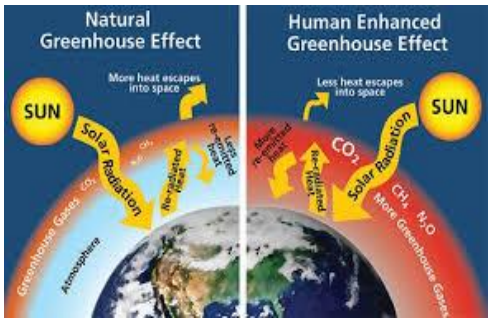
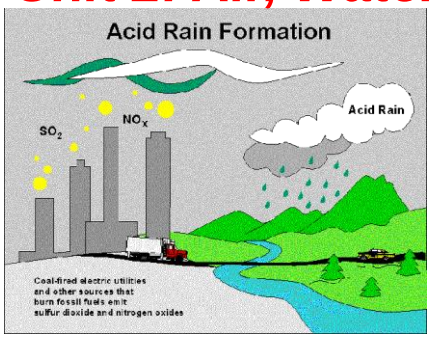


Unit 2: Air, Water and Soil Pollution



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Air Pollution

- **Air pollution may be described as contamination of the atmosphere by gaseous, liquid, or solid wastes or by-products that can endanger human health and welfare of plants and animals, attack materials, reduce visibility or produce undesirable odors.**

- **Air pollution is the introduction of chemical, particulates, biological materials, or other harmful materials into the earth's atmosphere possibly causing disease, death to humans, damage to other living organisms such as food crops, or the natural or built environment .**

- **The atmosphere is a complex natural gaseous system that is essential to support life on planet earth. Stratospheric ozone depletion due to air pollution has long been recognized as a threat to human health as well as to the Earth's ecosystems.**

- **Primary air pollutants are emitted directly into the air from sources. They can have effects both directly and as precursors of secondary air pollutants (chemicals formed through reactions in the atmosphere), which are discussed in the following section.**

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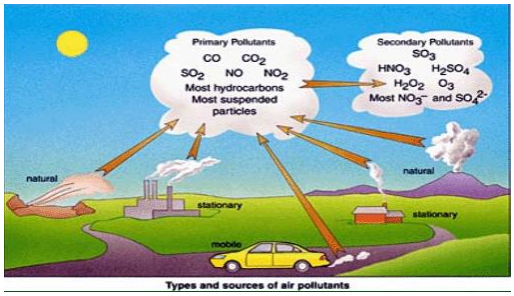

Types and sources of air pollutants

➢Air pollution occurs in many forms but can generally be thought of as gaseous and particulate contaminants that are present in the earth's atmosphere.

➢Gaseous pollutants include sulfur dioxide (SO_2), nitrogen oxides (NO_x), ozone (O_3), carbon monoxide (CO), volatile organic compounds (VOC), hydrogen sulfide (H_2S), hydrogen fluoride (HF), and various gaseous forms of metals.

➢These pollutants are emitted from large stationary sources such as fossil fuel fired power plants, smelters, industrial boilers, petroleum refineries, and manufacturing facilities as well as from area and mobile sources.

➢They are corrosive to various materials which causes damage to cultural resources, can cause injury to ecosystems and organisms, aggravate respiratory diseases, and reduce visibility.

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Sources of Air Pollution

Stationary and Area Sources

➢Stationary sources include factories, power plants, dry cleaners and degreasing operations.

➢The term area source is used to describe many small sources of air pollution located together whose individual emissions may be below thresholds of concern, but whose collective emissions can be significant. Residential wood burners are a good example of a small source, but when combined with many other small sources, they can contribute to local and regional air pollution levels.

➢Area sources can also be thought of as non-point sources, such as construction of housing developments, dry lake beds, and landfills.

Mobile Sources

A mobile source of air pollution refers to a source that is capable of moving under its own power. In general, mobile sources imply "on-road" transportation, which includes vehicles such as cars, sport utility vehicles, and buses. In addition, there is also a "non-road" or "off-road" category that includes gas-powered lawn tools and mowers, farm and construction equipment, recreational vehicles, boats, planes, and trains.

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Agricultural Sources

Agricultural operations, those that raise animals and grow crops, can generate emissions of gases and particulate matter. For example, animals confined to a barn or restricted area (rather than field grazing), produce large amounts of manure. Manure emits various gases, particularly ammonia into the air. This ammonia can be emitted from the animal houses, manure storage areas, or from the land after the manure is applied. In crop production, the misapplication of fertilizers, herbicides, and pesticides can potentially result in aerial drift of these materials and harm may be caused.

Natural Sources

Although industrialization and the use of motor vehicles are overwhelmingly the most significant contributors to air pollution, there are important natural sources of "pollution" as well. Wild land fires, dust storms, and volcanic activity also contribute gases and particulates to our atmosphere.

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Pollution due to following gases….

Sulfur dioxide (SO_2) is a gas formed when sulfur is exposed to oxygen at high temperatures during fossil fuel combustion, oil refining, or metal smelting. SO_2 is toxic at high concentrations, but its principal air pollution effects are associated with the formation of acid rain and aerosols. SO_2 dissolves in cloud droplets and oxidizes to form sulfuric acid (H_2SO_4).

Some major sources of SO_2

- **Thermal power plants**
- **Fertilizer plants**
- **Textile industry**
- **Steel Plants**
- **Sulfuric acid plants**
- **Petroleum industry**
- **Oil refining**
- **Smelting of Sulphide ores**

Effects of SO_2

- **High solubility is water allows it to get absorbed in the moist passages of upper respiratory tract, causing increased breathing rate and feeling starvation.**
- **Suffocation**
- **Respiratory irritation**
- **Asthma and chronic bronchitis**
- **Irritation of throat and eye.**

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Nitrogen oxides (NO and NO_2, referred together as NO_x) are highly reactive gases formed when oxygen and nitrogen react at high temperatures during combustion or lightning strikes. Nitrogen present in fuel can also be emitted as NO_x during combustion. Emissions are dominated by fossil fuel combustion at northern mid-latitudes and by biomass burning in the tropics.

In the atmosphere NO_x reacts with volatile organic compounds (VOCs) and carbon monoxide to produce ground-level ozone through a complicated chain reaction mechanism. It is eventually oxidized to nitric acid (HNO_3). Like sulfuric acid, nitric acid contributes to acid deposition and to aerosol formation.

Effects of NO_x

Respiratory irritation
Impairment of lung defense
Headache
Bronchitis
Loss of appetite
Corrosion of teeth
Leaf damage to sensitive plants

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Carbon monoxide (CO) is an odorless, colorless gas formed by incomplete combustion of carbon in fuel. The main source is motor vehicle exhaust, along with industrial processes and biomass burning. Carbon monoxide binds to hemoglobin in red blood cells, reducing their ability to transport and release oxygen throughout the body. Low exposures can aggravate cardiac ailments, while high exposures cause central nervous system impairment or death.

Effects of CO

- **Carbon monoxide interferes with the blood's ability to carry to oxygen to the cell of the body.**
- **During inhaled it readily binds to haemoglobin in the blood stream to form carboxy haemoglobin (COHb).**
- **Carbon monoxide infact has a much great affinity for haemoglobin than oxygen, so that even small amounts of CO can seriously reduce the amount of oxygen conveyed through out the body.**

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Smog

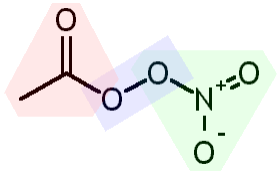
Smog is the combination of smoke and fog.

Photochemical Smog

When oxides of nitrogen, various hydrocarbons and sunlight come together, they can initiate a complex set of reactions that produce a number of secondary pollutants known as photochemical oxidants. Ozone is the most abundant of the photochemical oxidants, but it is responsible for many of the undesirable properties of photochemical smog. It causes eye irritation.

Eye irritation is caused by other components of photochemical smog, principally formaldehyde, peroxy benzoyl nitrare, peroxy acyl nitrate (PAN) and acrolenic.

Hydrocarbons NOx + Sunlight ⟶ Photochemical Smog



peroxy acyl nitrate (PAN)

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- **The probable mechanism of smog forming reactions are**
- **Reactive hydro carbons those with C═C groups) from auto exhaust with O_3 to form hydrocarbon free radical $RCH_2^{\cdot}$.**
- **$RCH_2^{\cdot}$ rapidly reacts with O_2 to form another free radical $RCH_2O_2^{\cdot}$.**
- **$RCH_2O_2^{\cdot}$ reacts with NO to form NO_2 and free radical $RCH_2O^{\cdot}$.**
- **This new free radical next interacts with O2 to yield a stable aldehyde, RCHO and hydroperoxyl radical.**
- **$HO_2^{\cdot}$ then reacts with another molecule of NO to give NO_2 and $^{\cdot}OH$.**
- **$^{\cdot}OH$ is extremely reactive and rapidly reacts with a stable hydrocarbon RCH_3 to yield H_2O and regenerate hydrocarbon free radical $RCH_2^{\cdot}$, thereby completing cycle.**

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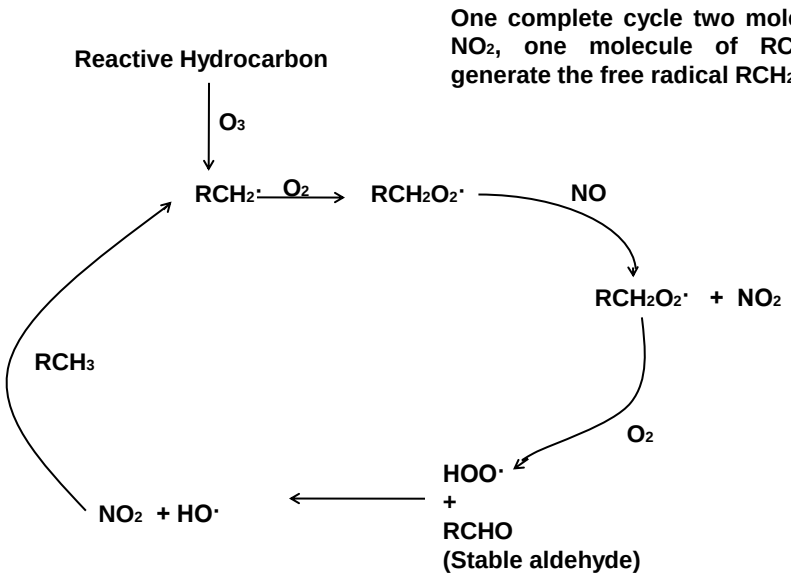

PAN is one of the most potent eye irritants found in smog.

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London Smog

✓The smog formed form oxides of sulphur (SOx), particulate matter coming from smoke and humidity or water is known as London Smog or 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, SOx and fog is chemically a reducing mixture and is also known as reducing smog.

✓SO_2 in the atmosphere gets converted into SO_3 by 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 the smog which is formed known as sulphurous smog.

$$2SO_2 + O_2 \longrightarrow 2SO_3 \qquad SO_2 + H_2O \longrightarrow H_2SO_3$$

or

$$SO_3 + H_2O \longrightarrow H_2SO_4 \qquad H_2SO_3 + O_2 \longrightarrow H_2SO_4$$

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Ozone-depleting substances (ODS)

➢**The ozone layer prevents most harmful UV wavelengths (280–315 nm) of ultraviolet light (UV light) from passing through the Earth's atmosphere.**

➢**The chemicals such as carbon tetrachloride and trichloroethane cause deplation in ozone layer.**

➢**It is suspected that a variety of biological consequences such as increases in skin cancer, cataracts, damage to plants, and reduction of plankton populations in the ocean's photic zone may result from the increased UV exposure due to ozone depletion.**

$CFCl_3$ + electromagnetic radiation $\longrightarrow$ $CFCl_2 + Cl$

$Cl + O_3 \longrightarrow ClO + O_2$

$ClO + O_3 \longrightarrow Cl + 2\,O_2$

The chlorine atom changes an ozone molecule to ordinary oxygen. The ClO from the previous reaction destroys a second ozone molecule and recreates the original chlorine atom, which can repeat the first reaction and continue to destroy ozone.

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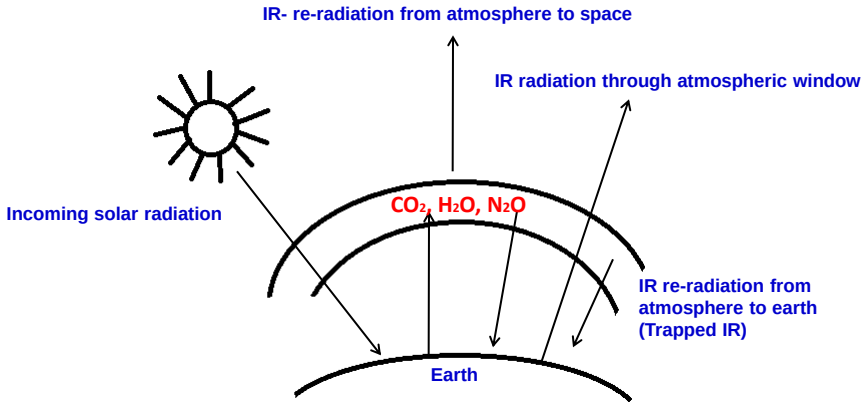
Greenhouse effect

➢**CO_2 (present level 356 ppm), is a significant non-pollutant species, however it has a major role in greenhouse effect. Among the constituents of the atmosphere only CO_2 and water vapour strongly absorb infrared radiation (1400-2500 nm) and effectively large fraction of earth's emitted radiation.**

➢**The radiation thus absorbed by CO_2 and water vapour is party re-emitted to earth's surface. The net result is that the earth's surface gets heated up by a phenomenon called the greenhouse effect.**



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Other Greenhouse Gases

CO_2 is not only culprit contributing greenhouse effect and global warming. It is the major greenhouse gas but there are other greenhouse gases such as metane (19%), chlorofluoro carbon (17%), nitrous oxide (4%), ozone (8%) and water vapour (2%)

Greenhouse gas	Concentration (ppm)	Increase % per year
CO_2	356	0.4
CH_4	1.7	1.0
N_2O	0.3	0.3
CFC	0.0005	5

It is the carbon dioxide concentration that is increasing, due to the burning of fossil fuels (as well as from some rainforest burning). Compared to a pre-industrial atmospheric concentration of around 270 parts per million (ppm), the average concentration has increased to close to 400 ppm in 2012. This causes the man-made portion of the greenhouse effect, and it is believed by many scientists to be responsible for the global warming of the last 50 years or more.

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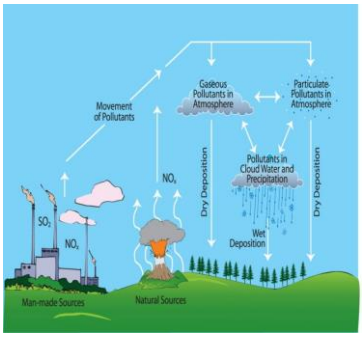
Acid Rain



- **Acid rain means the presence of excessive acids in rain water. The pH of acid rain generally varies from 3 to 6.**
- **Acid rain mainly contains H_2SO_4 and HNO_3 with weak H_2CO_3.**
- **The oxides of sulphur, nitrogen and carbon (NOx, SOx and COx) interact with other components of the atmosphere, and form corresponding acids.**
- **Acid rain is a rain or any other form of precipitation that is unusually acidic, meaning that it possesses elevated levels of hydrogen ions (low pH). It can have harmful effects on plants, aquatic animals and infrastructure. Acid rain is caused by emissions of sulfur dioxide and nitrogen oxide, which react with the water molecules in the atmosphere to produce acids.**
- **Nitrogen oxides can also be produced naturally by lightening strikes and sulfur dioxide is produced by volcanic eruptions. The chemicals in acid rain can cause paint to peel, corrosion of steel structures such as bridges, and erosion of stone statues.**

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Sources of Oxides

- ✓Burning of fossil fuel.
- ✓Thermal power plants.
- ✓Textile industry.
- ✓Steel plants.
- ✓Oil refining
- ✓Automobile exhaust
- ✓Explosive industry
- ✓Coal and gas fired furnace
- ✓Fertilizer industry

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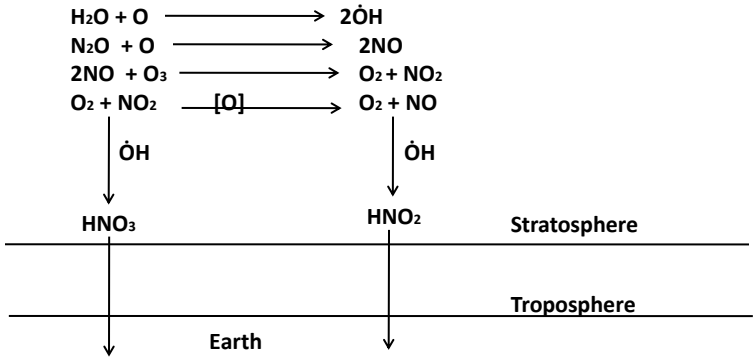
Source of NOx

The bulk of NOx on a global basis originates from microbial action in the earth's surface which yield N_2O.

This N_2O is inert in troposphere but it reacts with the oxygen atom in the stratosphere to form nitrogen oxide.

Then the NO enters into O_3 destruction cycle



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Formation Acid rain form SOx

In natural sunlight, at the 5-30 ppm level of SO_2 and relative humidity 32-90%, the overall reaction is

$SO_2 + ½ H_2O \longrightarrow H_2SO_4$

Which is promoted by the presence of hydrocarbons and nitrogen oxides, key component of photochemical smog.

In water droplets, ions such as Mn (II), Fe (II), Ni (II) and Cu (II) catalyze the oxidation reaction. These acids being soluble in water are quickly rained out.

Sulphur dioxide absorb solar radiation in region of 300-400 nm and produce electronically excited state of SO_2*.

$SO_2 + h\vartheta \longrightarrow SO_2$*

This undergoes oxidation to SO_3 and in the presence of H_2O, forms H_2SO_4.

Formation of acid rain from COx

Complete combustion of carbon containing materials forms CO_2 in atmosphere. CO2 in the atmosphere. CO_2 reacts with H_2O to form carbonic acid, which is another cause of acid.

$C + O \longrightarrow CO_2$

$CO_2 + H_2O \longrightarrow H_2CO_3$

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Adverse Effect of Acid Rain

Effects on aquatic biota

- **Many aquatic species disappear due to the acidification of lakes.**
- **Acid rain reduces the production of phytoplankton in the lake.**
- **Many bacteria and blue green algae are killed due to acidification.**
- **Activity of bacteria and many other microscopic animals are reduced in acidic condition. Thus the dead materials and many other accumulated materials lying at the bottom of the lakes are not decomposed rapidly. Therefore essential nutrients like nitrogen and phosphorus are locked up and less available for use.**

Effects on terrestrial eco-system

- **Leaves of the plants and trees are damaged and become yellow and brown, retarding photo synthesis.**
- **Acid rain weakens the structure of the trees, therefore making it vulnerable to pathogen.**
- **The reduction in photosynthesis results in reduced in agricultural productivity.**
- **Many essential nutrients like Fe, Ca, Mg, S, Mo, Co are leached out due to acid rain, hampering productivity.**

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Effects of Acid Rain on Building

➢**Acid rain causes extensive damage to build and sculpture materials of marbles, lime stone, slate, mortar etc. These materials become weakened mechanically as the soluble sulphates are leached out by rain water.**

$$CaCO_3 + H_2SO_4 \longrightarrow CaSO_4 + CO_2 + H_2O$$

➢**Acid rain attacks monuments, statues, bridges etc. this is one of the reasons why the Taj Mahal is in danger.**

Effects on human beings

➢**Solublilization of heavy metals like Cd, Hg and Cr due to acid water may reach human body via the plants and animals in food chain or through drinking water supplies.**

➢**Acid rain causes respiratory and skin disease and may attack nervous system in the extreme case.**

Control measures for acid Rain

➢**Short team control of acid deposition problem can be achieved by using lime (CaO).**

➢**The major step can be taken is to reduce acid forming gas like NOx and SO_2 and if possible, to stop.**

➢**General public awareness should be created regarding the ill effects of environmental pollution and consequences of acid rain.**

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Control of Air Pollution

There are different devices for removal of particulate matter from the air.

➢**Cyclone separator.**

➢**Baghouse**

➢**Scrubber.**

➢**Electrostatic precipitator.**

➢**Catalytic convertor.**

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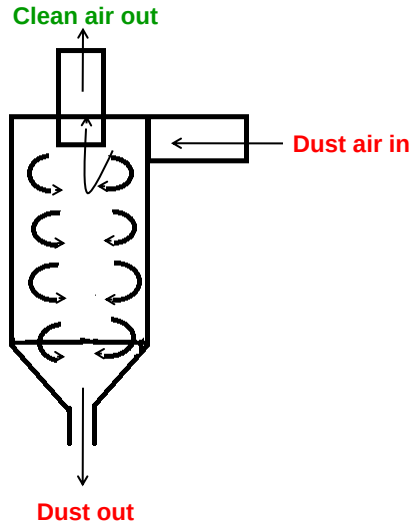
Cyclone separator

For particle diameter down to about 10 µm, the Collection device of choice is usually a cyclone. This is a simple economical unit with no moving parts, that relies on inertial effects for particulate removal. Particulate containing air is sent into a conical cylinder, where it is forced into a spiral flow path and accelerates. The centrifugal force imparted on the particulates forces them to move to the wall of the chamber, where they then slide down to the bottom of the cone and are removed. The clean air exists up through the centre of the cyclone.



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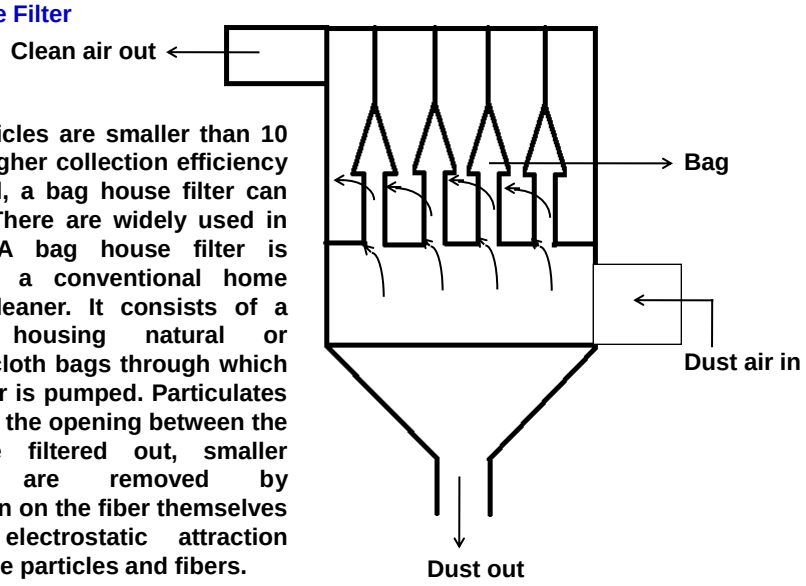
Baghouse Filter

When particles are smaller than 10 µm or a higher collection efficiency is required, a bag house filter can be used. There are widely used in industry. A bag house filter is similar to a conventional home vacuum cleaner. It consists of a chamber housing natural or synthetic cloth bags through which the dirty air is pumped. Particulates larger than the opening between the fibers are filtered out, smaller particles are removed by interception on the fiber themselves and by electrostatic attraction between the particles and fibers.



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Once particle begin to accumulate the openings become smaller and the importance of sieving increases. The cleaned air passes through the bag fabric and exists through an opening in the bag house chamber. Particulates collects on the inside surface of the bags. The bags are periodically shaken to remove the accumulated dust or the bag is isolated and air is blown into the bag from outside to dislodge particles. The released dust into a hoper below.

Baghouse filters are very efficient and can remove even sub micrometer size particles. However, they cannot be used for wet air stream, because the particulate may cake on the filter.

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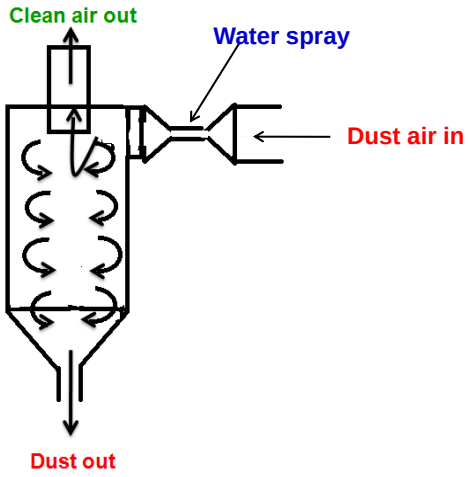
Scrubber

A scrubber is another device that can be used to remove particulates from air. Scrubber are of particular value where the contaminated air is wet, corrosive or hot applications where bag house can not be used. Simply spray chambers can be used for removal of large particle sizes. Dirty air flows through a chamber into which droplets are sprayed. The water droplets accumulate on the particulates in air, increase their size and weight and cause them to settle more rapidly and efficiently than in a settling chamber. The removed particulates in the collected spray water at the bottom of the spray chamber are drawn off to a setting basis, where the particulates are settled.



Particulate removal efficiency can be as high as 99% with a well designed scrubber system.

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Electrostatic Precipitator (ESP)

The ESP is a high efficiency dry collector of particulates from air. The particulate matter is removed by applying a high electrical direct current potential (30 – 75 kv) between alternating plates and wires.

A full scale ESP may have hundred of parallel plates, with very large surface areas.

As the particle gas stream passes through this ion-field, ions attached to the particulates, giving them a net negative charge.

The particulates then migrate to positively charged plates, where they are neutralized and stick.

They are periodically removed from the ESP plate surfaces by rapping the plates.

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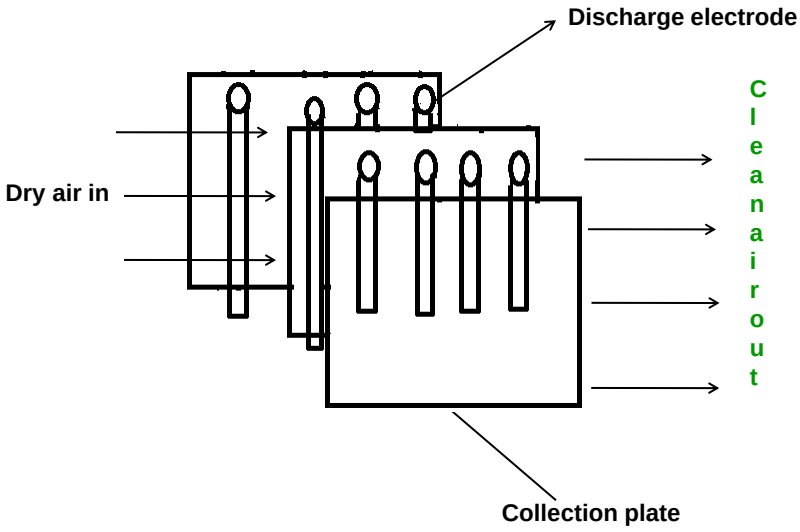
Electrostatic Precipitator



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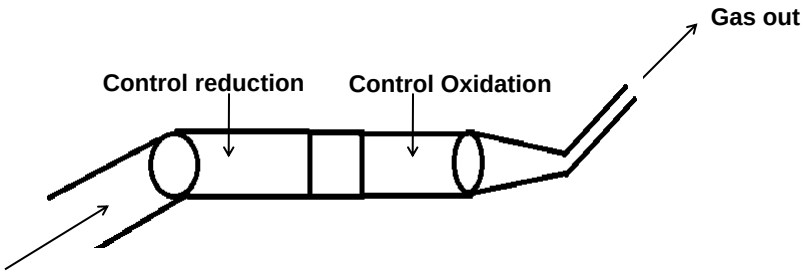
Catalytic Convertor

Catalytic convertor is used in the automobile engine for controlling emissions very effectively. Three way catalytic convertor is now available in the market. Three way means removal of three pollutants such as CO and NOx is reduced to N_2 in the same catalytic bed.

The catalytic convertors not only control emissions but also allow engines to operate at near stochiometric conditions. The efficiency of catalytic convertor however, gets reduced drastically when leaded petrol is used.



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