ENVIRONMENT AND ITS SEGMENTS

- Word **"Environment"** derived from French word **"Environner"** meaning "**To encircle or Surround**".

- Simply be defined as the **surrounding of an organism** in which the **organism lives**.

- **Surrounding** includes things-

✓ **Non-living (Abiotic)- Air, Water, Soil** etc.

✓ **Living (Biotic)- all other living beings which organism comes into regular contact in its environment.**

- Absence of these organism meaningless to speak of **environment and vice versa**.

- In other words exists a **mutual interaction** between **every organism and its environment**.

Global Environment

Consist four segments-

1. Atmosphere
2. Hydrosphere
3. Lithosphere
4. Biosphere

1. ATMOSPHERE

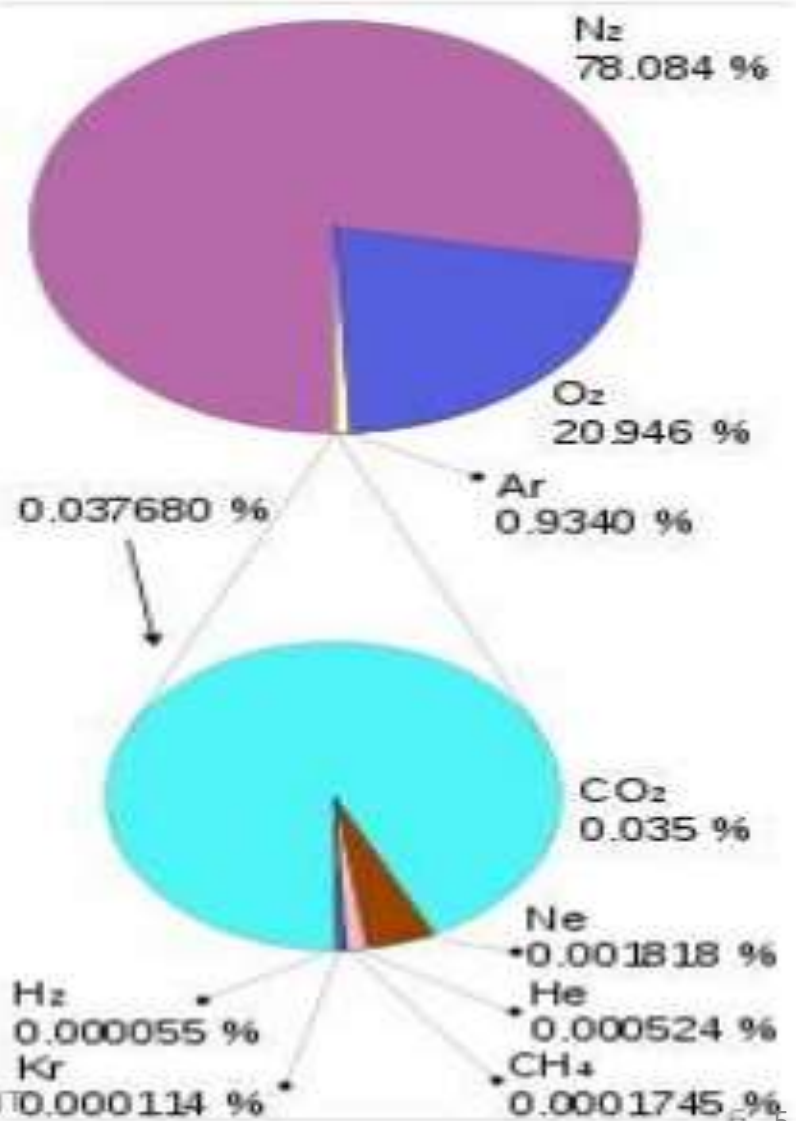
- **Definitions:** *"The **thin envelope of gases surrounding** the earth **Highly compressible"***
- **Absorb** most **cosmic rays from outer space and a major portion of electromagnetic radiation (EMR)** from Sun and transmits only **near UV, visible & IR radiation (300-2500nm)** and **radio wave** while filtering out **harmful UV radiation below 300nm**.
- **Atmosphere is bound to earth by gravity.**
- **Total mass of Atmosphere: $5x10^5$ tones** which is **1 millionth of Earth's total mass**.
- Density decreases **rapidly with height**

Cont....

- **Air:** *A mechanical mixture of* ***Gases and Aerosols***
- **Pure air- colorless, odorless, tasteless** and **can't felt except in motion**.
- By weight of **1 liter air= 1.3gm**
- Pressure at sea level= **1033.6g/sq.cm (called 1 Atmosphere)**
- **Source Of O_2 – essential for life**
- **Source Of CO_2 – essential for plants in photosynthesis**
- **Without that would be – no clouds, no winds or storm and hence no weather.**

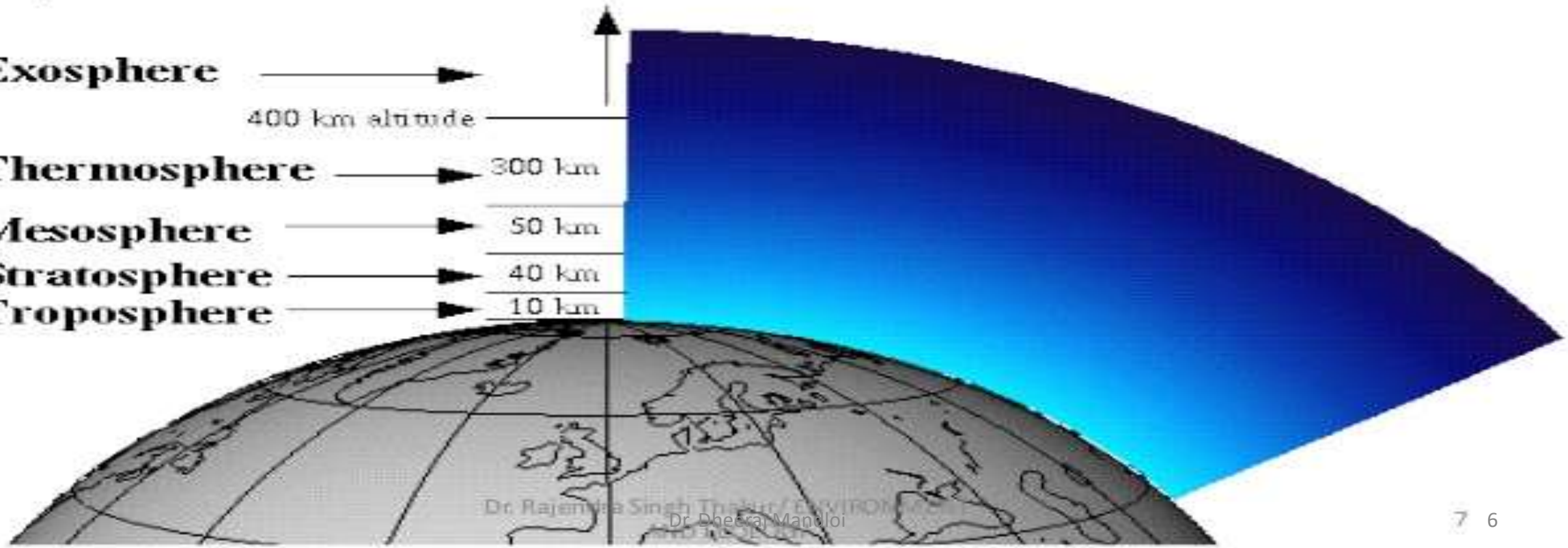
Composition of Atmosphere

ppmv: parts per million by volume (note: volume fraction is equal to mole fraction for ideal gas only, see volume (thermodynamics))		
Gas	Volume	%
Nitrogen (N_2)	780,840 ppmv	(78.084%)
Oxygen (O_2)	209,460 ppmv	(20.946%)
Argon (Ar)	9,340 ppmv	(0.9340%)
Carbon dioxide (CO_2)	397 ppmv	(0.0397%)
Neon (Ne)	18.18 ppmv	(0.001818%)
Helium (He)	5.24 ppmv	(0.000524%)
Methane (CH_4)	1.79 ppmv	(0.000179%)
Krypton (Kr)	1.14 ppmv	(0.000114%)
Hydrogen (H_2)	0.55 ppmv	(0.000055%)
Nitrous oxide (N_2O)	0.325 ppmv	(0.0000325%)
Carbon monoxide (CO)	0.1 ppmv	(0.00001%)
Xenon (Xe)	0.09 ppmv	(9×10^{-6}%) (0.000009%)
Ozone (O_3)	0.0 to 0.07 ppmv	(0 to 7×10^{-6}%)
Nitrogen dioxide (NO_2)	0.02 ppmv	(2×10^{-6}%) (0.000002%)
Iodine (I_2)	0.01 ppmv	(1×10^{-6}%) (0.000001%)
Ammonia (NH_3)	trace	
Not included in above dry atmosphere:		
Water vapor (H_2O)	~0.25% by mass over full atmosphere, locally 0.001%–5%	



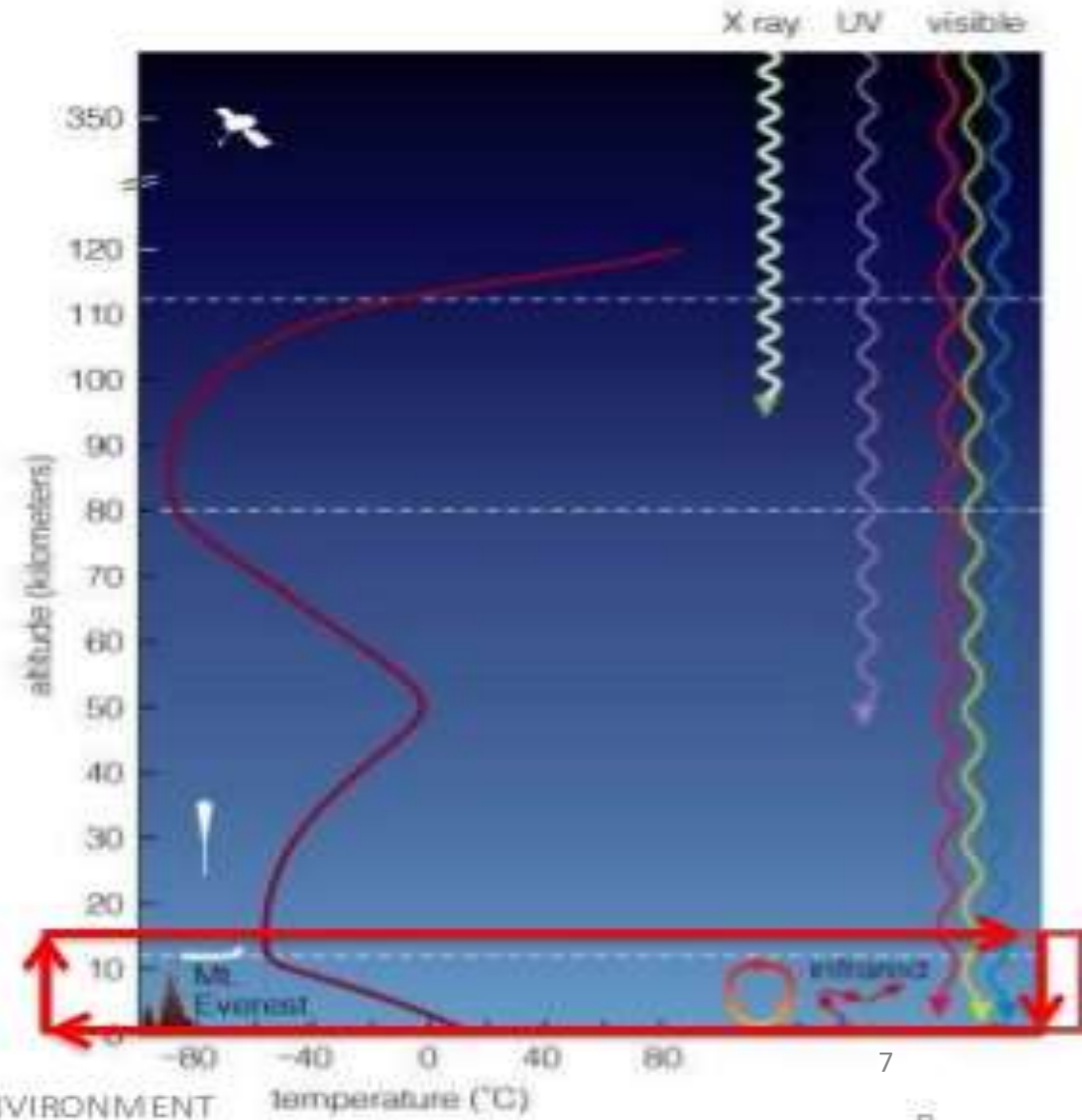
Structure of Atmosphere

- **No sharp boundary** with extraterrestrial space
- **Phenomena – magnetic and gravitational field** extend outward for thousand km to vague zone of **nebulas gases and radiation particle**.
- Basis of **Temperature and other related phenomenon** divided in to four major layer-



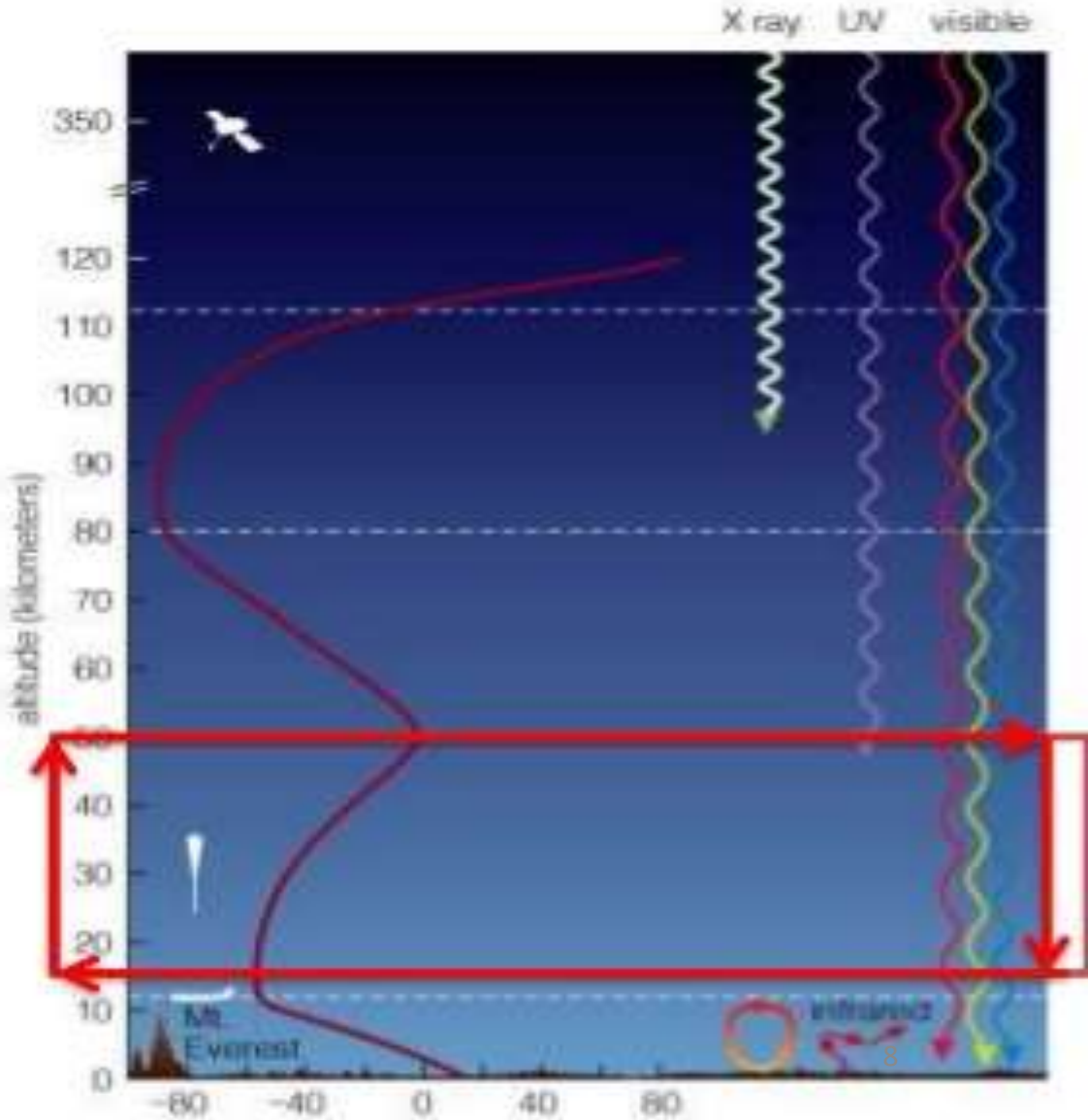
Troposphere

- Altitude extending about up to about **8km at the pole and 16 km at the equator**
- The **lowest region** of the atmosphere, where **life & weather exist**.
- **Temperature decreases** with altitude **(about 6°C/km) to minimum of -50° or -60°C.**
- **Long-wave radiation** emitted from Earth is absorbed by **the atmosphere**, the atmosphere becomes less dense with increasing altitude, less air to absorb.
- It contains **about ¾ of atmospheric mass** and is the **abode of clouds, storms and convection motion**.
- Top of the troposphere is known as the **tropopause** and **average global temperature is 17°C** but local averages vary widely.



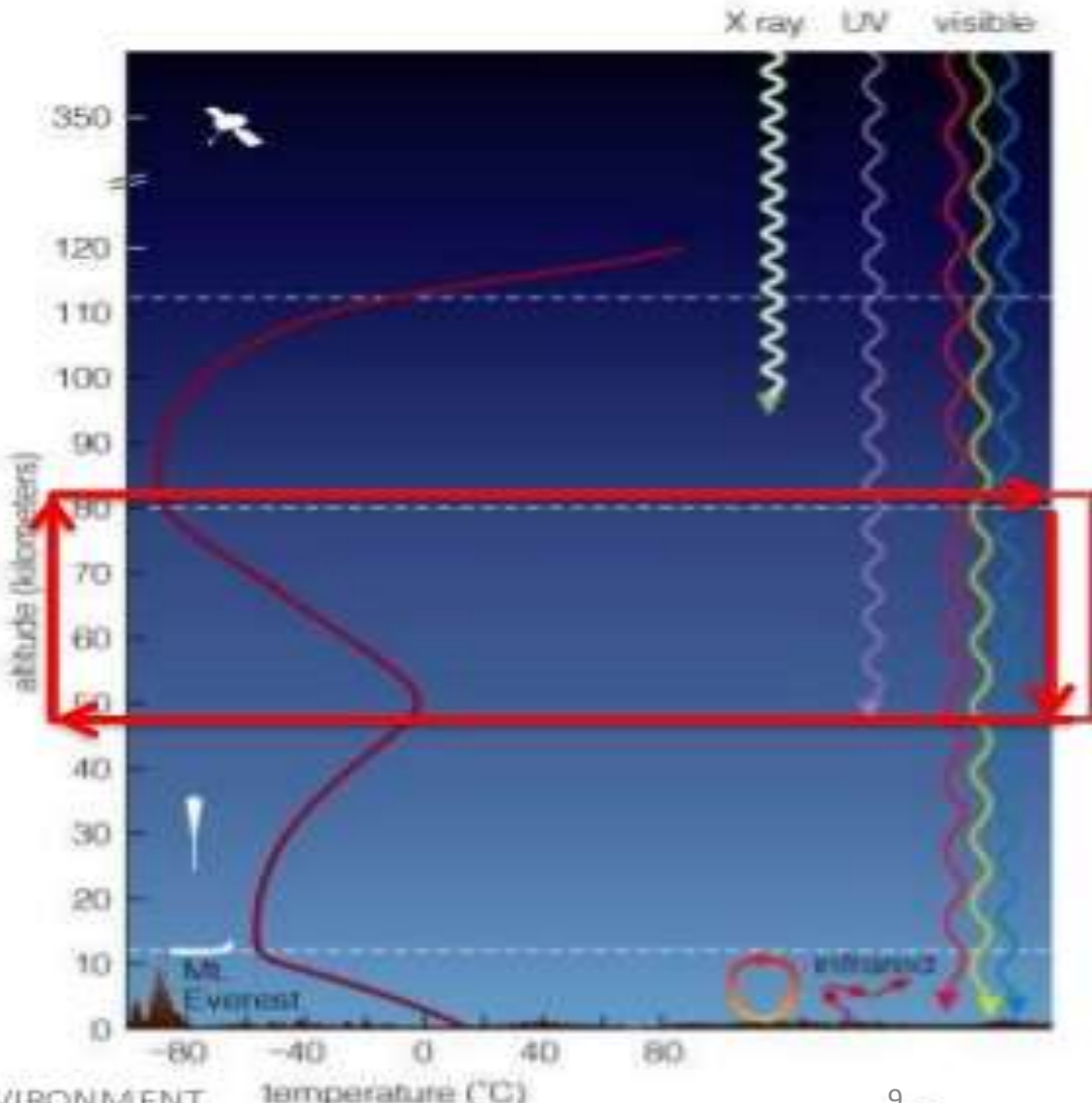
Stratosphere

- **16 to 50 km** altitude
- **Temperature increases** with altitude and **increases from -60°C up to a maximum of 0°C** near outer limits, **stratapause**.
- **Heating occurs because ozone (O_3) absorbs ultraviolet radiation** from the Sun.
- Top of the stratosphere is known as the **stratopause.**

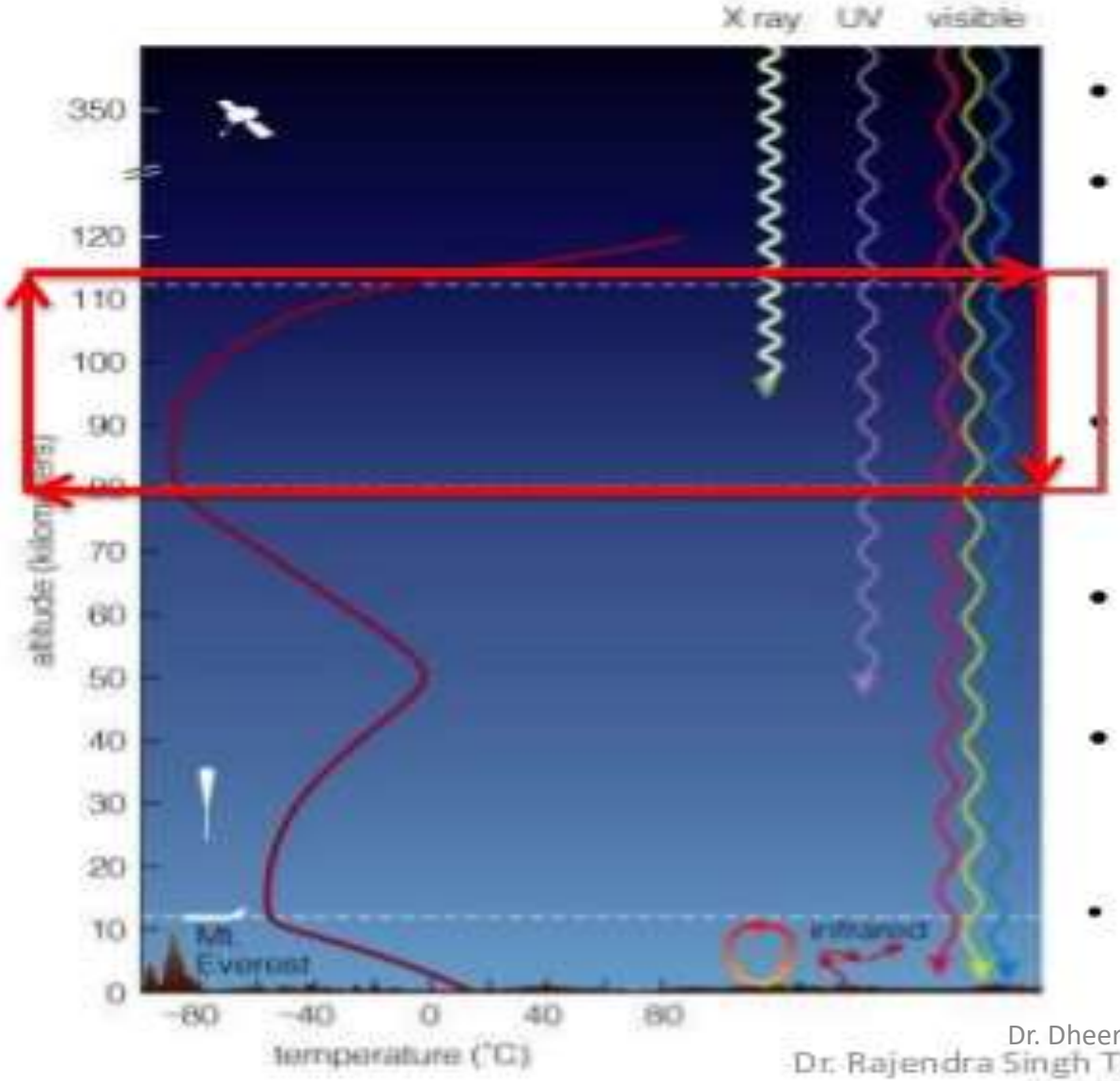


Mesosphere

- **50 to 80 km** altitude
- **Temperature decreases** slowly with altitude **0°C to minimum about -75°C** near the mesopause.
- The **lowest temperatures in the entire atmosphere** are found at the mesopause during summer at high latitudes.
- Top of the mesosphere is known as the **mesopause at 80km.**

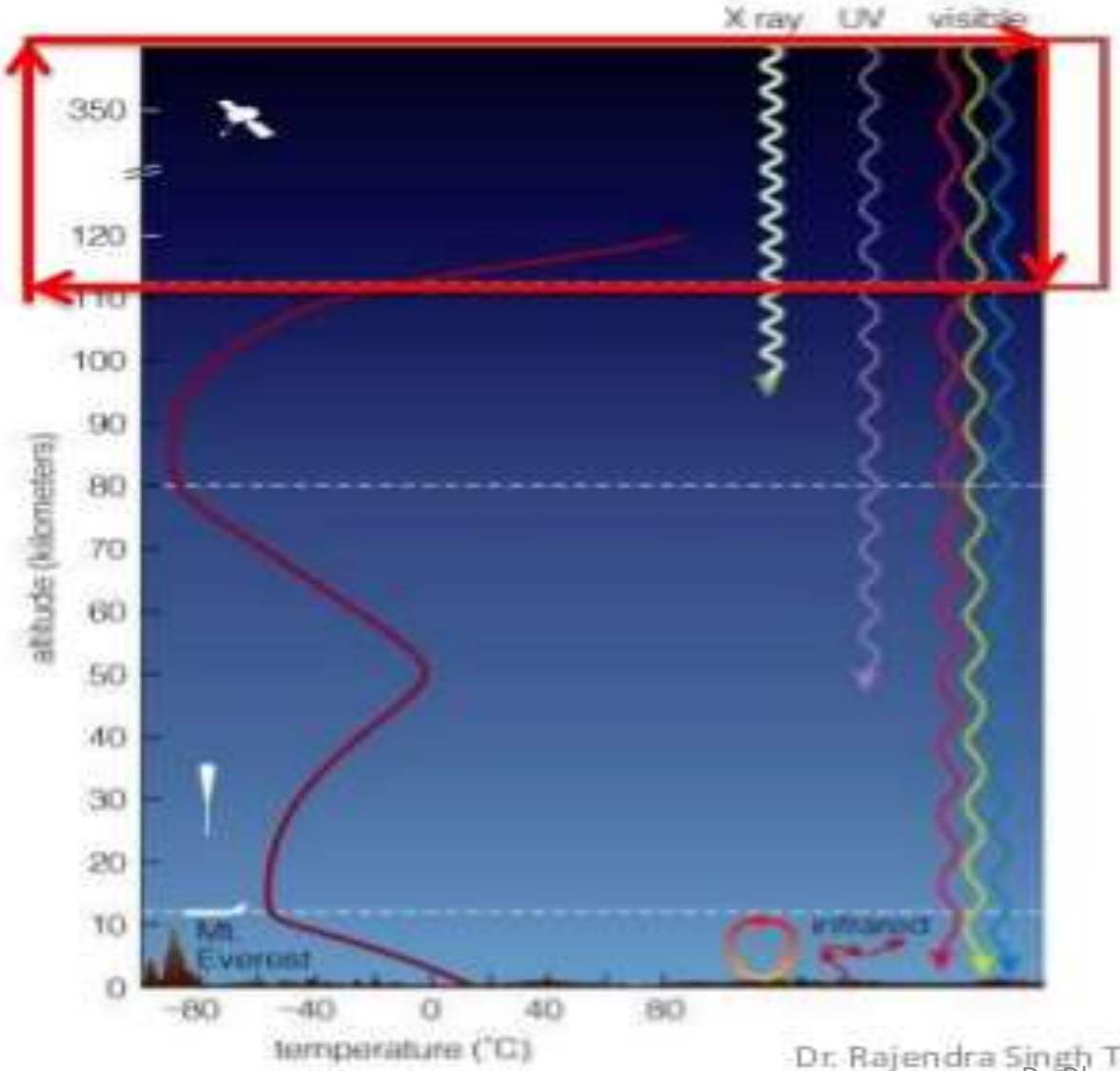


Thermosphere



- **Thermosphere:** Layer at about **80 to 500 km** altitude
- **Temperature increases** with altitude **above 80 km.**
- Additional vertical subdivision of atmosphere can identified on **the basis of chemical composition (ozonosphere)** or **physical properties** other than **temperature**.
- Coinciding with the lower portion is called **Ionosphere** **of the 100-400km**.
- It is due to this layer that **radio waves are reflected by ionized layer** at great height.
- This heating is due to **absorption of solar radiation (wavelengths less than 0.2 microns)** by **molecular oxygen (O_2).**
- **X rays and ultraviolet light** from the Sun **heat and ionize gases**.

Thermosphere



- **Exosphere:** Highest layer in which atmosphere gradually fades into space
- **Temperature rises** with altitude; **atoms** can escape into space
- The highest temperatures in the atmosphere can be found in the thermosphere, **2000°C** can occur.
- Warmed by **X rays and UV light**

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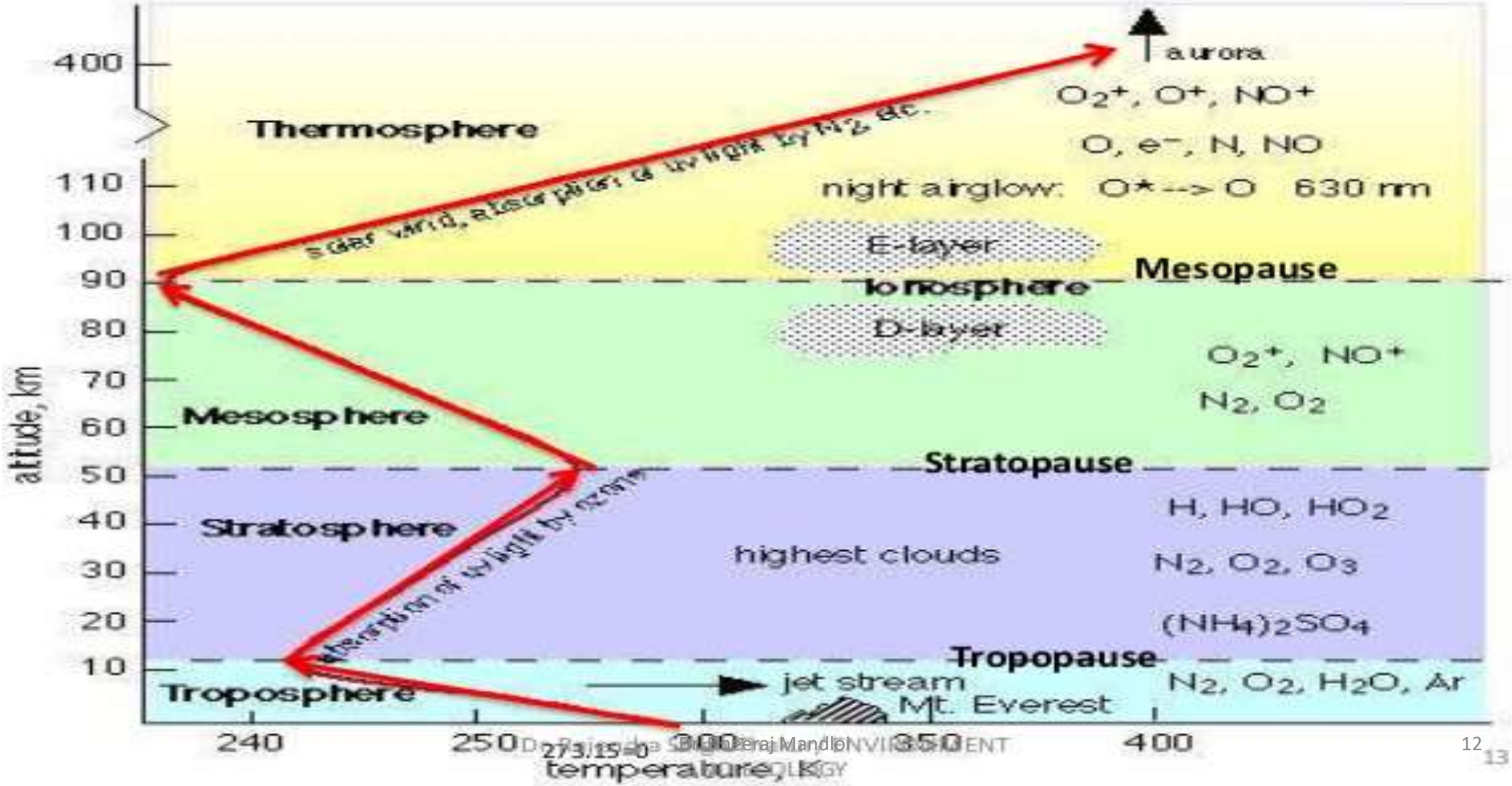
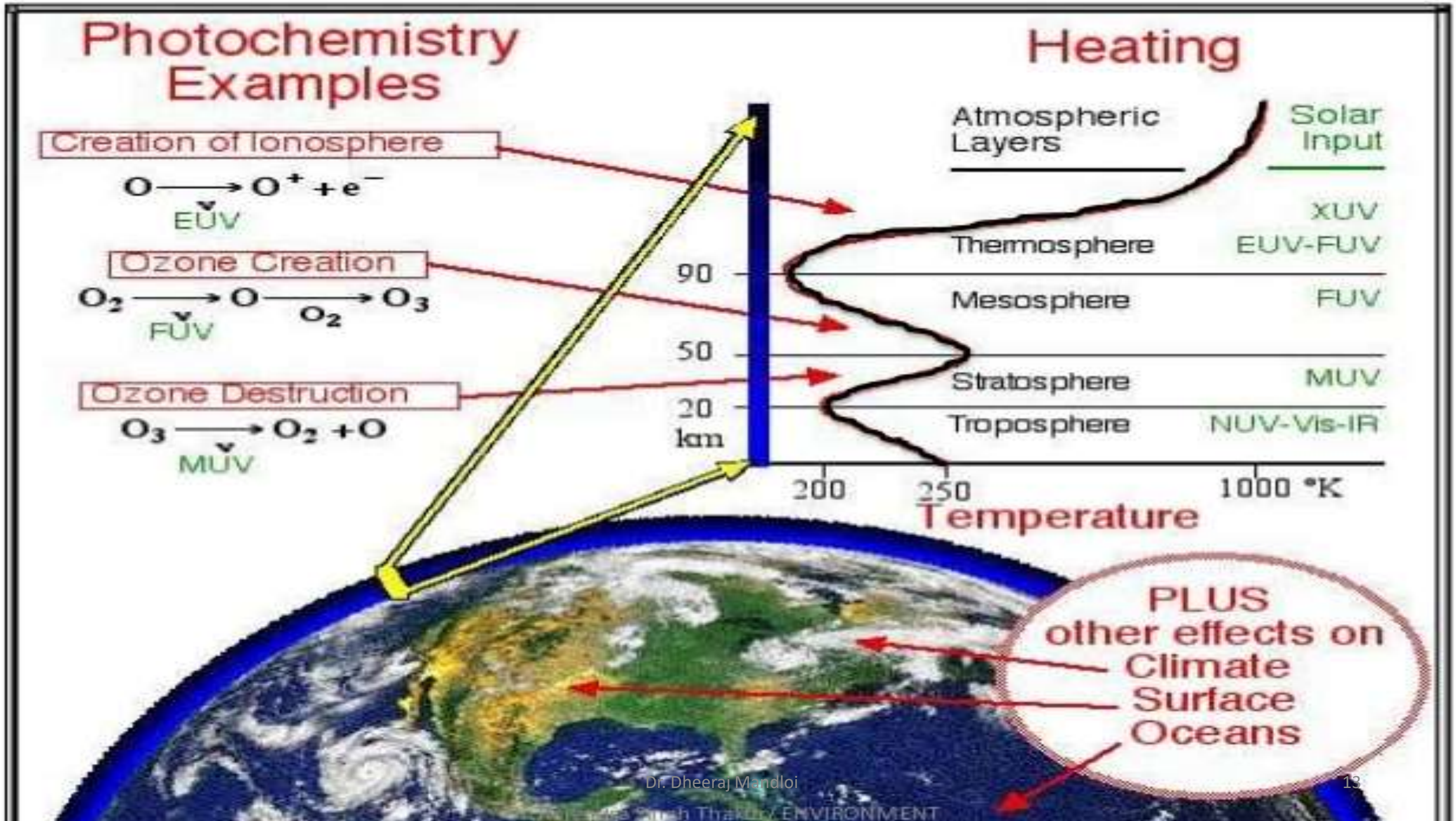
Structure of Atmosphere




Photochemistry Examples
Creation of Ionosphere
$O \xrightarrow{\nu} O^+ + e^-$
EUV
Ozone Creation
$O_2 \xrightarrow{\nu} O \xrightarrow{O_2} O_3$
FUV
Ozone Destruction
$O_3 \xrightarrow{\nu} O_2 + O$
MUV
Heating
Atmospheric Layers
Solar Input
XUV
Thermosphere
EUV-FUV
90
Mesosphere
FUV
50
Stratosphere
MUV
20
km
Troposphere
NUV-Vis-IR
200
250
1000 °K
Temperature
PLUS
other effects on
Climate
Surface
Oceans

2. HYDROSPHERE

- The hydrosphere includes **all water on Earth.**
- The abundance of water on Earth is a unique feature that **clearly distinguishes our "Blue Planet"** from others in the **solar system.**
- **Not a drop of liquid water** can be found anywhere else in the **solar system.**
- It is because the **Earth** has just **the <u>right mass</u>, the <u>right chemical composition</u>, the <u>right atmosphere</u>, and is the <u>right distance from the Sun</u>** that permits water to exist mainly as a liquid.

Hydrosphere

- The range of **surface temperatures and pressures** of our planet permit water to exist in **all three states:**
  Solid (ice),
  Liquid (water), and
  Gas (water vapour).
- Most of the water is **contained in the oceans and the high heat capacity of this large volume of water (1360 million cubic kilometres)** buffers the **Earth** surface from large **temperature changes.**
- Water is the **universal solvent and the basis of all life on our Planet**.
- It is an **essential life-sustaining resource.**

Hydrosphere

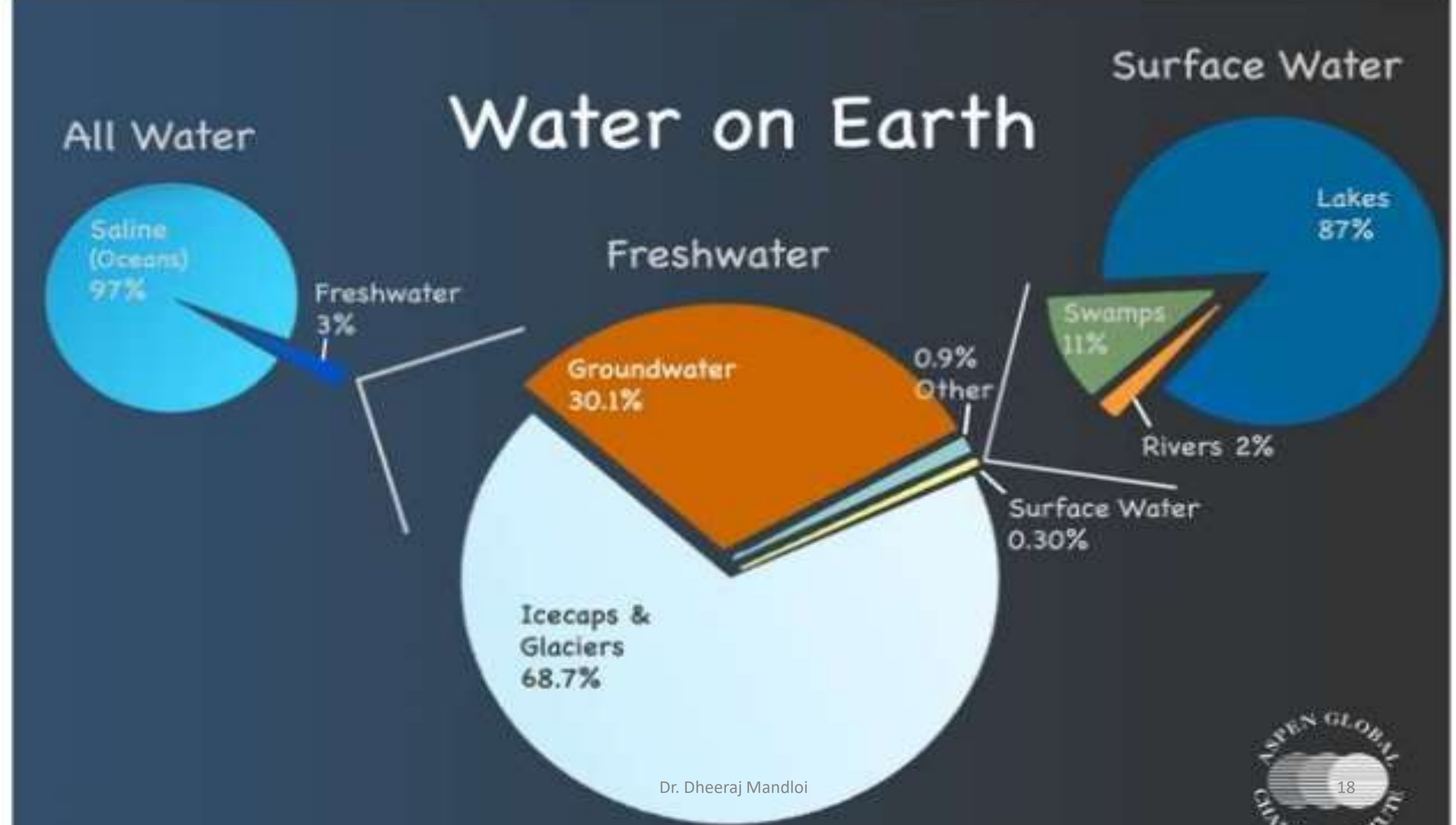
- Water Resources
  - The **hydrosphere** consists of the Earth's water resources: **oceans, seas, lakes, rivers, streams, groundwater inflow with surface water, reservoir's and glaciers**
  - Earth's surface is **covered by 71% water**
  - Essential for life – can survive only a **few days without water**

The Structure of Hydrosphere

- **Oceans—97%** of water is **salt water** and it found in **the oceans**.

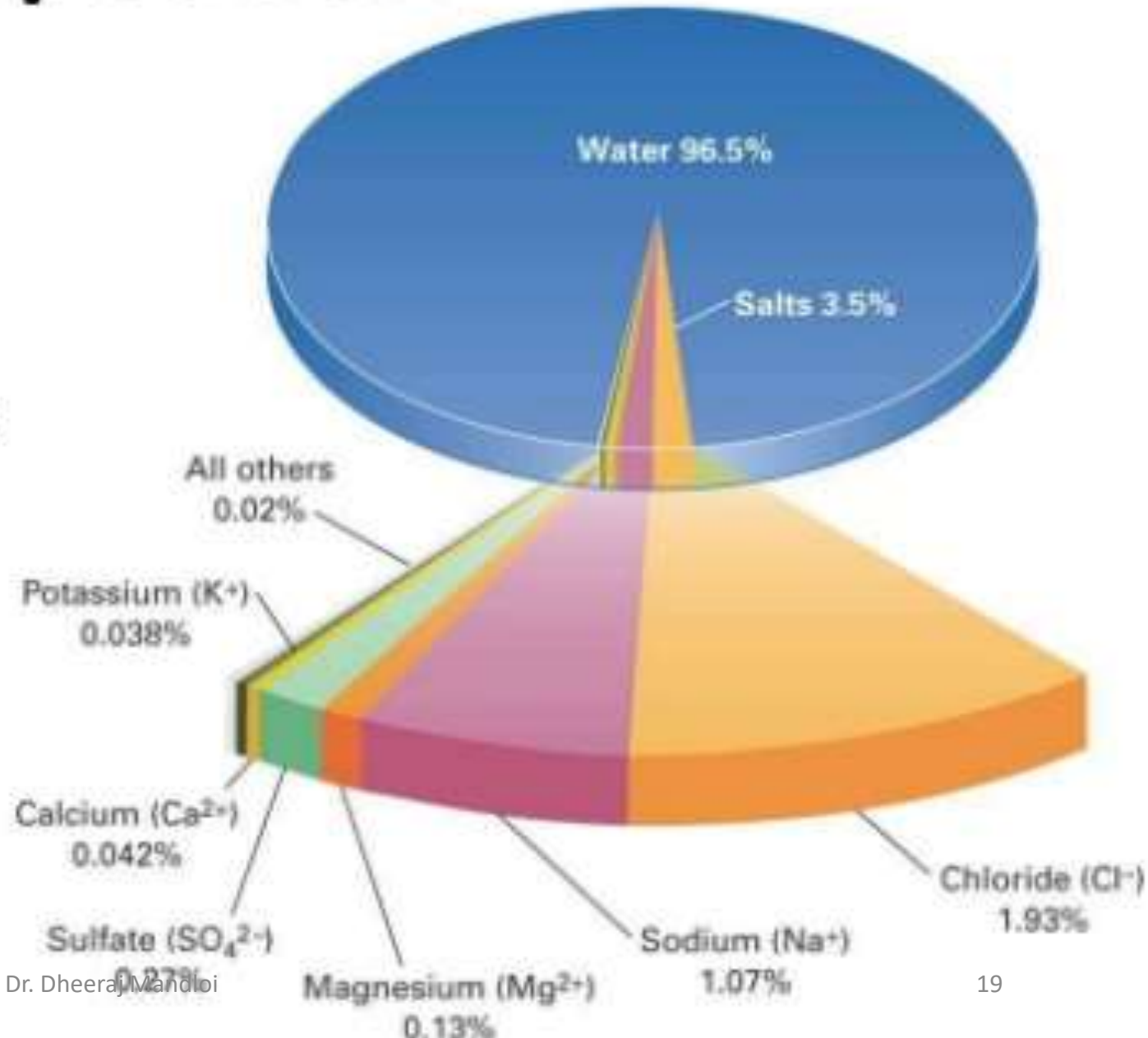
- **Fresh water**—the remaining **3%** is **freshwater**.

- Fresh water distribution:
  - **Ice: 1.762%**
  - **Groundwater: 1.7%**
  - **Surface Fresh Water: 0.014%**
  - **Atmosphere and soil: 0.002%**


Water on Earth
All Water
Saline (Oceans) 97%
Freshwater 3%
Freshwater
Groundwater 30.1%
0.9% Other
Icecaps & Glaciers 68.7%
Surface Water
Lakes 87%
Swamps 11%
Rivers 2%
Surface Water 0.30%

Composition

- ❑ Obviously water
- ❑ But also:
- Dissolved minerals
- Dissolved gases
- Particulates



WATER CYCLE

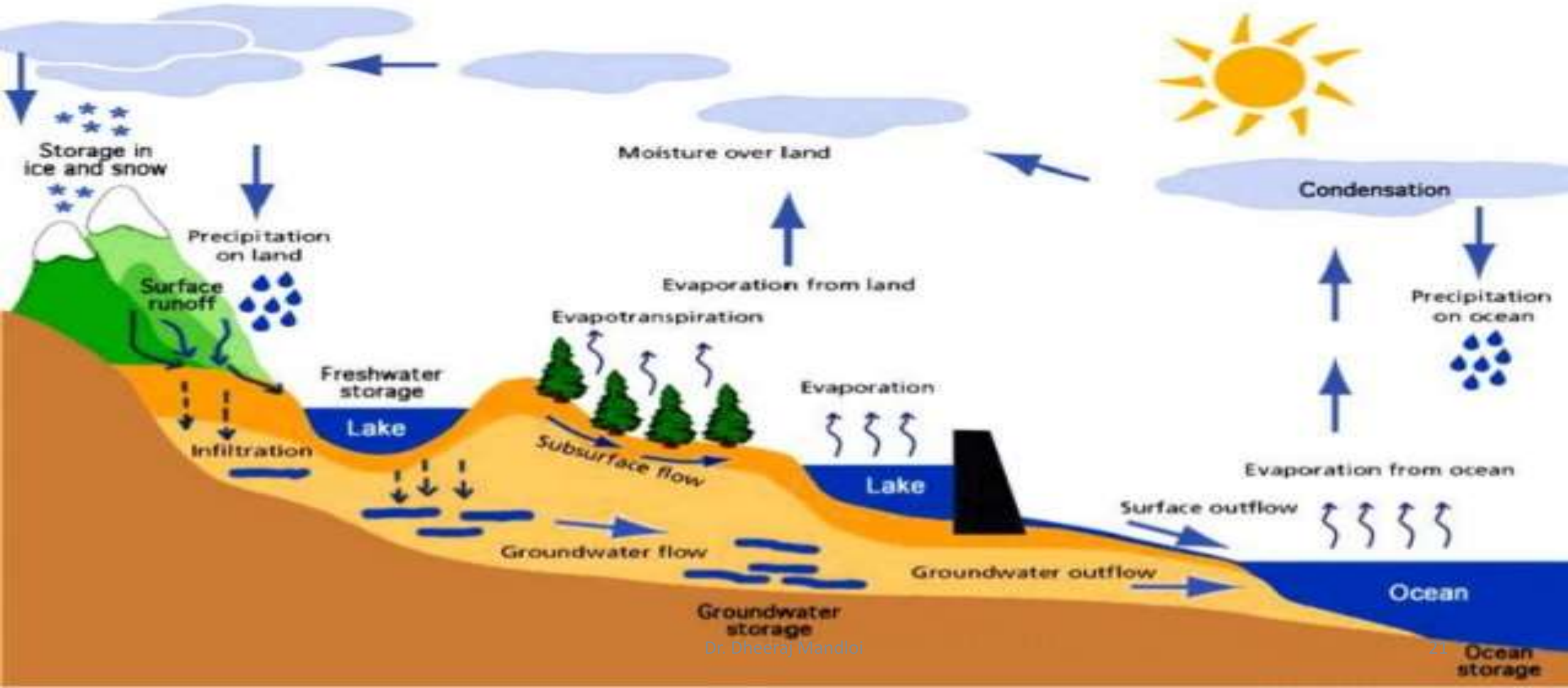
- The **continuous movement of water into the air, onto land and then back to water** sources is known **"Water cycle".**

- **Evaporation** is the process by which as **liquid water is heated by the sun and then rises** into the atmosphere as **"water vapour"**.
- Water continually evaporates from **Earth's oceans, lakes, streams, and soil,** but the majority of the water evaporates from the oceans.

- In the process of **Condensation, water vapour** forms **water droplets on dust particles**.
- These **water droplets form clouds**, in which the **droplets collide, stick together, and create larger, heavier droplets**.

- These larger droplets fall from clouds as rain in the process called

Water Cycle


Storage in ice and snow
Precipitation on land
Surface runoff
Freshwater storage
Lake
Infiltration
Evapotranspiration
Subsurface flow
Moisture over land
Evaporation from land
Evaporation
Lake
Groundwater flow
Groundwater storage
Condensation
Precipitation on ocean
Evaporation from ocean
Surface outflow
Groundwater outflow
Ocean
Ocean storage

3.LITHOSPHERE

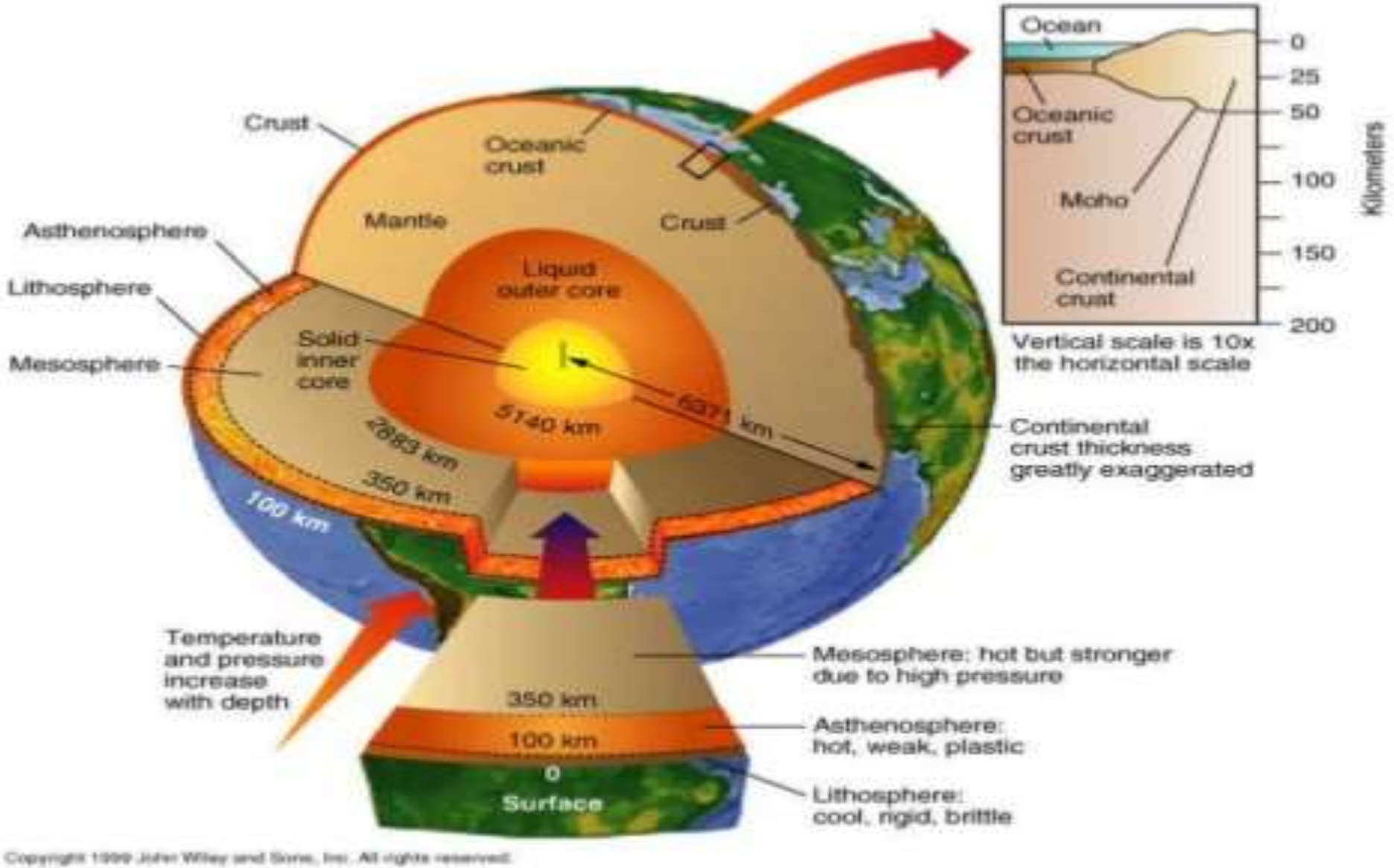
- The lithosphere is **the solid, outer part of the Earth**.
- Geological speaking, **top crust of the earth** on which the **continent and ocean basin rest**.
- The Earth consists of **three main layers**: **the core**, or the inner layer; **the mantle**, in the middle; and **the crust**, which includes **the continents and ocean floor**.
- Thickest in continental regions where **average thickness 40km** and **thinnest in ocean 10-12km.**
- The movement of the lithosphere, called **plate tectonics**, is the reason behind a lot of Earth's most dramatic geologic events.
- When **one plate moves beneath another**, or **when two plates rub together, they can create earthquakes and volcanoes**.

- The earth is **divided into three layers –the crust, mantle, and core-based** on what each one is made of- **The lightest materials make up the outermost layer**, and **the densest materials make up the innermost layers**.
- The **core is approximately 33% of the Earth's mass** and is the innermost layer.
- The **mantle is approximately 67% of the Earth's mass**.
- The outermost layer is the **crust approximately 1% of the Earth's mass**.
- Environmental scientist- **interest upper few feet of soil**.
- **Soil** which is important part for **organic matter and biological activities**
- To produce food for **human being & animals** but also **decomposition of organic waste** is carried out by a host of **micro-organism in the soil**.

Earth structure: The main units

Compositional:
- Crust
- Mantle
- Core

Rheological:
- Lithosphere
- Asthenosphere
- Mesosphere



4.BIOSPHERE

- The **interaction of life with environment** takes place of many levels.
- **A single bacterium in the soil interact** with the **water, air and particle of soil** within a fraction of **a cubic centimeter**.
- While **forest extending hundred square km interact with large volume of water, air and soil**.
- Part of Earth in which life exists including **land, water, and air or atmosphere**.
- We live in **the natural world and use its resources (water, space, food, etc).**
- The natural world effects our lives (**weather, fire, economy**).
- To protect **biodiversity.**
- Thus all **lower atmosphere and near surface part of lithosphere and hydrosphere** affected by life is whole exist **few meters of exists surface**.
- **This region of the earth where life exist** is known as **"Biosphere"**.
- **All living things** required **energy and materials**.
- In biosphere **energy received from the sun** and interior of the **earth received energy is then used** and **given off a material are recycled.**

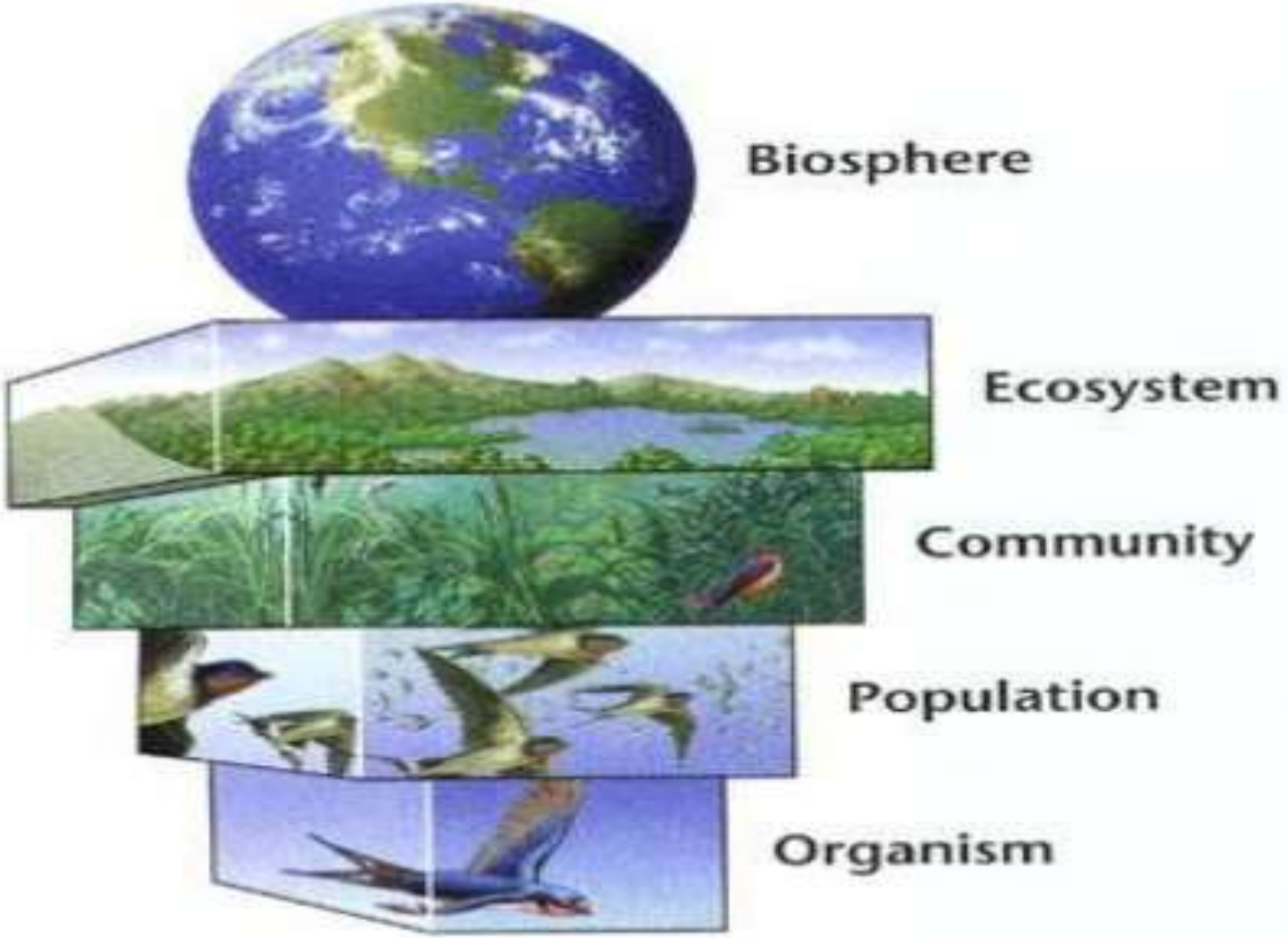
Biosphere

- The biosphere infect is **a thin shell that encapsulates the earth** which includes **all life as well as the lower atmosphere and the oceans, rivers, lakes, soils and solid sediments** that activity **interchange materials with life**.
- According to an estimate biosphere contains-

✓ More than **3.5 lacs species of plant** (including-**algae, fungi, mosses & higher from of plants**).

✓ More than **11 million species of animal** (ranging from **unicellular protozoa to man**).

- **Supplies all the essential requisite of life-**namely, **light, heat, air, water, food & living space (habitats) for all these species**.
- Since biosphere is **very large and complex** then it better understanding by **divided in to smaller units** called **"Ecosystems" or "Ecological systems."**


Biosphere
Ecosystem
Community
Population
Organism

Describe role of various Natural resources in Engineering and development. (including their role/ impact in our life)

NATURAL RESOURSES

Resources provided by Nature including

Forests, Water, Minerals, Food, Cultivars, Energy, Land etc.

Include our interaction with these natural resources and what role they play in our life and economy.

What is Natural Resource?

Definition/Meaning:

The environment is everything which surrounds on organism and influences its life in many ways. It includes physical and biological components. The physical components of the environment are soil, water, air, light and temperature (Abiotic components). The plants and animals are collectively referred to as Biotic components. All these components work together, interact and modify the effect of one another. The basic need of life are fulfilled by minerals present in the nature. These are referred to as Natural Resources.

Importance of Natural Resources

- Least wastage and maximum economic advantage.
- Availability of natural resources at minimum transportation cost.
- Selection of industrial zone.
- Integral use of Natural Resources to obtain long term Economic advantages. (eg., proper plan to utilize timber from forest for long period of time)
- To achieve multipurpose advantages. (eg., dam construction on a river serves for protection against the flood, proper irrigation project, development of fishing industry, electricity generation.

Classification of Natural Resources

1. Based on Origin:
   a. BIOTIC: (living organisms)
   b. ABIOTIC: (non living organisms)
2. Based on Availability:
   a. Inexhaustible: (replenishes naturally)
   b. Exhaustible: (replenishing process is extremely slow)
3. Based on Distribution:
   a. Omni present: (found everywhere)
   b. Location based: (found at some specific locations only)

Continue...

4. Based on Source:

a. Water Resources

b. Forest Resources

c. Mineral Resources

d. Marine Resources

5. Based on Chemical Composition:

a. organic: (vegetables, animals, bacteria, mineral oil)

b. Inorganic: (Air, water, minerals)

c. mixed: (land)

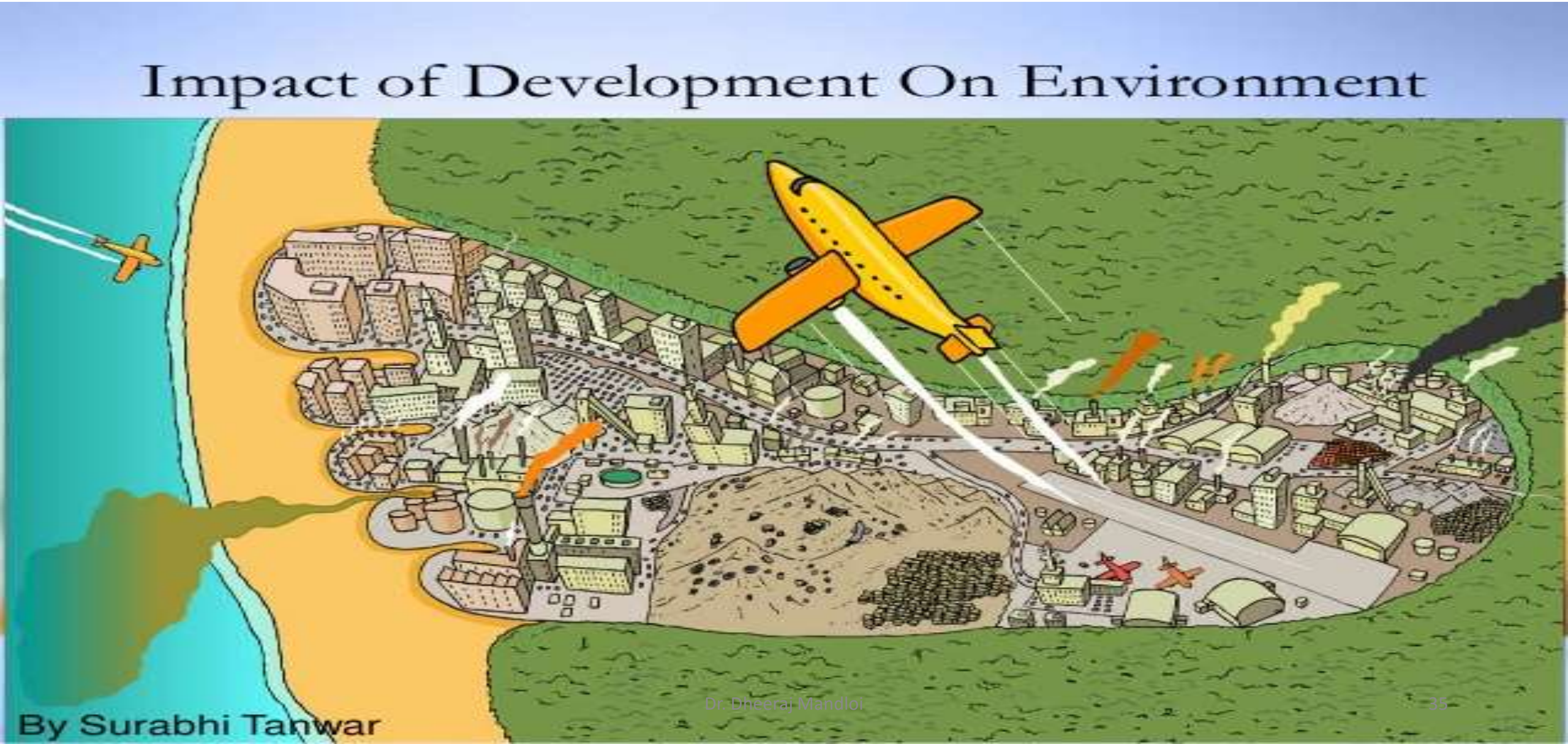
Importance of Land in India:

- India is an Agricultural Economy and it is inevitable to have Agricultural activities without proper usage of available land resource.
- 60% of the land in India is either cultivable or non cultivable in which 1/3 of which is not proper for crop-yield due to soil erosion and less mineral content in the land.
- 1/3 land is having less productivity.
- So we have only 1/3 land available for crop yield.
- Due to deforestation the problem of soil erosion is increasing day by day.
- To increase the crop production, we have to use scientific farming techniques and will have to look for the solutions towards soil erosion.

Steps to conserve the Land:

1. Waste land reclamation. (convert the non cultivable land into cultivable land)
2. Adopting diversity by the use of proper irrigation technique.
3. The Agricultural lands should be kept reserved for the Agricultural use only.
4. Use of Hybrid seeds should be promoted to maintain the fertility of the land for long period.
5. Grow more trees to avoid soil erosion.
6. Farmers should be given advices after proper testing of the land minerals.

Adverse Impacts of Development on our Environment



Industry

Economy, Conveniences and Productivity advances

Industrial Revolution mid 1800's.

- More "Stuff" → More Waste

Increase use of Tools, Technology and Sciences

Use of Fossil Fuels → Release of CO_2 → Green House Effect

Chemical and waste by products of manufacturing

Air, Water, Land, Noise Pollution

Including-

Definition

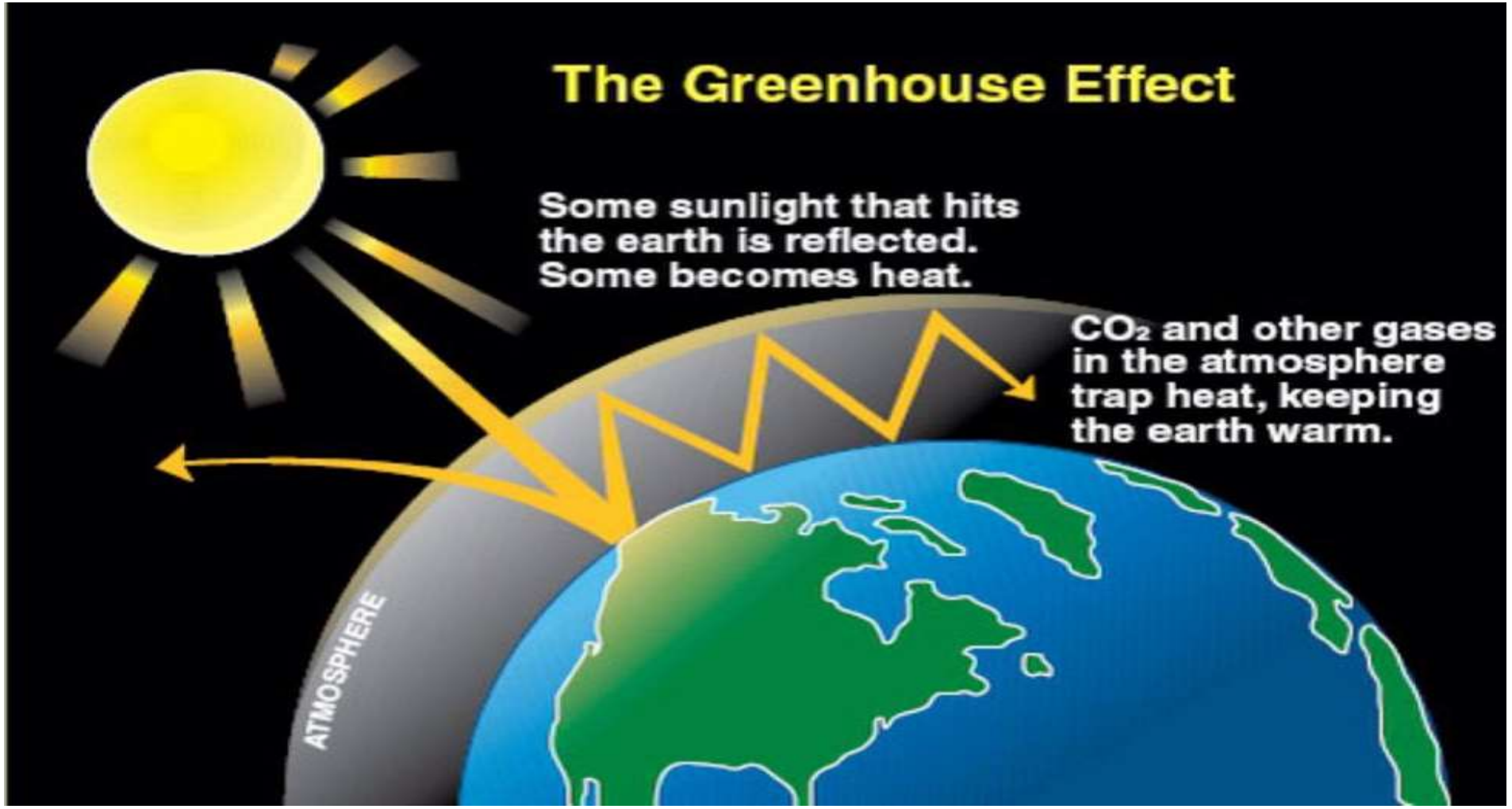
List and classification of pollutants with examples

Their sources

Harmful effects

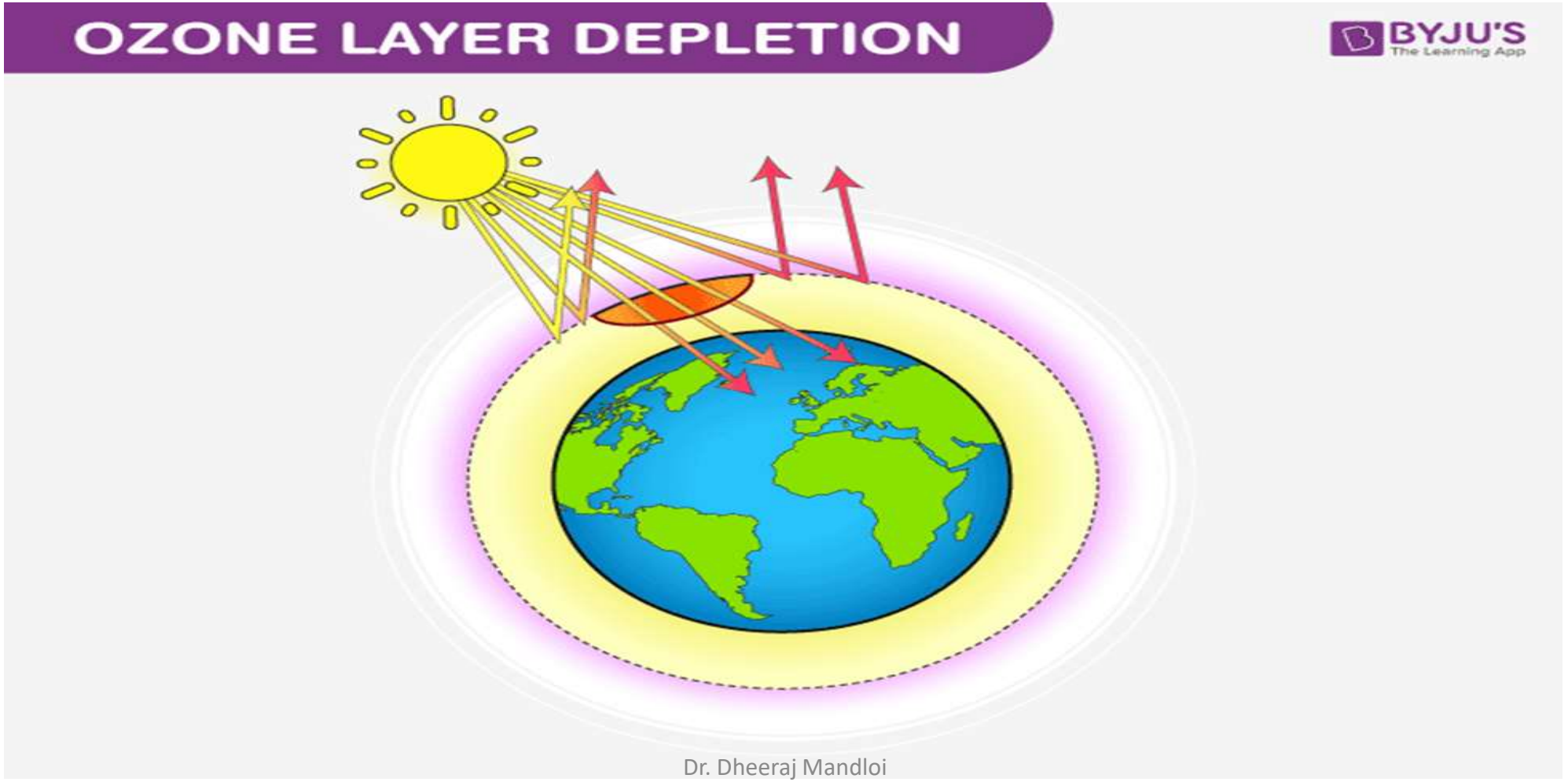
Control measures

Green House Effect and Global Warming

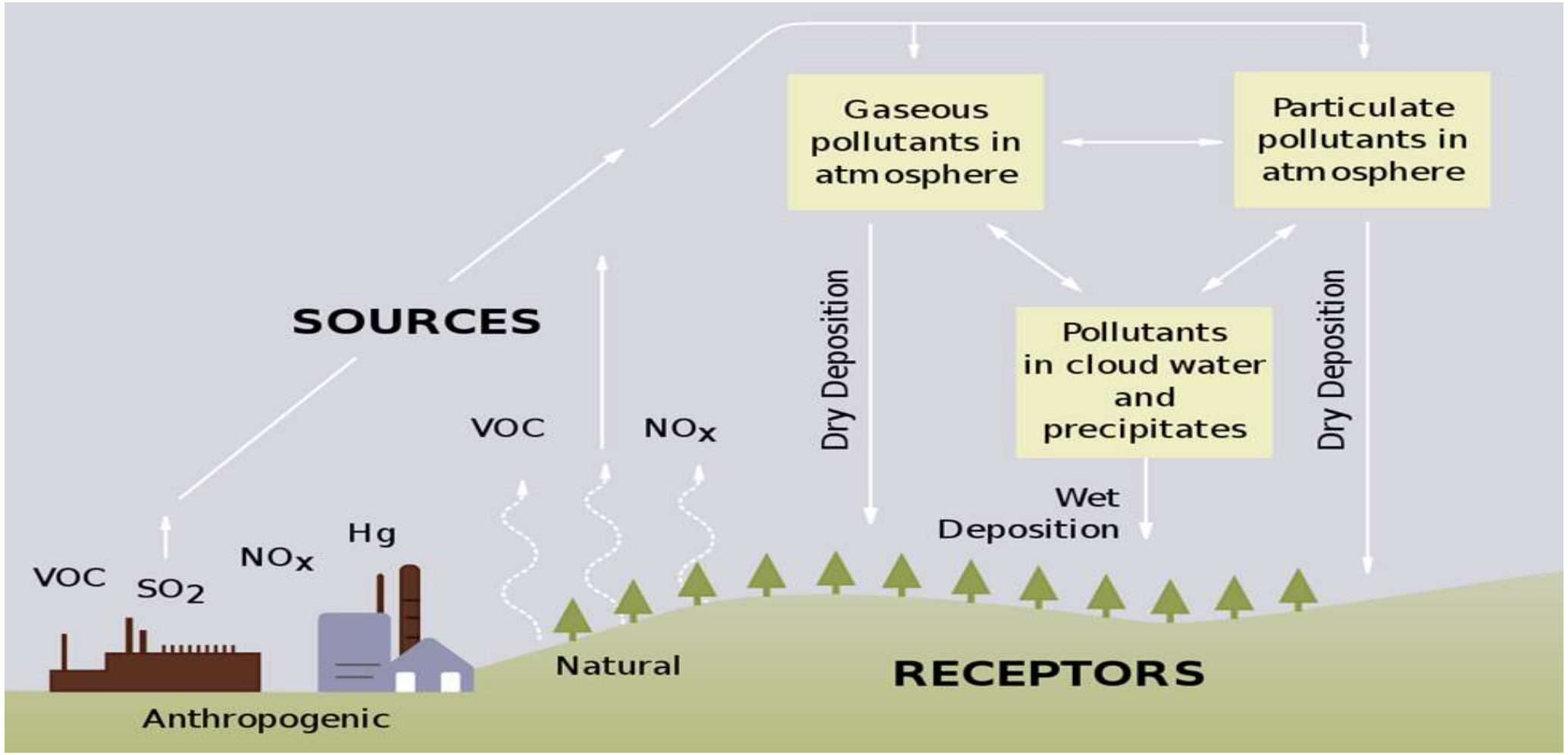


Explain concept of Green house effect and Global warming, green houses gases are increasing (why?), effects, control measures

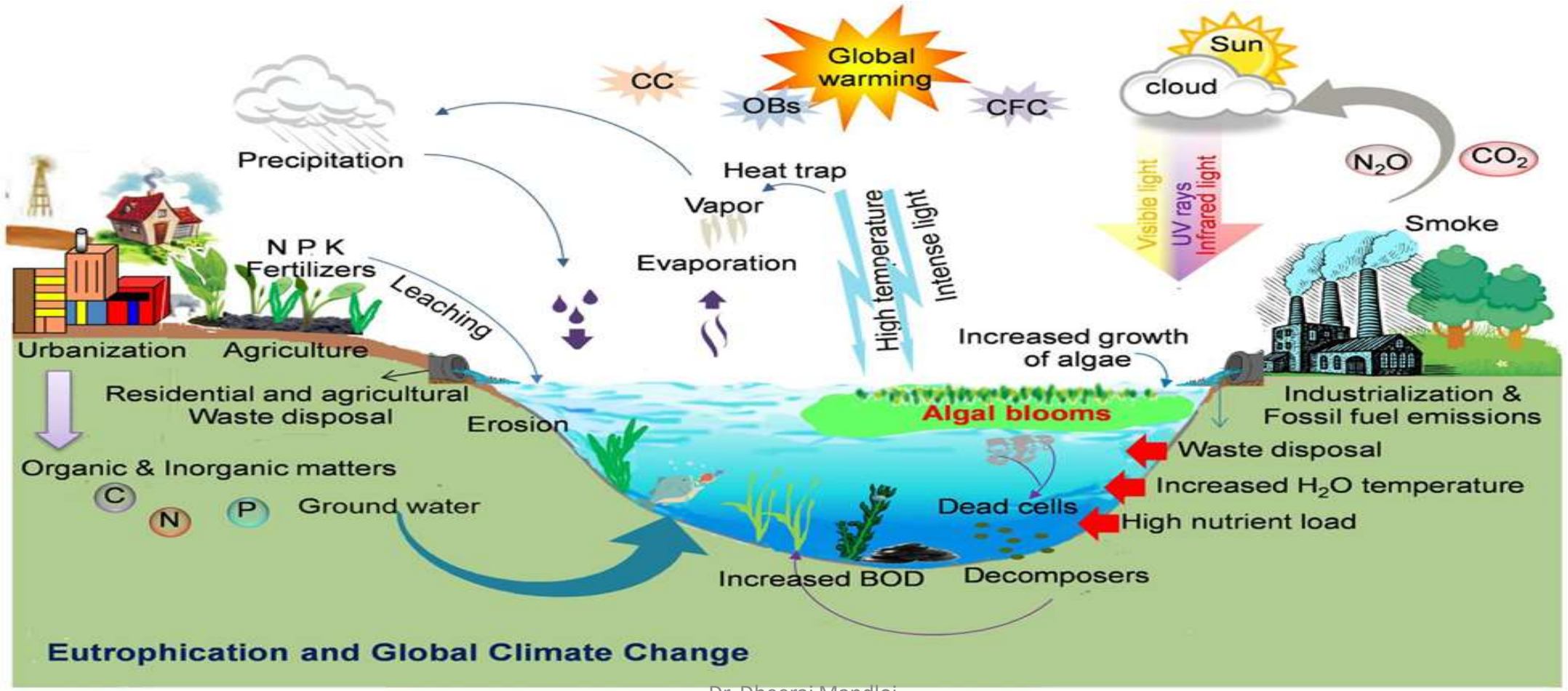
Chlorinated compounds are present in very small amount but causing maximum damage to Ozone layer in stratosphere. Why and how? (Chain reactions, more life of $Cl^{\cdot}$)



What causes Acid rains and what are its adverse effects to our environment? (SO_x, NO_x, sources, effects, control)

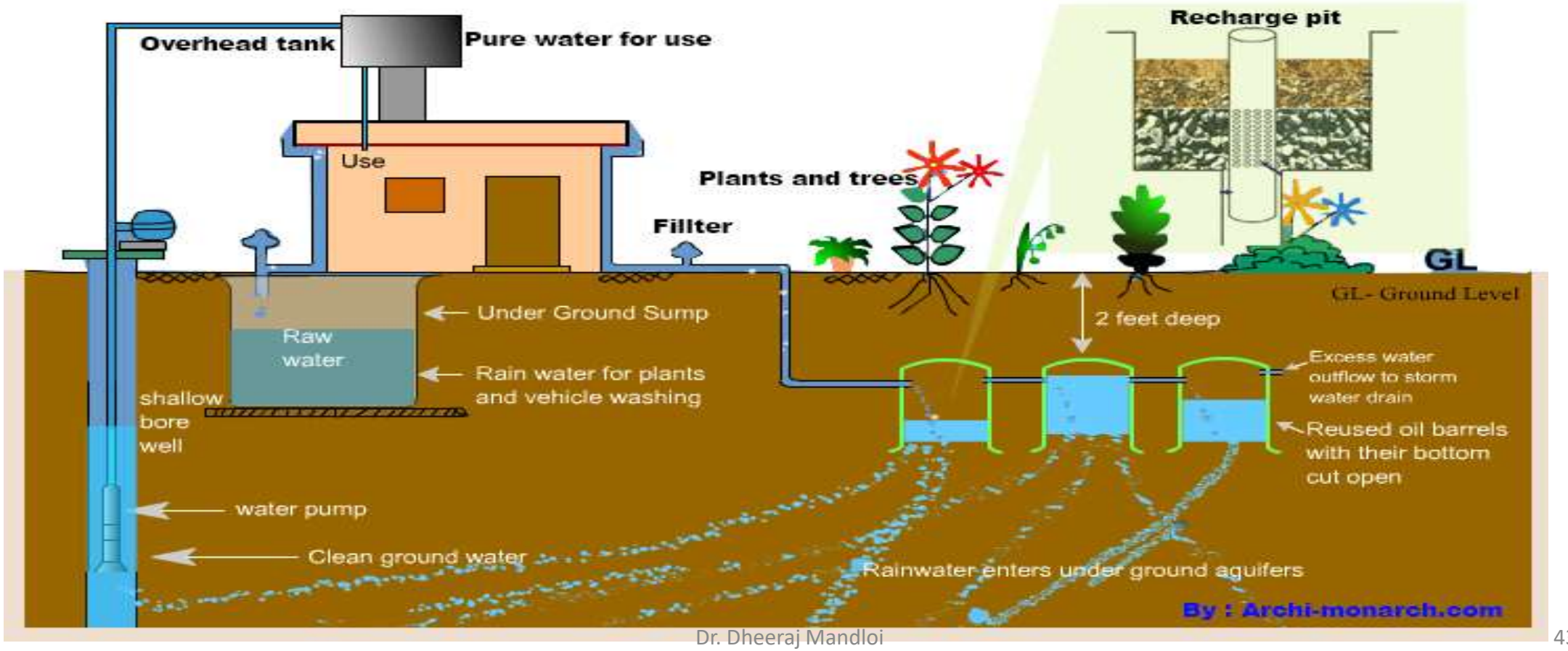


What is Eutrophication? What factors are responsible for this? Why this is considered very serious problem associated with water bodies? (gradual death of a water body)



Why Rain water harvesting is essentially required in present times? Explain various methods available for Rain water harvesting. (with examples)

Awareness, methods of rain water harvesting, its importance



What is Environment Impact Assessment? What steps are involved in EIA? How it is helpful in environment protection and pollution control?

EIA is considered as one of the most effective engineering and management tool to control pollution.

Now, mandatory in India also.

It includes prior assessment of various adverse impacts on environment before start of a project.

Need to compensate these adverse effects and then proceed with the project.

Environment Impact Assessment in India

Environment Impact Assessment (EIA) is a formal process used to predict the environmental consequences of any development project. Environment Impact Assessment in India is statutory backed by the Environment Protection Act in 1986, which contains various provisions on EIA methodology and process.

Rationale behind EIA

EIA looks into various problems, conflicts and natural resource constraints which may not only affect the viability of a project but also predict if a project might harm to the people, their land, livelihoods and environment. Once these potential harmful impacts are predicted, the EIA process identifies the measures to minimize those impacts. Thus, the objective of the EIA is to:

- Identify the environmental, social and economic impacts of a project prior to taking a decision on its implementation.
- Mitigation of harmful impacts and maximizes the beneficial effects.

Once the assessment is complete, the EIA findings are communicated to all stakeholders viz. developers, investors, regulators, planners, politicians, affected communities etc. On the basis of the conclusion of EIA process, the government can decide if a project should be given environment clearance or not. The developers and investors can also shape the project in such a way that its harms can be mitigated and benefits can be maximized.

Historical Facts

The EIA process finds its origin from United States where due to huge public pressure; the government enacted National Environmental Policy Act (NEPA) in 1970s. The role of EIA process was formally recognized at the Earth Summit in Rio Conference in 1992 in which the Rio declaration stated that EIA

1

Explain the concept and need for Sustainable development. (including Smart cities, local is vocal, economy, health, education, environment, good governance).

5 R – Reduce, Reuse, Recycle, Residue disposal, Research.

Take at least one example of each R


SUSTAINABLE DEVELOPMENT GOALS
1 NO POVERTY
2 ZERO HUNGER
3 GOOD HEALTH AND WELL-BEING
4 QUALITY EDUCATION
5 GENDER EQUALITY
6 CLEAN WATER AND SANITATION
7 AFFORDABLE AND CLEAN ENERGY
8 DECENT WORK AND ECONOMIC GROWTH
9 INDUSTRY, INNOVATION AND INFRASTRUCTURE
10 REDUCED INEQUALITIES
11 SUSTAINABLE CITIES AND COMMUNITIES
12 RESPONSIBLE CONSUMPTION AND PRODUCTION
13 CLIMATE ACTION
14 LIFE BELOW WATER
15 LIFE ON LAND
16 PEACE, JUSTICE AND STRONG INSTITUTIONS
17 PARTNERSHIPS FOR THE GOALS
SUSTAINABLE DEVELOPMENT GOALS


Open Data
Internet of Things
Smart Agriculture
Smart Retail
Smart Home
Smart Mobility
Education
Smart City
Smart Health
Smart Grid/
Smart Energy
Smart Government


Save
Environment
Save Earth

ACR1C2 Chemistry and Environmental Science

UNIT I- Water

Q.1 What is hardness? Discuss its type.

Soap consuming capacity of water is called hardness.

Definition: Hardness is the property of water which prevents the formation of lather or foam and needs large quantities of soap'. The water which does not produce lather with soap solution readily, but forms a white curd is called hard water. It forms scales in hot water pipes, heaters, boilers where the temperature of water is increased.

Hardness can be defined as "the soap consuming capacity of water simple" or it prevents the lathering of soap.

$$2C_{17}H_{35}COONa + CaCl_2 \rightarrow [C_{17}H_{35}COO]_2Ca \downarrow + 2NaCl$$

Soluble Soap **Hardwater** **Insoluble Soap**

Causes: This is caused due to dissolve salts of calcium and magnesium and other heavy metal ions.

Types of hardness

There are two types of hardness temporary and permanent hardness

1. **TEMPORARY HARDNESS** : Caused due to presence of carbonates and bicarbonates of calcium and magnesium this can be removed by boiling or by adding lime solution in water. Temporary hardness is also called carbonate hardness.

2. **PERMENET HARDNESS** : Caused due to the presence of sulphates, chlorites and nitrates of calcium and magnesium. They cannot be removed by simple boiling and require special treatment of water softening it is also called as Non-=carbonate hardness.

Difference between temporary and permanent hardness

Sr. No	Temporary hardness	Permanent hardness
1	Type of hardness which can be removed by simple techniques such as boiling is known as temporary hardness	Type of hardness which cannot be removed by simple techniques such as boiling is known as Permanent hardness
2	It is due to bicarbonates of Ca,Mg and carbonates of Mg hence known as carbonate hardness	It is due to other salts hence known as carbonate hardness
3	It is due to $Ca(HCO_3)_2$, $Mg(HCO_3)_2$, $MgCO_3$	It is due to $CaCl_2$,$MgCl_2$,$CaSO_4$, $MgSO_4$,$Ca(NO_3)_2$, $Mg(NO_3)_2$,$FeCl_2$,
		&$FeSO_4$
4	It is known as alkaline hardness	It is known as non alkaline hardness
5	It is removed by boiling not by chemicals	It is removed by chemicals lime and soda
6	$Ca(HCO_3)_2 \rightarrow CaCO_3+CO_2+2H_2O$ $Mg(HCO_3)_2 \rightarrow Mg(OH)_2+2CO_2$	$CaSO_4 + Na_2CO_3 \rightarrow CaCO_3+Na_2SO_4$

Q.2 Write a note on degree of hardness. Why it is express in term of Calcium carbonate ($CaCO_3$) equivalent hardness?

The hardness of water is expressed in terms of calcium carbonate equivalent hardness known as degree of hardness.

Formula
$CaCO_3$ equivalent hardness =

$$\frac{(\textbf{\textit{Mass of Hardness producing substance}}) * (\textbf{\textit{Chemical Equivalent of}}\ \mathbf{CaCO3})}{\textbf{\textit{Chemical Equivalent of Hardness producing substance}}}$$

Reason for expressing hardness in term of $CaCO_3$ equivalent hardness

1. The molecular weight of calcium carbonate is 100gm/mol. It is easy to calculate.
2. Calcium carbonate is insoluble in water therefore it is easy to calculate its amount in water.

CALCULATION OF EQUIVALENTS OF CALCIUM CARBONATE

Example 1

Example 1. Sample contains 180 mg/L of $MgSO_4$

- *Molar mass of $MgSO_4$ = 24 + 32 +(16 X 4) = 120*
- *Chemical equivalent of $MgSO_4$ = 120/2 = 60*
- *Chemical equivalent of $CaCO_3$ = 50*

$$\text{Equivalents of } CaCO_3 = \frac{\left(\text{Mass of hardness producing substance}\right) X \left(\text{Chemical equivalent of } CaCO_3\right)}{\left(\text{Chemical equivalent of hardness producing substance}\right)}$$

$$\text{Equivalents of } CaCO_3 = \frac{180 \; X \; 50}{60} = 150 \; mg/L \text{ or ppm}$$

Hardness of the sample = 150 mg/L or ppm

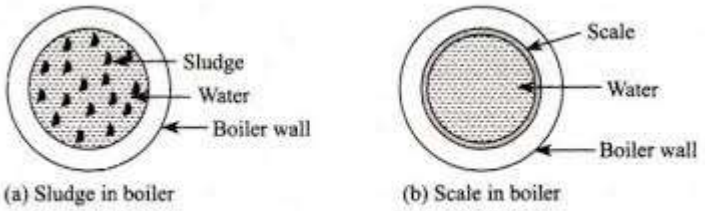
7

Q.3 Discuss sludge and scale formation in boiler. Write disadvantages of sludge and scale formation.

In boilers, water evaporates continuously and the concentration of the dissolved salts increases progressively. It leads to formation of precipitates in boiler.

Scale: If the precipitated matter forms a **hard, adhering crust/coating** on the inner walls of the boiler, it is called scale.

Sludge: If the precipitation takes place in the form of **loose and slimy precipitate**, it is called sludge. On the other hand, if the precipitated matter forms a hard, adhering crust/coating on the inner walls of the boiler, it is called scale.



(a) Sludge in boiler (b) Scale in boiler

Sludges and scales in boiler

Sludge is a soft, loosy and slimy precipitate formed within the boiler. It is formed at comparatively colder portions of the boiler and collects in the area where flow rate is slow. Ex: MgCO3, MgCl2, CaCl2, MgSO4.

Disadvantages of sludges:

1. Sludges are bad conductors of heat and results in the wastage of heat and fuel.
2. Excessive sludge formation leads to the settling of sludge in slow circulation areas such as pipe connections, plug openings, gauge–glass connections leading to the choking of the pipes.

Prevention of sludge formation:

1. By using soft water which is free from dissolved salts like MgCO3, MgCl2, CaCl2 and MgSO4 can beprevent sludge formation.
2. By blow down operation

Scales: Scales are hard, adhering precipitates formed on the inner walls of the boilers. Scales are stick very firmly on to the inner walls of the boiler. It is removed with chisel and hammer.

Reasons for formation of scales:

1. **Decomposition of calcium bicarbonate**: The calcium bicarbonate at high temperature decomposes to calcium carbonate which is insoluble salt, forms scale in low pressure boilers.

   $$Ca(HCO_3)_2 \rightarrow CaCO_3 + H_2O + CO_2$$

2. **Hydrolysis of Magnesium salts**: Magnesium salts gets hydrolyzed at high temperature forming $Mg(OH)_2$ precipitation which forms salt type scale.

   $$MgCl_2 + H_2O \rightarrow Mg(OH)_2\downarrow + 2HCl$$

3. **Decomposition of calcium sulphate**: The solubility of CaSO4 in water decreases with the increase in temperature and forms precipitation on the surface of the boiler further which forms hard scale. This type of scales is formed in high-pressure boilers.
4. **Presence of silica:** SiO_2 present even in small quantities, deposits as Calcium silicates ($CaSiO_3$) or Magnesium silicates ($MgSiO_3$). The deposits form hard scale and are very difficult to remove.
5.

Disadvantages of Scales:

1. Wastage of heat and fuels: Scales poor thermal conductivity so that rate of heat transformation is reduced.
2. Lowering of boiler safety is due to overheating of the boiler material becomes softer and weaker, which causes distortion of boiler.
3. Decrease in efficiency of the boiler due to scales deposited in the values and condensers of the boiler cause choking.
4. Danger of explosion which happens the formation of the scales, If the scale formation is soft it can be removed by a scrapper, wire brush.

Prevention of scales:

1. By giving thermal shocks, by sudden heating and sudden cooling which makes scale brittle and removed by scrubbing with wire brush.
2. If scale is very hard that is formed by CaCO3 can be removed by washing with 5-10% HCl and $CaSO_4$ can be removed with EDTA solution.
3.

Q.4 Difference between sludge and scale

Sludge	Scale
Sludge are oose and slimy precipitate	Scales are hard, adhering crust/coating
Easy to remove	Difficult to remove
Less dangerous	More dangerous
formed at comparatively colder portions of the boiler	formed at comparatively hotter portions of the boiler
Sludge are formed by salts like MgCO3, MgCl2, CaCl2, MgSO4.	Scales are formed by salts like CaSO4, MgOH2

Q.5 What is Priming and foaming? Explain its cause effects and preventive measure.

Priming: When a boiler produces steam rapidly, some particles of the liquid water are carried along with the steam. This process of "Water-steam" formation is called priming. Priming is caused by the following reasons:

1. The presence of large amount of dissolved solids.
2. High steam velocities.
3. Sudden boiling.
4. Improper boiling design and
5. Sudden increase in steam production rate.

Foaming: The production foam or bubbles in boilers, which do not break easily. Foaming is due to presence of substances like oil and alkali in boiler feed water.

Prevention

1. By removing oil or sludge by addition of coagulants.e.g $FeSO_4$, $NaAlO_2$
2. By addition of antifoaming chemicals e.g. Caster oil

Priming and foaming usually occur together. They are objectionable because

1. Dissolved salts in boiler water are carried by the wet steam to super-heater and turbine blades, where they get deposited as water evaporates. This water reduces their efficiency.
2. Dissolved salts may enter the parts of other machinery, where steam is being used, thereby decreasing the life of the machinery.

3. Actual height of the water column is judged properly; thereby making the maintenance of the boiler pressure becomes difficult.

Q.6 Write short notes on Boiler Corrosion

Boiler corrosion is decay of boiler material by a chemical or electro-chemical attack by its environment. Main reasons for boiler corrosion are:

1. **Dissolved oxygen** : Water usually contains about 8 ml of dissolved oxygen per litre at room temperature. Dissolved oxygen in water, in presence of prevailing high temperature, attacks boiler material:

$$2\,Fe + 2H_2O + O2 \rightarrow 2\,Fe(OH)_2$$

$$4\,Fe(OH)_2 + O2 \rightarrow 2\,(Fe_2O_3.2H_2O)$$

Ferrous hydroxide (Rust)

Removal of dissolved oxygen :

A. By adding calculated quantity of sodium sulphite or hydrazine or sodium sulphide. Thus;

$$2\,Na_2SO_3 + O_2 \rightarrow 2\,Na_2SO_4$$

$$N_2H_4 + O_2 \rightarrow N_2 + 2\,H_2O$$

Hydrazine

$$Na_2S + 2\,O_2 \rightarrow Na_2SO_4$$

B. By mechanical de-aeration, i.e., water spraying in a perforated plate-fitted tower, heated from sides and connected to vacuum pump (see Fig. 2). High temperature, low pressure and large exposed surface (provided by perforated plates) reduces the dissolved oxygen in water

2. **Dissolved carbon dioxide** : CO_2 is carbonic acid,

$$CO_2 + H_2O \rightarrow H_2CO_3$$

Which has a slow corrosive effect on the boiler material? Carbon dioxide is also released inside the boiler, if water used for steam generation it contains bicarbonate, e.g.,

$$Mg(HCO_3)_2 \rightarrow MgCO_3 + H_2O + CO_2$$

Removal of CO_2 :
By adding calculated quantity of ammonia. Thus,

$$2NH_4OH + CO_2 \rightarrow (NH_4)_2CO_3 + H_2O$$

By mechanical-aeration process along with oxygen.

Acids from dissolved salts: Water containing dissolved magnesium salts liberate acids on hydrolysis, e.g.,

$$MgCl_2 + 2H_2O \rightarrow Mg(OH)_2 + 2HCl$$

The liberated acid reacts with iron (of the boiler) in chain like reactions producing HCI again and again. Thus

$$Fe + 2HCI \rightarrow FeCl_2 + H_2$$

$$FeCl_2 + 2H_2O \rightarrow Fe(OH)_2 + 2HCl$$

Consequently, presence of even a small amount of $MgCl_2$ will cause corrosion of iron to a large extent.

Disadvantages/effects

1. Decrease in life of boiler
2. Decrease efficiency
3. Increase repair and maintenance cost
4. Formation of holes and pit
5. Leakage of joints and rivets

Q.7 Enumerate causes and preventive measures of Caustic embrittlement.

Caustic embrittlement:

The material of the boiler is weakened and becomes brittle due to the accumulation of caustic substances. It is a form of stress corrosion takes place in boilers operating at high temperature and pressure. Caustic embrittlement focus at stressed part of boilers such as cracks, rivets, bents, joints etc.

The boiler fed water usually contains some residual sodium carbonate (used for softening process). At high temperature and pressure it undergoes hydrolysis to form sodium hydroxide.

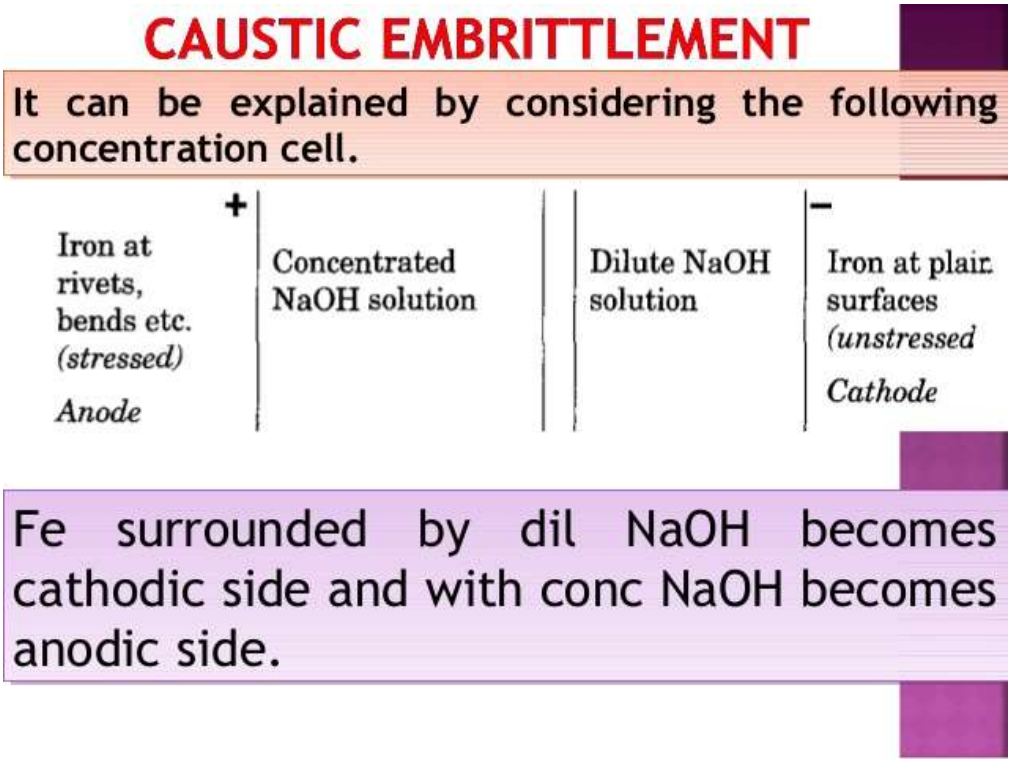
$$Na2CO_3 + H_2O \text{ ---------} 2\ NaOH + CO_2$$

The alkali water sweeps through the minute cracks, crevices between the rivets and joints by capillary action. Inside the cracks water gets evaporated leaving behind NaOH. The concentrations of the NaOH gradually increase on these sites due to poor circulation of water. When concentrations of the NaOH reaches a value of 10% it attacks the metal at the stressed region dissolving it in the form of sodium ferroate (Na**2**FeO**2**). Sodium ferroate undergoes hydrolysis-depositing magnetite as follows

$$3Na_2FeO_2 + 4H_2O \text{ -------- } 6NaOH + Fe_3O_4 + H_2$$

$$6Na_2FeO_2 + 6H_2O + O_2 \text{ -------- } 12NaOH + 2Fe_3O_4$$

Mechanistically embrittlement arises due to setting up of concentration cell



Preventive measure

1. Caustic embrittlement can be prevented by the addition of compounds like sodium sulphite, tannin, lignin, phosphates etc. which blocks the cracks thereby preventing the infiltration of alkali.
2. By phosphate conditioning of water

Q.8 Discuss Zeolite process of softening of hard water under following headings

a. Principle b. Process c. Softening and regeneration reactions d. Advantages

Principle: Zeolite is hydrated sodium alumino silicate. Zeolites are also known as permutits. Zeolite is capable of exchanging reversibly its sodium ions for hardness-prodcing ions in water.
Chemical Structure : Na2O.Al2O3.xSiO2.yH2O,where X=2-10 and Y=2-6.

Types of Zeolite Zeolites are of two types: Natural zeolite and Synthetic zeolite

Process : For softening of water by zeolite process,hard water is percolated at a specified rate through a bed of zeolite, kept in a cylinder. The hardness causing ions(Ca^{2+} ,Mg^{2+} ,etc.) are retained by the zeolite as CaZe and MgZe ; while the outgoing water contains sodium salts.

Reactions

$Na_2Ze + Ca(HCO_3)_2 = CaZe + 2NaHCO_3$

$Na_2Ze + Mg(HCO_3)_2 = MgZe + 2NaHCO_3$

(Zeolite) (Hardness)

$Na2Ze + CaCl_2 = CaZe + 2NaCl$

$Na2Ze + MgSO_4) = MgZe + Na_2SO_4)$

(Zeolite) (Hardness)

Regeneration : After some time, the zeolite is completely is completely converted into calcium and magnesium zeolite and it ceases to soften water, i.e., it gets exhausted. At this stage, the supply

of hard water is stopped and the exhausted zeolite is regenerated by treating the bed with a concentrated (10%) brine (NaCl) solution.

` $CaZ + 2NaCl = Na_2Ze + CaCl_2$

$MgZe + 2NaCl = Na_2Ze + MgCl_2$

(Exhausted zeolite) (Brine) (Reclaimed (Washings) zeolite) □

The washing (containing Cacl2 and MgCl2) are led to drain and the regenerated zeolite bed thus-obtained is used again for softening purpose.

Limitations of process:

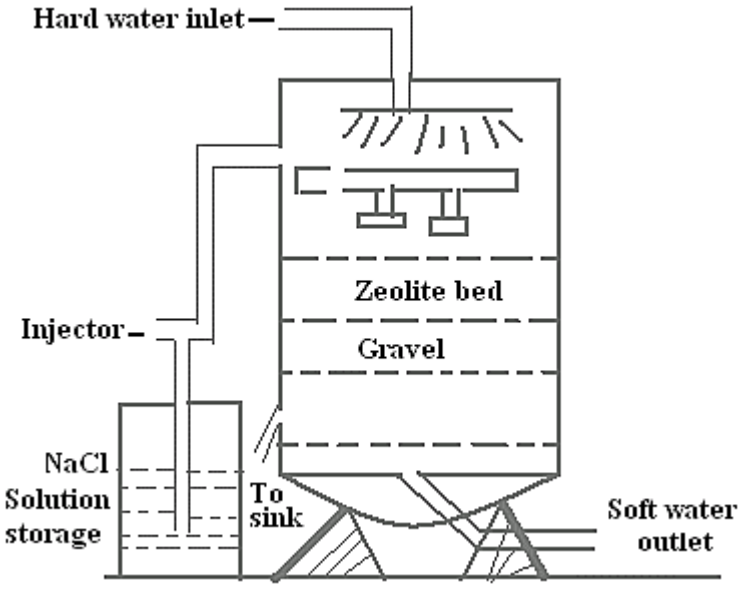
1. If the supply of water is turbid, it must be remove, otherwise the turbidity will clog the pores of zeolite bed, thereby making it inactive.
2. If water contains large quantities of coloured ions such as Mn^{2+} and Fe^{2+},they must be removed first, because these ions produce maganese and iron zeolite, which cannot be easily regenerated.
3. Mineral acids, if present in water, destroy the zeolite bed and,therefore, they must be neutralised with soda, before admitting the water to the zeolite softening plant.

Advantages of process:

1. It removes the hardness almost completely and water of about 10 ppm hardness is producted.
2. The equipment used is compact, occupying a small space.
3. No impurities are precipitated, so there is no danger of sludge formation in the treatedwater at a later stage.
5. It is quite clean.
6. It requires less time for softening.
7. It requires less skill for maintenance as well as operation.

Disadvantages of process :

1. The treated-water contains more sodium more sodium salts than in lime-soda process.
2. The method only replaces Ca^{2+} and Mg^{2+} ions, but leaves all the acidic ions (like HCO_3^- and CO_3^{2-}) as such in the softened water.



Q.9 Discuss ion exchange process of softening of hard water under following headings
a. Principle b. Process c. Softening and regeneration reactions d. Advantages

Ans. **Ion-exchange or Deionization or Demineralization Process** - Recently ion-exchange resins have been used to remove all minerals from water. It is a process by which ions held on a porous, essentially insoluble solid are exchanged for ions in water

Ion-exchange Resin – An ion-exchange resin is a crosslinked organic polymer network having some ionisable group. It may be of two types depending upon the nature of the ionizable group.

(i) Cation Exchange Resin or Cation Exchanger - Such resins have - SO_3H, -- COOH or -OH (phenolic) group as the ionizable group. Since these resins exchange the cationic portion of minerals by their hydrogen atom, they are known as cation exchangers.

(ii) Anion Exchange Resin or Anion Exchanger – These resins have $-NH_2$, $-NHCH_3$, $-N(CH_3)_2$ or -OH (alcoholic) group. They exchange the anionic portion of the minerals and they are known as anion exchanger.
Uses of Ion-exchange Resin – Water treatment by ion-exchange resin includes softening deionization and de-alkalization of water. Therefore, hard water can be converted into soft water by making use of ion-exchange resins.

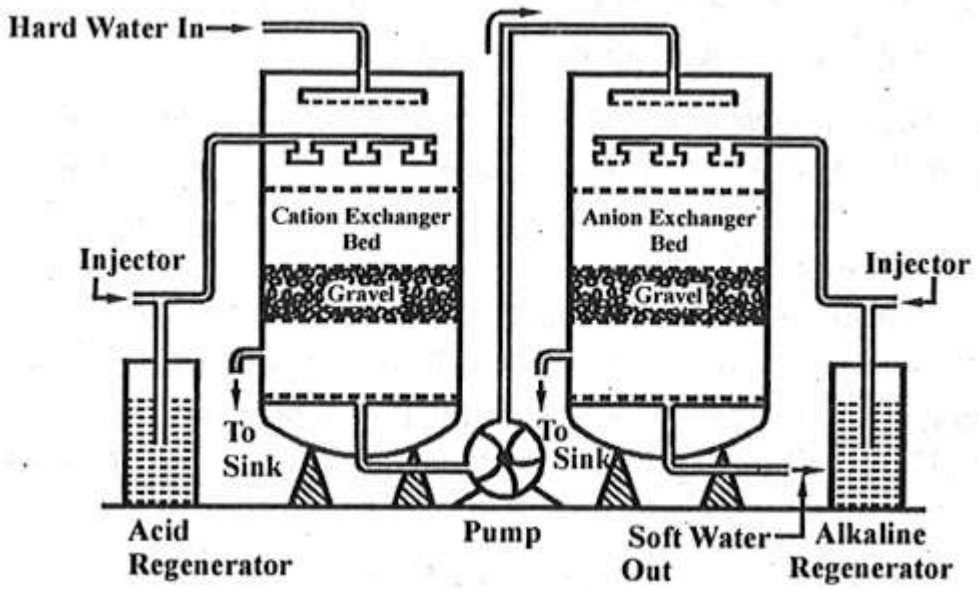


Fig. Demineralization of Water

Process – In this process first we passed hard water through cation exchange column, which removes all the cations (like Ca+2, Mg+2 etc.) from it and equivalent amount of H+ ions are released from this column to water.
Thus,

$$2RH^{+} + Ca^{+2} = R_2Ca^{+2} + 2H^{+}$$
$$2RH^{+} + Mg^{+2} = R_2Mg^{+2} + 2H^{+}$$

After this process, hard water is passed through anion exchange column, which removes all the anions (like SO4-2, Cl- etc.) from it, and equivalent amount of OH- ions are released from this column to water. Thus,

$$R'OH^{-} + Cl^{-} = R'Cl^{-} + OH^{-}$$

H+ and OH - ions get combined to produce water molecule

$$H^{+} + OH^{-} + H_2O$$

The water coming out from the exchanger is free from cations as well as anions. Ion-free water is known as a deionized or demineralized water.

Advantages

1. It is very effective and efficient method of water softening.
2. The process can be used to soften highly acidic or alkaline waters.
3. It produces water of very low hardness (say 2 ppm).

Disadvantages

1. Expensive
2. Problem of disposal of waste

Q.10 A sample of water is found to contains following dissolving salts in milligrams per litre Mg(HCO3)2 = 73, CaCl2 = 111, Ca(HCO3)2 = 81, MgSO4 = 40 and MgCl2 = 95. Calculate temporary and permanent hardness and total hardness.

Solution:

Name of the hardness causing salts	**Amount of the hardness causing salts(mg/L)**	**Molecular weight of hardness causing salts**	**Multiplication factor**	**CaCO3 equivalent hardness (mg/L)**
$Mg(HCO_3)_2$	73	146	100/146	73×100/146 = 50
$CaCl_2$	111	111	100/111	111×100/111 = 100
$Ca(HCO_3)_2$	81	162	100/162	81×100/162 = 50
$MgSO_4$	40	120	100/120	40×100/120 = 33.3
$MgCl_2$	95	95	100/95	95×100/95 = 100
NaCl	5	NaCl does not impart hardness		

Temporary hardness = $Mg(HCO_3)_2$+ $Ca(HCO_3)_2$
= 50 + 50 = 100mg/L
= 100×0.07°Cl = 7°Cl
= 100×0.1°Fr = 10°Fr

Permanent hardness = $CaCl_2$ + $MgSO_4$ + $MgCl_2$
= 100 + 33.3 + 100 = 233.3mg/L
= 233.3×0.07°Cl = 16.33°Cl
= 233.3×0.1°Fr = 23.33°Fr

Total hardness = Temporary hardness + Permanent hardness
= 100 + 233.3 = 333.3mg/L.
= 333.3×0.07°Cl = 23.33°Cl
= 333.3×0.1°Fr = 33.33°Fr

Q.11 Water quality (fitness) Parameters

Physical- Color, Taste, odor, turbidity, temperature, etc.
Chemical- Hardness, pH, Acidity, Alkalinity, Chlorine, TDS, DO, BOD, COD, Tests for specific chemicals, etc.
Biological- Coliforms (E Coli), Tests for specific pathogens etc.