

## Particulate control

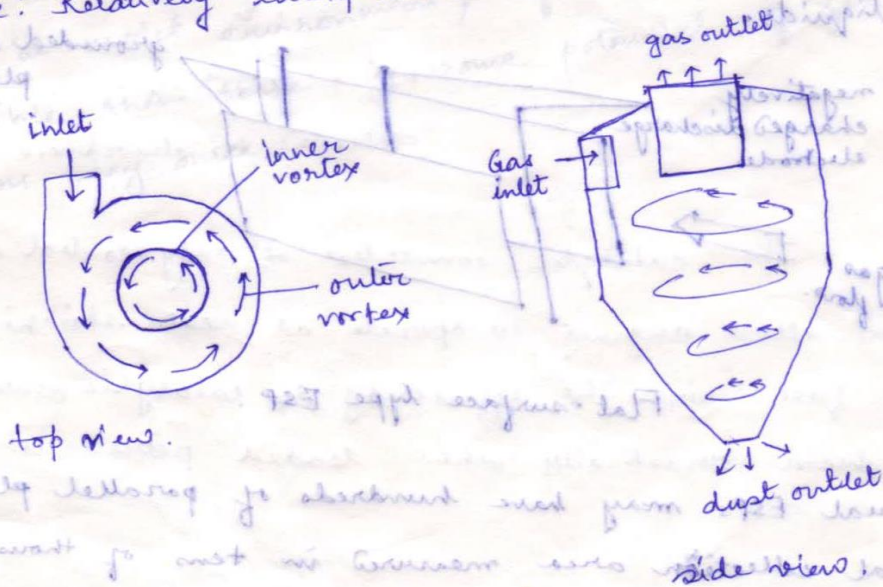
There are a number of gas cleaning devices that can be used to remove particulates. The most appropriate device for a given source will depend on factors like size, concentration, corrosivity, toxicity of particles, volumetric flow rate, required collection efficiency, allowable pressure drops and cost.

### 1) Cyclone collector / Separator

This is the most commonly used control device. The particle-laden gas enters tangentially near the top of the cyclone. As the gas spins in the cylindrical shell, the centrifugal force causes the particles to collide with the outer walls and then gravity causes them to slide down into a hopper at the bottom. The spiraling gas then exits the collector from the top.

Efficiency: Above 90% for particles larger than  $5 \mu\text{m}$ , but drops off rapidly for the small particles that are of most concern for human health.

Advantage: Relatively inexpensive and maintenance free.



top view.

side view

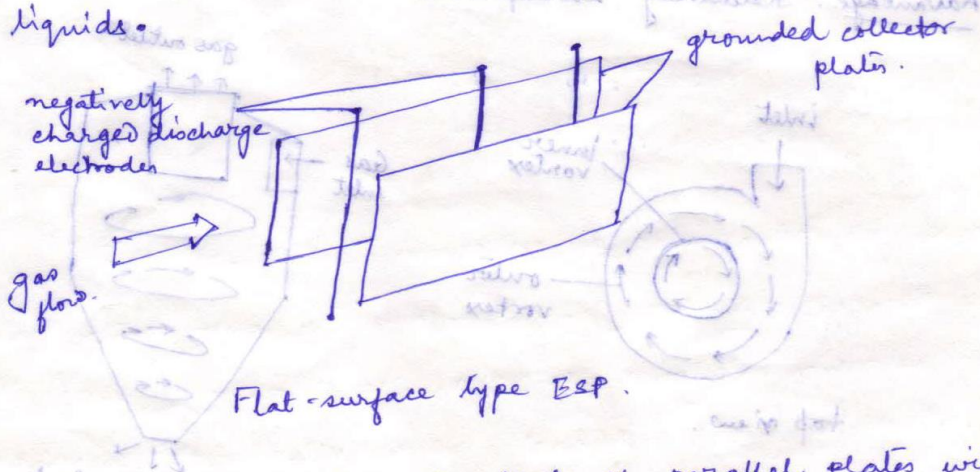
Cyclone separator.

To collect relatively smaller particles

② Electrostatic precipitator or ③ baghouses are used.

## ② Electrostatic precipitator (ESP)

In ESP, vertical wires placed between parallel collector plates. A strong electric field is created between the wires and the grounded plates by impressing a very high negative voltage on the wires (as high as 100,000 V). The intense field created near the wires causes a corona discharge, ionising gas molecules in the <sup>air</sup>-stream. The negative ions and free electrons thus created move toward the grounded plates, and along the way, some attach themselves to passing particulate matter. The particles now carry a charge which cause them to move under the influence of the electric field to a grounded collecting surface. They are removed from the collection electrode either by gravitational forces, by rapping or by flashing the collecting plates with liquids.



Actual ESPs may have hundreds of parallel plates with total collection area measured in tens of thousands of square meters.

Efficiency: greater than 98%. particles are removed including particles of submicrometer size.

Disadvantage: Expensive.

### 3) Bag house / Fabric filter

A major competition that ESPs have for efficient collection of small particles is fabric filter. Dust bearing gases are passed through fabric filter bags, which are suspended upside down in a large chamber, called baghouse. A baghouse may contain thousands of bags that are often distributed among several compartments. This allows individual compartments to be cleaned while others remain in operation.

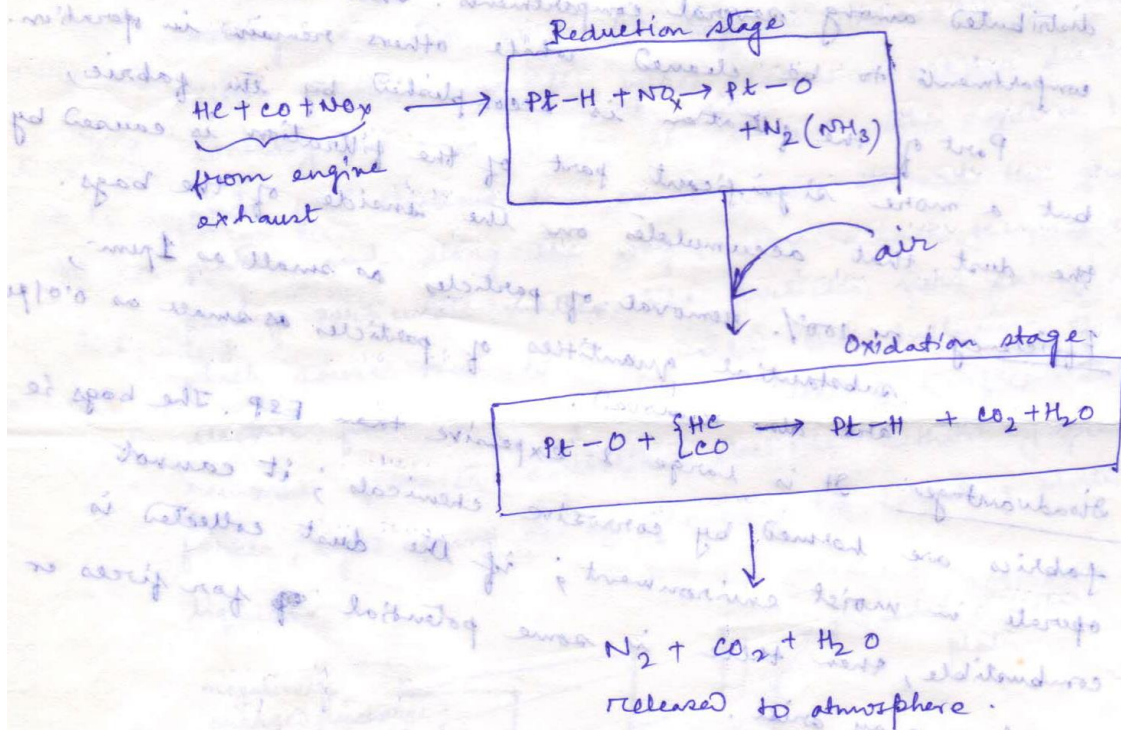
Part of the filtration is accomplished by the fabric, but a more significant part of the filtration is caused by the dust that accumulates on the inside of the bags.

Efficiency 1 or 100%. removal of particles as small as 1µm, substantial quantities of particles as small as 0.1µm are also removed.

Disadvantages: It is large & expensive than ESP. The bags are fabrics are harmed by corrosive chemicals; it cannot operate in moist environment; if the dust collected is combustible, then there is some potential for fires or explosions may arise.

Catalytic Converter : Removal of  $\text{NO}_x$ ,  $\text{CO}$  and hydrocarbon.

It is used in the automobile engine for controlling emissions very effectively. It removes mainly three pollutants :  $\text{CO}$ , hydrocarbons &  $\text{NO}_x$ . In this instrument  $\text{CO}$  and hydrocarbon are oxidized to  $\text{CO}_2$  and  $\text{NO}_x$  is reduced to  $\text{N}_2$  in the same catalytic bed.



The catalytic converter not only control emissions but also allow engines to operate at near stoichiometric ratio of fuel : air. The efficiency of catalytic converter gets reduced drastically when leaded petrol is used.

## Scrubber : Removal of $\text{SO}_2$

There are two methods :

(a) Wet method (b) Dry method

(a) Wet method : In wet method pulverized limestone ( $\text{CaCO}_3$ ) is mixed with water, slurry is made and sprayed into flue gases. Chemical reaction produce calcium sulphite ( $\text{CaSO}_3 \cdot 2\text{H}_2\text{O}$ ) and precipitate it out. The precipitate is removed as sludge, which is later used in construction industry.



It is a highly efficient method ( $\sim 90\%$ ) for removal of  $\text{SO}_2$ .

(b) Dry method : In this process lime ( $\text{CaO}$ ) is used for removal of  $\text{SO}_2$ .



Although the efficiency of removal of  $\text{SO}_2$  in dry method is  $\sim 95\%$ , it is expensive due to the use of lime.

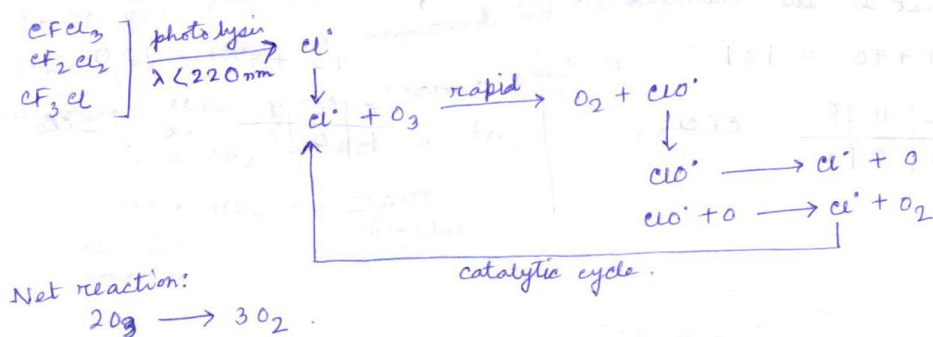
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## Chlorofluoro carbon and ozone layer depletion

Mixed chlorofluorocarbons (CFCs) such as  $\text{CFCl}_3$ ,  $\text{CF}_2\text{Cl}_2$  and  $\text{CF}_3\text{Cl}$  are known as Freons. They are unreactive and non-toxic and are widely used as refrigeration fluids, as the propellant in aerosols, washing computer boards etc. Freons are very much more effective 'greenhouse gases' in the atmosphere than  $\text{CO}_2$ , though the amount of Freons present is extremely small. Much more seriously Freons have penetrated the upper atmosphere (5-20 miles high), and are causing damage to the ozone layer. There has been a loss of ~6% of ozone between 1980 and 1990. A hole in the ozone layer has appeared over the South Pole (Antarctica) and a similar hole seems to be developing over the North Pole (Arctica).

A particularly important property of ozone is its strong absorption in the ultraviolet region of the spectrum between 220-290 nm ( $\lambda_{\text{max}} = 255.3 \text{ nm}$ ); this protects the surface of the earth and its inhabitants from the intense ultraviolet radiation of sun; excessive exposure of which might cause various effects like skin cancer (melanoma) etc to the humans.

In the upper atmosphere Freons undergo a photolytic reaction that produce free radicals (eg.  $\text{Cl}^\bullet$ ). These react readily with ozone, to give another radical  $\text{ClO}^\bullet$ . The later decompose slowly, re-forming chlorine radicals which react with more ozone and so on. The  $\text{Cl}^\bullet$  radical don't combine to form  $\text{Cl}_2$ , because they need a third body to collision to dissipate the energy. Such collisions are extremely rare in the upper atmosphere. There is no effective sink of  $\text{Cl}^\bullet$  radicals. Once formed they are used again and again, so a small number of radicals make a very effective scavenger for ozone.



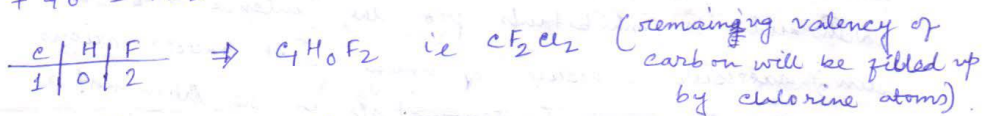
Several less harmful aerosol propellants are now in use. Hydrofluorocarbons (HFCs) such as  $\text{CH}_2\text{FCF}_3$  and hydrochlorofluorocarbons (HCFCs) such as  $\text{CHCl}_2\text{CF}_3$  are being used as substitutes. They are also greenhouse gases and may damage ozone layer, but they do less damage than CFCs because they don't remain in the atmosphere for so long. The H atoms are attacked by the hydroxyl radical ( $\text{OH}^\bullet$ ) in the upper atmosphere forming trifluoroacetic acid. The latter is not very toxic and is eventually decomposed by bacteria in the soil. CFCs, HFCs & HCFCs all are called ozone depleting substances (ODSs).

### Halocarbon numbering systems

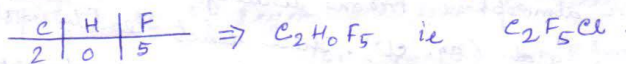
① Numerical designation to chemical formula.

CFC-12  $\longrightarrow$  ?

$$12 + 90 = 102$$



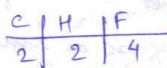
CFC-115  $\longrightarrow$  ?  $90 + 115 = 205$



② Chemical formula  $\longrightarrow$  numerical designation.

$\text{C}_2\text{H}_2\text{F}_4$   $\longrightarrow$  ?

$$224 - 90 = 134 \quad \text{ie, HFC-134}$$

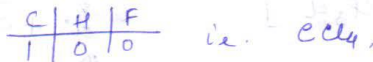


Q. What is the chemical formula of CFC-11 & CFC-10?

$$11 + 90 = 101$$



$$10 + 90 = 100$$

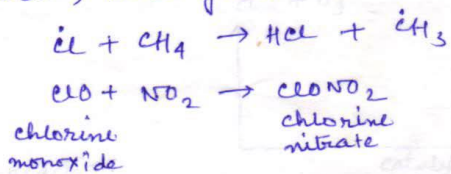


CFCs do not occur naturally and their presence in atmosphere is due to entirely human activity. ~~CFCs are strongly absorb the~~  
Mainly two CFCs that have received the most attention in both the ozone layer depletion and climate change context are CFC-11 ( $\text{CFCl}_3$ ) and CFC-12 ( $\text{CF}_2\text{Cl}_2$ ). These molecules are inert and non-water soluble, so they are not destroyed through chemical reactions. The only known removal mechanism is photolysis by short wavelength solar radiation, which occurs after the molecules drift into the stratosphere.

Because of their importance in the stratospheric ozone problem, CFCs have come under increasing regulatory attention and emissions should be reduced rapidly. The 1987 Montreal Protocol on substances that deplete the ozone layer requires a 20% reduction of ~~50~~ CFC emissions below by 1994 and total reduction of 50% by 1998. The gases specifically listed in the protocol are CFC-11, CFC-12, CFC-113, CFC-114 and CFC-115. The protocol was signed by more than 35 series, including United States.

Unfortunately, even if the Montreal Protocol is completely successful, the long atmospheric lifetimes of CFCs will mean their atmospheric concentrations will continue to increase. The complete elimination of ozone depleting substances should be established as a goal.

Due to the stability of CFCs, their residence time in stratosphere is  $\sim 75-150$  years. The atomic Cl generated from CFC destroys several  $\text{O}_3$  molecules and a part of it, however, can be removed through reaction with potent green house gas  $\text{CH}_4$  and harmful  $\text{NO}_2$ , producing  $\text{HCl}$  and  $\text{ClONO}_2$  which can then be removed by rain. Under these two circumstances, these gases become part of a cycle.



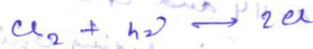


At this point the chlorine is effectively stored in an inactive form, unable to destroy more  $O_3$ .

In the month of September (Antarctic winter) the atmosphere becomes very cool ( $Temp < 90^\circ C$ ) and then the small ice crystals which make up polar clouds provide the surface of  $HCl$  and  $ClONO_2$  to stay for a longer duration and subsequent reaction follows.



Once sun rises (Antarctic spring) the chlorine thus formed in winter gets photolyzed and forms atomic chlorine.



This atomic chlorine leads to destruction of  $O_3$  layer.

Depletion of  $O_3$  layer will lead to increase in the flux of UV radiation over the earth's biosphere. This ultimately leads to:

- 1) skin cancer.
- 2) eye and lung irritation.
- 3) reduced photosynthesis.
- 4) affects crop productivity.
- 5) affects weather patterns through interference with  $O_2$ .



## Ozone depleting substances (ODS)

ODS are those substances which deplete the ozone layer and are widely used in refrigerators, air-conditioners, fire extinguishers, in dry cleaning, as solvents for cleaning electronic equipments and as agricultural fumigants.

ODS include chlorofluorocarbons (CFCs), hydrochlorofluorocarbons (HCFCs), Halons (fully halogenated chemicals),  $\text{CCl}_4$ ,  $\text{CH}_3\text{Br}$ , hydrobromofluorocarbons (HBFCs), bromochloromethane.

## Ozone depletion potential (ODP)

ODP of a chemical compound is the relative amount of degradation to the ozone layer it can cause with CFC-11 (trichlorofluoromethane) being fixed at an ODP of 1.0. eg. CFC-22 has ODP of 0.05. HCFCs have ODPs mostly in the range 0.005 - 0.2 due to the presence of hydrogen which causes them to react already in the troposphere & therefore reducing the chance to reach the stratosphere.

$$\text{ODP of any substance} = \frac{\text{total loss of } \text{O}_2 \text{ per unit mass of ODS}}{\text{total loss of } \text{O}_2 \text{ per unit mass of CFC-11}}$$

## Dobson Unit (D.U.)

D.U. is a unit of measurement of atmospheric ozone, specifically ozone in the stratospheric ozone layer.

1 D.U. = a layer of ozone that would be  $10 \mu\text{m}$  or  $0.01 \text{ mm}$  thick under standard temp & pressure.

For example 300 D.U. of ozone brought down to the surface of the earth at  $0^\circ\text{C}$  would occupy a layer only 3 mm thick.

Contaminants: Contaminants are the substances which are naturally abundant, but their concentration is increased due to human activity which ~~causes~~ causes some environmental problems.

eg.  $\text{CO}_2$ . The presence of  $\text{CO}_2$  in the earth's environment is required for

- i) photosynthesis of plants
  - ii) ~~to~~ maintaining the earth's temp. admissible for living organisms
- But the excess concentration of  $\text{CO}_2$  causes global warming & has various hazardous effects on environments.

Pollutants: These are not naturally found in nature but emitted due to human activity & cause various problems in environment. eg. CFCs.

Pollutants are of two types: (i) Primary & (ii) Secondary.

i) Primary pollutants are those which are directly emitted to the environment due to human activity. eg. CFC,  $\text{NO}$ ,  $\text{NO}_2$  etc.

ii) Secondary pollutants are those which formed from primary pollutants after some thermal or photochemical reactions.

eg: tropospheric  $\text{O}_3$ , Smog, PAN etc.

### Criteria Pollutants

There are six commonly found air pollutants whose concentration in air determines the air quality, i.e. they are the 'criteria' to tell whether a sample of air is called polluted or not & the extent of pollution is determined from their concentration.

The 6 criteria pollutants are:

- i) CO (Carbon monoxide)
- ii) Nitrogen oxides.
- iii) Sulfur oxides.
- iv) Tropospheric  $O_3$ .
- v) Lead (Pb)
- vi) Suspended particulate matter (SPM)

Among the six criteria pollutants, only tropospheric  $O_3$  is the secondary pollutant, all others are primary pollutants.

## 1) Carbon monoxide

It is a colourless, tasteless, odourless, poisonous gas. It combines with hemoglobin, the oxygen carrier in the blood, to form carboxy-hemoglobin, that ~~crosses~~ <sup>destroys</sup> the oxygen carrying property of Hb. Carboxy-hemoglobin is a very stable compound. Once a Hb molecule binds a CO, the CO never give up the Hb and thus the CO poisoning becomes fatal.

Some soil fungi, <sup>and higher plants</sup> absorb CO and destroy it by converting it to  $\text{CO}_2$ .

Source :-

- i) Incomplete combustion of coal, wood, petrol in automobiles, power plants, steel plants, jet engines etc.
- ii) Oxidation of  $\text{CH}_4$  formed through anaerobic decomposition of organic matter.

## 2) Oxides of Nitrogen ( $\text{NO}$ , $\text{N}_2\text{O}$ , $\text{NO}_2$ , $\text{N}_2\text{O}_3$ )

Two oxides of nitrogen  $\text{NO}$  and  $\text{NO}_2$  are important air pollutants.

Source :

- i) Burning of fossil fuels
- ii) Nitrogen based fertilizer plants
- iii) Textile, explosive industries.
- iv) Thunder showers
- v) Decomposition of organic wastes.
- vi) Manufacture of  $\text{HNO}_3$  etc.

- Effects
- i) Respiratory irritation
  - ii) Impairment of lung defense
  - iii) Bronchitis
  - iv) Headache, loss in appetite
  - v) Leaf damage to sensitive plants

- vi)  $\text{NO}$  and  $\text{NO}_2$  react with volatile organic compounds in presence of sunlight to produce photochemical smog.
- vii)  $\text{NO}_2$  reacts with  $\text{OH}^\cdot$  radical in the atmosphere to form  $\text{HNO}_3$  contributing to acid rain and corrosion of metal surfaces.

### 3) Sulphur dioxide ( $\text{SO}_2$ )

It is a colourless, poisonous gas, highly soluble in water. It has a pungent suffocating odour.

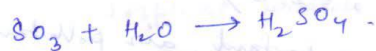
#### Sources

- i) Burning fossil fuel, eg coal
- ii) Thermal power plant, fertilizer plant, steel plant, textile & petroleum industry (oil refining)
- iii) Sulphuric acid plant

$\text{SO}_2$  react with OH radical



$\text{SO}_3$  thus formed reacts very fast with  $\text{H}_2\text{O}$  to form  $\text{H}_2\text{SO}_4$ , the principal cause of acid rain.



#### Effects

- i) High solubility in water allows the sulphur oxides to get absorbed in the moist passages of upper respiratory tract, causing increasing breathing rate and feeling of <sup>air</sup> starvation & suffocation, respiratory irritation.
- ii) Asthma & chronic bronchitis
- iii) Irritation of throat & eyes.
- iv) produces sulphurous smog.

#### A) Particulate matter

Small solid particles and liquid droplets are collectively known as particulates. The individual components aggregate to form molecular clusters (diameter:  $0.005 \mu\text{m} - 100 \mu\text{m}$ ) like fumes, dust, ash, smoke, fog, oil, fly ash. Particulates are categorised on the basis of size & phase (liquid or solid). The most general term is aerosol, which is a suspension of tiny solid particles ( $1 \mu\text{m} - 50 \mu\text{m}$ ) or liquid droplets, dispersed in the atmosphere.

- ✓ Dust - solid particles dispersed in air.
- ✓ Fume - Solid or liquid particles formed when vapours condense.
- ✓ Fog - liquid dispersed in gaseous medium.
- ✓ Smoke - carbon resulting from incomplete combustion.

#### Source:

- i) volcanic eruption, dust & soil blowing by the wind.
- ii) Stone, mineral crushing
- iii) Combustion of fuels eg, woods, oil, coal, natural gas, gasoline
- iv) polycyclic aromatic hydrocarbon.

#### Effects

- i) Respiratory disease, neural disorder
- ii) Deposition on plant leaves affect photosynthesis.
- iii) Block solar radiation, causes lowering of earth's temp, affects overall weather condition.

## B) Lead

### Source

- i) Mainly automobile emissions, due to burning of gasoline containing the anti knock additive tetraethyllead  $[Pb(C_2H_5)_4]$
- ii) Glass manufacturing.
- iii) Mining & plumbing.
- iv) Paints: Red paint containing  $Pb_3O_4$ , white paint containing  $Pb_3(CO_3)_2(OH)_2$

### Effects

- i) liver & kidney damage
- ii) mental retardation in children
- iii) abnormalities in fertility & pregnancy.

## G) Tropospheric $O_3$ or ground level $O_3$ .

$O_3$  in stratosphere protects the earth from harmful radiation. In the troposphere,  $O_3$  is a secondary pollutant. The mechanism of formation can be given as -



large concentration of  $NO_2$ , exposed to the atmosphere from various sources are photodissociated by photons ( $\lambda < 390nm$ ) to form  $NO$  and atomic oxygen. The atomic oxygen thus produced reacts with  $O_2$  gas in the presence of a third body especially  $N_2$ , which is abundant in air and forms  $O_3$ .



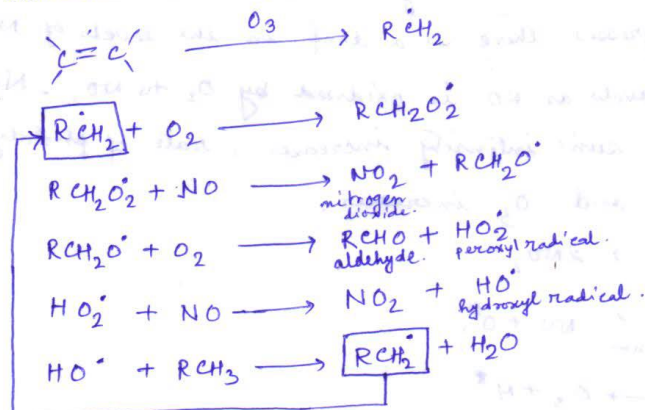
Effects: It is an ingredient for the formation of photochemical smog.



## Photochemical Smog.

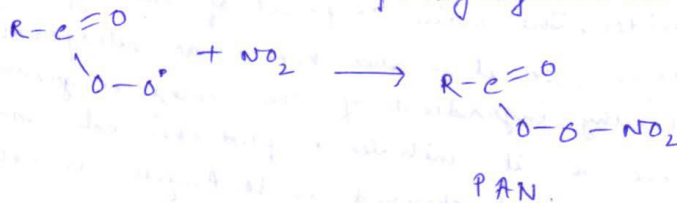
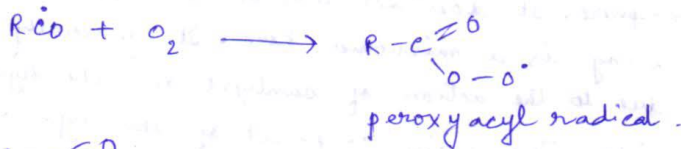
Photochemical smog is characterised by brown, hazy fumes which irritate the eyes and lungs, lead to the cracking of rubber and extensive damage of plant life. It results from photochemical reaction in atmosphere. It does not involve any smoke or fog and the word smog is a misnomer here. It generally forms in large cities due to the action of sunlight on the hydrocarbons and nitrogen oxides. The main component of this type of smog is oxides of nitrogen, so it is also known as nitrogenous smog. The main unhealthy ingredient of this smog is ground level or tropospheric ozone as it initiates a photochemical reaction. This type of smog was first observed in Los Angeles in 1950 and hence is named 'Los Angeles smog'.

Reactions involved in photochemical smog  
Reactive hydrocarbons (olefin having  $C=C$ ) from <sup>mobile</sup> auto<sub>1</sub> exhaust interact with tropospheric  $O_3$  to form free radical  $R\dot{C}H_2$



The hydrocarbon radical is again regenerated in the reaction. Due to the production of nitrogen dioxide in the reaction, photochemical smog is light brown or yellow in colour. The hydroxyl radical ( $OH$ ) produced in the reaction is the most reactive one that reacts with the aldehyde ( $RCHO$ ) to produce peroxy <sup>acyl</sup> nitrate (PAN)

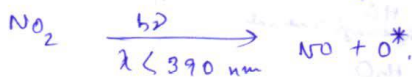
Reactions involved during production of PAN:



If  $R = CH_3 \Rightarrow$  peroxyacetyl nitrate.

• Tropospheric  $O_3$  is a secondary pollutant. — why?

In the early morning, concentration of volatile organic compounds and NO increases mainly due to automobile exhaust. As the morning progresses there is a drop in the levels of NO and a rise in  $NO_2$  levels as NO is oxidised by  $O_2$  to  $NO_2$ . Now as the day progresses, sun's intensity increases, rate of photolysis of  $NO_2$  is enhanced and  $O_3$  increases.



M is the third body, a molecule, usually  $N_2$  ~~or~~ which is most abundant in air, or it may be  $O_2$ . M absorbs the excess energy formed in the reaction to stabilize  $O_3$ , otherwise  $O_3$  would dissociate back to  $O_2$  and O.

## Smog

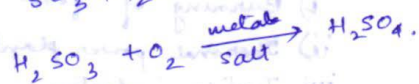
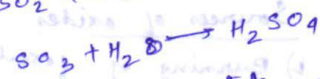
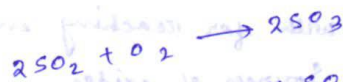
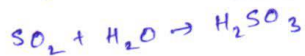
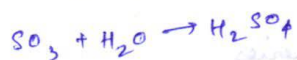
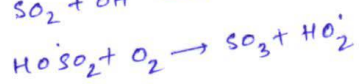
Smog is a secondary pollutant and it is the combination of smoke and fog. The fog in the atmosphere condenses on the carbon particles of smoke to form fog. However it may not be so simple as the name implies. Smog can have a number of other compositions and methods of formation. Depending upon the composition and method of formations smog is of two types:

### i) Sulphurous smog or London smog

The smog formed from oxides of sulphur ( $SO_x$ ), particulate matter coming from smoke and humidity of water is known as sulphurous smog. The smog affected London city badly in 1952 killing about 4000 people. The fuel introduced at that time was coal and was found to be main culprit. The mixture of smoke,  $SO_x$  and fog is chemically a reducing mixture and is also known as reducing smog.

Sulphurous smog occurs mainly in the early morning hours in winter, where there is a relatively high humidity. Air near the ground is cooled by conduction from cooled surface, especially on a clear night.

The following chemical reactions lead to the formation of sulphurous smog:



$SO_2$  in the atmosphere gets converted to  $SO_3$  on oxidation by a number of chemicals present in the particulates.  $SO_3$  so formed combines with water in the atmosphere forming a fog of sulphuric acid droplets. These droplets then condense on the

carbon particles of soot (smoke) and smog known as

sulphurous smog.

Sulphurous smog causes bronchitis and acute respiratory problems.

### Acid rain

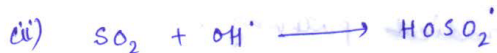
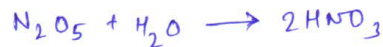
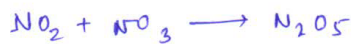
Rain is valued by mankind as good crops and abundant water supplies depend fully on plentiful rainfall.

Natural rain water is always slightly acidic ( $\text{pH} \approx 5.7$ ) due to the reaction of atmospheric carbon dioxide with water which produces carbonic acid. This amount of acidity is enough to dissolve minerals in the earth's crust and make them available to plants and at the same time not enough acidic to cause damage. The other natural calamities like volcanic eruptions, forest fires although cause rain acidity, contribute very little to any damage. The greatest threat is the contribution of  $\text{SO}_x$ ,  $\text{NO}_x$  etc due to anthropogenic activity, which have disturbed the acid balance and converted the natural mild acidic rain into more acidic ( $\text{pH}$  of acid rain varies from 3-5) with far-reaching environmental consequences.

### Sources of oxides.

- i) Burning of fossil fuels.
- ii) Thermal power plants.
- iii) Textile industry
- iv) Steel plants
- v) Oil refining or Petroleum refineries
- vi) Automobile exhausts
- vii) Explosive industry
- viii) Fertilizer industry

### Reactions involved in the formation of acid rain

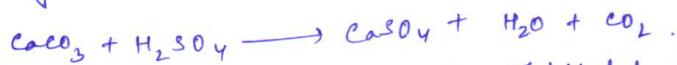


Contribution of acids in the 'acid rain' are in the order



### Adverse effects of acid rain

i) Acid rain causes severe damage to buildings, monuments, statues, bridges & other structural materials of marble, limestone, etc.



This is one of the reasons why Taj Mahal is in danger.

ii) Due to acid rain the river or pond water become acidic and thereby kill the population of algae, bacteria, phytoplankton as well as other aquatic species, i.e., disturb the total eco-system of the hydrosphere.

iii) Acid rain causes <sup>lowering of pH of soil and also causes</sup> leaching of Ca, Mg, Fe, Mo, Co, S and various other metals and nonmetals leading to greater concentration in the soil. This may hamper the growth of trees, reducing the rate of photosynthesis.

\* Adverse effects of photochemical smog.

Photochemical smog causes

- i) eye irritation.
- ii) sore throat
- iii) respiratory problems.
- iv) headache

PAN produces through free radical pathway.

The free radicals might cause various side reactions with active groups of enzymes. PAN is the active oxidising agent

and contain irritating ingredients of smog.

Green house gases.

$\text{CO}_2$  and water vapour absorb infrared radiation (14000-25000 nm) and effectively block a large fraction of earth's emitted radiation.

$\text{H}_2\text{O} \rightarrow$

$\text{CO}_2 \rightarrow$

$\text{CH}_4 \rightarrow$

$\text{N}_2\text{O} \rightarrow$

$\text{O}_3 \rightarrow$

CFC  $\rightarrow$

all of them absorb the IR radiation coming from earth surface or emitted by the earth surface. Thus they trap the solar radiation and hence are called green house gases.

Consequences of global warming on the global climate ( $\sim 3^\circ\text{C}$  rise of surface temp for doubling of the  $\text{CO}_2$  conc<sup>n</sup> in 2050AD)

1) Effect on sea level

sea level will rise as much as 2 meters due to expansion of sea water at increased temp, partial melting of glacier and polar ice caps.  $\sim 50-60$  island nations like Maldives, Bangladesh, Chennai, Goa, Sundarban may totally submerged.

2) Effect on agriculture:

increase in temp leads to increased rainfall but not evenly in all parts. some part will be under drought and in some part there will be excess rainfall. chances of soil erosion and washing away of the fertile top soil hampers plant growth.

3) Effect on marine food:

increase in temp leads to volume change expansion and that will differ the pH and salt concentration in sea water (pH will increase and salt concentration decrease) The increase in avg. temp changes the other factors which leads to unsuitable environment for different marine living organisms and eventually they die due to the adverse condition.

## Introduction

Land in the solid component of earth, which is alternatively named as lithosphere. The formation of lithosphere involving a number of physical, chemical and biological transformation of gaseous substances to rocky material. Geology is the branch of science which describes the composition, physical property, structure etc of these rocky substances in lithosphere.

## 5.1 LITHOSPHERE

Solid component of the earth is called lithosphere. It consists of three zones—crust, mantle and core.

### Crust

The outer most part of lithosphere consisting of different types of rocks is known as crust. Its thickness varies from 64 to 96 km. Earth crust contains mainly oxygen, aluminium, calcium, magnesium, iron etc as major elements. It is divided into two parts soil and sima.

The upper part of the earth crust is generally made up of silicon (Si) and aluminium (Al) known as soil. The average density of this part is 2.7 and extends up to 17 km. Sima, the lower part of the crust is composed of silicon (Si) and magnesium (Mg).

The density of this part is 3.0.

The line where soil and sima layer meet with each other is known as 'convad discontinuity'.

### Mantle

Mantle is situated just below the crust. The thickness of this layer is approximately 2880 km. It is consisted of two parts.

The lighter upper part of the mantle is called 'asthenosphere'. The major elements of this layer are chromium (Cr), iron (Fe), silicon (Si), and magnesium (Mg).

The lower part of the mantle is called 'mesosphere'. The major constituents of this layer are nickel (Ni), iron (Fe), silicon (Si) and magnesium (Mg).

### Core

The centre part of the lithosphere is called core. It is also known as barysphere. The thickness of this core layer is about 3500 km. Temperature, mass and density of this core zone is very high in comparison to the other parts of the lithosphere. The major components of this core layer are iron (Fe) and nickel (Ni) along with some other minor components like sulphur (S), silica (Si). Cobalt (Co) etc. The core can be divided into two parts. The outer core containing molten metal and inner core containing more solidified metallic minerals.

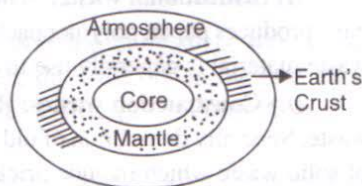


Fig. 1. The layers of the earth.



## 5.2 SOLID WASTE POLLUTION

The unwanted solid material which is generated due to our activity is known as solid waste. Due to the increase in population, the amount of solid waste generation has been increased day by day. Generally domestic solid wastes are biodegradable. Where as industrial solid wastes are non-biodegradable. If we consider the annual solid waste production from different sources, the maximum is coming from industries (15.2%), Mining and quarrying (67%). The generation of domestic and trade solid waste is only 8.5%. 2% of solid waste is generally produced in the environment for construction activities. Solid waste also include municipal solid waste (MSW), Sewage sludge, plastics, medical wastes from hospital etc. Proper solid waste management is necessary to avoid environmental pollution.

## 5.3 CLASSIFICATION OF SOLID WASTES

Classification of solid waste in broader sense is

(a) Domestic waste, (b) Trade waste and (c) Industrial waste

(a) **Domestic waste:** Waste material from houses and other residential area are classified as domestic waste.

(b) **Trade waste:** The unwanted material from retail, commercial and business premises are termed as trade waste. This can be also termed as commercial waste.

(c) **Industrial waste:** Waste originates from different types of industries are termed as industrial waste.

Depending on the origin of municipal waste it can be classified as:

(i) **Institutional waste:** Schools, colleges, research organizations, religious places, community halls produces paper, polymer packaging material, rejected office stationaries as waste material. These waste material is generally use to call as institution waste material.

(ii) **Construction wastes:** Repairing and construction activities produce huge amount of solid waste. Specially demolition of old construction for new construction activities generate large quantity of solid waste which include bricks, roofing, pipes, rods etc.

(iii) **Biomedical wastes:** The wastes generated from hospitals, nurshing homes, clinics are treated as biomedical solid waste. These biomedical wastes are also fall into the hazardous waste due to the presence of different infectious substances. The biomedical wastes are disposable syringes, used surgical dressing and gloves, expired drug etc.

(iv) **Agricultural solid waste:** Agricultural residue after harvesting of crop is generally treated as a agricultural solid waste. Generally these wastes consists of roots and stems of crops. Different type of insecticides are also contributing towards this type of waste material.

(v) **Burning ashes:** Ashes are produced after burning of solid fuel like wood, coal, coke etc. Burning of different type solid waste material will also produce ash.

(vi) **Hazardous wastes:** Those wastes which affect human, plant or animal life in adverse way. Some examples of hazardous wastes are toxic chemicals, radioactive wastes, explosives etc.

### Causes of solid waste pollution

The reasons for the rapid growth in the quantity of solid wastes are:

(a) **Over-population:** The quantity of solid wastes generation in big cities is fixed per person. But due to increase in population density the total amount of solid waste generation is increasing day by day.

(b) **Affluence:** With affluence there is a increase in per capita consumption. As a result of which solid waste formation will increase.

(c) **Technology:** Due to the advancement in technology for most economic goods indicate a shift in technology from the returnable packaging to non-returnable packaging. As a result of which returnable glass containers or bottles are being replaced by non returnable bottles and plastic containers.

It is very difficult to reuse those plastic packages specially in food packaging industry. Ultimately it will increase the solid waste formation.

#### 5.4 SOLID WASTE MANAGEMENT

Huge disposal of solid wastes, especially of hazardous wastes causes adverse effect to environment. The main objective of solid waste management is to minimize this adverse effect. Solid waste management can be done by the following steps:

(1) Collection, (2) Storage, (3) Transportation, (4) Recycling (5) Treatment and (6) Disposal.

**Collection:** The efficient collection of solid waste is most important aspect of solid waste management. Improper collection of solid waste leads to dumping of waste in the open spaces.

In order to avoid such problem our collection system should be hundred percent efficient. The number of bins provided are inadequate for solid waste disposal. Sometimes road sweeper burn or throw the solid waste into open spaces.

**Storage:** The waste bins act as storage points. Cleaning of those waste bins is necessary for avoiding unhygienic condition. Storage facilities are not yet developed in some urban areas.

**Transportation:** The solid waste collected from the bins are finally transported to the waste disposal site by truck. The frequency of transportation is controlled by municipal authorities and entirely depend on the rate of solid waste generation.

**Recycling:** Municipal solid waste contain both biodegradable and non-biodegradable material. Among non-biodegradable material those are non-toxic in nature but it has certain value, those can be recycle in order to minimize the solid waste formation. Instead of recycling we can reuse a product over a long time period to minimize the solid waste formation.

**Disposal:** This is the final step in solid waste management. Due to the unorganized solid waste disposal causes environmental pollution. Generally solid wastes are disposed off in low land area. Disposal of solid waste can be done by three ways (1) Land fill, (2) Incineration and (3) Composting.

(1) **Landfill:** Landfilling method is a very useful method for solid waste disposal. By using this method we can reduce the storage of huge amount of solid waste into open space. Which ultimately pollute water, land and air. In landfilling, the solid wastes are compacted and spread in thin layers over a low land area, each layer being uniformly covered by a thin layer of soil. The final layer is covered by a final cover of about one meter of earth to prevent solid waste scattering. Land filling is a biological method of solid waste degradation and it will produce  $\text{CO}_2$ ,  $\text{CH}_4$ ,  $\text{NH}_3$  as renewable sources of energy.

(2) **Incineration:** Combustion of solid waste at a temperature range of  $900\text{--}1200^\circ\text{C}$  in a specially designed furnace (called incinerator) is known as incineration. Various types of incinerators like, rotary kil, air-controlled incinerators have been used for this purpose. Volume of waste can be reduced up to 90% by this process. Incinerations are not, however, capable of destroying inorganic compounds, although they can concentrate them in ash, making transportation and disposal more efficient. In addition, metals that volatilize at temperatures below  $2000^\circ\text{F}$  pose a particular problem since, once vaporized, they are difficult to remove using conventional air pollution control equipment. The completion of combustion in an incinerator depends on following factors:

- (i) the temperature in the combustion chamber
- (ii) the time span that combustion takes place
- (iii) the amount of turbulence or degree of mixing
- (iv) the amount of oxygen available for combustion

In spite of numerous controls, hazardous waste incinerators have the potential to emit amounts of noxious gases that may be unacceptable to neighbours. Emissions may include unburned organic compounds from the original waste, various products of incomplete combustion formed in the incinerator itself, carbon monoxide, nitrogen and sulphur oxides, hydrogen chloride, particulates. In order to minimize this type of problem generally recyclable material should be removed before

- (a) Mining and processing units of ores to generate radioactive elements
- (b) From nuclear weapons
- (c) Use of radioactive materials in nuclear power plants.
- (d) Extensive use of radioactive isotopes in medical, research and industrial purpose.
- (e) Accidental leakage of radiation from nuclear reactor also produces radioactive waste to the environment. Chernobyl disaster in USSR is example of such accidental leakage.

**Effects:** Radiation from radioactive material has adverse effect on living system. It is important to know the extent of adverse effect that high energy radioactive radiations can cause to living organisms. Organic molecule present in biological system is ionized by high energy radioactive radiation. Ultimately this lead to the malfunctioning of the biological system. The extreme result will be death of the organism. Effect of radioactive elements on living organism depends on several factors.

- The intensity of the radiation. If intensity is high, it causes more amount of ionization in living organism.
- Exposure time for radioactive radiation.
- Half-life period of the radioactive pollutant.

### Radioactive wastes disposal

Radioactive wastes should be transformed into harmless form or stored in deep layer of lithosphere. Solid or liquid wastes of low activity are collected in paper or plastic containers and finally they can be disposed off into land or water. But before disposing into sea the toxicity level of the waste is measure and if it is found below threshold limit value then only it is disposed off. Other wise it has to be disposed off in land. High level radioactive wastes are generally put into a special type glass container and finally the container was stored after proper sealing. Generally those radioactive waste filled glass containers are stored at 100–150°C for million of years. The attempt is to convert these wastes into glassy material. Ground disposal of low or intermediate level wastes is only possible under certain soil, rock and ground water condition. Radioactive waste can also be disposed off in deep mine, salts cavaties, deep well disposal.

### (2) Biomedical wastes

The wastes generated by hospitals, health centre, testing laboratories, clinics are termed as biomedical wastes. If biomedical wastes are not properly disposed off, it causes a major environmental problem. Some examples of biomedical wastes are expired medicines and pychotoxic drugs, blood, liquid and chemical wastes associated with medical operations, pathological investigations, animal wastes, microbiological and biotechnological wastes etc.

Biomedical wastes will affect the living organism adversely if they are not properly disposed off. They can produce different type diseases into human body.

### Biomedical wastes management

Biomedical wastes are both hazardous as well as non-hazardous. Major amount of biomedical wastes are infectious. Amount of hazardous wastes under this category is very low. In order to get a systematic biomedical wastes disposal, Government of India notified biomedical wastes rules. These rules are applicable for all hospitals, nursing homes, laboratory and other places where biomedical wastes are generated. Segregation, transportation, storage and disposal steps have been mentioned in this rule. Wastes categories have been mentioned and disposal of each category is specified. Certain standards for biomedical wastes treatment like incineration, autoclaving, microwaving and land disposal have been mentioned. Normally biomedical wastes are disposed off by incineration at higher temperature. For liquid wastes chemical treatment is necessary for disinfection and finally discharged into drains.

### (3) Industrial wastes

Industrial wastes are different types of chemicals and ashes produced from different industries. The major amount of hazardous industrial wastes are disposed off in land. Prior to disposal it requires some treatment. Very less amount of hazardous industrial wastes are recyclable or incinerable. The

major sources of non-hazardous industrial solid wastes are steel plants, thermal power stations, non-ferrous industries, paper industries, etc. Proper disposal of industrial hazardous wastes involves following steps (1) storage (2) transport (3) treatment and (4) disposal.

### 5.6 HAZARDOUS WASTE MANAGEMENT

Hazardous waste management can be done by using following steps:

- (1) Identification of the waste
- (2) Segregation of the waste in different categories
- (3) Minimizing the quantity of wastes
- (4) Treatment of the waste before disposal
- (5) Recycling of hazardous industrial wastes
- (6) Finally, all steps involved in hazardous waste management *i.e.*, collection, transport, treatment, disposal etc should be done in a proper scientific manner. Everything should be done under control of administrative body.

**Identification:** First of all those peoples are involved in hazardous waste management they should aware about the categories of that waste. Which is described in the characteristic of hazardous waste. Without proper identification of the hazardous wastes they cannot follow the subsequent steps involved in waste management.

**Segregation:** Segregation step is required for specific treatment. After this step the segregated material should be packed and properly labelled for storage. After proper storage of hazardous waste they should be transported to treatment plant.

**Waste minimization:** Industries have to follow the alternate route of product formation where raw material consumption is minimum or raw material reacts with each other in such a way that it will produce non-hazardous waste. For example in zinc electroplating, replacement of chloride compound by sulphate compound will eliminate cyanide problem. Evaporation and precipitation method can also be followed for waste minimization. Segregation step will also reduce waste by separation of hazardous waste from non-hazardous waste.

#### Treatment of the waste prior to disposal

Treatment of hazardous wastes is very important and it may involve (i) chemical treatment (ii) physical treatment (iii) biological treatment (iv) solidification (v) incineration

Physical treatment can separate solid waste material from a mixture of solid and liquid waste by sedimentation technique. Sedimentation technique is most inexpensive technique for physical treatment of hazardous wastes. Some time solid waste can be separated from liquid by reverse osmosis or by ion exchange technique.

Chemical treatment involve complete breakdown of hazardous waste. Chemical treatment can be done by (a) neutralization, (b) oxidation-reduction (c) precipitation method.

Neutralization process will reduce the acidity or alkalinity of a particular waste by adding base and acid respectively. For neutralizing acid waste we generally use solution of lime. After neutralization reaction when the pH of the wastes approaches to 7 (*i.e.* pH at neutral condition), the waste materials are less corrosive towards environment.

Oxidation-reduction reaction can change the toxicity of waste chemicals.

The soluble toxic materials can be precipitated out by certain chemical reaction. Those are use to call as precipitation reaction. Generally toxic metal like Pb, Hg can be precipitated out as a sulphide by chemical reaction. Certain toxic metal ions can also be precipitated as its hydroxide by reacting with  $\text{Ca(OH)}_2$ .



Ion exchange method can also be employed for removal of toxic metal ion.

Biological process involve the degradation of wastes by micro-organism to a simpler form like  $\text{CO}_2$  and  $\text{H}_2\text{O}$ . As the micro-organisms can be destroyed by the toxic effect of hazardous wastes so the scope of biological degradation of hazardous wastes is very limited. If we want to degrade hazardous waste biologically the medium should be like that where microorganism can live and grow.

## 5.7 SOIL

Soil is a combination of caly minerals and organic matter produced by weathering of nature. Due to the presence of organic matters in soil, it can act as buffer zone between atmosphere and ground water. Soil have strong sorptive property because of electrical charges and large surface area of the clay minerals and humus. Soil is the upper layer of the earth's crust. Whose main characteristics depend on the parent rock material. Soil is made up of solid, liquid and gaseous substances along with some colloidal particle of organic and inorganic matter. The upper part of soil is called as top soil. Top soil part may be different in colour due to the difference in humus and mineral materials present in this part. Subsoil part is just below the top soil part. Which basically contain humus and minerals. The subsoil is followed by loose rock and finally the bedrock.

Soil is an essential component of terrestrial ecosystems because the growth of plants and biogeochemical cycling of nutrients depend upon it. Of the total area of the world's land mass ( $13.07 \times 10^9$  ha), only 11.3% is cultivated for crops; permanent grazing occupies 24.6%, forest and woodland 34.1% and 'other land' including urban/industry and roads, accounts for 31%. From a resource perspective, soil is vitally important for the production of food and fibre crops and timber and it is therefore essential that the total productive capacity of the world's soils is not impaired. Pollution, along with other types of degradation, such as erosion, and the continuing spread of urbanization poses a threat to the sustainability of soil resources. Soil pollution can also be a hazard to human health when potentially toxic substances move through the food chain or reach ground water used for drinking water supplies.

In comparison with air and water, soil is more variable and complex in composition and it functions as a sink for pollutants, a filter which retards the passage of chemicals to the ground water, and a bioreactor in which niany organic pollutants can be decomposed. As a consequence of its occurrence at the interface between the land and the atmosphere, soil is the recipient of a diverse range of polluting chemicals transported in the atmosphere. Further inputs of pollutants to the soil occur as a result of agricultural and waste disposal practises but, in general, the most severe pollution usually results from industrial and urban uses of land.

### The Nature of soil

Soil is the geochemically and biochemically complex material which forms at the interface between the atmosphere and the earth's crust and is highly heterogeneous in composition and spatial distribution. Soil comprises a mixture of mineral and organic solids, permeated by voids, containing aqueous and gaseous components and a microbial biomass. Soils are usually differentiated vertically into a series of distinctive layers, called 'horizons', which differ both morphologically and chemically from the layers above and below them. These horizons collectively form the soil profile (or pedon) which is the unit of classification of soils. Soil formation results from interactions between the weathered geological material on which the soil has formed, and climatic conditions, vegetation cover, landscape position and the time over which the soil has been forming. Soil formation is a dynamic process and major changes in any of the environmental factors (such as climate, drainage or vegetation) will result in changes in the nature of the soil horizons. As a result of the wide range of rock types and environmental conditions around the globe, soils differ markedly in physical, chemical and biological characteristics. Nevertheless, there are several properties which most soils have in common which relate to the behaviour of pollutants.

All soils contain humus which is highly polymerized organic material synthesized by microorganisms from the decomposition products of dead plant material. The organic matter contents of most soils lie in the range 0.1- 10% but peaty soils can contain more than 70% organic matter. Soils in hot, dry climates tend to contain much lower amounts of organic matter than soils in humid and cooler regions.

Soils contain varying amounts of different primary and secondary minerals. Primary minerals occur in unweathered fragments of igneous rock either from the parent material, or erratic stones

origin, tend to be soluble and can prevent metals from being adsorbed onto soil surfaces and thus render them more mobile and possibly more available for uptake by plant roots.

(d) *Chemisorption of Elements*

This occurs when the element is incorporated into the structure of the compound. The most common example of this is when metals, such as Cd, replace Ca in the mineral structure of calcite (CaCO<sub>3</sub>).

(e) *Sorption of Organic Contaminants on Humic Materials*

This is the main mechanism by which non-polar, hydrophobic organic molecules are bound in soils. This may be by physical means or by chemical bonding.

(f) *Co-precipitation of Elements*

This is the simultaneous precipitation of a chemical agent in conjunction with other elements. The elements typically found co-precipitated with secondary minerals in the soil include:

Fe oxides: V, Mn, Cu, Zn, Mo;

Mn oxides: Fe, Co, Ni, Zn, Pb;

Calcite: V, Mn, Fe, Co, Cd;

Clay minerals: V, Ni, Co, Cr, Cu, Pb, Ti, Mn, Fe.

### Soil Pollutants

There are different types of pollutants which can pollute the soil.

(a) Heavy Metals, (b) Hydrocarbon Pollutants, (c) Toxic Organic Micropollutants (TOMPs) (also called Persistent Organic Pollutants (POPs)), (d) Other Industrial Chemicals, (e) Nutrient-rich Wastes, (f) Radionuclides, (g) Pathogenic Organisms.

(a) **Heavy Metals**

Heavy metals have a density of greater than 6 g cm<sup>-3</sup> (but some authors use a value of > 5g cm<sup>-3</sup>) and an atomic number greater than 20, and occur naturally in rocks and soils but concentrations are frequently elevated as a result of pollution. The term 'heavy metal' is imprecise but is widely used although others such as "toxic metals", 'potentially toxic elements' and 'trace metals' are possible alternatives. Heavy metals belong to the group of elements described geochemically as 'trace elements' because they collectively comprise < 1 % of the rocks in the earth's crust. All trace elements are toxic to living organisms at excessive concentrations, but some are essential for the normal healthy growth and reproduction by either plants or animals at low but critical concentrations. These elements are referred to as 'essential trace elements' or 'micronutrients' and deficiencies can lead to disease and even death of the plant or animal. The essential trace elements include: Co (for bacteria and animals), Cr (animals), Cu (plants and animals), Mn (plants and animals), Mo (plants), Ni (plants), Se (animals) and Zn (plants and animals). In addition, B (plants), Cl (plants), Fe (plants and animals), I (animals) and Si (plants and animals -probably) are also essential trace elements but are not dense enough to be classed as heavy metals. Other elements, including: Ag, As, Ba, Cd, Hg, Tl, Pb, Sb, have no known essential function and, like the essential trace elements, cause toxicity above a certain tolerance level. The most important heavy metals with regard to potential hazards and occurrence in contaminated soils are: As, Cd, Cu, Cr, Hg, Pb and Zn.

(b) **Hydrocarbon Pollutants**

Hydrocarbon pollutants from petroleum mainly comprise a range of saturated alkanes from methane (CH<sub>4</sub>), ethane (C<sub>2</sub>H<sub>6</sub>) and propane (C<sub>3</sub>H<sub>8</sub>) through straight and branched chains to C<sub>76</sub>H<sub>54</sub>. Aromatic hydrocarbons and organic components containing nitrogen and sulfur can also be important constituents of some petroleum deposits. The hydrocarbons derived from coal and petroleum tends to form the main group of organic macropollutants in soils.

A commonly encountered group of aromatic molecule hydrocarbon pollutants are the BTEX compounds (benzene, toluene, ethyl benzene and xylene) which commonly occur in plumes in the groundwater beneath a wide range of industrial sites. Organic solvents are used widely in industry and can be important soil pollutants at industrial sites. These can include butane and n-hexane, benzene, toluene and organochlorine compounds such as vinyl chloride, chloroform, carbon tetrachloride and trichloroethane.

**(c) Toxic Organic Micropollutants (TOMPs) (also called Persistent Organic Pollutants (POPs))**

The most commonly encountered toxic organic micropollutants include: polycyclic aromatic hydrocarbons (PAHs), polyheterocyclic hydrocarbons (PHHs), polychlorinated biphenyls (PCBs), polychlorinated dibenzodioxins (PCDDs), polychlorinated dibenzofurans (PCDFs) and pesticide residues and metabolites.

**(d) Other Industrial Chemicals**

The huge amount of chemicals which are being used for industrial production can also pollute soil. It is estimated that between 60000 and 90000 chemicals are in current commercial use and thousands of new compounds are being brought into use (and dispersed in the environment) each year.

**(e) Nutrient-rich Wastes**

These are the residues from the treatment of waste water and large quantities are produced worldwide. Sewage sludge is a valuable source of plant nutrients (especially N and P) and a useful source of organic matter which has beneficial effects on soil aggregate stability. However, its value is somewhat diminished by its content of potentially harmful substances which include heavy metals, especially Cd, Cu, Ni, Pb and Zn, and organic pollutants. The most important persistent organic pollutant (POPs) in sewage sludges include: (a) halogenated aromatics, *e.g.* polychlorinated bi-phenyls (PCBs), polychlorinated terphenyls (PCTs), polychlorinated naphthalenes (PCNs) and polychlorinated benzenes, polychlorinated dibenzodioxins (PCDDs), (b) halogenated aliphatics, (c) polycyclic aromatic hydrocarbons (PAHs), (d) aromatic amines and nitrosamines, (e) phthalate esters, and (f) pesticides.

**(f) Radionuclides**

Nuclear accidents like those at Windscale (UK) in 1957 and Chernobyl (Ukraine) in 1986 resulted in many different radioactive substances being dispersed into the environment. The greatest long-term pollution problem is considered to be caused by  $^{137}\text{Cs}$  which has a half-life of 30 years and behaves in a manner similar to K in soils and ecosystems. Atmospheric testing of nuclear weapons dispersed large amounts of  $^{90}\text{Sr}$  which has a half-life of 29 years and behaves similarly to Ca in biological systems and poses a hazard to humans because it is stored in the skeleton.

**(g) Pathogenic organisms**

Soils can be contaminated with pathogenic organisms (bacteria, viruses, parasitic worm eggs) from various sources, including the burial of the dead bodies of animals and humans, manures and sewage sludges. The soil can act as a reservoir of these pathogens which can reach ground water, can infect livestock and humans through soil particles consumed directly by children or on unwashed hands or attached to herbage and vegetables. The latter is the main reason for the introduction of the sterilization of sewage sludges which are applied to agricultural land.

**Transport Mechanism Of Pollutants To Soil**

The major pathways of contamination of soil by pollutant are given below

- atmospheric deposition of particulates (washout or dry deposition)
- sorption of gases (*e.g.* volatile organic compounds) from the atmosphere,
- fluvial transport and deposition/sorption from flood waters,
- placement (agricultural amendments, dumping, injection, surface spreading *etc.*).

The sources of those soil pollutants are (1) Urban waste, (2) Industrial waste, (3) Biological waste, (4) Agricultural waste, (5) Radioactive wastes *etc.*

**Effect of Soil Pollution**

There is several adverse effect of pollutant on soil properties

- (1) Fertility of the top soil is reduced by soil erosion by different natural processes which ultimately affect the crop production.
- (2) The percentage of chemicals in soil increases day by day due to the disposal of huge quantity of solid and liquid wastes are mixed up with soil. Ultimately these chemicals will decrease the soil productivity.
- (3) The living organisms present in soil are killed by soil pollutant and thereby reduce the soil productivity.
- (4) The heavy metals like Pb, Cd and Hg will be introduced into the food chain through green vegetables and ultimately effects on animal and human health.

**Soil Pollution Control**

Pollution prevention means the minimization of waste generation. To maintain our day to day activity we have to produce the waste material. In order to reduce waste material, we would need less fertilizer and fewer pesticides if we could all adopt the three R's: Reduce, Reuse and Recycle. This would give us less solid waste. The following measures may be adopted to control soil pollution.

- (i) Huge plantation is necessary to prevent erosion of top soil which in turn reduce the fertility of top soil.
- (ii) Proper understanding the different natural cycle to maintain the natural balance.
- (iii) Minimum use of fertilizers and pesticides to maintain the soil property.
- (iv) Proper treatment of solid waste is necessary before disposal to land.
- (v) Crop rotation is necessary to maintain the nutrient concentration in soil.