(**Introduction to Environmental Studies**)

B. Tech 3rd semester

AIR POLLUTION

Unit 5
Environmental Pollution

Department: Chemistry
Subject: Environmental Studies (CHM2041)

Definition

Air pollution: Presence of *one or more contaminants* in air in excessive concentration which adversely affect wellbeing of the human beings, animals or causes damage to the property.

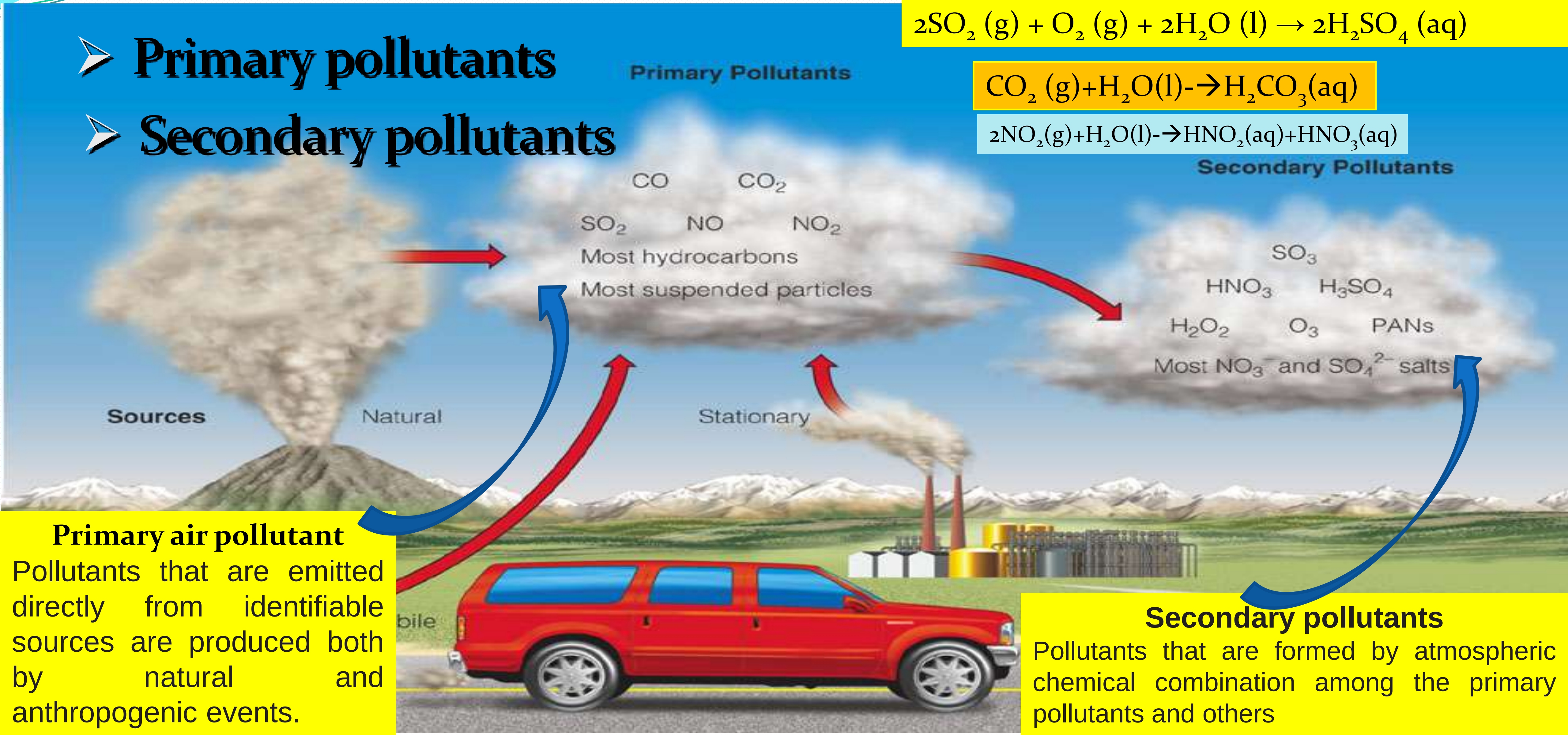
Major Classes of air pollutants

- **Primary pollutants**
- **Secondary pollutants**

$$2SO_2\ (g) + O_2\ (g) + 2H_2O\ (l) \rightarrow 2H_2SO_4\ (aq)$$

$$CO_2\ (g)+H_2O(l) \rightarrow H_2CO_3(aq)$$

$$2NO_2(g)+H_2O(l) \rightarrow HNO_2(aq)+HNO_3(aq)$$



Primary air pollutant
Pollutants that are emitted directly from identifiable sources are produced both by natural and anthropogenic events.

Secondary pollutants
Pollutants that are formed by atmospheric chemical combination among the primary pollutants and others

SO_2, NO_x , CO, CO_2 and other toxic pollutants

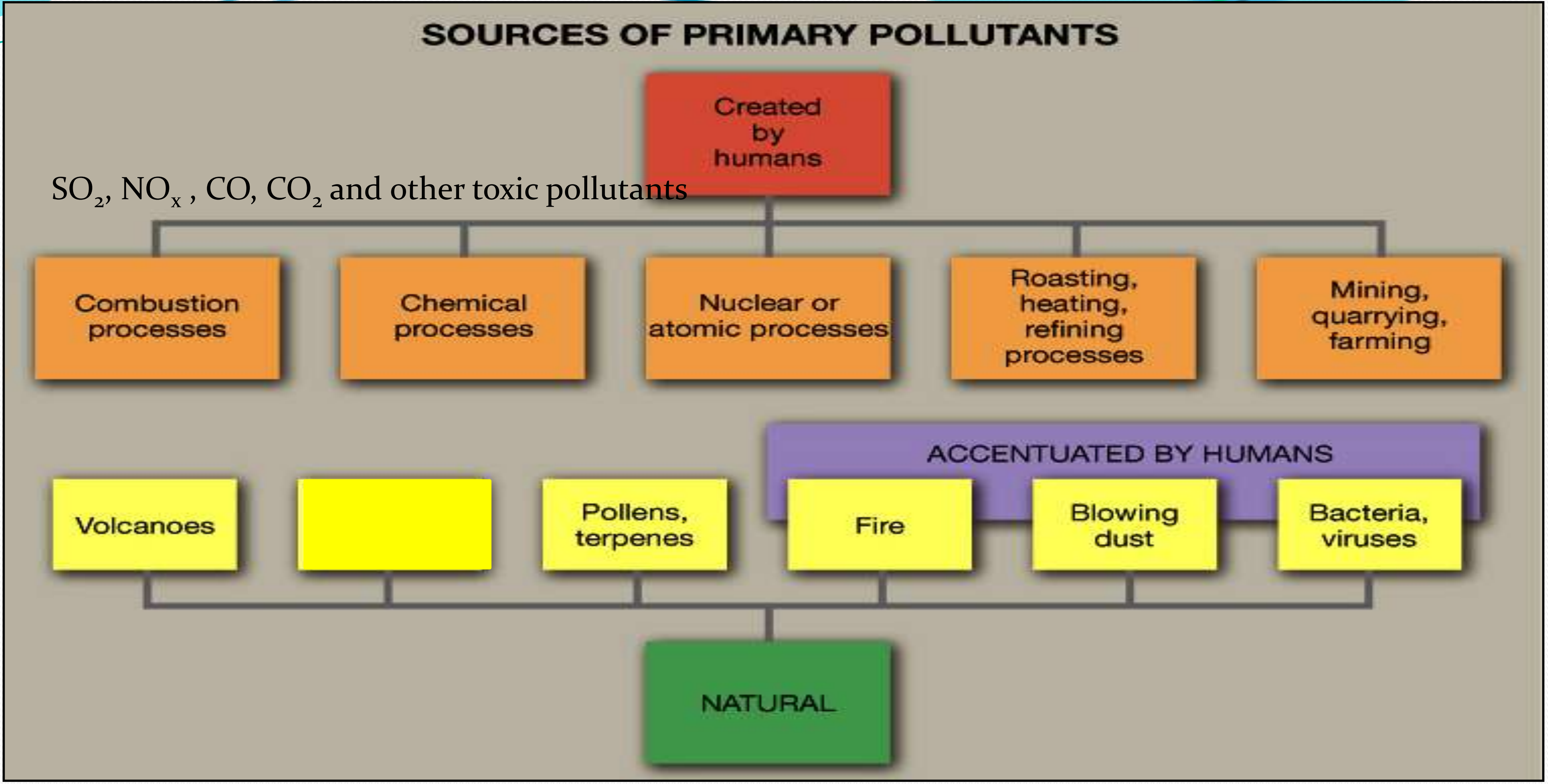
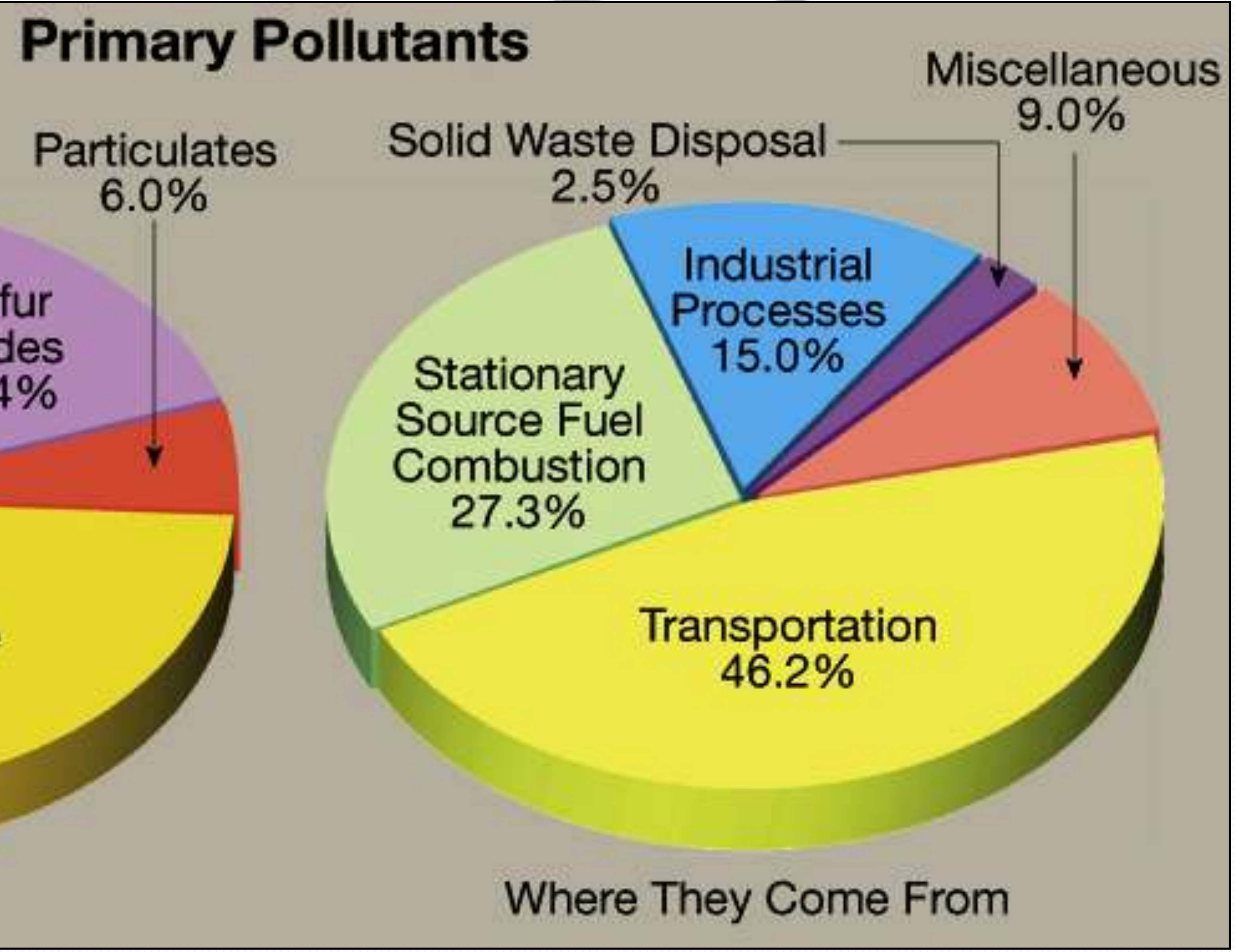


Table 1: Sources, Health and Welfare Effects for Criteria Pollutants

Pollutant	Description	Sources	Health Effects	Welfare Effects
Carbon Monoxide (CO)	Colorless, odorless gas	Motor vehicle exhaust, indoor sources include kerosene or wood burning stoves.	Headaches, reduced mental alertness, heart attack, cardiovascular diseases, impaired fetal development, death.	Contribute to the formation of smog.
Sulfur Dioxide (SO_2)	Colorless gas that dissolves in water vapor to form acid, and interact with other gases and particles in the air.	Coal-fired power plants, petroleum refineries, manufacture of sulfuric acid and smelting of ores containing sulfur.	Eye irritation, wheezing, chest tightness, shortness of breath, lung damage.	Contribute to the formation of acid rain, visibility impairment, plant and water damage, aesthetic damage.
Nitrogen Dioxide (NO_2)	Reddish brown, highly reactive gas.	Motor vehicles, electric utilities, and other industrial, commercial, and residential sources that burn fuels.	Susceptibility to respiratory infections, irritation of the lung and respiratory symptoms (e.g., cough, chest pain, difficulty breathing).	Contribute to the formation of smog, acid rain, water quality deterioration, global warming, and visibility impairment.
Ozone (O_3)	Gaseous pollutant when it is formed in the troposphere.	Vehicle exhaust and certain other fumes. Formed from other air pollutants in the presence of sunlight.	Eye and throat irritation, coughing, respiratory tract problems, asthma, lung damage.	Plant and ecosystem damage.
Lead (Pb)	Metallic element	Metal refineries, lead smelters, battery manufacturers, iron and steel producers.	Anemia, high blood pressure, brain and kidney damage, neurological disorders, cancer, lowered IQ.	Affects animals and plants, affects aquatic ecosystems.
Particulate Matter (PM)	Very small particles of soot, dust, or other matter, including tiny droplets of liquids.	Diesel engines, power plants, industries, windblown dust, wood stoves.	Eye irritation, asthma, bronchitis, lung damage, cancer, heavy metal poisoning, cardiovascular effects.	Visibility impairment, atmospheric deposition, aesthetic damage.

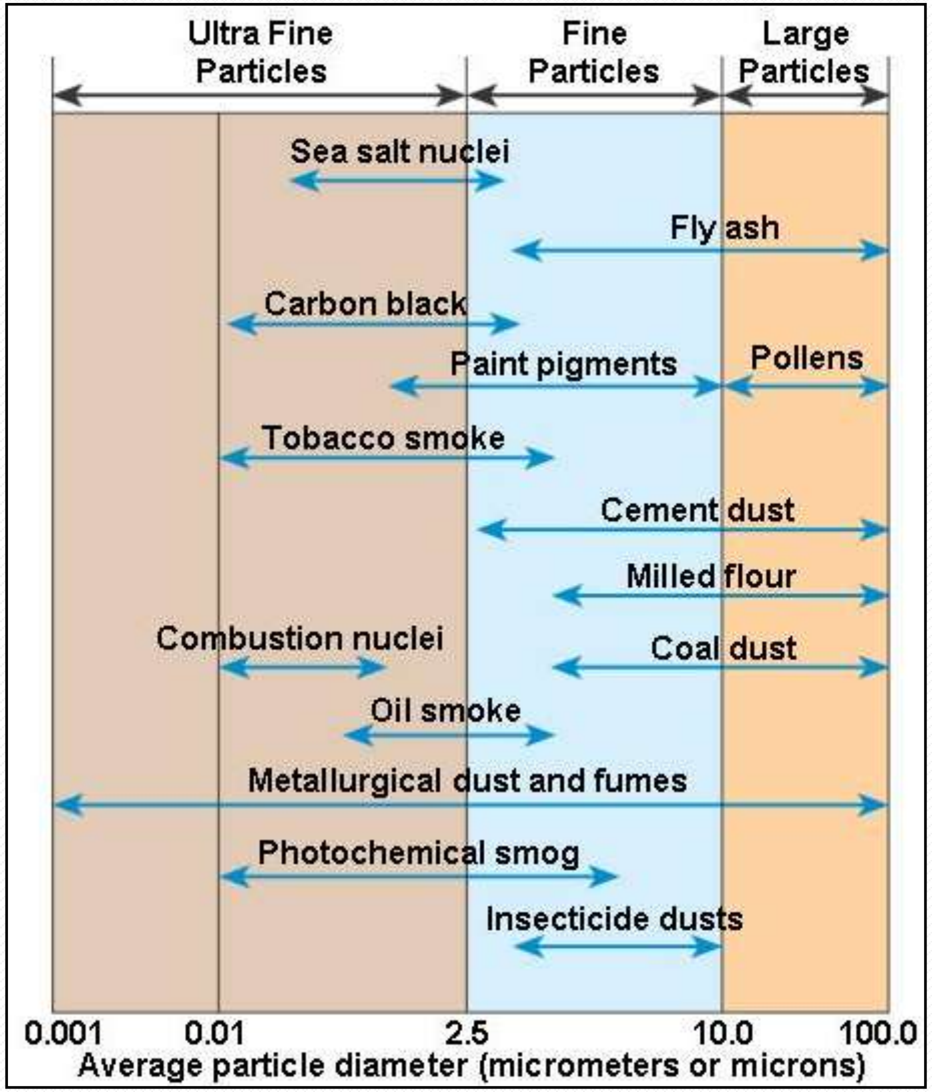
i) Gaseous air pollutant
ii) Particulate mater (Dust)



Particulate mater

Besides technical names PM10 and PM2.5, the popular names of particulate

- Mist: Aerosol consisting of liquid droplets Sulfuric acid mist
- Dust: solid particles produced from larger particles by grinding them down
- Smoke: solid particles or a mixture of solid, Cigarette smoke
- Fume: Generally means the same as smoke but often applies Zinc/lead fumes specifically to aerosols produced by condensation of hot vapors of metals.
- Fog: Aerosol consisting of water droplets



Air Quality Index (AQI) Values

TABLE 7.2 PSI VALUES AND AIR QUALITY DESCRIPTORS

PSI value	Descriptor
0–50	Good
51–100	Moderate
101–199	Unhealthful
200–299	Very unhealthful
≥300	Hazardous

TABLE 7.3 POLLUTANT STANDARDS INDEX (PSI) BREAKPOINTS

Index	1-hr O_3 $\mu g/m^3$	8-hr CO mg/m^3	24-h TSP $\mu g/m^3$	24-hr SO_2 $\mu g/m^3$	TSP × SO_2 $10^3\ (\mu g/m^3)^2$
0	0	0	0	0	—
50	118	5	75	80	—
100	235	10	260	365	—
200	400	17	375	800	65
300	800	34	625	1600	261

Source: 40 CFR (Code of Federal Regulations) 58, 1982.

National Ambient Air Quality Standard (NAAQS)-2009

It was notified on 16-11-2009 by government of India. Some of the important air quality parameters are mentioned in the table

Pollutant parameter	unit	Averaging	Concentration in ambient air
			Industrial/residential area
Sulfur dioxide	$\mu g/m^3$	24 hourly	80
Nitrogen dioxide	$\mu g/m^3$	24 hourly	80
Particulate PM10	$\mu g/m^3$	24 hourly	100
Particulate PM2.5	$\mu g/m^3$	24 hourly	60
Carbon monoxide	$\mu g/m^3$	8 hourly	2000
ozone	$\mu g/m^3$	8 hourly	100

Air pollution control:

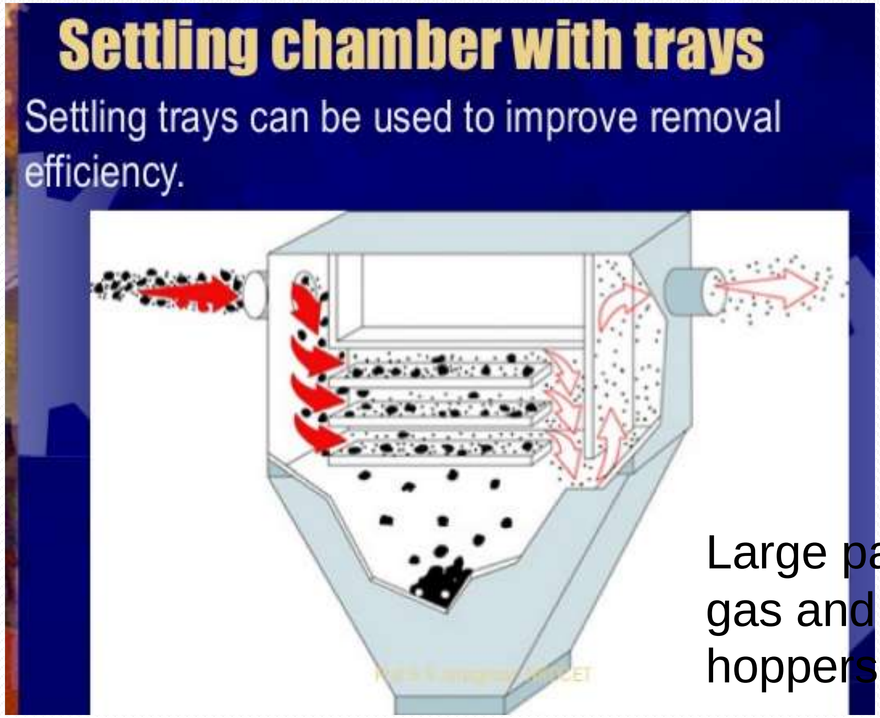
Control of Particulate matter

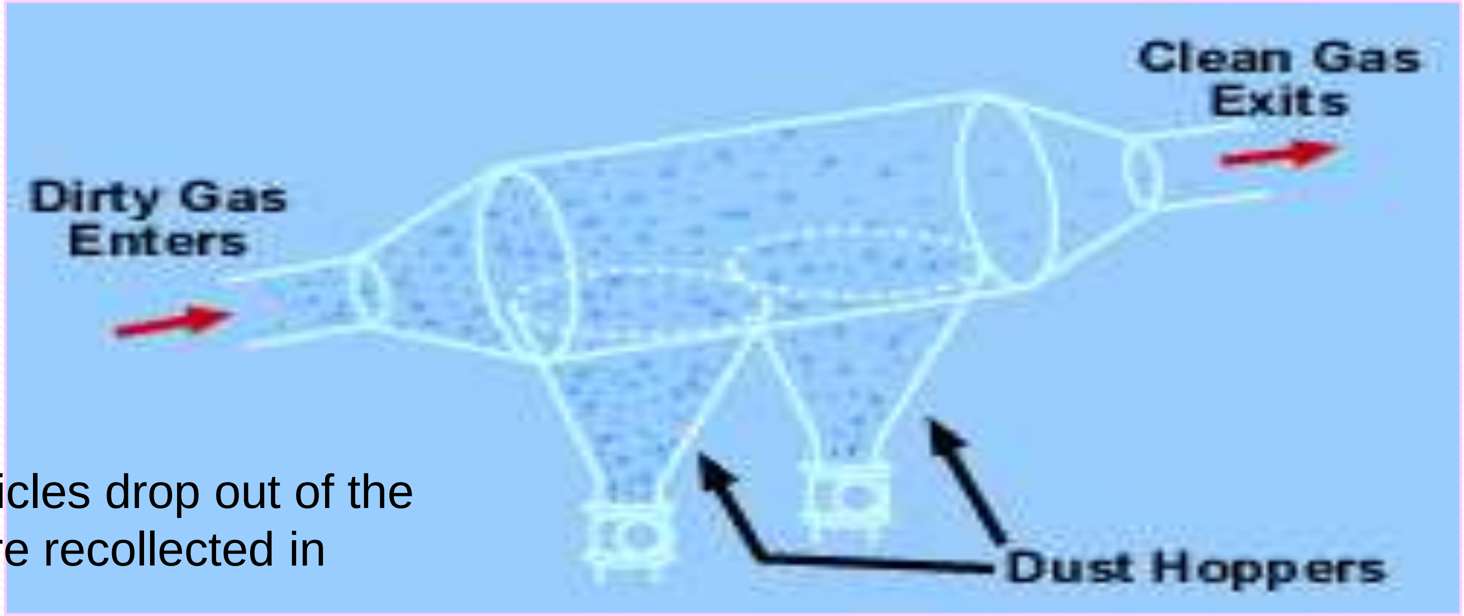
Pollution control methods	Removal mechanism	Particle size removal	efficiency	Design parameters
Gravity settling chamber	Gravity	>50 µ	>50%	-
Cyclone separator	Centrifugal forces and gravity	>5 µ	>85%	-
Bag filter	Interception, impaction and diffusion	< 0.1 µ	>99%	Air to cloth or filtering ratio 0.5 to 5 m/minute
Electrostatic precipitator (ESP)	Electrostatic forces of attraction	< 0.1 µ	>99%	

Settling Chambers

Principle: Suddenly increase in flow cross sectional area of the influent dust laden air from a to A at constant flow rate, the horizontal velocity of the particulate matter drop down from V to v when it enter in to the settling chamber (with high cross sectional area) from a pipe (small cross sectional area) thus the horizontal momentum of the Particulate matter floating in the air decreases and the gravitational force over come the horizontal momentum, as a result the particulate matter move down ward due to gravity and settled in the bottom, and clean air exhausted in the out pipe of the settling chamber

Application many tray in settling chamber increases the settling area also reduces the vertical distance facilitate settling efficiently and quickly





Large particles drop out of the gas and are recollected in hoppers

Figure: Settling chambers

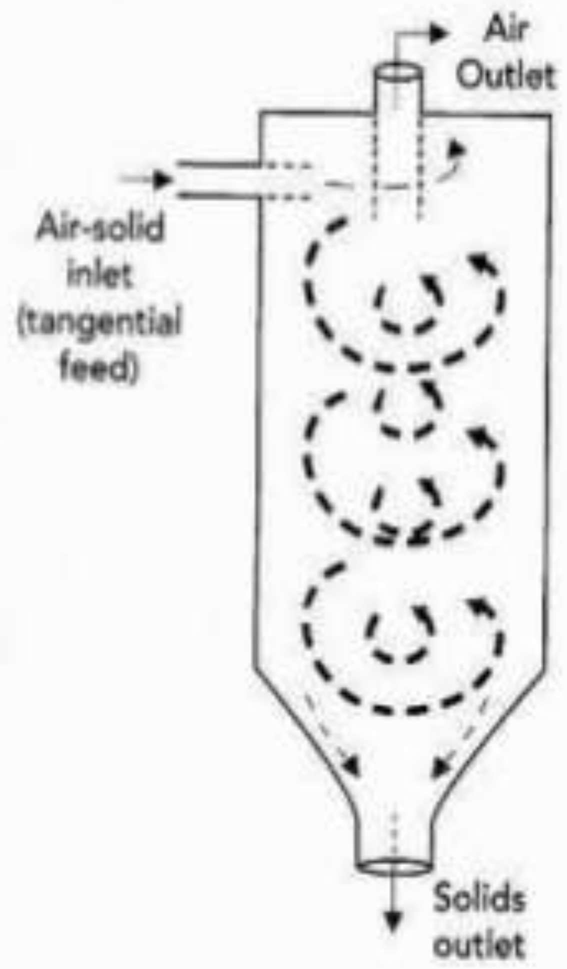
Cyclone Separator

- In a Cyclone, the air or vapor containing particulate material is forced into along the tangential axis. A helical flow pattern is set up within the chamber.

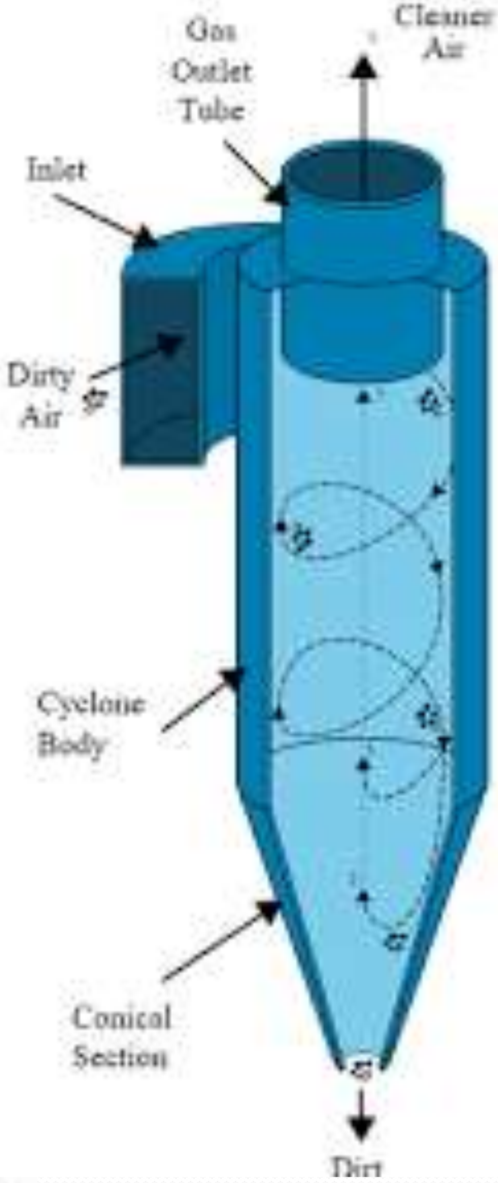
The centrifugal force causes the particles to migrate tothe outside of the chamber. Here they fall down to the bottom of the cyclone by gravity.

The collected particulates are allowed to exit out an underflow pipe while the gas phase reverses its axial direction of flow and exits out through the vortex finder (gas outlet tube) .

- The air moves up the center of the cyclone and reaches the top.



9.11 Figure Flow patterns in a gas-solid cyclone separator (adapted from Geankoplis, 1983).



13.5 FABRIC FILTRATION SYSTEM

Dust laden gas is allowed to pass through the fabric bags, wherein the dust from air is filtered out allowing the clean gas to come out. The different physical mechanisms involved in the separation of dust particles from the gas stream are direct interception, inertial impaction and diffusion. After a dust mat has formed on the fabric more effective collection of submicron particle is accomplished by sieving.

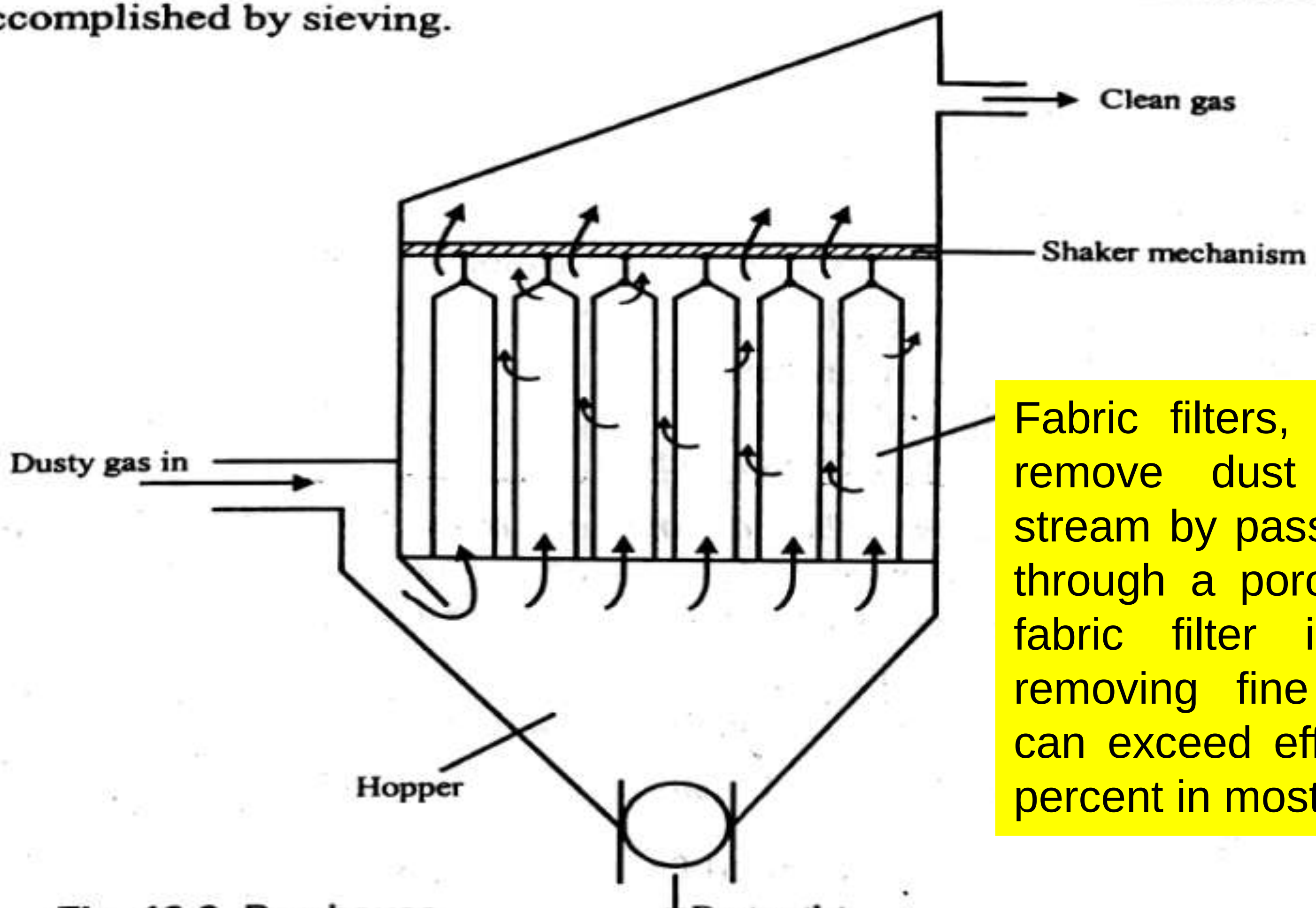


Fig. 13.8 Bag house

Fabric filters, or baghouses, 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.

Filter bags are usually tubular or envelope shaped with size ranging from 1.8 to 9 m long. As particulates build up on the inside surface of the bags, the pressure drop increases, then cleaning of the bags is required. The cleaning may be accomplished by shaking the bags or by

13.6 ELECTROSTATIC PRECIPITATION (ESP)

ESP is one of the most widely used collection devices for particulates. The basic force which acts to separate the particles from the gas is electrostatic attraction. The particle-charging process is done by means of a corona surrounding a highly charged electrode such as wire. The electric field used in collecting the particles is set up between two electrodes. The dust particles collected on the plates can be removed by mechanical means like rapping (for dry collection and use of fly ash) or by washing and making the slurry to be taken to ash pond.

Four main steps in dust collection in ESP.

– Establishment of an electric field with a very high potential gradient. The central electrode is connected to the negative terminal of high DC voltage about 50 kV. Surrounding plate is maintained at +ve potential.
– Corona discharge ionisation and subseqent charging (negative) of the particulates.
– Particle migration and collection on plate with charge neutralisation.
– Particle removal - Rapping for dry collection for use.
  Washing - and making slurry for disposal in ash pond.

Efficiency of ESP (η) = 1- exp(- Aw/Q)

η = 0 to 1

A = Collector plate area in m2

w = particulate velocity

Q = Gas flow in m3/sec

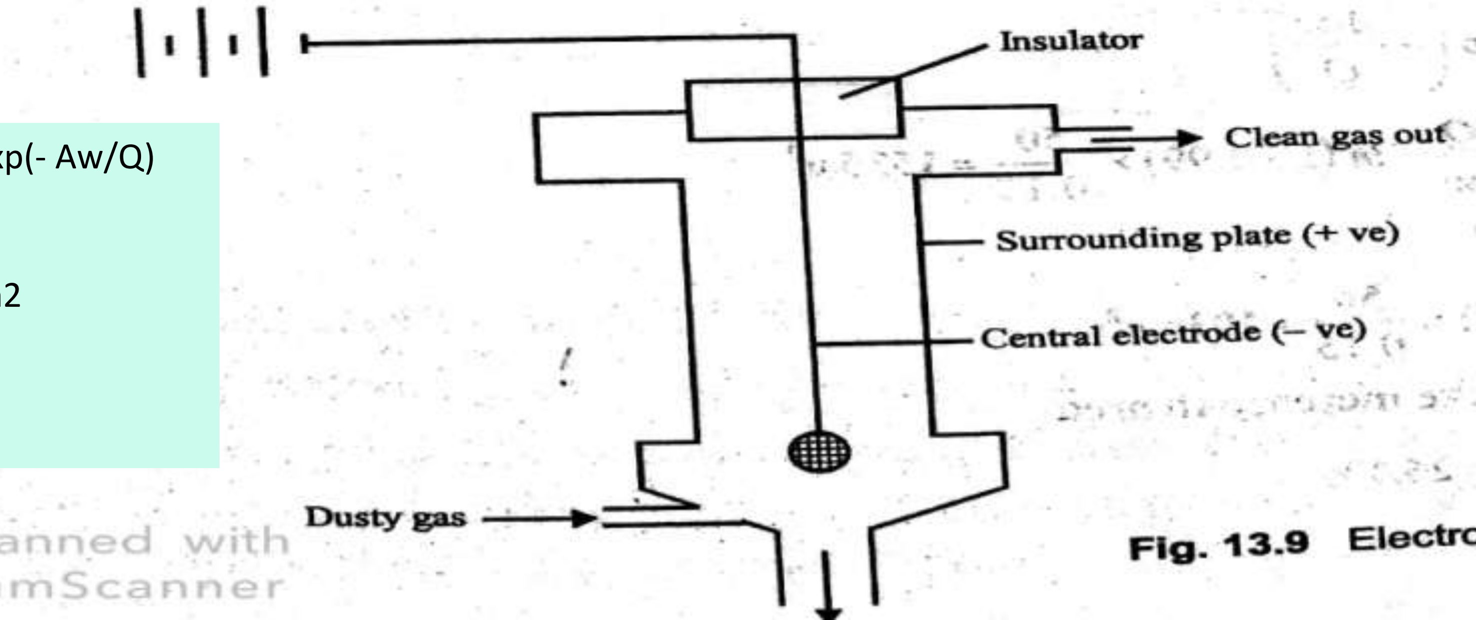


Fig. 13.9 Electrostatic precipitator

Numerical on bag filter

Q- A bag house is to be constructed using bags of 0.25 m diameter and 6 m long. It is to receive 15 m^3/s of air. Assuming the filtration rate of 2.2 m/min. Determine the no bags required in the bag house.

Ans:-Total filtration area required= gas flow rate /filtration rate= 15x60 m^3/min/2.2 m/min= 409.1 m2

Area of one bag = pi*D*H= 3.14*0.25*6 =4.71 m^2

No of bags required in bag house= 409.1/4.71 =86.8 that is 87 bags

Numerical on ESP

Efficiency of ESP (η) = 1- exp(- Aw/Q)

η = 0 to 1

A = Collector plate area in m^2

w = particulate velocity

Q = Gas flow in m^3/sec

Compute the plate area of ESP handling a flow of 3600 m^3/min. If the particulate velocity is taken as 0.15 m/s, and efficiency of ESP as 99 %

(η) = 1- exp(- Aw/Q)

0.99 = 1- exp (0.15*A/3600/60)

A = Area of plate =1842.1 m^2

Control of gaseous pollutants from stationary sources

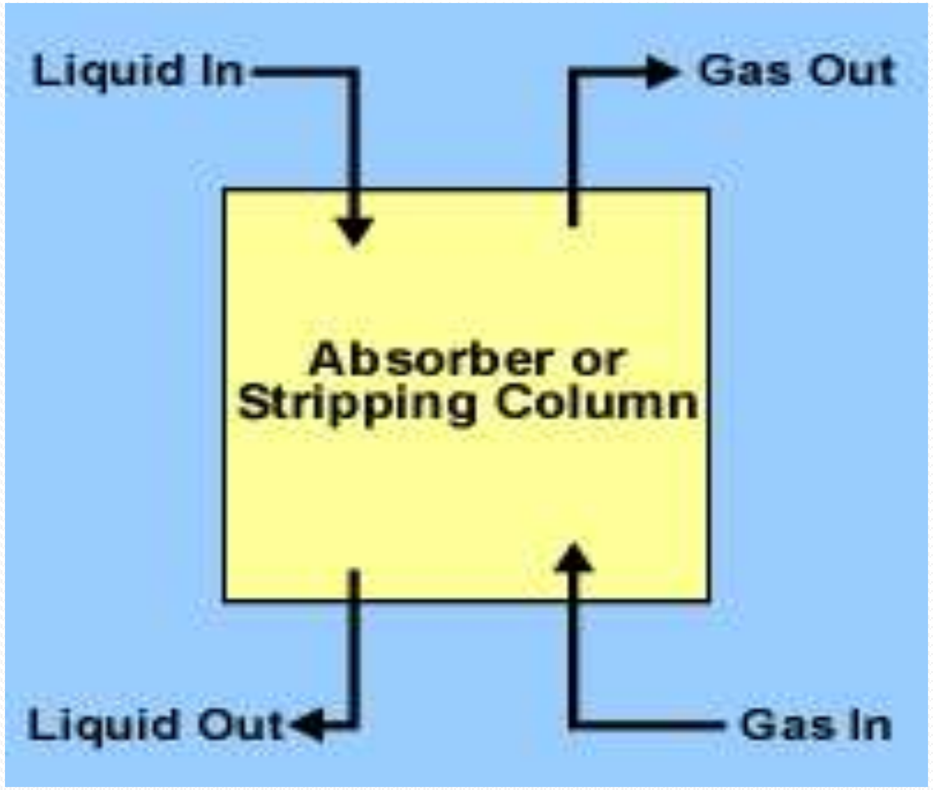
- The most common method for controlling gaseous pollutants is the addition of add-on control devices to recover or destroy a pollutant.
- There are four commonly used control technologies for gaseous pollutants:
  - Absorption,
  - Adsorption,
  - Condensation, and
  - Incineration (combustion)

Absorption

Absorption: involves transfer of pollutant from gas stream to liquid stream. Examples are removal of ammonia by water, hydrogen sulphide by sodium hydroxide etc.

- Absorption is a process in which a **gaseous pollutant is dissolved in a liquid**.

Absorbers are often referred to as **scrubbers**,



Typical Packed Column Diagram

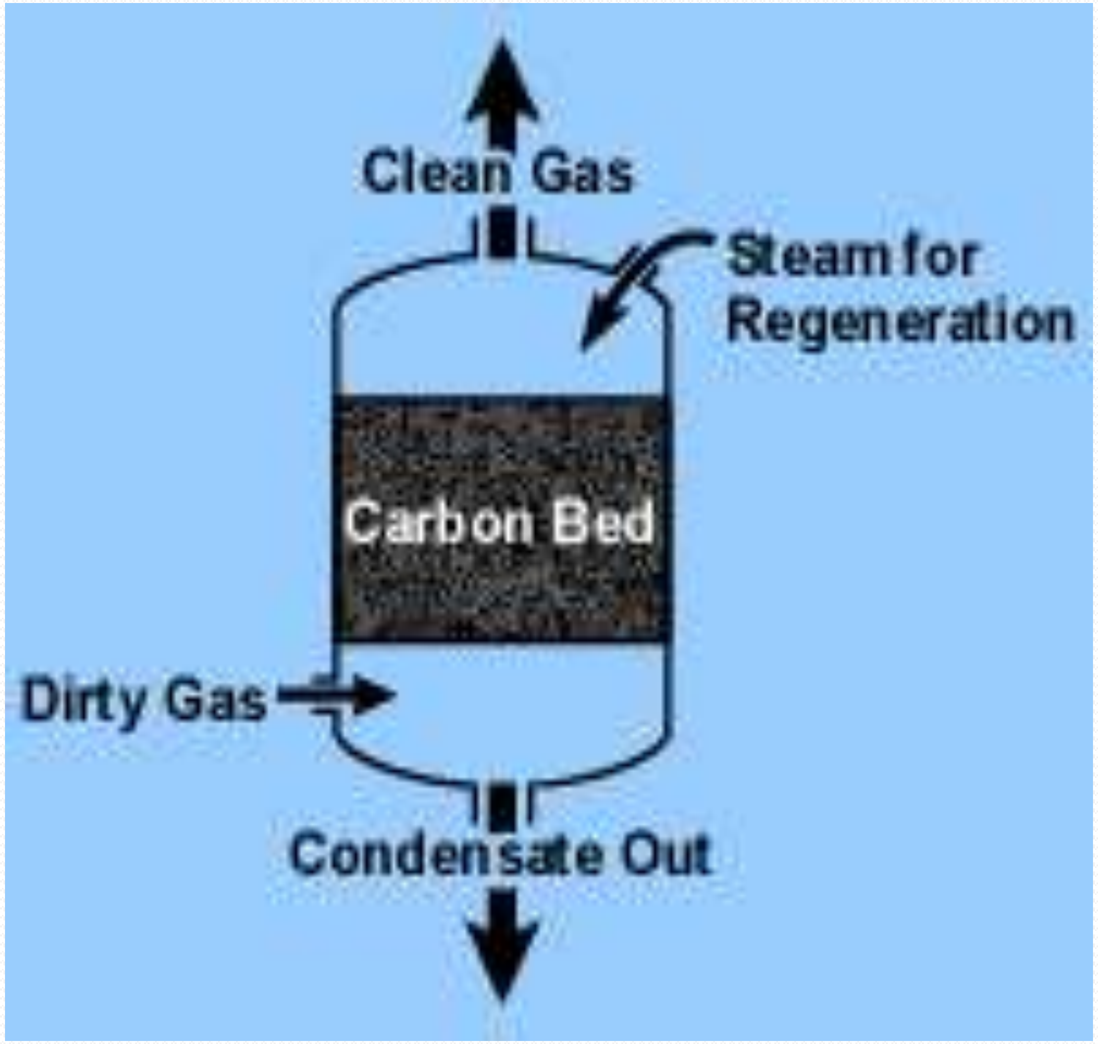
In general, absorbers can achieve removal efficiencies grater than **95 percent**.

One potential problem with absorption is the generation of waste-water, which converts an air pollution problem to a water pollution

Adsorption

Adsorption involves transfer of pollutant from gas or liquid stream to solid surfaces having desirable surface properties.

- The most common industrial adsorbents are;
- **Activated carbon**
- **Silica gel**
- **Alumina**,
- because they have enormous surface areas per unit weight.



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.
  - 3T= Temperature, Time, and turbulence


Measure consumption of environmental resources
Reduce emissions
Calculate emissions
Environment Sustainability
Reduce consumption
Report consumption and emissions externally
Identify reduction

THANK YOU


MASS EXTINCTION
BUSH FIRES
SEVERE DROUGHT
NEXT 100 YEARS