Air Pollution

- Air pollution can be defined as the presence of one or more impurities like dust, mist, smoke and colour in the atmosphere that are harmful to human beings, plants and animals.
- Air Pollution indicates the contamination of the atmosphere that causes harm to living organisms and the environment.

The composition of air:

- Nitrogen 78%
- Oxygen 21%
- Argon 0.9%
- Carbon dioxide 0.04%
- Water vapour Variable
- Other Gases Trace amount

Sources of Air pollution

Natural sources

- Natural sources of pollution are those that are caused due to some natural event.
- Volcanic eruptions, forest fires, biological decay, pollen grains, marshes, sea salt sprays, photochemical oxidation of organic compounds, pollen grains of flowers, spores, meteorites etc.
- Radioactive substances present in the earth are the sources of radioactivity in the atmosphere.

Artificial or Man Made sources

- Artificial sources are those which are created by man. Ex: Thermal power plants, emissions from vehicles, industrial units, burning of fossil fuels, agricultural activities etc.
- Thermal power plants are the major sources for generating electricity in India. These plants emit two main pollutants viz. sulphur dioxide and fly ash.
- Fertilizer plants, smelters, textile mills, tanneries, refineries, chemical industries, paper and pulp mills are other sources of air pollution.
- Automobile exhaust is another major source of air pollution. Automobiles release gases such as carbon monoxide, oxides of nitrogen, unburnt hydrocarbons and suspended particulate matter.

Classification of Air Pollutants

Air pollutants can be divided into two categories

- Primary pollutants
- Secondary pollutants
- Primary pollutants are those that are directly emitted in the atmosphere in the harmful form.

  Ex: CO, NO, SO_2, benzophyrene (from cigarette smoke), NH_3(ammonia), lead bromide (from automobile exhaust), and soot etc.
- Secondary pollutants are those that are formed by reaction of primary pollutants with other component of the atmosphere; especially such reactions may take place in the presence of sunlight.

  Examples are: O_3, PAN (peroxyacetyl nitrate), H_2SO_4, HNO_3, aldehydes, etc.

Indoor air pollution

Sources:

Indoor air pollutants are primary air pollutants.

Indoor air pollution can be caused by many things like dust, dirt or gases in the air inside buildings such as your home or workplace that could be harmful to breathe in.

Poor indoor air quality can be caused by:

- heating and cooking at home
- damp and mould
- smoke and vapour
- chemicals we use for cleaning and decorating
- building materials

- Cookers, heaters, stoves and open fires can release pollutants into your home. High levels of exposure to these pollutants can lead to lung and heart disease.
- Burning wood and coal in a stove or on an open fire released particulate matter (PM). This can irritate your nose and throat, giving you a cough or breathing problems.
- Heating and cooking with gas releases tiny particles of nitrogen dioxide (NO_2) and carbon monoxide (CO) and SO_2 into the air you breathe. However, gas is much cleaner to burn than coal and wood. Coal burning produces 125 times more sulphur dioxide than gas, on average. If you use a gas cooker, the most important thing is to keep the room ventilated when cooking by using an extraction fan and opening windows.

- Electric is seen as the cleanest form of heating and cooking, as it releases less particles than gas, and much less than burning wood and coal. You may want to consider switching to electric cooking if possible - especially if you have a flare-up of your symptoms from breathing in gas, wood or coal particles.

- The most important indoor air pollutant is Radon gas.
- Radon gas formed by decomposition of radioactive elements present in building materials like bricks, concrete, etc. that are derived from soil containing radium.
- Radon is also found in natural gas and ground water and is emitted while being used.
- Burning fuel in the kitchen and cigarette smoke release pollutants like CO, SO_2, HCHO (Formaldehyde) and BAP (Benzo-(α) pyrene).

Pollutants from combustion system:

- Combustion pollutants are gase or particles that come from the burning of fuels like wood, oil, kerosene, coal etc.
- Combustion pollutants are sometimes called combustion by products because they are produced by the burning of fossi fuels.
- Most common pollutants from combustion system are:

1) Carbon monoxide (CO)
2) Nitrogen dioxide (NO2)
3) Sulphur dioxide (SO2)
4) Particulates

Carbon monoxide (CO):

- It is a highly poisonous gas which is colourless and odourless.
- A gas slightly lighter than air.
- Also nown as carbonus oxide.
- It is a flammable gas burns with a blue flame.
- It is formed by incomplete combustion of carbon or its compound.
- Main source of carbon monoxide is incomplete burning of fossil fuels like wood, coal and other naturally occuring substances on the earth surface (more than three fourth comes from motor vehicle exhaust).

CO formation in the atomosphere

- CO_2 gas is formed when carbon reacts with oxygen.
- However, if relative amount of carbon increases or that of oxygen decreses the reactin takes place as below:

$$2C + O_2 \longrightarrow 2CO$$

carbon or its compound + oxygen → carbon monoxide

- The gas formed in the reaction is carbon monoxide.
- Thus, CO is formed by the incomplete combustion of carbon or its compound in a limited supply of air (oxygen).

- For example, Huge quantities of carbon monoxide are produced during a forest fire or a volcanic eruption. The amount of carbon monoxide produced in such reactions depends on the availability of oxygen and the combustion temperature. High levels of oxygen and high temperatures tend to produce complete oxidation of carbon, with carbon dioxide as the final product. Lower levels of oxygen and lower temperatures result in the formation of higher percentages of carbon monoxide in the combustion mixture.

- Carbon monoxide gas inhibits the ability of red blood cells to carry oxygen to body cells and tissues.
- Oxygen binds with Haemoglobin (Hb) to form oxyhaemoglobin (less stable).
- Breathing air having high concentration of CO reduces the binding capacity of oxygen with Hb and itself bind with Hb to form carboxyhaemoglobin (more stable).
- The toxic character of carbon monoxide has been well known for many centuries. At low concentrations, carbon monoxide may cause nausea, vomiting, restlessness, and euphoria. As exposure increases, a person may lose consciousness or cause coma and go into convulsions. Death is a common result.

- Examples of CO producing sources:

a) Motor Vehicles, gasoline powered tools.

b) Volcanoes.

c) Heaters.

d) Cooking equipment.

e) Gas stoves

f) Unvented kerosene etc.

Control techniques of Carbon monoxide:

- The internal combustion engines in the automobiles are the primary sources of CO emission.
- The engines emits a mixture of gases consisting of CO, Nox, Hydrocarbons and particulates.
- It is observed that if a particular method is used to control any one of these polutants, then it results in the increase of other pollutants.

- **For example**: When air fuel ratio (wt/wt) is 16:1, the emission of CO and Hydrocarbons are reduced but the emissions of oxides of nitrogen increases.
- Thus, to minimize the emission of CO, suitable modifications are needed in the internal combustion engine or in the quality of the fuel.
- A few of these modifications proposed are as follows:

1) The carburettor is adjusted as to ensure proper air-fuel ratio. The presence of excessof air makes complete combustion of the fuel.

2) Exhuaust system is equipped with catalytic converter which converts CO into harmless products. Lead free gasoline is preferred these days as catalyst gets easily poisoned by lead.

3) Fuel such as CNG (condensed natural gas) and LNG (liquified natural gas) which release minimum quantity of pollutants on combustion are advised to be used in place of gasoline.

Nitrogen Dioxide:

- It is a reddish-brown irritating gas that causes photochemical smog.
- In the atmosphere, it gets converted into nitric acid (HNO_3) by reaction with H_2O vapor. Which is component of acid rain.
- Health effects include lung irritation and damage. Environmental effects include acid rain leading to damage of trees, lakes, soil and ancient monuments.

Sources:

- It is caused by burning fossil fuels in houses, industries and power plants.
- The oxides of nitrogen in atomosphere come from bacterial decay of organic matter by soil microorganisms on the surface of the earth.

Control Techniques of NO_x Pollution

- Nitrogen oxides are produced in the combustion process by two different mechanisms: (a) burning the nitrogen in the fuel like primarily coal or heavy oil (fuel NOx); and (b) high-temperature oxidation of the molecular nitrogen in the air used for combustion (thermal NOx).
- Formation of fuel NOx depends on combustion conditions, such as oxygen concentration and mixing patterns, and on the nitrogen content of the fuel. Formation of thermal NOx depends on combustion temperature.

- The flue gases coming out from power plants or industrial units can be made free from oxides of nitrogen and SO_2 by scrubbing them with akaline solution of $Ca(OH)_2$ and $Mg(OH)_2$ or with H_2SO_4.
- The following reactions occur when H_2SO_4 is used for scrubbing.

$$NO_2 + SO_2 + H_2O \longrightarrow H_2SO_4 + NO$$

$$NO + NO_2 \longrightarrow N_2O_3$$

$$N_2O_3 + 2H_2SO_4 \longrightarrow 2NOHSO_4 + H_2O$$

Thus, the flue gases thus freed from NO_2 and SO_2 are released into atomosphere.

- Mainly 3 control techniques are used to control Nox emissions:

1) <u>Combustion Control :</u>

- It may involve any of three strategies: (a) reducing peak temperatures in the combustion zone; (b) reducing the gas residence time in the high-temperature zone; and (c) reducing oxygen concentrations in the combustion zone.
- These changes in the combustion process can be achieved either through process modifications or by modifying operating conditions on existing furnaces.
- Process modifications include using specially designed low-NOx burners, reburning, combustion staging, gas recirculation, reduced air preheat and firing rates, water or steam injection, and low excess air (LEA) firing.
- These modifications are capable of reducing NOx emissions by 50 to 80%.
- The method of combustion control used depends on the type of boiler and the method of firing fuel.

2) **Flue gas treatment (FGT):**

- It is more effective in reducing NOx emissions than are combustion controls, although at higher cost.
- FGT is also useful where combustion controls are not applicable. Pollution prevention measures, such as using a high-pressure process in nitric acid plants, is more cost-effective in controlling NOx emissions.
- The flue gases coming out from power plants or industrial units can be made free from oxides of nitrogen and SO_2 by scrubbing them with alkaline solution of $Ca(OH)_2$ and $Mg(OH)_2$ or with sulphuric acid (H_2SO_4).

- The techniques can be classified as selective catalytic reduction, selective noncatalytic reduction, and adsorption. Selective catalytic reduction (SCR) is currently the most developed and widely applied FGT technology.
- In the SCR process, ammonia is used as a reducing agent to convert NOx to nitrogen in the presence of a catalyst in a converter upstream of the air heater.
- The catalyst is usually a mixture of titanium dioxide, vanadium pentoxide, and tungsten trioxide . SCR can remove 60–90% of NOx from flue gases. Unfortunately, the process is very expensive and the associated ammonia injection results in an ammonia slipstream in the exhaust.

3) Catalytic converters are used in automobiles which convert the ventricular exhausts into free nitrogen and traces of ammonia.

Sulphur Dioxide:

- It is a colourless gas that is formed by combustion of sulphur containing fossil fuels especially coal and diesel oil. In the atmosphere it is converted into Sulphuric acid which is a major component of acid rain.
- Health effects involve breathing problems for healthy people.
- Environmental effects involve smog formation and acid deposition on trees, lakes, soils and monuments leading to their deterioration and adverse effect on aquatic life.
- **Sources:** Volcanic eruptions and forest fires are the main natural source. Burning of fossil fuels and combustion of gasoline in the automobiles and industrial processes are anthropogenic sources.

Control Techniques of SO_2 Pollution

- SO_2 pollution can be controlled by the use of low sulphur content fuels such as natural gas or sulphur free fuels.
- A number of steps are being taken to make coal sulphur free before it is put to combustion.
- The combined sulphur such as iron pyrites is removed by subjecting grounded coal to hydraulic washing.
- Iron pyrites being heavier settle down while coal from pyrites floats on the surface and is collected.
- The free sulphur is removed by passing hydrogen gas over the fuel in presence of catalyst.the sulphur is converted into H_2S which is absobed in a solution of diethanolamine.

- The oxides of sulphur can be removed from flue gases by use of chemical scrubbers. The flue gases are passed through the scrubber containing slurry of limestone or lime.

$$CaCO_3 + SO_2 \longrightarrow CaSO_3 + CO_2$$

$$CaCO_3 + SO_3 \longrightarrow CaSO_4 + CO_2$$

$$Ca(OH)_2 + SO_2 \longrightarrow CaSO_3 + H_2O$$

- SO_2 can also be removed by the use of a solution containing citrate ions.

$$SO_2 + H_2O \rightleftharpoons HSO_3^- + H^+$$

$$HSO_3^- + H_2Cit \rightleftharpoons HSO_3.H_2\ Cit]^{2-}$$

- Citrate ions are regenerated by use of H_2S gas. Pure sulphur is obtained as a byproduct.

- The principal approaches to controlling SO_2 emissions include use of low-sulfur fuel; reduction or removal of sulfur in the feed; use of appropriate combustion technologies, by using alternate source of energy such as hydroelectric power plants and nuclear power plants instead of thermal power plants; and emissions control technologies such as sorbent injection and flue gas desulfurization (FGD).
- The two major emissions control methods are:

1) sorbent injection and

2) flue gas desulfurization

1) **Sorbent injection:** involves adding an alkali compound to the coal combustion gases for reaction with the sulfur dioxide. Typical calcium sorbents include lime and variants of lime. Sodium-based compounds are also used. Sorbent injection processes remove 30–60% of sulfur oxide emissions.
2) **Flue gas desulfurization:** may be carried out using either of two basic FGD systems: regenerable and throwaway. Both methods may include wet or dry processes. Currently, more than 90% of utility FGD systems use a wet throwaway system process.

Particulates: The term particulates refers to all atomospheric substances that are not gases i.e. They are minute solid particles or liquid droplets or mixtures of the two in air.

- Suspended Particulate Matter (SPM): Includes a variety of particles and droplets (aerosols) that can be suspended in atmosphere for short to long periods.
- SPM are formed due to: burning coal in power plants, burning fossil fuels in vehicles, agricultural activities, construction, etc.
- Health effects include nose and throat irritation, lung damage, bronchitis, asthama, reproductive problems and cancer.
- Environmental Effects include reduced visibility and deposition. Deposition may lead to damaged tree leaves etc.

Equipment used to control air pollution

- **Method of removal of Particulate Matter**

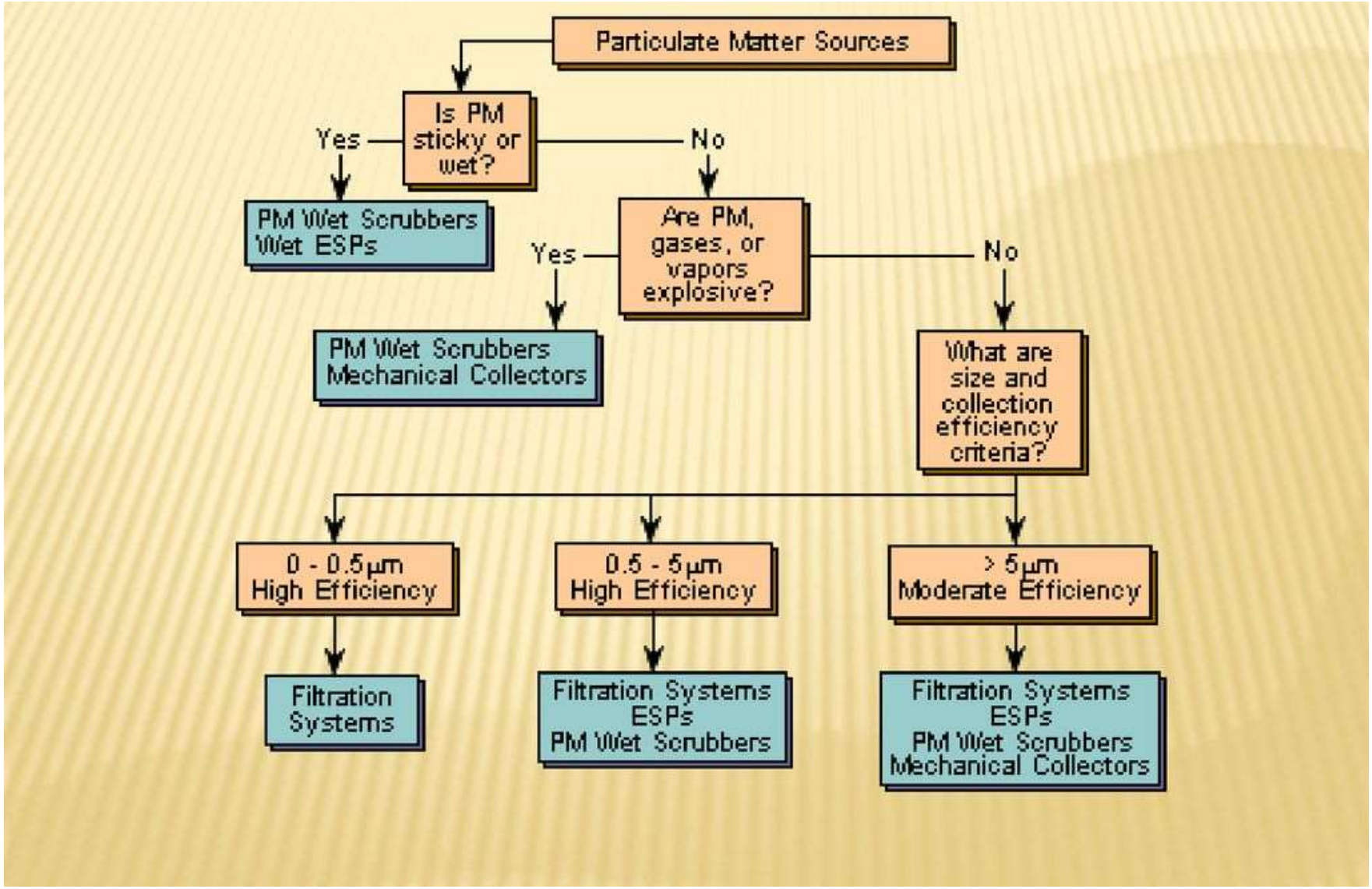
1. Gravitational settling chamber (Removal of SPM by gravitation)
2. Cyclone (Removal of SPM by centrifugation)
3. Fabric filters or bag filter (Removal of SPM by filtration)
4. Wet scrubber (Removal of SPM by scrubbing)
5. Electrostatic Precipitator (Removal of SPM by Electrostatic precipitator).

- **Method of Removal of gaseous impurities**

1. Absorption
2. Adsorption
3. Condensation
4. Combustion

- The selection of air pollution control device is based on factors such as characterstics of the air pollutant and the desired removal efficiency.

Applicability of particulate control system



SETTLING CHAMBERS

- Settling chambers use the force of gravity to remove solid particles.
- The gas stream enters a chamber where the velocity of the gas is reduced. Large particles drop out of the gas and are recollected in hoppers. Because settling chambers are effective in removing only larger particles, they are used in conjunction with a more efficient control device.

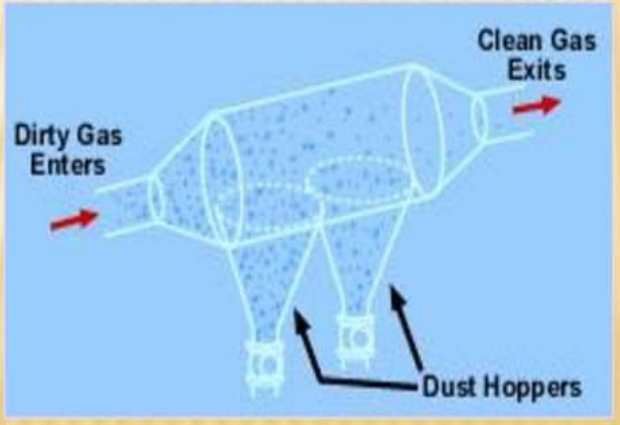


Figure: Settling chambers

ADVANTAGES

- Simple construction.
- low initial cost
- Low maintenance cost.
- Low pressure drop.
- Dry and continuous disposal of solid particulates

DISADVANTAGES

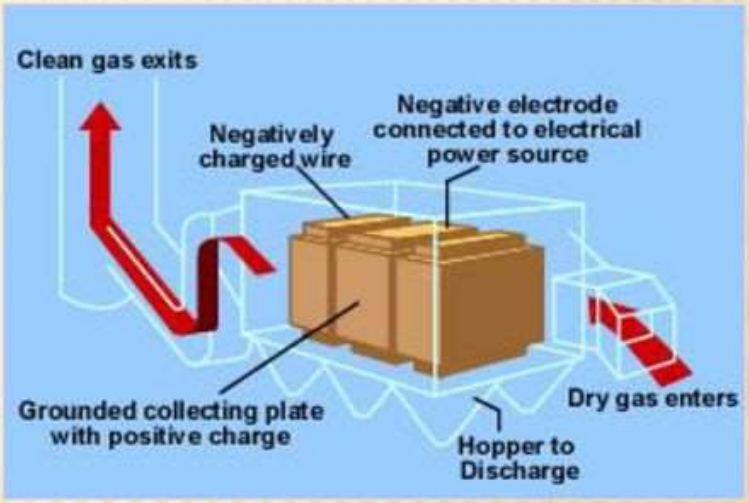
- Large space requirements.
- Only comparatively large particles can be collected.

APPLICATIONS

- Industrial application of this equipments is limited.
- Settling chamber are used widely for removal of large solid particulates from natural draft furnaces, kilns etc.
- They are also sometimes used in the process industries ,particularly the food and metallurgical industries, as a first step in dust control.

ELECTROSTATIC PRECIPITATORS (ESP)

- An ESP is a particle control device that uses electrical forces to move the particles out of the flowing gas stream and onto collector plates.
- The ESP places electrical charges on the particles, causing them to be attracted to oppositely charged metal plates located in the precipitator.



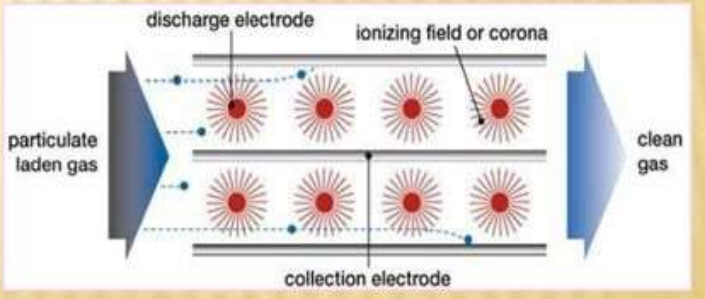


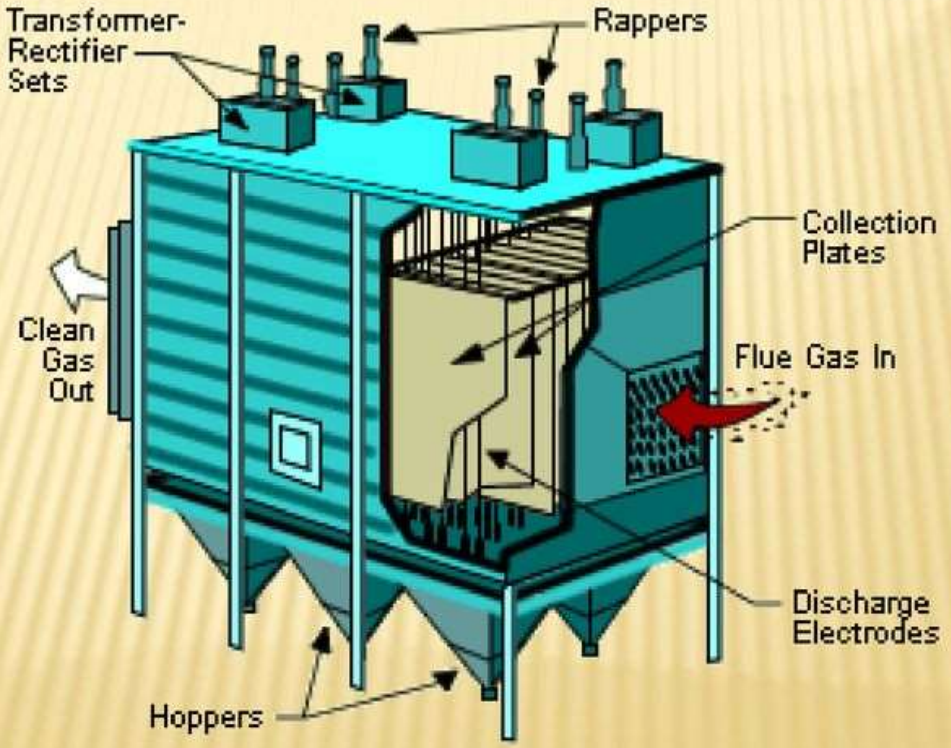
Figure: Electrostatic precipitator components

CONTI....

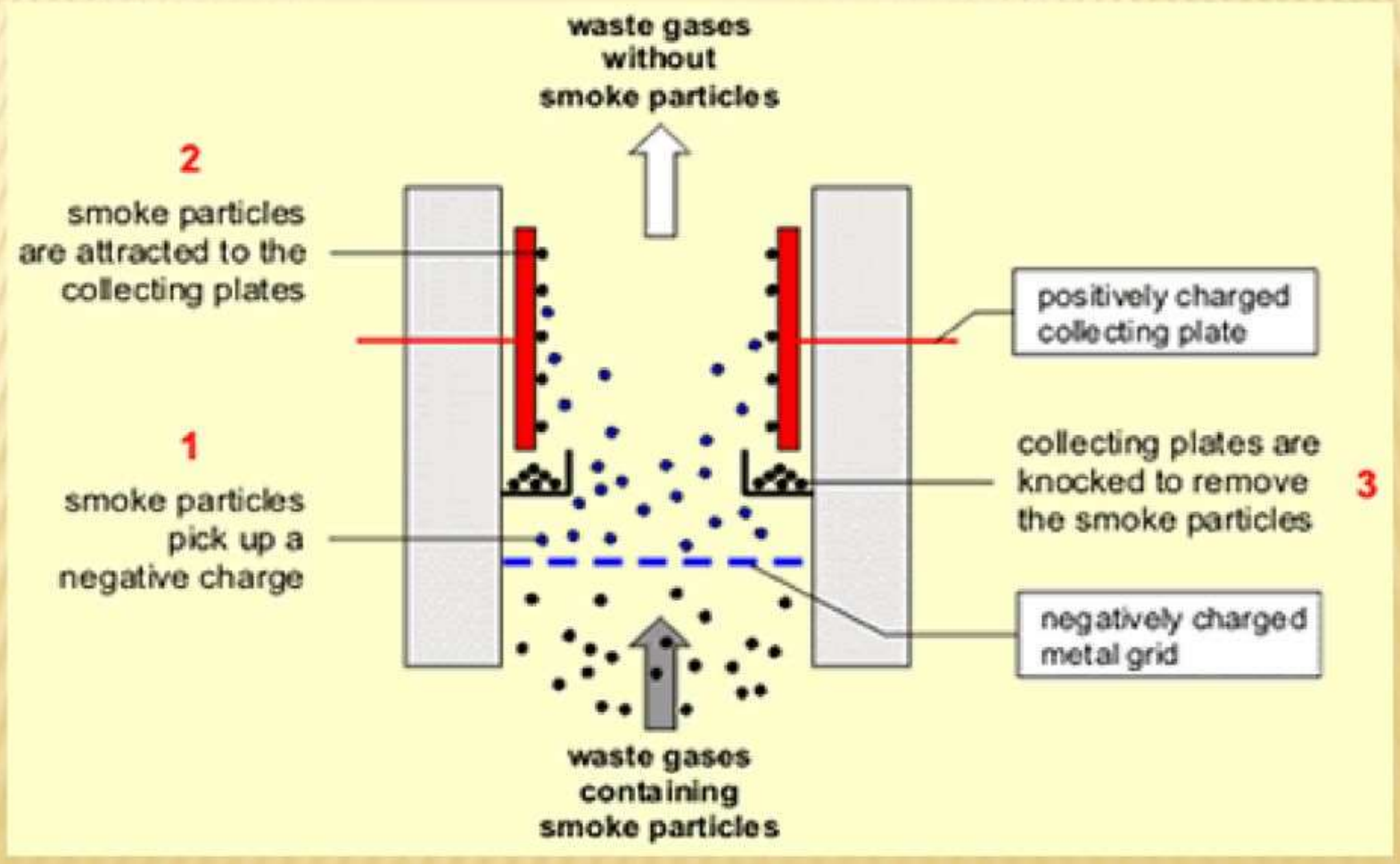
- The particles are removed from the plates by "rapping" and collected in a hopper located below the unit.
- The removal efficiencies for ESPs are highly variable; however, for very small particles alone, the removal efficiency is about 99%.
- Electrostatic precipitators are not only used in utility applications but also other industries (for other exhaust gas particles) such as cement (dust), pulp & paper (salt cake & lime dust), petrochemicals (sulfuric acid mist), and steel (dust & fumes).

ELECTROSTATIC PRECIPITATOR (ESP)

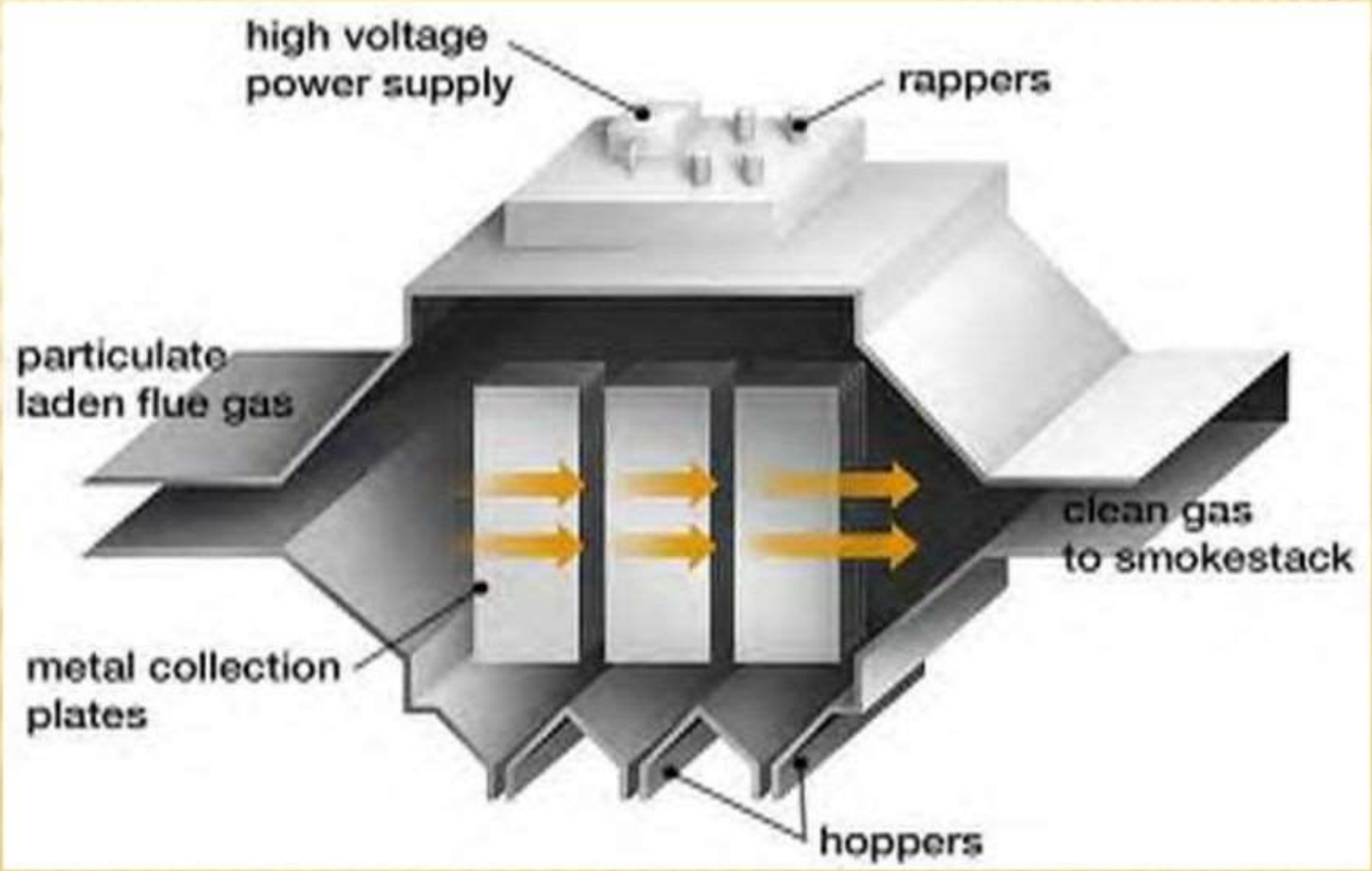
Figure 9. Conventional Electrostatic Precipitator



WORKING PHENOMENA



ELECTROSTATIC PRECIPITATOR (ESP)



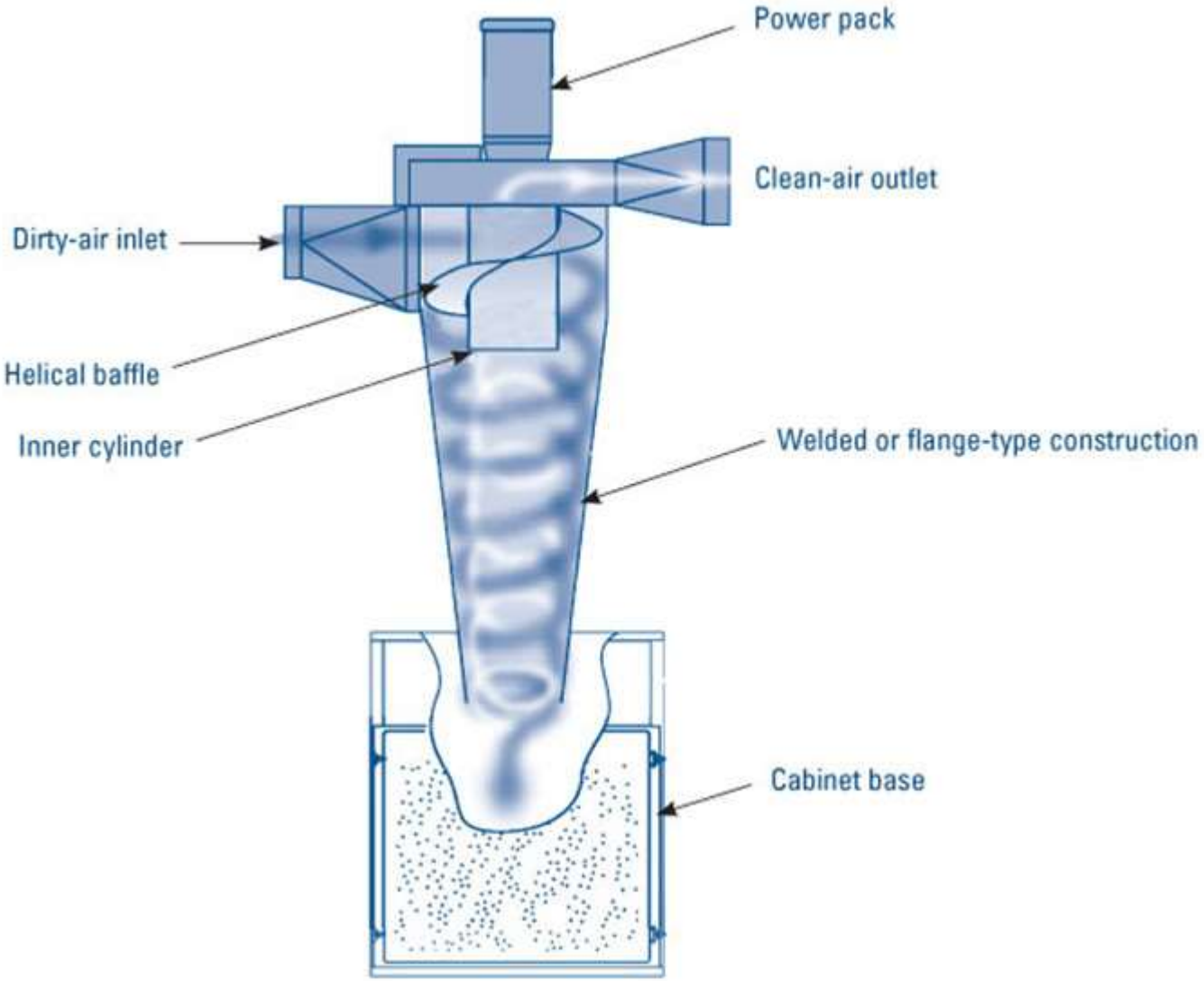
ADVANTAGES

- High collection efficiency.
- Particles as small as 0.1μm can be removed.
- Low maintenance and operating cost.
- Low pressure drop.
- Treatment time is negligible.
- Cleaning is easy by removing units of the precipitator from operation.
- There is no limit to solid, liquid or corrosive chemical usage.

DISADVANTAGES

- High initial cost
- Space requirement is more.
- Possible explosive hazardous during collection of gases.
- Precautions are very necessary during operation.
- The poisonous gas, ozone is produced .

Cyclone Separator



Cyclone Separator

- Centrifugation is a process that involves the use of centrifugal force for sedimentation of a heterogeneous mixture with a centrifuge. It involves removal of particulates from air, gas or a liquid stream without use of filters with a vortex separation. When removing particulates from a gaseous stream, a gas cyclone is used while a hydrocyclone is used to remove particulates from a liquid stream. This method can also be used to separate fine droplets of liquid from a gaseous stream.
- Their efficiency is between 50-99%. Cyclone separators work best on flue gases that contain large amount of big particulate matter.
- **Advantages:**
- Cyclones are less expensive to install or maintain as they do not contain any moving parts
- It is easy to dispose particulate matter as it is collected in the dry state
- Space requirement is very less
- **Disadvantages:**
- They are not efficient in collecting particulate matter smaller than 10 microns
- They cannnot handle sticky material

FABRIC FILTERS

- Fabric filters, or bughouses, remove dust from a gas stream by passing the stream through a porous fabric. The fabric filter is efficient at removing fine particles and can exceed efficiencies of 99 percent in most applications.

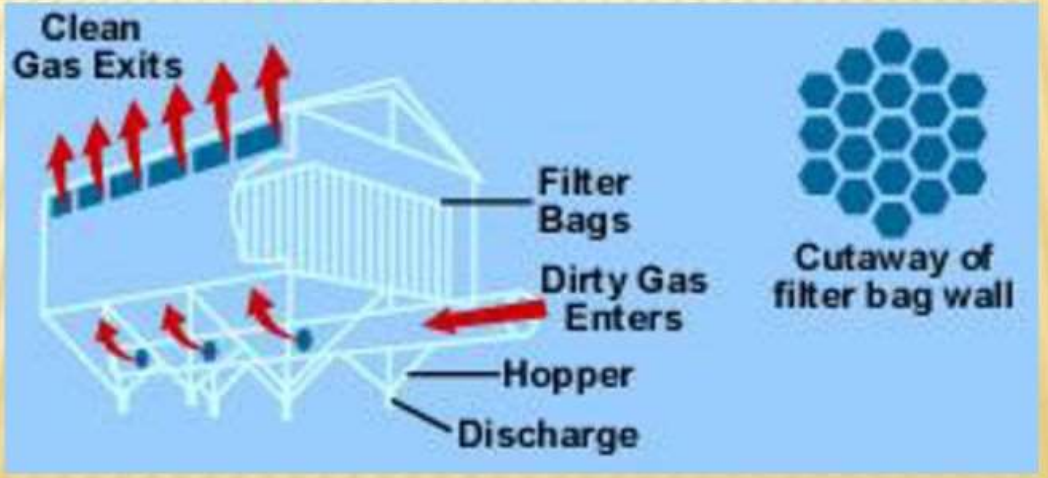


Figure: Fabric filter (baghouse) components

Fabric filter or Bag Filter

In a fabric filter system, a stream of the polluted gas is made to pass through a fabric that filters out the particulate pollutant and allows the clear gas to pass through. The particulate matter is left in the form of a thin dust mat on the insides of the bag. This dust mat acts as a filtering medium for further removal of particulates increasing the efficiency of the filter bag to sieve more sub micron particles (0.5 µm).

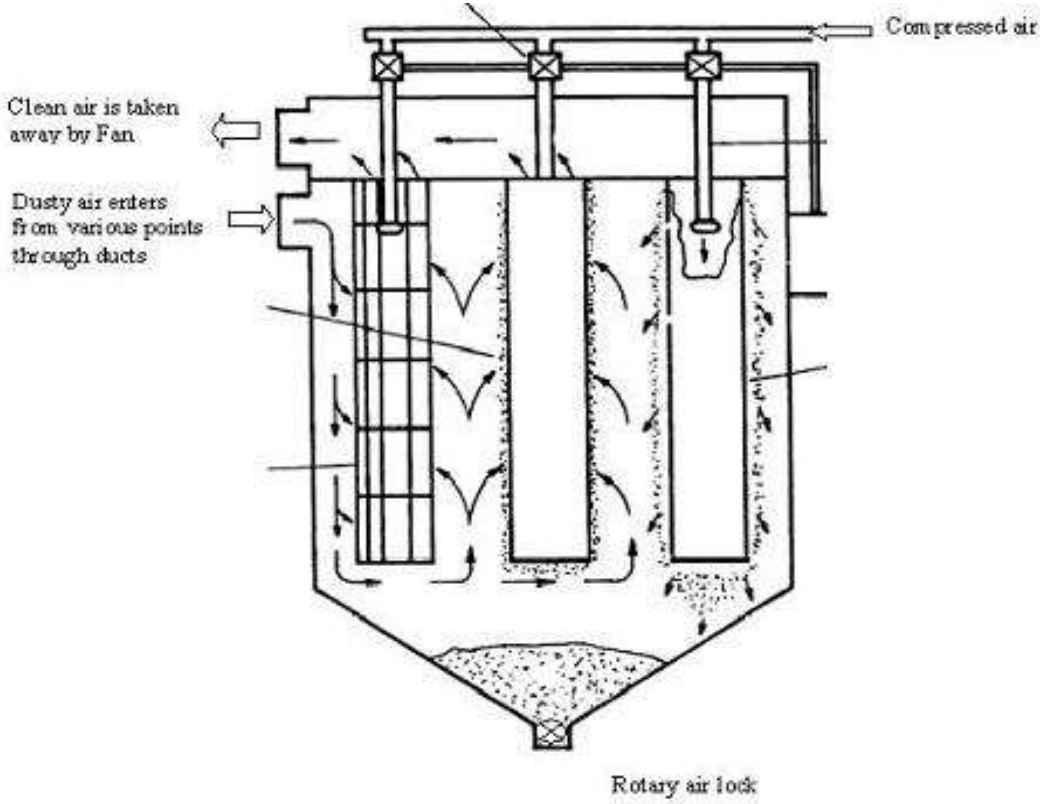
Advantages:

- Bag filter is a high quality performance instrument to effectively control particulate emissions and its efficiency is as high as 99%
- Collection efficiency is not affected by sulphur content in fuel
- It is not sensitive to particle size distribution
- It does not require high voltage
- It can be used to collect flammable dust
- Special fiber or filter aids can be used to sub-micron level smoke and fumes

DISADVANTAGES:

- Fabric life is reduced due to presence of highly acidic or alkaline atmospheres, especially at high temperatures
- Maximum operating temperature is 500 F
- Collection of hygroscopic materials or condensation of moisture can lead to fabric plugging, loss of cleaning efficiency and large pressure losses.
- Certain dusts may require special fabric treatments.

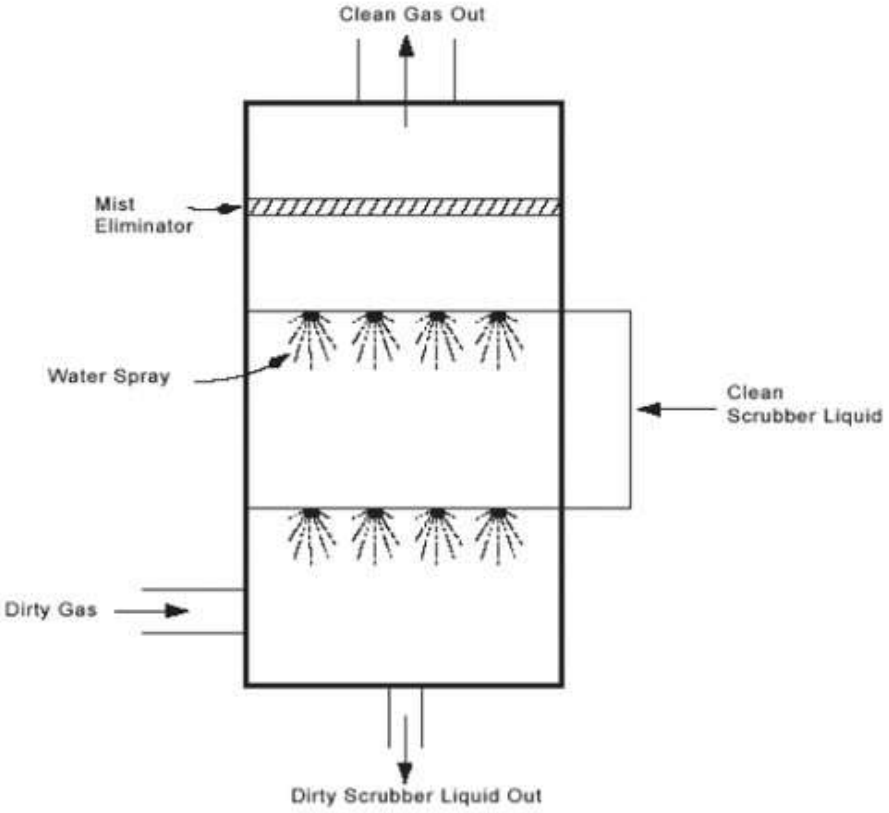
Bag Filter

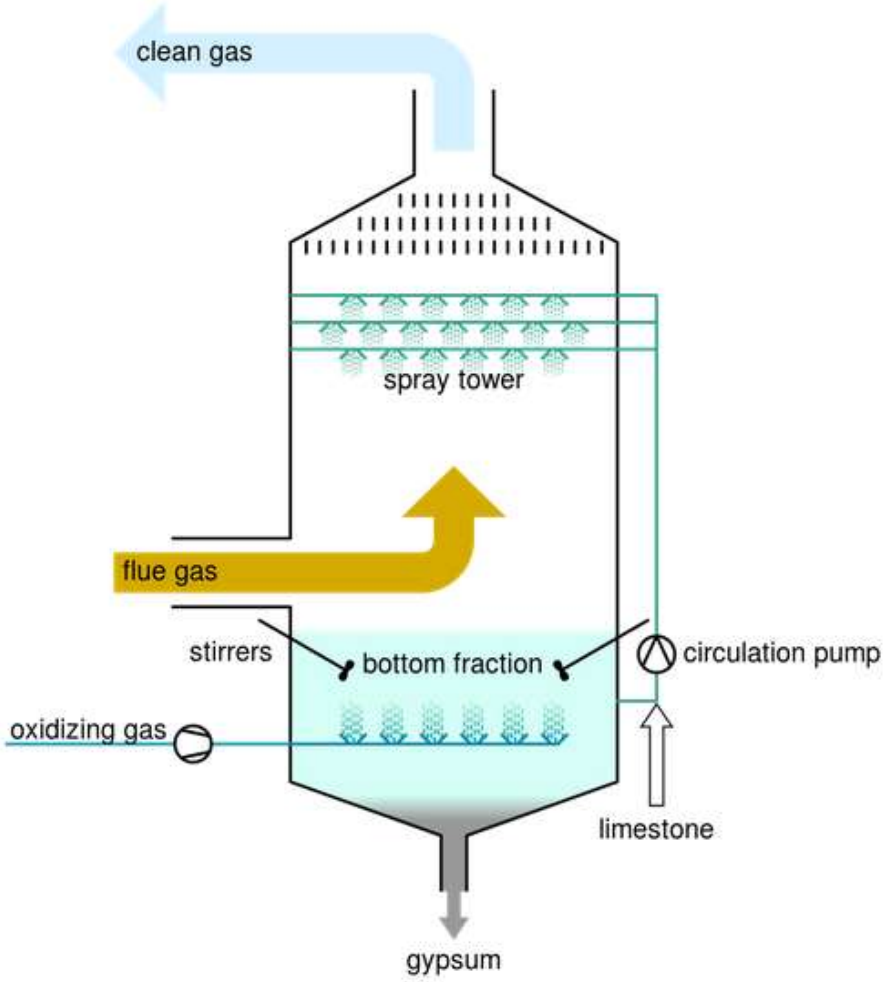

Compressed air
Clean air is taken away by Fan
Dusty air enters from various points through ducts
Rotary air lock

Wet Scrubber/ Spray Tower

In this method, the effluent gases are allowed to enter a spray tower or chamber.

it is used for the removal of gases and particulate matter from an exhaust stream by dissolving the gaseous contaminants in the liquid stream and by entrapping the solids in the liquid.





SPRAY TOWERS

- Simplest type of Wet Scrubber.
- Water is applied through nozzles.
- It can be circular or rectangular.
- The flue gas is passed with the fluid (usually water) from nozzles.
- The clean gas is collected from the top while water with the particles is collected at the hopper bottom.
- It shows very less energy loss and can handle very large quantity of gases.

- The most common method for controlling gaseous pollutants is the addition of add-on control devices to recover or destroy a pollutant.
- There are four commonly used control technologies for gaseous pollutants:
  - Absorption,
  - Adsorption,
  - Condensation, and
  - Incineration (combustion)

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.

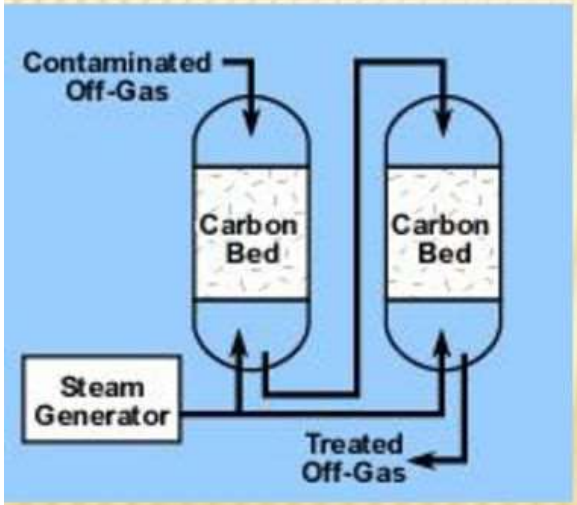
Typical Packed Column Diagram

- 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.
- 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.

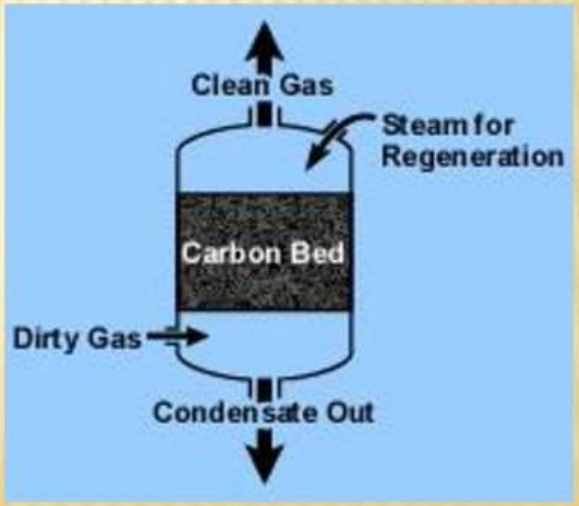
ADSORPTION

- 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 and the latter adsorption.
- 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 systems are either regenerative or non-regenerative
  - **Regenerative system** usually contains more than one carbon bed. As one bed actively removes pollutants, another bed is being regenerated for future use.
  - **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.



Regenerative Carbon Adsorption System

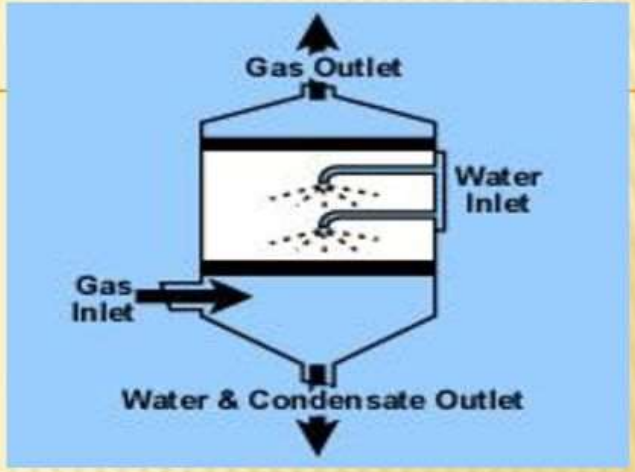


Non-Regenerative Carbon Adsorption System

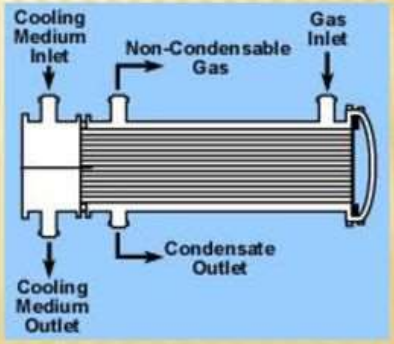
CONDENSATION

- Condensation is the process of converting a gas or vapor to liquid. Any gas can be reduced to a liquid by lowering its temperature and/or increasing its pressure.
- Condensers are typically used as pretreatment devices. They can be used ahead of absorbers, adsorbers, and incinerators to reduce the total gas volume to be treated by more expensive control equipment.
- Condensers used for pollution control are contact condensers and surface condensers.

- **In a contact condenser**, the gas comes into contact with cold liquid.
- In a **surface condenser**, the gas contacts a cooled surface in which cooled liquid or gas is circulated, such as the outside of the tube.
- Removal efficiencies of condensers typically range from 50 percent to more than 95 percent, depending on design and applications.



Contact condenser



Surface condenser

INCINERATION

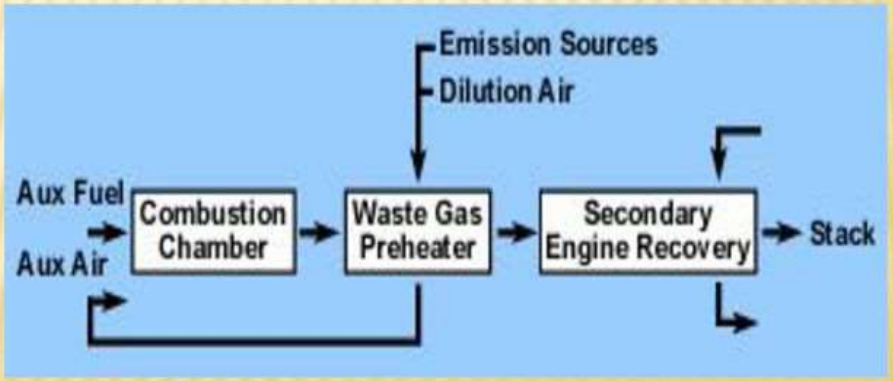
- Incineration, also known as combustion, is most used to control the emissions of organic compounds from process industries.
- This control technique refers to the rapid oxidation of a substance through the combination of oxygen with a combustible material in the presence of heat.
- When combustion is complete, the gaseous stream is converted to carbon dioxide and water vapor.
- Equipment used to control waste gases by combustion can be divided in three categories:
  - Direct combustion or flaring,
  - Thermal incineration and
  - Catalytic incineration.

DIRECT COMBUSTOR

- **Direct combustor** is a device in which air and all the combustible waste gases react at the burner. Complete combustion must occur instantaneously since there is no residence chamber.
- A flare can be used to control almost any emission stream containing volatile organic compounds. Studies conducted by EPA have shown that the destruction efficiency of a flare is about 98 percent.

- In **thermal incinerators** the combustible waste gases pass over or around a burner flame into a residence chamber where oxidation of the waste gases is completed.

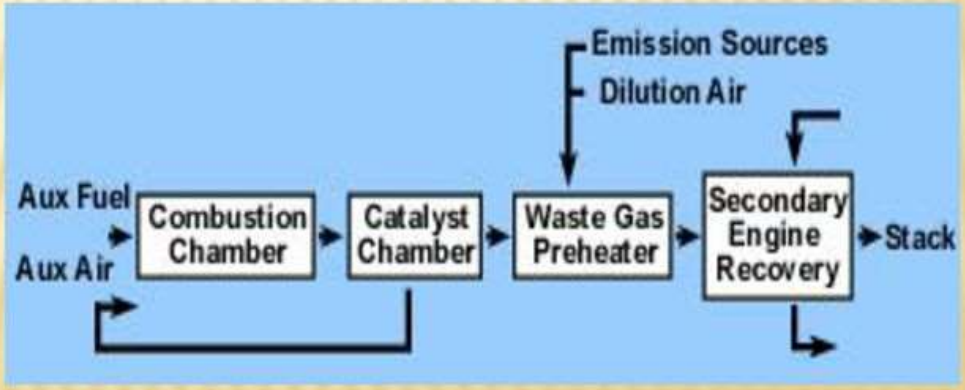
Thermal incinerators can destroy gaseous pollutants at efficiencies of greater than 99 percent when operated correctly.



Thermal incinerator general case

➢**CATALYTIC INCINERATORS** Are very similar to thermal incinerators. The main difference is that after passing through the flame area, the gases pass over a catalyst bed.

A catalyst promotes oxidation at lower temperatures, thereby reducing fuel costs. Destruction efficiencies greater than 95 percent are possible using a catalytic incinerator.



Catalytic incinerator

Organic Pollutants

- Organic pollutants are toxic substances made of organic compounds. (Organic substances and compounds refer to any compound that contains carbon).
- They are usually industrial chemicals or products from industrial processes.
- Organic pollutants can be found anywhere- water, soil, and air.
- Small amounts of these compounds can cause nervous system damage, immune system diseases, reproductive disorders, and cancer.

- With the rapid population increase, the amounts of fuel consumption and development of industrial chemicals, fertilizers, pesticides, and pharmaceuticals increased, resulting in the release of a significant amount of OPs into air, water and mainly soil environments.
- According to their half-life in environments, OPs are classified into persistent organic pollutants (POPs) and non-POPs.
- The former type is a hotspot because of their high persistence and toxicity in soil, posing high health risks to human health through food chains.

- **Persistent organic pollutants (POPs)** are toxic chemicals that adversely affect human health and the environment around the world. Because they can be transported by wind and water, most POPs generated in one country can and do affect people and wildlife far from where they are used and released. They persist for long periods of time in the environment and can accumulate and pass from one species to the next through the food chain.

- These pollutants are especially dangerous because their toxins don’t break down easily and they can accumulate in the body fat of humans and other animals.

- These toxins are chemical contaminants, also called the dirty dozen. Being volatile substances, POPs evaporate into the air in warm regions of the globe, are transported by air currents up to cold regions and in mountainous regions where they condense .

- POPs are organic compounds categorized as a special group based on their salient properties. These salient features which make an organic compound a POP are its
- ***Persistence***—POPs are extremely resistant to physical, chemical, and biological degradation. They have long half-lives in soil, water, and air.
- ***Bioaccumulation***—They accumulate in the organism to a level which can be harmful to the human health and environment.
- ***Ability for long range transport***—It can be transported by the environmental media to far sites where they have never been used or produced, such as in the Arctic regions.
- ***Toxicity***—POPs are extremely toxic and pose a threat both to the human health and the environment.

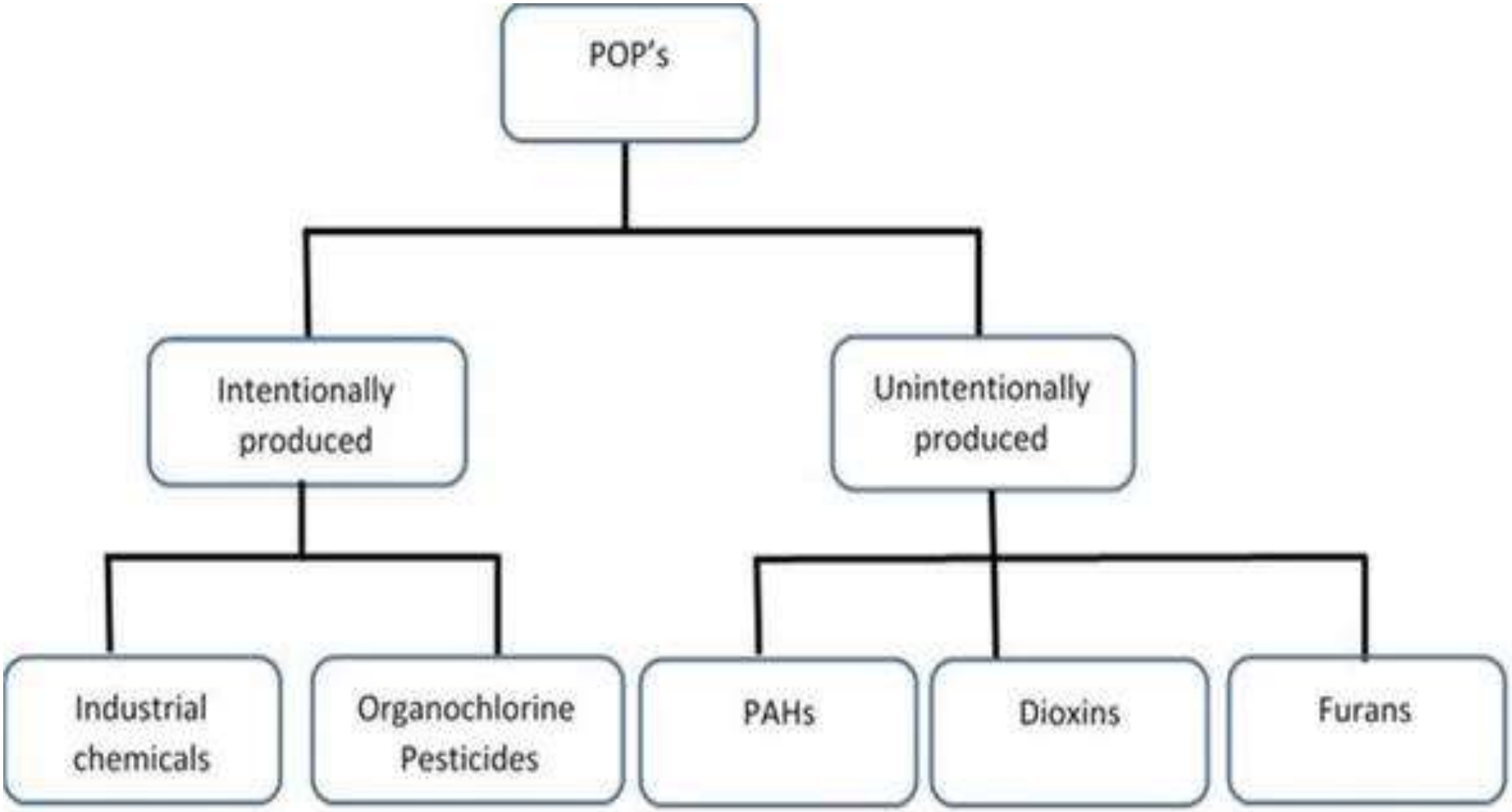
Non persistent OPs are those chemicals that linger only for a brief period after their release in the environment.

For eg:

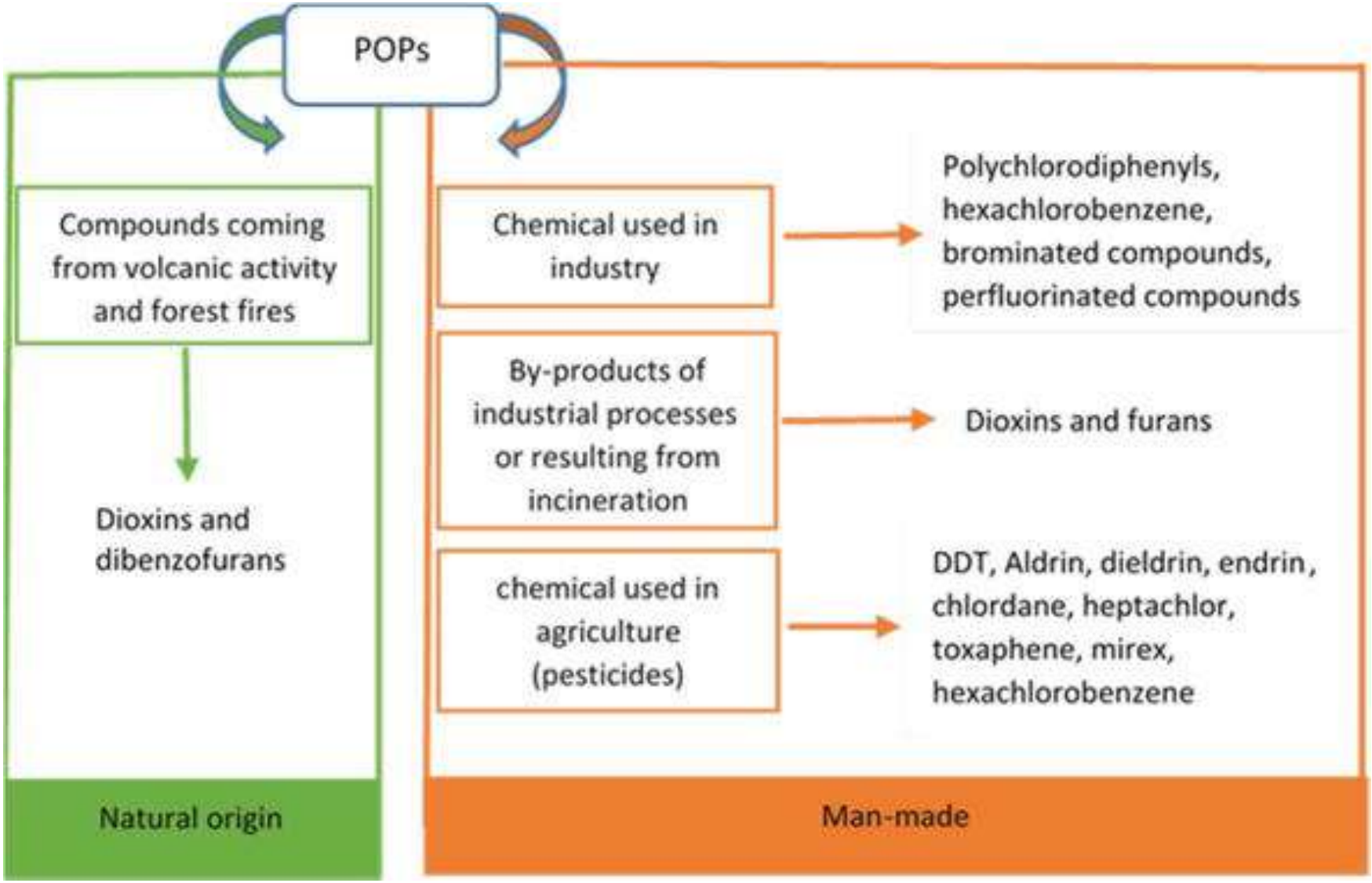
1) organophosphates such as guthion and malathion.
2) chlorinated hydrocarbons such as endosulfan.

- Physical and chemical properties of POPS which determine their fate in the environment are their low water solubility, high lipid solubility, high molecular mass, and low volatility.
- The organic pollutants that constitute the POPs can be broadly classified into two categories, intentionally manufactured POPs and unintentionally produced by-products .

Types of POPs



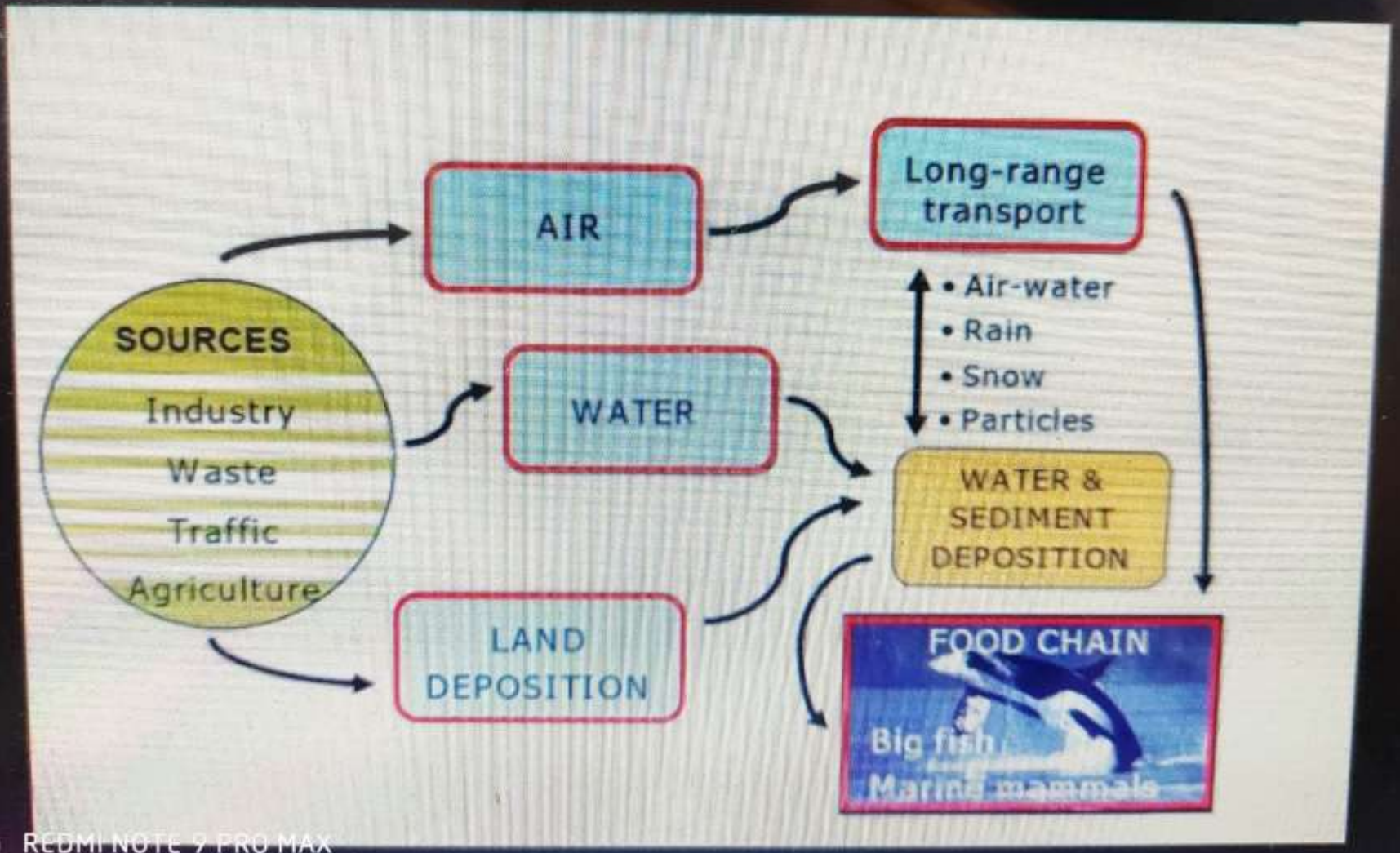
Sources of POPs



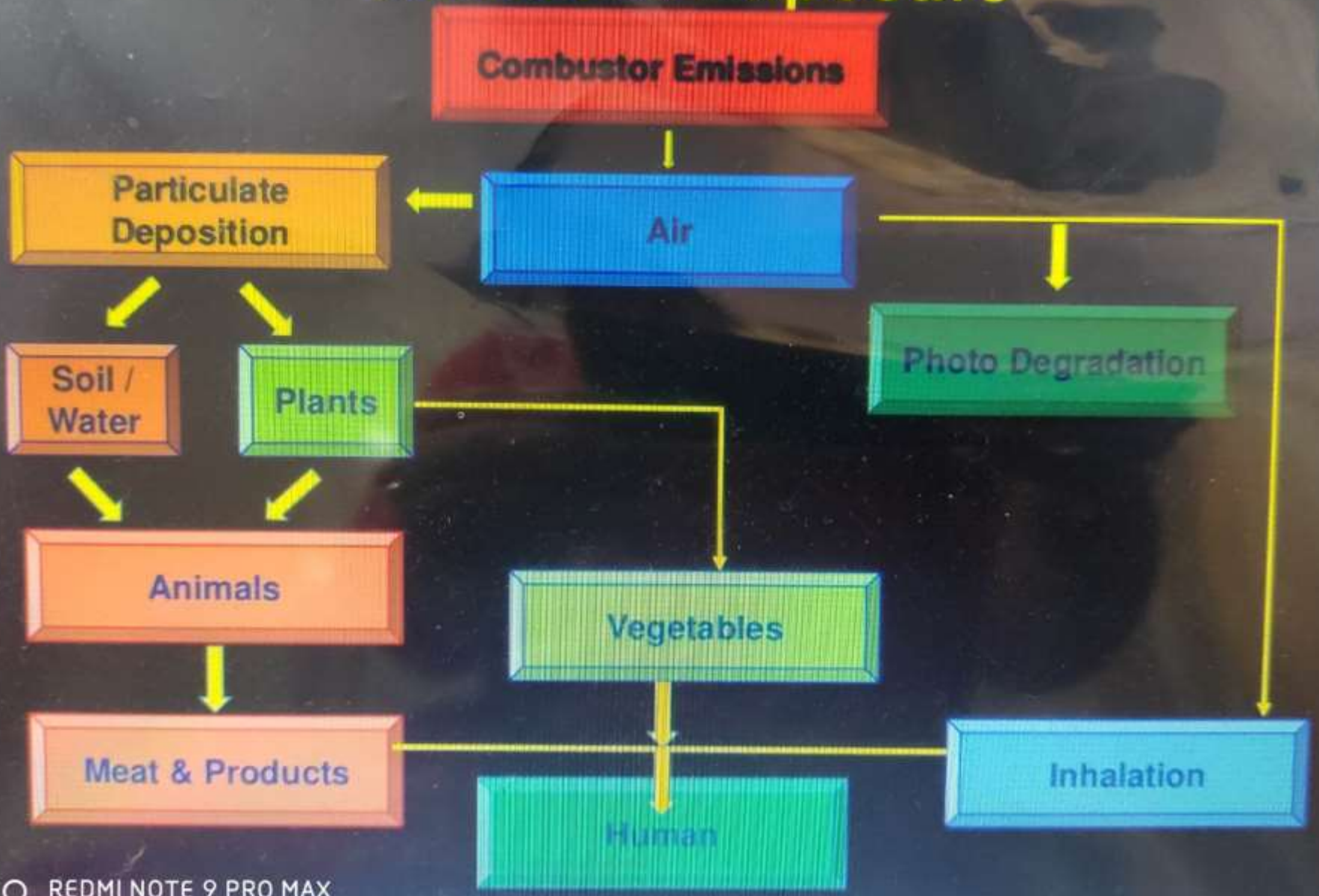
Name	Category	Uses	Effects
Aldrin	Pesticides	Termites, grasshoppers, corn worms	Neurotoxin, liver and biliary cancer, as well as a mutagen
Chlordane	"	Corn and citrus, and lawns and domestic gardens	Nervous, digestive systems and liver, convolutions and death
DDT	"	Malaria, typhus, and other diseases	Toxic to more organisms than intended to kill
Dieldrin	"	Termites and textile pests	Parkinson's disease, immune & reproductive
Endrin	"	Pests of cotton, rice and corn	Nervous system, toxic to aquatic organisms
Heptachlor	"	Cotton insects, grasshoppers	Human carcinogen
Mirex	"	Fire retardant	Placenta, breast milk
Toxaphene	"	Ticks and mites in livestock	Damage to lungs, nervous system, kidneys

Name	Category	Uses	Effects
Category II			
PCBs (Polychlorinated biphenyls)	Industrial Chemicals	Heat exchange fluids, additives in paint etc	Carcinogenic, mutagenic
HCB (hexachlorocyclohexane)	"	Fungi of food crops	Reproductive and immune function, crosses the placenta, breast milk
Category III			
Dibenzodioxins	Unintended by products	No use	Cancers, teeth abnormality, thyroid disorders, damage to immune systems, endometriosis and even disbetes
Dibenzofurans	"	"	"

Distribution of Persistent Organic Pollutants



Routes of Exposure



Effect of POPs:

- Exposure to POPs can lead to potential risk of adverse health effects including cancer, allergies, reproductive disorder, endocrine and immune system disruption, obesity, diabetes.
- Fish can also contain other organic pollutants, such as PCBs and dioxins. Whereas mercury accumulates in the muscles of larger predatory fish, PCBs and dioxins are found in the fatty tissues of fish. Most human exposure to PCBs and dioxins comes from dietary sources because they accumulate in the lipid fractions of meat, fish, milk and milk products, eggs, grains, and oils.
- PCBs and dioxins have been linked with increased rates of some cancers due to exposure of high amounts of these chemicals via vocational exposure or accidental environmental contamination.

- Thus, The POPs are organic compounds of anthropogenic origin mainly, are resistant to environmental degradation through chemical, biological, or photolytic processes and as a result, accumulate in the food chain. Contamination by POPs is widespread, and circulate globally via the atmosphere, oceans, and other pathways.
- Various advanced wastewater treatment technologies such as, activated carbon adsorption, biodegradation using membrane bioreactor and advanced oxidation processes have been applied in the treatment of POPs.

Photochemical Smog

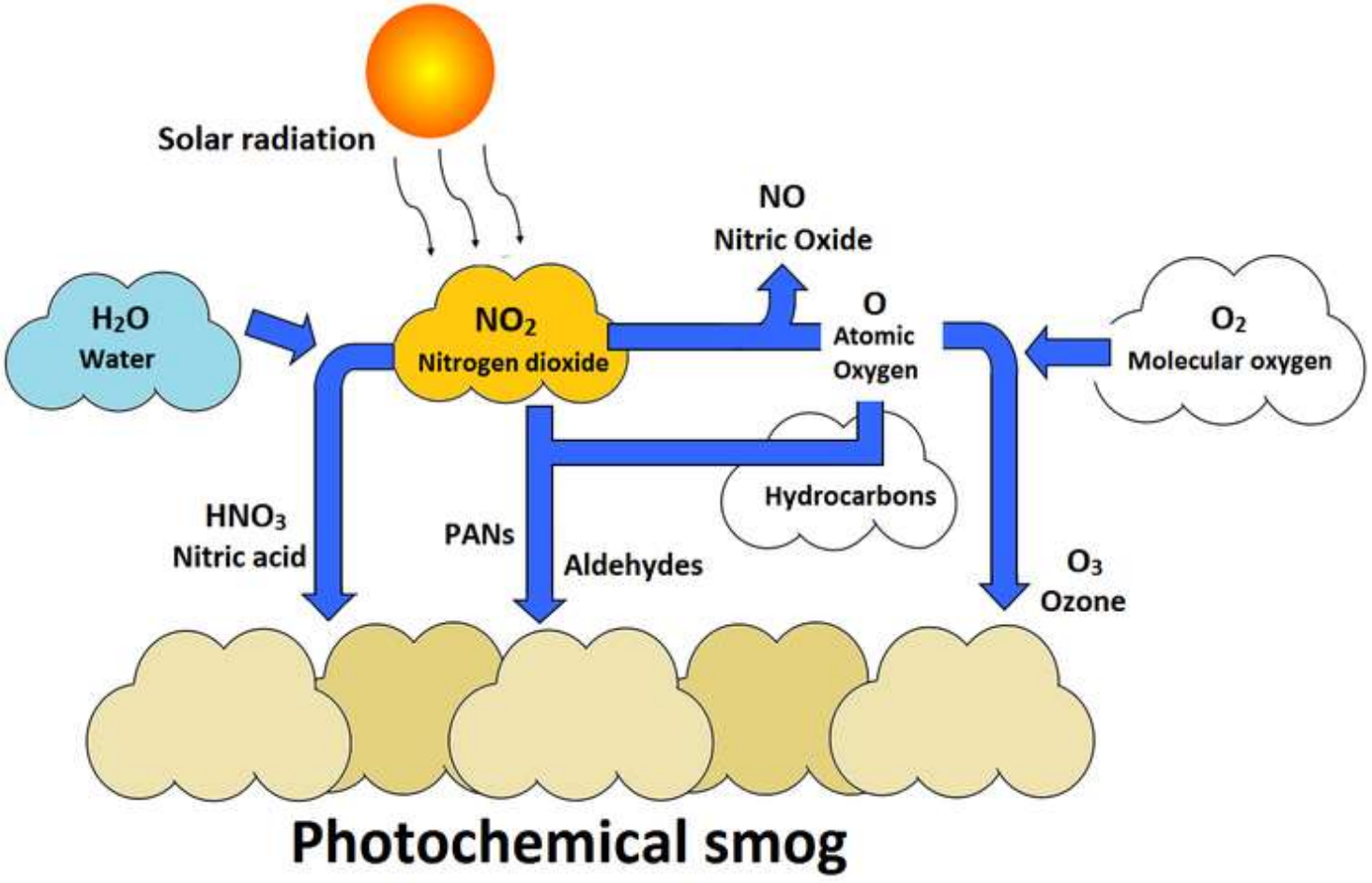
- Photochemical smog occurs in summer season and hence is also known as summer smog.(also called Los Angeles smog as it was observed for the 1st time in los Angeles in 1950.)
- It is visible as a brown haze, and is most prominent during the morning and afternoon, especially in densely populated, warm cities.
- It is mainly caused by the reaction of sunlight with the nitrogen oxides and other pollutants present in the atmosphere.
- This reaction results into the formation of secondary pollutants such as ground level ozone.

- Nitric oxide (NO) and nitrogen dioxide (NO_2) are emitted from the combustion of fossil fuels, along with being naturally emitted from things such as volcanos and forest fires . When exposed to ultraviolet radiation, NO_2 goes through a complex series of reactions with hydrocarbons to produce the components of photochemical smog—a mixture of **ozone**, **nitric acid**, **aldehydes**, **peroxyacyl nitrates** (**PANs**) and other secondary pollutants.
- NO_2, ozone and PANs are called **photochemical oxidants** because they can react and oxidize certain compounds in the atmosphere or within a person's lungs that are not normally oxidized. Even small traces of these chemicals can affect the respiratory tract of humans and animals, and damage crops and trees.

- The primary pollutants in photochemical smog are mainly nitrogen oxides such as nitric oxide (NO) and nitrogen dioxide (NO_2), CO, and some other volatile organic compounds (unburnt hydrocarbons).
- The secondary pollutants are peroxylacyl nitrates (PANs), tropospheric ozone and aldehydes.
- When nitric oxide present in the air combines with the atmospheric oxygen, it results into nitrogen dioxide which combines with hydrocarbons in the presence of sunlight to form ozone known as ground level ozone. Some nitrogen oxides react in sunlight to form ozone while some form nitric acid which results in acid rain as it falls on the ground with the rain. Acid rain is highly reactive and oxidizing which corrodes human properties and also destroys crops and natural vegetation.

Formation of photochemical smog:

- Smog begins with primary pollutant.
- Secondary pollutants, formed photochemically from pri. Pollutants, are responsible for the buildup of smog.



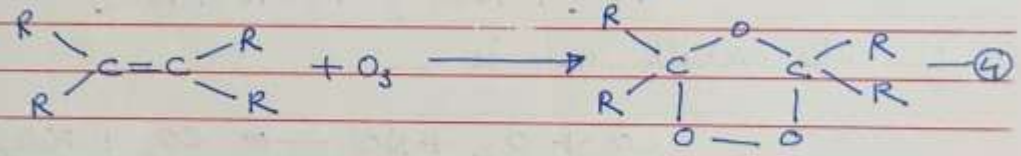
Reactions involved in photochemical smog :-

$$2NO + O_2 \longrightarrow 2NO_2 \quad \text{—— ①}$$

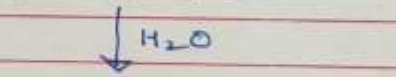
$$NO_2 + h\nu \longrightarrow NO + O \quad \text{—— ②}$$

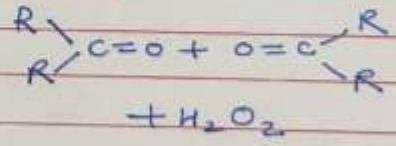
$$O_2 + O + M \longrightarrow O_3 + M \quad \text{—— ③}$$

Where M is an inert gas such as nitrogen. it takes up the excess energy.



—④





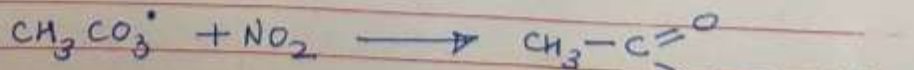
$$O + RH \longrightarrow R^{\bullet} + RCO^{\bullet}$$

hydrocarbons

$$RCO^{\bullet} + O_2 \longrightarrow RCO_3^{\bullet}$$

$$RCO_3^{\bullet} + NO_2 \longrightarrow RCO_3NO_2$$

if $R = CH_3$



PAN

[Peroxy acetyl nitrate]

When free oxygen-atom reacts with aldehydes, hydroxy radicals are formed which lead to a series of reactions.

$$RCHO + O \longrightarrow RCO + \dot{O}H$$

$$\dot{O}H + CO \longrightarrow CO_2 + H^{\cdot}$$

$$H^{\cdot} + O_2 + M \longrightarrow HO_2^{\cdot} + M$$

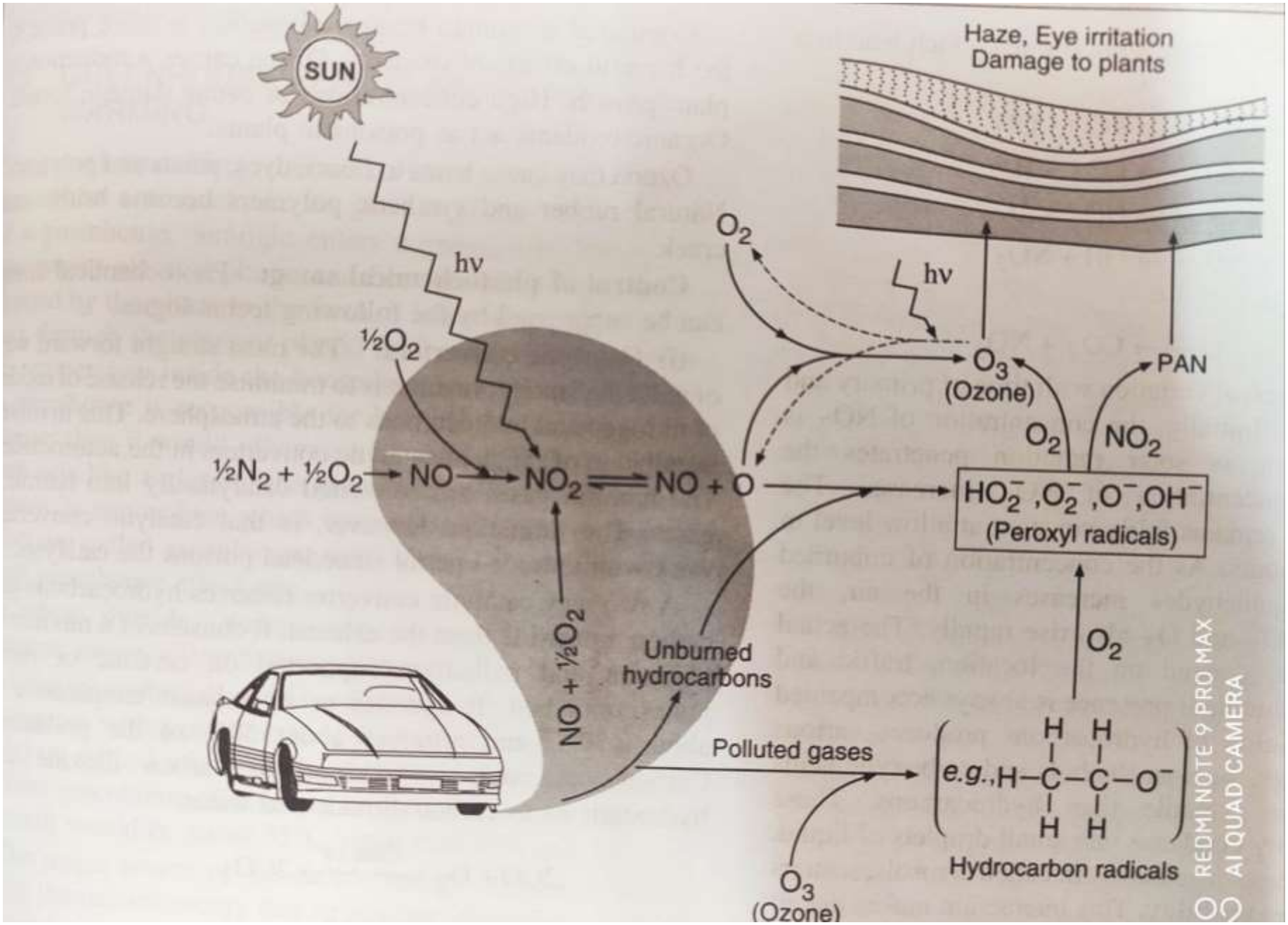
$$HO_2^{\cdot} + NO \longrightarrow OH^{\cdot} + NO_2$$

The overall m. is,

$$CO + O_2 + NO \longrightarrow CO_2 + NO_2$$

- **Peroxyacyl nitrates** (also known as **Acyl peroxy nitrates**, **APN** or **PAN**s. It is formed by following equation:

Hydrocarbons + O_2 + NO_2 + light → $CH_3COOONO_2$


SUN
hν
½O2
½N2 + ½O2
NO
NO2
NO + O
NO + ½O2
Unburned hydrocarbons
O2
hν
O3 (Ozone)
Haze, Eye irritation
Damage to plants
PAN
O2
NO2
HO2−, O2−, O−, OH−
(Peroxyl radicals)
O2
Polluted gases
e.g., H–C(H)(H)–C(H)(H)–O−
Hydrocarbon radicals
O3 (Ozone)

Harmful effects of photochemical smog

- Smog consists of ground level ozone, sulfur oxide, nitrogen dioxide and carbon monoxide which are all harmful pollutants and can cause damage to human health and property.
- It can cause problems such as emphysema, bronchitis, asthma etc.
- It is more harmful for children and senior citizens.
- It can cause damage to the respiratory system by inflaming breathing passage, decreasing the working capacity of lungs, causing pain while inhaling, and cough and sneezing issues etc.

- It can cause irritation to the eyes, nose and skin. It can cause premature death due to cancer and respiratory diseases.
- Magnetic particles are also detected in smog which can cause Alzheimer's disease. It can also cause birth defects in children if a pregnant woman is exposed to it which may include low birth weight, underdeveloped brain etc.
- Vegetation is also effected by harmful effects of oxidants.
- Ozone causes a reduction in plant growth.
- Hih conc. Of ozone damage forests.
- Organic oxidant acts as poisons to plant.
- Ozone may cause harm to fibres, dyes, paints and polymers. Natural rubber and synthetic polymers become brittle and crack.

Control of photochemical smog

It can be controlled by reducing the release of oxides of nitrogen and hydrocarbons to the atomosphere. It is done by following methods:

1) **Catalytic converters:** Installation of efficient catalytic converters in the automobiles. The harmful gases are converted catalytically into harmless gases. Catalytic converters consists mainly mixture of either Pt and Pd supported on ceramic or metal honeycomb or, mixture of Pt, Pd and Rh deposited on a high surface area ceramic and metal honeycomb.

2) **Chemical method**:

- PCS can be supressed by certain compounds which acts as free radical traps. When theses compounds are sprayed to the atomosphere they generate free radicals which readily combine with free radical precursors of PCS (such as O, R, RO, H radicals etc.).
- The compound diethylhydroxylamine has been found to posses smog inhibiting chacterstics. However it produces unpleasant odour.

Coal combustion

- Coal combustion is a dirty process, releasing a range of pollutants including sulphur dioxide, nitrogen oxides, carbon dioxide, volatile organic compounds, ash and a range of heavy metals.
- Many of the heavy metals released in the mining and burning of coal are environmentally and biologically toxic elements, such as **lead, mercury, nickel, tin, cadmium, antimony, and arsenic**, as well as radio isotopes of thorium and strontium.
- If these are not controlled they can enter the atmosphere, causing damage to the environment and to human health.
- Air quality standards limit the amount of each of these that can be released into the atmosphere.
- Some pollutants can be removed by cleaning coal before combustion. Most are removed after combustion.
- The production of nitrogen oxides is controlled during combustion using special burners and they can be removed from flue gases using reduction reactions involving ammonia or urea.
- Sulphur dioxide is most commonly removed using a wet flue gas scrubber although dry techniques are also possible.
- Dust particles can be captured with an electrostatic precipitator or by using a baghouse filter.
- Heavy metals may be captured during these processes too, but new methods may be required to remove mercury when legislation controlling its emission comes into force.

Volatile organic compounds (VOCs)

- VOCs are substances that evaporates at room temp.
- Volatile organic compounds (VOCs) are harmful gases emitted by certain household products or processes.
- VOCs include a variety of chemicals that cause adverse health effects and negatively impact the environment.
- Common examples of VOCs that may be present in our daily lives are: **benzene, ethylene glycol, formaldehyde, methylene chloride, tetrachloroethylene, toluene, xylene, and 1,3-butadiene** etc.
- Concentrations of VOCs are significantly higher indoors than outdoors. In fact, according to the Environmental Protection Agency, the level of organic pollutants is two to five times higher inside homes than outside regardless of whether the home is located in an urban or rural area.

- VOCs are organic chemical compounds whose composition makes it possible for them to evaporate under normal indoor atmospheric conditions of temperature and pressure.
- the volatility of organic compounds are sometimes defined and classified by their boiling points.
- The higher the volatility (lower the boiling point), the more likely the compound will be emitted from a product or surface into the air.
- VOCs are sometimes categorized by the ease they will be emitted. For example, the World Health Organization (WHO) categorizes indoor organic pollutants as:

1. Very volatile organic compounds (VVOCs)
2. Volatile organic compounds (VOCs)
3. Semi-volatile organic compounds (SVOCs)

description	Abbreviation	Boiling Point Range (°C)	Example Compounds
Very volatile (gaseous) organic compounds	VVOC	<0 to 50-100	Propane, butane, methyl chloride
Volatile organic compounds	VOC	50-100 to 240-260	Formaldehyde, d-Limonene, toluene, acetone, ethanol (ethyl alcohol) 2-propanol (isopropyl alcohol), hexanal
Semi volatile organic compounds	SVOC	240-260 to 380-400	Pesticides (DDT, chlordane, plasticizers (phthalates), fire retardants (PCBs, PBB))

Sources Of VOCs: Some of the most common sources of VOCs include:

- Aerosol sprays;
- Pesticides;
- Wood preservatives;
- Paint and paint strippers;
- Disinfectants and cleansers;
- Air fresheners;
- Stored fuels and automotive products;
- Dry-cleaned clothing;
- Office equipment such as copiers and printers;
- Gasoline;
- Wood burning;
- Diesel emissions
- graphics and craft materials including glues and adhesives, permanent markers and photographic solutions.
- building materials and furnishings
- Other common emissions sources of VOCs include auto body shops, trucks and buses, lawnmowers, and industrial painting and coating operations.

Impact of VOCs on Health:

- When VOCs are released, they react with nitrogen oxides in the air and form ground-level ozone. Ground-level ozone can irritate the eyes, nose, and throat. It can also aggravate asthma and other types of lung diseases.
- Exposure to VOCs themselves can also cause both short-term and long-term health effects.

- **Health effects may include:**

- Eye, nose and throat irritation
- Headaches, loss of coordination and nausea
- Damage to liver, kidney and central nervous system
- Some organics can cause cancer in animals, some are suspected or known to cause cancer in humans such as benzene and formaldehyde are proven carcinogens.
- VOCs can also potentially cause visual impairment and memory loss.

Key signs or symptoms associated with exposure to VOCs include:

- conjunctival irritation
- nose and throat discomfort
- headache
- allergic skin reaction
- dyspnea
- declines in serum cholinesterase levels
- nausea
- emesis
- epistaxis
- fatigue
- dizziness

VOCs impact on the environment:

- When VOCs react with nitrogen oxides and create ozone molecules, they also create fine particulates. Ground-level ozone and fine particulates are both key pollutants in the creation of smog. Ground-level ozone can also harm plants by reducing their growth and leaving them vulnerable to pests and disease.
- VOCs are also a contributor to acid rain. Acid rain can kill aquatic wildlife and wash away important nutrients from the soil. Acid rain also releases aluminum, which can harm animals and trees.

Steps to Reduce Exposure

- Increase ventilation when using products that emit VOCs.
- Meet or exceed any label precautions.
- Do not store opened containers of unused paints and similar materials within the school.
- Formaldehyde, one of the best known VOCs, is one of the few indoor air pollutants that can be readily measured.
  - Identify, and if possible, remove the source.
  - If not possible to remove, reduce exposure by using a sealant on all exposed surfaces of paneling and other furnishings.
- Use integrated pest management techniques to reduce the need for pesticides.
- Use household products according to manufacturer's directions.
- Make sure you provide plenty of fresh air when using these products.
- Throw away unused or little-used containers safely; buy in quantities that you will use soon.
- Keep out of reach of children and pets.
- Never mix household care products unless directed on the label.