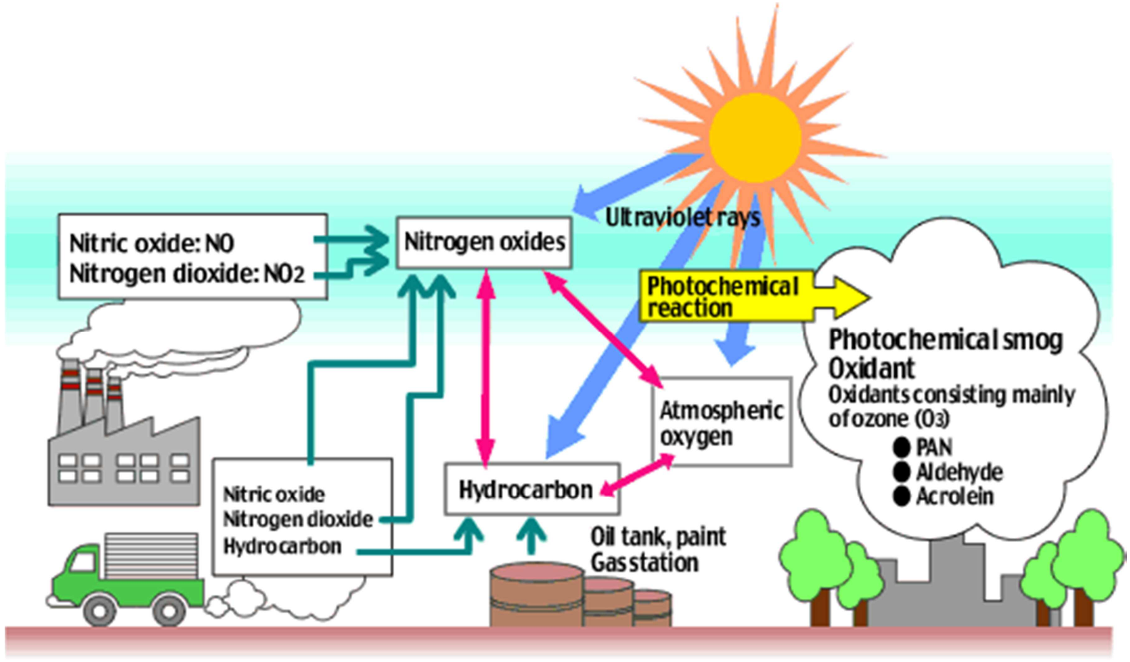
Los Angeles Smog

INTRODUCTION

Photochemical smog was first described in the 1950s. It is the chemical reaction of sunlight, nitrogen oxides and volatile organic compounds in the atmosphere, which leaves airborne particles and ground-level ozone. This noxious mixture of air pollutants can includes Aldehydes, Nitrogen oxides, such as nitrogen dioxide, Peroxyacyl nitrates Tropospheric ozone, Volatile organic compounds etc. All of these chemicals are usually highly reactive and oxidizing.

Photochemical smog is considered to be a problem of modern industrialization. It is present in all modern cities, but it is more common in cities with sunny, warm, dry climates and a large number of motor vehicles. Because it travels with the wind, it can affect sparsely populated areas as well.

$$\text{VOCs} + \text{NOx} + \text{sunlight} \rightarrow \text{photochemical smog}$$



To begin the chemical process of photochemical smog development the following conditions must occur:

- Sunlight.
- The production of oxides of nitrogen (NOx).
- The production of volatile organic compounds (VOCs).
- Temperatures greater than 18 degrees Celsius.

Nitrogen oxide is an essential ingredient of photochemical smog that is produced during the high temperatures associated with combustion of vehicle’s engines. Nitrogen oxide is an essential ingredient of photochemical smog that is produced during the high temperatures associated with combustion of vehicle’s engines.

Formation

Sunlight can break down nitrogen dioxide back into nitrogen oxide.

NO2 + sunlight »»» NO + O

The atomic oxygen formed in the above reaction then reacts with one of the abundant oxygen molecules producing ozone.

O + O2 »»» O3

Nitrogen dioxide can also react with radicals produced from volatile organic compounds in a series of reactions to form toxic products such as peroxyacetyl nitrates.

NO2 + R »»» products such as PAN

Note the symbol R represents a hydrocarbon (a molecule composed of carbon, hydrogen and other atoms) which is primarily created from volatile organic compounds.

Steps

1) Nitrogen oxides generate oxygen atoms

2) Oxygen atoms form hydroxyl radicals

3) Hydroxyl radicals generate hydrocarbon radicals

4) Hydrocarbon radicals form hydrocarbon peroxides

5) Hydrocarbon peroxides form aldehydes

6) Aldehydes form aldehyde peroxides

7) Aldehyde peroxides form peroxy-acyl-nitrates

Health effects

It can cause eye and nose irritation and it dries out the protective membranes of the nose and throat and interferes with the body's ability to fight infection, increasing susceptibility to illness.

Chapter 3

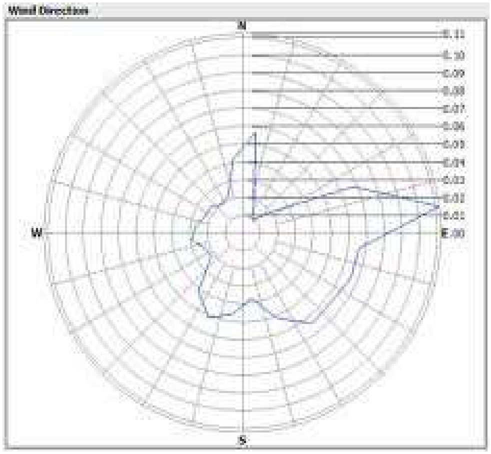
Air Pollution and Meteorology

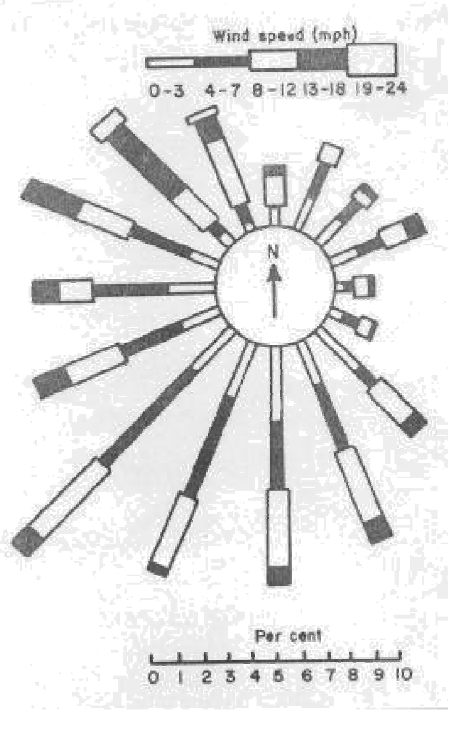
The science of meteorology has great bearing on air pollution. An air pollution problem involves three parts: the source, the movement of the pollutant and the recipient. All meteorological phenomena are a result of interaction of the elemental properties of the atmosphere, heat, pressure, wind and moisture.

Wind

Wind is simply air in motion. On global or macroscale wind patterns are set up due to unequal heating of earth surface by solar radiation at the equator and the polar regions, rotation of the earth and the difference between conductive capacities of land and ocean masses. Secondary or mesoscale circulation patterns develop because of the regional or local topography. Mountain ranges, cloud cover, waterbodies, deserts, forestation, etc., influence wind patterns on scales of a few hundred kilometers. Accordingly a pattern of wind is setup, some seasonal and some permanent. Microscale phenomenon occurs over areas of less than 10 km extent. Standard wind patterns may deviate markedly due to varying frictional effects of the earth surface, such as, rural open land, irregular topography and urban development, effect of radiant heat from deserts and cities, effect of lakes, etc. The movement of air at the mesoscale and microscale levels is of concern in control of air pollution. A study of air movement over relatively small geographical regions can help in understanding the movement of pollutants.

It is obviously important in predicting pollutant dispersion to know the direction of wind. The wind direction and speed data may be collected every hour in a month and classified according to speed and direction. It is then summarized in the form of a polar diagram called *wind rose.* Figure shows a hypothetical wind rose. The position of the spokes show the direction from which the wind was blowing, the length of various segments of the spokes show the percent of time the wind was of the designated speed. Thus from the diagram, most often (12% of time) the wind was from SE; the strongest wind (9-11 m/s) was from NW and NNW.

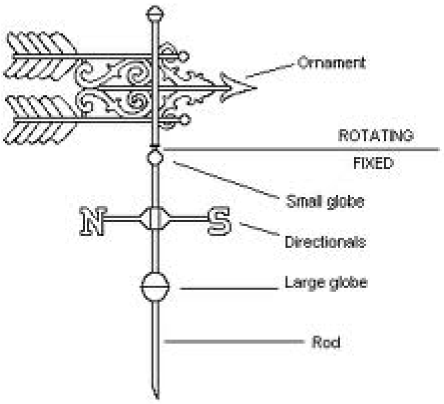


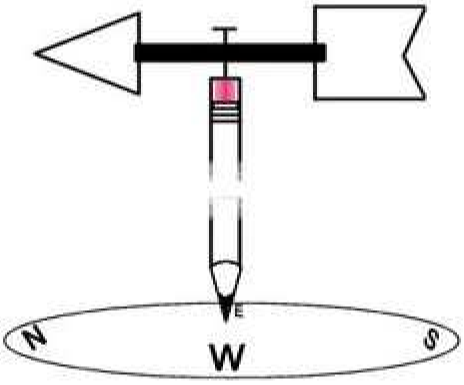


Importance of wind rose in air pollution studies

A wind rose is a graphic tool used by meteorologists to give a succinct view of how wind speed and direction are typically distributed at a particular location. It assists in city planning and siting of industries.

An anemometer is a device for measuring wind speed, and is a common weather station instrument. Anemometers can be divided into two classes: those that measure the wind's speed, and those that measure the wind's pressure; but as there is a close connection between the pressure and the speed, an anemometer designed for one will give information about both. A simple type of anemometer, consistS of four hemispherical cups each mounted on one end of four horizontal arms, which in turn were mounted at equal angles to each other on a vertical shaft. The air flow past the cups in any horizontal direction turned the cups in a manner that was proportional to the wind speed. Therefore, counting the turns of the cups over a set time period produced the average wind speed for a wide range of speeds. On an anemometer with four cups it is easy to see that since the cups are arranged symmetrically on the end of the arms, the wind always has the hollow of one cup presented to it and is blowing on the back of the cup on the opposite end of the cross.



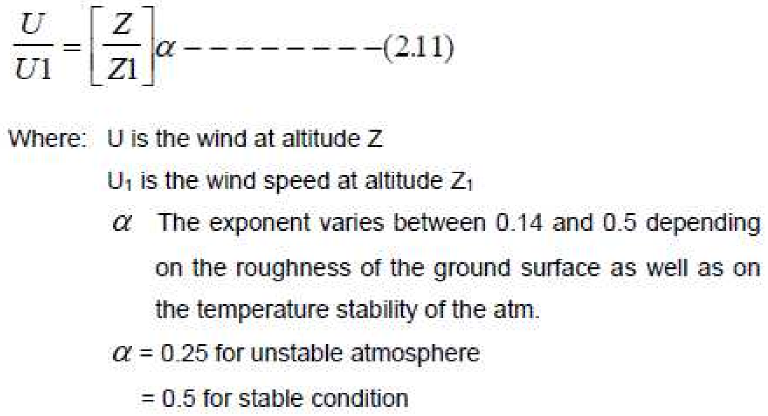


A weather vane (or weathercock) is an instrument for showing the direction of the wind . They are typically used as an architectural ornament to the highest point of a building. Although partly functional, weather vanes are generally decorative, often featuring the traditional cockerel design with letters indicating the points of the compass. Other common motifs include ships, arrows and horses.

The design of a wind vane is such that the weight is evenly distributed on each side of the surface, but the surface area is unequally divided, so that the pointer can move freely on its axis. The side with the larger surface area is blown away from the wind direction, so that the smaller side, with the pointer, is pivoted to face the wind direction. Most wind vanes have directional markers beneath the arrow, aligned with the geographic directions.

Wind vanes, especially those with fanciful shapes, do not always show the real direction of a very gentle wind. This is because the figures do not achieve the necessary design balance: an unequal surface area but balanced in weight. To obtain an accurate reading, the wind vane must be located well above the ground and away from buildings, trees, and other objects which interfere with the true wind direction. Changing wind direction can be meaningful when coordinated with other apparent sky conditions, enabling the user to make simple short range forecasts. From the street level the size of many weathercocks is deceptive.

The mean wind speed variation with altitude is the planetary boundary layer can be represented by a simple empirical power.



$$\frac{U}{U1} = \left[\frac{Z}{Z1}\right]\alpha \text{---------}(2.11)$$

Where: U is the wind at altitude Z

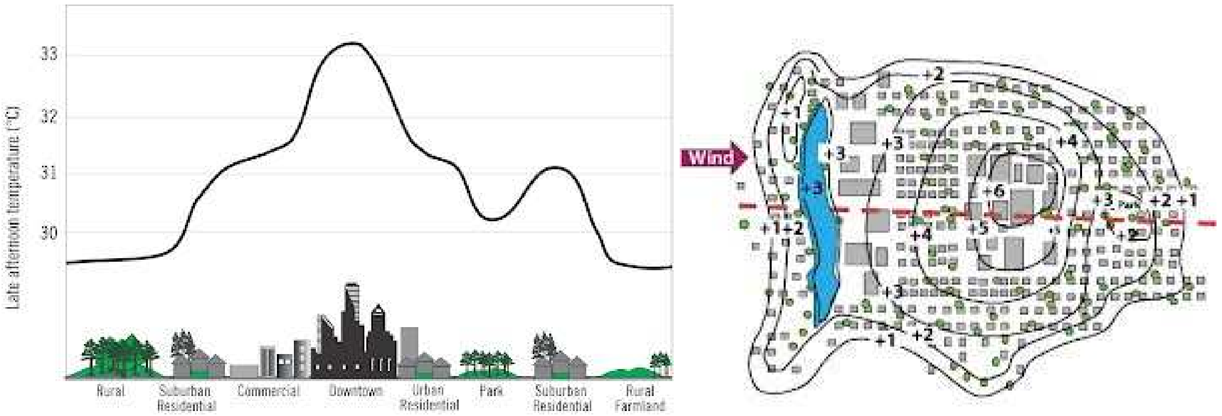
U_1 is the wind speed at altitude Z_1

α The exponent varies between 0.14 and 0.5 depending on the roughness of the ground surface as well as on the temperature stability of the atm.

α = 0.25 for unstable atmosphere

= 0.5 for stable condition

Urban Heat Islands



Urbanization negatively impacts the environment mainly by the production of pollution, the modification of the physical and chemical properties of the atmosphere, and the covering of the soil surface. Considered to be a cumulative effect of all these impacts is the UHI, defined as the rise in temperature of any man-made area, resulting in a well-defined, distinct "warm island" among the "cool sea" represented by the lower temperature of the area’s nearby natural landscape.

Though heat islands may form on any rural or urban area, and at any spatial scale, cities are favoured, since their surfaces are prone to release large quantities of heat. Nonetheless, the UHI negatively impacts not only residents of urban-related environs, but also humans and their associated ecosystems located far away from cities. In fact, UHIs have been indirectly related to climate change due to their contribution to the greenhouse effect, and therefore, to global warming.

It is well-known that the progressive replacement of natural surfaces by builtsurfaces, through urbanization, constitutes the main cause of UHI formation. Natural surfaces are often composed of vegetation and moisture-trapping soils. Therefore, they utilize a relatively large proportion of the absorbed radiation in the evapotranspiration process and release water vapour that contributes to cool the air in their vicinity. In contrast, built surfaces are composed of a high percentage of non-reflective and water-resistant construction materials. As consequence, they tend to absorb a significant proportion of the incident radiation, which is released as heat.

Vegetation intercepts radiation and produces shade that also contributes to reduce urban heat release. The decrease and fragmentation of large vegetated areas such as parks, not only reduces these benefits, but also inhibits atmospheric cooling due to horizontal air circulation generated by the temperature gradient between vegetated and urbanized areas (i.e. advection), which is known as the park cool island effect. On the other hand, the narrow arrangement of buildings along the city's streets form urban canyons that inhibit the escape of the reflected radiation from most of the three-dimensional urban surface to space. This radiation is ultimately absorbed by the building walls (i.e. reduced sky view factor), thus enhancing the urban heat release. Additional factors such as the scattered and emitted radiation from atmospheric pollutants to the urban area, the production of waste heat from air conditioning and refrigeration systems, as well from industrial processes and motorized vehicular traffic (i.e. anthropogenic heat), and the obstruction of rural air flows by the windward face of the built-up surfaces, have been recognized as additional causes of the UHI effect

As it would be expected, the characteristic inclination towards warming of urban surfaces is exacerbated during hot days and heat waves, which reinforces the air temperature increase, particularly in ill-ventilated outdoor spaces or inner spaces of residential and commercial buildings with poor thermal isolation. This increases the overall energy consumption for cooling (i.e. refrigeration and air-conditioning), hence increasing the energy production by power plants, which leads to higher emissions of heat-trapping greenhouse gases such as carbon dioxide, as well as other pollutants such as sulfur dioxide, carbon monoxide and particulate matter. Furthermore, the increased energy demand means more costs to citizens and goverments, which in large metropolitan areas may induce significant economic impacts. On the other hand, UHIs promote high air temperatures that contribute to formation of ozone precursors, which combined photochemically produce ground level ozone.

A direct relationship has been found between UHI intensity peaks and heat-related illness and fatalities, due to the incidence of thermal discomfort on the human cardiovascular and respiratory systems. Heatstroke, heat exhaustion, heat syncope,and heat cramps, are some of the main stress events, while a wide number of diseases may become worse, particularly in the elderly and children. In a similar way, respiratory and lung diseases have shown to be related to high ozone levels induced by heat events. Other meteorological impacts of the UHI are associated with reductions in snowfall frecuencies and intensities, as well as reductions in the diurnal and seasonal range of freezing temperatures. Lastly, high temperatures may produce physiological and phenological disturbances on ornamental plants and urban forests.

There are two main UHI reduction strategies: first, to increase surface reflectivity (i.e. high albedo), in order to reduce radiation absorption of urban surfaces, and second, to increase vegetation cover, mainly in the form of urban forests and parks, in order to maximize the multiple vegetation benefits in controlling the temperature rises. Reflective surfaces simply results from light colored or white paint on the surface of a given construction material or from cover the construction material surface with a white membrane. Both techniques have been mainly applied on roofs and pavements. Cool roofs are specially important in commercial and residential buildings, where significant energy demand for cooling can be saved by reducing heat gain to the building. Cool pavements have mainly based on the use of whitened asphalt roads, a very warm material.

Urban Dust Domes

Urban dust domes are a meteorological phenomenon in which soot, dust, and chemical emissions become trapped in the air above urban spaces. This trapping is a product of local air circulations. Calm surface winds are drawn to urban centers, they then rise above the city and descend slowly on the periphery of the developed core. This cycle is often a cause of smog

through photochemical reactions that occur when strong concentrations of the pollutants in this cycle are exposed to solar radiation. These are one result of urban heat islands: pollutants concentrate in a dust dome because convection lifts pollutants into the air, where they remain because of somewhat stable air masses produced by the urban heat island.

Atmospheric Stability

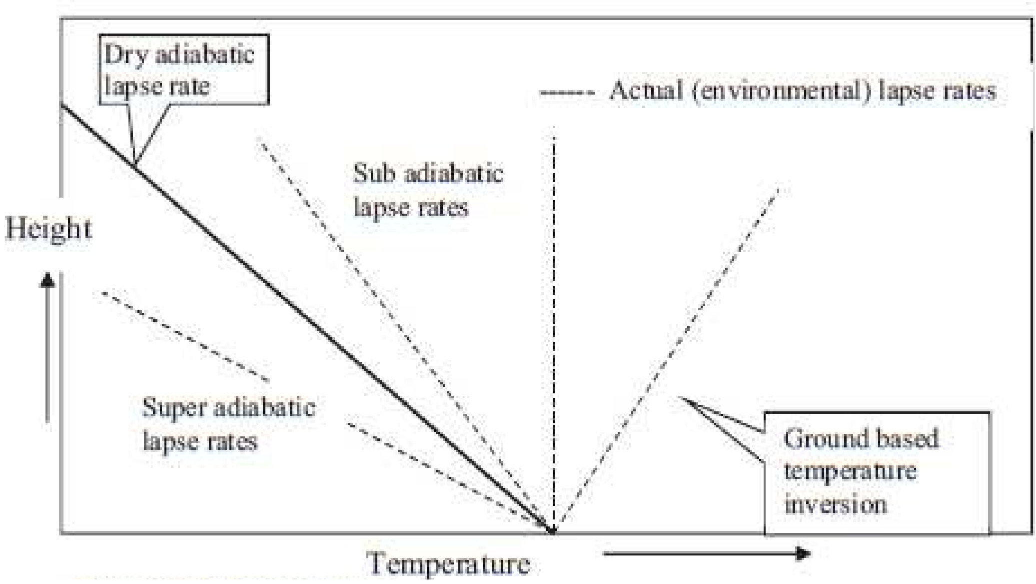
The ability of the atmosphere to disperse the pollutants emitted in to it depends to a large extent on the degree of stability. A comparison of the adiabatic lapse rate with the environmental lapse rate gives an idea of stability of the atmosphere. When the environmental lapse rate and the dry adiabatic lapse rate are exactly the same, a raising parcel of air will have the same pressure and temperature and the density of the surroundings and would experience no buoyant force. Such atmosphere is said to be neutrally stable where a displaced mass of air neither tends to return to its original position nor tends to continue its displacement

Lapse rate

As a parcel of air rises in the earth's atmosphere it experiences lower and lower pressure from the surrounding air molecules, and thus it expands. This expansion lowers its temperature. Ideally, if it does not absorb heat from its surroundings and it does not contain any moisture, it cools at a rate of 1ºC/100 m rise. This is known as *dry adiabatic lapse rate.*

If the parcel moves down it warms up at the same rate. For a particular place at a particular time, the existing temperature can be determined by sending up a balloon equipped with a thermometer. The balloon moves through the air, and not with it. The temperature profile of the air, which the balloon measures, is called the *ambient lapse rate, environmental lapse rate,* or the *prevailing lapse rate.*

A super-adiabatic lapse rate also called a strong lapse rate occurs when the atmosphere temperature drops more than 1ºC/100m. A sub-adiabatic rate also called weak lapse rate, is characterized by drop of less than 1ºC/100 m. A special case of weak lapse rate is the inversion, a condition which has warmer layer above colder air.



During super-adiabatic lapse rate the atmospheric conditions are unstable. If a parcel of air at 500m elevation, at 20ºC is pushed upward to 1000m, its temperature will come down to 15ºC (according to adiabatic lapse rate). The prevailing temperature is however 10ºC at 1000m. The parcel of air will be surrounded by colder air and therefore will keep moving up.

Similarly if the parcel is displaced downwards, it will become colder than its surroundings and therefore will move down. Super-adiabatic conditions are thus unstable, characterized by a great deal of vertical air movement and turbulence. The sub-adiabatic condition shown in is by contrast a very stable system. Consider again a parcel of air at 500 m elevation at 20ºC. If the parcel is displaced to 1000 m it will cool by 5ºC to 15ºC. But the surrounding air would be warmer. It will therefore fall back to its point of origin. Similarly if a parcel of air at 500 m is pushed down, it will become warmer than its surrounding and therefore will rise back to its original position. Thus such systems are characterized by very limited vertical mixing.

Inversion

An inversion is an extreme sub-adiabatic condition, and thus the vertical air movement within the inversion is almost nill. The two most common kind of inversion are *subsidence inversion* and *radiation inversion.* The base of the subsidence inversion lies some distance above earth's surface. This type of inversion is formed due to adiabatic compression and warming of sinking air mass to a lower altitude in the region of a high pressure center. In the case of radiation inversion, the surface layers of the atmosphere during the day receive heat by conduction, convection and radiation from the earth's surface and are warmed. This results in a temperature profile in the lower atmosphere, which is represented by a negative temperature gradient. On a clear night, the ground surface radiates heat and quickly cools. The air layer adjacent to the earth surface are cooled to a temperature below that of the layers of air at higher elevations. This type of the inversion is strongest just before daylight when it may extend to 500 m. It breaks up as the morning sun heats the ground.

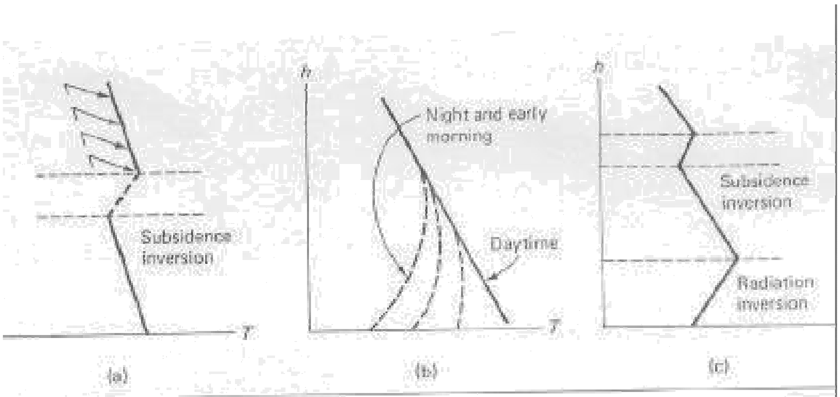


FIGURE 4 ILLUSTRATIONS OF SUBSIDENCE AND RADIATION INVERSIONS.

Maximum mixing depth

The dispersion of pollutants in the lower atmosphere is greatly aided by the convective and turbulent mixing that takes place. The vertical extent to which this mixing takes place depends on the environmental lapse rate which varies diurnally, from season to season and is also affected by topographical features. The depth of the convective mixing layer in which vertical movement of pollutants is possible, is called the maximum mixing depth (MMD). Figure illustrates these MMDs for different lapse rate profiles.

These profiles are usually measured at night or early in the morning. An air parcel at a temperature (maximum surface temperature for the month) warmer than the existing ground level temperature rises and cools according to adiabatic lapse rate. The level where its temperature becomes equal to the surrounding air gives the MMD value. Urban air pollution episodes are known to occur when MMD is 1500 m or less.

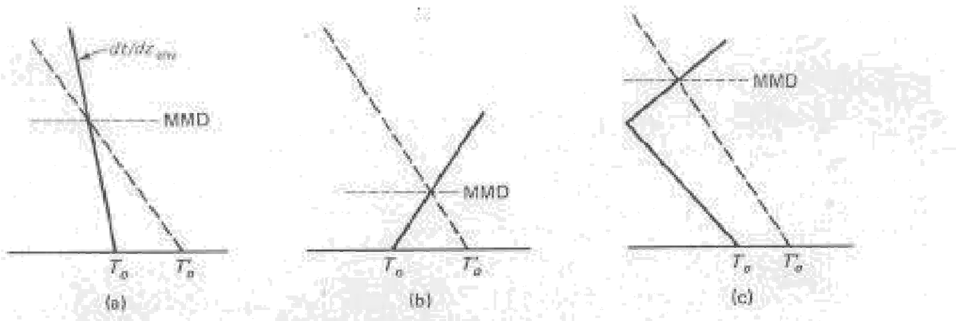
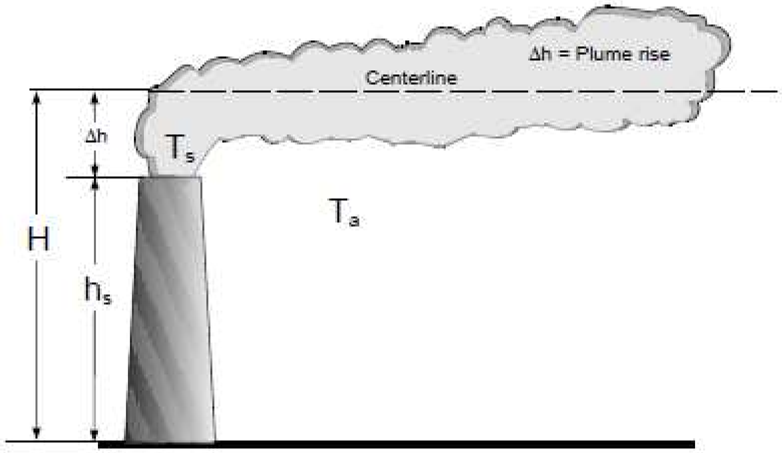


FIGURE 5 MAXIMUM MIXING DEPTH (MMD) UNDER VARIOUS ATMOSPHERIC CONDITIONS, (ADIABATIC PROFILE -------, ENVIRONMENTAL PROFILE———).

Plume Dispersion

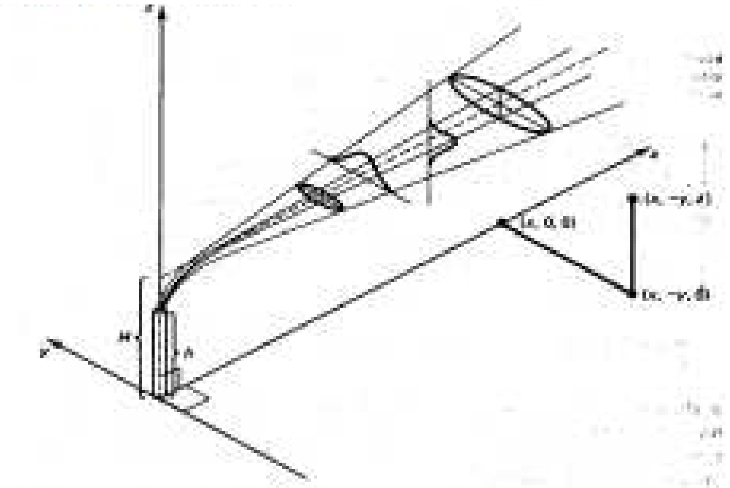
Gases that are emitted from stacks are often pushed out by fans. As the turbulent exhaust gases exit the stack they mix with ambient air. This mixing of ambient air into the plume is called entrainment. As the plume entrains air into it, the plume diameter grows as it travels downwind. These gases have momentum as they enter the atmosphere. Often these gases are heated and are warmer than the outdoor air. In these cases the emitted gases are less dense than the outside air and are therefore buoyant. A combination of the gases' momentum and buoyancy causes the gases to rise. This is referred to as plume rise and allows air pollutants emitted in this gas stream to be lofted higher in the atmosphere. Since the plume is higher in the atmosphere and at a further distance from the ground, the plume will disperse more before it reaches ground level.



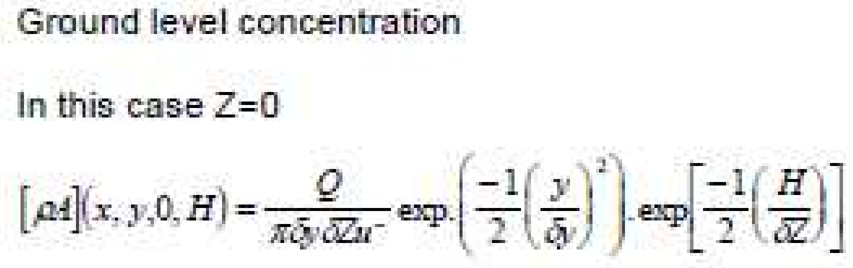
The final height of the plume, referred to as the effective stack height (H), is the sum of the physical stack height (hs) and the plume rise (Δh). Plume rise is actually calculated as the distance to the imaginary centerline of the plume rather than to the upper or lower edge of the plume (Figure 6-1). Plume rise depends on the stack's physical characteristics and on the effluent's (stack gas) characteristics. The difference in temperature between the stack gas (Ts) and ambient air (Ta) determines the plume density which affects plume rise. Also, the velocity of the stack gases which is a function of the stack diameter and the volumetric flow rate of the exhaust gases determines the plume's momentum.

The Gaussian plume model

The present tendency is to interpret dispersion data in terms of the Gaussian model. The standard deviations are related to the eddy diffusivities.



Plume dispersion coordinate sysem, showing Gaussian distributions in the horizontal and vertical directions (Turner, 1970)



Ground level concentration

In this case Z=0

$$[\rho A](x, y, 0, H) = \frac{Q}{\pi \delta y\, \delta Z u^{-}} \exp.\left(\frac{-1}{2}\left(\frac{y}{\delta y}\right)^{2}\right).\exp\left[\frac{-1}{2}\left(\frac{H}{\delta Z}\right)\right]$$

Dispersion characteristics of stack plumes

Dispersion is the process of spreading out pollution emission over a large area and thus reducing their concentration. Wind speed and environmental lapse rates directly influence the dispersion pattern.

Coning

A *coning* plume, shown in, occurs under essentially neutral stability, when environmental lapse rate is equal to adiabatic lapse rate, and moderate to strong winds occur. The plume enlarges in the shape of a cone. A major part of pollution may be carried fairly far downwind before reaching ground.

Looping

Under super-adiabatic condition, both upward and downward movement of the plume is possible. Large eddies of a strong wind cause a *looping* pattern. Although the large eddies tend to disperse pollutants over a wide region, high ground level concentrations may occur close to the stack.

Fanning

A *fanning* plume occurs in the presence of a negative lapse rate when vertical dispersion is restricted. The pollutants disperse at the stack height, horizontally in the from of a fanning plume.

Fumigation

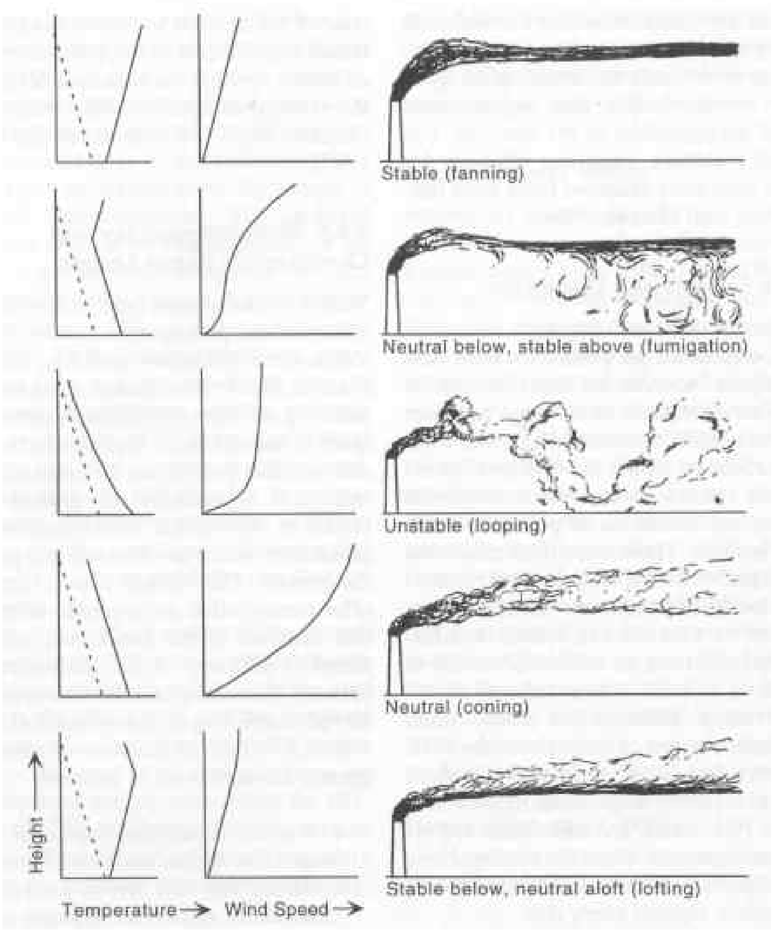
When the emission from the stack is under an inversion layer, the movement of the pollutants in the upward direction is restricted. The pollutants move downwards. The resulting *fumigation* can lead to a high ground level concentration downwind of the stack.

Lofting

When the stack is sufficiently high and the emission is above an inversion layer, mixing in the upward direction is uninhibited, but downward motion is restricted. Such *lofting* plumes do not result in any significant concentration at ground level. However, the pollutants are carried hundreds of kilometers from the source.

Trapping

It occurs when the plume effluent is caught between two inversion layers. The diffusion of the effluent is severely restricted to the unstable layer between the two unstable layers.



Unit – 4

10CV765 APC

Industrial Plant Location and Planning

General factors considered while siting an industrial location include water supply, raw material supply, proximity to nearest railway station, land availability, power supply etc. Hence it's most evident that air pollution and its control are most ignored.

Following are the factors to be considered while deciding industrial installation, keeping in mind air pollution and its impacts.

1] Existing levels of air contaminates

This involves a pre-operational survey, to know the existing level of contaminants under prevailing meteorological conditions, and if not and even if any existing industries. This gives idea if existing pollution levels is high or low. It also gives idea if upcoming industry will aggravate the pollution levels and by how much. It gives idea at what levels must the pollution be released based on existing levels.

2] Potential effects on the surrounding area

The effect of air pollution shall vary from area to area depending on its environment and build forms. Any industrial emission near a city shall endanger more lives than that closer to a forest or un-habituated place.

3] Meteorological factors and the climate

Role of wind direction, wind speed, stability conditions is pivotal to air pollution. Areas having more inversions should be avoided.

4] Availability of clean air

Some industries need clean air for production or in their processes. Polluted air shall make it costlier towards clean-up process and may also impair its regular operations.

5] Topographical features

Industries situated in valleys are more prone to severe impacts during depression, when compared to flat terrains. As inversions or depressions in a valley system shall result in more deposition, less dispersion, no circulation of pollutants.

6] City planning and zoning. (Explanation provided in further sections)

City Planning

Urban Planning is a process of guiding the use and development of land with the aim of making the city a better place to live and work. Particularly important today as more than one-half of the world's population now resides in urban places. Cities, towns and other urban forms are therefore the sites for most of mankind's activities. Yet in most cities and towns, land and access to basic resources and services are usually scarce and unevenly distributed. Planning is 'a general activity…the making of an orderly sequence of action that will lead to the achievement of a stated goal or goals' (Hall 2002). It involves written statements supplemented as appropriate by statistical projections, quantified evaluations and diagrams. Planning involves an attempt to (re)shape prevailing social and economic dynamics to achieve particular developmental ends. The process has different names e.g. town & country planning, town planning, city planning, physical planning etc.it may be thought as a rational (highly technical) and systemic process of forethought set in motion by the need to resolve urban and regional problems, and yet it may be interpreted as a highly political and economistic process.

What do urban planners do?

Determine the best uses of land and resources for homes, businesses, and recreation.
Devise ways to renovate slums, expand cities, modernize transportation systems, and distribute public facilities such as schools and parks.
Urban planners design new communities and develop programs to revitalize and expand existing cities.
Regional planners work on a much larger scale, studying the problems of states, multistate regions, and sometimes entire countries.

Impact of bad planning w.r.t. air pollution

More traffic jams
Irregular dispersions and dissipation air pollutants
More cases of casualty's w.r.t acute and chronic effects.
Blocking of regular wind-paths and thereby hampering free circulation of air.

Lack of proper planning results in failure of remedial measures, and is aggravated by increased costs of control equipment. The main aspect of planning hence must resort to industrial zoning. Cumulative zoning in the past has resulted in less availability of land for industries. This system has now been modified as permissive systems. However this system has now been modified as permissive system. However this system has also resulted in the crowding of industrial zones with other uses besides industries. The next system over this is called excusive zonings system. This type of planning provided for compatible uses for each zones, excluding all other uses. In this system suitable industrial zones are provided and thus there is no air pollution problem.

Zoning criteria for industries:

1] Functional requirement: this includes the inter industry linkages, railways siding, grouping, land traffic generation utilities etc. these aspects are covered under govt. policies.

2] Performance characteristics: this includes the traffic congestion, obnoxious and hazardous character of the industries, industrial nuisance etc. The nuisance includes dust, heat, smoke, fire, odor etc. It is necessary to place obnoxious industries away from neat industries. If planning is done in early stages, its impact analysis can be done for effective execution.

While classifying industries on basis of differential zoning, the following aspects might be followed.

There are 3 categories of industries.

Group 1.] These are smaller industries with a variety of products and with close relations to cities. Their emissions have very little impact on the natural environment. These industries can hence be located on the fringes of the cities.

Group 2] These include cottage and small scale industries requiring less land but indulge in creative and artistic productions. These can be located within cities. As they have no or little adverse effects on the cities.

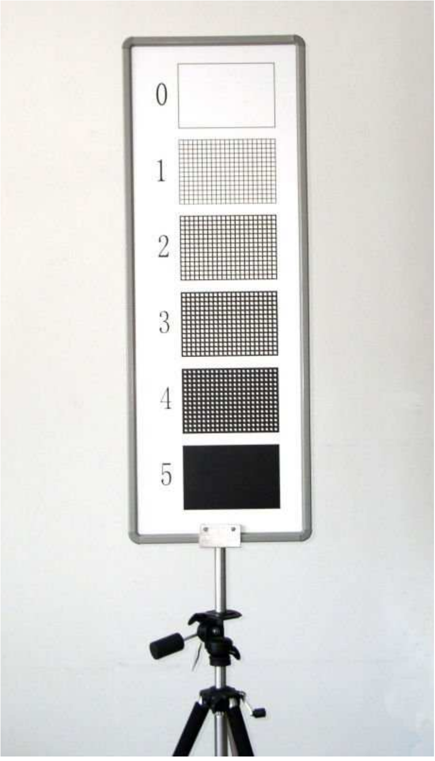
Group 3] These include big industries with relatively less number of unit process and having remote relevance to the central residential areas of the cities. These have profound effect on the cities and hence should be located as far as possible from the residential vicinities.

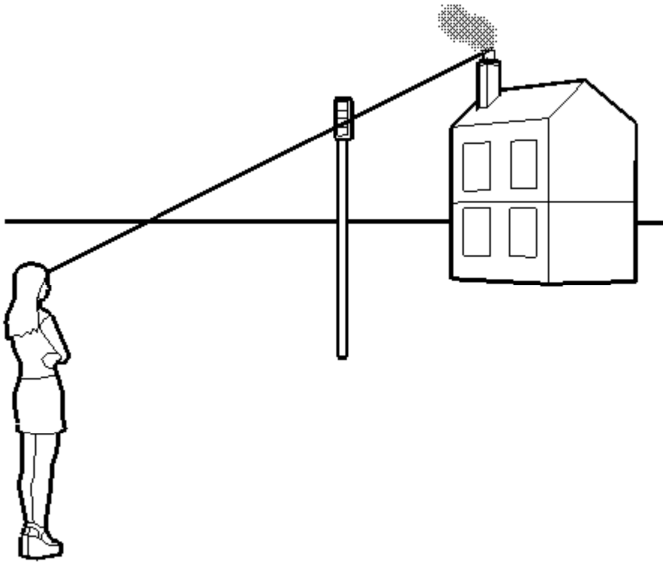
The buffer zone for light industries is about half kilometer, for that of heavy industries it is 0.6 to 1.5 km. for explosive industries it is more than 2 km.

10CV765 / AIR POLLUTION AND CONTROL / R.G.

Unit – 5

MEASUREMENT OF SMOKE DENSITY





Dark smoke is partially burned particles of fuel, the result of incomplete combustion. It can be dangerous because small particles are absorbed into the lungs. **White smoke** is mainly tiny water droplets, generated when vapour released during combustion condenses in cool air. Generally, dark smoke is clearly visible against a light sky but difficult to see at night or against a dark background, white smoke is visible in darkness when illuminated but will be more difficult to see against a light sky background. Smoke is commonly measured in terms of its apparent density in relation to a scale of known greyness.

The most widely-used scale is that developed by Professor Maximilian Ringelmann of La Station d'Essais de Machines in Paris in 1888. It has a 5 levels of density inferred from a grid of black lines on a white surface which, if viewed from a distance, merge into known shades of grey. There is no definitive chart, rather, Prof. Ringelmann provides a specification; where smoke Level '0' is represented by white, levels '1' to '4' by 10mm square grids drawn with 1mm, 2.3mm, 3.7mm and 5.5 mm wide lines and level '5' by all black. It should be remembered that the data obtained has definite limitations. The apparent darkness of a smoke depends upon the concentration of the particulate matter in the effluent, the size of the particulate, the depth of the smoke column being viewed, and natural lighting conditions such as the direction of the sun relative to the observer while the accuracy of the chart itself depends on the whiteness of the paper and blackness of the ink used.

USING THE CHARTS

The large chart on page 4 should be printed with black ink onto very white card and mounted vertically on a board. It is preferably fixed to a pole or held by an assistant at a sufficient distance (typically c20m) for the lines to appear to merge into uniform grey rectangles and to be seen in line with the top of the chimney. The addition of a white (No. 0) square can provide a useful indication that both the chart and chimney are equally illuminated. If a larger chart is needed, the shaded rectangles can be made up into larger ones as mosaics. The observer glances from the smoke, as it issues from the stack, to the chart and notes the number most nearly corresponding with the shade of the smoke. A clear stack is recorded as No. 0, and 100 percent black smoke as No. 5. There is very little value in making a single observation. A series of observations should be made, preferably by two or more observers, over an extended period, at regular intervals.

The Miniature Charts are not the official Ringelmann chart, but a handy interpretation of it, intended to be held at arm's length.

SAMPLING

Selection of sampling procedure:

There are two types of sampling – continuous and time averaged in –situ samplings. Continuous sampling is carried out by automatic sensors, optical or electrochemical, and spectroscopic methods which produce continuous records of concentration values. The specific time-averaged concentration data can then be obtained from continuous records. Time-averaged data can also be obtained by sampling for a short time – i.e. by sampling a known volume of air for the required averaging time. Samples are then analyzed by established physical, chemical, and biological methods for the concentration values which are the effective average over the period of sampling.

Sampling locations

Sampling locations are in general governed by factors like objectives, method of sampling and resources available. If the objective is to study health hazards and material damages, then locations should be kept close to the objects where the effects are being studied and should be kept at breathing level in the population centres, hospitals, schools, etc. For vegetation, it should be at foliage level. For background concentration, sampling location should be away from the sources of pollution. It can also be done by gridding the entire area to get statistically recommended values. The number of locations however depends upon the variability of concentration over the area under survey. A spot checking may be done to decide the location besides considering practical factors.

Period of sampling, frequency and duration:

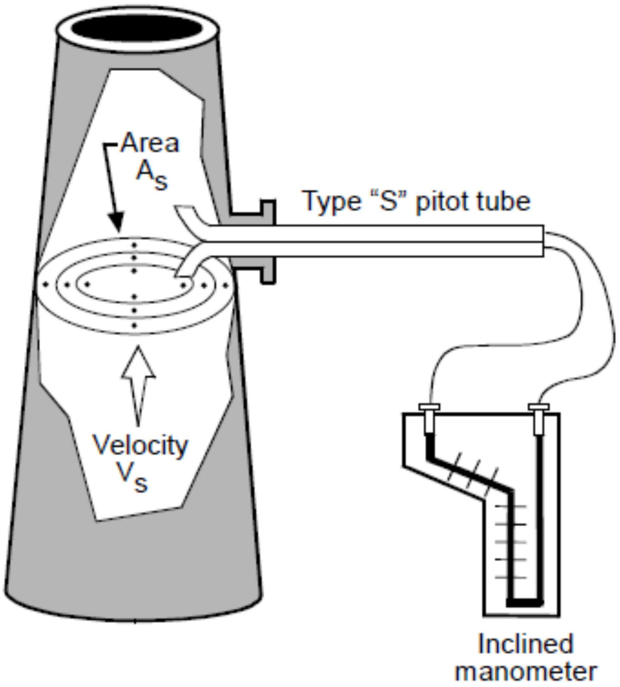
Period, frequency and duration of sampling should be appropriate to the objectives of the study. It should be such that the measurable quantities are trapped in the sample at the end of the sampling. It is preferable to observe sampling period consistent with the averaging times for which air quality standards of the given pollutants are specified.

SOURCE SAMPLING METHODOLOGY

Stationary source emissions occur primarily as either a gas or solid. The ability to collect a representative sample of particulate or gaseous pollutants largely determines the success of the measurement. Since no single method of measurement can accurately analyze every form of pollutant emitted from an exhaust stack, it is important to understand the properties of particulate and gaseous pollutants and the methods used to measure them.

Distributed Sampling Points.

A representative sample of the effluent is taken by first measuring the velocity, as shown in Figure, then extracting gas from an array of sampling points distributed over equal areas of the cross section of the stack or duct. If only gaseous pollutants are to be sampled, less sampling points are required since the stack gases are considered sufficiently mixed.

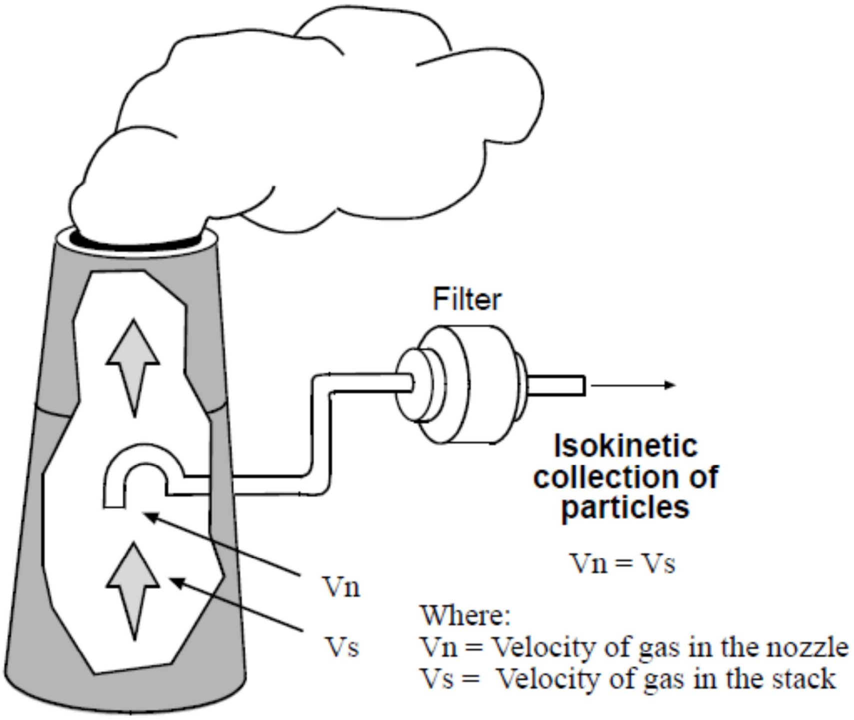


Sampling Distributed Over Time.

Each point should be sampled for an equal period of time, with the total sampling time or run usually lasting about an hour. Typically, three runs are performed after which their results are then averaged.

Isokinetic Sampling.

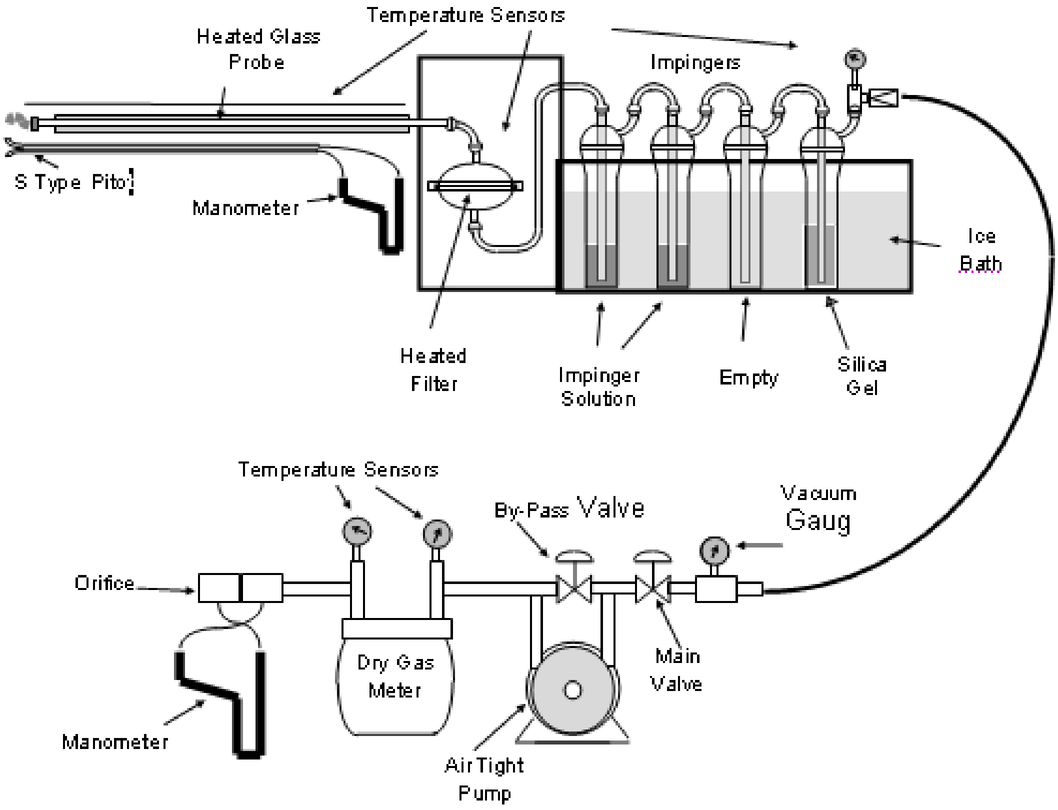
When sampling for particles it is essential that the sample be extracted at the same rate at which the gas is flowing through the stack or duct. The stack gas velocity is measured at each individual sample point and the sample extraction rate is adjusted to withdraw the sample at the same rate as the sampled points velocity. This kind of sampling is called *isokinetic* sampling and is meant to ensure that a representative sample, equal in concentration to the stack, is extracted from the gas stream (see Figure). If the sample is isokinetic, the distribution of particles sizes (from small to large) entering the probe will be exactly the same as that in the stack gas itself.



$Vn = Vs$

Where:
Vn = Velocity of gas in the nozzle
Vs = Velocity of gas in the stack

SAMPLING TRAIN



SAMPLING TRAIN

Separation of Gas Constituents.

A known quantity of the stack gas is then drawn from the stack or duct through a *sampling train*, or a leak-proof series of equipment components configured to capture pollutants. Capturing water vapor and gaseous pollutants is best achieved by condensation—or bubbling the sample gas through chilled *impingers* (sealed glass vessels), some which may contain liquid *reagents* to absorb gases. Solids are captured on filter paper, which is heated and connected to the probe with inter-connecting glassware. The first component of the sampling train is a heated probe, or a hollow glass tube that is inserted into the stack or duct. The last component—a pump—draws gases through the other pieces of equipment (the probe, filters and impingers). The volume of sampled gas is measured by a gas meter and is finally exhausted into the atmosphere through the orifice, which is used for sample train flow adjustments at the by-pass valve.

Sample Recovery and Analysis.

Filters are pre-weighed and reagent volumes pre-measured prior to use. After each run, the content of each sampling train component is carefully recovered to a sealed vessel, then weighed, measured, or otherwise evaluated under laboratory conditions.

Data Recording.

Throughout each run, appropriate measurement data are recorded. On a point-by-point basis, the sampling time, sample train vacuum, differential pressures across the gas temperature, orifice meters, and dry gas meter readings are recorded. Averages of these values, along with the total sample gas volume, are then used to calculate the test results.

Calculation of Results.

The concentration of a pollutant in the sampled gas is calculated as the proportion of captured pollutant's mass to the volume of gas sampled. These results are corrected to a standard temperature and pressure and expressed on a dry basis. This standardized measure allows the results of a test performed under specific conditions to be comparable to a regulatory standard or other test results.

AIR POLLUTION CONTROL PROCEDURES FOR INDUSTRIES

The control of stationary source emissions can be accomplished through the application of a sound control strategy. The control strategy required for an industrial environmental impact is a four step process: (1) elimination of the problem source or operation, (2) modification of the source operation, (3) relocation of the source, and (4) selection and application of the appropriate control technology.

Exhaust stacks do not reduce emissions from a stationary source; rather they reduce the local effects of the pollution by elevating the exhaust stream to a point where it can be more effectively dispersed. High exhaust stacks were an inexpensive solution in the absence of expensive control technology.

Compliance with emission standards may require the use of control technology, but many industrial operations have reduced emissions by changing operational methods. Some of these changes include pretreating process materials, fuel or material substitution, and changes in the manufacturing process. Another way to comply with emission standards is to substitute cleaner fuels during the refining process. Natural gas and low-sulfur fuel oil are just two examples of fuels that emit less pollution during combustion. However, cleaner fuels can be more expensive and can increase national reliance on foreign fuel sources. Reduction in emissions from stationary sources can also be accomplished through increased attention to plant maintenance.

Use of CONTROL EQUIPMENTS (Control Technology)

A final way to reduce emissions from stationary sources is through the use of advanced, addon control technology. Control devices can destroy or recover gaseous compounds or particulate matter for proper disposal or re-use. The pollution control operations used to destroy or capture gases include combustion, adsorption, absorption, and condensation. Control devices that implement these processes include thermal incinerators, catalytic incinerators, flares, boilers, process heaters, carbon absorbers, spray towers, and surface condensers.

The most important process parameters for selecting air pollution control equipment are the exhaust gas characteristics obtained from emissions tests and process or site characteristics.

Exhaust Gas Characteristics

- Total exhaust gas flow rate
- Exhaust gas temperature
- Required control efficiency
- Particle size distribution
- Particle resistivity
- Composition of emissions
- Corrosiveness of exhaust gas over operating range
- Moisture content
- Stack pressure
- Exhaust gas combustibility and flammability properties

Process or Site Characteristics

- Reuse/recycling of collected emissions
- Availability of space
- Availability of additional electrical power
- Availability of water
- Availability of wastewater treatment facilities
- Frequency of startup and shutdowns
- Environmental conditions
- Anticipated changes in control regulations
- Anticipated changes in raw materials
- Plant type – stationary or mobile

Technologies used to control particulate matter focus on removing particles from the effluent gas stream. Many factors (such as particle size and chemical characteristics) determine the appropriate particulate control device for a process.

Devices most commonly used to control particulate matter include

electrostatic precipitators,
fabric filters,
venture scrubbers,
cyclone collectors,
settling chambers.

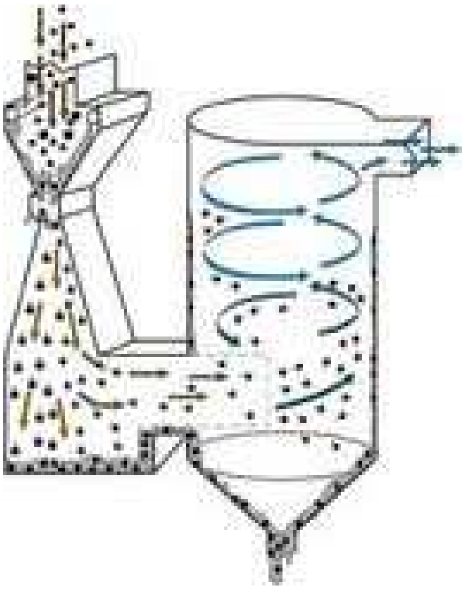
The following section provides a more detailed discussion of each type of control technology used for both particulate and gaseous emissions

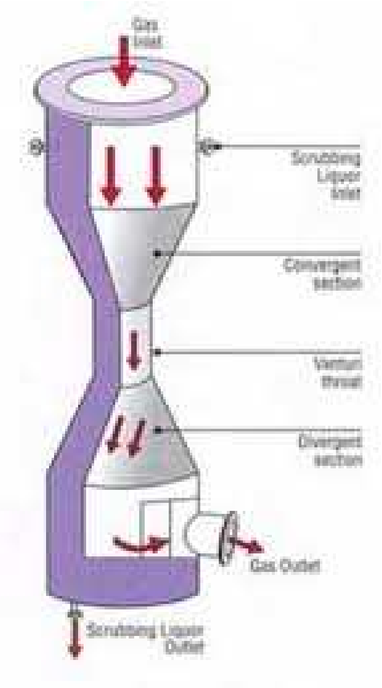
CONTROL DEVICES FOR PARTICULATE EMISSIONS

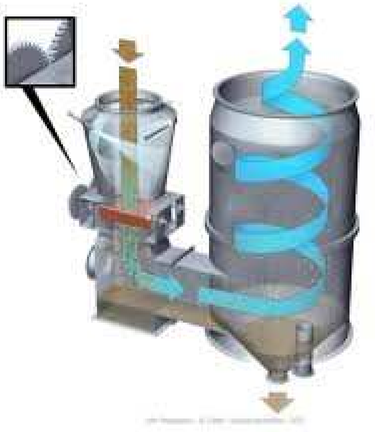
Particulate matter is any finely divided liquid or solid substance. Examples of particulate matter include smoke, dust, or some forms of fine mist and is entrained in effluent gas streams or suspended in ambient air. Any particulate less than 10 micrometers (µm) in diameter is defined as PM10 and is regulated as a criteria pollutant. The purpose of such regulation is to control smaller, respirable particles that can bypass the body's respiratory filters and penetrate deeply into the lungs, which could cause harm to human health. Toxic substances, such as sulfates, sulfites, nitrates, heavy metals, and polycyclic organic matter are predominantly carried by particles in this size range. Therefore, control devices used today, to prevent particles from reaching the ambient air, focus on capturing particulate matter $\leq 10\mu m$ in diameter. Several factors must be considered when selecting an appropriate particulate control device. Typically, particles must be captured from an effluent gas stream; therefore, characteristics of the particles and the gas stream will determine the appropriate control device. Characteristics that must be considered include the particle size and resistivity, exhaust flow rate, temperature, moisture content, and various chemical properties of the exhaust stream such as explosiveness, acidity, alkalinity, and flammability.

VENTURI SCRUBBERS

Venturi scrubbers use a liquid stream to remove solid particles. A venturi scrubber accelerates the waste gas stream to atomize the scrubbing liquid and to improve gas-liquid contact. In a venturi scrubber, a "throat" section is built into the duct that forces the gas stream to accelerate as the duct narrows and then expands. As the gas enters the venture throat, both gas velocity and turbulence increase. Depending on the scrubber design, the scrubbing liquid is sprayed into the gas stream before the gas encounters the venturi throat, or in the throat, or upwards against the gas flow in the throat. The scrubbing liquid is then atomized into small droplets by the turbulence in the throat and droplet-particle interaction is increased. Some designs use supplemental hydraulically or pneumatically atomized sprays to augment droplet creation. However, the disadvantage of these designs is that clean liquid feed is required to avoid clogging. After the throat section, the mixture decelerates, and further impacts occur causing the droplets to agglomerate. Once the particles are captured by the liquid, the wetted PM and excess liquid droplets are then separated from the gas stream by an entrainment section, which usually consists of a cyclonic separator and/or a mist eliminator. Particle collection efficiencies of venturi scrubbers range from 70 to greater than 99 percent, depending on the application. Typically, venturi scrubbers are applied where it is necessary to obtain high collection efficiencies for fine PM. Thus, they are applicable to controlling emission sources with high concentrations of submicron PM.







Advantages of Venturi Scrubbers

- Capable of handling flammable and explosive dusts
- Can handle mists in process exhausts
- Relatively low maintenance
- Simple in design and easy to install
- Collection efficiency can be varied
- Provides cooling for hot gases
- Neutralizes corrosive gases and dusts

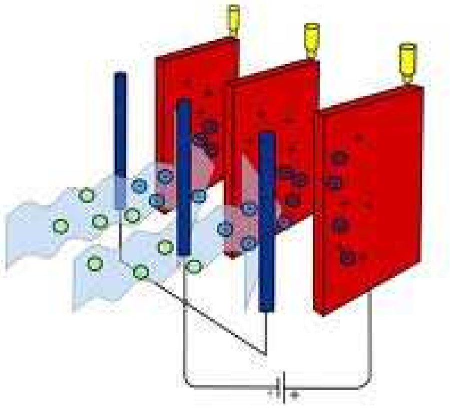
Disadvantages of Scrubbers

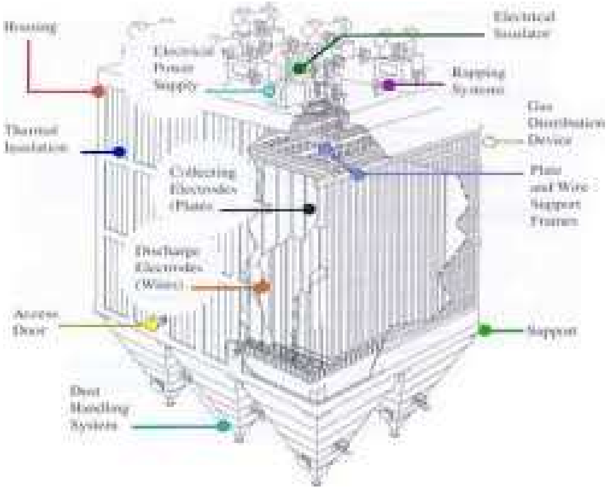
- Effluent liquid can create water pollution problems
- Waste product collected wet
- High potential for corrosion problems
- Requires protection against freezing
- Final exhaust gas requires reheating to avoid visible plume
- Collected PM may be contaminated, and not recyclable
- Disposal of waste sludge may be very expensive

ELECTROSTATIC PRECIPITATORS.

An ESP is a PM control device that uses electrical forces to move particles entrained within an exhaust stream onto collection surfaces. The entrained particles are given an electrical charge when they pass through a corona, a region where gaseous ions flow. Electrodes in the center of the flow lane are maintained at high voltage and generate the electrical field that forces the particles to the collector plates. The high voltage electrodes are long wires or rigid “masts” suspended from a frame in the upper part of the ESP that run through the axis of each tube. Rigid electrodes are generally supported by both an upper and lower frame. The power supplies for the ESP convert the industrial AC voltage to pulsating DC voltage in the range of 20,000 to 100,000 volts as needed. The voltage applied to the electrodes causes the gas between the electrodes to break down electrically, an action known as a “corona.” The electrodes are usually given a negative polarity because a negative corona supports a higher voltage than does a positive corona before sparking occurs. The ions generated in the corona follow electric field lines from the electrode to the collecting pipe. Therefore, each electrode-pipe combination establishes a charging zone through which the particles must pass.

As larger particles (>10µm diameter) absorb many times more ions than small particles (>1µm diameter), the electrical forces are much stronger on the large particles. When the collection plates are filled to capacity, the particulate is removed from the plates by “rapping,” which is a mechanical means to dislodge the particulate. The collected particulate material slides downward into a hopper located below the unit. The collection efficiency of an ESP is quite reliably about 99 percent for particles less than 10 micrometers. ESPs, in general, are very expensive to operate and are not very well suited for use in industrial processes because they are too sensitive to fluctuations in the gas stream. The Electrostatic Precipitator (ESP) separates particles from the gas stream by electrically charging the particles.





FABRIC FILTER

In a fabric filter, flue gas is passed through a tightly woven or felted fabric, causing PM in the flue gas to be collected on the fabric by sieving and other mechanisms. Fabric filters may be in the form of sheets, cartridges, or bags, with a number of the individual fabric filter units housed together in a group. Bags are the most common type of fabric filter. The dust cake that forms on the filter from the collected PM can significantly increase collection efficiency. Fabric filters are frequently referred to as baghouses because the fabric is usually configured in cylindrical bags. Bags may be 6 to 9m (20 to 30 ft) long and 12.7 to 30.5 centimeters (cm) (5 to 12 inches) in diameter. Groups of bags are placed in isolable compartments to allow cleaning of the bags or replacement of some of the bags without shutting down the entire fabric filter). Operating conditions are important determinants of the choice of fabric. Some fabrics (i.e., polyolefins, nylons, acrylics, polyesters) are useful only at relatively low temperatures of 95° to 150ºC (200° to 300ºF). For high temperature flue gas streams, more thermally stable fabrics such as fiberglass, Teflon, or Nomex must be used.

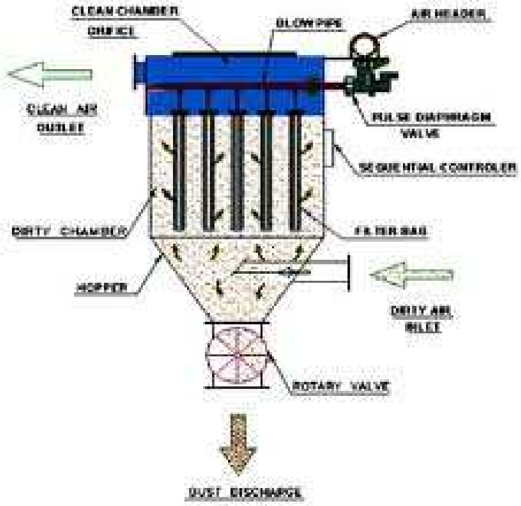
The practical application of fabric filters requires the use of a large fabric area in order to avoid an unacceptable pressure drop across the fabric. Baghouse size for a particular unit is determined by the choice of air-to-cloth ratio, or the ratio of volumetric airflow to cloth area. The selection of air-to-cloth ratio depends on the particulate loading and characteristics, and the cleaning method used. A high particulate loading will require the use of a larger baghouse in order to avoid forming too heavy a dust cake.

Determinants of baghouse performance include the fabric chosen, the cleaning frequency and methods, and the particulate characteristics. Fabrics can be chosen which will intercept a greater

fraction of particulate. In order to accomplish this, some fabrics are coated with a membrane of very fine openings for enhanced removal of submicron particulate. However, such fabrics tend to be more expensive. Cleaning intensity and frequency are important variables in determining removal efficiency because the dust cake can affect the fine particulate removal capability of a fabric. Cleaning procedures, which may be too frequent or too intense, will also lower the removal efficiency of the fabric filter. On the other hand, if removal is too infrequent or too ineffective, then the baghouse pressure drop will become too high.

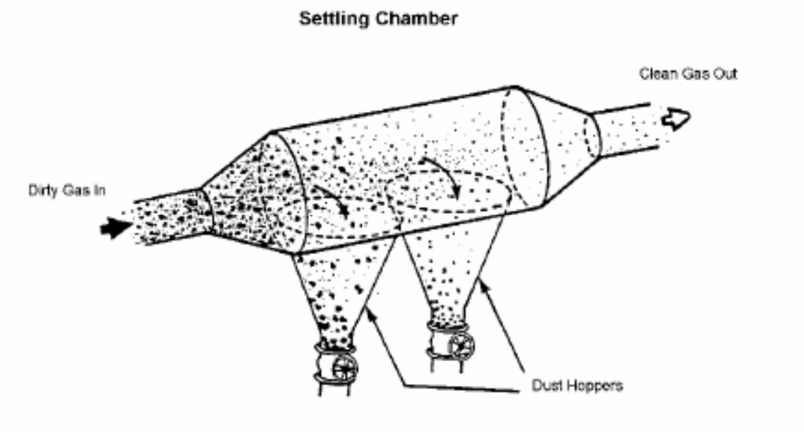
Mechanical shaking of the bags has been a popular cleaning method for many years because of its simplicity as well as its effectiveness. In a typical operation, dusty gas enters an inlet pipe to the shaker. Very large particles are removed from the stream when they strike the baffle plate in the inlet duct and fall into the hopper. The particulate-laden gas is drawn from beneath a cell plate in the floor and into the filter bags. The gas proceeds from the inside of the bags to the outside and through the outlet pipe. The particles are collected on the inside surface of the bags and a filter cake accumulates. In mechanical shaking units, the tops of bags are attached to a shaker bar, which is moved briskly (usually in a horizontal direction) to clean the bags. The shaker bars are operated by mechanical motors or by hand, in applications where cleaning is not required frequently. Reverse-air cleaning is another popular fabric filter cleaning method that has been used extensively and improved over the years. It is a gentler but sometimes less effective cleaning mechanism than mechanical shaking. Most reverse-air fabric filters operate in a manner similar to shaker-cleaned fabric filters. Typically, the bags are open on bottom, closed on top, and the gas flows from the inside to the outside of the bags with dust being captured on the inside. However, some reverse-air designs collect dust on the outside of the bags. In either design, forcing clean air through the filters in the opposite direction of the dusty gas flow performs reverse-air cleaning. The change in direction of the gas flow causes the bag to flex and crack the filter cake. In internal cake collection, the bags are allowed to collapse to some extent during reverse-air cleaning. The bags are usually prevented from collapsing entirely by some kind of support, such as rings that are sewn into the bags. The support enables the dust cake to fall off the bags and into the hopper. Cake release is also aided by the reverse flow of the gas because felted fabrics retain dust more than woven fabrics. Therefore, they are more difficult to clean. For this reason, felts are usually not used in reverse-air systems.

Fabric filters in general provide high collection efficiencies on both coarse and fine (submicron) particulates. Typical new equipment design efficiencies are between 99% and 99.9%.



SETTLING CHAMBERS

This type of technology is a part of the group of air pollution controls collectively referred to as “precleaners.” They are referred to as precleaners because they are often used to reduce the inlet loading of particulate matter (PM) to downstream collection devices by removing larger, abrasive particles. Settling chambers are also referred to as gravity settling chambers, gravity collectors, expansion chambers, and outfall chambers. This is because settling chambers are quite effective in removing only large particles; therefore, they can be frequently used in combination with other control devices. Settling Chambers rely on simple gravitation to remove particles from a gas stream.



Settling chambers, which rely on gravitational settling as a collection mechanism are the simplest and oldest mechanical collectors. Settling chambers are generally built in the form of long, horizontal, rectangular chambers with an inlet at one end and an exit at the side or top of the opposite end. Flow within the chamber must be uniform and without any macroscopic mixing. Uniform flow is can be improved by flow straighteners at the inlet to the chamber. Hoppers are used to collect the settled-out material, though drag scrapers and screw conveyers have also been employed. The dust removal system must be sealed to prevent air from leaking into the chamber which increases turbulence, causes dust reentrainment, and prevents dust from being properly discharged from the device. There are two primary types of settling chambers: the expansion chamber and the multiple-tray chamber. In the expansion chamber, the velocity of the gas stream is significantly reduced as the gas expands in a large chamber. The reduction in velocity allows larger particles to settle out of the gas stream.

A multiple-tray settling chamber is an expansion chamber with a number of thin trays closely spaced within the chamber, which causes the gas to flow horizontally between them. While the gas velocity is increased slightly in a multiple-tray chamber, when compared to a simple expansion chamber, the collection efficiency generally improves because the particles have a much shorter distance to fall before they are collected. Multiple-traysettling chambers have lower volume requirements than expansion-type settling chambers for the collection of small particles (<15μm). Settling chambers are most effective when collecting large or dense particles, but often fail when the chamber becomes plugged with collected dust.

The most common failure of settling chambers is when chambers become plugged with collected dust. In expansion settling chambers the plugging can result from hopper bridging or hopper discharge seal failure. Multiple-tray settling chambers may experience plugging of the individual gas passages. Such failures can be prevented or minimized by use of hopper level indicators or by continuous monitoring of the dust discharge. Scheduled internal inspection can determine areas of air leakage and condensation, both of which may cause hopper bridging. Normal instrumentation for a settling chamber generally includes only an indicator of differential static pressure. An increase in static pressure drop can indicate plugging

Advantages of Settling Chambers

- Low capital cost
- Very low energy cost
- No moving parts
- Few maintenance requirements
- Low operating costs
- Excellent reliability
- Low pressure drop through device
- Device not subject to abrasion due to low gas velocity
- Provide incidental cooling of gas stream
- Dry collection and disposal

Disadvantages of Settling Chambers

- Relatively low PM collection efficiencies
- Unable to handle sticky or tacky materials
- Large physical size
- Trays in multiple-tray settling chamber may warp

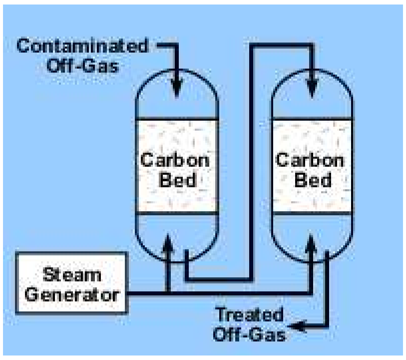
Control of gaseous pollutants from stationary sources - Adsorption

When a gas or vapor is brought into contact with a solid, part of it is taken up by the solid. The molecules that disappear from the gas either enter the inside of the solid, or remain on the outside attached to the surface. The former phenomenon is termed absorption (or dissolution) and the latter adsorption. Adsorption is the binding of molecules or particles to a surface. In this phenomenon molecules from a gas or liquid will be attached in a physical way to a surface. The binding to the surface is usually weak and reversible. The most common industrial adsorbents are activated carbon, silica gel, and alumina, because they have enormous surface areas per unit weight.

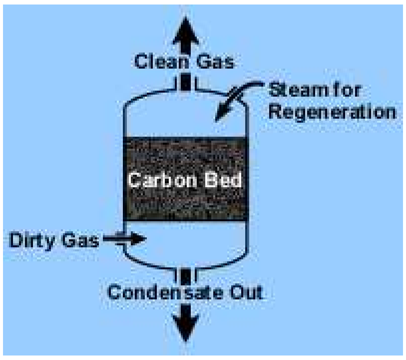
Activated carbon is the universal standard for purification and removal of trace organic contaminants from liquid and vapor streams. Carbon adsorption uses activated carbon to control and/or recover gaseous pollutant emissions. In carbon adsorption, the gas is attracted and adheres to the porous surface of the activated carbon. Removal efficiencies of 95 percent to 99 percent can be achieved by using this process. Carbon adsorption is used in cases where the recovered organics are valuable. For example, carbon adsorption is often used to recover perchloroethylene, a compound used in the dry cleaning process.

Carbon adsorption systems are either regenerative or non-regenerative. A regenerative system usually contains more than one carbon bed. As one bed actively removes pollutants, another bed

is being regenerated for future use. Steam is used to purge captured pollutants from the bed to a pollutant recovery device. By "regenerating" the carbon bed, the same activated carbon particles can be used again and again. Regenerative systems are used when concentration of the pollutant in the gas stream is relatively high. Non-regenerative systems have thinner beds of activated carbon. In a non-regenerative adsorber, the spent carbon is disposed of when it becomes saturated with the pollutant. Because of the solid waste problem generated by this type of system, non-regenerative carbon adsorbers are usually used when the pollutant concentration is extremely low.



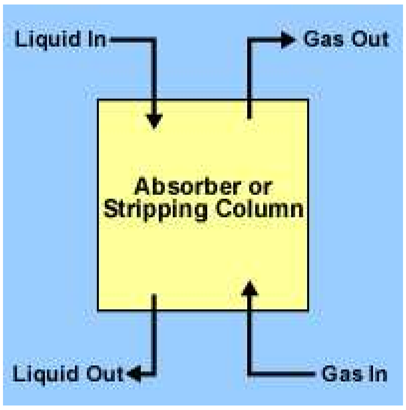
Regenerative Carbon Adsorption System



Non-Regenerative Carbon Adsorption System

Control of gaseous pollutants from stationary sources – Absorption

The removal of one or more selected components from a gas mixture by absorption is probably the most important operation in the control of gaseous pollutant emissions. Absorption is a process in which a gaseous pollutant is dissolved in a liquid. Water is the most commonly used absorbent liquid. As the gas stream passes through the liquid, the liquid absorbs the gas, in much the same way that sugar is absorbed in a glass of water when stirred. Absorption is commonly used to recover products or to purify gas streams that have high concentrations of organic compounds. Absorption equipment is designed to get as much mixing between the gas and liquid as possible. Absorbers are often referred to as scrubbers, and there are various types of absorption equipment. The principal types of gas absorption equipment include spray towers, packed columns, spray chambers, and venture scrubbers. The packed column is by far the most commonly used for the absorption of gaseous pollutants. The packed column absorber has a column filled with an inert (non-reactive) substance, such as plastic or ceramic, which increases the liquid surface area for the liquid/gas interface. The inert material helps to maximize the absorption capability of the column. In addition, the introduction of the gas and liquid at opposite ends of the column causes mixing to be more efficient because of the counter-current flow through the column. In general, absorbers can achieve removal efficiencies greater than 95 percent. One potential problem with absorption is the generation of waste-water, which converts an air pollution problem to a water pollution problem.



Typical packed column diagram

Unit–6 -- 10CV765 -- APC
AUTOMOBILE POLLUTION

The addition of chemicals released from automobile emissions constituting NO_X, HC's, CO, SPM, SO_2, Pb resulting in deterioration of ambient air is termed as automobile pollution. Five of these are also criteria air pollutants.

SOURCE, EFFECT AND CONTROL OF AUTOMOBILE POLLUTANTS

1] **SO2**.

The formation of Sulphur di Oxide in exhaust gases is caused by the oxidation of the sulphur in the fuel during the combustion process. In the atmosphere however, SO2 combines with moisture to form H2SO4, which then falls as acid rain, and has been linked to environmental damage.The major health concerns associated with exposure to high concentrations of SO2 include effects on breathing (decreased lung function), respiratory illness, alterations in pulmonary defences, and aggravation of existing cardiovascular disease. Children, the elderly, and people with asthma, cardiovascular disease or chronic lung disease (such as bronchitis or emphysema), are most susceptible to adverse health effects associated with exposure to SO2.

2] **Pb**.

Exposure to lead mainly occurs through inhalation of air and ingestion of lead in food, paint, water, soil, or dust. Lead accumulates in the body in blood, bone, and soft tissue. Because it is not readily excreted, lead can also affect the kidneys, liver, nervous system, and other organs. Excessive exposure to lead may cause anemia, kidney disease, reproductive disorders, and neurological impairments such as seizures, mental retardation, and/or behavioral disorders. Even at low doses, lead exposure is associated with changes in fundamental enzymatic, energy transfer, and other processes in the body. Fetuses and children are especially susceptible to low doses of lead, often suffering central nervous system damage or slowed growth. Lead may also contribute to osteoporosis in post-menopausal women.

3] **SPM**.

The composition and properties of particulates varies greatly and is therefore difficult to define. Furthermore, there is not a quantitative relationship between the smoke opacity and the particulate emission. Particle emissions from engines can originate from:

a) agglomeration of very small particles of partly burned fuel;
b) partly burned lub oil;
c) ash content of fuel oil and cylinder lub oil; or
d) sulphates and water.

The smaller particles that are likely responsible for adverse health effects because of their ability to reach the lower regions of the respiratory tract. Major concerns for human health from exposure to PM-10 include: effects on breathing and respiratory systems, damage to lung tissue, cancer, and premature death. The elderly, children, and people with chronic lung disease, influenza, or asthma, are especially sensitive to the effects of particulate matter. Acidic PM-10 can also damage human-made materials and is a major cause of reduced visibility.

The most effect method of reducing particulate emissions is to use lighter distillate fuels however, this leads to added expense. Additional reductions in particulate emissions can be achieved by increasing the fuel injection pressure to ensure that optimum air-fuel mixing is achieved, however, as fuel injection pressure increases, the reliability of the equipment decreases. Much research has also been conducted on cyclone separators, which are effective for particle sizes greater than 0.5μm while electrostatic precipitators are more effective, capable of reduction emissions by up to 99%. Unfortunately, precipitators are expensive, prone to clog and are large in size.

4] **Unburnt Hydrocarbons**.

The emission of unburned hydrocarbons (HC) generally results from fuel, which is unburned as a result of insufficient temperature. This often occurs near the cylinder wall (wall quenching) where the temperature of the air/fuel mixture is significantly less than in the centre of the cylinder. Bulk quenching can also occur as a result of insufficient pressure or temperature within the cylinder itself. Still further, HC production may also be a result of poorly designed fuel injection systems, injector needle bounce, excessive nozzle cavity volumes or fuel jets reaching a quench layer.

Volatile Organic Compounds or VOCs are organic chemicals that easily vaporize at room temperature. VOCs include a very wide range of individual substances, such as hydrocarbons (for example benzene and toluene), halocarbons and oxygenates.

Hydrocarbon VOCs are usually grouped into methane and other non-methane VOCs. Methane is an important component of VOCs, its environmental impact principally related to its contribution to global warming and to the production of ground level or lower atmosphere ozone. Most methane is released to the atmosphere via the leakage of natural gas from distribution systems. Benzene, a non-methane hydrocarbon, is a colourless, clear liquid. It is fairly stable but highly volatile, readily evaporating at room temperature. Since 80% of man-made emissions come from petrol-fuelled vehicles, levels of benzene are higher in urban areas than rural areas. Benzene concentrations are highest along urban roadsides. Evaporation of solvents, used for example in paints, cause a release of hydrocarbons, oxygenates and halocarbons to the atmosphere.

Some VOCs are extremely harmful, including the carcinogens benzene, polycyclic aromatic hydrocarbons (PAHs) and 1,3 butadiene. Benzene may increase susceptibility to

leukaemia, if exposure is maintained over a period of time. There are several hundred different forms of PAH, and sources can be both natural and man-made processes. PAHs can cause cancer. Sources of 1,3 butadiene include the manufacturing of synthetic rubbers, petrol driven vehicles and cigarette smoke. There is an apparent correlation between butadiene exposure and a higher risk of cancer.

HC reduction would most likely only be possible using primary and further secondary oxidation catalysts.

5] **NOx**.

NOx is formed during the combustion process within the burning fuel sprays and is deemed one of the most harmful to the environment and contributes to acidification, formation of ozone, nutrient enrichment and to smog formation, which has become a considerable problem in most major cities world-wide.

The amount of NOx produced is a function the maximum temperature in the cylinder, oxygen concentrations, and residence time. At cylinder temperatures, nitrogen from the intake air and fuel becomes active with the oxygen in the air forming oxides of nitrogen. Increasing the temperature of combustion increases the amount of NOx by as much as 3 fold for every 100_oC increase. NO is formed first in the cylinder followed by the formation of NO_2 and N_2O, typically at concentrations of 5% and 1%; respectively. NO_2 is soluble and washed out by rain which increases the acidity level of the soil.

Nitrogen dioxide can irritate the lungs and lower resistance to respiratory infections such as influenza. The effects of short-term exposure are still unclear, but continued or frequent exposure to concentrations that are typically much higher than those normally found in the ambient air may cause increased incidence of acute respiratory illness in children. Nitrogen oxides contribute to ozone formation and can have adverse effects on both terrestrial and aquatic ecosystems. Nitrogen oxides in the air contribute to acid rain and eutrophication. (Eutrophication occurs when a body of water suffers an increase in nutrients that leads to a reduction in the amount of oxygen in the water, producing an environment that is destructive to fish and other animal life.)

The best way to reduce NOx generation, is to reduce peak cylinder temperatures.

6] **CO**.

CO is formed due to the incomplete combustion of organic material where the oxidation process does not have enough time or reactant concentration to occur completely. In engines, the formation of CO is determined by the air/fuel mixture in the combustion chamber and as diesels have a consistently high air to fuel ratio, formation of this toxic gas is minimal. Nevertheless, insufficient combustion can occur if the fuel droplets in a

diesel engine are too large or if insufficient turbulence or swirl is created in the combustion chamber.

Carbon monoxide enters the bloodstream and reduces oxygen delivery to the body's organs and tissues. The health threat from exposure to CO is most serious for those who suffer from cardiovascular disease. Healthy individuals are also affected, but only at higher levels of exposure. Exposure to elevated CO levels is associated with visual impairment, reduced work capacity, reduced manual dexterity, poor learning ability, and difficulty in performing complex tasks.

The intensity and frequency of the afore-mentioned impacts essentially depends on several other factors such as age of the vehicle, type of fuel used, condition of engine, type of engine, maintenance and operation mode of vehicle etc.

PETROL ENGINE vs. DIESEL ENGINE

Petrol engine	**Diesel engine**
High CO, HC’s concentration in emissions	Lesser HC’s concentration i.e., 1/10 CO that of petrol
Less smoke	Major problem odor and smoke, at least 80% SPM than in petrol exhaust
Less SO2, NOX,PM	More NO_X, SO_2, PM/SPM

Inference: The major pollutants in diesel exhaust emissions are a direct result of the diesel combustion process itself. Diesel engines have higher compression ratio than petrol. First air is compressed, then fuel injected, then ignition but in petrol, air fuel mixed first, compressed and the n ignited. HC’s concentration is less, because blowby is negligible as only air is present in compression stroke & evaporative emissions. Hydrocarbons are as well low because diesel uses a closed injection fuel system.

SMOKE

When compared to diesel emissions, petrol emissions are more toxic w.r.t. human; while diesel emissions contribute towards environmental impacts. Yet smoke emission from diesel cannot be ignored.

Maximum smoke is produced when vehicle runs at 60% of total power. It is measured in Ringlemann’s Scale.

Effects of smoke: Irritation of eye membrane, ear membrane and respiratory tract, soiling of clothes, disfiguring of buildings.

Control means: High A/F ratio, Smokeless fuel – Vehicle maintenance - Lean mixture.

2 STROKE ENGINE vs. 4 STROKE ENGINE

When compared to 4 stroke, 2 stroke engine produces more pollution [HC's, CO, SPM, Smoke] as it burns an oil gasoline mixture, but 2 stroke engine is more powerful, lighter, less expensive. On the contrary, 4 stroke engine gives more mileage, produces less HC's and VOC's [volatile organic carbon] as there is no short circuit of raw fuel.

TYPES OF EMISSIONS

1. Tailpipe emissions: This is what most people think of when they think of vehicle air pollution; the products of burning fuel in the vehicle's engine, emitted from the vehicle's exhaust system. The major pollutants emitted include:

Hydrocarbons: This class is made up of unburned or partially burned fuel, and is a major contributor to urban smog, as well as being toxic. They can cause liver damage and even cancer.

Nitrogen oxides (NOx): These are generated when nitrogen in the air reacts with oxygen under the high temperature and pressure conditions inside the engine. NOx emissions contribute to both smog and acid rain.

Carbon monoxide (CO): A product of incomplete combustion, carbon monoxide reduces the blood's ability to carry oxygen and is dangerous to people with heart disease.

Carbon dioxide (CO_2): Emissions of carbon dioxide are considered to pollute because it is a significant greenhouse gas and increasing its levels in the atmosphere contributes to global climate change.

Exhaust emissions contain 100% CO, 100% NO_X, 100% Pb and 60-65% HC's

2. Blowby/Crankcase emissions: 20% unburnt HC's mainly due to leakage of oil vapor around Worn-out piston rings.

3. Evaporative emissions: These are produced from the evaporation of fuel, and are a large contributor to urban smog, since these heavier molecules stay closer to ground level. Fuel tends to evaporate in these ways:

Gas tank venting: the heating of the vehicle as the temperature rises from the night-time temperature to the hottest temperatures of the day mean that gasoline in the tank evaporates, increasing the pressure inside the tank above atmospheric pressure. This pressure must be relieved, and before emissions control it was simply vented into the atmosphere.

Running losses include the escape of gasoline vapors from the hot engine. **Refueling losses** include these can cause a lot of hydrocarbon vapor emission. The empty space inside a vehicle's tank is filled with hydrocarbon gases, and as the tank is filled, these gases are forced out into the atmosphere. In addition, there is loss from further evaporation and fuel spillage.

Bird view of emission of net pollution

65 % from Exhaust + 15 % from Blowby + 20 % Evaporative = 100%

Bird view of Hydrocarbon emissions [mainly as Benzopyrene]

60 % from Exhaust + 20 % from Blowby + 20 % Evaporative = 100%

Evaporative emissions: 20% HC'S via gas tank venting, refueling & running losses.

Operation w.r.t Emissions

Mode of Operation	Unburnt HC's [ppm]	CO [% by volume]	NO_X [ppm]	A/F RATIO
IDLE	750	5.2	30	11:1-12:1
CRUISING	300	0.8	1500	11:1-13:1
ACCELERATION	400	5.2	3000	13:1-15:1
DECELERATION	4000	4.2	60	11:1-12.5:1

Comparative study

When A/F ratio is high, then less CO, HC's but high NOx
When Vehicle decelerates high HC's [hydrocarbon]
When vehicle is idle [engine not switched off during signals] high CO, low NO_X, moderate HC's.
When vehicle accelerates low HC'S , high CO, high CO, and high NOx
When vehicle cruises high NOx, low CO, moderate HC's and high CO_2.

Drawbacks

Pb is released from exhaust as lead halides which are a cumulative toxin, a chief environmental pollutant capable of affecting neural development resulting in lower IQ.

Also lead acts as poison for catalytic converter. This resulted in advent of unleaded petrol. The alternative used was MTBE. But it has been found to be non-bio-degradable and possible ground contamination. This resulted in the use of ethanol as anti-knocking agent to boost octane rating. But ethanol causes fuel to absorb moisture from air, over long time it leads to rusting, corrosion in fuel line. Also it is poorly soluble and enhances possibility of bacterial contamination.

TEL now banned in road sector continues to be used in aviation fuel as additive called as AVGAS. The catch is despite using unleaded petrol; the emissions consist of benzene which causes cancer, anemia and blood cancer. The other option w.r.t knocking phenomenon is utilize branched chain alkanes, which results pre ignition, loss of power, lower octane rating.

Catalytic converters

The air fuel ratio must be so high that all CO formed is converted to CO_2, but if ratio is less [lack of O_2], it facilitates formation of CO, Unburnt HC's, NO_X. Also due to higher temperature [2000-2500 ^{0}C], high pressure formation of Nitric oxide takes place.

If a car burns fuel with perfect efficiency, its only exhaust products would be CO_2 and H_2O. Unfortunately not every molecule burns to completion. Catalytic converter consists of an array of tubes, each coated with porous ceramics. Embedded in this coating are tiny particles of platinum and rhodium which serve as catalyst. Previously V_2O_5, Vanadium Pentoxide served the purpose.

$$HC+CO+NO_X \rightarrow H_2O+CO_2+N_2$$

Nowadays Rhodium, Platinum, Palladium serve the role as 3-way catalyst, once the exhaust heats the converter above 300^{0}C, unwanted molecules bind temporarily to catalyst and are converted. 95% of HC's, CO, NO_X is removed by converter but the presence of Pb in fuel as lead Halide gets coated over surface inactivating them. Catalytic converters have no moving parts, but its limitations include poisoning by lead, deterioration with time and pressure loss.

Indirect Control measures

Car pool system, eco-friendly fuels, hybrid vehicles, use of bio fuels, use of alternate energy such as solar driven, use of unleaded petrol, complying to rules and regulation, frequent periodical emission testing, stringent norms and enforcement on violation,

Minimizing the use of vehicles by walking for small distances, pooling of the vehicles, switching off the vehicles on red lights, maintaining the vehicles in proper order, adopting efficient ways of driving, ban on overloading, better design and maintenance of roads collectively can reduce automobile air pollution.

Direct Control measures

The amount of SO2 formed is a function of the sulphur content of the fuel used and therefore the only effective method of reducing SOx is by reducing the sulphur content of the fuel. Unfortunately, low-sulphur fuels are more expensive to purchase (10 to 20% greater cost, when switching from 3.5% to 1% sulphur) and there is a practical lower sulphur limit desired as desulphurisation of fuel lowers the lubricity of the fuel which can lead to increase wear on fuel pumps and injectors.

proper operation and maintenance of vehicles

Using catalytic converter for HC’s, CO, NOx, C_6H_6

Increasing air-fuel ratio for HC’s, CO and Benzene

Recycling exhaust gas for NO_x, [15-25%]

In case of SPM, ensure proper maintenance and operation process, such has change air filter regularly, change engine oil as per manufacturer’s specification, use moderate acceleration and avoid slowing of engine atop gear.

The industry may be compelled to manufacture the vehicles in such a way, i.e. enforcing the Euro standards, that they produce minimum pollutants.

To maintain the vehicle by its proper servicing (tuning of engine) in such a way that the exhaust emissions are under control.

Control on the quality of fuel. Use unleaded petrol. Sometimes Kerosene is mixed with petrol or diesel (as it is cheaper) than the emissions are more pollutant and are of different nature.

Unit – 7

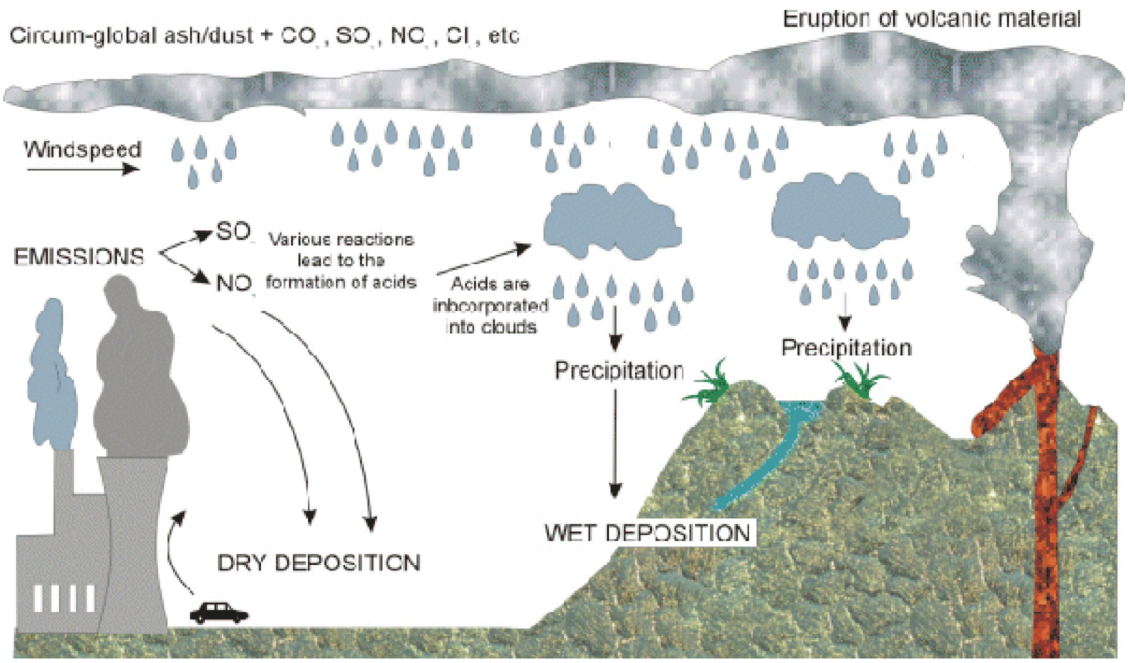
ACID RAIN

Definition

Normal Rain water p^H is slightly acidic due to certain concentration of CO_2 dissolved as rainwater trickles down atmosphere, i.e. $CO_2+H_2O \rightarrow HCO^{3-}+H^+$

Acid rain is defined as any type of precipitation with a p^H that is unusually low or lower than 5.7. Acid rain was first found in Manchester, England. In 1852, Robert Angus Smith found the relationship between acid rain and atmospheric pollution. Though acid rain was discovered in 1852, it wasn't until the late 1960s that scientists began widely observing and studying the phenomenon.

Causes



The principal natural phenomena that contribute acid-producing gases to the atmosphere are emissions from volcanoes and those from biological processes that occur on the land, in wetlands, and in the oceans. The major biological source of sulfur containing compounds is dimethyl sulfide.

The principal cause of acid rain is sulfuric and nitrogen compounds from human sources, such as electricity generation, factories and motor vehicles. Coal power plants are one of the most polluting. The gases can be carried hundreds of kilometres in the atmosphere before they are converted to acids and deposited. Factories used to have short funnels to let out smoke, but this caused many problems, so now, factories have longer smoke funnels. The problem with this is those pollutants get carried far off, where it creates more destruction.

Sulfur dioxide contributes to about seventy percent of acid rain while nitrogen oxides provide the remaining thirty percent. The sources of sulfur in the atmosphere include coal combustion, smelting, organic decay, and ocean spray. Approximately ninety percent of atmospheric sulfur results from human activities.

In the atmosphere, sulfur dioxide combines with water vapor to form hydrogen sulfite gas: $SO_2 + H_2O + 1/2O_2 \rightarrow H_2SO_4$

Next, hydrogen sulfite reacts with oxygen to form sulfuric acid, a major component of acid rain: $H_2SO_3 + 1/2O_2 \rightarrow H_2SO_4$

The sources of nitrogen oxides include the combustion of oil, coal and natural gas, forest fires, bacterial action in soil, volcanic gases, and lighting-induced atmospheric reactions.

In the atmosphere, nitrogen monoxide reacts with oxygen gas to form nitrogen dioxide gas: $NO + 1/2O_2 \rightarrow NO_2$

Then, nitrogen dioxide reacts with water vapor in the atmosphere to form hydrogen nitrite and hydrogen nitrate: $2NO_2 + H_2O \rightarrow HNO_2 + HNO_3$

Henceforth, acid rain is a mixture of HNO_3, H_2SO_4 + HCl. however conditions needed to favor formation of these are sunlight, temperature, humidity, hydrocarbons, NO_X, SO_2.

Effects

Both the lower p^H and higher aluminum concentrations in surface water that occur as a result of acid rain can cause damage to fish and other aquatic animals. At p^H lower than 5 most fish eggs will not hatch and lower p^H can kill adult fish. As lakes become more acidic biodiversity is reduced. Soil biology can be seriously damaged by acid rain. Some tropical microbes can quickly consume acids but other microbes are unable to tolerate low p^H and are killed.

Acid rain can slow the growth of forests, cause leaves and needles to turn brown and fall off and die. In extreme cases trees or whole areas of forest can die. The death of trees is not usually a direct result of acid rain; often it weakens trees and makes them more susceptible to other threats.

Some scientists have suggested direct links to human health, but none have been proven. However, fine particles, a large fraction of which are formed from the same gases as acid

rain (sulfur dioxide and nitrogen dioxide), have been shown to cause illness and premature deaths such as cancer and other deadly diseases

Toxic metals released into the environment by acid rain may enter water supplies or accumulate in fish and crops. Acid deposition also destroys statues, headstones, buildings, and fountains. Limestone structures are especially susceptible because they dissolve easily in acidic solutions.

Acid rain can also cause damage to certain building materials and historical monuments. Acid rain can cause weathering on ancient and valuable statues and has caused considerable damage. This is because the sulfuric acid in the rain chemically reacts with the calcium compounds in the stones (limestone, sandstone, marble and granite) to create gypsum, which then flakes off. Acid rain also causes an increased rate of oxidation for iron.

Control

- Design more efficient automobile engines in order to reduce nitrogen oxide emissions.
- Increase efficiency of power plants that burn coal in order to reduce waste that contains sulfur dioxide and nitrogen oxide.
- Increase penalties on industries that do not meet air pollution guidelines.
- Increase tax incentives to industries that do meet guidelines.
- Use alternative energy sources, Increase funding for alternative energy sources; for example, give tax incentives to buyers of hybrid cars.
- Provide tax incentives to companies that use alternative energy sources.
- Add $CaCO_3$ (calcium carbonate) to lakes suffering from acid deposition; calcium carbonate acts as a buffer, resisting a change in p^H and lessening the negative effects of acid rain.

OZONE DEPLETION

Definition

Ozone layer is an umbrella 24 km [15 miles] from earth surface, an essential component of the stratosphere that absorbs short wavelength ultraviolet radiation from the sun, heating the gases of the stratosphere in the process. World ozone day is celebrated on Sept, 16 of every year.

Stratospheric ozone is measured in Dobson units [DU] named after G.M.B Dobson who pioneered the study; [I Dobson unit = 0.01 mm thickness of stratospheric ozone], Average ozone thickness in stratosphere is 300 DU, & when it falls below 200 DU, it’s considered as Ozone hole. It is thinnest around equator and thickest near poles.

Stratospheric ozone depletion is the term applied to the loss of stratospheric ozone molecules (O_3) and the disruption of Oxygen-Ozone concentration equilibrium in stratosphere [i.e., when chlorine atoms upset the natural O_2/O_3 equilibrium in the stratosphere]. Oxygen molecules interact with the intense solar radiation present at this elevation to form oxygen atoms. The oxygen atoms thus generated react with other oxygen molecules to form ozone (O_3).

Causes

Ozone depletion is caused by the release of chlorofluorocarbons (CFC's) and other ozone-depleting substances (ODS), which were used widely as refrigerants, insulating foams, and solvents. The discussion below focuses on CFCs, but is relevant to all ODS [NO, NO_2 (aircraft exhaust), Br^-, UV rays, [O] Atomic oxygen etc].

Although CFCs are heavier than air, they are eventually carried into the stratosphere in a process that can take as long as 2 to 5 years. When CFCs reach the stratosphere, the ultraviolet radiation from the sun causes them to break apart and release chlorine atoms which react with ozone, starting chemical cycles of ozone destruction that deplete the ozone layer. One chlorine atom can break apart more than 100,000 ozone molecules.

Other chemicals that damage the ozone layer include methyl bromide (used as a pesticide), halons (used in fire extinguishers), and methyl chloroform (used as a solvent in industrial processes). As methyl bromide and halons are broken apart, they release bromine atoms, which are 40 times more destructive to ozone molecules than chlorine atoms.

Chapman's Reaction

$$\begin{array}{ll} O_2 + UV \rightarrow 2\,O & \\ O + O_2 \rightarrow O_3 & \text{(ozone production)} \\ O_3 + UV \rightarrow O + O_2 & \text{(ozone destruction)} \\ O + O_2 \rightarrow O_3 & \text{(ozone production)} \\ O_3 + O \rightarrow O_2 + O_2 & \text{(ozone destruction)} \end{array}$$

Ozone Depletion by CFC's

$$CF_2Cl_2 + h\nu \longrightarrow Cl^{\cdot} + CCl_2F^{\cdot}$$

$$Cl^{\cdot} + O_3 \longrightarrow ClO^{\cdot} + O_2$$

$$ClO^{\cdot} + O \longrightarrow Cl^{\cdot} + O_2$$

All above reactions occur in the presence of UV rays, while the 2nd set of reactions governs the oxygen-ozone equilibrium due to its spontaneity.

Effects

Effect of ozone hole include cataract, genetic mutation, constriction of blood vessels, reduced crop yield, leukemia, breast cancer, damage to crop, aqua culture, etc.,

The higher energy UV radiation absorbed by ozone is generally accepted to be a contributory factor to skin cancer. In addition, increased surface UV leads to increased tropospheric ozone, which is a health risk to humans such as Snow Blindness [photo keratosis], i.e., inflammation of cornea (outer coating of eyeball). The most common forms of skin cancer in humans, basal and squamous cell carcinomas have been strongly linked to UVB exposure. Another form of skin cancer, malignant melanoma, is much less common but far more dangerous, being lethal in about 15% - 20% of the cases diagnosed. In India there is no standard for Ozone. However WHO standard is 100 ppm for 8 hrs – avg.

Control Measures

The Montreal Protocol, an international agreement signed by 139 nations, banning the production of CFCs by the year 2000. We can't make enough ozone to replace what's been destroyed, but provided that we stop producing ozone-depleting substances, natural ozone production reactions should return the ozone layer to normal levels by about 2050. It is very important that the world comply with the Montreal Protocol; delays in ending production could result in additional damage and prolong the ozone layer's recovery. Control mechanism stresses on replacement of the banned chemical by ammonia, steam, helium etc.

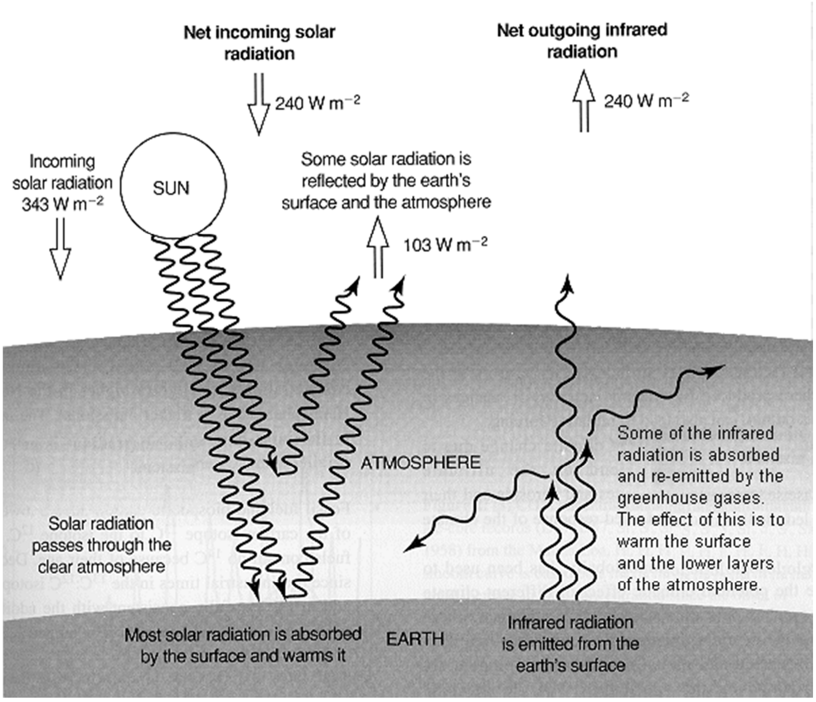
GREEN HOUSE EFFECT

Introduction

Objects that absorb all radiation upon them are called "blackbody" absorbers. The earth is close to being a black body absorber. Gases, on the other hand, are selective in their absorption characteristics. While many gases do not absorb radiation at all some selectively absorb only at certain wavelengths. Those gases that are "selective absorbers" of solar energy are the gases we know as "Greenhouse Gases."

Definition

The greenhouse effect is a phenomenon that ought to create a condition in the upper atmosphere, causing a trapping of excess heat and leading to increased surface temperatures.



Mechanism

The Earth receives energy from the Sun in the form of radiation. The Earth reflects about 30% of the incident solar flux; the remaining 70% is absorbed, warming the land, atmosphere and oceans. The visible solar radiation heats the surface, not the atmosphere, whereas most of the infrared radiation escaping to space is emitted from the upper atmosphere, not the surface. The infrared photons emitted by the surface are mostly absorbed by the atmosphere and do not escape directly to space. Hence earth's greenhouse effect is a natural phenomenon that helps regulates the temperature of our planet. Simply put, the sun heats the earth and some of this heat, rather than escaping back to space, is trapped in the atmosphere by clouds and greenhouse gases, such as water vapor and carbon di oxide. If all these greenhouse gases were to suddenly disappear, our planet would be 60° F colder and uninhabitable.

GREENHOUSE GASSES – SOURCES & SINKS

On Earth, the major natural greenhouse gases are water vapor, which causes about 36–70% of the greenhouse effect (not including clouds); carbon dioxide (CO_2), which causes 9–26%; methane (CH_4), which causes 4–9%; and ozone, which causes 3–7%.

Carbon Dioxide

Sources: Released by the combustion of fossil fuels (oil, coal, and natural gas), flaring of natural gas, changes in land use (deforestation, burning and clearing land for agricultural purposes), and manufacturing of cement.
Sinks: Photosynthesis and deposition to the ocean.
Significance: Accounts for about half of all warming potential caused by human activity.

Methane

Sources: Landfills, wetlands and bogs, domestic livestock, coal mining, wet rice growing, natural gas pipeline leaks, biomass burning, and termites.
Sinks: Chemical reactions in the atmosphere.
Significance: Molecule for molecule, methane traps heat 20-30 times more efficiently than CO_2. Within 50 years it could become the most significant greenhouse gas.

Nitrous Oxide [296 times potential than CO_2]

Sources: Burning of coal and wood, as well as soil microbes' digestion.
Sinks: Chemical reactions in the atmosphere.
Significance: Long-lasting gas that eventually reaches the stratosphere where it participates in ozone destruction.

Ozone

Sources: Not emitted directly, ozone is formed in the atmosphere through photochemical reactions involving nitrogen oxides and hydrocarbons in the presence of sunlight.
Sinks: Deposition to the surface, chemical reactions in the atmosphere.
Significance: In the troposphere ozone is a pollutant. In the stratosphere it absorbs hazardous ultraviolet radiation.

Chlorofluorocarbons (CFCs)

Sources: Used for many years in refrigerators, automobile air conditioners, solvents, aerosol propellants and insulation.
Sinks: Degradation occurs in the upper atmosphere at the expenses of the ozone layer. One CFC molecule can initiate the destruction of as many as 100,000 ozone molecules.
Significance: The most powerful of greenhouse gases — in the atmosphere one molecule of CFC has about 20,000 times the heat trapping power on a molecule of CO_2.

GLOBAL WARMING - CLIMATE CHANGE

Definition

Global warming is the increase in the average temperature of the Earth's near-surface air and oceans in recent decades and its projected continuation.

Impacts

- Consequences may include changes in agricultural yields, glacier retreat, reduced summer stream flows, species extinctions and increases in the ranges of disease vectors.

- The melting of Arctic ice and increased regional precipitation can add freshwater to the oceans, and potentially affect ocean currents in the North Atlantic.

- Forest fires could become more frequent.

- Due to the warming; insect outbreaks will increasingly disturb large areas of forest.

- Many Arctic animals, such as polar bears, seals, walruses, and seabirds, rely on the sea's biological productivity and on the presence of sea ice, both of which are highly dependent on climatic conditions.

- Changes in sea surface temperatures or currents could have a strong effect on Arctic marine fish stocks, which are an important food source for the world and play a vital role in the region's economy.

- Additional anticipated effects include 18% to 35% of a sample of 1,103 animal and plant species to be extinct by 2050, based on future climate projections.

Control

The world's primary international agreement on combating global warming is the Kyoto Protocol, an amendment to the United Nations Framework Convention on Climate Change (UNFCCC), negotiated in 1997. The Protocol now covers more than 160 countries globally and over 55% of global greenhouse gas (GHG) emissions.

How to Combat Global Warming

Use Compact Fluorescent Bulbs
Use Recycled Paper
Use Solar-heated Water
Take Shorter Showers
Buy Products Locally
Buy a Hybrid Car, Bio-fuel driven
Carpool When You Can
Plant a Tree
Replace Old Appliances
Unplug Un-Used Electronics
Insulate Your Home

Change Your Air Filter
Check Your Water Heater
Change the AC Filter
Install a Low-Flow Showerhead
Buy Minimally Packaged Goods
Buy a Fuel Efficient Car,
Reduce Garbage
Buy Organic Food
Use a Push Mower
Air Dry Your Clothes
Switch to Double Pane Windows

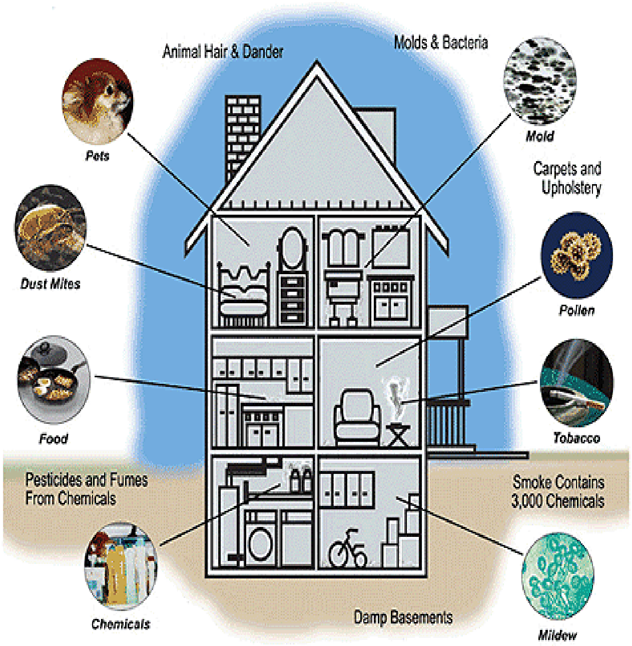
Bring Cloth Bags to the Market & Turn off Your Computer Whenever Possible

INDOOR AIR POLLUTION

Introduction

The indoor environment represents an important microenvironment in which people spend a large part of their time each day.

Source



The major sources of indoor air pollution worldwide include combustion of solid fuels indoors, tobacco smoking, outdoor air pollutants, emissions from construction materials and furnishings, and improper maintenance of ventilation and air conditioning systems.

About half of the world’s population, largely in developing countries, relies on traditional fuels such as biomass (wood, agricultural residues and animal dung), charcoal and coal as the primary source of domestic energy.

Use of solid fuels in open or poorly ventilated stoves for cooking and heating exposes an estimated three billion people to high concentrations of PM and gases that are some 10–20 times higher than levels commonly found in international health guidelines (including the WHO air quality guidelines). Although relatively clean sources of household energy predominate in developed countries, improvements in energy efficiency have led to homes being relatively airtight, reducing ventilation and raising indoor pollutant levels. In such circumstances even minor sources of pollution, such as gas cookers, new furnishings, damp conditions, household products or naturally occurring radon gas, can lead to significant exposures and recognized health effects.

In developing countries, the most significant issue for indoor air quality is exposure to pollutants released during combustion of solid fuels, including biomass (wood, dung and crop residues) or coal (mainly in China), used for cooking and heating. The majorities of households using such fuels are located in poor rural communities and use inefficient devices such as earthen or metal stoves in kitchens that are often poorly ventilated, resulting in very high exposures.

Sources Outside Building

Contaminated outdoor air
pollen, dust, fungal spores
industrial pollutants
general vehicle exhaust

Emissions from nearby sources
exhaust from vehicles on nearby roads or in parking lots, or garages
loading docks
odors from dumpsters
re-entrained (drawn back into the building) exhaust from the building itself or from neighboring buildings
unsanitary debris near the outdoor air intake

Soil gas-Radon
leakage from underground fuel tanks
contaminants from previous uses of the site (e.g., landfills)
pesticides

Equipment-HVAC system
dust or dirt in ductwork or other components
microbiological growth in drip pans, humidifiers, ductwork, coils
improper use of biocides, sealants, and/or cleaning compounds
improper venting of combustion products
refrigerant leakage

Non-HVAC equipment
emissions from office equipment (volatile organic compounds, ozone)
supplies (solvents, toners, ammonia)
emissions from shops, labs, cleaning processes
elevator motors and other mechanical systems

Human Activities

Personal activities
Smoking, cooking
body odor
cosmetic odors

Housekeeping activities
cleaning materials and procedures
emissions from stored supplies or trash
use of deodorizers and fragrances
airborne dust or dirt (e.g., circulated by sweeping and vacuuming)

Maintenance activities
microorganisms in mist from improperly maintained cooling towers
airborne dust or dirt
volatile organic compounds from use of paint, caulk, adhesives, and other products
pesticides from pest control activities
emissions from stored supplies
Building Components and Furnishings
Locations that produce or collect dust or fibers
textured surfaces such as carpeting, curtains, and other textiles
open shelving
old or deteriorated furnishings
materials containing damaged asbestos

Impact

Indoor air quality (IAQ) is a term which refers to the air quality within and around buildings and structures, especially as it relates to the health and comfort of building occupants. IAQ can be affected by gases (including carbon monoxide, radon, volatile organic compounds), particulates, microbial contaminants (mould, bacteria) or any mass or energy stressor that can induce adverse health conditions.

Sick Building Syndrome, a phenomenon where building occupants experience acute health and comfort effects linked to time spent in the building. Most of the complainants report relief soon after leaving the building. The causes of contributing factors to sick building syndrome are inadequate ventilation & chemical contamination from indoor and outdoor sources. Concentrations of indoor pollutants are often two to five times higher than outdoor concentrations. These pollutants can build up rapidly indoors to levels much higher than those usually found outdoors. This is especially true if large amounts of a pollutant are released indoors. Moreover, "tighter" construction in newer homes can prevent pollutants from escaping to the outdoors.

Radon (Rn) gas, a carcinogen, is exuded from the Earth in certain locations and trapped inside houses.

Building materials including carpeting and plywood emit formaldehyde (H2CO) gas.

Paint and solvents give off volatile organic compounds (VOCs) as they dry. Lead paint can degenerate into dust and be inhaled.

Intentional air pollution is introduced with the use of air fresheners, incense, and other scented items.

Controlled wood fires in stoves and fireplaces can add significant amounts of smoke particulates into the air, inside and out.

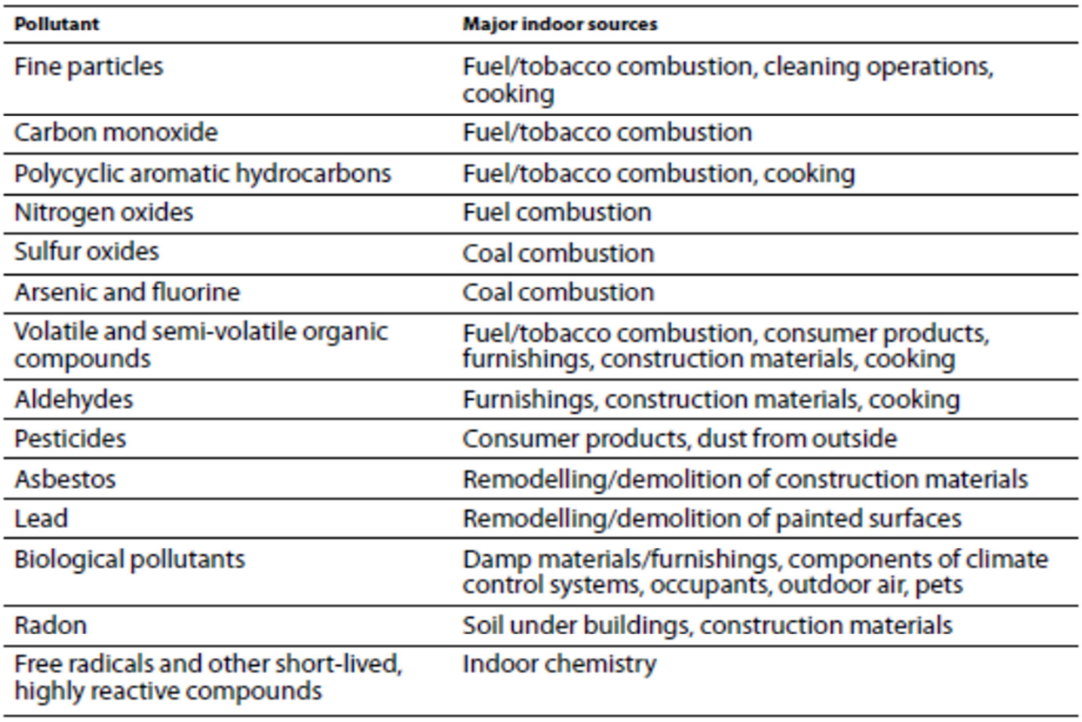
Indoor pollution fatalities may be caused by using pesticides and other chemical sprays indoors without proper ventilation.

Carbon monoxide (CO) poisoning and fatalities are often caused by faulty vents and chimneys, or by the burning of charcoal indoors. Chronic carbon monoxide poisoning can result even from poorly adjusted pilot lights.

Clothing emits tetrachloroethylene, or other dry cleaning fluids, for days after dry cleaning.

Though its use has now been banned in many countries, the extensive use of asbestos in industrial and domestic environments in the past has left a potentially very dangerous material in many localities. Asbestosis is a chronic inflammatory medical condition affecting the tissue of the lungs. Sufferers have severe dyspnea (shortness of breath) and are at an increased risk regarding several different types of lung cancer.

Table 1. Major health-damaging pollutants generated from indoor sources



Pollutant	Major indoor sources
Fine particles	Fuel/tobacco combustion, cleaning operations, cooking
Carbon monoxide	Fuel/tobacco combustion
Polycyclic aromatic hydrocarbons	Fuel/tobacco combustion, cooking
Nitrogen oxides	Fuel combustion
Sulfur oxides	Coal combustion
Arsenic and fluorine	Coal combustion
Volatile and semi-volatile organic compounds	Fuel/tobacco combustion, consumer products, furnishings, construction materials, cooking
Aldehydes	Furnishings, construction materials, cooking
Pesticides	Consumer products, dust from outside
Asbestos	Remodelling/demolition of construction materials
Lead	Remodelling/demolition of painted surfaces
Biological pollutants	Damp materials/furnishings, components of climate control systems, occupants, outdoor air, pets
Radon	Soil under buildings, construction materials
Free radicals and other short-lived, highly reactive compounds	Indoor chemistry

Biological sources of air pollution are also found indoors, as gases and airborne particulates. Pets produce dander, people produce dust from minute skin flakes and decomposed hair, dust mites in bedding, carpeting and furniture produce enzymes and micrometre-sized fecal droppings, inhabitants emit methane, mold forms in walls and generates mycotoxins and spores, air conditioning systems can incubate Legionnaires' disease and mold, and houseplants, soil and surrounding gardens can produce pollen, dust, and mold.

The presence of many biological agents in the indoor environment is due to dampness and inadequate ventilation. Excess moisture on almost all indoor materials leads to growth of microbes, which subsequently emit spores, cells, fragments and volatile organic compounds into indoor air. Moreover, dampness initiates chemical or biological degradation of materials, which also pollutes indoor air.

Recent studies estimate that exposure to indoor air pollutants associated with household solid fuel use may be responsible for nearly 1.6 million excess deaths and about 3% of the global burden of disease.

Factors governing the indoor air quality problem

Air exchange rate
Indoor rate of removal of pollutants
Outdoor concentration of air pollutant
Infiltration and exfiltration rate.

When there isn't an effective air exchange rate, which is the rate at which outdoor air replaces indoor air, indoor pollutant levels can increase. Air exchange rate is managed through natural and/or mechanical ventilation.

Natural ventilation occurs when air moves through opened doors and windows by wind or temperature differences. Mechanical ventilation occurs when devices such as fans or air handling systems distribute or move air. A proper air exchange rate it is vital for maintaining healthy indoor air.

Control

Source control, filtration and the use of ventilation to dilute contaminants are the primary methods for improving indoor air quality in most buildings.

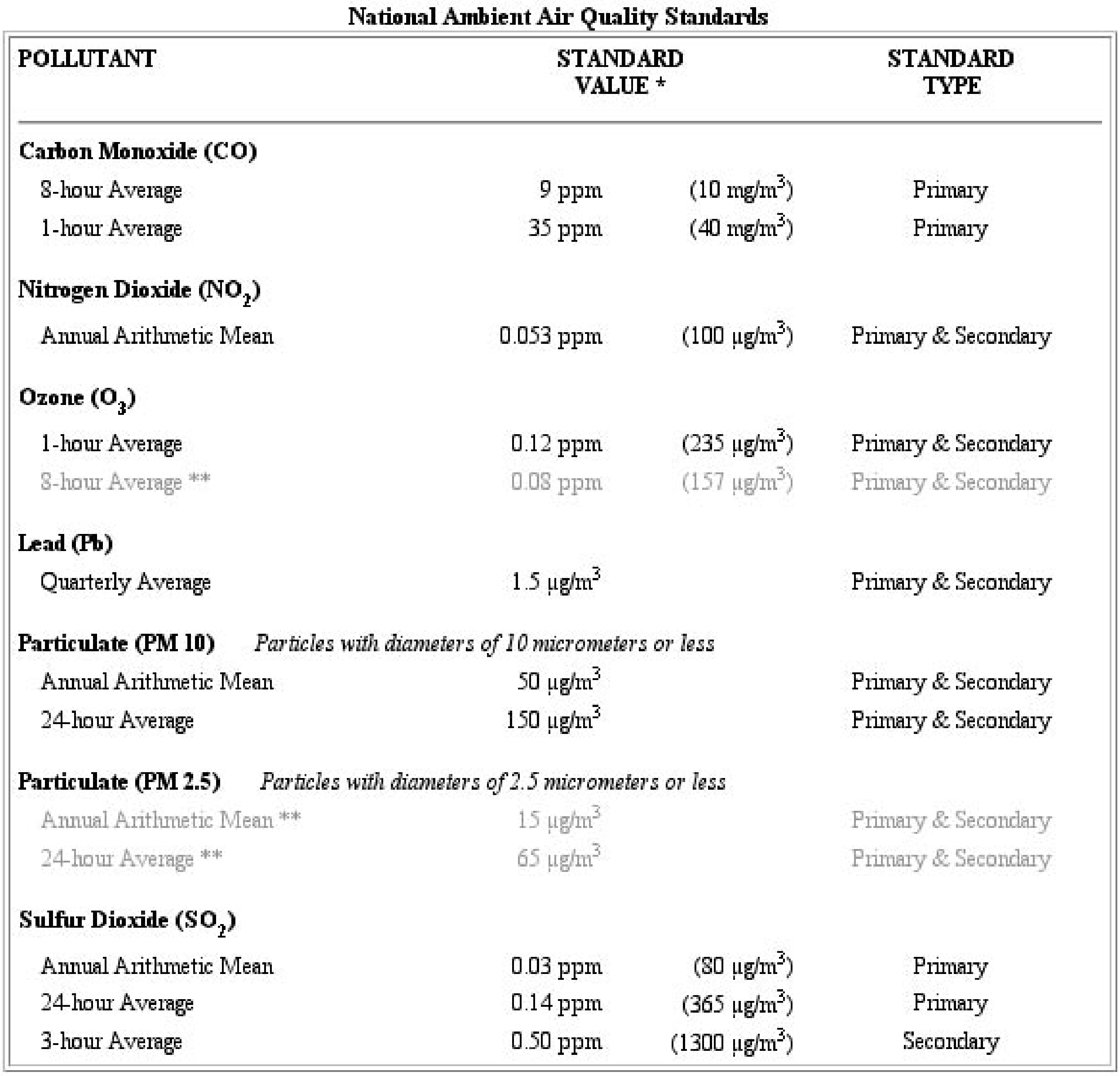
Often seen outdoors, indoor plants are the best, natural and economical purifiers available to combat indoor air pollution.

Properly utilize and maintain air filters and cleaners

10CV765 / AIR POLLUTION AND CONTROL / R.G.

Unit – 8 (Standards and legislation)

Air Quality and Emission Standards



National Ambient Air Quality Standards

POLLUTANT	STANDARD VALUE *		STANDARD TYPE
Carbon Monoxide (CO)			
8-hour Average	9 ppm	(10 mg/m^3)	Primary
1-hour Average	35 ppm	(40 mg/m^3)	Primary
Nitrogen Dioxide (NO_2)			
Annual Arithmetic Mean	0.053 ppm	(100 μg/m^3)	Primary & Secondary
Ozone (O_3)			
1-hour Average	0.12 ppm	(235 μg/m^3)	Primary & Secondary
8-hour Average **	0.08 ppm	(157 μg/m^3)	Primary & Secondary
Lead (Pb)			
Quarterly Average	1.5 μg/m^3		Primary & Secondary
Particulate (PM 10) *Particles with diameters of 10 micrometers or less*			
Annual Arithmetic Mean	50 μg/m^3		Primary & Secondary
24-hour Average	150 μg/m^3		Primary & Secondary
Particulate (PM 2.5) *Particles with diameters of 2.5 micrometers or less*			
Annual Arithmetic Mean **	15 μg/m^3		Primary & Secondary
24-hour Average **	65 μg/m^3		Primary & Secondary
Sulfur Dioxide (SO_2)			
Annual Arithmetic Mean	0.03 ppm	(80 μg/m^3)	Primary
24-hour Average	0.14 ppm	(365 μg/m^3)	Primary
3-hour Average	0.50 ppm	(1300 μg/m^3)	Secondary

EMISSION STANDARD

Emission standards are requirements that set specific limits to the amount of pollutants that can be released into the environment. Many emissions standards focus on regulating pollutants released by automobiles (motor cars) and other powered vehicles but they can also regulate emissions from industry, power plants, small equipment such as lawn mowers and diesel generators. Frequent policy alternatives to emissions standards are technology standards (which mandate Standards generally regulate the emissions of nitrogen oxides (NOx), sulfur oxides, particulate matter (PM) or soot, carbon monoxide (CO), or volatile hydrocarbons (see carbon dioxide equivalent).

LEGISLATION AND REGULATION

Short title, extent and commencement.

THE AIR (PREVENTION AND CONTROL OF POLLUTION) ACT, 1981

(1) This Act may be called the Air (Prevention and Control of Pollution) Act, 1981.

(2) It extends to the whole of India, with effect from 16 May 1981.

(3) It shall come into force on such date as the Central Government may, by notification in the Official Gazette, appoint.

Definitions.

In this Act, unless the context otherwise requires,-

(a) "air pollutant" means any solid, liquid or gaseous substance 2[(including noise)] present in the atmosphere in such concentration as may be or tend to be injurious to human beings or other living creatures or plants or property or environment;

(b) "air pollution" means the presence in the atmosphere of any air

(c) "approved appliances" means any equipment or gadget used for the bringing of any combustible material or for generating or consuming any fume, gas of particulate matter and approved by the State Board for the purpose of this Act;

(d) "approved fuel" means any fuel approved by the State Board for the purposes of this Act;

(e) "automobile" means any vehicle powered either by internal combustion engine or by any method of generating power to drive such vehicle by burning fuel;

(h) "chimney" includes any structure with an opening or outlet from or through which any air pollutant may be emitted,

(i) "control equipment" means any apparatus, device, equipment or system to control the quality and manner of emission of any air pollutant and includes any device used for securing the efficient operation of any industrial plant;

(j) "emission" means any solid or liquid or gaseous substance coming out of any chimney, duct or flue or any other outlet;

(k) "industrial plant" means any plant used for any industrial or trade purposes and emitting any air pollutant into the atmosphere;

4[(m) "occupier", in relation to any factory or premises, means the person who has control over the affairs of the factory or the premises, and includes, in relation to any substance, the person in possession of the substance;]

Powers and functions of boards

Functions of Central Board.

(1) Subject to the provisions of this Act, and without prejudice to the performance, of its functions under the Water (Prevention and Control of Pollution) Act, IL974 (6 of 1974), the main functions of the Central Board shall be to improve the quality of air and to prevent, control or abate air pollution in the country.

(2) In particular and without prejudice to the generality of the foregoing functions, the Central Board may-

(a) advise the Central Government on any matter concerning the improvement of the quality of air and the prevention, control or abatement of air pollution;

(b) plan and cause to be executed a nation-wide programme for the prevention, control or abatement of air pollution;

(c) co-ordinate the activities of the State and resolve disputes among them;

(d) provide technical assistance and guidance to the State Boards, carry out and sponsor investigations and research relating to problems of air pollution and prevention, control or abatement of air pollution;

(e) plan and organise the training of persons engaged or to be engaged in programmes for the prevention, control or abatement of air pollution on such terms and conditions as the Central Board may specify;

(f) organise through mass media a comprehensive programme regarding the prevention, control or abatement of air pollution;

(g) collect, compile and publish technical and statistical data relating to air pollution and the measures devised for its effective prevention, control or abatement and prepare manuals, codes or guides relating to prevention, control or abatement of air pollution;

(h) lay down standards for the quality of air.,

(i) collect and disseminate information in respect of matters relating to air pollution;

(j) perform such other functions as may be prescribed.

(3) The Central Board may establish or recognise a laboratory or laboratories to enable the Central Board to perform its functions under this section efficiently.

FUNCTIONS OF STATE BOARDS.

(1) subject to the provisions of this Act, and without prejudice to the performance of its functions, if any, under the Water (Prevention and Control of Pollution) Act, 1974 (Act 6 of 1974), the functions of a State Board shall be-

(a) to plan a comprehensive programme for the prevention, control or abatement of air pollution and to secure the execution thereof-,

(b) to advise the State Government on any matter concerning the prevention, control or abatement of air pollution;

(c) to collect and disseminate information relating to air pollution;

(d) to collaborate with the Central Board in organising the training of persons engaged or to be engaged in programmes relating to prevention, control or abatement of air pollution and to organise mass-education programme relating thereto;

(e) to inspect, at all reasonable times, any control equipment, industrial plant or manufacturing process and to give, by order, such directions to such persons as it may consider necessary to take steps for the prevention, control or abatement of air pollution;

(f) to inspect air pollution control areas at such intervals as it may think necessary, assess the quality of air therein and take steps for the prevention, control or abatement of air pollution in such areas;

(g) to lay down, in consultation with the Central Board and having regard to the standards for the quality of air laid down by the Central Board, standards for emission of air pollutants into the atmosphere from industrial plants and automobiles or for the discharge of any air pollutant into the atmosphere from any other source whatsoever not being a ship or an aircraft:

(h) to advise the State Government with respect to the suitability of any premises or location for carrying on any industry which is likely to cause air pollution;

(i) to Perform such other functions as may be prescribed or as may, from time to time, be entrusted to it by the Central Board or the State Government;

(j) to do such other things and to perform such other acts as it may think necessary for the proper discharge of its functions and generally for the purpose of carrying into effect the purposes of this Act.

(2) A State Board may establish or recognise a laboratory or laboratories to enable the State Board to perform its functions under this section efficiently.

Powers under the Act

Power to declare air pollution control areas

Power to give instructions for ensuring standards for emission from automobiles.

Power of Board to make application to court for restraining person from causing air pollution.

Restrictions on use of certain industrial plants.

Power to obtain information.

Power of entry and inspection.

PENALTIES AND PROCEDURE

Penalties for certain acts. Whoever-

(a) destroys, pulls down, removes, injures or defaces any pillar, post or stake fixed in the ground or any notice or other matter put up, incsribed or placed, by or under the authority of the Board, or

(b) obstructs any person acting under the orders or directions of the Board from exercising his powers and performing his functions under this Act, or

(c) damages any works or property belonging to the Board, or

(d) fails to furnish to the Board or any officer or other employee of the Board any information required by the Board or such officer or other employee for the purpose of this Act, or

(e) fails to intimate the occurrence of the emission of air pollutants into the atmosphere in excess of the standards laid down by the State Board or the apprehension of such occurrence, to the State Board and other prescribed authorities or agencies as required under sub-section (1) of section 23, or

(f) in giving any information which he is required to give under this Act, makes a statement which is false in any material particular, or

(g) for the purpose of obtaining any consent under section 21, makes a statement which is false in any material particular shall be punishable with imprisonment for a term which may extend to three months or with fine which may extend to 29[ten thousand rupees] or with both.

Penalty for contravention of provisions of the Act.

Whoever contravenes any of the provisions of this Act or any order or direction issued thereunder, for which no penalty has been elsewhere provided in this Act, shall be punishable with imprisonment for a term which may extend to three months or with fine which may extend to ten thousand rupees or with both, and in the case of continuing contravention, with an additional fine which may extend to five thousand, rupees for every day during which such contravention continues after conviction for the first such contravention.)

40. Offences by companies.

(1) Where an offence under this Act has been committed by a company, every person who, at the time the offence was committed, was directly in charge of, and was responsible to, the company for the conduct of the business of the company, as well as the company, shall be deemed to be guilty of the offence and shall be liable to be proceeded against and punished accordingly:

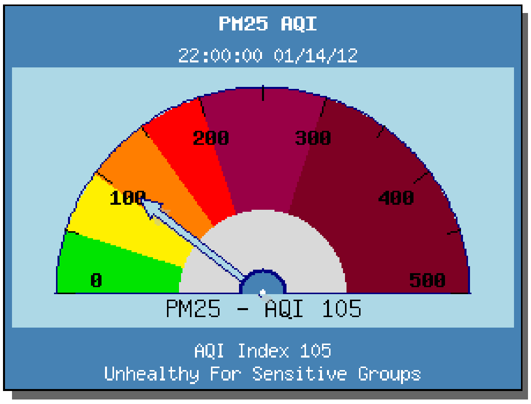
Provided that nothing contained in this sub-section shall render any such person liable to any punishment provided in this Act, if he proves that the offence was committed without his knowledge or that he exercised all due diligence to prevent the commission of such offence.

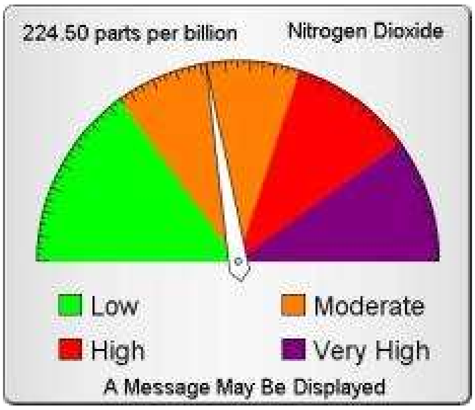
AIR POLLUTION INDEX

The Air Pollution Index (API) is a simple and generalized way to describe the air quality in. It is calculated from several sets of air pollution data. The API level is based on the level of 5 atmospheric pollutants, namely sulfur dioxide (SO2), nitrogen dioxide (NO2), suspended particulates (PM10), carbon monoxide (CO), and ozone (O3) measured at the monitoring stations. An air quality index (AQI) is a number used by government agencies to communicate to the public how polluted the air is currently or how polluted it is forecast to become. As the AQI increases, an increasingly large percentage of the population is likely to experience increasingly severe adverse health effects. Different countries have their own air quality indices which are not all consistent. Different countries also use different names for their indices such as Air Quality Health Index, Air Pollution Index and Pollutant Standards Index.

Air quality is defined as a measure of the condition of air relative to the requirements of one or more biotic species or to any human need or purpose.[1] To compute the AQI requires an air pollutant concentration from a monitor or model. The function used to convert from air pollutant concentration to AQI varies by pollutant, and is different in different countries. Air quality index values are divided into ranges, and each range is assigned a descriptor and a color code. Standardized public health advisories are associated with each AQI range.

PSI	Descriptor	General Health Effects
0 - 50		None
51 - 100	Moderate	Few or none for the general population
101 - 200	Unhealthy	Mild aggravation of symptoms among susceptible persons i.e. those with underlying conditions such as chronic heart or lung ailments; transient symptoms of irritation e.g. eye irritation, sneezing or coughing in some of the healthy population.
201 - 300	Very Unhealthy	Moderate aggravation of symptoms and decreased tolerance in persons with heart or lung disease; more widespread symptoms of transient irritation in the healthy population.
301 - 400	Hazardous	Early onset of certain diseases in addition to significant aggravation of symptoms in susceptible persons; and decreased exercise tolerance in healthy persons.
Above 400	Hazardous	PSI levels above 400 may be life-threatening to ill and elderly persons. Healthy people may experience adverse symptoms that affect normal activity.





Sri Chandrasekharendra Saraswathi Viswa Mahavidyalaya
(Declared as Deemed to be University u/s 3 of UGC Act 1956)
Enathur, Kanchipuram 631561.

B.E. DEGREE EXAMINATIONS
SEMESTER - VII, JULY 2020

SUB.CODE : SE8EB
SUB.NAME : AIR POLLUTION AND CONTROL ENGINEERING
Time: 3 Hours **Maximum Marks: 100**

1. (a) Discuss in detail about the effects of air pollution on human beings and animals? (20)

Or

(b) (i) Describe the method of analysis for oxides of nitrogen. (10)
(ii) Write a note on "Ozone layer depletion". (10)

2. (a) Write short notes on following:
(i) Atmosphere Stability (10)
(ii) Air pollution indices (10)

Or

(b) Explain with neat sketches, how different atmospheric conditions give rise to different kinds of plume. (20)

3. (a) Explain with neat sketches the principle and working of the following:
(i) Cyclone Separator (10)
(ii) Electro static precipitator (10)

Or

(b) Explain in detail about gravitational settling chambers with neat sketch. (20)

4. (a) (i) Write the general principle involved in absorption. (10)
(ii)Explain the criteria to achieve high performance in gas absorption equipment? (10)

Or

(b) Write a brief note about control and monitoring of gaseous pollutants on environment. (20)

5. (a) Explain the methods that could be adopted to control Noise source by design. (20)

Or

(b) Discuss about the effects of noise pollution. (20)

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B.E. DEGREE EXAMINATIONS
SEMESTER - VII, JULY 2020

SUB.CODE : SE8EB
SUB.NAME : AIR POLLUTION AND CONTROL ENGINEERING
Time: 3 Hours **Maximum Marks: 100**

1. (a) (i) Write the sources and classification of air pollutants. (10)
   (ii) Discuss the chemical methods of analysis of air pollutants.
(10)

Or

(b) (i) Discuss the global warming -pollutants responsible, their sources and impacts (10)
   (ii) Briefly explain the methods of sampling for gaseous pollutants? (10)

2. Explain the role meteorological elements in the dispersion of air pollutants in the atmosphere. (20)

Or

(b) (i) What is adiabatic lapse rate? Discuss the types of adiabatic lapse rate? (10)
   (ii) Mention and explain the types of sampling of gaseous pollutants? (10)

3. (a) (i) Explain the cyclonic spray scrubber with a neat sketch? (10)
   (ii) What are the Advantages and Disadvantages of electro static precipitators (10)

Or

(b) (i) Write short notes on settling chamber. (10)
   (ii) What is bag house filter? How it works? What are the operational problems involved? (10)

4. (a) Discuss the sources of pollutants and its control in a cement industry? (20)

Or

(b) Compare the functions of Central and State Pollution Control Board in the area of air pollution control. (20)

5. (a) (i) How could noise control be achieved at the source by design? (10)

(ii) How does noise pollution impact on human beings? (10)

Or

(b) State and discuss the various sources of noise pollution. (20)

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B.E. DEGREE EXAMINATIONS
SEMESTER - VII, JULY 2020

SUB.CODE : SE8EB
SUB.NAME : AIR POLLUTION AND CONTROL ENGINEERING
Time: 3 Hours **Maximum Marks: 100**

1. (a) (i) Write the sources and classification of air pollutants. (10)
 (ii) Discuss the chemical methods of analysis of air pollutants. (10)

Or

(b) (i) Explain the effects of CO, SO_2 and heavy metals on human being. (10)
 (ii) List out the methods for quantitative analysing of air pollutants? (10)

2. (a) (i) Explain the significance of wind rose diagram ? (10)
 (ii) With neat sketch, explain how different atmospheric conditions give rise to different kind of plume. (10)

Or

(b) Describe with neat sketches the plume dispersion under different stability classes. (20)

3. (a) With a neat sketch, explain the working principle of bag filter. Give the equation for average velocity coming to the filter surface? (20)

Or

(b) Explain in detail about gravitational settling chambers with neat sketch. (20)

4. (a) (i) Explain briefly about the methods of biological air treatment system. (10)
(ii) Briefly discuss on types of carbon adsorption system with suitable neat sketch. (10)

Or

(b) Explain air quality standards and air quality monitoring. (20)

5. (a) Explain in briefly the major factor and action that may help in noise abatement in a modern society. (20)

Or

(b) State and discuss the various sources of noise pollution. (20)

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B.E. CIVIL ENGINEERING
IV YEAR VII SEMESTER
AIR POLLUTION AND CONTROL ENGINEERING
TWO MARKS QUESTIOM BANKS

Unit I

1. Define Air pollution?
2. Define primary and secondary air pollutants.
3. List out the types of air pollutants.
4. With a neat sketch show the different layers of atmosphere.
5. Define air pollutants.
6. Define global warming.
7. Name any two effects on plants and also pollutants responsible.
8. What are the instruments used for sampling of waste gases?
9. List out air pollutants responsible for ozone layer depletion.
10. List out the emission standards

Unit II

1. Mention two effects of air pollution on meteorological conditions.
2. Write the methods of measurement of meteorological parameters in ambient air.
3. What is wind rose?
4. Define lapse rate.
5. What do you understand by Air Quality Standards?
6. What is dry adiabatic lapse rate?
7. Define atmospheric stability.
8. Define plume rise.
9. Define Environmental lapse rate.
10. Define stack gas sampling.

Unit III

1. Write the formula to calculate the efficiency in cyclone separators.
2. What is control efficiency?
3. Define electrostatic precipitation.
4. Mention any two control equipment for removing fine particulate matters.
5. State the two broad methods for controlling the gaseous pollutants.
6. Define Venturi scrubbers.
7. What do you mean by Gravity seperators?
8. What are the advantages of scrubbers?
9. Define Venturi scrubbers.
10. What is gravitational settling chamber?

Unit IV

1. Mention the environmental legislation for air pollution control.
2. How the gaseous pollutants can be controlled?
3. What do you understand by biofilter?
4. Differentiate adsorption and absorption.
5. Define air quality monitoring.
6. Name the equipment that uses the principle of absorption for the removal of gaseous pollutant.
7. What are the types of condensation system?
8. Define absorbers.
9. Distinguish between Contact condenser and Surface condenser.
10. What is the chemical composition of air?

Unit V

1. Define Indoor air pollution.
2. Define power of sound.
3. Define "Hearing Threshold Level"?(HTL)
4. List the various ill effects of noise pollution.
5. Identify the primary sources of environmental noise.
6. What is acoustic zoning?
7. What are the various indoor air pollutants?
8. Define sick building syndrome.
9. What are the effects of noise on human health?
10. List out the control and preventive measures of noise pollution.