

EWCE 105

ENVIRONMENTAL CHEMISTRY

Lecture – 6

Lecture Outlines

- Air Pollution
- Components of Air Pollution
- Categories of Air Pollution
- Classification of Air Pollutants
- Measurements of Units

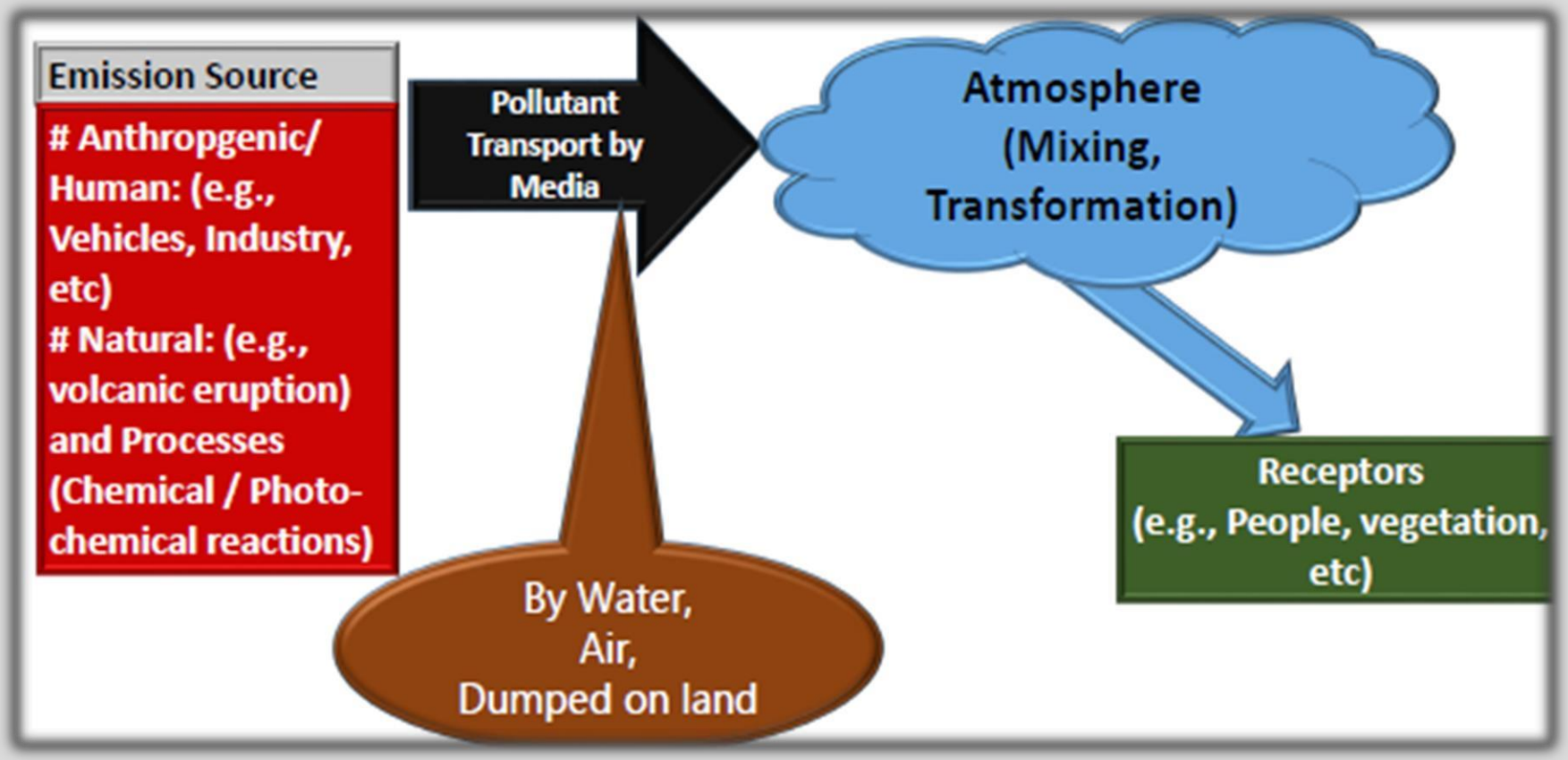
Air Pollution



Defined as any atmospheric condition in which substances are present at concentrations, above their normal ambient levels, to produce measurable adverse effects on people, animal, vegetation or materials.

- Key Issues:
  - Types of Pollutants
  - Concentration in Air
  - Time of Exposure

Components of Air Pollution



Components of Air Pollution

Media: Pollutants/contaminants interact with the components of the environment which are called media.

Sink: Media that is not hampered due to interaction is called sink and sometimes even benefited. For example: Water is a sink of CO_2.

Receptor: Media that is hampered due to interaction. For example: Human being is a receptor of CO.

Human being is a receptor of NOx, while soil is a sink--- HOW????

Overview of Emissions of Air Pollution

Two categories :

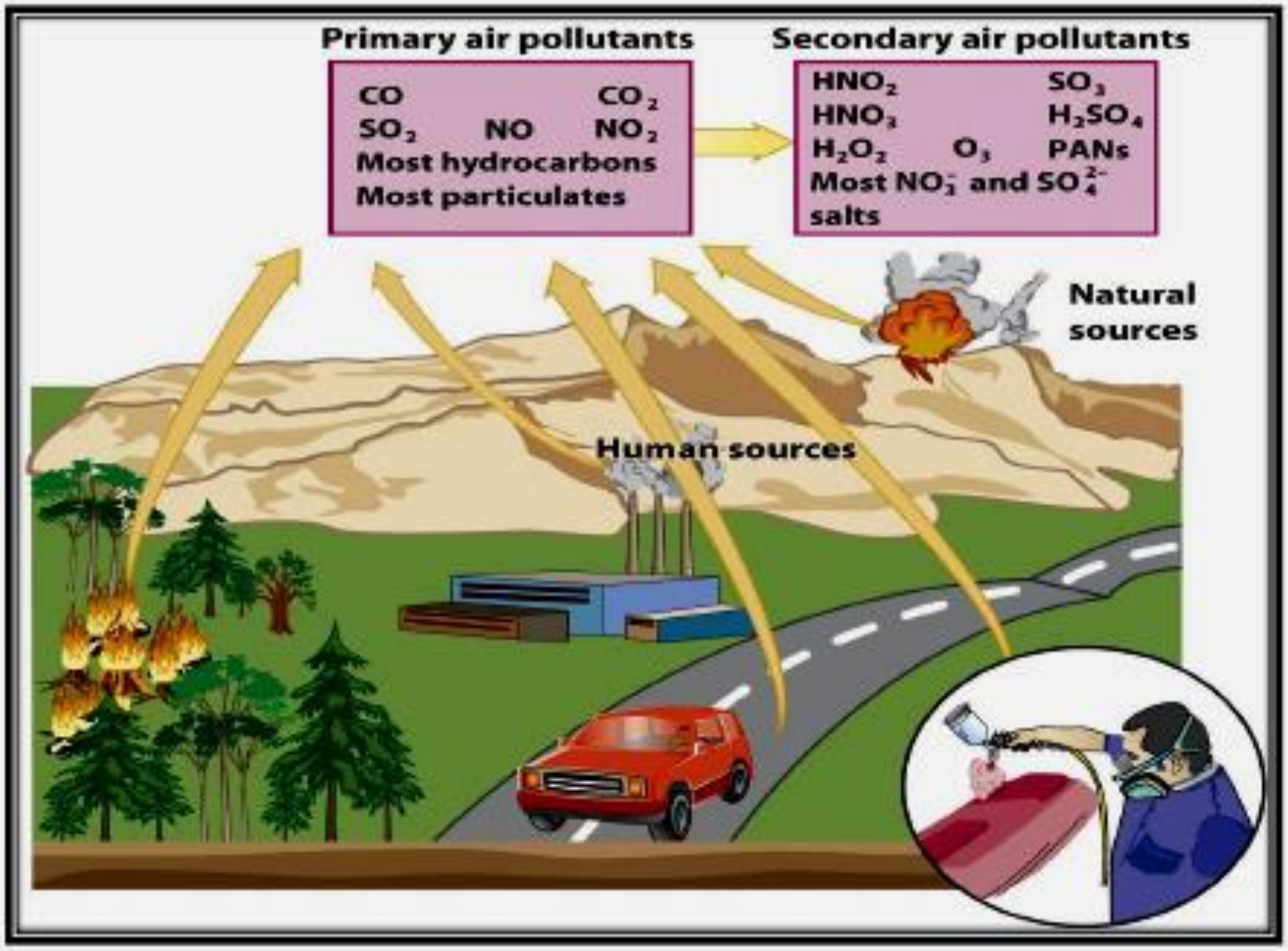
- **Primary Air Pollutant**

Harmful substances that are emitted directly into the atmosphere (e.g., NO_2 and CO when fuels are burned).

- **Secondary Air Pollutant**

Harmful substances formed in the atmosphere when a primary air pollutant reacts with substances normally found in the atmosphere or with other air pollutants by physical, chemical and photochemical reaction (e.g., Ozone -O_3).

Major Air Pollutants



Processes Leading to Emission of "Primary Pollutants"

Combustion: Mainly fossil fuel for the purpose of heating/cooling, transportation, industry, and energy conversion. **Accounts for great majority of emission**.

Evaporation: Volatile substances like gasoline, paint and cleaning fluid enter into the atmosphere by evaporation.

Grinding and Abrasion: Brick/stone chips are made, or dust kicked up when land is plowed.

Combustion ("Primary Pollutants")

- Pure hydrocarbon/fuel (complete combustion):

  $CH_4 + 2O_2$ ----------→ $CO_2 + 2H_2O$

- Pure hydrocarbon / fuel (incomplete combustion):

  $CH_4 + O_2$ ----------→ Mainly [$CO_2 + H_2O$] + Traces of [CO + HC]

- **Combustion in Air:**

  Air [$N_2 + O_2$] + Heat ----------→ Thermal NOx (mainly NO and NO_2)

- Combustion of fuel containing impurities in air:

  Fuel [H, C, S, N, Pb, Ash] + Air [$N_2 + O_2$] ----------→ Emissions [CO_2, H_2O, CO, NOx, SOx, Pb, Particulate Matter] + Ash

Combustion ("Secondary Pollutants")

- HC/VOCs + NOx + Sunlight ----------→ Photochemical Smog (O_3 , etc)
- SO_2 ----------→ H_2SO_4 ----------→ Sulfate Particles

Important Issues and Facts

- It is impossible to eliminate all man-made emissions into the atmosphere.
- The aim usually is **to reduce** pollutant emissions to a point such that noticeable adverse effects associated with air pollution are eliminated.
- Lack of ability to associate health effects with air pollutant doses in an unambiguous way has been one of the principal obstacles in gaining public support and fund for air pollution control **(Positive example: Banning leaded fuel in Bangladesh)**

Categories of Air Pollution

- Outdoor Air Pollution






- Indoor Air Pollution (cooking, heating, tobacco smoking, radon)





Effects of Air Pollution

- Effects on human health
- Effects on vegetation
- Effects on materials
- Effects on atmospheric properties /Climate

Effects of Air Pollution – Health Facts

Outdoor Air Pollution

- Globally, 1.2 million (Urban) and 3.7 million (Urban plus Rural) premature deaths each year due to outdoor air pollution.

- Compliance to WHO standard could avoid:
  - 14850 premature deaths (Dhaka 10,800) in Bangladesh
  - 6.54 millions hospital admissions or medical treatments (Dhaka 4.74 millions) in Bangladesh

Effects of Air Pollution – Health Facts

Indoor Air Pollution

- Around 2 million people die each year prematurely from illness attributable to indoor air pollution.

- WHO estimates that globally acute respiratory infections from indoor air pollution are responsible for an estimated 900,000 deaths among children under 5 every year.

- About 3 billion people cook and heat using open fires, exposing them to air pollution.

Major Sources of Outdoor Air Pollution

- Mobile Sources/Transportation : Include both on-road and off-road-vehicles (rail, ship).
- Stationary Sources: Utility, industrial, institutional and commercial facilities, e.g., power plant, brick kiln, refineries, cement industry.
- Area Sources: Include many individually small activities, gasoline service stations, small paint shops, cooking in slum areas.
- Incineration/ Burning of Wastes: Household, commercial, industrial, hazardous waste burning, agricultural burning.
- Miscellaneous: Re-suspension from road, forest fire, volcanic eruption, pollen grains, evaporation of chemical, certain bacteria/virus.

Outdoor Air Pollutants

- Oxides of Carbon – CO, CO_2
- Oxides of Sulfur – SO_2, SO_3
- Oxides of Nitrogen – NO, NO_2
- Volatile Organic Compounds–CH_4, C_6H_6
- Photochemical Oxidants–O_3, PAN
- Particulates – H_2SO_4 droplets, fine dust particles
- Radioactive Substances – Radon-222

Indoor Air Pollution

- People spend 70-98% time indoors where common pollutants are 2-5 times higher (in some cases 70 times) than outdoors (source : EPA (United States Environmental Protection Agency | US EPA)).
- Pollution levels inside cars in traffic –clogged urban areas can be up to 18 times higher than outside the vehicles.
- In 1990, EPA placed indoor air pollution at the top of the list of 18 sources of cancer risk and it is rated by the Risk Analysis Scientists as a high-risk health problem for human being.
- At the highest risk are smokers, infants and children under age 5, the old and sick people, pregnant women, people with respiratory or heart problems and factory workers.

Common Indoor Air Pollutants

- Tobacco smoke
- Radon
- CO
- Asbestos fiber
- Styrene - Chloroform
- Lead (Pb) particles
- Nitrogen oxides

Control of Indoor Pollution/Remedy

- Avoid smoking indoors.
- Ensure well ventilated areas.
- keep the trash covered.
- Steps to minimize toxins from carpets, tiles, stones etc.
- Have large windows to exchange air
- Make breathing wall!!

Breathing wall



The **breathing wall** is a simple **concept**, but often confused by linking it only to particular **wall** constructions All timber **walls breathe**. The original **concept** of a **breathing wall** was of internal air flowing out through the **walls** to reduce the concentration of indoor air pollutants.

Classification of Pollutants

According to **Origin**

- Primary Pollutants: Emitted directly into the atmosphere and found in the form in which the were emitted, e.g., CO, SO_2, NO_2, etc.
- Secondary Pollutants: Derived from primary pollutants by chemical/photo-chemical reactions in the atmosphere, e.g. Ozone (O_3), peroxy-acetyl nitrate (PAN).

HC/VOCs + NO_x + Sunlight → Photochemical Smog (O_3, etc)

Classification of Pollutants

According to **Chemical Composition**

- Inorganic: CO, SO_2, NO_2, H_2SO_4, NH_3.
- Organic: HC, Aldehydes and Ketones, VOCs, PCBs, PAHs

According to **State of Matter**

- Gaseous: CO, SO_2, NO_2, H_2SO_4, NH_3, VOCs, O_3
- Particulates/Aerosols:
  - Dust, smoke, fume, fly ash (SOLID)
  - Mist, spray (LIQUID)
  - Pollen, bacteria, virus (NATURAL)

Classification of Pollutants

According to **Residence Time in Atmosphere**

- Short Lived Climate Pollutants (**SLCPs**) - refers to 4 types of pollutants :

  Black Carbon (BC) (Soot)
  Methane (CH_4)
  Tropospheric Ozone (O_3)
  Some Hydro-fluro-carbons (HFCs)

They are relatively short lived in the atmosphere, and have significant adverse impacts on:

Human Health
Agriculture (crop yield) and
Ecosystem productivity (due to O_3)

Classification of Pollutants

SLCPs life time in Atmosphere :

Substance	Lifetime
CO_2	Decades to centuries and about 205 will persist for many millennia
Ozone	4-18 days
Methane	12 years
Black Carbon	3-8 days
HFCs	Average of Mix: 15 years

Classification of Pollutants

Important Terms :

Criteria Pollutants: are a set of air pollutants that cause smog, acid rain, and other health hazards. Six major air pollutants that cause health effects, and for which health based standards/guidelines have been established. These are:

Particulate Matter (PM), Pb, CO, NO_2 , SO_2 & O_3.

Air Toxins: Pollutants that are known or suspected to cause cancer or other serious health effects. Examples include:

Benzene (from gasoline);
Perchloroethylene (from dry cleaners);
Methyl Chloride (used as solvent and paint stripper).

Units of Measurement

- Particulate Matter: mass/unit volume of air (e.g., mg/m^3, $\mu g/m^3$, ng/m^3)

- Gaseous Pollutants:

  Mass/unit volume: (e.g., mg/m^3)

  ppm= ppmv= volume of pollutant per million volume of air mixture.

Sometimes also expressed as "parts per billion" (ppb) and "parts per trillion" (ppt).

Units of Measurement

Gases and Vapors

Conditions

- STP (standard temperature and pressure)
  - 0°C and 760 mmHg (32° F and 29.92 inHg; 1 mole of any gas occupies 22.4 liters @ STP)
- NTP (normal temperature and pressure)
  - 25° C & 760 mmHg; 77° F and 29.92 inHg; 1 mole of any gas occupies 24.45 liters @ NTP

Ideal Gas Law

$$PV = nRT$$

- P = Pressure (atmospheres)
- V = Volume (liters)
- n = Number of moles of gas (mass in g/molecular weight)
- R = Molar gas constant (0.0821 liter atm/mol K)
- T = Temperature (Kelvin)

Units of Measurement

$$PV = nRT$$

P = pressure
V = volume
T = temperature (Kelvin)
n = number of moles
R = gas constant

Solve for constant (R)

$$\frac{PV}{nT}$$

Substitute values:

$$\frac{(1\ \text{atm})\ (22.4\ \text{L})}{(1\ \text{mole})(273\ \text{K})} = R$$

R = 0.0821 atm L / mol K

Standard Temperature and Pressure (STP)

T = 0 °C or 273 K

P = 1 atm = 101.3 kPa = 760 mm Hg

1 mol = 22.4 L @ STP

Recall: 1 atm = 101.3 kPa

$$R = 0.0821\ \frac{\text{atm L}}{\text{mol K}}\ \frac{(101.3\ \text{kPa})}{(1\ \text{atm})} = 8.31\ \frac{\text{kPa L}}{\text{mol K}}$$

R = 0.0821 atm L / mol K or R = 8.31 kPa L / mol K

Units of Measurement

Formula for Conversion for Gaseous Pollutants

Concentration in mg/m3 = Concentration in ppm x (MW/22.4) x (273 x P/T)

Concentration in ppm = Concentration in mg/m3 x (22.4/MW) x (T /273x P)

Where :
P in Atmospheric Pressure
T in Kelvin

Problem: The concentration of CO_2 in air in a particular area is found to be 450 ppm at STP. What is its concentration in mg/m3 at STP and NTP?

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The End