Air Pollution

FEC-7

Lecture on 09.04.2020

What is air pollution?

- Air pollution is the presence of un-desirable solid and liquid particles and certain gases in the air in quantities that are harmful to human health and environment.
- The solid and liquid particles suspended in our air are called **aerosols**.

When we say air pollution – what picture comes to our mind?..

SOURCES?

Credit: NASA/JPL-Caltech

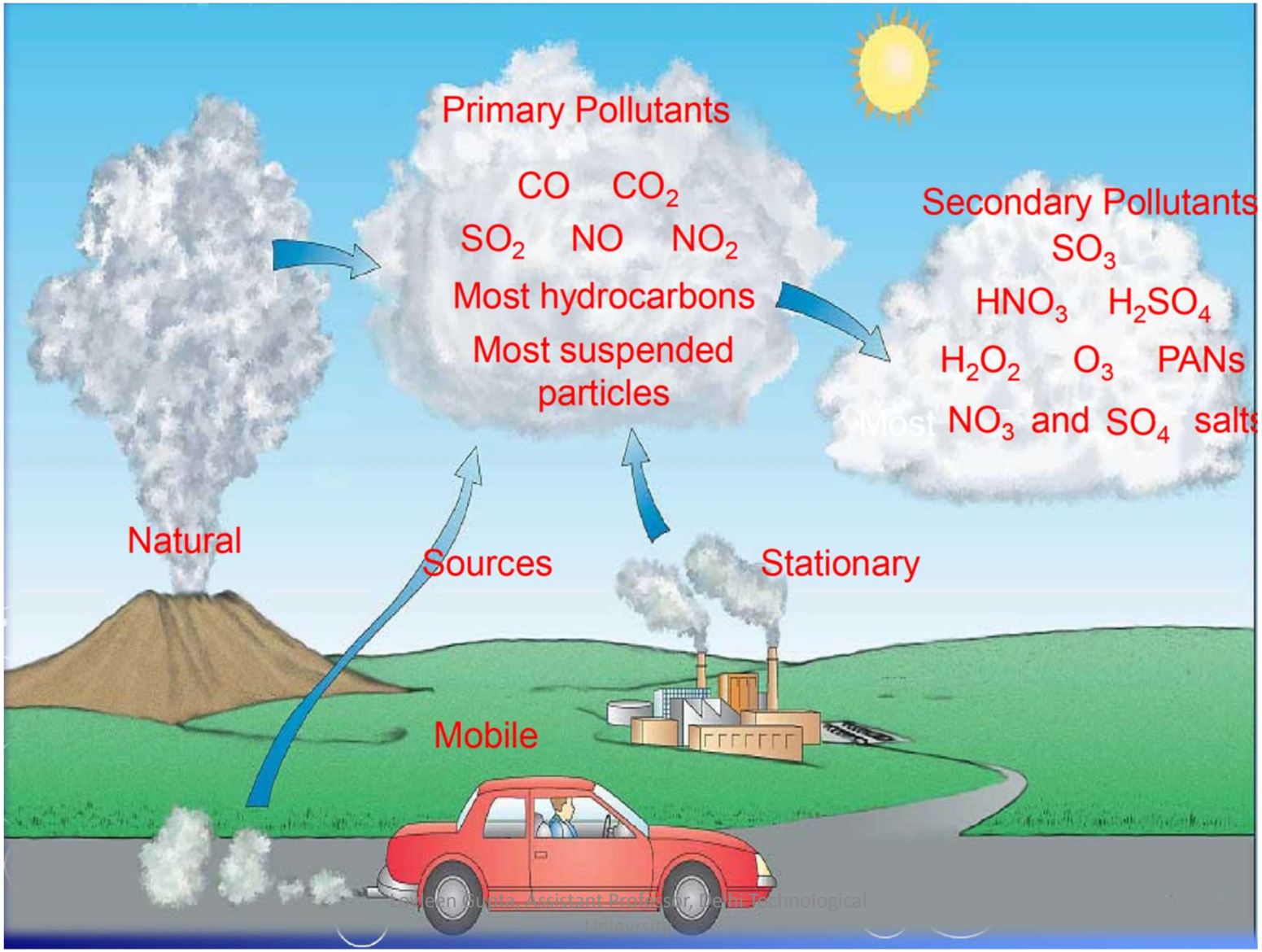
Sources of air pollution

These particles and gases (or air pollutants) can come from:

- Vehicle exhaust;
- Factories;
- Dust;
- Pollen;
- Mold spores;
- Volcanoes;
- Wildfires;
- Cookstoves; and
- Many more …

Classification – sources of air pollutants

Air Pollutants		
	Based on origin	Natural or **Biogenic** sources (like forest fires, volcanic eruptions, biological decay, etc.)
		Anthropogenic sources (like vehicle exhaust, industries, cooking, etc.)
	Based on location	Stationary sources: **Point sources** like industries, volcano and **Area sources** like industrial area
		Mobile sources also called **Line sources** like highway vehicles, railways
	Based on states of matter	Gaseous pollutants like CO, NO_x, SO_x, etc.
		Particulate pollutant like smoke, dust, etc.
	Based on chemical composition	Organic pollutants like ketones, alcohols, hydrocarbons, etc.
		Inorganic pollutants like CO, NO_x, SO_x, etc.
	Based on formation mechanism	Primary pollutants like CO, NO_2, PM – **emitted from identifiable sources**
		Secondary pollutants like O_3, PAN, Smog – **formed by the reaction of primary pollutants**


Primary Pollutants
CO CO_2
SO_2 NO NO_2
Most hydrocarbons
Most suspended particles
Secondary Pollutants
SO_3
HNO_3 H_2SO_4
H_2O_2 O_3 PANs
NO_3 and SO_4 salts
Natural
Sources
Stationary
Mobile

Major air pollutants

Six primary pollutants that contribute to ~ 90% of the global air pollution are:

- CO
- CO_2
- NO_x
- SO_x
- VOCs
- PM

CO

Pollutant	Sources	Effects
Carbon Monoxide Colourless, odourless and toxic gas	• Burning of fossil fuels • Emissions are higher when engines are not tuned properly, and when fuel is not completely burned. • **<u>Vehicles are the largest source of CO found outdoors.</u>** • Furnaces and cook stoves at homes can emit lot of CO indoors if not properly maintained.	• Exposure to CO makes people feel dizzy and tired and give them headaches. • CO makes it hard for body parts to get the Oxygen they need. • In high concentrations, CO is fatal and may lead to death

CO is however not a persistent pollutant –
Natural processes can convert CO to CO_2 and other pollutants.

NO_x – Oxides of Nitrogen

Pollutant	Sources	Effects
NO_2: Reddish brown gas Strong smell.	• NO_2 formed in 2 ways – when nitrogen in the fuel is burned, or when nitrogen in the air reacts with O2 at very high temperatures. • Mostly comes from car exhaust and power plants	• High levels of NO_2 exposure can give people coughs and can make them feel short of breath. • Effects lungs and increases chance of respiratory infection. • NO_2 can also react in the atmosphere to form Ozone, Acid rain.

NO_x are significant as they are involved in the production of secondary air pollutants like Ozone and acid rain.

SO_x – Oxides of Sulfur

Pollutant	Sources	Effects
Sulfur Dioxide (SO_2): Corrosive gas that cannot be seen or smelled at low levels but can have a "rotten egg" smell at high levels.	• Produced when Sulfur containing fuels are burned. • Mostly comes from the burning of coal or oil in power plants. • Also comes from factories that make chemicals, paper or fuel.	• Exposure to SO2 can affect people who have asthma by making it more difficult for them to breathe. • Also irritates peoples eyes, noses and throats. • SO_2 can harm trees and crops, damage buildings, and make it harder for people to see long distances. • Like NOx, SOx also reacts in the atmosphere to form acid rain and particles.

SO_x also contributes to acid rain.

HC - Hydrocarbons

Pollutant	Sources	Effects
Compounds consisting of Hydrogen and Carbon.	• Either evaporate from fuel supplies or • Are remnants of of fuel that did not burn completely. Using higher oxygen concentrations in the fuel air mixture and using valves to prevent the escape from supplies are some of the modifications needed to prevent HC release in atmosphere.	• HCs are washed out of the air when it rains and run into surface water. They cause an oily film on the surface and do not as such cause a serious issue until they react to form secondary pollutants. • HC also combines with NO_x to form Ozone – a pollutant in troposphere.

HC along with NO_x involved in the production of secondary air pollutants like Ozone.

Particulate Matter (PM)

Pollutant	Sources	Effects
Particulate Matter: Solid or liquid particles suspended in air. PM_{10} – dia <=10 µm – coarse particles $PM_{2.5}$ – dia <=2.5 µm – fine particles PM_1 – dia <= 1 µm – ultrafine particles	• Coarse particles are formed from sources like road dust, construction dust, sea sprays, etc. • Fine particles – results from combustion – may be from vehicles, power plants, etc. • Ultrafine partciles – also a results from combustion.	• PM is small enough that it can enter the lungs and cause health problems. Some of these problems include more frequent asthma attacks, respiratory problems and premature death. Repeated exposure to PM can cause them to accumulate in the lungs and interfere with the ability of the lungs to exchange gases. • Some PM have also been found to be carcinogenic (cancer causing)

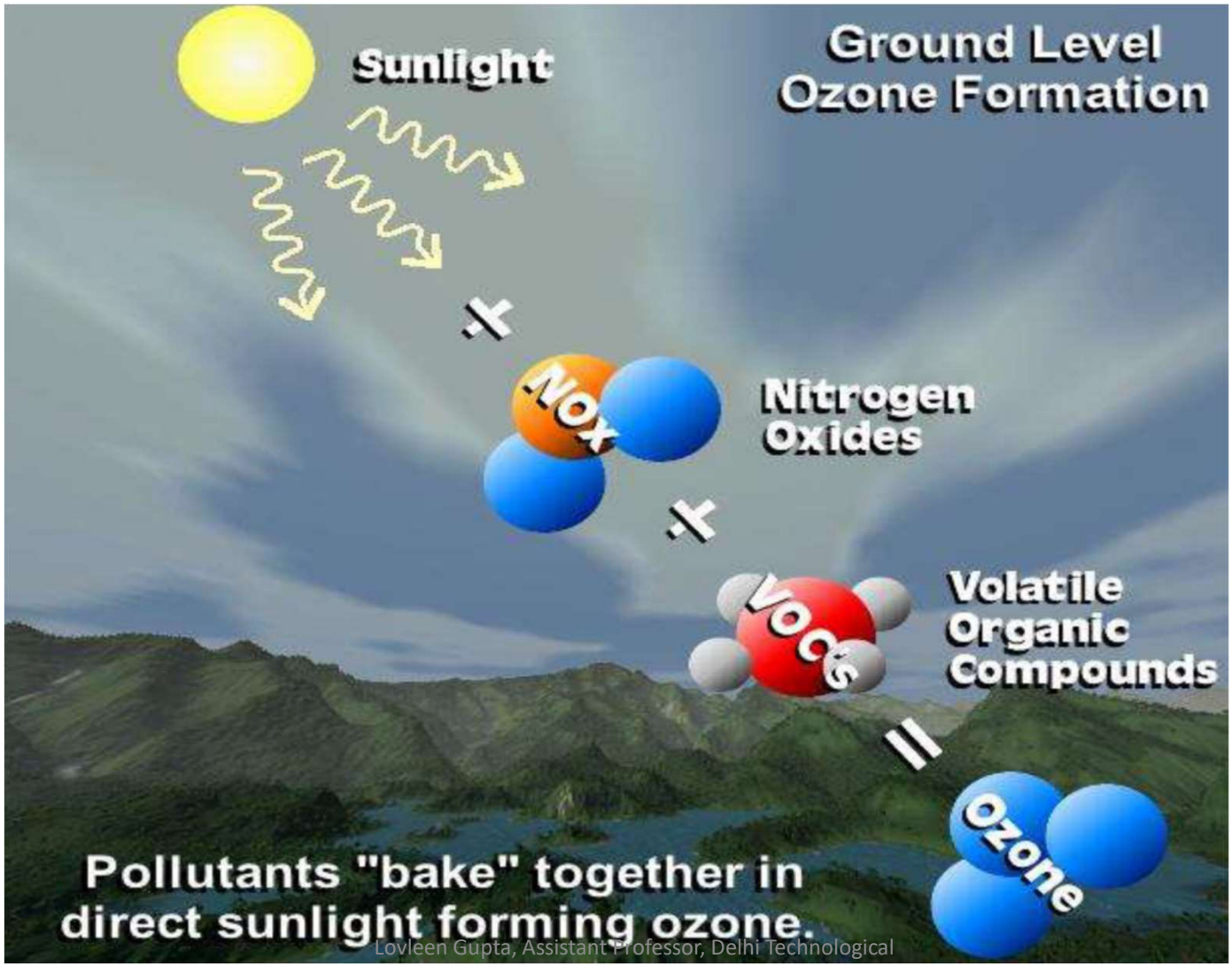
Types of particulates

Term	Meaning	Examples
Aerosol	General term for particles suspended in air	Sprays from pressurized cans
Mist	Aerosol consisting of liquid droplets	Sulfuric acid mist
Dust	Aerosol consisting of solid particles that are blown into the air or are produced from larger particles by grinding them down	Dust storm
Smoke	Aerosol consisting of solid particles or a mixture of solid and liquid particles produced by chemical reaction such as fires	Cigarette smoke, smoke from burning garbage
Fume	Generally means the same as smoke but often applies specifically to aerosols produced by condensation of hot vapors of metals.	Zinc/lead fumes
Plume	Geometrical shape or form of the smoke coming out of a chimney	
Fog	Aerosol consisting of water droplets	
Smog	Term used to describe a mixture of smoke and fog.	

Some secondary air pollutants

Ground Level Ozone

Pollutant	Sources	Effects
Ozone: • O_3 found in troposphere and stratosphere. • Troposheric Ozone is harmful or "bad ozone". • Stratospheric Ozone is "good ozone" which screens out harmful UV rays.	• Formed when NOx and VOCs (Volatile Organic compounds – category of HCs) mix in the presence of sunlight. • That's why, tropospheric ozone is mostly found in summers.	• Troposheric Ozone can lead to more frequent asthma attacks in people and can cause sore throats, coughs, and breathing difficulty. • It can even lead to premature death. • Ozone can also hurt plants and crops.

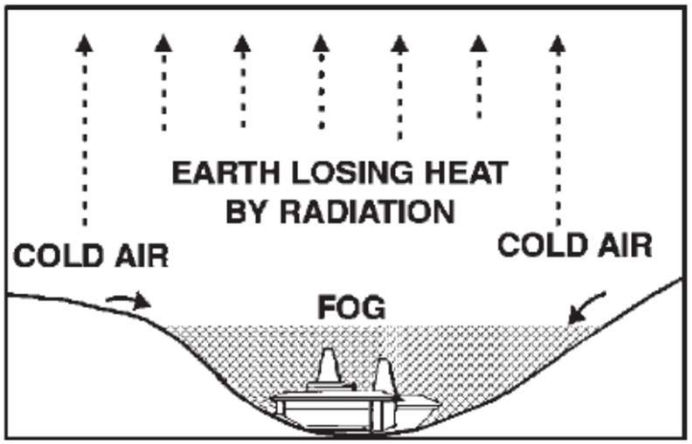

Sunlight
Ground Level
Ozone Formation
NOx
Nitrogen
Oxides
VOCs
Volatile
Organic
Compounds
ozone
Pollutants "bake" together in
direct sunlight forming ozone.

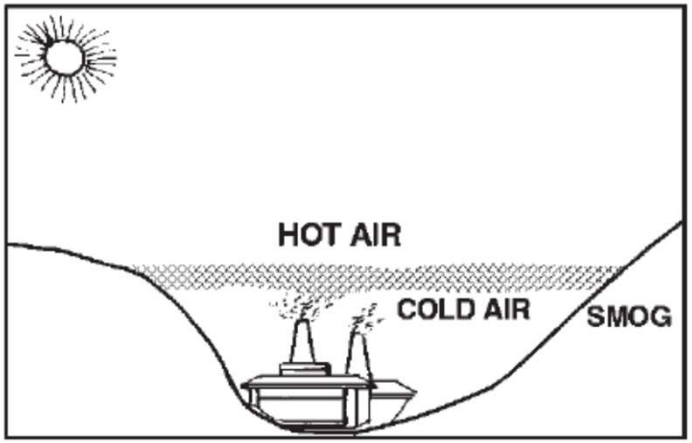
What happens to pollutants in the atmosphere?

What happens to pollutants in the atmosphere?

- Once pollutants enter troposphere, they are:
  - Transported downwind;
  - Diluted by the large volume of air or pollutant get dispersed;
  - Transformed through physical or chemical processes;
  - Removed from the atmosphere by rain
- Dispersion depends on:
  - Topography
  - Meteorology

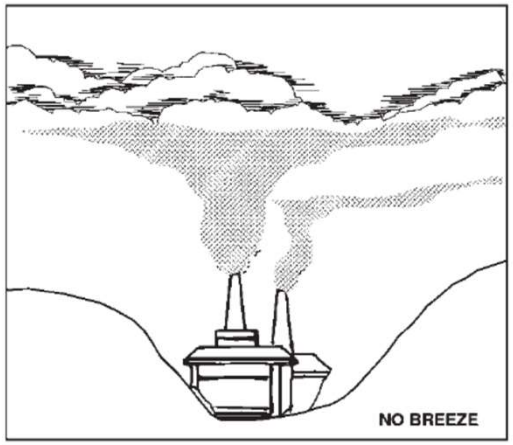
Topographical Effect

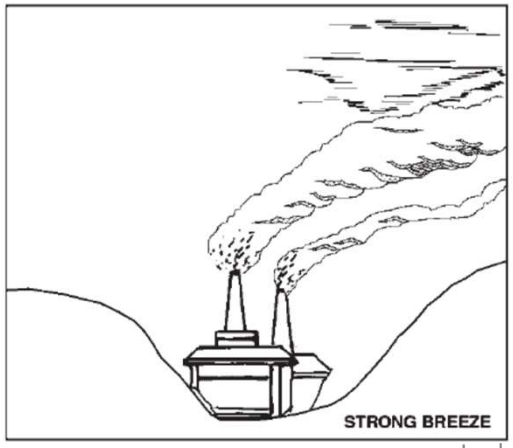




- Earth is powered by sun's energy.
- The air in contact with the ground / earth also gets heated by the radiated energy from earth.
- So, during day time, the hot air (near the ground) is lense dense than the cold air above it, so it rises.
- However, during evening, the process starts reversing and the air being cooler near the ground cannot go up and thus the pollutants gets trapped.
- In addition if there are hills surrounding the area, the situation gets worse.
- In colder regions, this situation can persist for several days.

Meteorological Effect





- Velocity of wind affects the dispersal of pollutants.
- Strong winds mix polluted air more rapidly with the surrounding air diluting the pollutants quickly.
- With lower wind velocities, pollutant concentration remains high.

Controlling Air Pollution

Control – two fundamental approaches

1. Preventive Techniques
   - Very high stacks so that the pollutanst are released at a greater height as far from ground as possible.
   - Industries to be located in areas considering meteorology and topography in mind.
   - Substitution of raw materials with those that causes less pollution.

2. Exhaust Control
   - to have proper equipment in place for removal of pollutant.

Climate Change & Global Warming

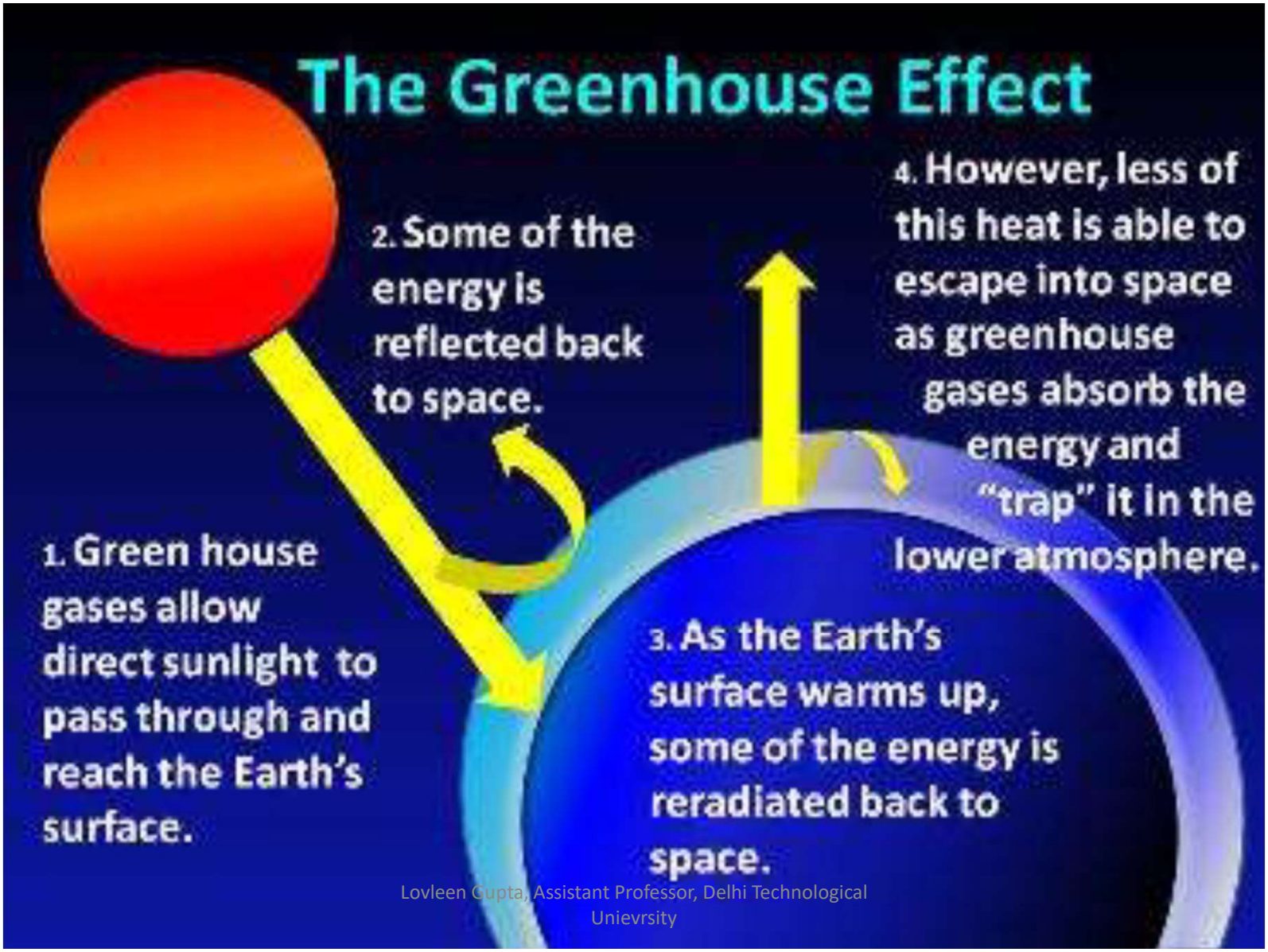
Difference

- Climate change refers to any significant change in measures of climate (such as temperature, precipitation, wind speed, hurricanes, cyclones, etc.) lasting for an extended period (decades or longer).

- Global Warming refers to an average increase in temperature of the atmosphere near the earth's surface, which can contribute to changes in global climate pattern. However, rising temperatures is just one aspect of climate change.

Impacts – Climate Change

- Increase in rainfall (regional changes)
- In some regions – parts of Asia and Africa – Increase in frequency and intensity of droughts
- Increase in Floods
- Human health concern
- Food production affected


The Greenhouse Effect
1. Green house gases allow direct sunlight to pass through and reach the Earth's surface.
2. Some of the energy is reflected back to space.
3. As the Earth's surface warms up, some of the energy is reradiated back to space.
4. However, less of this heat is able to escape into space as greenhouse gases absorb the energy and "trap" it in the lower atmosphere.

Green House Gases (GHGs)

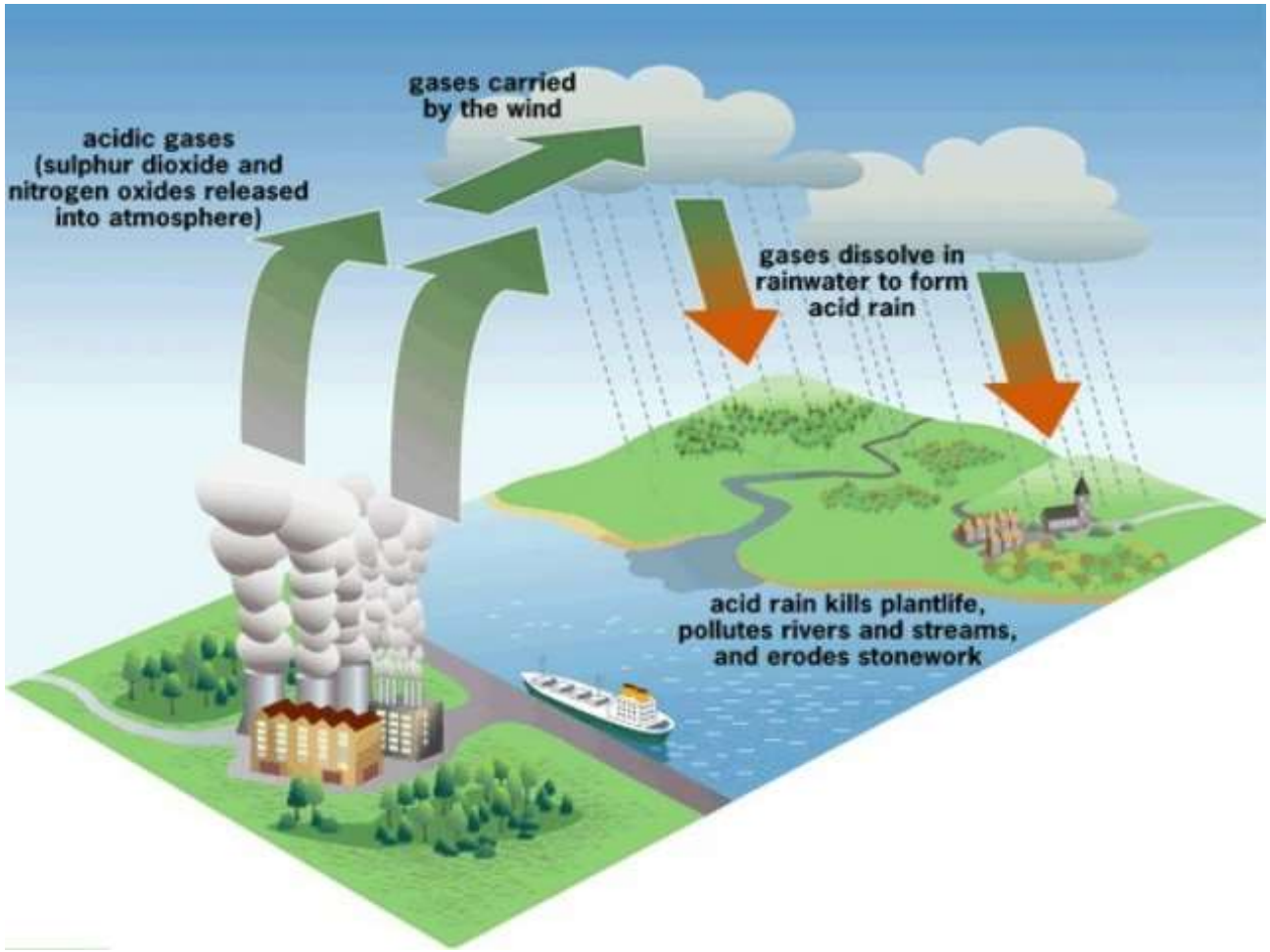
- CO_2
- CH_4
- N_2O
- HFC
- PFC
- SF_6
- O_3
- H_2O

Regulated under international protocol.

Acid Rain

What is Acid Rain?

- Acid rain is a rain or any other form of precipitation which is usually acidic i.e. elevated level of hydrogen ions (low pH).
- pH lower than 5.6 is termed as acid rain.
- Mainly of two types:
  - Wet Deposition: When any form of precipitation (snow, fog, rain)removes acid from atmosphere and fall on the earth's surface.
  - Dry Deposition: When particles and gases stick to the ground, plants or other surfaces. Responsible for as much as 20-60% of total acid deposition
- SO_x and NO_x are two main pollutants responsible for acid rain.


gases carried
by the wind
acidic gases
(sulphur dioxide and
nitrogen oxides released
into atmosphere)
gases dissolve in
rainwater to form
acid rain
acid rain kills plantlife,
pollutes rivers and streams,
and erodes stonework

Chemical Reactions:

- $SO_2 + H_2O \rightarrow H_2SO_4$

- $2NO_2 + H_2O \rightarrow 2HNO_3$

Acid rain effect on structures

- Dissolve limestone, sand, stone, ceramic, etc.
- Damages buildings, monuments and sculptures
- Also destroys textile, paints, rubber, leather.

Effect on plants / forests

- Corrodes the waxy protective coating of leaves
- Dissolves the beneficial minerals and nutrients in the soil, which are then washed away before the plants and trees have a chance of using them in order to grow.

Effects on humans and aquatic life

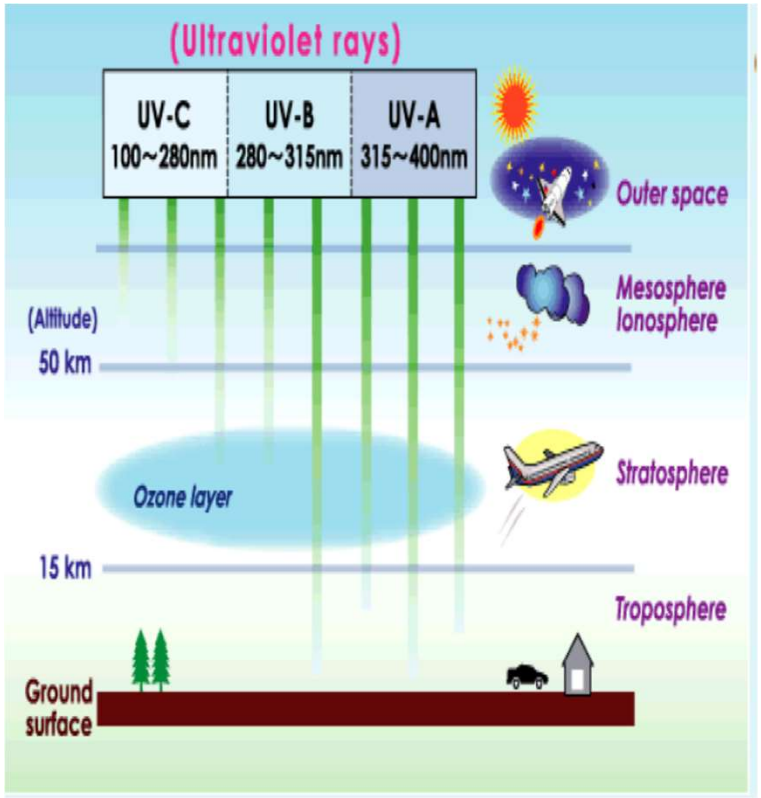
- Acid rain harm us via the soil where the food we eat is grown.
- Contaminated food can damage the nerves, results in barin damage and even death.
- Components of acid rain may also infiltrate into the ground water which is a source of drinking water
- High amount of acid interferes with the ability of fish to take in Oxygen from water
- Change in the pH levels also impairs fish's ability to maintain their calcium levels which causes deformed bones.

Ozone Layer Depletion /Ozone Hole

Ozone is..

- A form of Oxygen with 3 Oxygen atoms (O_3)
- Is a highly corrosive and toxic gas.
- Is considered a pollutant in troposphere, however, necessary in stratosphere.

Ozone Hole



- Ozone layer is present at an altitude of 25 km in stratosphere.
- Ozone hole is thinning of ozone layer [NOT A HOLE IN OZONE LAYER]

Ozone Depletion

Reaction of Ozone with chlorine:

$$Cl\cdot + O_3 \rightarrow ClO + O_2$$

The ClO from this reaction destroys a 2nd Ozone molecule and recreates the original Chlorine radical which can repeat the first reaction and continue to destroy Ozone.

$$ClO + O_3 \rightarrow Cl\cdot + 2O_2$$

- Chlorine radical in stratosphere mainly come from CFCs, which can only be broken down by the extremely high UV radiation found above most of the Ozone layer.

1 $Cl\cdot$ Is capable of destroying 10^5 molecules of O_3.

Why are we concerned?

- Ozone Hole results in:
  - Increased cases of skin cancer and cataracts
  - Damage to crops thus affecting food chains and food webs
  - Increase in CO_2.

  With the signing of the Montreal Protocol in 1987, a treaty for the protection of the Ozone layer, the use of CFCs were banned by the year 2000.

Questions please!

Notes:

- These slides will be shared on ERP portal.
- Also, recorded lecture will be shared on Google Drive. Will share the link with the class.