M.Sc 2nd Semester

ENV C25

Topic: Air Pollution

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CONTROL DEVICES OF AIR POLLUTION

Prevention is always better than cure. So we should try to prevent the air pollution by changing the raw material, the process conditions, procedure and by having the preventive maintenance one can prevent the air pollution.

In addition to the preventive measures we need to have control technologies to minimize pollution. Depending upon the situation different control technologies are adopted.

Control of pollutant from stationary sources

➢ Particulate matter

The control of particulate matter is an important aspect of industrial air pollution engineering. Particles are collected by a combination of several mechanisms. The six available mechanisms are gravitational settling, centrifugal impaction, inertial impaction, direct interception, diffusion and the electrostatic attraction.

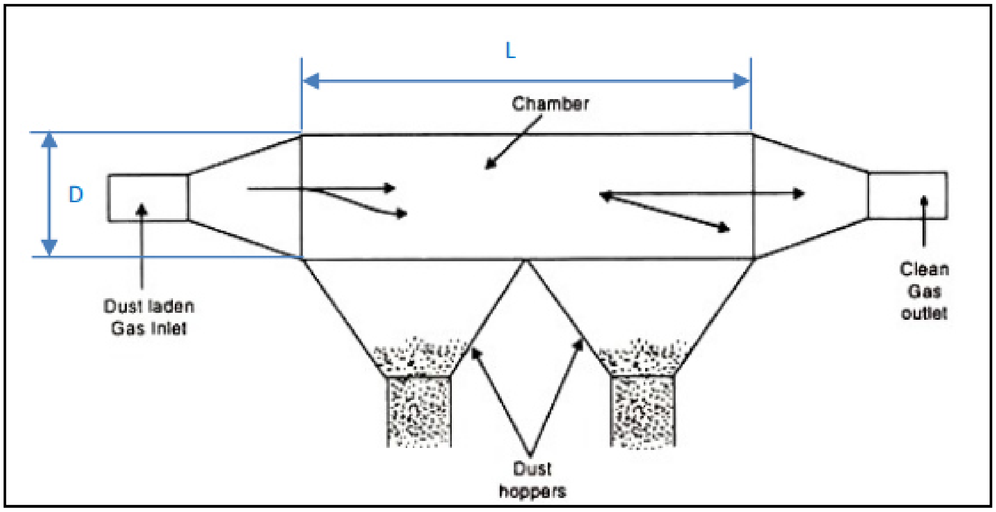
There are five basic types of dust collectors used for particulate pollutant control

- Gravitational Settling chambers
- Cyclone separators
- Fabric filters
- Electrostatic precipitators
- Wet collector (scrubbers)

The first two of the above are used for coarse particulates where as the other threeare used for fine particulates

Gravitational Settling Chambers

This is a simple particulate collection device using the principle of gravity to settle the particulate matter in a gas stream passing through its long chamber. The primary requirement of such a device would be a chamber in which the carrier gas velocity is reduced so as to allow the particulate matter to settle out of the moving gas stream under the action of gravity. This particulate matter is then collected at the bottom of the chamber. The chamber is cleaned manually to dispose the waste. The gas velocities in the settling chamber must be sufficiently low for the particles to settle due to gravitational force. Literature indicates that gas velocity less than about 3 m/s is needed to prevent re-entrainment of the settled particles. The gas velocity of less than 0.5 m/s will produce good results.



Gravitational settling chamber

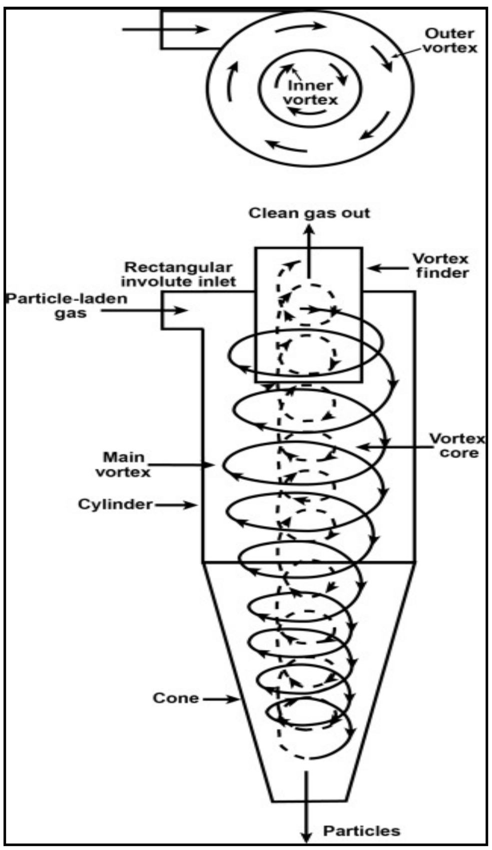
- **The advantages of settling chambers are:**
  - low initial cost,
  - simple construction,
  - low maintenance cost,
  - low pressure drop,
  - dry and continuous disposal of solid particles,
  - use of any material for construction, and
  - temperature and pressure limitations will only depend on the nature of the construction material.
- **The disadvantages of this device are**
  - large space requirements and
  - only comparatively large particles (greater than 10 micron) can be collected.
  -

Cyclone separators or Cyclone Collectors

Gravitational Settling chambers discussed above are not effective in removing small particles. Therefore, one needs a device that can exert more force than gravity force on the particles so that they can be removed from the gas stream. Cyclones use centrifugal forces for removing the fine particles. They are also known as centrifugal or inertial separators.

The cyclone consists of a vertically placed cylinder which has an inverted cone attached to its base. The particulate laden gas stream enters tangentially at the inlet point to the cylinder. The velocity of this inlet gas stream is then transformed into a confined vortex, from which centrifugal forces tend to drive the suspended particles to the walls of the cyclone. The vortex turns upward after reaching at the bottom of the cylinder in a narrower inner spiral. The clean gas is removed from a central cylindrical opening at the top, while the dust particles are collected at the bottom in a storage hopper by gravity.

The efficiency of a cyclone chiefly depends upon the cyclone diameter. For a given pressure drop, smaller the diameter, greater is the efficiency, because centrifugal action increases with decreasing radius of rotation. Centrifugal forces employed in modern designs vary from 5 to 2500 times gravity depending on the diameter of the cyclone. Cyclone efficiencies are greater than 90% for the particles with the diameter of the order of 10 μ. For particles with diameter higher than 20 μ, efficiency is about 95%.



- **The advantages of cyclones are:**
  - low initial cost,simple in construction and operation,
  - low pressure drop,
  - low maintenance requirements,
  - continuous disposal of solid particulate matter, and
    use of any material in their construction that can withstand the temperature and pressure requirements.
- The disadvantages of cyclones include:
  - low collection efficiency for particles below 5 - 10 μ in diameter,

- severe abrasion problems can occur during the striking of particles on the walls of the cyclone, and
- a decrease in efficiency at low particulate concentration.

Fabric filters

Fabric filtration is one of the most common techniques to collect particulate matter from industrial waste gases. The use of fabric filters is based on the principle of filtration, which is a reliable, efficient and economic method to remove particulate matter from the gases. The air pollution control equipment using fabric filters are known as **bag houses**.

➢ **Bag Houses**

A bag house or a bag filter consists of numerous vertically hanging, tubular bags, 4 to 18 inches in diameter and 10 to 40 feet long. They are suspended with their open ends attached to a manifold. The number of bags can vary from a few hundreds to a thousand or more depending upon the size of the bag house. Bag houses are constructed as single or compartmental units. In both cases, the bags are housed in a shell made of rigid metal material. Occasionally, it is necessary to include insulation with the shell when treating high temperature flue gas. This is done to prevent moisture or acid mist from condensing in the unit, causing corrosion and rapid deterioration of the bag house.

Hoppers are used to store the collected dust temporarily before it is disposed in a landfill or reused in the process. Dust should be removed as soon as possible to avoid packing which would make removal very difficult. They are usually designed with a 60 degrees slope to allow dust to flow freely from the top of the hopper to the bottom discharge opening. Sometimes devices such as strike plates, poke holes, vibrators and rappers are added to promote easy and quick discharge. Access doors or ports are also provided. Access ports provide for easier cleaning, inspection and maintenance of the hopper.

A discharge device is necessary for emptying the hopper. Discharge devices can be manual (slide gates, hinged doors and drawers) or automatic trickle valves, rotary airlock valves, screw conveyors or pneumatic conveyors)

➢ ***Filter Media***

Woven and felted materials are used to make bag filters. Woven filters are used with low energy cleaning methods such as shaking and reverse air. Felted fabrics are usually used with low energy cleaning systems such as pulse jet cleaning.
While selecting the filter medium for bag houses, the characteristics and properties of the carrier gas and dust particles should be considered. The properties to be noted include:

a) Carrier gas temperature
b) Carrier gas composition
c) Gas flow rate
d) Size and shape of dust particles and its concentration

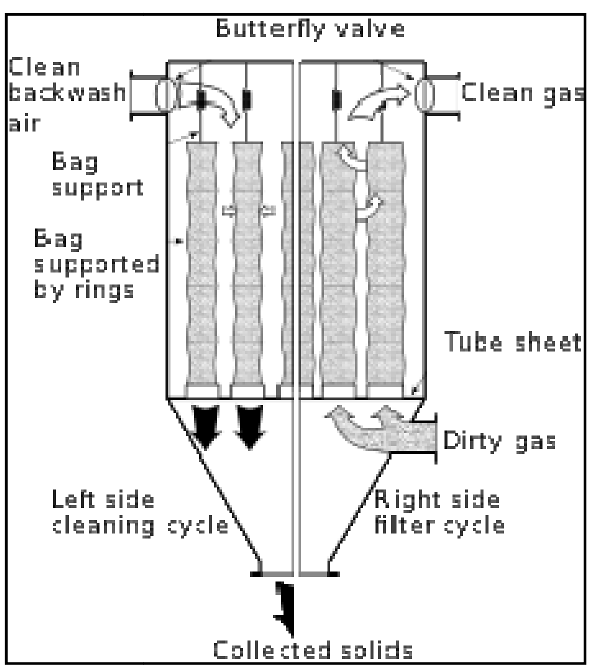
The abrasion resistance, chemical resistance, tensile strength and permeability and the cost of the fabric should be considered. The fibers used for fabric filters can vary depending on the industrial application. Some filters are made from natural fibers such as cotton or wool. These fibers are relatively inexpensive, but have temperature limitations (< 212 ^{0}F) and only average abrasion resistance. Synthetic fibers such as nylon, orlon and polyester have slightly higher temperature limitations and chemical resistance. Synthetic fibers are more expensive than natural fibers. Polypropylene is the most inexpensive synthetic fiber and is used in industrial applications such as foundries, coal crushers and food industries. Nylon is the most abrasive resistant synthetic fiber making it useful for applications filtering abrasive dusts. Different types of fibers with varying characteristics are available in the market.

Fabrics are usually pre-treated, to improve their mechanical and dimensional stability. They can be treated with silicone to give them better cake release properties. Natural fibers (wool and cotton) are usually preshrunk to eliminate bag shrinkage during operation. Both synthetic and natural fabrics usually undergo processes such as calendering, napping, singeing, glazing or coating. These processes increase the fabric life and improve dimensional stability and ease of bag cleaning.

Operation of a bag house:

The gas entering the inlet pipe strikes a baffle plate, which causes larger particles to fall into a hopper due to gravity. The carrier gas then flows upward into the tubes and outward through the fabric leaving the particulate matter as a "cake" on the insides of the bags.
Efficiency during the pre-coat formation is low, but increases as the pre-coat (cake) is formed, until a final efficiency of over 99% is obtained. Once formed, the pre-coat forms part of the filtering medium, which helps in further removal of the particulate. Thus the dust becomes the actual filtering medium. The bags in effect act primarily as a matrix to support the dust cake. The cake is usually formed within minutes or even seconds.

The accumulation of dust increases the air resistance of the filter and therefore filter bags have to be periodically cleaned. They can be cleaned by rapping, shaking or vibration, or by reverse air flow, causing the filter cake to be loosened and to fall into the hopper below



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The efficiency of bag filters may decrease on account of the following factors:

a) Excessive filter ratios - 'Filter ratio' is defined as the ratio of the carrier gas volume to gross filter area, per minute flow of the gas. Excessive filter ratios lower particulate removal efficiency and result in increased bag wear. Therefore, low filter ratios are recommended. Therefore, low filter ratios are recommended for high concentration of particulate.

b) Improper selection of filter media - While selecting filter media, properties such as temperature resistance, resistance to chemical attack and abrasion resistance should be taken into consideration.

Various problems during the operation of a bag house are:

a) **Cleaning** -
b) **Rupture of the cloth** -
c) **Temperature** - *Fabric filters will not perform properly if a gross temperature overload occurs. If the gas temperature is expected to fluctuate, a fiber material that will sustain the upper temperature fluctuation must be selected.*
d) **Bleeding** -*This is the penetration of the fabric by fine particles, which is common in fabric filtration. It can occur if the weave is too open or the filter ratio is very high. The solution is to use a double layer material or a thick woven fabric.*
e) **Humidity** -*This is a common and important problem, especially if the dust is hygroscopic. It would therefore be advisable to maintain moisture free conditions within the bag house, as a precautionary measure.*
f) **Chemical attack** -*This is another problem associated with fabric filters. The possibility of chemical attack due to corrosive chemicals present in the effluent. A proper choice of fabric filter will avoid this problem.*

- **The advantages of a fabric filter are:**
  - High collection efficiencies for all particle sizes, especially for particles smaller than 10 micron in diameter.
  - Simple construction and operation.
  - Nominal power consumption.
  - Dry disposal of collected material.

- **The disadvantages of a fabric filter are:**
  - Operating limits are imposed by high carrier gas temperatures, high humidity and other parameters.
  - High maintenance and fabric replacement costs. iii) Large size of equipment.
  - Problems in handling dusts which may abrade, corrode, or blind the cloth.

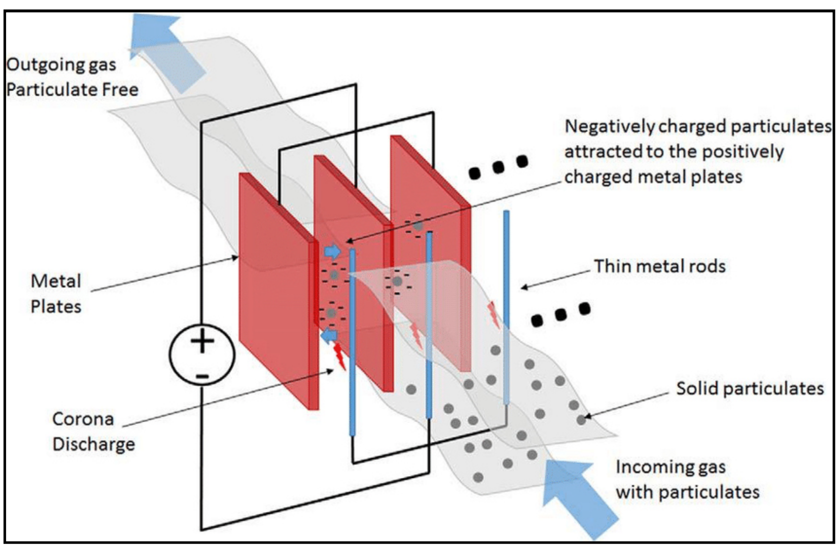
Electrostatic Precipitators

Electrostatic precipitators (ESP) are particulate collection devices that use electrostatic force to remove the particles less than 5 micron in diameter. It is difficult to use gravity settlers and cyclones effectively for the said range of particles. Particles as small as one-tenth of a micrometer can be removed with almost 100% efficiency using electrostatic precipitators.

The principle behind all electrostatic precipitators is to give electrostatic charge to particles in a given gas stream and then pass the particles through an electrostatic field that drives them to a collecting electrode.

The electrostatic precipitators require maintenance of a high potential difference between the two electrodes, one is a discharging electrode and the other is a collecting electrode. Because of the high potential difference between the two electrodes, a powerful ionizing field is formed. Very high potentials - as high as 100 kV are used. The usual range is 40- 60 kV. The ionization creates an active glow zone (blue electric discharge) called the **'corona' or 'corona glow'**. Gas ionization is the dissociation of gas molecules into free ions.

As the particulate in the gas pass through the field, they get charged and migrate to the oppositely charged collecting electrode, lose their charge and are removed mechanically by rapping, vibration, or washing to a hopper below.



In summary, the step by step process of removing particles using ESPs is:

1. Ionizing the gas.
2. Charging the gas particles.

3. Transporting the particles to the collecting surface.
4. Neutralizing, or removing the charge from the dust particles.
5. Removing the dust from the collecting surface.

The major components of electrostatic precipitators are:

- A source of high voltage
- Discharge and collecting electrodes.
- Inlet and outlet for the gas.
- A hopper for the disposal of the collected material.
- An outer casing to form an enclosure around the electrodes.

➢ **The advantages of using the ESP are:**

- High collection efficiency.
- Particles as small as 0.1 micron can be removed.
- Low maintenance and operating cost.
- Satisfactory handling of a large volume of high temperature gas.
- Treatment time is negligible (0.1-10s).
- Cleaning is easy by removing the units of precipitator from operation.
- There is no limit to solid, liquid or corrosive chemical usage.

➢ **The disadvantages of using the ESP are:**

- High initial cost.
- Space requirement is more because of the large size of the equipment.
- Possible explosion hazards during collection of combustible gases or particulate.
- Precautions are necessary to maintain safety during operation. Proper gas flow distribution, particulate conductivity and corona spark over rate must be carefully maintained.
- The negatively charged electrodes during gas ionization produce the ozone.

Scrubbers

Scrubbers are devices that remove particulate matter by contacting the dirty gas stream with liquid drops. Generally water is used as the scrubbing fluid. In a wet collector, the dust is agglomerated with water and then separated from the gas together with the water.

The mechanism of particulate collection and removal by a scrubber can be described as a four-step process.

i) **Transport:** The particle must be transported to the vicinity of the water droplets which are usually 10 to 1000 times larger.

ii) **Collision:** The particle must collide with the droplet.
iii) **Adhesion**: This is promoted by the surface tension property.

iv) **Precipitation**: This involves the removal of the droplets, containing the dust particles from the gas phase.

The physical principles involved in the operation of the scrubbers are: i) impingement, ii) interception, iii) diffusion and iv) condensation.

i) **Impingement** :
When gas containing dust is swept through an area containing liquid droplets, dust particles will impinge upon the droplets and if they adhere, they will be collected by them. If the liquid droplet is approximately 100 to 300 times bigger than the dust particle, the collection efficiency of the particles is more, because the numbers of elastic collisions increase.
ii) **Interception:**
Particles that move with the gas stream may not impinge on the droplets, but can be captured because they brush against the droplet and adhere there. This is known as interception.
iii) **Diffusion:**
Diffusion of the particulate matter on the liquid medium helps in the removal of the particulate matter.
iv) **Condensation:**
Condensation of the liquid medium on the particulate matter increases the size and weight of the particles. This helps in easy removal of the particles.

The various types of scrubbers are:
- Spray towers.
- Venturi scrubbers.
- Cyclone scrubbers.
- Packed scrubbers.

- Mechanical scrubbers.

The simpler types of scrubbers with low energy inputs are effective in collecting particles above 5 - 10 µ in diameter, while the more efficient, high energy input scrubbers will perform efficiently for collection of particles as small as 1 - 2 µ in diameter.

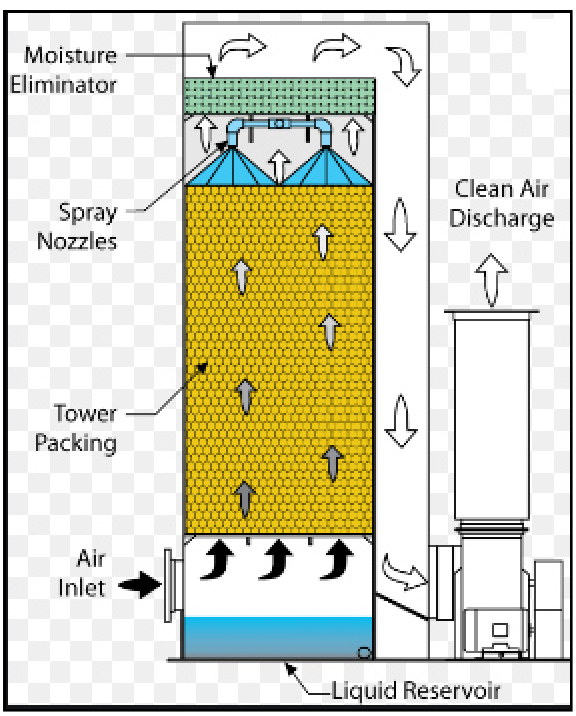
➢ **The advantages of scrubbers are:**

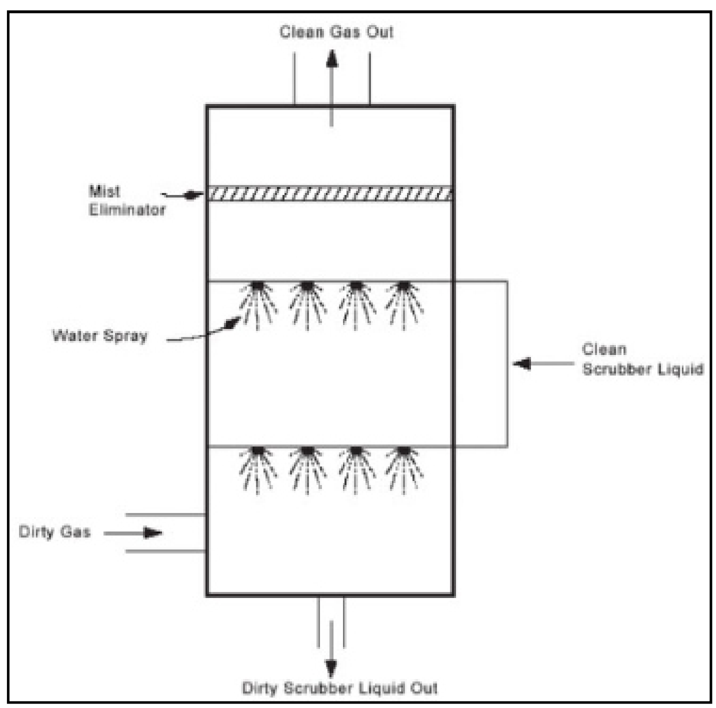
i) Low initial cost.
ii) Moderately high collection efficiency for small particles.
iii) Applicable for high temperature installations.
iv) They can simultaneously remove particles and gases.
v) There is no particle re- entrainment.

➢ **The disadvantages of scrubbers are:**

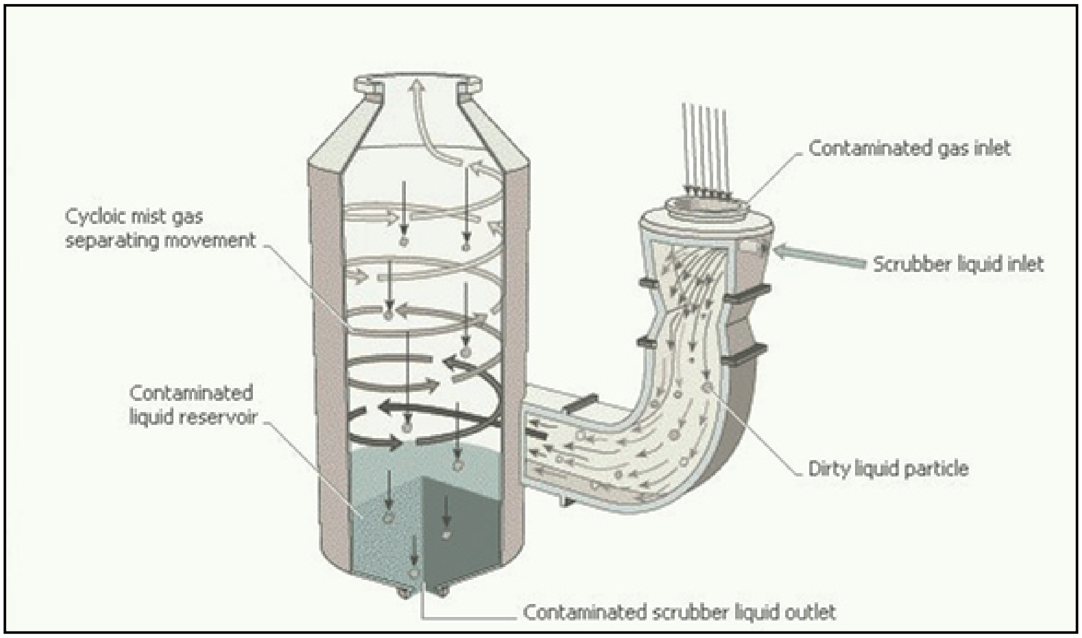
i) High power consumption for higher efficiency.
ii) Moderate to high maintenance costs owing to corrosion and abrasion.
iii) Wet disposal of the collected material.

The scrubbers are used in a variety of applications. Some of the situations are:
i) They're particularly useful in the case of a hot gas that must be cooled for some reason.
ii) If the particulate matter is combustible or if any flammable gas is present, even in trace amounts, in the bulk gas phase, a scrubber is preferred to an electrostatic precipitator.
iii) Scrubbers can be used when there are waste water treatment systems available on the site, with adequate reserve capacity to handle the liquid effluent.
iv) Scrubbers are also used when gas reaction and absorption are required simultaneously with particulate control.





Packed scrubbers Spray towers



Venturi scrubbers

- **For gaseous pollutants the following control technologies are used**
  - Condensation
  - Absorption
  - Adsorption
  - Combustion

For the control of gases such as NO_2 and SO_2 produced in combustion, wet and dry scrubbers are used.

Control of pollutant from mobile sources

CONTROL OF AUTOMOBILE POLLUTION

The major automobile pollutants are carbon monoxide, unburnt hydrocarbons and the oxides of nitrogen. These are generated by evaporation of fuel from carburetor, leakage between piston rings and cylinder wall and combustion of fuel (exhaust gases). To prevent the automobile pollution the law can be enforced at two levels. The industry can be compelled to manufacture the vehicles in such a way, i.e. enforcing the Euro standards, that they produce minimum pollutants. Secondly, the user has to maintain the vehicle by its proper servicing (tuning of engine) in such a way that the exhaust emissions are under control. Actually, at this level nobody bothers, as the checking systems and the provision of genuine penalty is very difficult. The general public is not aware of the bad effects of pollution particularly the air pollution that is many times more effective. The third control should be on the quality of fuel. If the fuel is having lead in it, neither the vehicle nor the owner can prevent its emission to the ambient air. That is why unleaded petrol is being supplied these days. Sometimes Kerosene is mixed with petrol or diesel (as it is cheaper) than the emissions are more pollutant and are of different nature. Even after exercising all such checks on quality of vehicles, maintenance and the adulteration some pollution is inevitable. This can be reduced by changing the fuel, such as by the use of CNG. The other most important way of reducing the air pollution is changing the life style of the urban population. Minimizing the use of vehicles by walking for small distances, pooling of the vehicles, switching off the vehicles on red lights, maintaining the vehicles in proper order, adopting efficient ways of driving, ban on overloading, better design and maintenance of roads, collectively can reduce automobile air pollution.

The vehicular pollution can also be controlled by using the catalytic converter. (*Details will be given later*).