Air Pollution Control Techniques

Lecture 1 – An Introduction

- **Air pollution** is the presence of substances in the atmosphere that are harmful to the health of humans and other living beings, or cause damage to the climate or to materials.

- There are different types of air pollutants, such as gases (such as ammonia, carbon monoxide, sulphur dioxide, nitrous oxides, methane and chlorofluorocarbons), particulates (both organic and inorganic), and biological molecules.

- Air pollution may cause diseases, allergies and even death to humans; it may also cause harm to other living organisms such as animals and food crops, and may damage the natural or built environment. Both human activity and natural processes can generate air pollution.

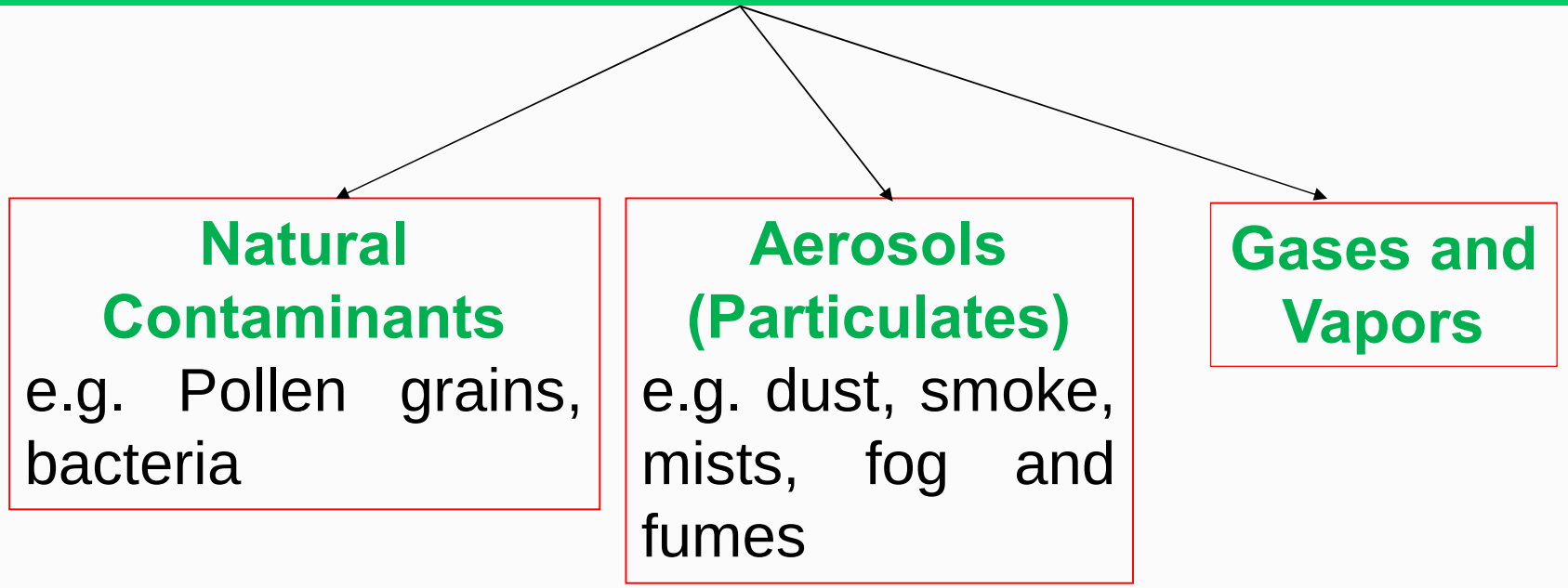
- Air pollution is a significant risk factor for a number of pollution-related diseases, including respiratory infections, heart disease, stroke and lung cancer.
- The human health effects of poor air quality are far reaching, but principally affect the body's respiratory system and the cardiovascular system.
- Individual reactions to air pollutants depend on the type of pollutant a person is exposed to, the degree of exposure, and the individual's health status and genetics.

- Outdoor air pollution alone causes 2.1 to 4.21 million deaths annually. Overall, air pollution causes the deaths of around 7 million people worldwide each year, and is the world's largest single environmental health risk.

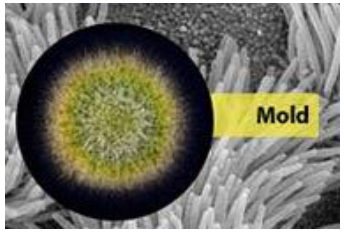
- An air pollutant is a material in the air that can have adverse effects on humans and the ecosystem.

Major Air Pollutants

Major Air Pollutants



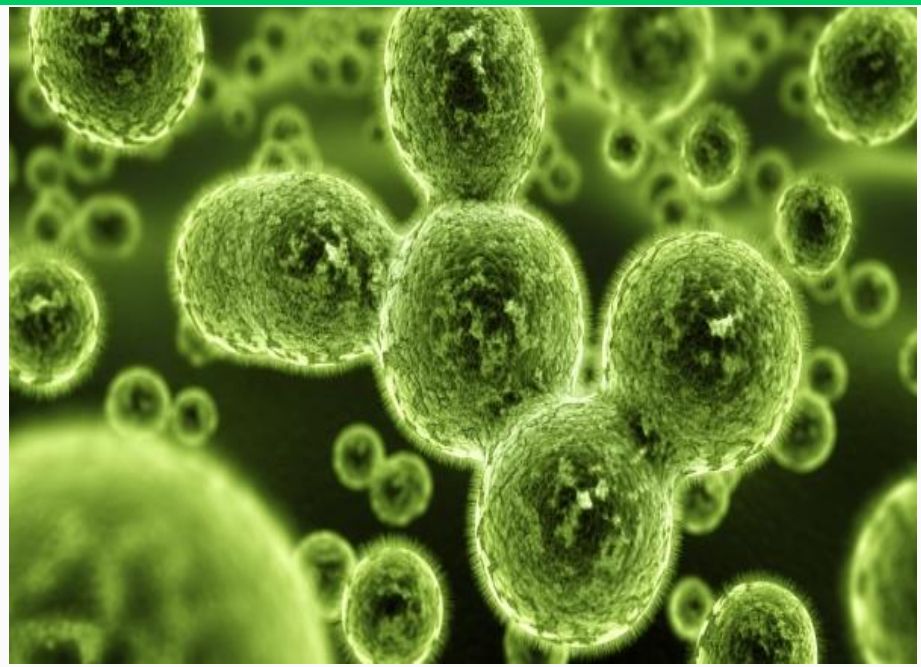
Natural Contaminants



Pollen

- Pollen is very fine powder that comes from trees, grasses, flowers.
- Wind and birds carry this pollen from plant to plant to fertilize them.
- When people who have a pollen allergy inhale the pollen, they get allergy symptoms.
- People can be allergic to different types of pollen.
- Some are allergic to pollen from only beech trees; others are allergic to pollen from only certain kinds of grasses.

Mold



- Mold is a fungus, which makes spores.
- These spores float in the air like pollen.
- When people who have a mold allergy inhale the spores, they get allergy symptoms.
- Molds live indoors (especially in moist places like bathrooms, kitchens, and basements) and outdoors (on rotting logs and fallen leaves).

Aerosols

- An **aerosol** can be defined as a colloidal system in which the dispersion medium is a gas and the dispersed phase is solid or liquid.

OR

- An aerosol is a colloid of fine solid particles or liquid droplets in air or another gas.

- The term aerosols covers a wide spectrum of small particles, like sea salt particles, mineral dust, pollen, drops of sulphuric acid and many others
- **The term aerosol is used during the time it is suspended in the air.**

Particulate Matter

- Particulateò refers to all substances that are not gases.
- It can be suspended droplets / solid particles / mixture of two.
- Size: 100 µm to 0.1 µm and less

Dust

- Dust is made up of solid particles predominantly larger than those found in colloids and capable of temporary suspension in air or other gases.
- They do not tend to flocculate except under electrostatic forces.; they also do not diffuse but settle under the influence of gravity.
- These are formed by natural disintegration of rock and soil or by the crushing, grinding etc. of organic or inorganic materials.

Dust

- Fly ash from chimneys varies from 3-80 μm
- Cement from 10-150 μm
- Foundry dust from 1-200 μm

- They have large settling velocities and are removed from the air by gravity and other inertial processes.

- Fine dust particles act as centers of catalysis for many of the chemical reaction-taking place in the atmosphere

- It contains particles of the size ranging from **1 to 200 μm** .

Sources of Atmospheric Dust

	Sources	Examples
1.	Combustion	Fuel burning (coal, wood, fuel oil) Incineration (house and municipal garbage) Others (open fires, forest fires, tobacco smoking)
2.	Materials handling and processing	Loading and unloading (sand, gravel, coal, ores, lime, cement) Crushing and grinding (ores, stone, cement, rocks, chemicals) Mixing and packaging (chemicals, fertilisers) Food processing (flour, corn starch, grains) Cutting and forming (saw mills, wall board, plastics) Metallurgical (foundries, smelters) Industrial (paper, textiles manufacture)

Sources of Atmospheric Dust

	Sources	Examples
3.	Earth moving operations	Construction (road, buildings, dams, site clearance) Mining (blasting) Agriculture (soil filling, land preparation) Winds
4.	Miscellaneous	House cleaning Mud road cleaning Crop spraying Poultry feeding Engine exhaust

Smoke

- It contains fine particles of the size ranging from **0.01 to 1 μm** which can be liquid or solid and are formed by combustion or other chemical processes.

- It consists predominantly of carbon particles and other combustible materials.

- The size of **coal smoke** particles range from **0.2-0.01 μm** and **oil smoke** particles from **1-0.03 μm .**

Smoke

- May have **different color** depending on the nature of material burnt.
  - White smoke: During cold start
  - Blue smoke: Burning of lubricating oil and additives
  - Black smoke: A product of incomplete combustion

Fumes

- Fumes are formed when a metal is heated above its boiling point and its vapours condense into very fine, particles (solid particulates).

OR

- It is consisted of the particles formed by condensation, sublimation or chemical reaction of which the predominant part consists of particles ranging from **0.1 μm to 1 μm** in size.

- Released from chemical or metallurgical processes.

  e.g. tobacco smoke, condensed metal oxides

Fog and Mists

Fog is a thick cloud of tiny water droplets suspended in the atmosphere at or near the earthôs surface which obscures or restricts visibility (reducing visibility below 1 km).

Mist is a cloud of tiny droplets of water suspended in the atmosphere at or near the earthôs surface that limits visibility to a lesser extent than fog.

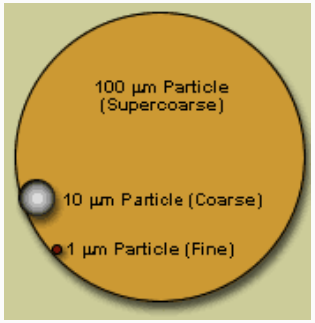
Mist

Mist may result from the condensation of gases or vapors to liquid state.

They can also be formed by breaking up a liquid through splashing, spraying or foaming.

Classification of Air Pollutants

EPA description	Particle size
Super coarse	$d_{pa} > 10\ \mu m$
Coarse	$2.5\ \mu m < d_{pa} \leq 10\ \mu m$
Fine	$0.1\ \mu m < d_{pa} \leq 2.5\ \mu m$
Ultrafine	$d_{pa} \leq 0.1\ \mu m$



Particle size comparisons

Gaseous Pollutants

Gaseous Pollutants

No.	Group	Examples
1	Sulphur compounds	SO_2, SO_3, H_2S, mercaptants
2	Nitrogen compounds	NO, NO_2, NH_3
3	Oxygen compounds	O_3, CO, CO_2
4	Halogen compounds	HF, HCl
5	Organic compounds	Aldehydes, hydrocarbons
6	Radioactive compounds	Radioactive gases

Note: Some of these contaminants undergo chemical reactions when they enter the atmosphere. As a result, the end product formed are more harmful than the original contaminants.

Unsaturated hydrocarbons react with nitrogen dioxide in sunlight to form smog.

Carbon monoxide (CO)

- It is a **tasteless, colorless and odorless** gas **with slightly lesser density than air.**

- **Sources:** Incomplete combustion of fossil fuels and other carbonaceous matter, some industrial processes, solid waste combustion, cigarette smoke, transportation (The gas is emitted when vehicles burn gasoline and when kerosene and wood stoves are used to heat homes)

Carbon monoxide (CO)

- **Natural source:** Volcanoes, lightening and photochemical degradation of some reactive organic compounds. CO is also formed biologically by certain brown algae, various microorganisms and also some oceanic organisms.

- **Mean residence time:** 1 month to 5 years

Carbon monoxide (CO)

Effects:

- Combines with hemoglobin (reduce the normal capacity of blood to transport oxygen to the tissue) & may create problems for infants, the elderly & those with heart or respiratory diseases.

- The effects of carbon monoxide include headaches, reduced mental alertness, heart damage; it may even cause death, and it contributes to smog.

Carbon monoxide (CO)

- At higher concentration of **100 ppm** it may cause people to experience dizziness, headache, lassitude and other symptoms

- A concentration of **4000 ppm** is lethal in less than one hour.

- 75.1% CO is produced by total fuel combustion, 7.7% from industrial processes, 9.3% from agricultural burning, 4.9% from solid waste disposal and 3% from miscellaneous sources.

CO_2 (Carbon Dioxide)

Sources

- Decay of organic matter and respiration of organisms.
- Combustion of fossil fuels such as coal, oil and natural gas.
- About half of the excessive quantities discharged into the atmosphere are absorbed by the oceans while much are utilized in photosynthesis.

CO_2 (Carbon Dioxide)

Effects

- Higher concentrations can affect respiratory function and cause excitation followed by depression of the central nervous system.
- Contact with liquefied CO_2 can cause frostbite.
- Workers briefly exposed to very high concentrations have effects like damage to the retina, sensitivity to light (photophobia), abnormal eye movements, constriction of visual fields, and enlargement of blind spots.

Sulfur oxides (SO_2, SO_3)

SO_2 (Sulphur dioxide):

- SO_2 is a **colorless gas** processing a pungent and **irritation odour** at higher concentration above 300 ppm.

Source

- Smelting, combustion of coal & oil (esp. coal)
- Ores of Cu, Zn, Pb and Ni etc. contain as much as 10 % or more of sulphur.
- **Lifetime:** 2 to 4 days

Sulfur oxides (SO_2)

Effects

- It can harm human and animal lungs, as well as plants and trees.

- Exposure to SO_2 can cause impairment of respiratory function, aggravation of existing respiratory disease (especially bronchitis), decrease in the ability of the lungs to clear foreign particles.

Sulfur oxides (SO_2)

- Sulfur dioxide is the main contributor to acid rain. It reacts with the oxygen in the air to become sulfur trioxide, which then reacts with water in the air to form sulfuric acid.

- Acid rain can slowly kill both animal populations in lakes and rivers and trees and other plants by damaging leaves and root systems.

Sulfur oxides (SO_2)

- It can deteriorate metal and stone on buildings and statues.
- The effects of acid rain are not only local, but they can occur hundreds of miles from the sources of sulfur dioxide.

Sulfur trioxide (SO_3)

- Sulphur trioxide is formed by oxidation of sulphur dioxide.
- It may exits in the form of vapor and readily combines with water to form H_2SO_4.
- **Source:** Combustion of sulphur containing material

Nitrogen oxides NO_x

- The most abundant and important oxides of nitrogen forming air pollutants are Nitric Oxide (NO), Nitrogen Dioxide (NO_2), Nitrous oxide (N_2O)

- **Lifetime:** Less than 2 days

Nitric Oxide

- It is colorless and relatively harmless gas, but its get readily converted into NO_2 by photochemical reactions.

Source:

- High temperature combustion, motor vehicles (40 % of NO_x discharge) & industry, biologically in nature
- Nitrogen Oxides are formed naturally by bacteria in soil and play an important role in plant growth.

Nitrogen Dioxide

- It is reddish brown gas with pungent odor.
- The gas is corrosive, irritating and physiologically toxic.
- It reacts with water to form nitric acid, which may be a significant component of acid rain. It is formed primarily by photo oxidation of NO.
- Its fate is oxidation to nitric acid, nitrates or photo dissociation

Ozone

- Ozone is a **gaseous, secondary pollutant** and is formed during photochemical smog in the atmosphere.
- The interaction of NO_2 with VOCs produces ozone in the presence of sunlight.
- If the air over the city does not move, pollutants become trapped close to the earth's surface forming smog and increasing ozone problems which can lead to breathing problems.

Ozone

- High ozone levels at the ground level harm plants, including trees and crop plants, and causes the accelerated deterioration of materials such as rubber and fabrics.
- There is another type of ozone problem which came to attention in late sixties. Concerns were expressed on the destruction of ozone layer due to the use of supersonic transports. At present the destruction of ozone layer in the stratosphere due to the use of certain chemical compounds (chlorofluorocarbons or CFCs, methane etc.) is an environmental issue.

Hydrocarbons

- Hydrocarbons are composed of only hydrogen and carbon.
- The volatile organic compounds (VOC) are the compounds which take part in atmospheric photochemical process.
- VOCs are composed of hydrogen and carbon, and may also contain elements such as oxygen, nitrogen, sulfur, chlorine, and fluorine.
- Hydrocarbons are methane, benzene, propane, & chlorofluorocarbons (CFC's) etc.

Hydrocarbons

- Concentrations of many VOCs are consistently higher indoors than outdoors.

Effects:

- Eye and respiratory tract irritation, headaches, dizziness, visual disorders, and memory impairment are among the immediate symptoms that some people have experienced soon after exposure to some organics.
- Many organic compounds are known to cause cancer in animals; some are suspected of causing, or are known to cause, cancer in humans.

Lead

- Lead is fairly abundant and is derived from ore bearing minerals.
- The gray metal can be easily molded, formed and worked.
- It can withstand weathering and chemical erosion.
- Lead has been used in the manufacture of pipes, paint house hold pottery, gasoline additives and storage batteries.

Lead

- Automobiles and leaded gasoline are major sources of atmospheric lead.
- Lead was more of a problem a few years ago when all vehicles used gasoline with lead additives.
- When lead gasoline is burned, lead is released into the air.