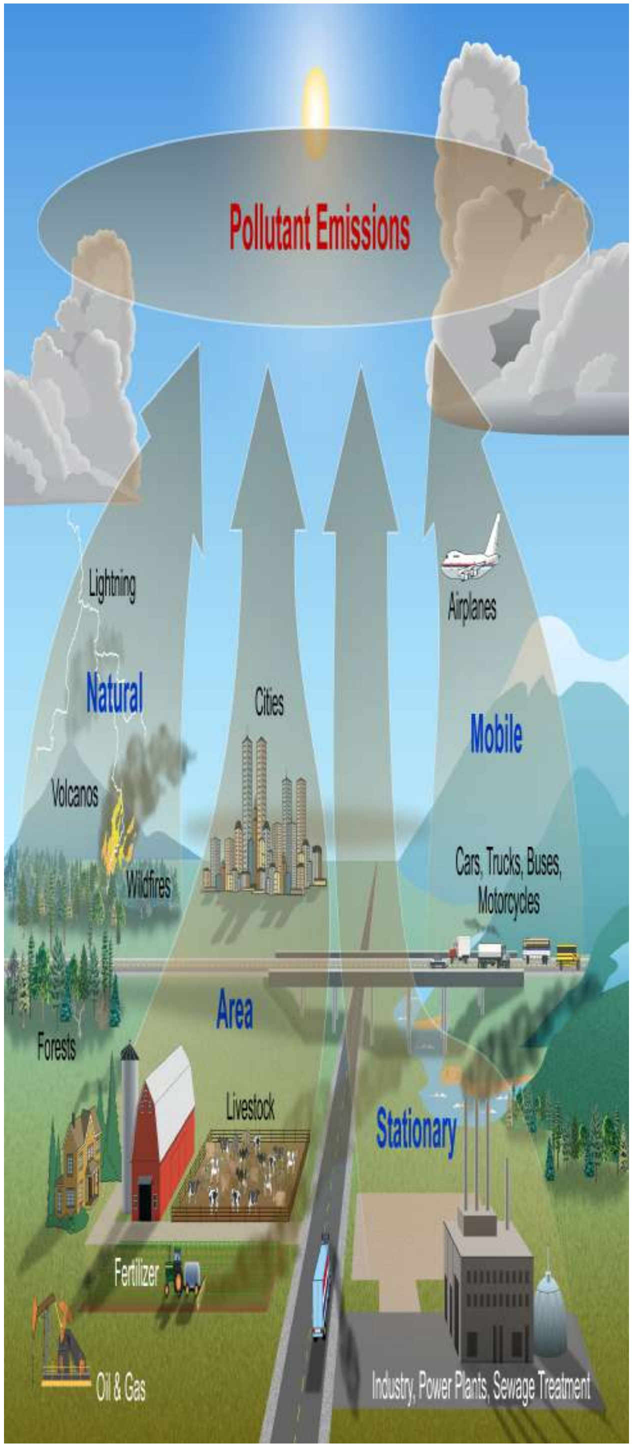

SOURCES AND TYPES OF AIR POLLUTANT

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Course Title: Environmental Pollution and Control Technique-I
M.SC 2nd Semester

AIR POLLUTION

Definition –

- **Air pollution may be defined as the presence one or more contaminants or combinations thereof in air in such quantities and of such durations as may be or tend to be injurious to human, animal or plant life, or property, or which unreasonably interferes with the comfortable enjoyment of life or property or conduct of business.**

AIR POLLUTANT

- **It is a substance or effect dwelling temporarily or permanently in the air , which adversely alters the environment by interfering with the health, the comfort, or the food chain, or by interfering with the property values of people.**

- **A pollutant can be solid (large or sub-molecular), liquid or gas .**

SOURCES OF AIR POLLUTION

- **Air Pollution may originate from a natural or anthropogenic source or from both sources.**

- **E.g. of natural source – an erupting volcano, accidental fire etc**

- **Nonpoint Sources vs. Point Sources**

❖**The term "nonpoint source" is defined to mean any source of water pollution that does not meet the legal definition of "point source" in section 502(14) of the Clean Water Act**

❖**The term "point source" means any discernible, confined and discrete conveyance, including but not limited to any pipe, ditch, channel, tunnel, conduit, well, discrete fissure, container, rolling stock, concentrated animal feeding operation, or vessel or other floating craft, from which pollutants are or may be discharged. This term does not include agricultural storm water discharges and return flows from irrigated agriculture.**

Non-point source pollution can include:

- **Excess fertilizers, herbicides and insecticides from agricultural lands and residential areas**
- **Oil, grease and toxic chemicals from urban runoff and energy production**
- **Sediment from improperly managed construction sites, crop and forest lands, and eroding streambanks**
- **Salt from irrigation practices and acid drainage from abandoned mines**
- **Bacteria and nutrients from livestock, pet wastes and faulty septic systems**
- **Atmospheric deposition and hydromodification**

Air pollutant classification

- Gases - compounds of Sulphur, nitrogen, carbon, oxygen etc.

- Natural contaminants-
- Pollen particles, bacteria's

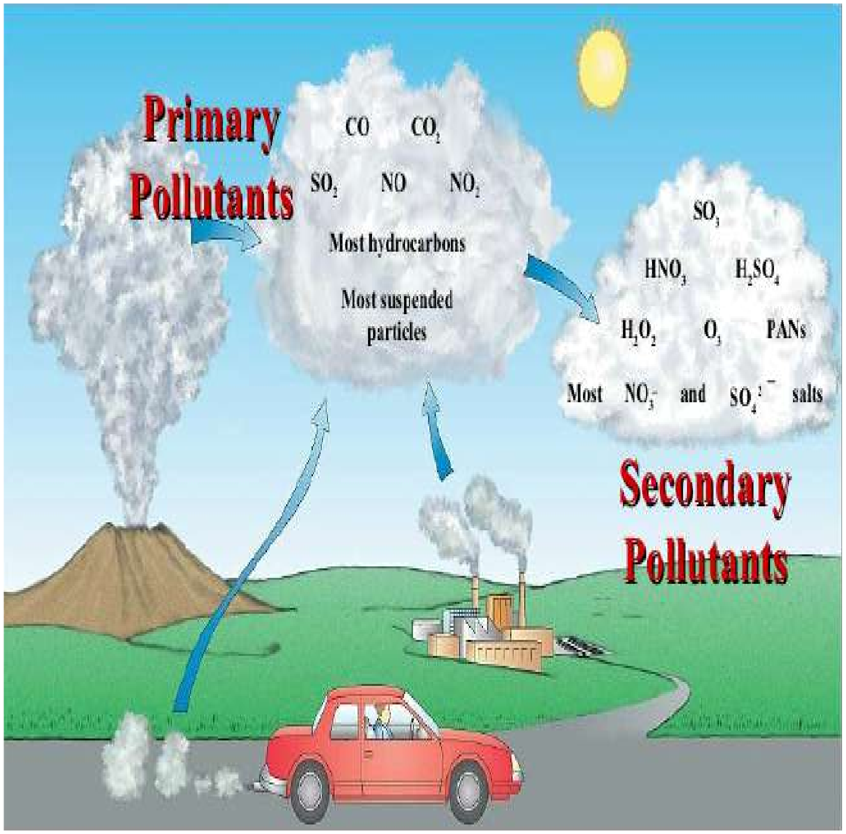
- Aerosols-
- Dust, smoke, mist, fumes, fogs

TYPES OF AIR POLLUTANT

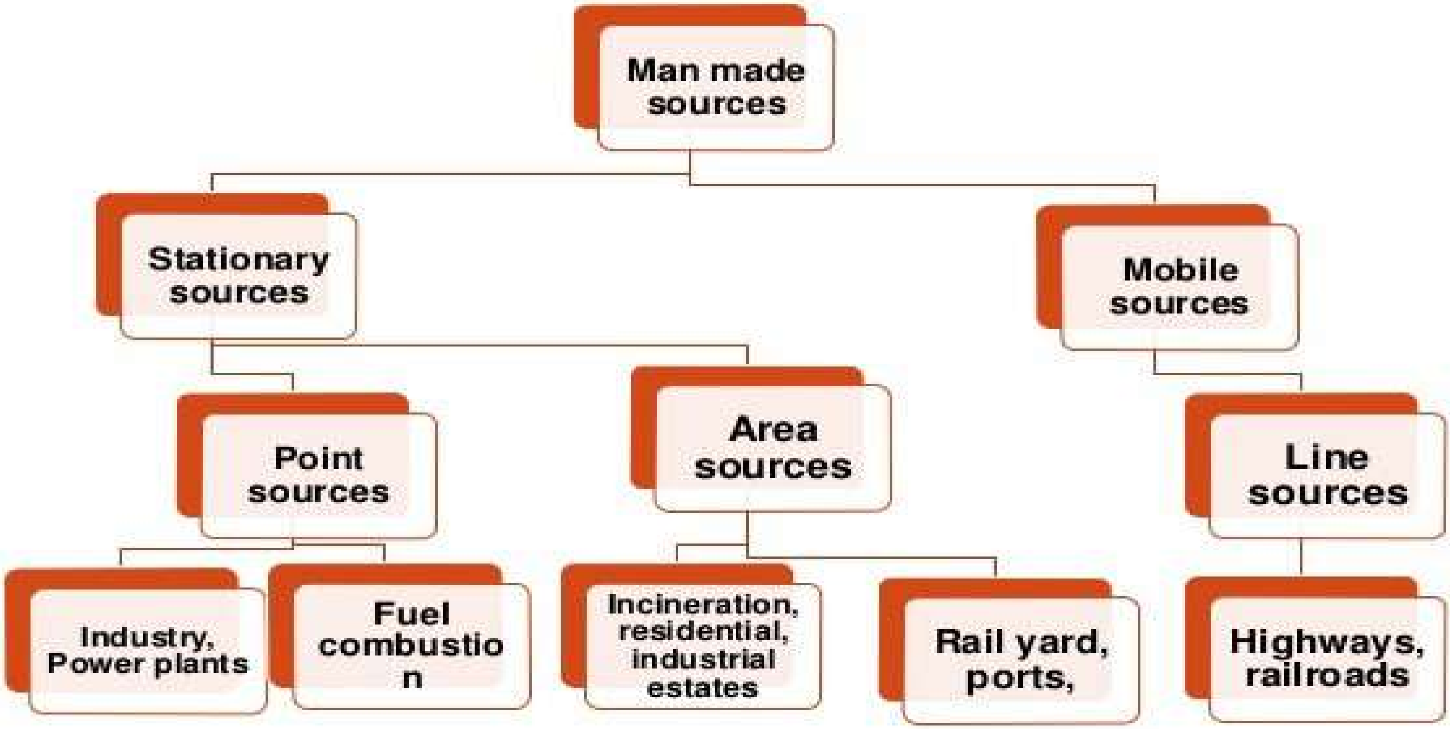
- The *primary pollutants* ***are "directly" emitted*** **from the processes such as fossil fuel consumption, Volcanic eruption and factories. The major** *primary pollutants* **are Oxides of Sulphur, Oxides of Nitrogen, Oxides of Carbon, Particulate Matter, Methane, Ammonia, Chlorofluorocarbons, Toxic metals etc.**

- **The** ***secondary pollutants are not emitted directly.***

The secondary pollutants form when the primary pollutants react with themselves or other components of the atmosphere. Most important ***secondary level Air Pollutants*** **are** ***Ground Level Ozone, Smog and POPs (Persistent Organic Pollutants).***



Man made sources



Percentage of Manmade Pollution

Source	CO (%)	SO_2 (%)	HC(%)	NO – Nox (%)
TRANSPORTATIO N	92	4	65	42
INDUSTRIES	4	32	26	21
POWER PLANTS	-	48	-	32
SPACE HEATING	3	12	3	5
COMBUSTION	1	4	6	0

INDUSTRIAL SOURCES OF POLLUTION

- Liquid soap factory
- Sulphuric Acid factory
- Plastic industry
- Acid manufacturing units
- Phosphate fertilized industry
- Inorganic chemical plants
- Metal industry
- Aluminum plants

MAJOR PRIMARY POLLUTANTS

- **Nitrogen Oxides (NOx)**
- **Ammonia (NH3)**
- **Carbon monoxide (CO)**
- **Sulphur Oxides (SOx)**
- **Heavy metals (As,Cd,Pb,Hg)**
- **Volatile Organic Compounds**

Nitrogen Oxides (NOx)

- **Nitrogen oxides, particularly nitrogen dioxide, are expelled from high temperature combustion, and are also produced during thunderstorms by electric discharge.**

- **Nitrogen oxides (NOX) are emitted during fuel combustion, such as by industrial facilities and the road transport sector. As with SO2, NOX contributes to acid deposition.**

- **NO2 that is associated with adverse affects on health, as high concentrations cause inflammation of the airways (wind pipe,layrnx).**

Carbonmonoxide (CO)

- ❑colourless and odourless,toxic gas
- ❑comes from the incomplete combustion of fuel in vehicles.
- ❑ can be absorbed by haemoglobin in the blood, thus blood can no longer absorb O2
- ❑ extra amounts of CO result in tiredness, headaches, heart damage and small amounts can be lethal

Sulphur-dioxide (SO_2)

- **Fuels (coal and petroleum) contain sulphur as an impurity; when fuels are burnt, sulphur is oxidised or burnt to SO2**

- **Emitted from volcanoes eruptions**

- **Irritates the eyes and causes breathing difficulties causes asthmetic problems.**

- **In the presence of a catalyst such as NO2, forms H2SO4, and results of acid rain**

Ammonia (NH_3)

- **A gas with a characteristic pungent odor.**

- **Odors — such as from garbage, sewage, and industrial processes**

- **Radioactive pollutants - produced by nuclear explosions, nuclear events, war explosives, and natural processes such as the radioactive decay of radon.**

- **come from the agricultural sector, from activities such as manure storage, slurry spreading and the use of synthetic ammonia fertilizers**

Heavy Metals

❑The heavy metals arsenic (As), cadmium (Cd), lead (Pb), mercury (Hg) and nickel (Ni) are emitted mainly as a result of various combustion processes and industrial activities.

❑ These chemicals are known as toxins and are linked to thyroid disorders, cancer, women's hormonal conditions, chronic fatigue syndrome, fibromyalgia and other several illnesses & symptoms includes.

- Fatigue
- Lung Cancer
- Cardiopulmonary diseases

Volatile organic compound (VOC)

VOC is emitted from a large number of sources including paint application, road transport, dry-cleaning and other solvent uses.

- **Methane VOC**
- **Non methane VOC**
- **Benzene Methyl Chloride**
- **CFCs**

▪ **Methylene chloride is highly dangerous to human health. It can be found in adhesive removers and aerosol spray paints and the chemical has been proven to cause cancer in animals. In the human body, methylene chloride is converted to carbon monoxide and a person will suffer the same symptoms as exposure to carbon monoxide.**

• **Benzene, is a chemical found in environmental tobacco smoke, stored fuels, and exhaust from cars. Benzene has also been known to contaminate food and water and if digested can lead to vomiting, dizziness, sleepiness, rapid heartbeat, and at high levels, even death may occur.**

• **Chlorofluorocarbons (CFCs) widely used cleaning products and refrigerants. Tetrachloroethene is used widely in dry cleaning harmful to ozone layer which prevents human by having skin cancer and various skin diseases,**

Volatile organic compounds (VOCs) are emitted as gases from certain solids or liquids. VOCs include a variety of chemicals, some of which may have short- and long-term adverse health effects. **VOCs** are emitted by a wide array of products numbering in the thousands.

Examples :
paints pesticides, building materials and furnishings, glues and adhesives etc

SECONDARY POLLUTANTS

Major Secondary Air Pollutant

- **Particulate matter (PM)** **Particulates created from gaseous primary pollutants and compounds in photochemical smog. PM is one of the most important pollutants as it penetrates into sensitive regions of the respiratory system**

- **Particulate matter includes both primary and secondary PM**

- **primary PM is the fraction of PM that is emitted directly into the atmosphere, secondary PM forms in the atmosphere following the oxidation and transformation of toxic gases (mainly SO2, NOX, NH3 and some volatile organic compounds (VOCs).**

Ground level Ozone (O_3)

- **Ground level ozone (O3) formed from NOx and VOCs.**

- **Ozone (O3) is a secondary pollutant and a key constituent formed in the troposphere.**

- **Photochemical and chemical reactions involving it drive many of the chemical processes that occur in the atmosphere by day and by night.**

- **At abnormally high concentrations brought about by human activities (largely the combustion of fossil fuel), it is a pollutant, and a constituent of smog.**

- **Ozone is a powerful and aggressive oxidising agent, elevated levels of which cause respiratory and cardiovascular health problems and lead to premature mortality.**

- **High levels of O3 can also damage plants, leading to reduced agricultural crop yields and decreased forest growth.**

What is Particulate Matter?

❖**Particulate matter (PM)** : A wide variety of airborne material. PM pollution consists of materials (including dust, smoke, and soot), that are directly emitted into the air or result from the transformation of gaseous pollutants.

❖Particles come from natural sources (e.g., volcanic eruptions) and human activities such as burning fossil fuels, incinerating wastes, and smelting metals.

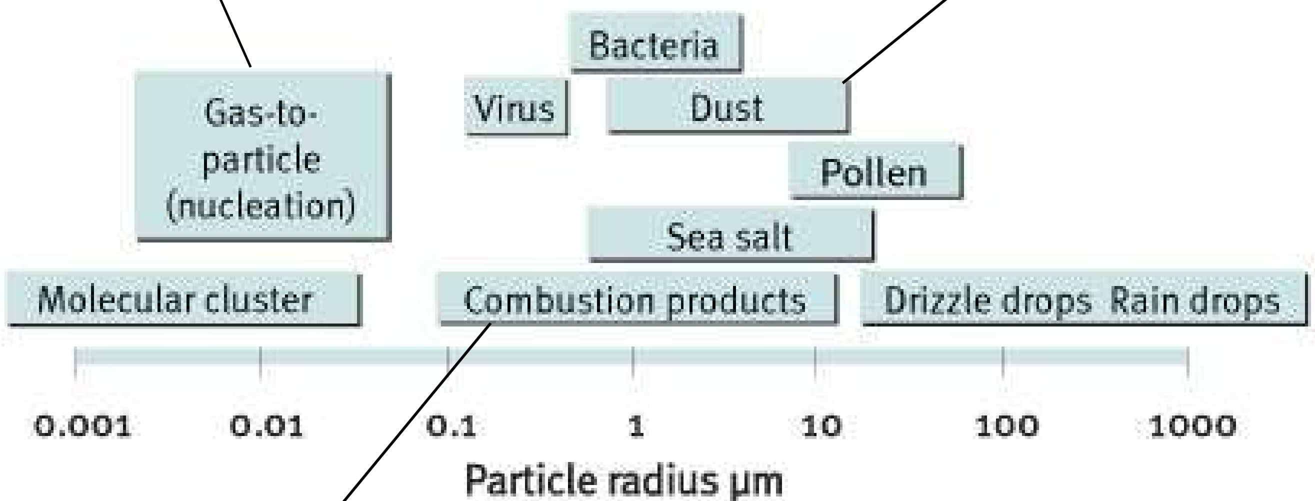
❖Coal grinding, fugitive road dust and dust from rock quarries are examples of *physical processes* that release particulate matter to the atmosphere. These particles are usually large (>100 mm diameter), do not have a long residence time in the atmosphere, and are not taken into the body during respiration.

❖PM formed through chemical reactions are typically much smaller (<10 mm diameter) . *Chemical processes* that release particulate matter to the atmosphere include all forms of combustion (*automobiles, fossil fuel power plants, forest fires and residential fireplaces*) and. *atmospheric emissions from volcanoes).*

Sources

e.g NH_4Cl,
SO_4^{2-} / NO_3^- salts

Mineral dust from weathering of rocks and soils

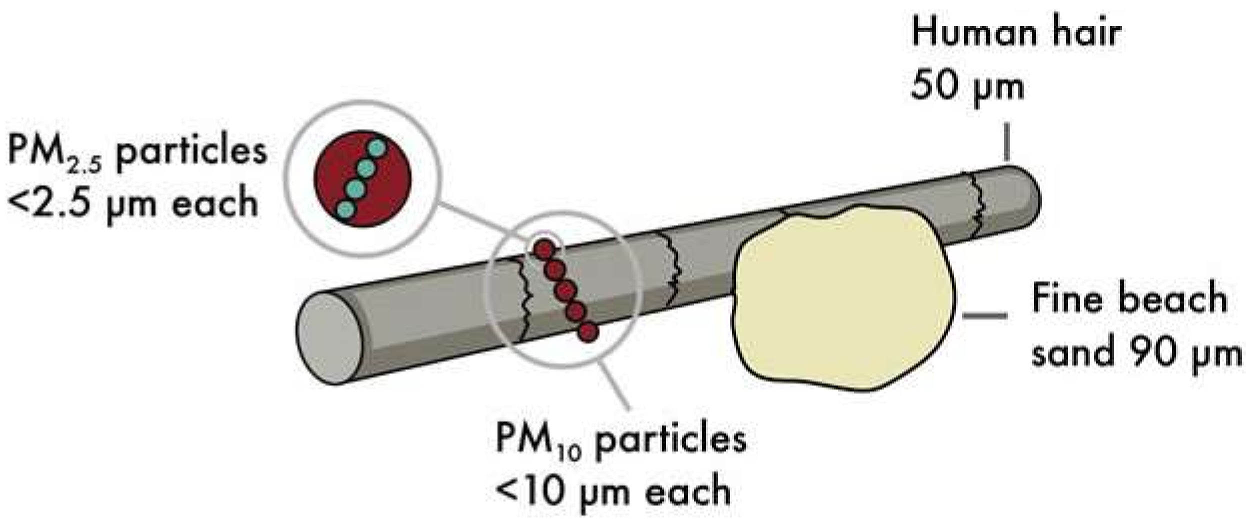


Natural: forest fires, volcanoes etc.

Man-made: fossil-fuel combustion, industry

PM_{10}	particles with a diameter of 10 micrometres or less
$PM_{2.5}$	particles with a diameter of 2.5 micrometres or less
TSP	total suspended particulate

PM_{10} and $PM_{2.5}$	Fuel combustion such as burning coal, oil, wood and light fuel oil in domestic fires, transportation and industrial processes.
TSP	Sources include dusty roads, soil tiling, quarries and fuel combustion.



These are classified as:

Figure compares the size of PM_{10} and $PM_{2.5}$ particles to a strand of hair and a type of beach sand. They are tiny – too small for the human eye to see.

Particles in the Atmosphere

Term	Meaning
Condensation aerosol	Formed by condensation of vapors or reactions of gases
Aerosol	Colloidal-sized atmospheric particles
Dispersion aerosol	Formed by grinding of solids, atomization of liquids, or dispersion of dusts
Fog	Denotes high level of water droplets
Haze	Decreased visibility due to particles
Mists	Liquid particles
Smoke	Particles from incomplete fuel combustion

Characteristics of Particles

❖The most important characteristic of particulate matter (PM) is the particle size.

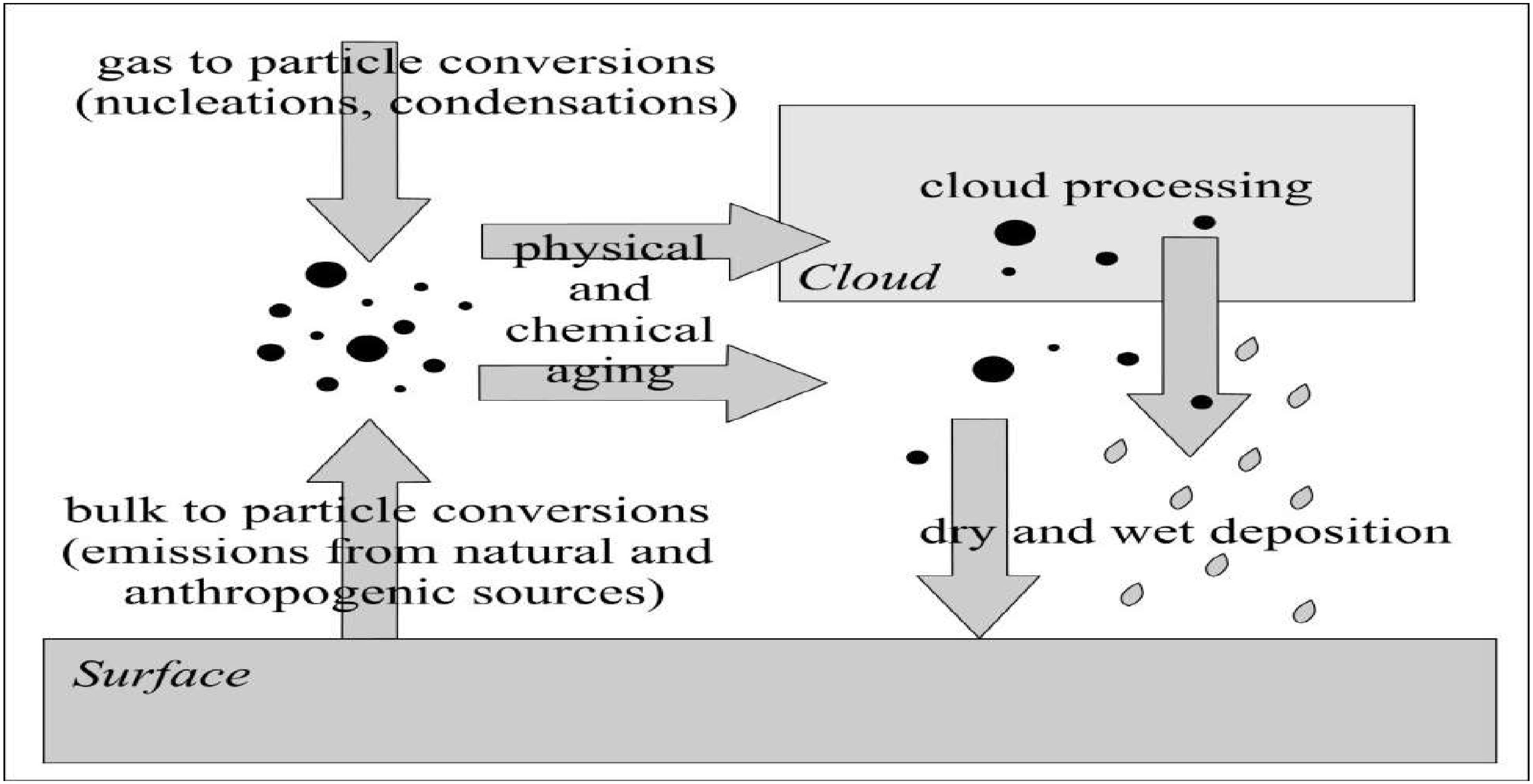
❖This property has the greatest impact on the behavior of particulate matter in control equipment, the atmosphere, and the respiratory tract.

❖Particles of importance in air pollution control span a broad size range from extremely small (0.01 micrometer) to more than 1,000 micrometers. A human hair has a diameter of approximately 50 micrometers.

❖The chemical composition of the particulate matter is also important.

❖Absorption and heterogeneous nucleation of vapor phase pollutants onto existing particles can create toxic particulate matter.

Sources and sinks of atmospheric aerosols



After the emission of aerosol particles, they undergo various physical and chemical processes. During these processes, size, composition and structure of particles can be changed. Finally, they can be removed from the atmosphere to the surfaces by dry or wet deposition processes

Mechanism of aerosol formation

Nucleation: Defined as creation of molecular embryos or clusters prior to formation of a new phase during the transformation of vapour → liquid → solid. Nucleation can occur within the original phase (homogeneous nucleation), or on another phase, e.g. on a small particles (heterogeneous nucleation).

Condensation: gas to liquid phase change.

Cloud condensation nuclei (CCN): hygroscopic aerosol particles that can serve as nuclei of atmospheric cloud droplets, that is, particles on which water vapour condenses.

Particle coagulation: a process, in which small particles collide with each other and coalesce completely to form a larger particle

- **SO_2 is emitted from fossil combustion and also forms from oxidation reactions of the biogenically emitted organic sulfur compounds. OH forms from the following atmospheric reactions:**

hγ

$O_3 \rightarrow O(1D) + O_2$ (4)

$O(1D) + H_2O \rightarrow 2OH$

- **Nucleation starts from the formation of sulfuric acid (H_2SO_4), because of its low vapour pressure. Formation of H_2SO_4 involves the following reactions:**

$SO_2 + OH \rightarrow HSO_3$ (Rate limiting step) (1)

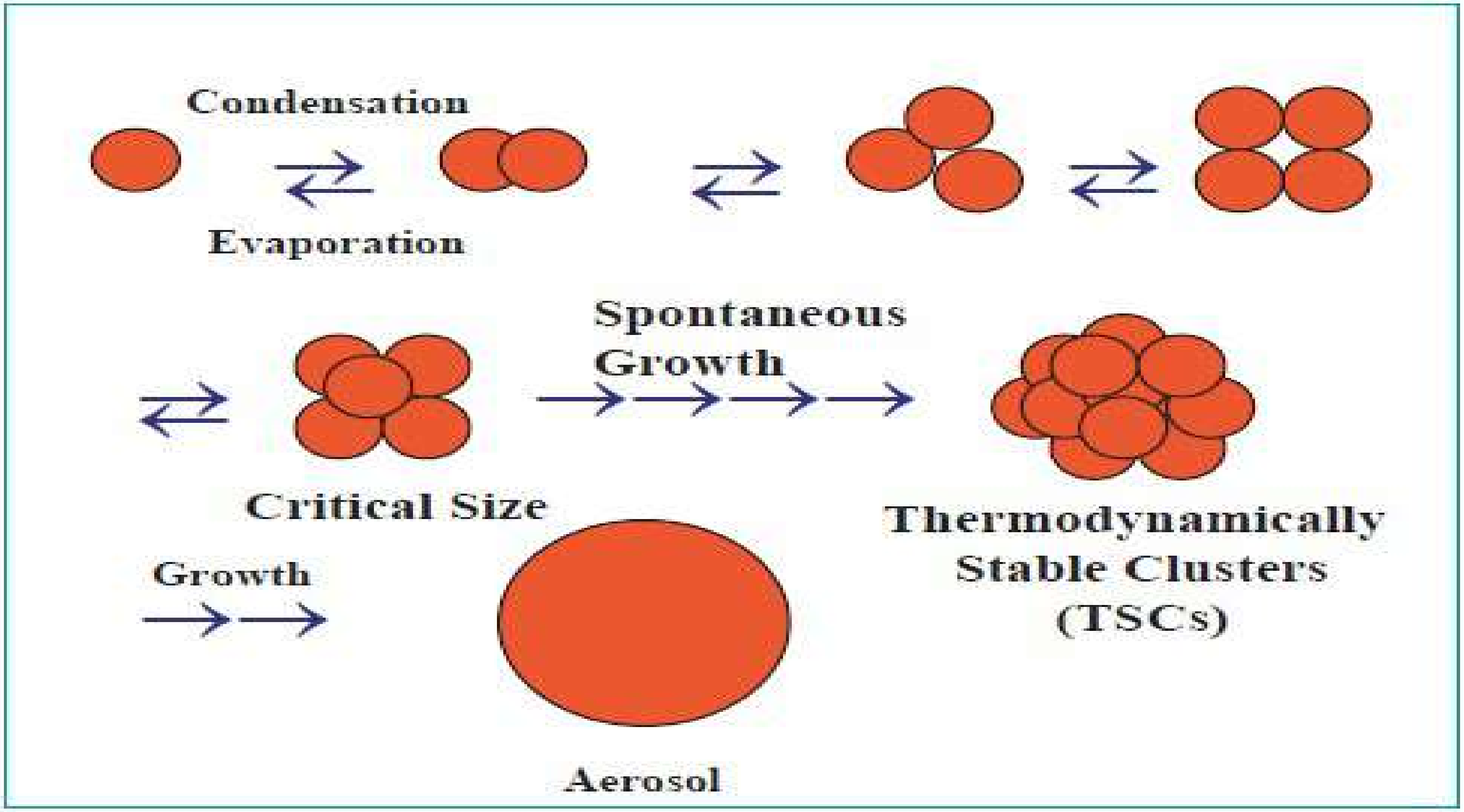
$HSO_3 + O_2 \rightarrow HO_2 + SO_3$ (2)

$SO_3 + H_2O \rightarrow H_2SO_4$ (3)

- **Once formed, H_2SO_4 immediately becomes hydrated. The hydrated H_2SO_4 molecules are nuclei, and nucleation takes place by condensation of H_2SO_4 molecules and coagulation.**

That is, monomer becomes dimer, and dimer becomes trimer, and so on.

$H_2SO_4 + H_2SO_4 \rightarrow 2\ H_2SO_4$ (6)
$2\ H_2SO_4 + H_2SO_4 \rightarrow 3\ H_2SO_4$ (7)
$3\ H_2SO_4 + H_2SO_4 \rightarrow 4\ H_2SO_4$ (8)
$4\ H_2SO_4 + H_2SO_4 \rightarrow 5\ H_2SO_4$



HOMOGENOUS NUCLEATION

If NH_3 dissolves in some H_2O

$$NH_3 + H_2O \longrightarrow NH_4^+ + OH^-$$

$$2NH_4^+ + SO_4^{2-} \longrightarrow (NH_4)_2SO_{4(aq)}$$

Thus, particles form through complex gas phase, heterogeneous, and liquid phase reactions

SINK PROCESSES

Wet deposition processes (the main sink of atmospheric aerosol particles)

- **Rain-out and washout: a part of cloud droplets form precipitation which reaches Earth's surface removing aerosols from cloud and from the column of air below the cloud.**
- **Cloud deposition: deposition form of aerosols in high elevation ecosystems due to interception of cloud droplets by vegetation.**

Dry deposition processes (less important on a global scale)

- **Turbulent diffusion: for larger particles (with a diameter larger than 1 µm)**
- **Gravitational settling (sedimentation): larger particles are influenced more by gravity and fall back to the surface. This process becomes increasingly important for particle sizes above 1 µm.**
- **Impaction: if a particle cannot follow the flow streamline around an obstacle, small particle can hit this obstacle**
- **Interception: if an object is not directly in the path of particle moving in the gas stream but particle approaches the edge of the obstacles, it may collected by the obstacle**

History of Smog

- **Name comes from a mix of "Smoke" and "Fog"**
- **First observed in London during the industrial revolution**
- **There are 2 types of smog:**
  - ❖ **Industrial Smog (London) and**
  - ❖ **Photochemical Smog (Los Angeles)**

Industrial Smog (Reducing)

- **Source: Pollution from the burning of coal and oil that contains sulfur**
- **Consists mainly of: Sulfur Dioxide, Sulfur Trioxide, soot and ash (particulate matter) and sulfuric acid**
- **It can cause breathing difficulties in humans, plus acid rain damage to plants, aquatic systems, and metal or stone objects**
- **London and Chicago have problems with industrial smog.**
- **Methods of reducing this smog: Alkaline Scrubbers reduce SO_2 and SO_3 levels; electrostatic precipitators reduce particulates.**

Photochemical Smog (Oxidizing)

- **Source: Mainly automobile pollution**
- **Contains: Nitrogen Oxides, Ozone, Alkanals, Peroxyacyl Nitrates (PANs), plus hundreds of other substances**
- **Effects: PANs cause eyes to water and can damage plants, O_3 irritates eyes and deteriorates rubber and plants, NO_x causes acid rain.**
- **First observed in Los Angeles in the 1940s, Manila and Mexico City also experience this kind of smog**
- **Catalytic Converters change NO to N_2, Lean burning engines reduce No_x, but create more CO and Hydrocarbons.**

Reactions of Smog

- **Sulfur Dioxide can be oxidized to Sulfur trioxide, a secondary pollutant:**

- **Metallic Particulates act as a catalyst for this reaction.**
- **In addition, free radicals from NO_2 also speed up the reaction:**

When fossil fuels are burnt, a variety of pollutants are emitted into the earth's troposphere. Two of the pollutants that are emitted are hydrocarbons (unburnt fuels) and nitric oxide (NO). When these pollutants build up to suffidently high levels, a chain reaction occurs from their interaction with sunlight in which NO is converted to nitrogen dioxide (NO_2). This NO_2 absorbs energy from sunlight and breaks up into nitric oxide and free oxygen atom.

NO + O_2 ---> NO_2 + u.v. ---> O + NO

$$NO_2(g) \xrightarrow{h\nu} NO(g) + O(g)$$

Oxygen atoms are very reactive and can combine with the O_2 of the air to produce ozone.

$$O(g) + O_2(g) \longrightarrow O_3(g)$$

The ozone formed in the above reaction (H) reacts rapidly with the NO(g) formed in reaction (i) to regenerate NO_2. NO_2 is a brown gas and at sufficiently high levels can contribute to haze.

$$NO(g) + O_3(g) \longrightarrow NO_2(g) + O_2(g)$$

Ozone is a toxic gas and both NO_2 and O_2 are strong oxidising agents and can react with the unburnt hydrocabrons in the polluted air to produce chemicals such as formaldehyde (HCHO), acrolein CH_2=CHO) and peroxy acetyl nitrate (PAN).

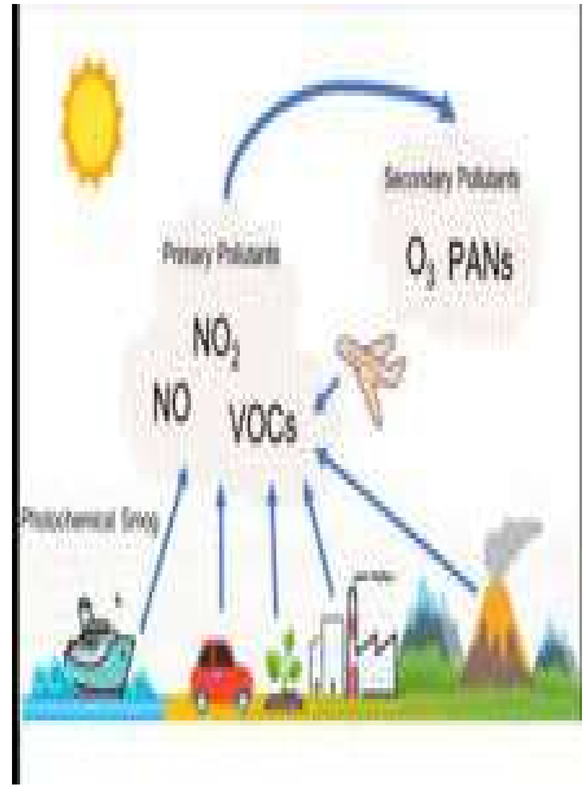
$$3CH_4 + 2O_3 \longrightarrow \underset{\text{Formaldehyde}}{3HCHO} + 3H_2O$$

$$\underset{\text{Acrolein}}{CH_2 = CH{-}CH = O};\ \underset{\text{Peroxyacetyl nitrate (PAN)}}{CH_3CO_3NO_2}$$

NITROGEN OXIDE mostly comes from the smoke of vehicles and

Trucks ,contact of this with sunlight results in the smog formation

Peroxyacetyl Nitrate Definition(PAN): PANs are secondary pollutants, which means they are not directly emitted as exhaust from power plants or internal combustion engines, but they are formed from other pollutants by chemical reactions in the atmosphere



INTERNAL COMBUSTION ENGINES

POWER PLANTS

❖**Photochemical smog occurs in dry, stagnant air masses, usually stabilized by a temperature inversion, that are subjected to intense sunlight.**

❖**A smoggy atmosphere contains ozone, O_3, organic oxidants, N oxides, aldehydes, and other noxious species, as well as a haze of fine particles.**

❖**The chemical ingredients of smog are nitrogen oxides and organic compounds, both released from the automobile, as well as from other sources.**

❖**The driving energy force behind smog formation is electromagnetic radiation with a wavelength at around 400 nm or less, in the ultraviolet region, just shorter than the limit for visible light.**

❖**Formation of active species starting *photochemical reactions*.**

How Does Photochemical Smog Form?

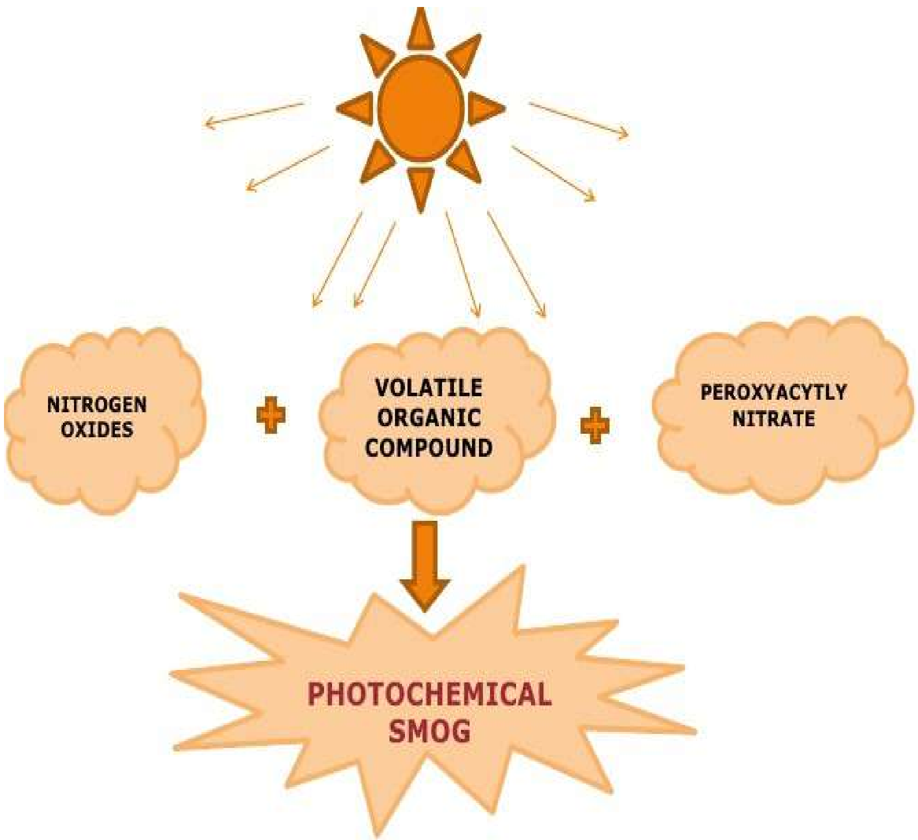
❖**The formation of photochemical smog involves three primary ingredients: nitrogen oxides, hydrocarbons and sunlight. The nitrogen oxides and hydrocarbons are by-products of fossil fuel-burning energy plants, and they can even come from natural processes, but the main source is the internal combustion engines in gasoline-powered automobiles.**

❖**Nitrous oxide and nitrogen dioxide dissociate in sunlight and combine with trace hydrocarbons to ultimately produce a large number of pollutants. The complex process proceeds in stages:**
Sunlight causes the photo-dissociation of nitrogen and oxygen to yield ozone and oxygen atoms.

❖**Oxygen atoms react with water to form hydroxyl radicals (OH).**
Hydroxyl radicals oxidize hydrocarbons to form hydrocarbon radicals.
Hydrocarbons oxidize to form a class of chemicals known as aldehydes.
Aldehydes oxidize to form aldehyde peroxides and aldehyde peroxyacids, which are the pollutants that create most of the health problems.

Peroxyacetyl nitrate, $CH_3COOONO_2$

Hydrocarbons + O_2 + NO_2 + light → $CH_3COOONO_2$



Photochemical Smog is an air pollution ,formed when photons of sunlight hit molecules of different kinds of pollutants in the atmosphere


Thank you!

EFFECT AND CONTROL OF AIR POLLUTION

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EFFECT OF AIR POLLUTION ON HUMAN HEALTH

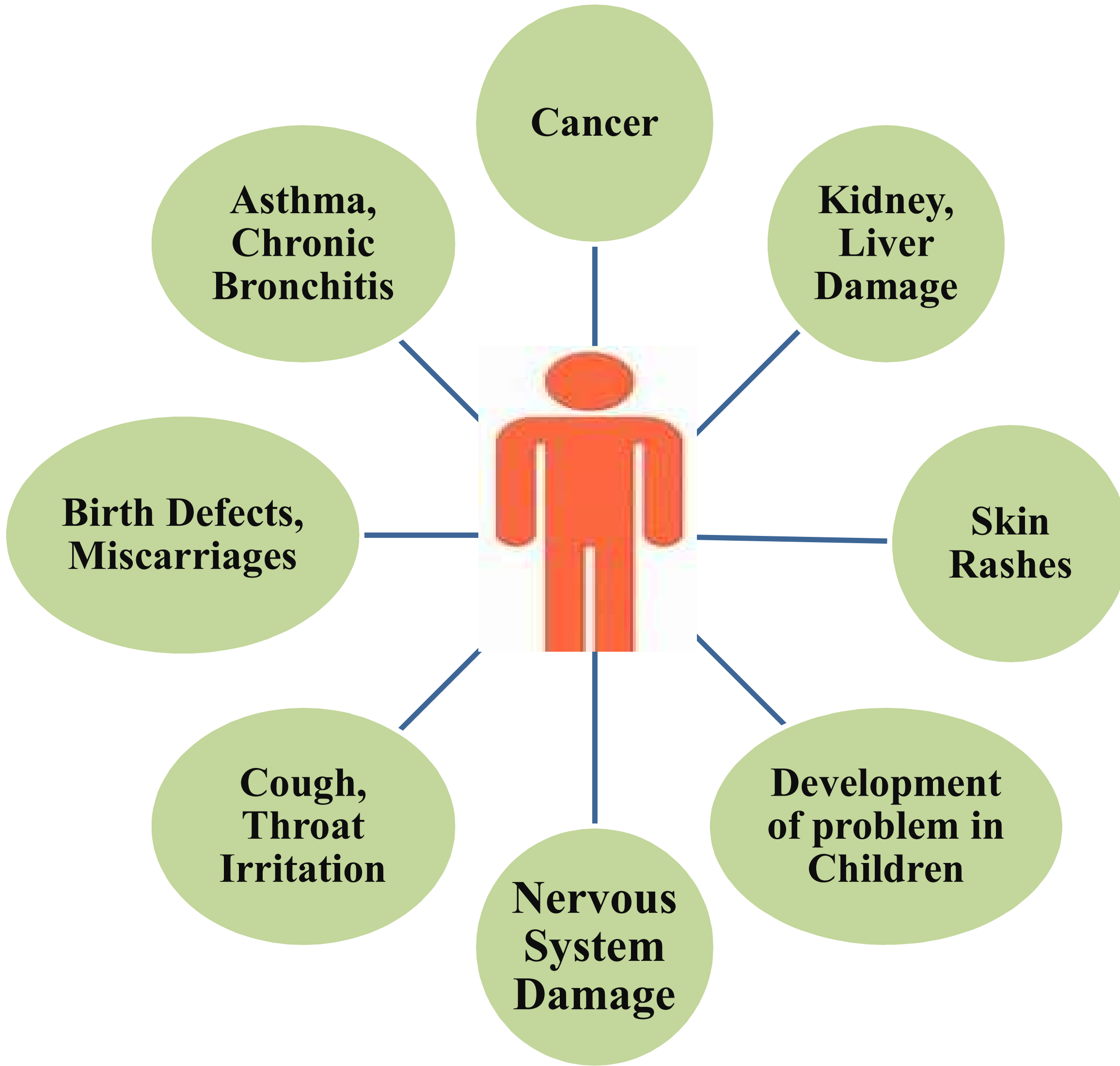
INTRODUCTION

- **Air pollution : one of the greatest "ENVIRONMENTAL EVIL".**
- **The air we breathe has not only LIFE SUPPORTING properties but also LIFE DAMAGING properties.**
- **An average man breathes 22,000 times a day and takes in 16 kg of air each day.**
- **All the impurities in the inhaled air do not necessarily cause harm. Some may be harmful when present in air in small concentration and others only if they are present in high concentration.**

Factors affecting human health

- Nature of the pollutants
- Concentration of the pollutants
- Duration of exposure
- State of health of the receptor
- Age group of the receptor

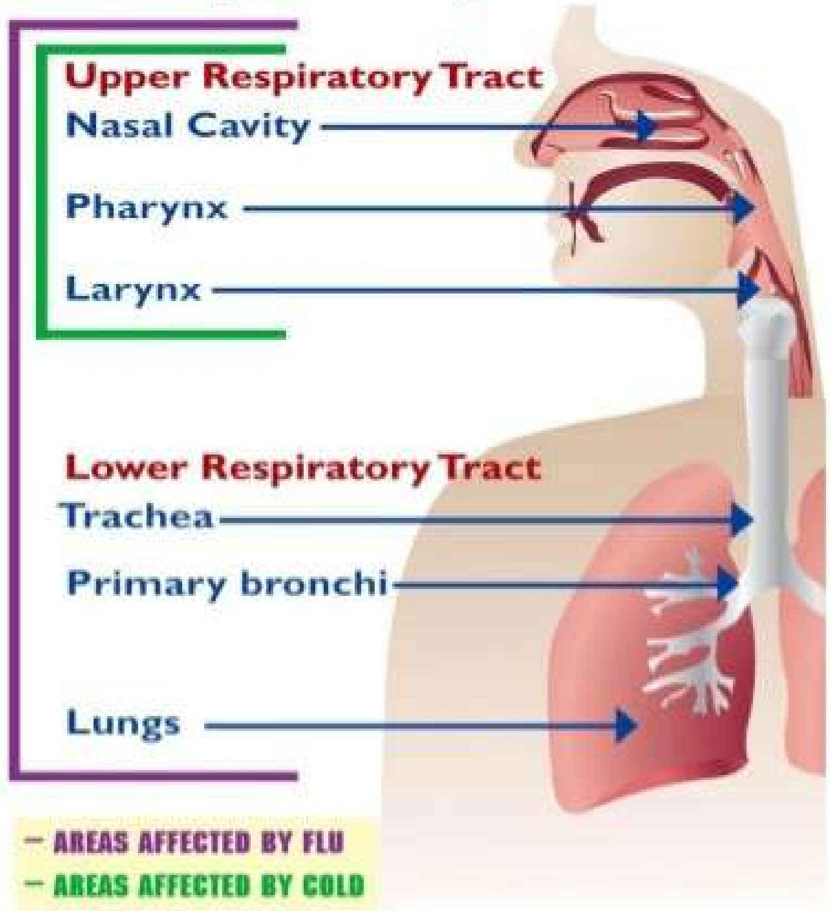
Target organ systems of air pollution



- **Acute effects** are usually immediate and often reversible when exposure to the pollutant ends. Some acute health effects include eye irritation, headaches, and nausea.

- **Chronic effects** are usually not immediate and tend not to be reversible when exposure to the pollutant ends.
  - Some chronic health effects include decreased lung capacity and lung cancer resulting from long-term exposure to toxic air pollutants.

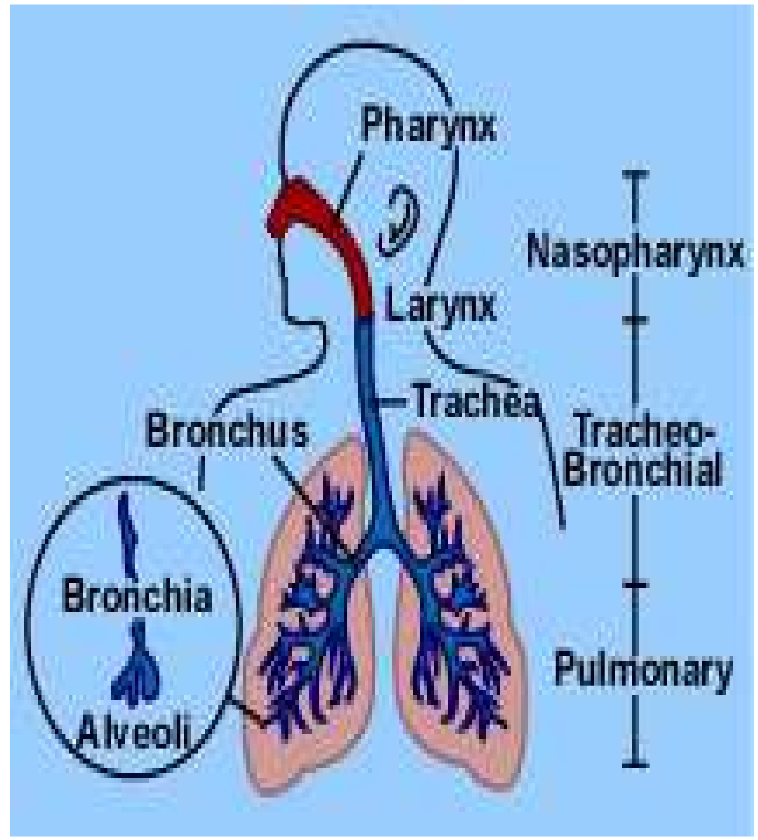
Respiratory Tract

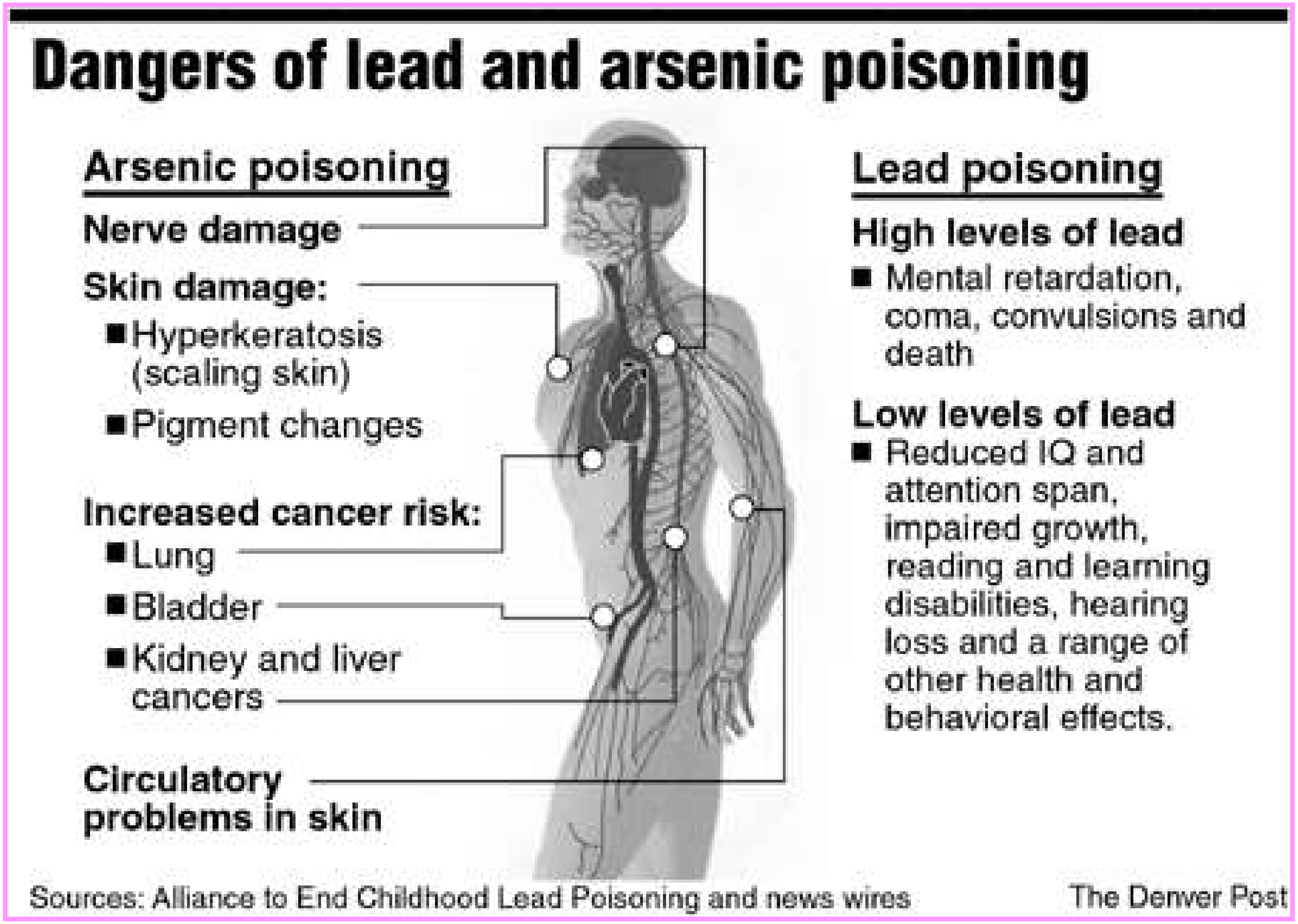


Effects on Human respiratory system

pollutants can have negative effects on the lungs.

- Solid particles can settle on the walls of the trachea, bronchi, and bronchioles.
- Continuous breathing of polluted air can slow the normal cleansing action of the lungs and result in more particles reaching the lower portions of the lung.
- Damage to the lungs from air pollution can inhibit this process and contribute to the occurrence of respiratory diseases such as bronchitis, emphysema, and cancer.




Dangers of lead and arsenic poisoning
Arsenic poisoning
Nerve damage
Skin damage:
■ Hyperkeratosis (scaling skin)
■ Pigment changes
Increased cancer risk:
■ Lung
■ Bladder
■ Kidney and liver cancers
Circulatory problems in skin
Lead poisoning
High levels of lead
■ Mental retardation, coma, convulsions and death
Low levels of lead
■ Reduced IQ and attention span, impaired growth, reading and learning disabilities, hearing loss and a range of other health and behavioral effects.
Sources: Alliance to End Childhood Lead Poisoning and news wires
The Denver Post

Diseases caused by air pollutants

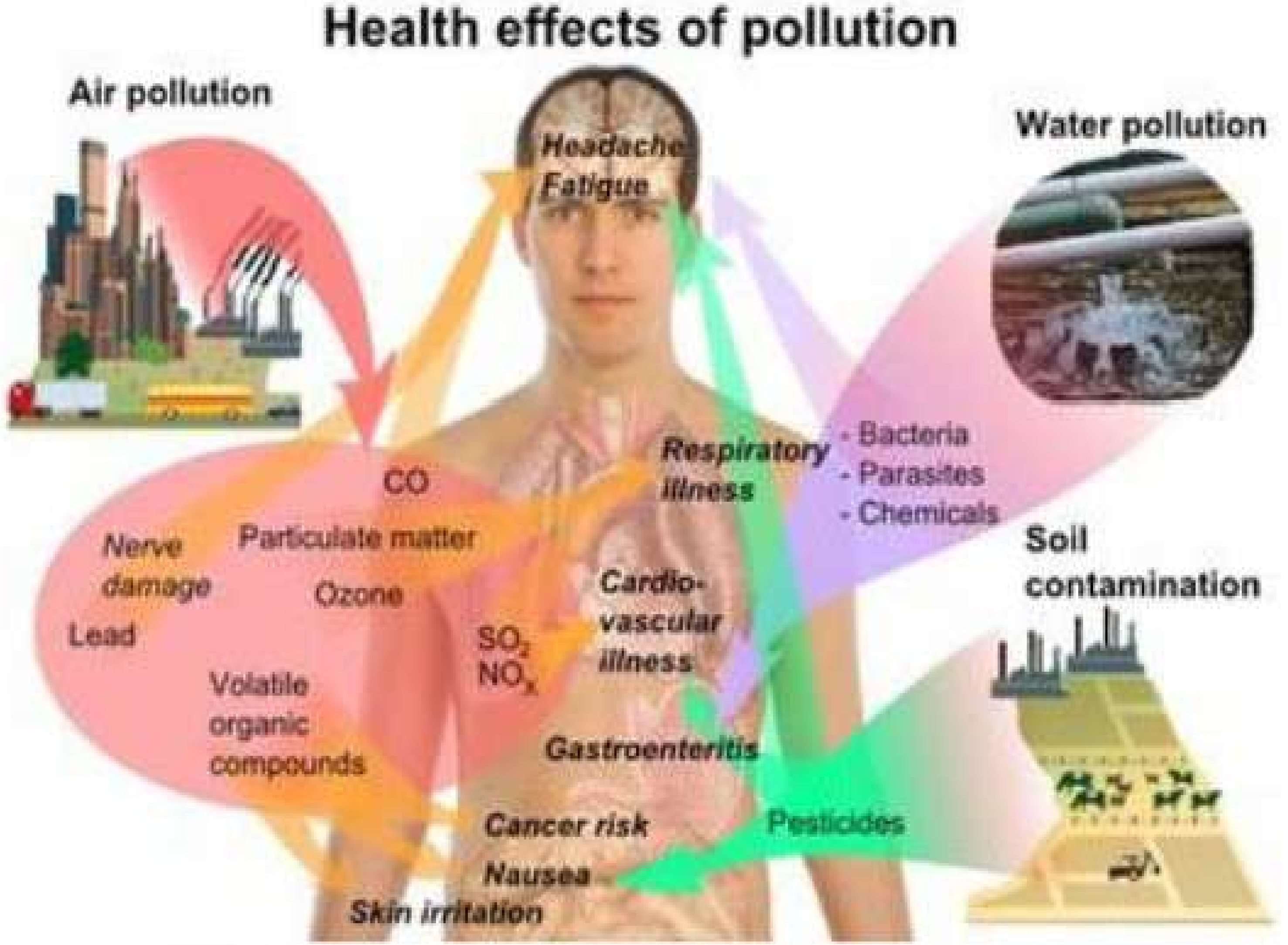


Table 1: Sources, Health and Welfare Effects for Criteria Pollutants				
Pollutant	**Description**	**Sources**	**Health Effects**	**Welfare Effects**
Carbon Monoxide (CO)	Colorless, odorless gas	Motor vehicle exhaust, indoor sources include kerosene or wood burning stoves.	Headaches, reduced mental alertness, 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.

Effects of Air Pollution

- Reduced lung functioning
- Irritation of eyes, nose, mouth and throat
- Asthma attacks
- Respiratory symptoms such as coughing and wheezing
- Increased respiratory disease such as bronchitis
- Reduced energy levels
- Headaches and dizziness
- Disruption of endocrine, reproductive and immune systems
- Neuro behavioural disorders
- Cardiovascular problems
- Cancer
- Premature death

Particulate Matter effect

❑ **Health effects**
✓ **Wheezing and coughing**
✓ **Heart attacks and death**
❑ **TSP (Total Suspended Particles)**
✓ **In presence of SO_2, direct correlation between TSP and hospital visits for bronchitis, asthma, emphysema, pneumonia, and cardiac disease**
✓ **~60,000 deaths from PM**

✓**1% increase in mortality for every 10 mg/m3 increase in PM**
- **Respiratory mortality up 3.4% for the same**
- **Cardiovascular mortality up 1.4% for the same**

❑ **PM_{10} (<10 µm, coarse (2.5-10 µm) and fine particles) – Anything larger deposited in the HAR (nasal- pharangycal)**

 $PM_{2.5}$ (<2.5 µm, fine particles)

✓ **Most serious health effects in alveolar/gas exchange region**

✓**shift in regulation focus**

✓**May adsorb chemicals & intensify their effects**

✓**Toxic or carcinogenic – pesticides, lead, arsenic, radioactive material**

✓**8% increase in lung cancer for each 10 µg/m^3 increase of $PM_{2.5}$**

Carbon Monoxide effect

- ❑ Colorless, odorless, tasteless gas --"Silent Killer"
- ✓ Cause: incomplete combustion
- ✓Source: transportation sector, energy production, residential heating units, some industrial processes
- ✓Ambient concerns addressed by NAAQS
- ✓Reacts with hemoglobin in blood – Forms carboxyhemoglobin (HbCO) rather than oxyhemoglobin (HbO2) – Prevents oxygen transfer

❑Toxic effects on humans

- ✓Low-level: cardiovascular and neurobehavioral
- ✓High-level: headaches/nausea/fatigue to possible death
- ✓Oxygen deficient people esp. vulnerable (anemia, chronic heart or lung disease, high altitude residents, smokers)
- ✓ Cigarette smoke: 400-450 ppm; smoker's blood 5- 10% HbCO vs 2% for non-smoker

Ozone effect

❑Cause: product of photochemical reactions
❑ Source: cars, power plants, combustion, chemical industries

❑Acute Health effects
✓ Severe E/N/T (ear/nose/throat) irritation
✓Eye irritation at 100 ppb
✓Interferes with lung functions
✓• Coughing at 2 ppm

❑ Chronic Health Effects - Irreversible, accelerated lung damage

NOx effect

- ❑Cause: Fuel combustion at high temps
- ❑Source: mobile and stationary combustion sources
- ✓ Prolonged exposure
- ✓ pulmonary fibrosis, emphysema, and higher LRI (lower respiratory tract illness) in children
- ✓ Toxic effects at 10-30 ppm –
  - Nose and eye irritation
  - Lung tissue damage
  - Pulmonary edema (swelling)
  - Bronchitis
  - Pneumonia
  - Aggravate existing heart disease

SOx effect

- ❑ Cause: Burning fuel that contains sulfur

- ❑Source: Electric power generation, diesel trucks
- ❑Gas and particulate phase
- ❑ Soluble and absorbed by respiratory system
- ❑ Short-term intermittent exposures
- ✓Bronchoconstriction (temporary breathing difficulty)
- ✓E/N/T irritation
- ✓ Mucus secretion
- Long-term exposures
- ✓ Respiratory illness
- ✓Aggravates existing heart disease
- Intensified in presence of PM
- ✓London issues were combination of the two

Lead (Pb) effect

❑Source: burning fuels that contain lead (phased out), metal processing, waste incinerators

❑ Absorbed into blood; similar to calcium

❑Accumulates in blood, bones, muscles, fat

✓ Damages organs – kidneys, liver, brain, reproductive system, bones (osteoporosis)

✓Brain and nervous system – seizures, mental retardation, behavioral disorders, memory problems, mood changes,

• Young children - lower IQ, learning disabilities

✓Heart and blood – high blood pressure and increased heart disease

✓Chronic poisoning possible

Bio-aerosols effect

❑Aerosols with organic origin
✓ Non-viable: pollen, dander, insect excreta, sea salt
✓Viable: microorganisms
✓Cause: aerosolization of organic material
Sources:
✓Human: sneezing, coughing
✓ Non-human: wind, waves, WWTP
Health Effects: allergies (pollen) to death (pathogenic organisms) – Pathogenic – Minimum Infectious Dose
Allergies
✓ Pollen, dander, fungi (spores)
✓Airborne transmission of disease – Bird flu, SARS, Legionnella (pneumonia)
✓Indoor Air Quality
•Ventilation Systems – moist ductwork, protection, recycled air
• Office Buildings – Sick Building Syndrome – Hospital (nosocomial)
• Biological Warfare – Anthrax, Ebola virus

EFFECT OF AIR POLLUTION ON VEGETATION

PRESENTED BY
DR PALLAVI DAS

AIR POLLUTANTS

- **Air pollutants affect plants worldwide.**
- **These effects may be severe or subtle.**
- **Various air pollutants have been identified as phytotoxic agents.**
- **Phytotoxicity of sulfur dioxide (SO_2) has been recognized for about a century .**
- **Effects of ozone (O_3) for more than 30 years).**
- **Acidic precipitation for almost 20 years .**
- **Effects of elevated levels of nitrogen compounds (nitrogen oxides [NO_X] and ammonia [NH_3]) in the last decade .**

HOW TO DETERMINE EFFECTS OF AIR POLLUTANTS ON PLANTS

- Under field conditions detection of physiological changes in plants and identification of their causes is difficult.
- Therefore visible symptoms of injury are most commonly used for detecting air pollution damage.
- However, changes in physiology of plants may occur before visible, morphological damage takes place.

Pollutant deposition to plants

❑ **Pollutants can be deposited to plants as**

✓ **gases.**

✓ **wet precipitation.**

✓ **particulate matter.**

❑ **Gaseous pollutants may be taken up by plants via**

✓ **stomata or**

✓ **cuticle.**

❑ **The effects of pollutants can be observed at various levels of biological. Organs like:**

✓ **subcellular,**

✓ **cellular,**

✓ **plant organ,**

✓ **whole plant,**

✓ **plant population**

✓ **community.**

EFFECTS ON VEGETATİON

Injury vs damage

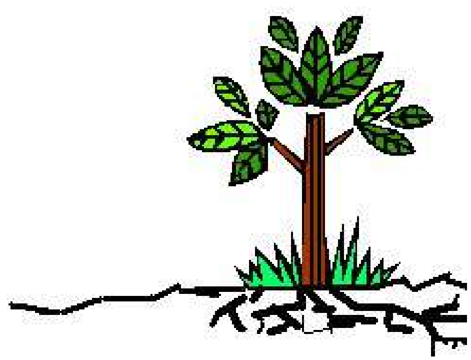
Injury: An observable alteration in the plant when exposed to air pollution

Damage: An economic or aesthetic loss due to interference with the use of a plant

Injury - **Generally, pollution injury first appears as leaf injury. Spots between the veins, leaf margin discoloration, and tip burns are common.**

Two ways of pollutant entrance to plant

- **Direct way: Through stomates which open and close to allow air through the interior parts**
- **Indirect way: Through the root system. Pollutants deposit in soil and water and these pollutants were taken by the roots of the plant.**



Leafs are important because of its functions

- **Photosynthesis accomplished by chloroplasts**

$6CO_2+6H_2O \longrightarrow C_2H_{12}O_6+6O_2$

- **Transpiration**: Movement of water from the root system up to the leaves. Nutrient movement and cooling
- **Respiration**:Oxidation of carbonhydrates, energy producing process.
- $C_2H_{12}O_6+6O_2 \longrightarrow 6CO_2+6H_2O$

COMMON SYMPTOMS OF DAMAGE ON PLANTS DUE TO AIR POLLUTION

❑ **CHLOROSIS (Yellowing of leaf)**

✓ **Due to lack of chlorophyll**

✓ **Damage of system where chlorophyll is produced**

❑ **NECROSIS : When the chlorotic area is exposed to pollutants for a larger duration then the chlorosis become necrosis. That area is called necrotic.**

✓**Most of time this area become red and brittle. The cell or tissue is not remain alive and became dead cells.**

✓**They are not metabolically active. They are unable to respire.**

✓**Necrosis is the acute stage of damage. This is the point where no return to the original stage takes place.**

OZONE INJURY

- Symptoms vary depending on the concentration of ozone in the air and the length of exposure, Ozone injury occurs on the most recently emerged leaves.

- Typical ozone injury may not be evident on leaves exposed to a mixture of pollutants. Symptoms differ in different areas of the province

- Ozone, the major component of oxidants is formed by the action of sunlight on products of fuel combustion and can be moved to nearby growing areas by wind.

Foliage with flecking "pepper spotting" injury typical of ozone injury

Ozone damage Note stippling symptoms on leaves

Ozone injury to soybean foliage

PAN İNJURY

Typical of Peroxyacetyl Nitrate (PAN) creates a glazy bronzing on the underside of newly expanded potato leaves.

<u>SO_2 Damage</u>: **SO_2 causes an interveinal necrosis.**

Acute sulfur dioxide injury to raspberry. The injury occurs between the veins and that the tissue nearest the vein remains healthy.

Fluorine Damage: **Marginal necrosis**

Fluoride injury to plum foliage. The fluoride enters the leaf through the stomata and is moved to the margins where it accumulates and causes tissue injury. Note, the characteristic dark band separating the healthy (green) and injured (brown) tissues of affected leaves.

Cement-dust coating on apple leaves and fruit. The dust had no injurious effect on the foliage, but inhibited the action of a pre-harvest crop spray.

Damage by acid rain

Severe ammonia injury to apple foliage and subsequent recovery through the production of new leaves.

Examples of physiological changes in trees caused by air pollution

Chlorophyll fluorescence: also proved to be a good indicator of ozone effects. Under the conditions of a well-defined ozone stress ponderosa pine seedlings showed a wide range of responses:

1- Gradual increase of visible injury (chlorotic mottle) was accompanied by reduction of net photosynthesis, stomatal conductance, starch accumulations and pigment concentrations.

2- More pronounced reduction of net photosynthesis than stomatal conductance suggested that ozone injury to mesophyll, carboxylation, or excitation components of the CO_2 diffusion pathway were greater than injury to the stomata. As a result of all these changes plants reduced their growth and biomass production (TEMPLE & BYTNEROWICZ 1993).

Effects on materials

Effects on metals

- Rusting
- Corrosion due to moisture, temperature and pollutants
- Alteration of electrical properties

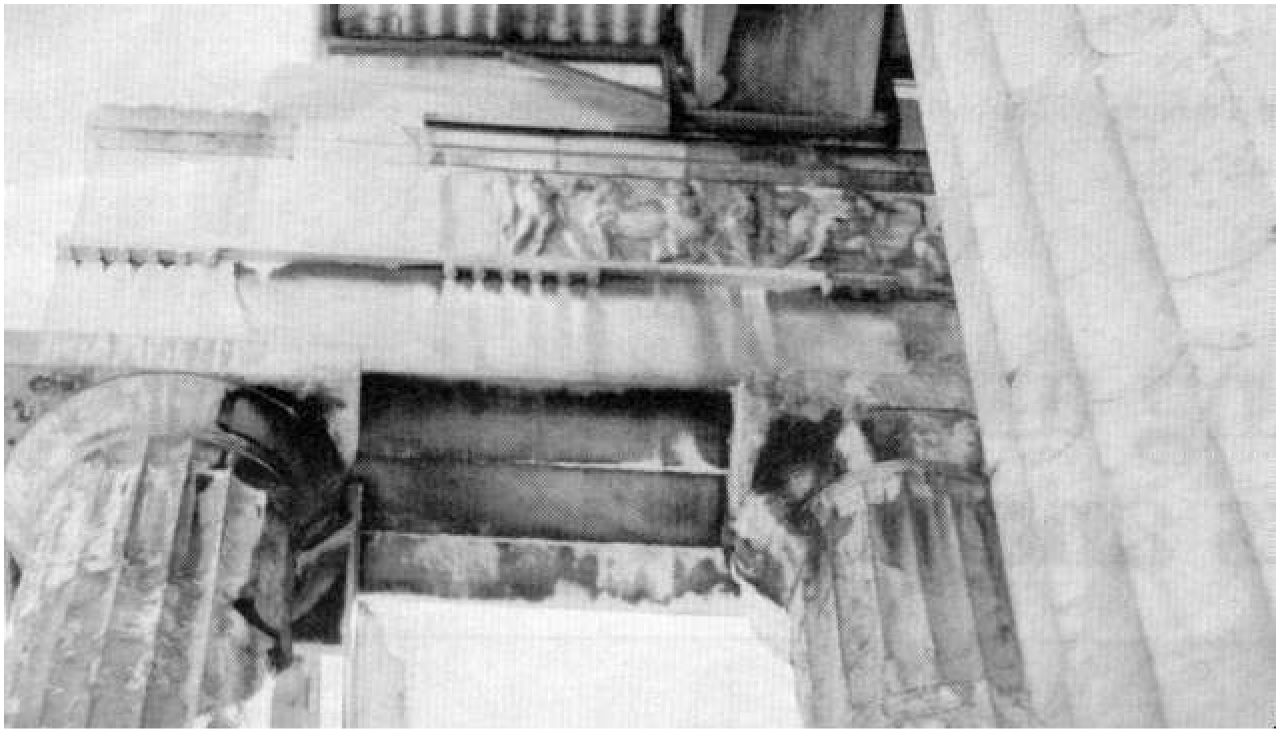
Effects on stone

- Discoloration
- Blackening
- gypsum formation
- Cracking

Gypsum formation

$$CaCO_3 + H_2SO_4 + 2H_2O \rightarrow CaSO_4.2H_2O + H_2CO_3$$

$$CaCO_3 + H_2CO_3 \rightarrow Ca(HCO_3)_2$$



These damaged areas seem to receive rain or rain runoff and seem to be formed by sulfur dioxide uptake, in the presence of moisture, on the stone surface.
Subsequent conversion of the sulfur dioxide to sulfuric acid results in the formation of a layer of gypsum on the marble surface.

Pollutant effects on stone monuments

The outcome can be predicted with reasonable certainty

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An oil refinery is being built nearly 30 km upwind from the Taj Mahal in Agra, India. This refinery is expected to emit 25–30 tons of sulfur dioxide daily, which is likely to travel towards the Taj Mahal from October to March due to the prevailing northwesterly winds (*1*). Such SO_2 emissions are expected to corrode the marble at the Taj Mahal in the same fashion that air pollution has contributed to the corrosion of marble at the nearly 70-year-old Field Museum of Natural History in Chicago.

In December 1978, the senior (first) author of this paper collected a few marble samples at the Taj Mahal to compare their condition with the marbles exposed at the Field Museum of Natural History in Chicago and the Erechtheion at the Acropolis in Athens. Knowledge of the mechanisms of marble decay enables the conclusion that the marble at the Taj Mahal—in the wake of the effluents of industrial combustion expected to pervade the environment of Agra—shall meet the same fate as the monuments of antiquity in industrial Europe and North America.

Of constituents produced by the combustion of fossil fuels, NO_x and SO_2 are the most potent for stone decay. During periods of dryness, they accumulate as particulate matter on stone surfaces and are activated by subsequent wetness. Dissolved in precipitation, they descend as acid solutions due to acid nitrates (*3*).

Emissions rising from stationary sources are commonly deposited at considerable distances from their sources. The pollutants generated in the Ohio Valley (*4*), for instance, have significantly contributed to the acidity of precipitation in the northeastern U.S., just as Scandanavian precipitation has become contaminated with the emission effluents of Western Europe in the wake of prevailing westerly winds (*5*).

Precipitation in equilibrium with atmospheric CO_2, the natural cause of acidity, has a pH of 5.65. The weak carbonic acid (H_2CO_3) that forms by the dissolution of CO_2 in water has been, until recently, the major cause of marble decay. NO_x and SO_2 emissions, however, have increased the acidity of precipitation. The black crusts and crumbling stone on marble structures in industrialized regions are

Figure 1A. The black crust, made of gypsum and soot, occurs in areas protected from rain. A portion of the crust is exfoliated at the site of the braids, obliterating details of the sculpture (Field Museum of Natural History, Chicago)

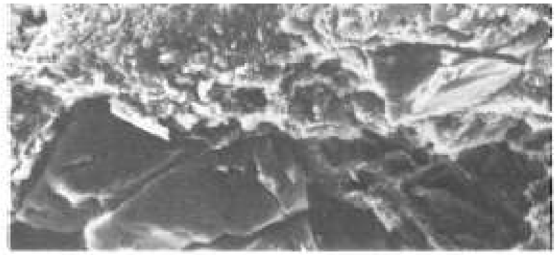


Figure 1B. The top one-fourth of this scanning electron micrograph shows the surface of the crust; beneath this is the entire thickness of the crust, followed by the calcite grains of marble, which is unaltered but has gypsum in the intergranular space

Figure 1C. An enlargement of the lower right corner of 1B shows the intercalated gypsum in continuity with the crust

may be written as follows:

$$CaCO_3 \xrightarrow[H_2O]{SO_2} CaSO_3 \cdot 1/2H_2O + CO_2$$
$$CaSO_3 \cdot 2H_2O + CO_2$$
$$\xrightarrow[H_2O]{O_2} CaSO_4 \cdot 2H_2O \quad (1)$$

$$CaCO_3 + SO_4^{2-} + 2H^+ + H_2O \rightarrow CaSO_4 \cdot 2H_2O + CO_2 \quad (2)$$

$$CaCO_3 + 2NO_3^- + 2H^+ \rightarrow Ca(NO_3)_2 + CO_2 + H_2O \quad (3)$$

Some of the gypsum ($CaSO_4 \cdot 2H_2O$) in solution is able to penetrate into the intergranular space (our methods of study—x-ray diffraction, and SEM and petrographic microscopy—have not enabled us to resolve $Ca(NO_3)_2$ as yet) while the rest is either washed away or deposited in the form of a crust on the marble surface. Continued weathering behind these crusts causes them to fall off in layers, seriously damaging the structures (Figure 2).

In unprotected areas of buildings (those washed by rain), crusts are unable to form. However, acidic solutions freely migrate around the grains. The dissolution of calcite results in the grain-by-grain dissociation of marble. It may seem paradoxical, but marble in sheltered regions suffers more serious damage than marble in unprotected regions (Figure 2).

In crusted marble, the thickness of the zone of weathering—the region including the surface crust as well as the depth to which the gypsum has intercalated the intergranular space—varies with different marbles. This is controlled by the porosity characteristics of the marbles. Georgia marble is highly massive and contains bands of fine-grained minerals—is nearly 0.5 mm thick. A carrara-type marble, however, used in the construction of certain belt courses at the Field Museum, is more porous and lacks the secondary fine-grain minerals in the interstices. This permits a freer circulation of chemically active solutions through the pore space. As a result, the zone of weathering in this marble is much thicker, approaching a thickness of nearly 4 mm.

In unprotected, naturally cleaned surfaces, the zone of weathering lacks a definite identity. However, the enlarged space between calcite grains is clearly visible (Figure 3). Here, in fact, the thin zone of weathering is the region with enlarged intergranular space. X-ray diffraction and optical observations do not reveal any gypsum, but its presence has been confirmed by atomic absorption spectrophotometric analysis (Table 1). To obtain correlations between different samples, the

EFFECT OF AIR POLLUTION

❖ **GLOBAL WARMING**

❖ **Global warming is largely caused by increasing CO2 and other heat trapping gases (e.g. methane) in the atmosphere.**

❖ **Large amount of heat trapped on Earth; Earth becomes hotter.**

❖ **It results in rise in sea levels, flooding of low-lying lands, melting of polar ice caps and changes in global climate.**

❖**Measures to reduce global warming-use of fossil fuels (to reduce CO2 emission)**

❖ **Use tidal, wind and hydroelectric energy to generate electricity -use of solar energy.**

Introduction to acid rain

Normal rain water is always slightly acidic because CO_2 present in atmosphere. get dissolved in it form carbonic acid. Normal acidity of rain water is 5.6

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

Because of SO_2 & NO_2 gases as pollutants in atmosphere. The pH of rain is further lowered to as 2.4 & this type of Precipitation is called as **ACID RAIN**.

Acid rain is combination of H_2SO_4, HNO_3 and HCl is third

ACID RAIN

WHAT IS ACID RAIN?

- **Generally, rain water has a pH valueof 5.6 because of the carbondioxide from air dissolved in it.**

- **Any rainfall has a pH value lessthan 5.6 is defined as acid rain.**

- **When emissions of sulphur dioxide and nitric oxide from stationary sources are transported long distances by winds, they form secondary pollutants such as nitrogen dioxide, nitric acid vapor, and droplets containing solutions of sulphuric acid, sulphate, and nitrate salts.**

- **These chemicals descend to the earth's surface in wet form as rain or snow and in dry form as a gases fog, dew, or solid particles, it is known as acid rain or acid deposition**

When gas pollutants e.g. sulphurdioxide, nitrogen dioxide dissolve in rain water, various acids are formed.

$CO_2 + H_2O \rightarrow H_2CO_3$ (carbonic acid)
$SO_2 + H_2O \rightarrow H_2SO_4$ (Sulphuric acid)
$NO_2 + H_2O \rightarrow HNO_3$ (nitric acid)

IMPACT OF ACID RAIN

Acid Rain can impact

- ❖ **Surface water (lakes, river etc) and aquatic animals**
- ❖**Soils**
- ❖ **Forest and Vegetation**
- ❖ **Human Health**
- ❖**Building and the urban environment**

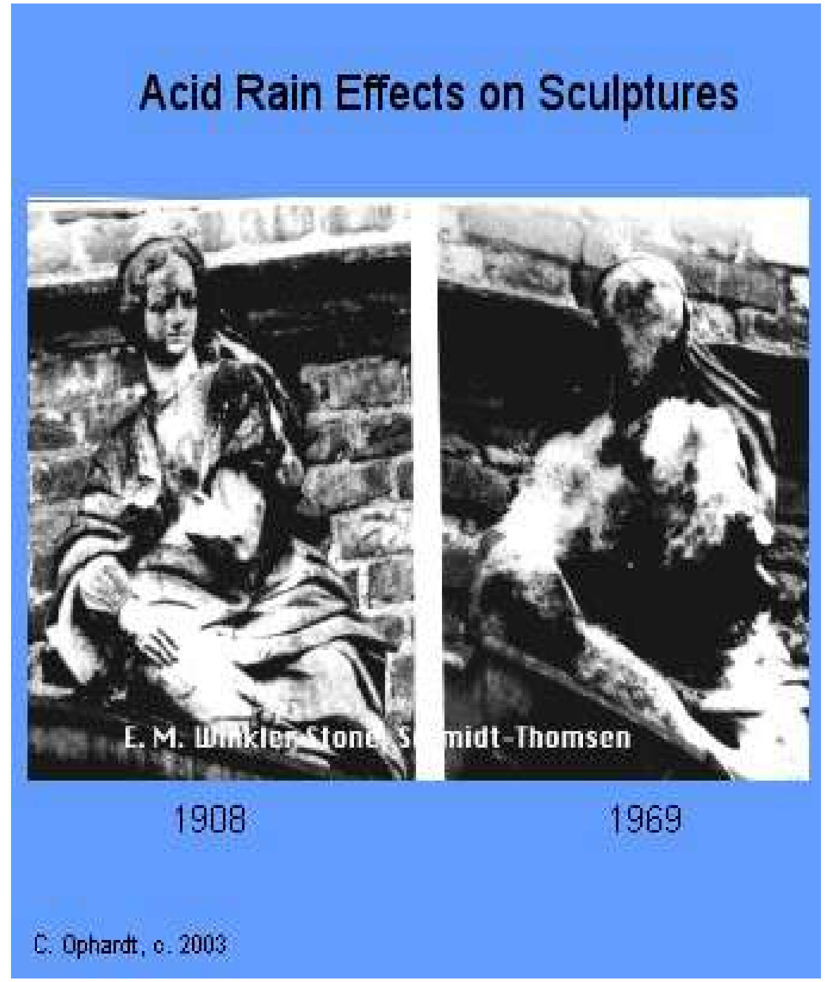
Effect On Buildings

➢Causes extensive damage to buildings, structural materials of marble ,limestone, slate etc.

$CaC0_3+H_2S0_4+ CaS0_4+H_2 0+C0_2$

➢In Greece and Italy invaluable stone statues have been partially dissolved by acid rain.

➢Taj Mahal in Agra is also due to acid fumes from refinery. suffering Mathura Acid Rain Effects on Sculptures



Effect on Soil

- **Acid Rain also affects the soil by the soil neutralizing the acids.**

- **Soils that contain Limestone and Calcium Carbonate can neutralize the acids.**

- **Leaching- a process in which acid deposition adds hydrogen ions which displaces important nutrients like Calcium, Magnesium, and Potassium.**

- **Leaching pushes the ions deeper in the soil so the plants roots can’t reach them.**

Effect on Fish

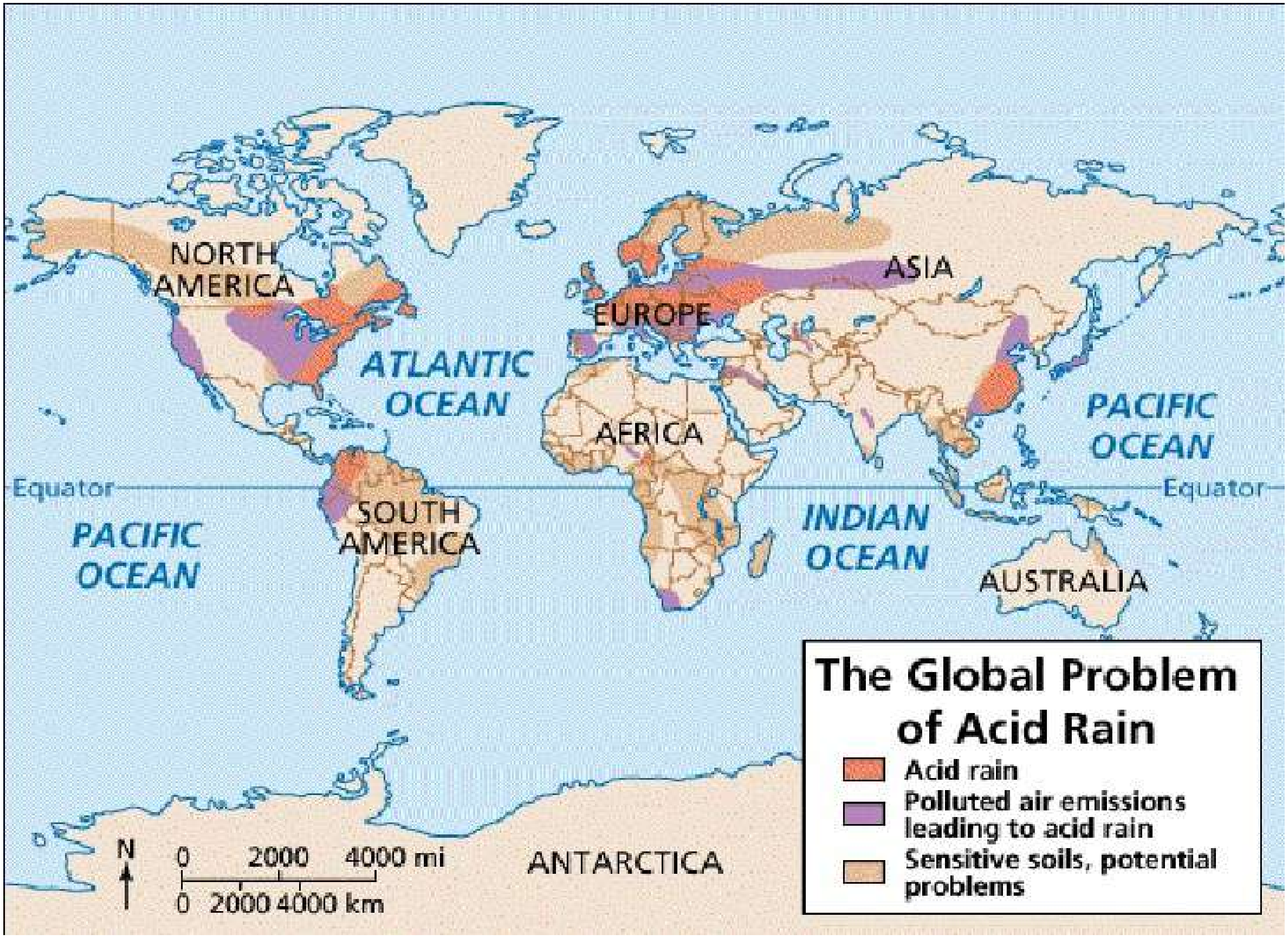
- **During the winter dangerously acidic pollutants have built up in the snow and when the snow melts in spring all the acid drains into the water system killing many fish.**
- **Even those who survive suffer from Acid Stress**

Other affect on the fish are reduced egg composition, decreased growth, inability to regulate there own body chemistry, and deformities in young fish and increased susceptibility to naturally occurring diseases.

- **These mass fish disappearances affects the birds and eventually our whole ecosystem.**

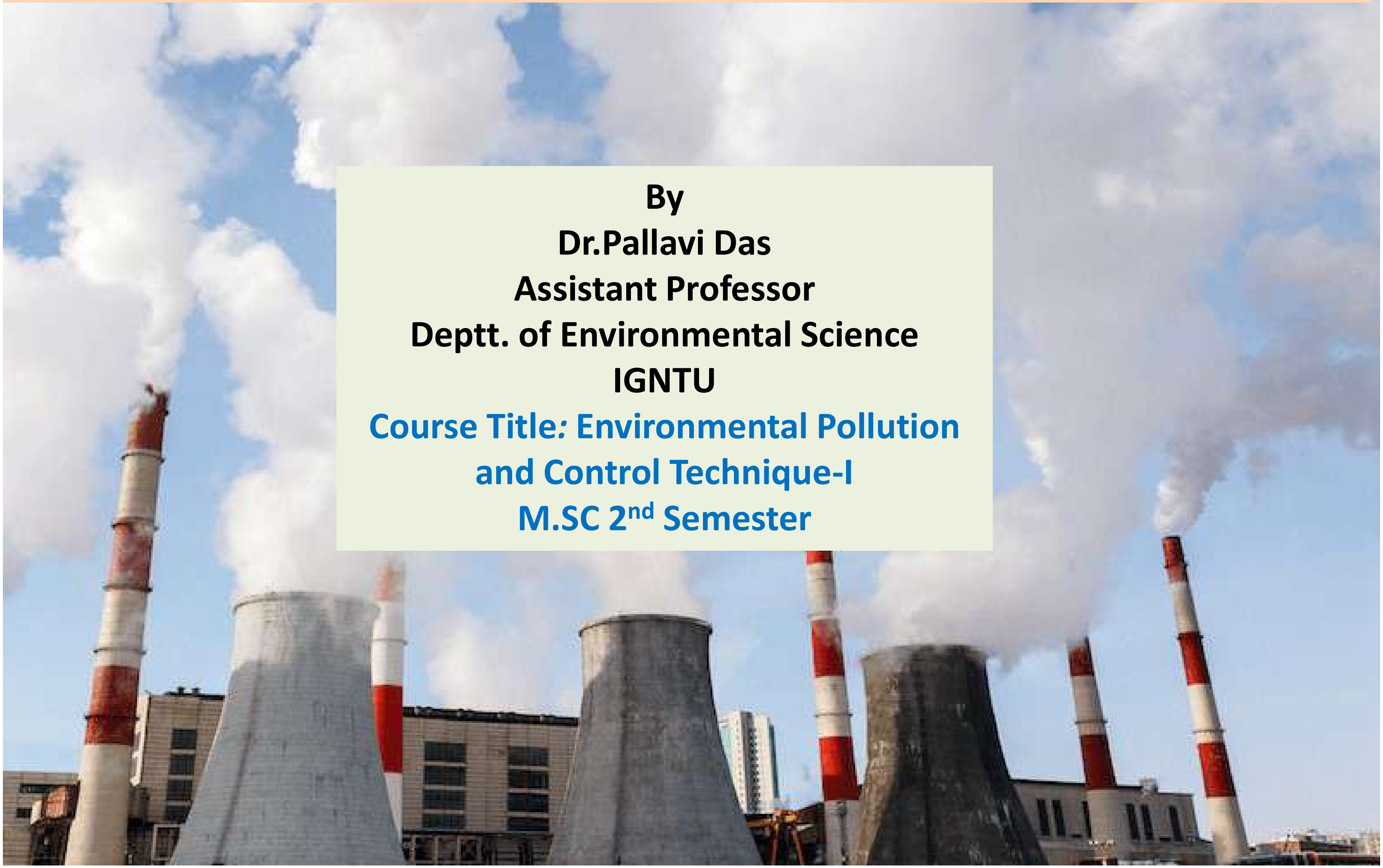
Destruction of Forests and Natural Resources

- **The extinction of the plants and animals leads to diminished gene pool.**
- **The lack of biodiversity and a reduced planetary gene pool could have many unforeseen consequences, some of which could be fatal to the future of humanity.**
- **Acid Rain can contaminate drinking water supplies . If someone were to drink water from this supply then they could sustain many health related problems.**


NORTH AMERICA
EUROPE
ASIA
ATLANTIC OCEAN
PACIFIC OCEAN
AFRICA
Equator
Equator
SOUTH AMERICA
PACIFIC OCEAN
INDIAN OCEAN
AUSTRALIA
ANTARCTICA
N
0 2000 4000 mi
0 2000 4000 km
The Global Problem of Acid Rain
Acid rain
Polluted air emissions leading to acid rain
Sensitive soils, potential problems

Thanks

AIR POLLUTION CONTROL TECHNIQUE



By

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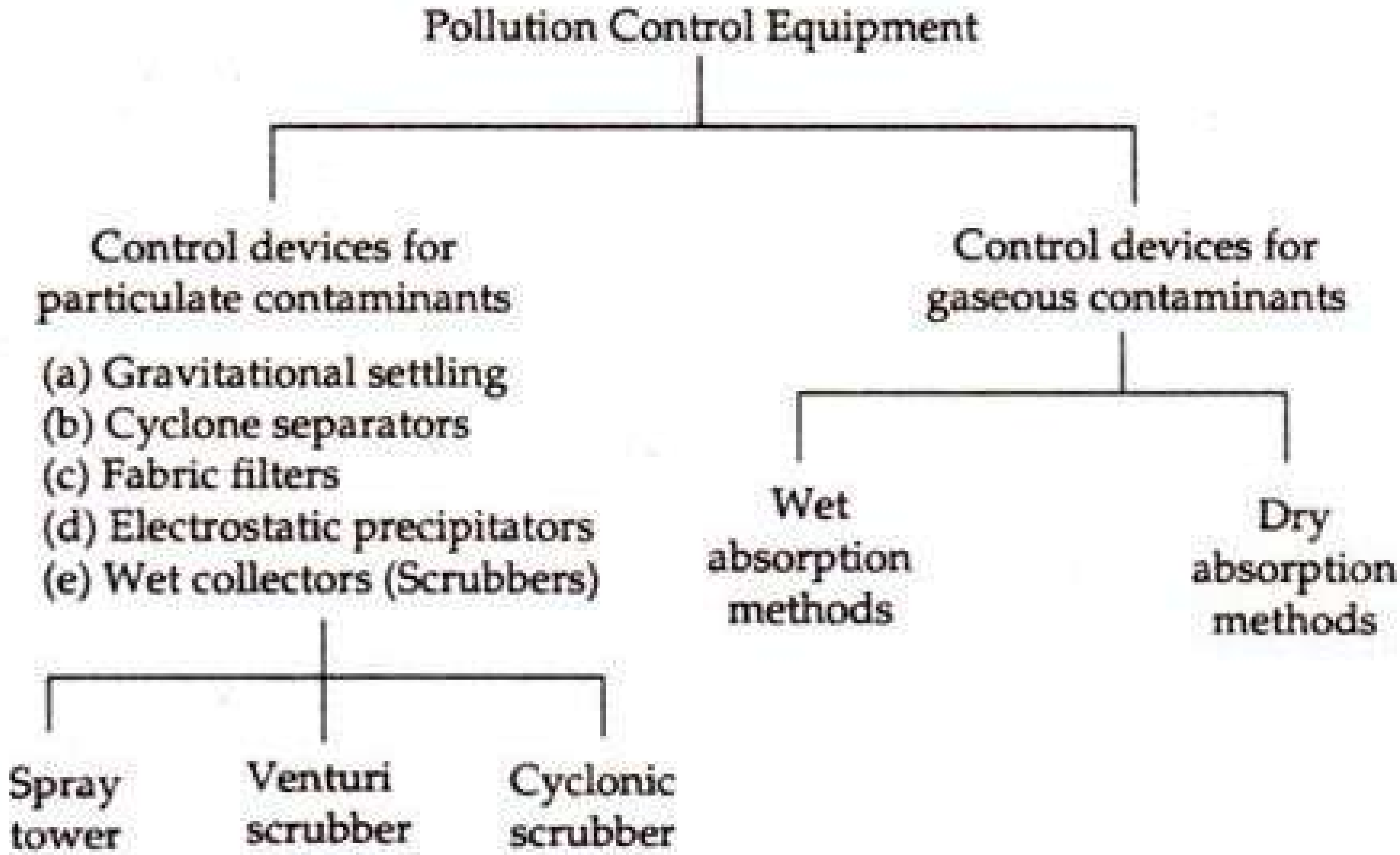
Deptt. of Environmental Science

IGNTU

Course Title*:* Environmental Pollution and Control Technique-I

M.SC 2nd Semester


Pollution Control Equipment
Control devices for particulate contaminants
(a) Gravitational settling
(b) Cyclone separators
(c) Fabric filters
(d) Electrostatic precipitators
(e) Wet collectors (Scrubbers)
Spray tower
Venturi scrubber
Cyclonic scrubber
Control devices for gaseous contaminants
Wet absorption methods
Dry absorption methods

Objectives of control equipment

- ✓ Prevention of nuisance
- ✓ Prevention of physical damage to property
- ✓ Elimination of health hazards to plant personnel
- ✓ Recovery of valuable waste product
- ✓ Minimization of economic losses
- ✓ Improvement of product quality

Control Devices for Particulate Contaminants:

(1) Gravitational Settling Chamber

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

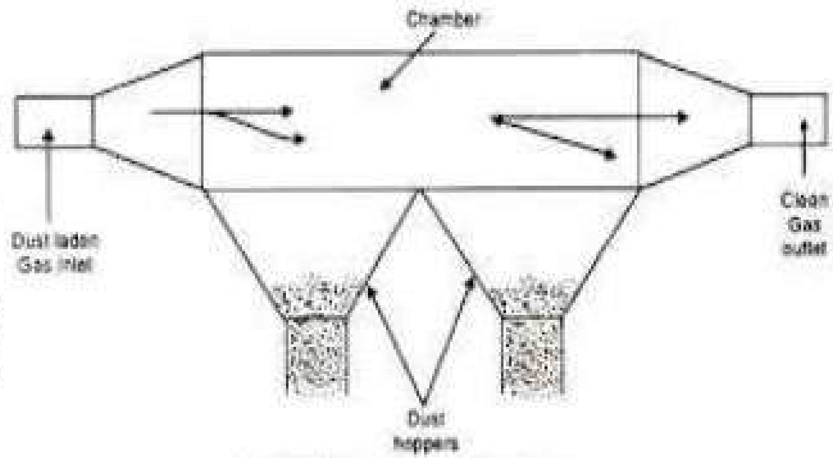


Fig. 6.4. Horizontal Flow Settling Chamber.

$$V_s = hV/L \text{ ----------- (i)}$$

L= length of chamber
V= horizontal velocity of carrier gas
Vs= settling velocity of particulates
h= height through which particulates travel before settling down

By stokes law

$$V_s = g(\rho p - \rho)D^2/18\mu \text{ --------- (ii)}$$

D= dia of particle; g= acceleration due to gravity; ρp= density of particle; ρ = density of gas; μ= viscosity of gas

From eq- i and ii

$$D = [18Vh\mu / Lg(\rho p - \rho)]1/2$$

D = is minimum size of particle that can be removed in a settling chamber

(2) Cyclone Separators (Reverse flow Cyclone)

❖Instead of gravitational force, centrifugal force is utilized by cyclone separators, to separate the particulate matter from the polluted gas.

❖ A simple cyclone separator consists of a cylinder with a conical base. A tangential inlet discharging near the top and an outlet for discharging the particulates is present at the base of the c

❖The dust laden gas enters tangentially, receives a rotating motion and generates a centrifugal force due to which the particulates are thrown to the cyclone walls as the gas spirals upwards inside the cone.

❖The particulates slide down the .walls of the cone and are discharged from the outlet.

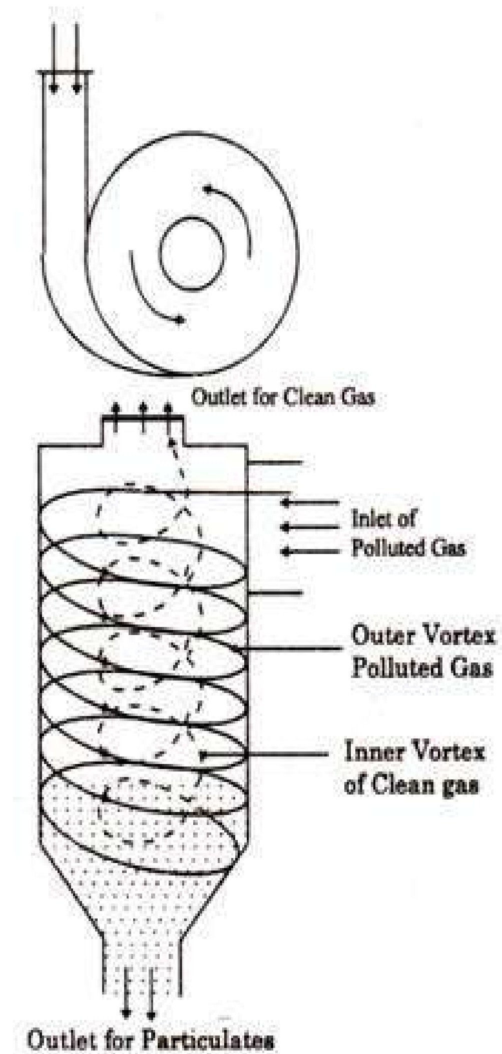


Fig. 5.2. Cyclone Separator
(Reverse Flow Cyclone)

(3) Fabric Filters (Baghouse Filters)

❖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 mi-cron particles (0.5 µm).

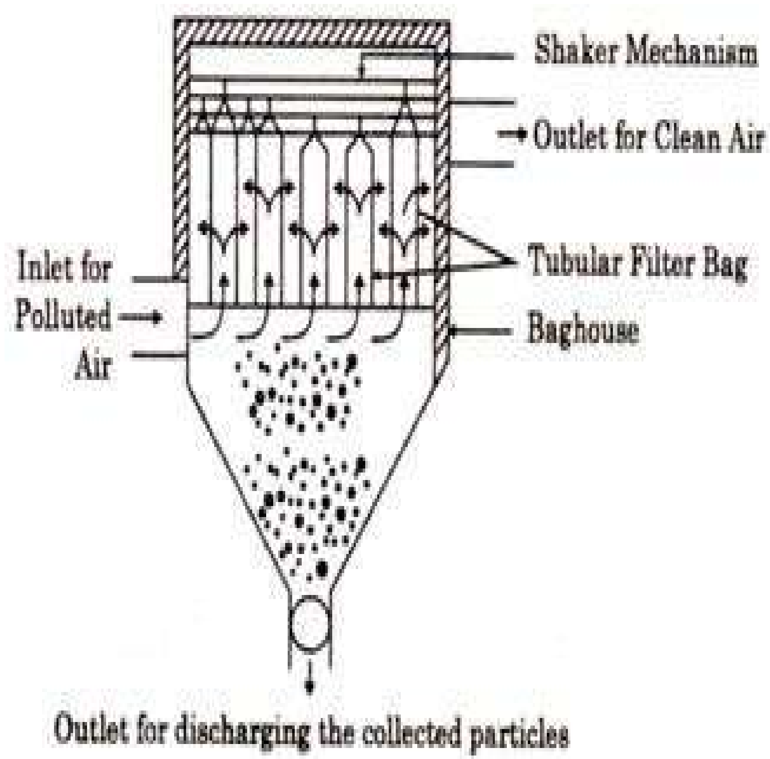
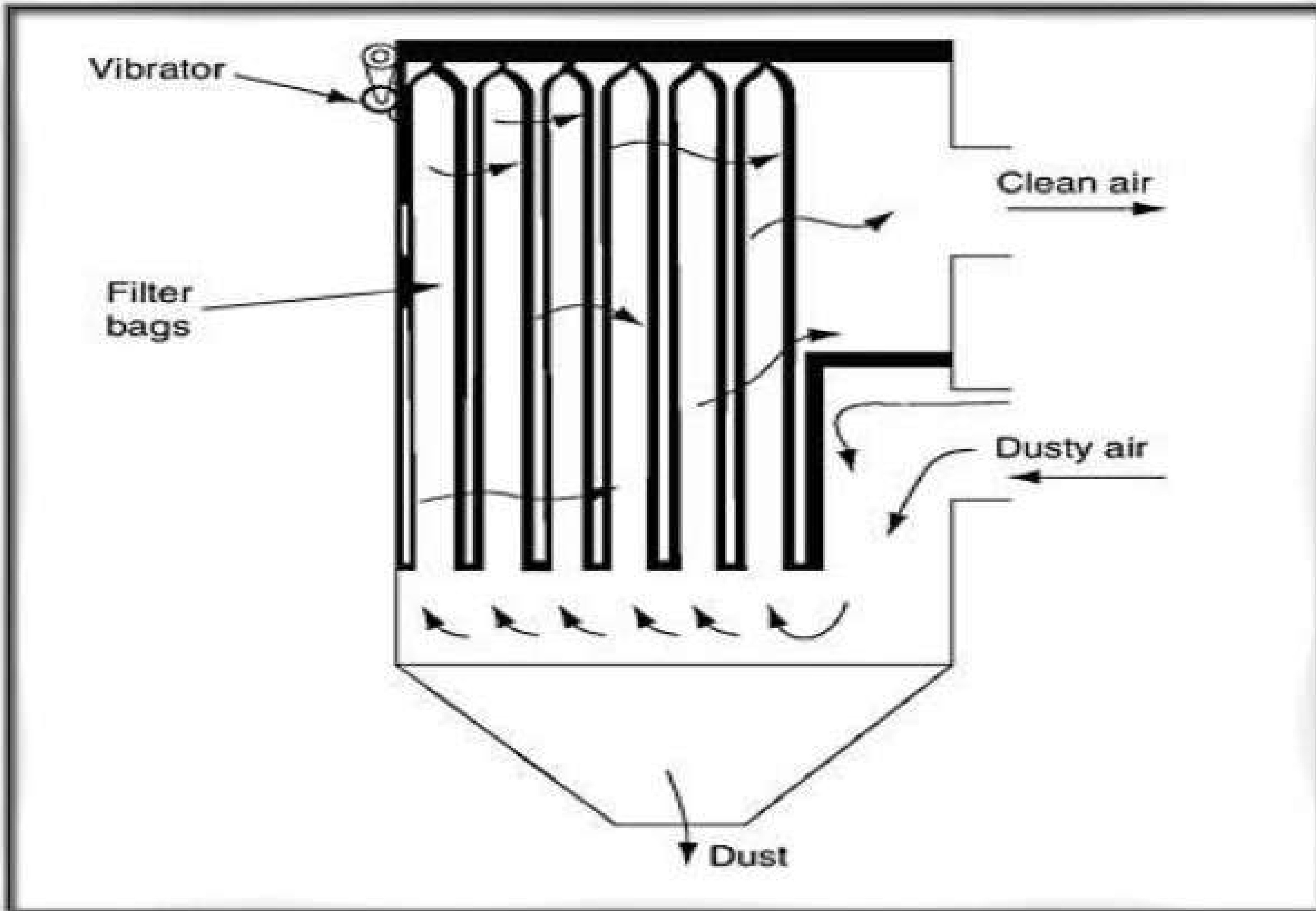


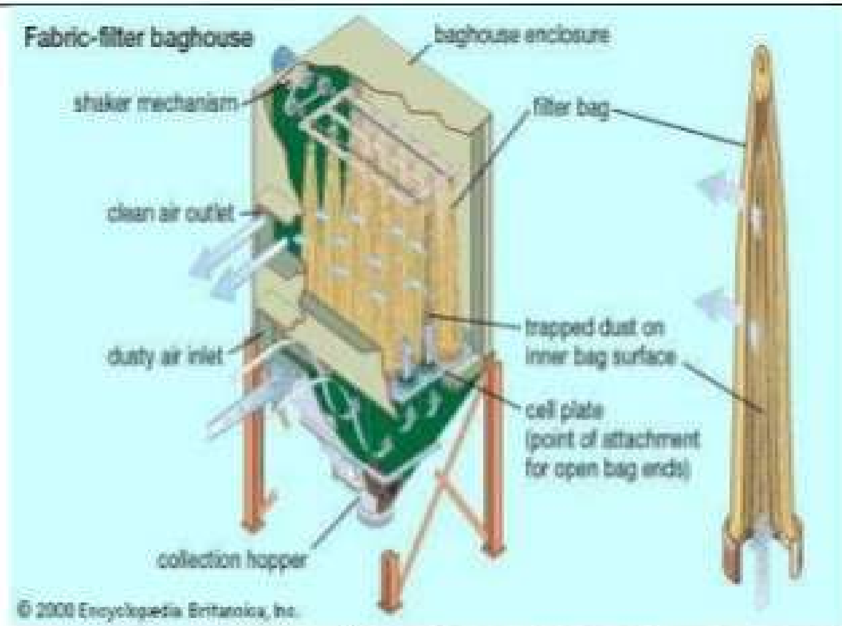
Fig. 5.3 Fabric Filter (Baghouse Filter)

- **A typical filter is a tubular bag which is closed at the upper end and has a hopper attached at the lower end to collect the particles when they are dislodged from the fabric.**

- **Many such bags are hung in a baghouse.**

- **For efficient filtration and a longer life the filter bags must be cleaned occasionally by a mechanical shaker to prevent too many particulate layers from building up on the inside surfaces of the bag.**


Vibrator
Clean air
Filter
bags
Dusty air
Dust


Fabric-filter baghouse
baghouse enclosure
shaker mechanism
filter bag
clean air outlet
trapped dust on
inner bag surface
dusty air inlet
cell plate
(point of attachment
for open bag ends)
collection hopper
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APPLICATION

- Metallurgical Industry
- Foundries
- Cement Industry
- Chalk and Lime
- Brick Works
- Ceramic Industry
- Flour mills

Electrostatic precipitators

❖Works on the principle of electrical charging of particulate Matter (-ve) and collecting it in a (+ve) charged surface. 99% efficiency. Can remove particle size range of 0.1 µm to 1 µm.

❖ Six major components

✓ A source of high voltage

✓Discharge electrodes and collecting electrodes

✓Inlet and outlet for gas

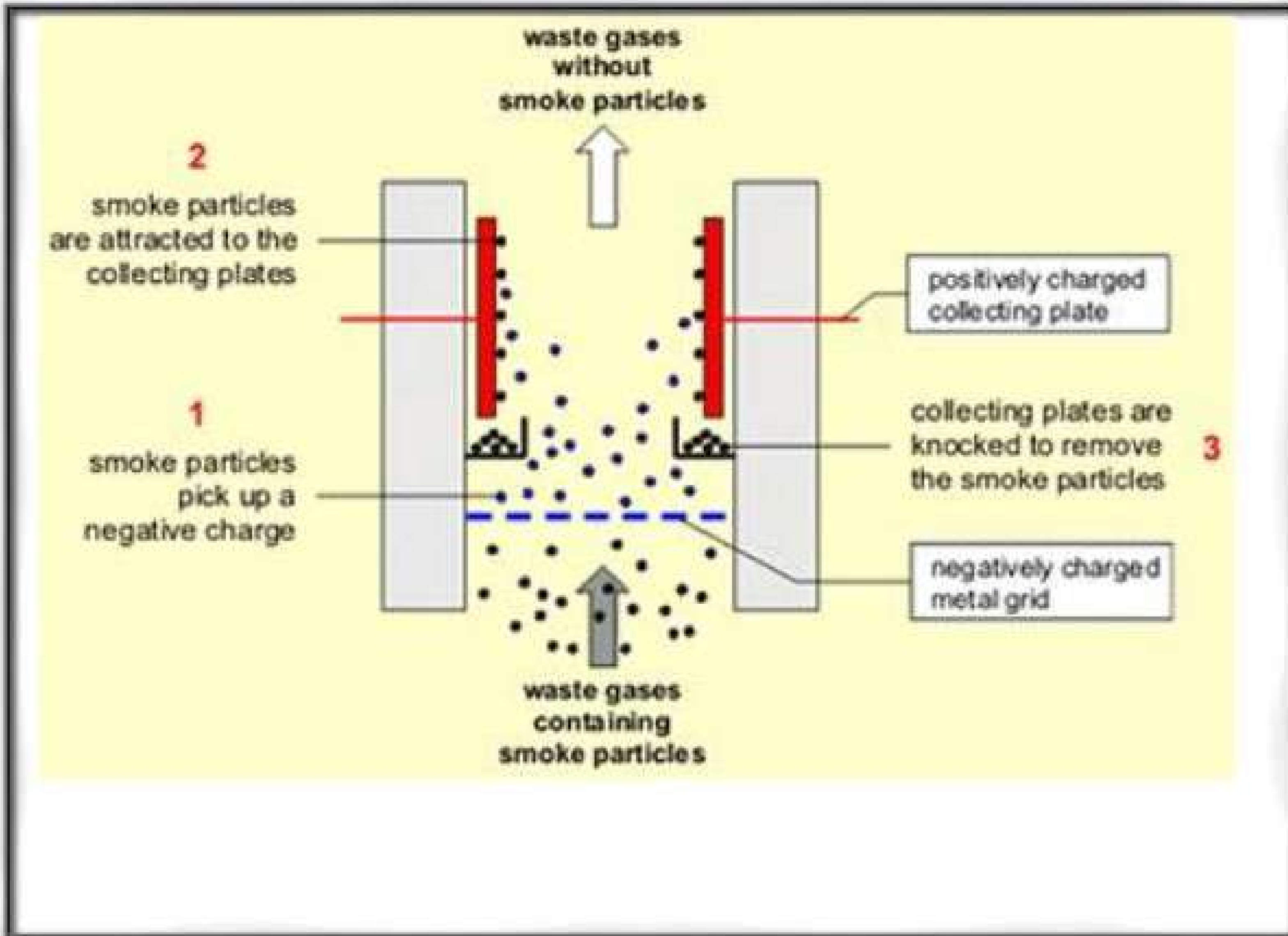
✓A hopper for disposal of collected material A

✓An electronic cleaning system

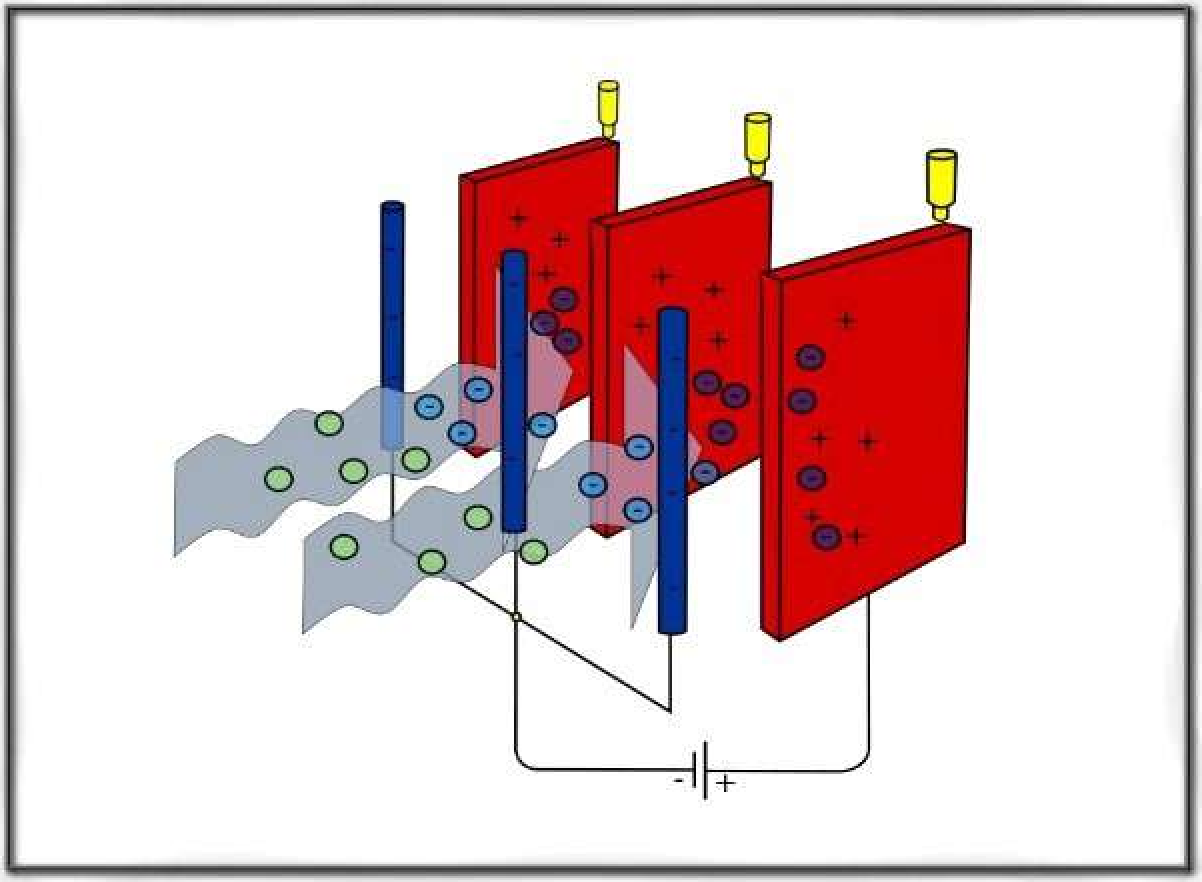
✓An outer casing to form an enclosure around electrodes

Principles

- Gas stream passed two electrodes.
- High potential difference is maintained.
- Out of two electrodes, one is discharging other collecting.
- Potentials of 100 kv are used. Ionization creates active glow zone called “corona”.
- Gas ionization is dissociation of gas molecules into free ions. As particulates pass through field, they get charged and migrate to oppositely charged electrode.
- Particles deposited on collecting electrodes, lose charge and removed mechanically by rapping., vibration or washing to a hopper.



waste gases
without
smoke particles
2
smoke particles
are attracted to the
collecting plates
positively charged
collecting plate
1
smoke particles
pick up a
negative charge
collecting plates are
knocked to remove
the smoke particles
3
negatively charged
metal grid
waste gases
containing
smoke particles



Single stage and two stage precipitators

- ❑Single stage gas ionization and particulate collection in a single stage.

- ❑ Two stage, particle ionized in first chamber and collected in second chamber.

- ❑Industrial precipitators single stage design.

- ❑ Two stage used for lightly loaded gases.

- ❑ Single stage for more heavily loaded gas streams.

❑Advantages

- ✓High collection efficiency.
- ✓Particles may be collected dry or wet.
- ✓ Can be operated at high temp. (300-450°c).
- ✓ Maintenance is normal.
- ✓Few moving parts

❑ Disadvantages

- ✓High initial cost.
- ✓Require high voltage.
- ✓Collection efficiency reduce with time.
- ✓ Space requirement is more.
- ✓ Possible of explosion during collection of combustible gases or particulates.

Applications

- ✓ **Cement factories**
- ✓ **Pulp and paper mills**
- ✓ **Steel plants**
- ✓ **Non- ferrous metal industry**
- ✓ **Chemical industry**
- ✓ **Petroleum industry**
- ✓ **Carbon black industry**
- ✓ **Electric power industry**

(5) Wet Collectors (Scrubbers):

In wet collectors or scrubbers, the particulate contaminants are removed from the polluted gas stream by incorporating the particulates into liquid droplets.

Common wet scrubbers are:

(i) Spray Tower

(ii) Venturi Scrubber

(iii) Cyclone Scrubber

(i) Spray Tower

❖Water is introduced into a spray tower by means of a spray nozzle (i.e. there is downward flow of water).

❖As the polluted gas flows upwards, the particulates (size exceeding 10 µm) present collide with the water droplets be-ing sprayed downward from the spray nozzles.

❖Under the influence of gravita-tional force, the liquid droplets containing the particulates settle to the bottom of the spray tower.

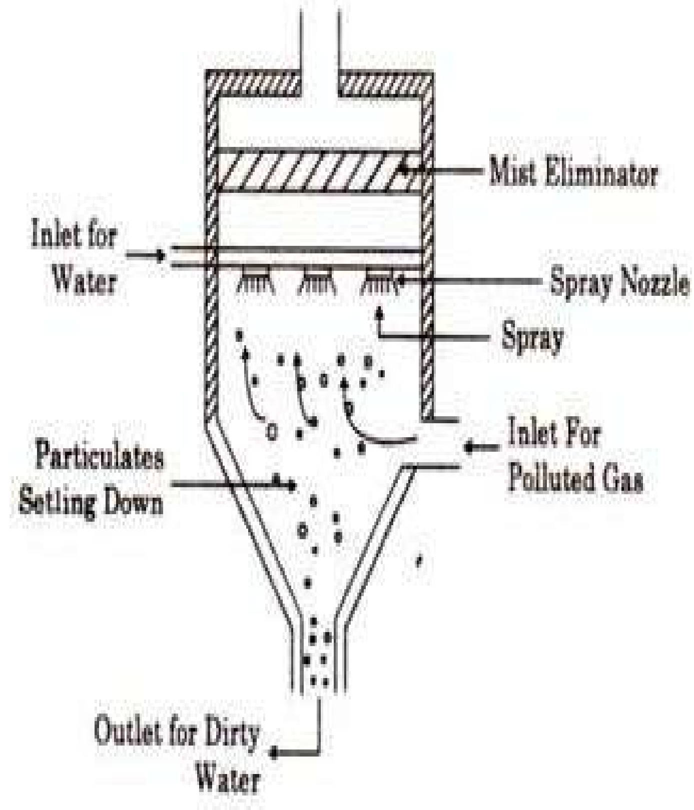


Fig. 5.5. Spray Tower

(ii) Venturi Scrubber

❖Submicron particulates (size 0.5 to 5 μn) associated with smoke and fumes are very effectively removed by the highly efficient

❖Venturi Scrubbers. Venturi Scrubber has a Venturi shaped throat section.

❖The polluted gas passes downwards through the throat at the velocity of 60 to 180 m/sec.

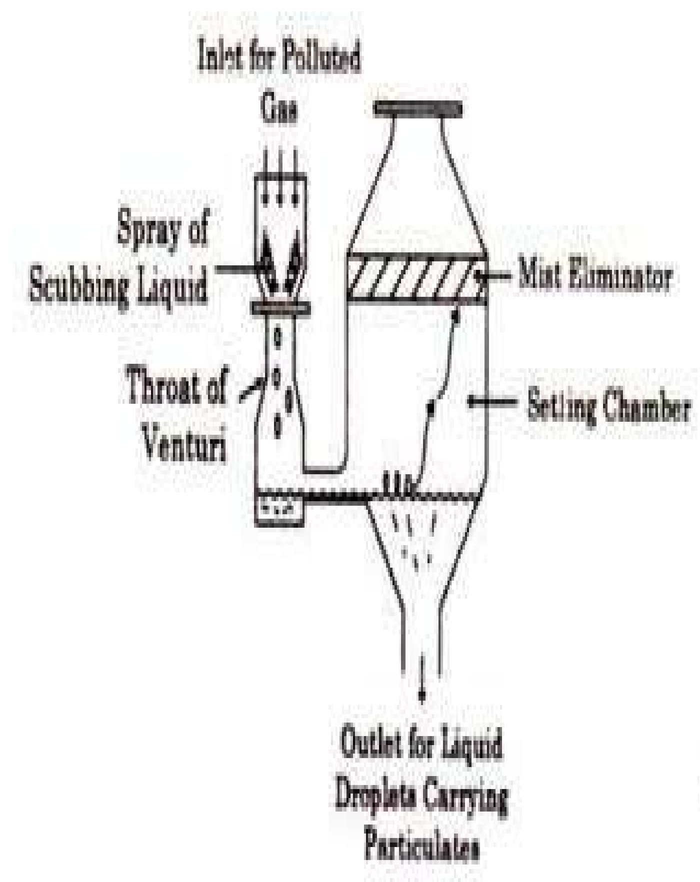


Fig. 5.6. Venturi Scrubber Connected to a Cyclone Separator

❖A coarse water stream is injected upwards into the throat where it gets atomised (i.e. breaks the water into droplets) due to the impact of high velocity of the gas.

❖The liquid droplets collide with the particulates in the polluted gas stream.

❖The particles get entrained in the droplets and fall down to be removed later on.

❖Venturi Scrubbers can also remove soluble gaseous contami-nants. Due to the atomisation of water there is proper contact between the liquid and the gas increasing the efficiency of the Venturi Scrubber (their power cost is high because of the high inlet gas velocity).

(iii) Cyclone Scrubber

❖The dry cyclone chamber can be converted into a wet cyclone scrubber by in-serting high pressure spray nozzles at various places within the dry chamber

❖The high pressure spray nozzles generate a fine spray that intercepts the small particles in the polluted gas. The centrifugal force throws these particles to-wards the wall from where they are drained downwards to the bottom of the scrubber.

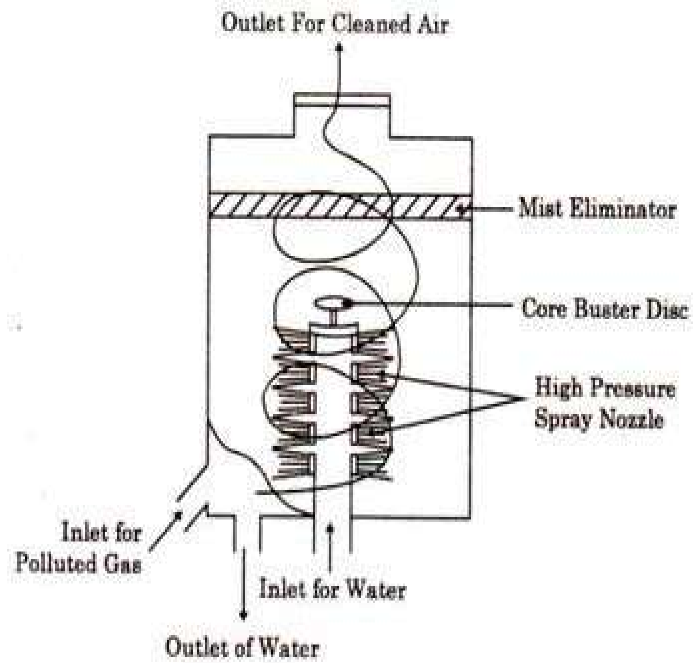


Fig. 5.7. Cyclone Scrubber

(d) Vegetation:

❖Plants contribute towards controlling air-pollution by utilizing carbon dioxide and releasing oxygen in the process of photosynthesis. This purifies the air (re-moval of gaseous pollutant—CO_2) for the respiration of men and animals.

❖Gas-eous pollutants like carbon monoxide are fixed by some plants, namely, Coleus Blumeri, Ficus variegata and Phascolus Vulgaris. Species of Pinus, Quercus, Pyrus, Juniperus and Vitis depollute the air by metabolising nitrogen oxides.

❖Plenty of trees should be planted especially around those areas which are de-clared as high-risk areas of pollution.

(e) Zoning:

This method of controlling air pollution can be adopted at the planning stages of the city. Zoning advocates setting aside of separate areas for industries so that they are far removed from the residential areas. The heavy industries should not be located too close to each other.

Control of gaseous pollutants from stationary sources

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)

Equipments using principles of absorption for removal of gaseous pollutants

- ✓ Packed tower
- ✓ Plate tower
- ✓ Bubble cap plate tower
- ✓ Spray tower
- ✓ Liquid jet scrubber absorbers

Gaseous pollutants	Common absorbents used in solution form
SO_2	Dimethylaniline, ammonium sulphite, ammonium sulphate, sodium sulphide, calcium sulphite, alkaline water,
H_2S	NaOH and phenol mix (3:2), tripottasium phosphate, sodium alamine, sodium thioarsenate, soda ash
HF	Water, NaOH
NOX	Water, aqueous nitric acid

Absorption

- **Effluent gas passed through absorbers (scrubbers), which contain liquid absorbent.**

- **Efficiency depends on**

1. **Amount of surface contact between gas and liquid**
2. **Contact time**
3. **Conc. of absorbing medium**
4. **Speed of reaction between the absorbent and gases**

- **Absorbents used to remove SO_2, H_2S, SO_3, F and oxides of nitrogen.**

Adsorption

- **Surface phenomenon, require large solid surface**

- **Adsorption towers use adsorbents to remove the impurities from the gas stream.**

- **The impurities bind either physically or chemically to the adsorbing material.**

- **The impurities can be recovered by regenerating the adsorbent.**

- **Adsorption towers can remove low concentrations of impurities from the flue gas stream.**

Construction and Operation

- Adsorption towers consist of cylinders packed with the adsorbent.

- The adsorbent is supported on a heavy screen.

- Since adsorption is temperature dependent, the flue gas is temperature conditioned.

- Vapor monitors are provided to detect for large concentrations in the effluent. Large concentrations of the pollutant in the effluent indicate that the adsorbent needs to be regenerated.

Advantages of Adsorption Towers

- Very low concentrations of pollutants can be removed.
- Energy consumption is low.
- Do not need much maintenance.
- Economically valuable material can be recovered during regeneration.

Gaseous pollutants	Adsorbents used in solid form
SO_2	Pulverized limestone or dolomite, alkalized alumina
H_2S	Iron oxide
HF	Lump limestone, porous sodium fluoride pellets
NOX	Silica gel
Organic solvent vapours	Activated carbon

Condensation

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, absorbers, 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

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.

ECONOMICAL ASPECTS

1. **Cyclones:- cheap to install, power consumption moderate, maintenance cost normal.**

2. **Filters:- expensive to install, power consumption moderate. Maintenance cost high.**

3. **Electrostatic precipitators:- most expensive regarding installation, power consumption moderate to low as pressure drops. Maintenance cost moderate**

4. **Scrubbers :- installation cost moderate, maintenance cost not high, high rate of power consumption.**


Thank you