Chapter One

Air Pollution Control

Definition: Air pollution 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 .

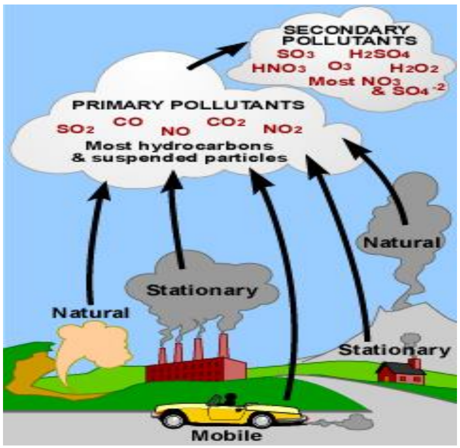
- It is an increasing problem in all countries
- It is increased with population and industrial activities
- It has huge economical effects

There are many air pollution disasters such as Dinora, Loss angelis, London, Belgium, Meuse river vally, India, Tschernobil

Pollutant Sources:

1- Stationary sources, factories, industries

2- Movable, cars , automobiles



They are classified as:

1- Man made , 2- natural processes.

Pollutants are also defined as:

1- primary pollutants resulting from combustion of fuels and industrial operations and

2- secondary pollutants, those which are produced due to reaction of primary pollutants in the atmosphere. (FOG, photochemical smog)

Smog in Los Angeles

The ambient air quality may be defined by the concentration of a set of pollutants which may be present in the ambient air we breath in. These pollutants may be called criteria pollutants.

Emission standards express the allowable concentrations of a contaminant at the point of discharge before any mixing with the surrounding air .

Automobiles, industries and thermal power plants are the major sources of air pollutants from human activities. It may be mentioned here that pollution is caused not only by the activities of man but also by natural processes. For example:

1. Volcanic eruptions release large amounts of gases and particulate matter in the air
2. Forest fires release CO_2 and smoke
3. Decomposition of plant and animal residue
4. Pollen grains, storms
5. Methane gas

However, the contribution from these natural processes is within tolerable limits. On the other hand, the contribution from man-made sources is much larger.

Types of Air Pollutants

On the basis of particle size, there are three major categories of air pollutants: gaseous pollutants, particulate pollutants and aerosols.

1. Gaseous pollutants consist of atoms, molecules and include harmful gases, which can freely mix with air without settling down. Some examples of gaseous pollutants of air are carbon monoxide, carbon dioxide, sulphur dioxide, hydrogen sulphide, nitrogen oxides and hydrocarbons.
2. Particulate pollutants include finely divided solids as well as liquids having particle size from 10^{-4} to 10^{-3} cm. Particulates are harmful to the living as well as non-living things. The examples of particulate pollutants in the air are: dust, smoke, clouds, fumes, mist, spray and smog.
3. Aerosols are suspensions of fine particulate matter in the air. Aerosols have particle size smaller than particulates. Their particle size ranges from 10^{-7} cm to 10^{-4} cm. Aerosols can be either liquid or solid particles. They are small enough to remain suspended in the atmosphere for long periods of time. Smoke, fine dust, fog, clouds are examples of aerosols.

Particulates and aerosols serve as collectors of chemically active sulphur oxides, nitrogen oxides, ozone, hydrocarbons and other pollutants and are serious health hazards.

Pollutants Sources

Name	Source

Suspended particulate Matter, SPM[a]	Automobile, power plants, boilers ,Industries requiring crushing and grinding such as quarry, cement .
Chlorine	Chlor -alkali plants
Fluoride	Fertilizer, aluminum refining
Sulphur oxides ,	Power plants, boilers, sulphuric acid manufacture, ore refining , petroleum refining
Lead	Ore refining, battery manufacturing, automobiles.
Oxides of nitrogen,[a] NO, NO_2 (NOX),	Automobiles, power plants, nitric acid manufacture, and also secondary pollutant
Peroxyacetyl Nitrate PAN	Secondary pollutant
Formaldehyde	Secondary pollutant
Ozone[a]	Secondary pollutant
Carbon monoxide[a]	Automobiles
Hydrogen sulphide	Pulp and paper, petroleum refining .
Hydrocarbons	Automobiles, petroleum refining
Ammonia	Fertilizer plant
Volatile organic Compounds, (VOC)	Automobiles, petroleum refining, Waste decomposition
Smoke	Volcanies, industries, forest fires
Radioactive	Laboratories, hospitals, nuclear industries

a- Criteria pollutants

Factors Affecting Reaction Rate

1- Concentration of the reactants
2- Amounts of moisture
3- Degree of photoactivation
4- Presence of some metals like Fe, Mg, work as a catalyst or provide a surface for the reaction
5- Meterological conditions
6- Local topography and geography

Units

Air pollution is expressed either as ppm or microgram µg/m^3

1 ppm = 1 volume of pollutant/(10^6 volume of air plus pollutant)

1 ppm = 0.0001% by volume

For solid pollutants it is usual to use µg/m^3, i.e mass/volume.

At 25 C, 298K and 1 atmosphere, 101326 kpa:

$$\frac{pollutant\ mass}{volume\ of\ air} = \frac{\rho_p}{V_{air}} V_p \qquad (1)$$

$$PV = nRT = \frac{wt}{MW} R T$$

$$\frac{PVMW}{wt\ RT} = \frac{PMW}{RT\rho_p} = 1$$

Multiply equation 1 by 1:

$$\frac{pollutant\ mass}{volume\ of\ air} = \frac{\rho_p V_p}{V_{air}} \frac{P * MW}{RT\rho_p}$$

$$\frac{pollutant\ mass}{volume\ of\ air} = \frac{V_p}{V_{air}} \frac{P * MW}{RT}$$

For 1 atm., T = 298K, R = 0.08208(atm.m^3)/(kg. Mole.K)

$$\frac{pollutant\ mass}{volume\ of\ air} = \frac{V_p}{V_{air}}\frac{MW}{24.5}, multiply\ by\ 10^9\ to\ convert\ kg\ to\ mg\ and\ divide\ by\ 10^6\ to\ convert\ to\ ppm$$

$$\frac{\mu g}{m^3} = ppm * MW * \frac{1000}{24.5}$$

For same conditions but 0 C the constant 24.5 becomes 22.41

Ex: Certain gas contains 1.5% by volume of CO, find the concentration in mg/L, and µg/L

1% = 10000 ppm

1.5% = 15000 ppm

$\mu g/m^3$ = 15000*(16+12)*1000/24.5 = $17.1*10^6$

= 17.1 * 10^6*(1/1000)(mg/µg)/(1/1000)(L/m^3) = $17.1*10^6$mg/L

Example

Calculate SO_2 concentration in flue gas when one mole of C_7H_{13} containing 1 % sulphur is burnt in presence of stochiometric amount of oxygen .

Solution

First we write stochiometric equation for combustion :

C_7H_{13} + 1 0.25O_2 = 7 CO_2 + 6.5 H_2O

Since O_2 is supplied through air which also contains nitrogen and in air each mole of oxygen is accompanied by 3.76 mole N_2, for 10.25 mole O_2, 38.54 mole N_2 will be supplied. Therefore we may write .

C_7H_{13} + 1 0.25O_2 + 38.54 N_2 = 7 CO_2 + 6.5 H_2O +38.54N_2

Therefore quantity of flue gas at STP is = 45.54 mole

22.4 L = 1 mole

45.54 mole = 45.45*22.4/1 = 1020 L

Since one mole C_7H_{13} = 7 x 12 + 13 x 1 = 97 g, sulfur contents of fuel = 97 x 0.01 = 0.97g .

1 mole of sulfur plus one mole of oxygen produce 1 mole of sulfur dioxide and the molecular weight of sulfur = 64 which is the same of oxygen, therefore 1 gram of sulfur react with I gram of oxygen.

Therefore SO_2 produced = 1.94 g or 1940 mg/mole of fuel .

As an approximation, neglecting the volume of oxygen consumed in production of SO_2 ,concentration of SO_2 = 1940 mg/1020 L = 1902 mg/m^3, at STP .

Or 1920*273/298 = 1742mg/m^3

Automobiles

In urban areas automobiles form a significant source of a number of air pollutants ,namely, particulates, NOx, hydrocarbons, carbon monoxide and lead. These pollutants are produced when fuel is burnt under less than ideal conditions. Non-uniform oxygen supply within the combustion chamber and lower flame temperature leads to incomplete combustion releasing CO, HC and un burnt particles in the exhaust .

Tetraethyl lead, $(C_2H_5)_4$ Pb, is added to petrol as anti-knock additive. Where such petrol is used lead is emitted in the exhaust fumes as inorganic particulates .

Industrial sources

Only two sources are discussed here as illustrative examples .

Cement manufacture

Raw materials include lime, silica, aluminum and iron. Lime is obtained from calcium carbonate. Other raw materials are introduced as sand, clay, shale, iron are and blast furnace slag. The process consist of mining, crushing, grinding, and calcining in a long cylindrically shaped oven or kiln. Air pollutants can originate at several operations as listed below .

Source	Emission
Raw material	crushing, grinding Particulates
Kiln and cooling	Particulates, CO, SO_2, NOx, HC
Product grinding and packaging	Particulates

Sulphuric Acid Manufacture

Sulphuric acid is produced from sulphur, which is burnt to obtain SO_2. Sulphur dioxide is converted to trioxide in presence of vanadium pentaoxide catalyst. The sulphur trioxide is absorbed in recycling concentrated sulfuric acid. Unreacted SO_2 escapes with the flue gas. New large plants now a days use double conversion double absorption (DCDA) process realizing above 99 percent efficiency .

Example

A 250 T/d double conversion double absorptionDCDA sulphuric acid plant burns 82T/d sulphur in the manufacturing process. Flue gas containing 350 ppm SO_2 is discharged at the rate of 35 Nm^3/s ,What is the percent recovery of sulfur in the product .

Solution :

350 ppm SO_2 = 350*64/24.5 = 916 mg/Nm^3

Therefore SO_2 discharged with flue gas:

$$\frac{916}{Nm^3} * \frac{35\,Nm^3}{s} * \frac{3600\,s}{1\,hr} * \frac{24\,hr}{d} * \frac{1\,kg}{(10^6)\,mg} * \frac{1\,\square}{1000\,kg} = 2.\frac{77\,T}{d}$$

The quantity of sulphur in 2.77 T/d SO_2 is

2.77 T   32 g S

-------- x -----------= 1.38 T/d

d   64 g SO_2

Therefore sulphur recovery= (82-1.38)/82= 98.3 %

Note: DCDA plants are expected to give better than 99% recovery. Therefore the reason for poor performance should be investigated and corrected .

Particulate Matters:

It is a term employed to describe airborne solid and liquid particles larger than single molecule (0.0002 micron = 0.2 nanometer) but smaller than 50 micron.

1 Micron = (1/10000)cm

- It have a life time in suspension ranging from few seconds to several months.
- Below 0.1 micron undergo random Browinian motion and greater than 20 micron is removed by gravity or inertial processes.
- Particulate is used interchangeably with aerosol which is a dispersion of solid or liquid matter of microscopic size in gaseous media less than 1 micron.

It is a small discrete mass of solid or liquid

Dust

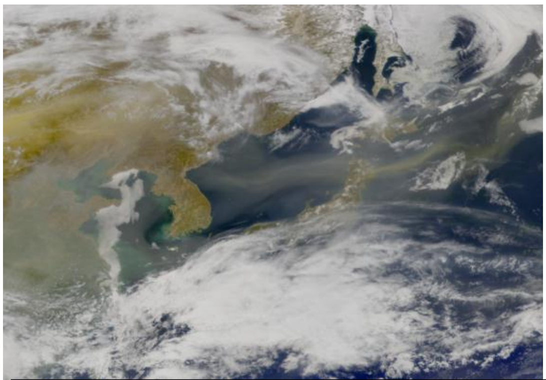
It is a solid particle larger than colloidal size capable of temporary suspension in air. It does not flocculate and diffuse but settle

Sand 20-2000 micron **pulverized coal 3-400 micron**

paint pigment < 10 **fly ash <10 micron**

Dust fall

It refers to particle of sufficient size that they fall quickly. They are measured by dust fall or Jars. (weight/area),30 ton/sq. mile – typical

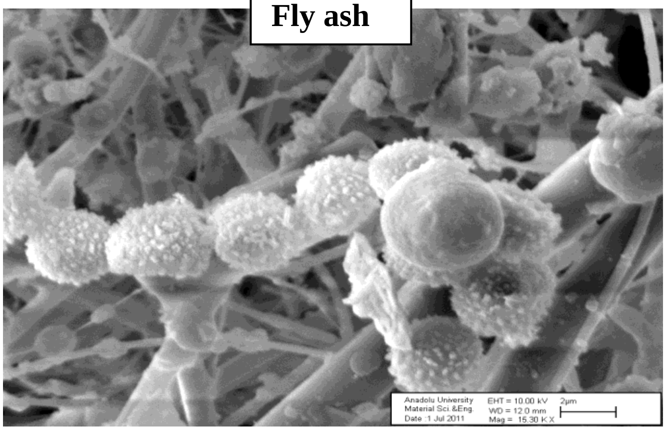


An Asian dust cloud during the spring of 2001. The dust cloud was generated By high winds over China's Gobi Desert

Fly ash

It is finely divided particles of ash entrained in flue gas

Fly ash



Fume:Particles formed by condensation or chemical reaction with a diameter less than 1 micron

Mist

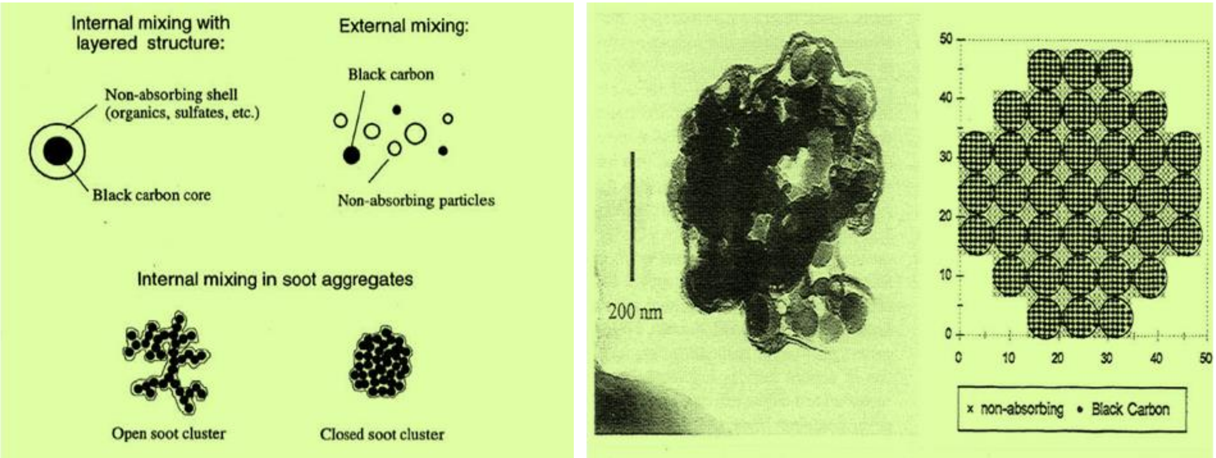
Dispersion of small liquid droplets of sufficient size to fall from air

Smoke

Small gas borne particles resulting from combustion

Soot

An agglomeration of carbon particles



Composition and shape of soot