Environmental Science & Green Technology

DR. NOOPUR

ASSISTANT PROFESSOR

DEPTT OF HUMANITIES SOCIAL SCIENCES AND MANAGEMENT

IIIT RANCHI

COURSE OBJECTIVES

- Provide awareness on the adverse effects of environmental changes
- Introduce the concept of ecosystem and the importance of natural resources
- Summarize the various types of pollutions
- Instil an attitude of respecting mother nature
- Inspire to design eco - friendly engineering solutions for real world problems
- To familiarize the structural and functional components of an ecosystem

COURSE OUTLINE

CHAPTER 1	: INTRODUCTION	- 2 hrs
CHAPTER 2	: AIR POLLUTION	- 4 hrs
CHAPTER 3	: WATER POLLUTION	- 4 hrs
CHAPTER 4	: SOIL POLLUTION	- 4 hrs
CHAPTER 5	: NOISE POLLUTION	- 2 hrs
CHAPTER 6	: RADIOACTIVE POLLUTION	- 2 hrs
CHAPTER 7	: GREEN TECHNOLOGY	- 2 hrs

INTRODUCTION

India-Maldives imbroglio: Fallout on tourism in Lakshadweep

https://www.hindustantimes.com/ht-insight/international-affairs/indiamaldives-imbroglio-fallout-on-tourism-in-lakshwadeep-101705308528903.html

Example: 1

WHAT DOES THE PICTURE SAY ?

Courtesy : https://www.ndtv.com/india-news/expert-on-reasons-behind-sinking-of-uttarakhands-joshimath-3670440

Reasons

- Geographical properties of Joshimath – naturally a sinking land
- Not good for residential or industrial purpose – Fragile area
- After 2000, population increased
- Construction works for promoting tourism
- Construction of tunnel and related works for Tapovan Hydel power project

https://www.youtube.com/watch?v=oEkLUWdrt-8

Example 2 - Cold Wave In North India

https://indianexpress.com/article/india/delhi-north-india-weather-cold-wave-fog-8345719/

Example 3: Frequent Earthquakes

Massive earthquake in Nepal kills 157

https://www.who.int/southeastasia/news/detail/08-11-2023-who-responding-to-western-nepal-earthquake-2023

Example 4 -Floods and landslides on August 14 2023 in the Indian Himalayan Region killed at least 72 people. Losses were estimated at $1.2 billion, and several hundred roads were closed. Portions of Himachal Pradesh received rainfall amounts of more than 12 inches (300 mm).

https://www.youtube.com/watch?app=desktop&v=pwpIzMj6bSE

Example 5: Landslides in Kerala

Kerala recorded the highest number of major landslides in the country in the past seven years, the ministry of earth sciences informed Lok Sabha on Wednesday. Of the 3,782 landslides between 2015 and 2022 so far, 2,239 alone were reported in the southern state

https://www.youtube.com/watch?v=D8Pl2xT126o

ENVIRONMENT

- The term ‘Environ’ is taken from French which means ‘surroundings’
- Environment refers to the area/surroundings that we live in at a given point of time
- Comprises of all physical, chemical and natural forces that exist in our planet

Here the famous first lines of the poem Auguries of Innocence by the English poet, William Blake (1757-1827)

To see a world in a grain of sand
And a heaven in a wild flower
Hold infinity in the palm of your hand
And eternity in an hour

Overview of Environmental Changes

Can be classified broadly into two

- Human made – due to undesirable human interventions
- Natural – due to ecological processes

Changes include both physical and **biogeochemical** processes

ENVIRONMENTAL CHANGES

I. Pollution
II. Deforestation
III. Climate Change
IV. Depletion of Ozone
V. Loss of Biodiversity
VI. Desertification

Case Study - Songbird Coffee

Connections: Drink Coffee in US and make the songbird vanish in South America.
Birds like Warblers and Orchard Orioles.
Conservation groups like the Rainforest Alliance and the American Birding Association have initiated programmes to certify coffee as "*shadegrown*" and encourage consumers to ask for such varieties.

Source: Shutterbug

Case Study: Get rid of malaria, but invite the plague….

Location: Indonesian island of Sabah, earlier known as North Borneo

Role of WHO: started spraying Dieldrin (a chemical related to DDT)

Dieldrin → Insects (Flies/Cockroaches) → Lizards → Cats → Rats (Increased) ⇒ **Plague (WHO dropped healthy cats via parachute)**

Dieldrin → Wasps and other Insects → Caterpillar (Increased) ⇓ **Caving of Thatched Roofs**

Definition of Ecosystem

An ecosystem is a structural and functional unit of ecology where the living organisms interact with each other and the surrounding environment.

In other words, an ecosystem is a chain of interactions between organisms and their environment. The term "Ecosystem" was first coined by ***A.G.Tansley***, an English botanist, in 1935.

Broadly classified into **TERRESTRIAL** and **AQUATIC** **based on their location**

Terrestrial can also be classified as **NATURAL** and **HUMAN MODIFIED**

"The living community of plants and animals in any area together with the non-living components of the environment such as soil, air and water, constitute the ecosystem."

Terrestrial Ecosystems

NATURAL

- Forest Ecosystems
- Desert Ecosystems
- Grassland Ecosystems
- Tundra Ecosystems (‘Tundra’ comes from a Russian word with meaning ‘upland’ or “treeless mountain tract”)

Human Modified

- Agricultural
- Industrial
- Urban

Snippets of videos: Ecosystem

Masai mara

https://www.youtube.com/watch?v=3289oqk6zug

Sahara

https://www.youtube.com/watch?v=58UK5bM9adU

Pacific

https://www.youtube.com/watch?v=oebE0cb86n8

Amazon

https://www.youtube.com/watch?v=YxyDNrTIViw

Examples

Rainforest

Semi Arid Desert

Examples

Temperate Grassland

Alaska

https://education.nationalgeographic.org/resource/tundras-explained

Aquatic Ecosystems

Freshwater Ecosystems

Marine Ecosystems

Structure of an Ecosystem

Two major components

- Abiotic(Non Living) Components
- Biotic (Living) Components

1. Living Components(Biotic)

a. Producers (autotrophs)
- Green plants that produce food by photosynthesis

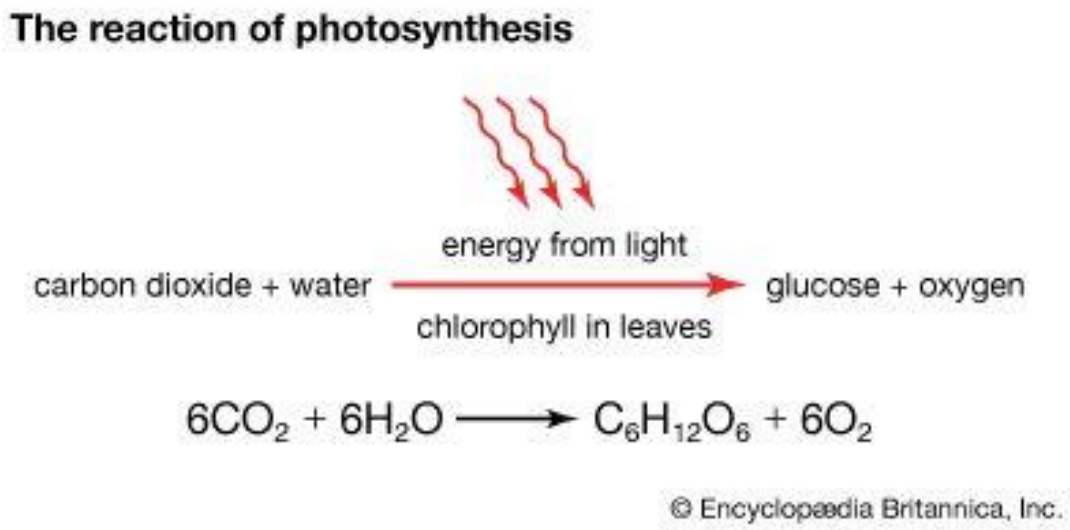
b. Consumers (heterotrophs)
- All plants and animals who depend on green plants for food

c. Decomposers or Detrivores (saprophytes)
- Insects, worms and microorganisms that breaks down complex organic compounds

a. Producers (Autotrophic Elements)

- Green plants absorbs minerals and water from soil, Carbon dioxide from air and produces chemical energy in the presence of radiant sunlight with the help of chlorophyl

Chemical energy is stored in the plant in its different parts



Examples

Saguaro cactus

Water Lilly

Lichens (Tundra)

Barrel cactus

River Algae

Seaweed

b. Consumers

- Primary Consumers
- Secondary Consumers
- Tertiary Consumers
- Parasites, Scavengers and saprobes

Primary Consumers

- Herbivores who depend directly on green plants
- Deer, rabbit, cow, lemming,

Lemming

Tortoise

Gazelle

Secondary Consumers

- Can be carnivores or Omnivores
- Depends on primary consumers for food
- Cat, dog, fox, sparrow, arctic owl, trout, rattlesnake

Tertiary Consumers

Tertiary Consumers

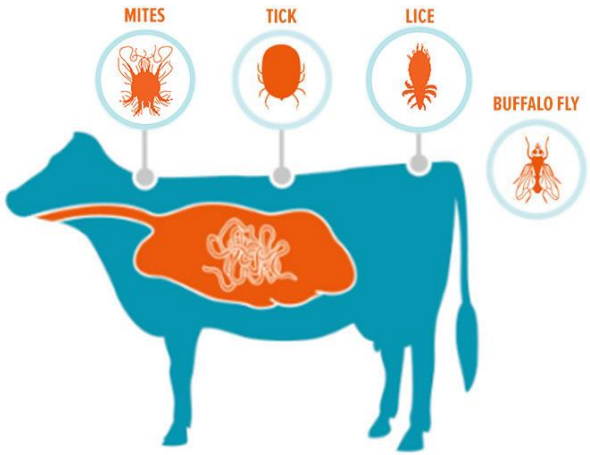
- Predators who prey upon herbivores, carnivores and omnivores for their food
- Top carnivores/Consumers
- Tiger, lion, hawk

Parasites

- Parasites

  Plants and animals who utilise the living tissues of different plants and animals

Viscum Album



Scavengers and Saprobes

Who utilize the dead remains of plants and animals for their food

Jackal

Vulture

Big Gyms

c. Decomposers or Detrivores

Act upon dead portions of producers and consumers and convert the complex organic structure into simpler structure

Eg. Worms, insects, bacteria and fungi

Another group of decomposers called transformers, act upon the simpler compounds to transform them into simple inorganic compounds that can be used by producers

Eg, Bacteria

2. Non Living Components (Abiotic)

a. Geographical Structure
- Topography – Hills, mountains, Rivers, plain lands, coastal areas or islands

b. Climatic Regime
- Amount of Sunlight, temperature, moisture, rainfall

➢c. Soil Characteristics
- Amount of water, carbonates, phosphates and organic compounds

d. Inorganic and Organic Compounds
- Inorganic – Nitrogen, Oxygen, Carbon dioxide
- Organic – Proteins, Carbohydrates, Lipids (Link between biotic and abiotic)

Functions of Ecosystem

The functions of the ecosystem are as follows:

- It regulates the essential ecological processes, supports life systems and renders stability.
- It is also responsible for the cycling of nutrients between biotic and abiotic components.
- It maintains a balance among the various trophic levels in the ecosystem.
- It cycles the minerals through the biosphere.
- The abiotic components help in the synthesis of organic components that involve the exchange of energy.

So the functional units of an ecosystem or functional components that work together in an ecosystem are:

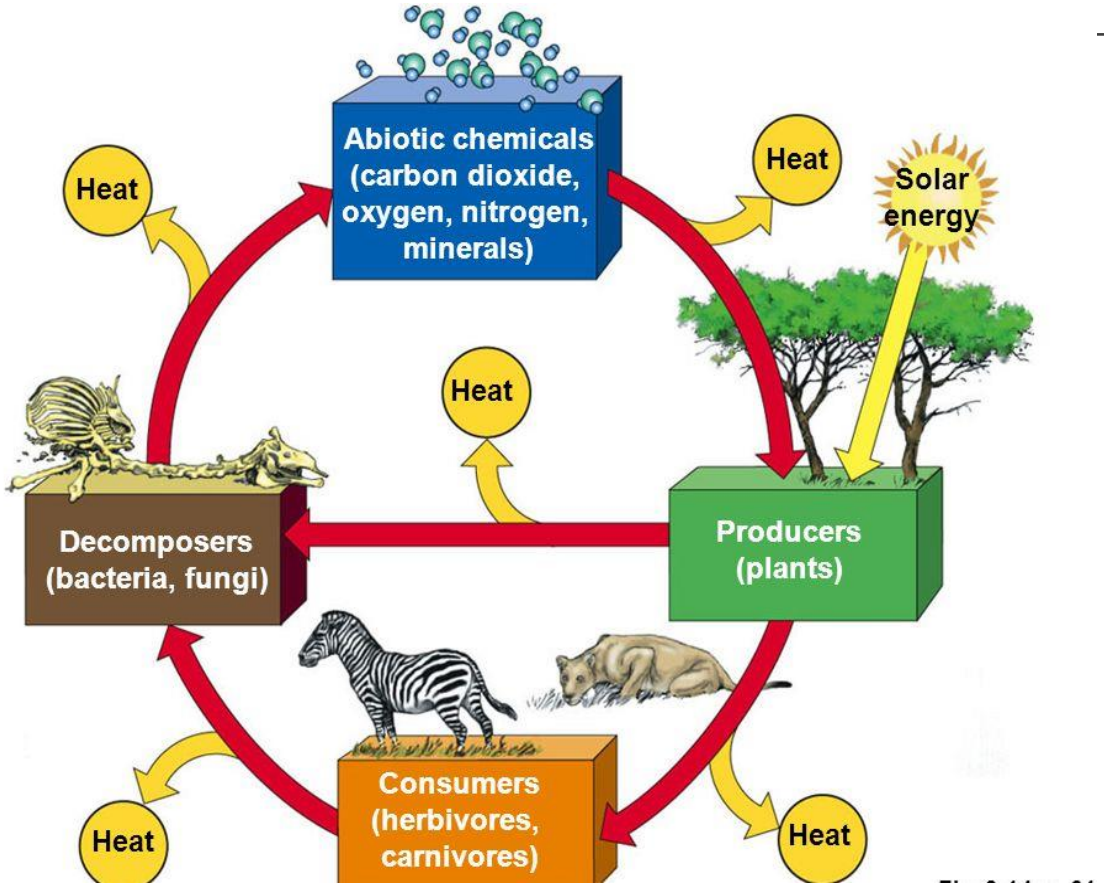
Productivity – It refers to the rate of *biomass* production.

Energy flow – It is the sequential process through which energy flows from one trophic level to another. The energy captured from the sun flows from producers to consumers and then to decomposers and finally back to the environment.

Decomposition – It is the process of breakdown of dead organic material. The top-soil is the major site for decomposition.

Nutrient cycling – In an ecosystem nutrients are consumed and recycled back in various forms for the utilisation by various organisms.

Energy Flow

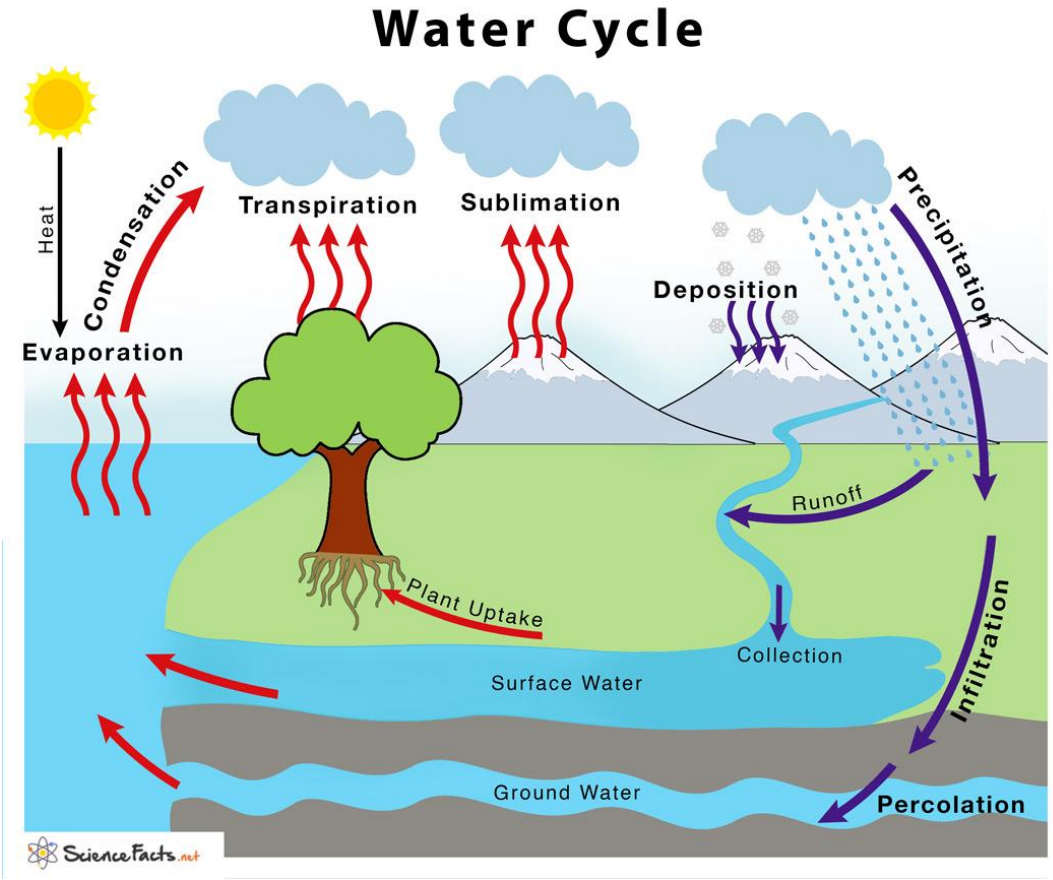

Abiotic chemicals (carbon dioxide, oxygen, nitrogen, minerals)
Heat
Heat
Solar energy
Heat
Decomposers (bacteria, fungi)
Producers (plants)
Consumers (herbivores, carnivores)
Heat
Heat

Nutrient Flow

The important biogeochemical cycles in nutrient flow are

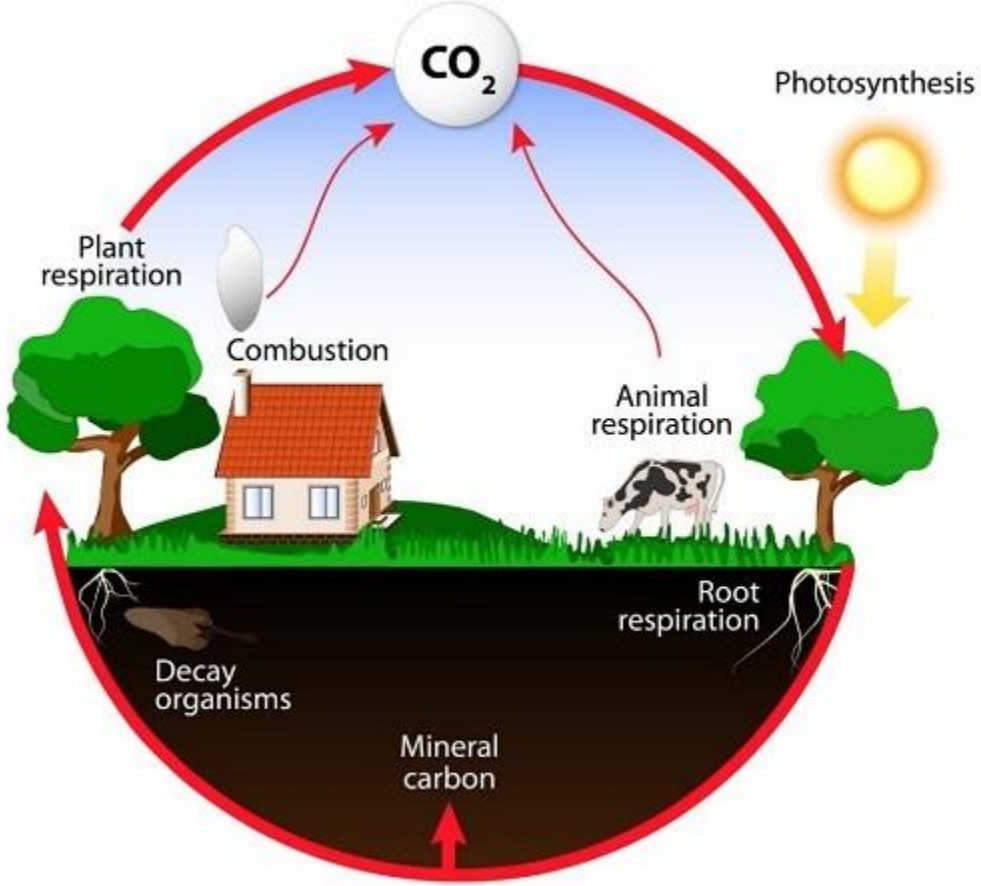
- Water Cycle
- Carbon Cycle
- Oxygen Cycle
- Nitrogen Cycle

Water Cycle


Water Cycle
Heat
Condensation
Evaporation
Transpiration
Sublimation
Deposition
Precipitation
Runoff
Plant Uptake
Collection
Surface Water
Infiltration
Ground Water
Percolation
ScienceFacts.net

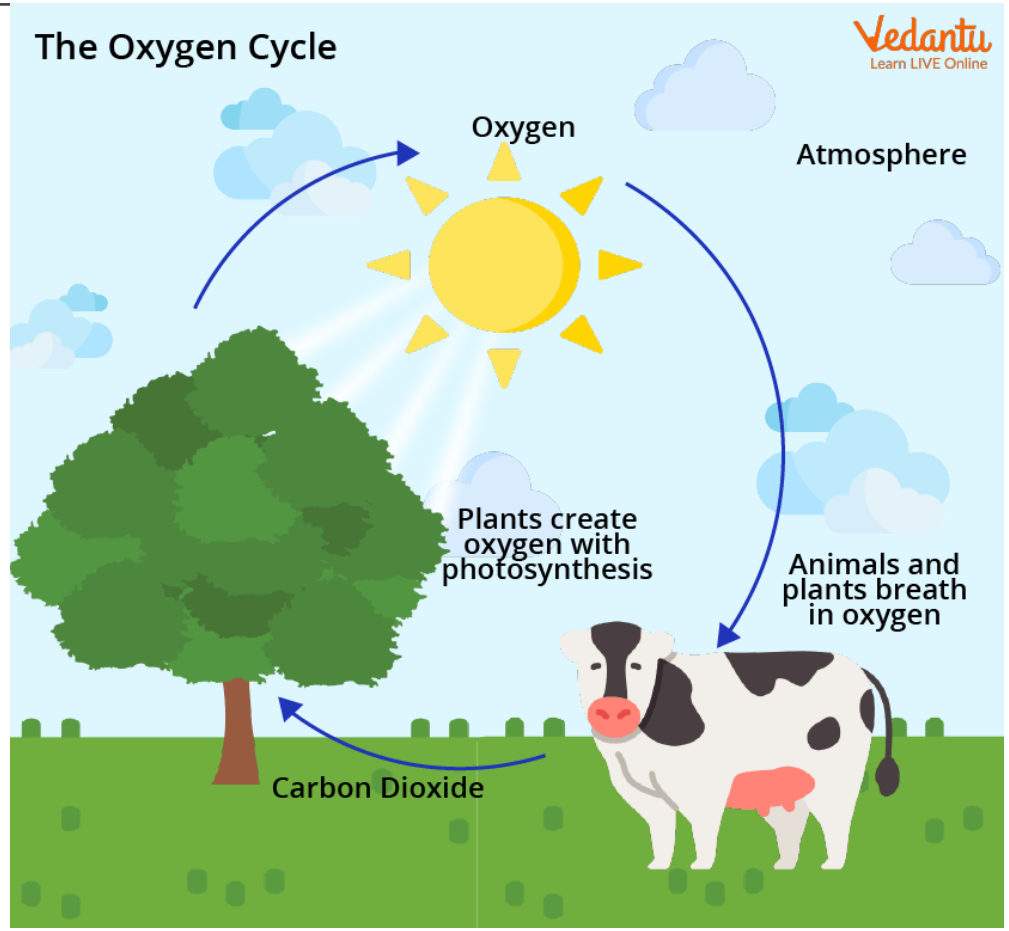
Carbon Cycle

- Release of Carbon Dioxide in different ways
- Absorption of Carbon Dioxide by green plants
- The percentage of CO2 should not go beyond certain limit

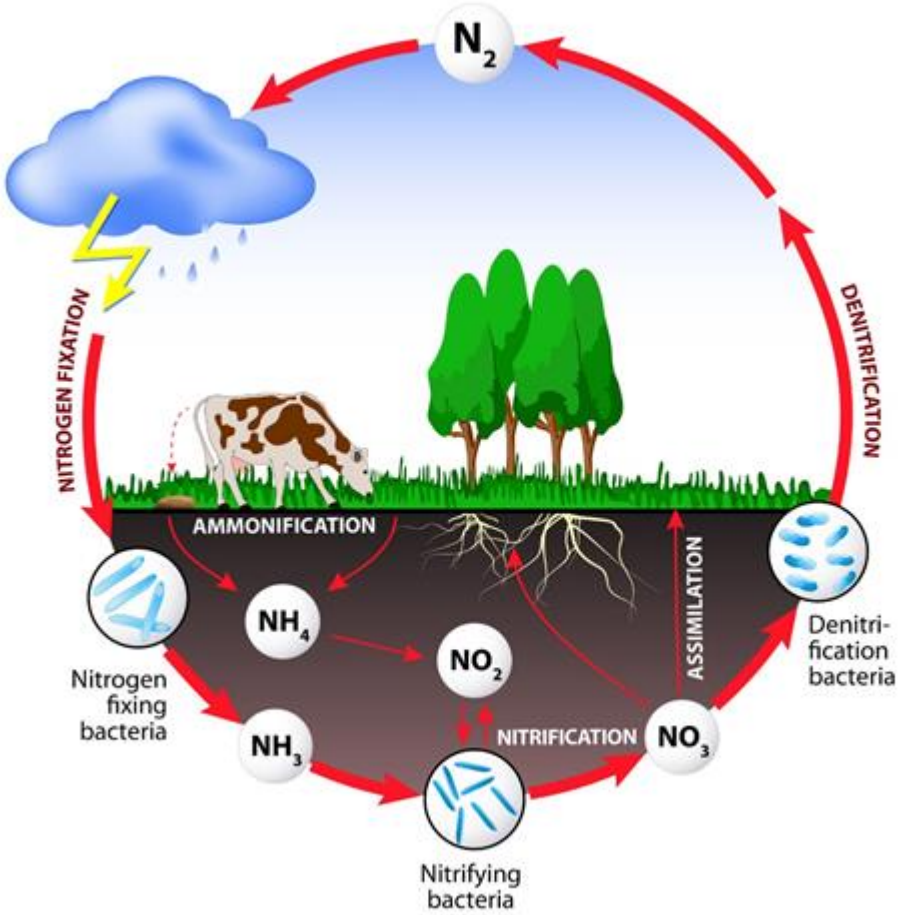


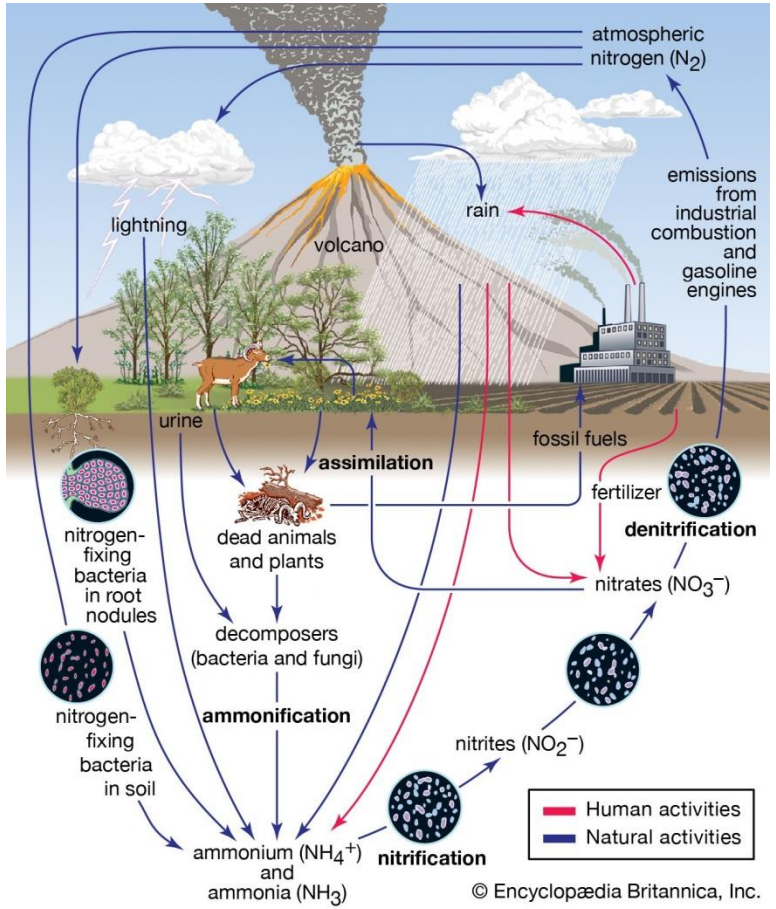
Oxygen Cycle

- Release of Oxygen by green plants
- Absorption of Oxygen by different biotic components of the ecosystem
- Photosynthesis connects between carbon cycle and oxygen cycle
- Green plants play key role in regulating and monitoring the percentile of Oxygen and CO2

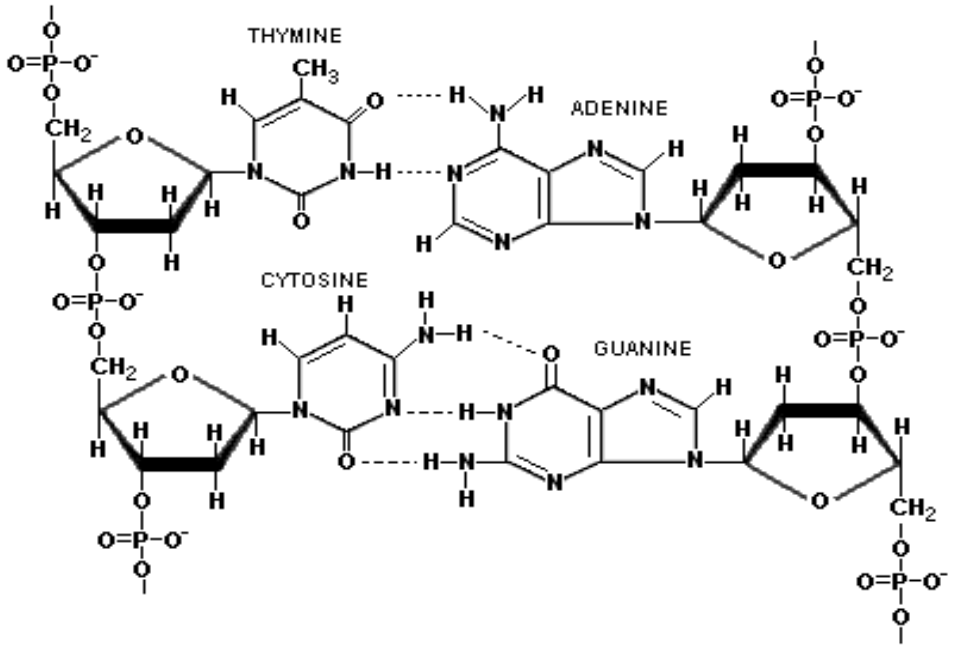


Nitrogen Cycle





DNA structure (why nitrogen is important)



- About 96 percent of the plant is made up of Carbon, Hydrogen, Oxygen and Nitrogen
- Nitrogen is present in the atmosphere as N2.
- Plants cannot absorb gaseous nitrogen.
- Nitrogen fixation and nitrification done by Microorganisms transforms nitrogen into nitrates

Chemical Reactions in Nitrogen Cycle

NITROGEN FIXATION

$$N_2 + 8\,H^+ + 8\,e^- \longrightarrow 2\,NH_3 + H_2$$

NITRIFICATION

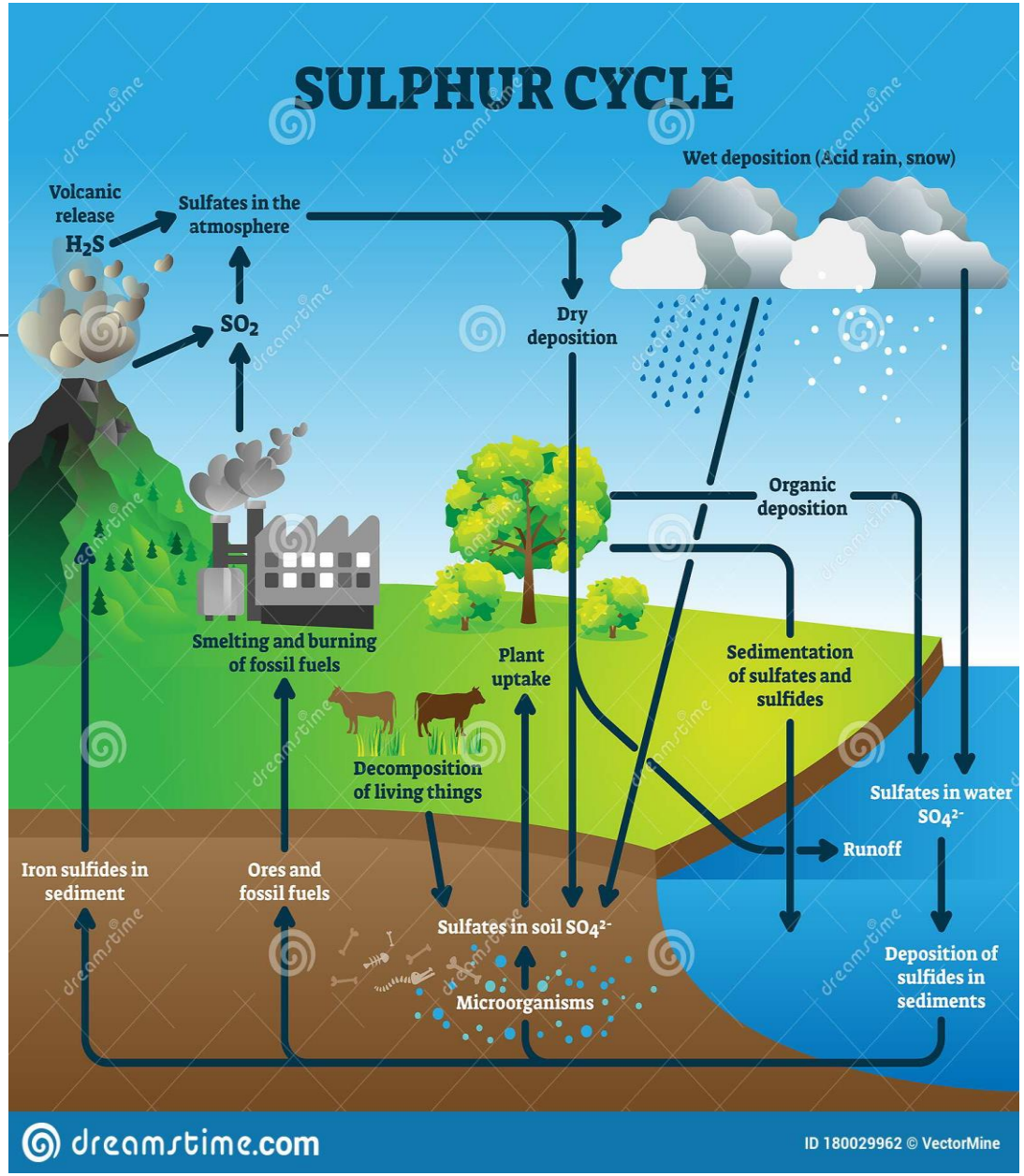
1) $NH_3 + O_2 + 2\,e^- \longrightarrow NH_2OH + H_2O$

2) $NH_2OH + H_2O \longrightarrow NO_2^- + 5\,H^+ + 4\,e^-$

$$NO_2^- + \frac{1}{2}O_2 \longrightarrow NO_3^-$$

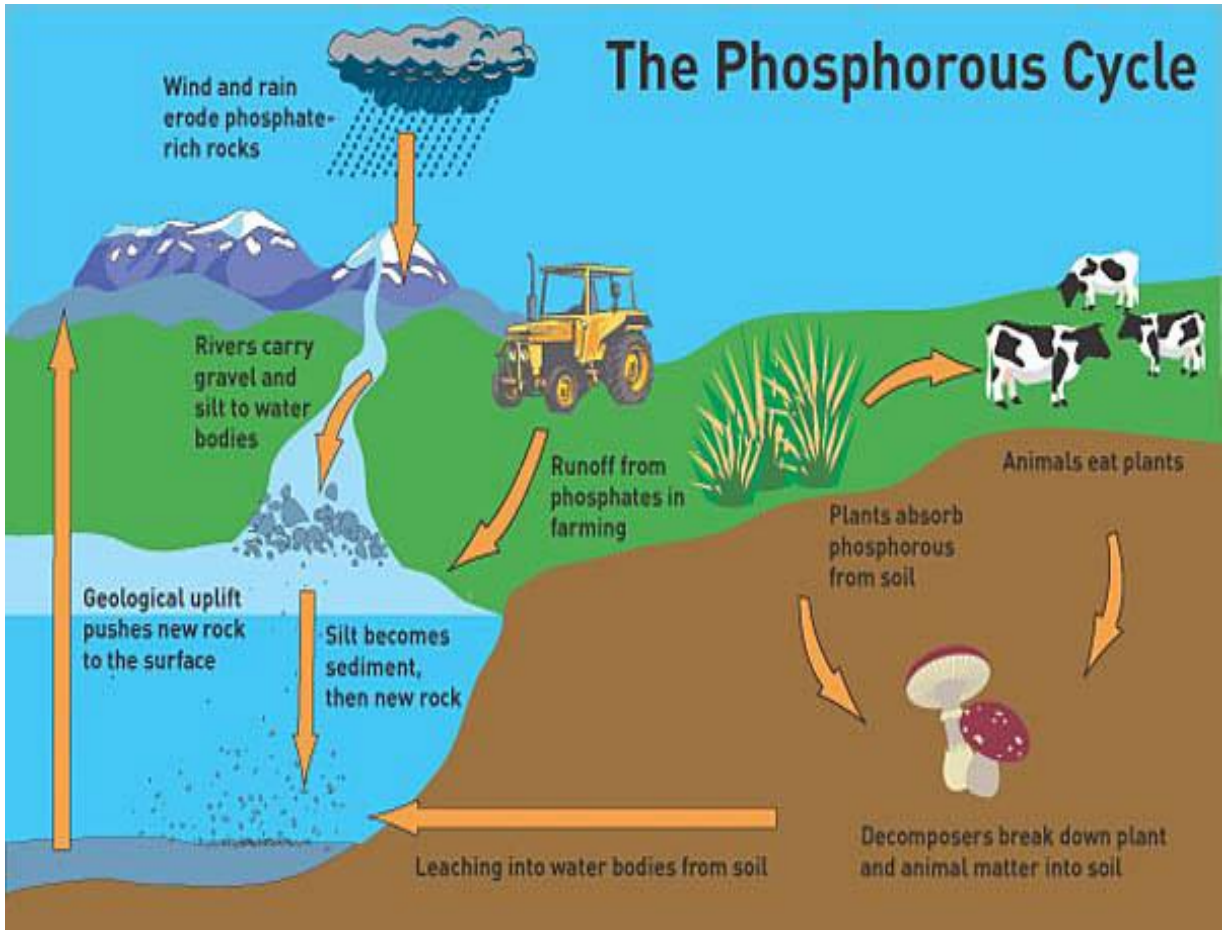
Sulphur Cycle

- Sulphur present in all living things in the form of Proteins
- Proteins are broken down into amino acids
- Amino acids are broken down into H2S
- H2S is converted into Sulphur and sulphates
- Sulphates are converted back to H2S



Phosphorous Cycle

- Weathering forms phosphorous in the form of rocks
- Phosphorous present in soil and water as Phosphates
- Plants absorbs phosphates from soil
- Animals get phosphorous from plants
- When plants and animals die, their dead remains are converted back into phosphorus



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Lecture Objectives

- Introduce the concept of environmental pollution
- Revisit the various spheres of natural resources
- Pertain into the details of pollution of the sphere of water resources

There is so much pollution in the air now that

If it weren't for our lungs

There'd be no place to put it all

Robert Orben (1927-2023)

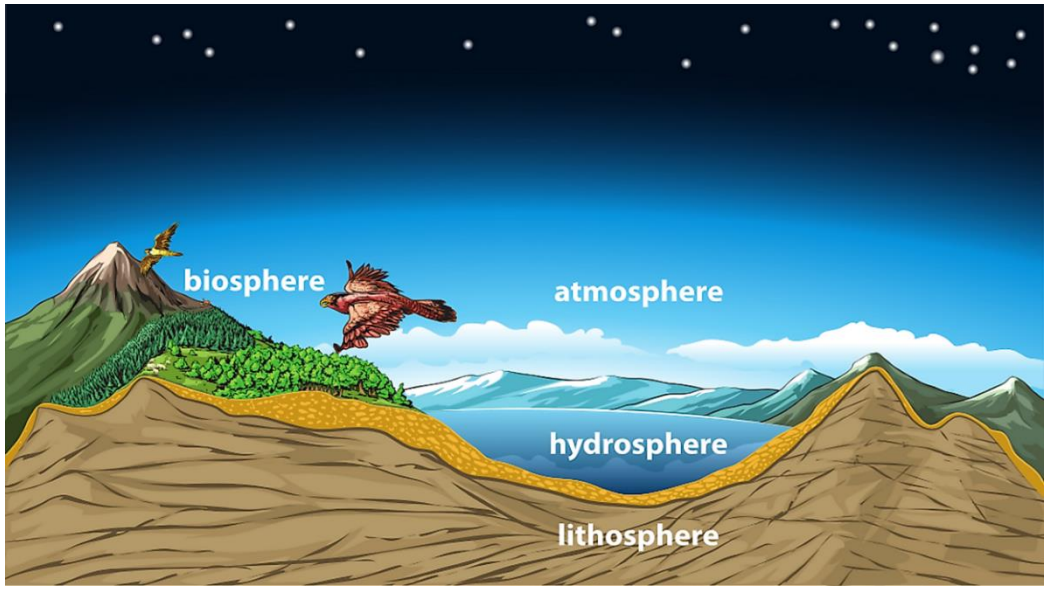
American magician and comedy writer

Environmental Pollution

- Pollution is the introduction of harmful or contaminated matter (pollutants) into the environment
- Most vital change in the environment that is introduced by the undesirable human interventions on earth.
- Pollution stands as the basic cause of other environmental changes like global warming, ozone depletion etc
- Pollution is analysed based on its degree of impact on various natural resources

Natural Resources

- Earth is the only planet in the solar system known for existence of life.
- The unique resources of earth provide the opportunity to create and support ‘life’ upon it.
- These natural resources are designated as the ‘***spheres of earth***’ that weave the web of life
  - Atmosphere
  - Hydrosphere
  - Lithosphere
  - Biosphere



Atmosphere

- The source of Oxygen for all living organisms and plants
- Forms the protective shell of Earth
- Subdivided into different layers based on
  - *thermal characteristics (temperature changes)*
  - *chemical composition*
  - *movement*
  - *density*
- Layers are

  Troposphere , Stratosphere, Mesosphere , Thermosphere

  Exosphere

A Bird View

Troposphere - Reason for life and weather, temperature falls with height, provides path for aeroplanes

Stratosphere - Ozone Layer, temperature increases with height

track for jets, 19% of atmosphere's gases

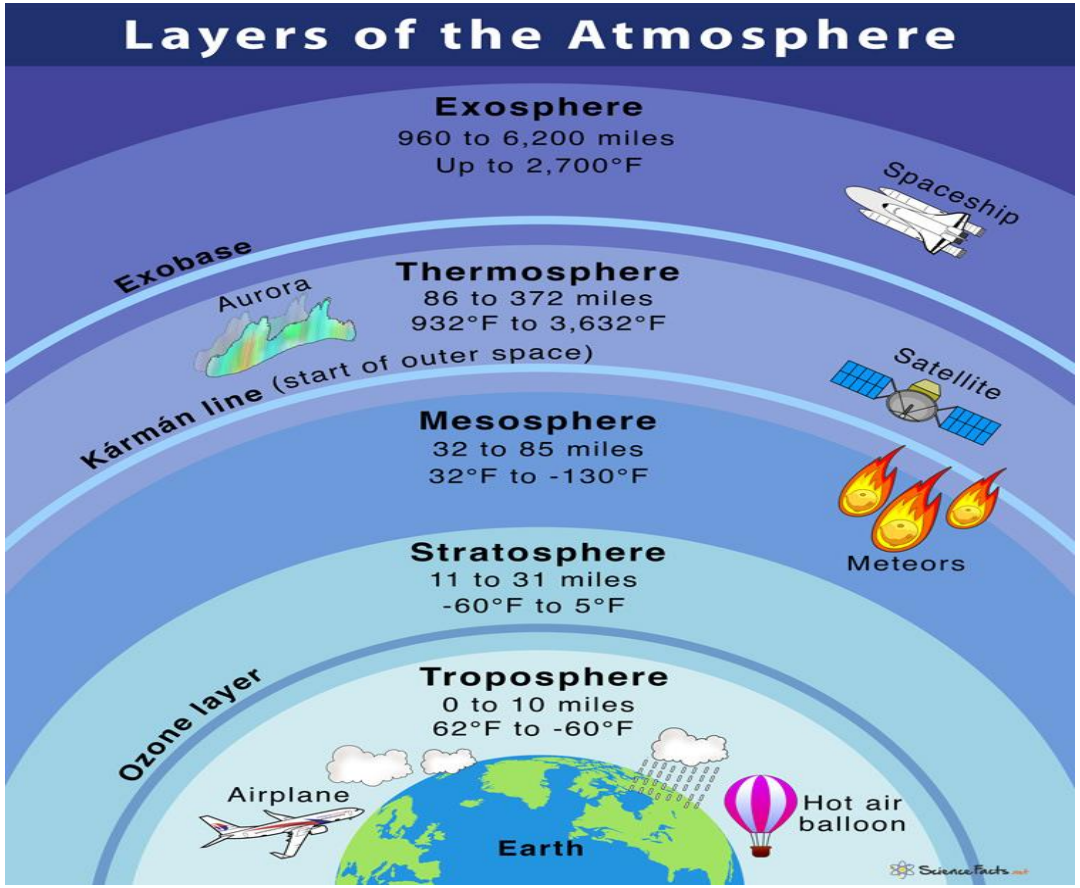
Mesosphere - temperature falls with altitude

only rocket fired aircrafts can reach

Thermosphere - lowest part is ionosphere

International Space Station is located

Exosphere - merges with solar wind at the top



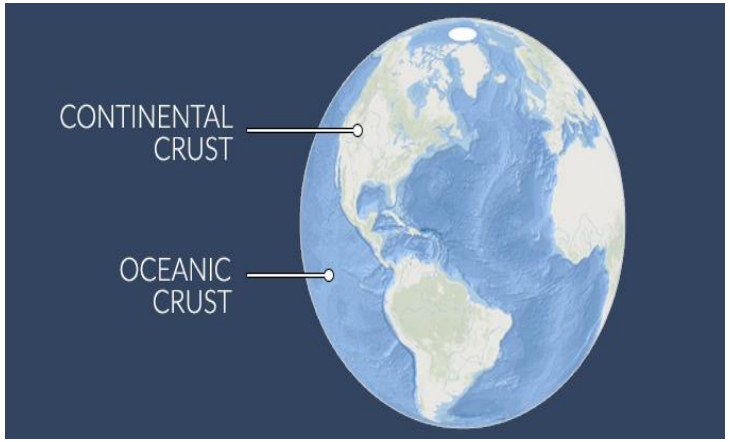
https://www.noaa.gov/jetstream/atmosphere/layers-of-atmosphere

Hydrosphere

- Total amount of water on a planet forms its hydrosphere
  - Water in the form of solid, liquid or gas
  - Water on the surface, under the ground and in the atmosphere
- Earth is abundant in water that covers 67% of its surface.
- Sources of water beneath the ground are termed as aquifers
- Water cycle maintains the equilibrium of hydrosphere

Lithosphere

- The solid outer part of the planet that comprises of continental crust ,ocean crust and upper brittle portion of mantle
- Span of up to a depth of 100km
- Oceanic part is denser than that of continental
- Top part of the crust contains the fertile soil that supply micronutrients for plants to grow
- Crust is a treasure of various types of minerals, stones and sand
- Interaction between the huge plates of lithosphere is called **tectonic activity**



Biosphere

- Sphere of ‘life’
- All living organisms including *microbiome*
- Biosphere is linked to all other spheres and depends on them for the existence and growth of living organisms

Types of pollution

Air Pollution

Definition as per WHO

"*Air pollution is contamination of the indoor or outdoor environment by any chemical, physical or biological agent that modifies the natural characteristics of the atmosphere*".

- Mainly affects stratosphere and troposphere layers of the atmosphere.
- Every year, seven million death around the globe due to air pollution
- Nine out of ten around the world breathe unhealthy air that exceeds the WHO's guideline limit for pollutants
- Threat for all biotic components of ecosystem

Case Study: 1 The story of Juvenile Asthma: Polluted Air, Suffering Children

THE STORY OF JUVENILE ASTHMA: POLLUTED AIR, SUFFERING CHILDREN

Eight-year-old Moni caught pneumonia during winter rains three years ago and she is now an asthmatic, visiting the government hospital every week. Her father, who earns Rs 60 per day, spends Rs 80 per week on her treatment. The family of five cannot buy rations and the house rent is six months overdue.

Moni is not alone. Seven-year-old Umesh Kumar, one-year-old Mushtab, and many more children among the poor of Kanpur city are all asthmatics, condemned for a long period of medical treatment and unaffordable expenses. Anuj Rawal is perhaps among the few happy people of the city, since his medical shop sells Rs 50,000 worth of asthma medicines every month!

Kanpur is one of the worst polluted cities in India. It is home to many textile mills and leather units. The most popular form of transport is the rickety three-wheeler tempo, which spews out volumes of smoke from old engines. Dust is thick in the air and the smog never goes away. And the hospitals are full of juvenile asthmatics. The story is the same in the shantles of Delhi, slums of Mumbai, or colonies of Chennai.

WHO estimates that 10–15 per cent of Indian children in the 5–11 age group suffer from asthma. It costs an average of Rs 300 per month to buy a child's

Scanned with OKEN Scanner

Case Study: 1 The story of Juvenile Asthma: Polluted Air, Suffering Children

asthma medicines. Since there is little awareness of asthma among the poor and even health officials, often the disease is not even diagnosed. Even if it is diagnosed, the child is given steroids because they are cheap. Steroids will have long-term adverse effects on their health.

Several studies have shown the link between pollution and asthma. According to a Delhi study, the city's polluted air is responsible for a 40 per cent increase in asthma cases. More people were admitted to the emergency ward on days when the air pollution was high.

Case Study 2: The story of Jharia City of Fire

Lives of around half a million people in Jharia in the eastern state of Jharkhand are at risk from land subsidence over abandoned coal mines, where fires have been raging for over a century.

Noxious fumes from the coalfield fires and opencast mining with little heed to environmental safeguards have turned Jharia into the pollution capital of the country, severely impacting the health of local residents.

A plan to relocate people to safer areas has moved at a snail's pace, with a mere 3,000 families out of 140,000 rehabilitated to a nearby township.

https://india.mongabay.com/2019/10/the-burning-coalfields-of-jharia-belch-poison-for-local-residents/

Sources of Air Pollution

Air pollution can be human made or natural

Human made pollution is called anthropogenic pollution

Sources of *human made* contamination :

- Increased urban population→ emission of CO_2 ,CO, CFC, HFC (hydrofluorocarbon) and
- Emission of fuming and pollutant gases by industry (SO_2, NO_2 , dioxins, benzene, mercury and lead)
- Combustion of plastic, fuels, cooking gas, any commercial/ domestic waste (CO, CO_2,SO_2, dioxins)
- Rice cultivation and livestock farming – release of methane

Sources of *natural contamination* -

- Wild fire
- Volcano eruption

Detrimental Effects

- Formation of Smog and Soot
- Release of Hazardous pollutants into air
- Emission of Greenhouse gases

Major impact in the environment

Ozone depletion

Global warming

Climate change

Smog and Soot

Smog – smoke + fog

Formed when the gases emitted by fossil fuel combustion reacts with sunlight

Concentrated pollutants when blocked by tall mountains or buildings form a cloud type structure

Soot (Particulate Matter) formed by tiny particles of chemicals, soil, dust, smoke and allergens

Both smog and soot comes from automobiles, incinerators and factories that use fossil fuel

Log Angeles is known as SMOG CITY

Harmful Effects

- Smog creates irritation to eyes and skin, damage lungs
- Soot can penetrate into lungs or bloodstream , threat for human or animal life.

https://www.nrdc.org/stories/air-pollution-everything-you-need-know#effects

Hazardous pollutants

Most common are lead, mercury, dioxins, benzene

VOC s (Volatile Organic Compounds) and PAHs (Polycyclic Aromatic Hydrocarbons)

Polycyclic Aromatic Hydrocarbons (PAHs) Polycyclic aromatic hydrocarbons (PAHs) are a class of chemicals that occur naturally in coal, crude oil, and gasoline. They result from burning coal, oil, gas, wood, garbage, and tobacco. also play key role.

Case Study on LEAD Poisoning:

Lead is a toxic element of the environment which leads to major complications once it enters the blood stream, affecting multiple organs and systems of the body. History revealed that the girl participated in the process of pottery, her father was also diagnosed with lead poisoning 2 years before. The patient's personal history underlined that approximately 1 year ago she presented with severe abdominal pain, being diagnosed with acute appendicitis and she underwent appendectomy, but the pain persisted, thus due to family history of lead poisoning, the suspicion of saturnine colic rose, and she was diagnosed with lead poisoning.

Dioxins

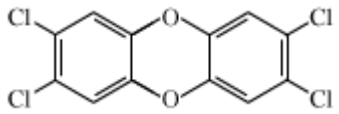
Chemical formula for dioxin is 2,3,7,8- tetrachlorodibenzo para dioxin (TCDD). The name "dioxins" is often used for the family of structurally and chemically related polychlorinated dibenzo para dioxins (PCDDs) and polychlorinated dibenzofurans (PCDFs)

Dioxins are termed as persistent organic pollutants (POPs)

These are generated by the incineration process of medical waste.

Dioxins are unwanted by-products of a wide range of manufacturing processes including smelting, chlorine bleaching of paper pulp and the manufacturing of some herbicides and pesticides

Highly toxic.



Mercury

Mining and fossil fuel combustion have led to widespread global mercury pollution

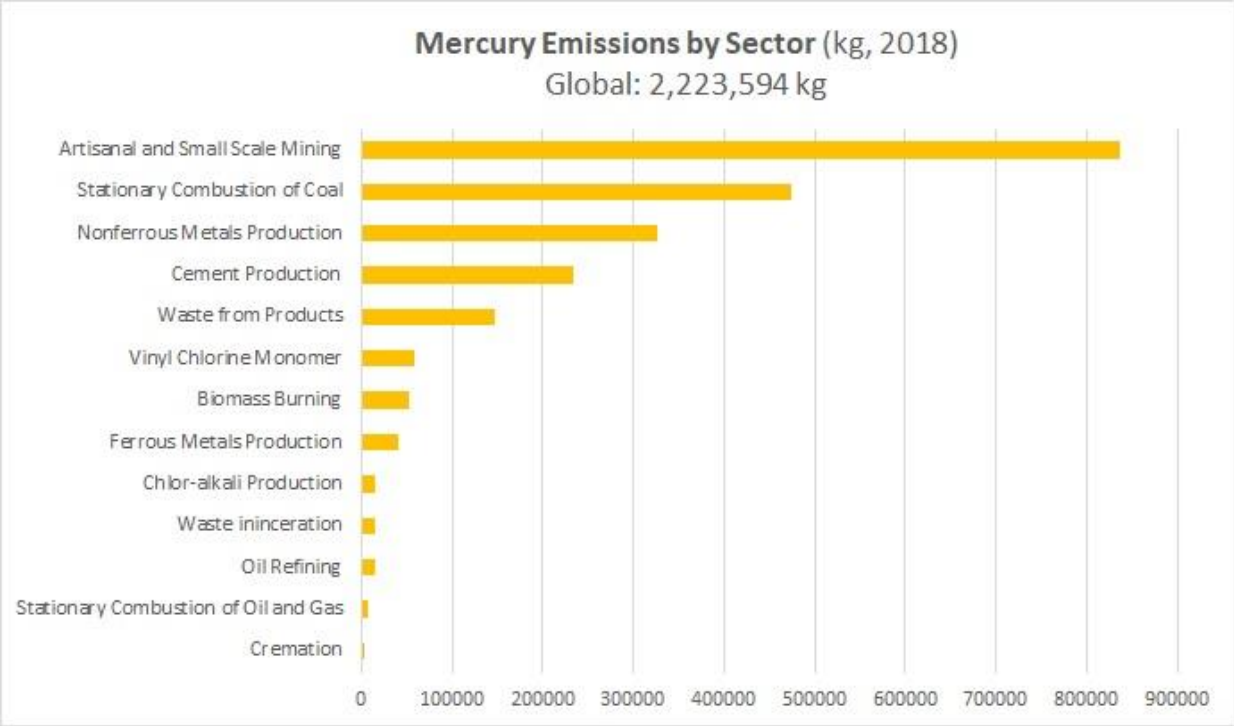
Mercury emitted into the air eventually settles into water or onto land where it can be washed into water.

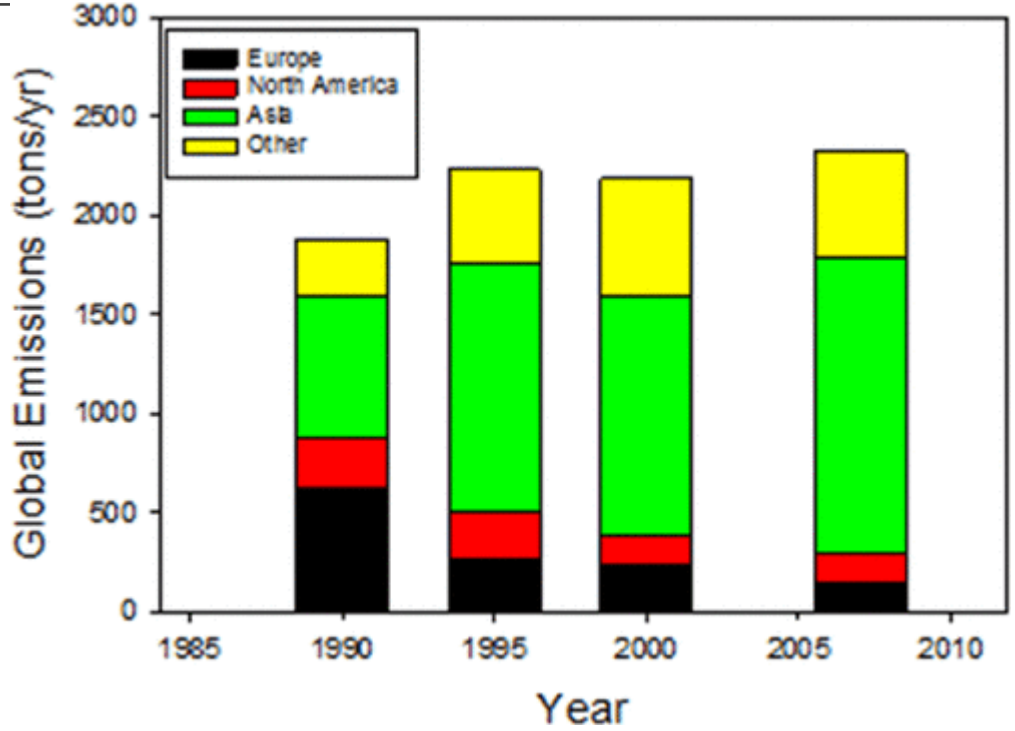
Once deposited, certain microorganisms can change it into methylmercury (CH_3Hg), a highly toxic form that builds up in fish, shellfish and animals that eat fish.

Most human exposure to mercury is from eating fish and shellfish contaminated with methylmercury

https://www.epa.gov/international-cooperation/mercury-emissions-global-context

Sources of mercury emission





Lead

Sources of lead

- Paints used in houses built before 1980s
- Toys and jewellery made for children
- Aviation gas used in piston engine aircrafts

Harmful effects

- Adverse affect on children who inhale air contains lead
- Affects nervous system and brain functioning of kids
- Threat for the fetus if pregnant woman inhale lead

Benzene

- Benzene is formed from both natural processes and human activities.
- Natural sources of benzene include volcanoes and forest fires.
- Benzene is also a natural part of crude oil, gasoline, and cigarette smoke.
- Benzene is widely used in the United States. It ranks in the top 20 chemicals for production volume.
- Some industries use benzene to make other chemicals that are used to make plastics, resins, and nylon and synthetic fibers. Benzene is also used to make some types of lubricants, rubbers, dyes, detergents, drugs, and pesticides.
- Benzene is less soluble in water and hence floats on water
- Quickly evaporates but thicker than air and hence stay in the low lying layers of atmosphere

Detrimental Effects

Short term effects

- Dizziness
- Drowsiness
- Unconsciousness
- Vomiting

Long term effects

- Can seriously affect red blood cells → leading to bone marrow issues and anaemia
- Can act on reducing the count of white blood cells → reducing the immunity level of the human body
- Animal studies have shown low birth weights, delayed bone formation, and bone marrow damage when pregnant animals breathed benzene.
- Exposure to benzene for a very long period of time can cause blood cancer

Green House Gases (GHGs)

Any gas that has the property of absorbing infrared radiation (net heat energy) emitted from Earth's surface and reradiating it back to Earth's surface, thus contributing to the **greenhouse effect.**

Carbon dioxide is the largest contributor , accounting for around three-quarters (74.4%) of total emissions. Methane contributes 17.3%; nitrous oxide, 6.2%; and other emissions (HFCs, CFCs, SF_6), 2.1%.

https://ourworldindata.org/greenhouse-gas-emissions

Carbon dioxide

The most significant greenhouse gas. Natural sources of atmospheric CO_2 include outgassing from volcanoes, the combustion and natural decay of organic matter, and respiration by aerobic organisms

Carbon cycle is balanced by photosynthesis, biological pumping by phytoplankton and by marine organisms that use CO2 to make CaCO3.

Anthropogenic emissions currently account for the annual release of about 7 gigatons (7 billion tons) of carbon into the atmosphere, causing imbalance in the carbon cycle.

The total radiative forcing by anthropogenic CO_2 emissions since the beginning of the industrial age is approximately 1.66 watts per square meter.

Methane

The second most important greenhouse gas

CH_4 is more potent than CO_2 because the radiative forcing produced per molecule is greater.

In addition, the infrared window is less saturated in the range of wavelength of radiation absorbed by CH_4, so more molecules may fill in the region.

CH_4 exists in far lower concentrations than CO_2 in the atmosphere and its concentrations by volume in the atmosphere are generally measured in parts per billion (ppb) rather than ppm

The major anthropogenic sources of atmospheric CH_4 are **rice cultivation**, livestock farming, the burning of coal and natural gas, the combustion of biomass, and the decomposition of organic matter in landfills

The total radiative forcing by anthropogenic methane emission is 0.5 watts per square meter

Nitrous Oxide and fluorinated gas

Less effective green house gases

Fluorinated gases include,

Chlorofluorocarbons (CFCs),

hydrofluorocarbons(HFCs),

Sulphur hexa Fluoride (SF6)

Perfluoro carbons (PFCs)

Nitrous oxide has radiative forcing of 0.16 watt per square meter and fluorinated gases collectively has a radiative forcing of 0.34 watt per square meter

Most polluted Cities 2023

(124.11 µg/m3)
DAMMAM

(111.63 µg/m3)
Lahore

(84.73 µg/m3)

Dhaka

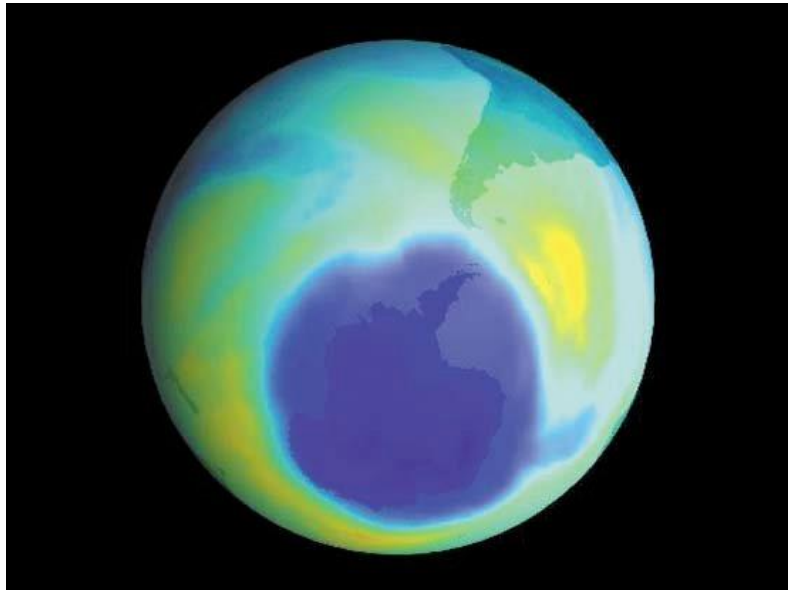
(84.39 µg/m3)
Delhi

Environmental Impacts of pollution

- Ozone Depletion
- Global warming
- Climate change

Ozone Depletion

- Reduction of ozone in the stratosphere layer into oxygen molecule thereby reducing the amount of ozone column values.
- Generally, the **ozone hole** is defined as the area for which ozone column values amount to 220 Dobson Units (DU) or less
- The **Dobson unit** (DU) is a unit of measurement of the amount of a trace gas in a vertical column through the Earth's atmosphere
- A typical column amount of 300 DU of atmospheric ozone therefore would form a 3 mm layer of pure gas at the surface of the Earth
- Ozone depletion is mainly due to the emission of CFC, HFC and PFC



https://www.epa.gov/ozone-layer-protection/basic-ozone-layer-science

Ozone formation

The production of ozone in the stratosphere results primarily from the breaking of the chemical bonds within oxygen molecules (O_2) by high-energy solar photons.

This process, called photodissociation, results in the release of single oxygen atoms, which later join with intact oxygen molecules to form ozone.

Rising atmospheric oxygen concentrations some two billion years ago allowed ozone to build up in Earth's atmosphere, a process that gradually led to the formation of the stratosphere.

Scientists believe that the formation of the ozone layer played an important role in the development of life on Earth by screening out lethal levels of UVB radiation (ultraviolet radiation with wavelengths between 315 and 280 nm) and thus facilitating the migration of life-forms from the oceans to land.

Principal steps in the depletion of stratospheric ozone

Emissions

Halogen source gases are emitted at Earth's surface by human activities and natural processes.

Accumulation

Halogen source gases accumulate in the atmosphere, and they are distributed throughout the lower atmosphere by winds and other air motions.

Transport

Halogen source gases are transported to the stratosphere in air currents.

Conversion

Most halogen source gases are converted in the stratosphere to reactive halogen gases in chemical reactions that involve the Sun's ultraviolet radiation.

Chemical reaction

Reactive halogen gases cause the chemical depletion of stratospheric total ozone over all parts of the globe except tropical latitudes.

Polar stratospheric clouds increase ozone depletion by providing surfaces upon which reactive halogen gases can form, causing severe ozone loss in polar regions in winter and spring.

Removal

Air containing reactive halogen gases returns to the troposphere, and these gases are removed from the air by moisture in clouds and rain.

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Source: U.S. Department of Commerce

Demography of ozone holes

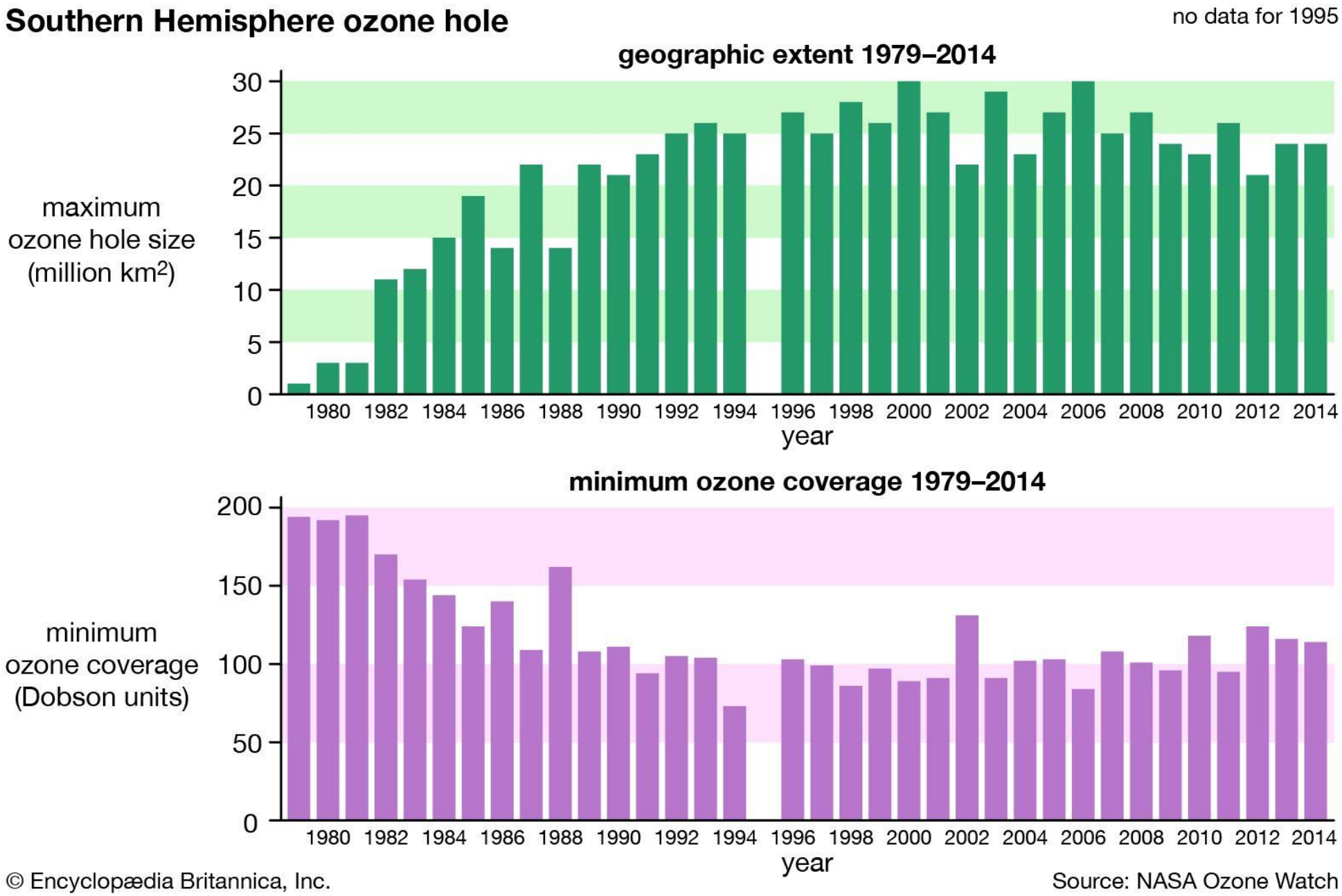
- **Depletion of stratospheric ozone** occurs over both hemispheres of the Earth.

- The phenomenon is more pronounced in the Southern Hemisphere (Antarctica) than in the Northern Hemisphere (Arctic).

- The formation of the ozone hole is directly linked to the stratosphere's temperature. Once temperatures drop below -78°C, polar stratospheric clouds tend to form, which exacerbate ozone depletion.

- In the Antarctic, long presence of low **temperatures in the stratosphere** are stimulating their formation, whereas the Arctic is characterized by larger year-to-year meteorological variability.

https://www.nationalgeographic.com/environment/article/ozone-depletion



https://www.nps.gov/subjects/air/howwemeasure-ozone.htm#:~:text=An%20ozone%20analyzer%20measures%20the,tipping%20tower%20by%20a%20pump.

Ozone holes – latest trends

The largest historical extent of the ozone hole - 28.4 million km² - occurred in September 2000.

This area is equivalent to more than six times the territory of the EU

In late September 2022, the Antarctic ozone hole reached its maximum area with 24.5 million km².

Up until early November 2022, the Antarctic ozone hole has been similarly large and long-lasting to the ones in 2021 and 2020

Montreal Treaty

- International treaty adopted in Montreal on September 16, 1987
- The target was to regulate the production and use of chemicals that
- contribute to the depletion of Earth's ozone layer
- Initially signed by 46 countries, the treat now has nearly 200 signatories
- 100 ozone depleting substances were identified and decision was taken to reduce or ban the production and use of these substances.
- The major substances controlled by the treaty are listed in Annexes A (CFCs, halons), B (other fully halogenated CFCs, carbon tetrachloride, methyl chloroform), C (HCFCs), E (methyl bromide) and F (HFCs).
- As a result of the treaty, concentration of ozone depleting substances were substantially reduced in the last two decades

Montreal treaty

The Multilateral Fund for the Implementation of the Montreal Protocol was established in 1991 under Article 10 of the treaty.

The Fund's objective is to provide financial and technical assistance to developing countries who adhere to the Montreal Protocol whose annual per capita consumption and production of ODS is less than 0.3 kg to comply with the control measures of the Protocol.

The Multilateral Fund’s activities are implemented by four international agencies - UN Environment Programme (UNEP) , UN Development Programme (UNDP), UN Industrial Development Organisation (UNIDO) and the World Bank

Environmental Science & Green Technology

DR. NOOPUR

ASSISTANT PROFESSOR

DEPTT OF HUMANITIES SOCIAL SCIENCES AND MANAGEMENT

IIIT RANCHI

Lecture Objectives

- Discuss the harmful effects of air pollution

Air Pollution

Definition as per WHO

"Air pollution is contamination of the indoor or outdoor environment by any chemical, physical or biological agent that modifies the natural characteristics of the atmosphere".

- Mainly affects stratosphere and troposphere layers of the atmosphere.
- Every year, seven million death around the globe due to air pollution
- Nine out of ten around the world breathe unhealthy air that exceeds the WHO's guideline limit for pollutants
- Threat for all biotic components of ecosystem

Pollution due to carelessness

Massive fire breaks out in cosmetic factory in Himachal Pradesh's Solan; 19 injured

New Delhi’s Air Turns Toxic, and the Finger-Pointing Begins

https://www.youtube.com/watch?v=-wBIPVu3AJw

Reasons and harmful effects

Reasons

Lack of strategy for the segregation of waste

Lack of proper plan and implementation of biomining

Lack of initiatives to reduce the plastic waste or finding alternatives for plastic in daily life

Harmful Effects

Dioxin is inhaled by people who resides within 20km radius of the waste treatment plant

Large scale liberation of methane gas and CO2

Severe respiratory and growth issues for children (age below 12)

Solutions?

Segregation of waste

Bio waste into useful product

Solutions?

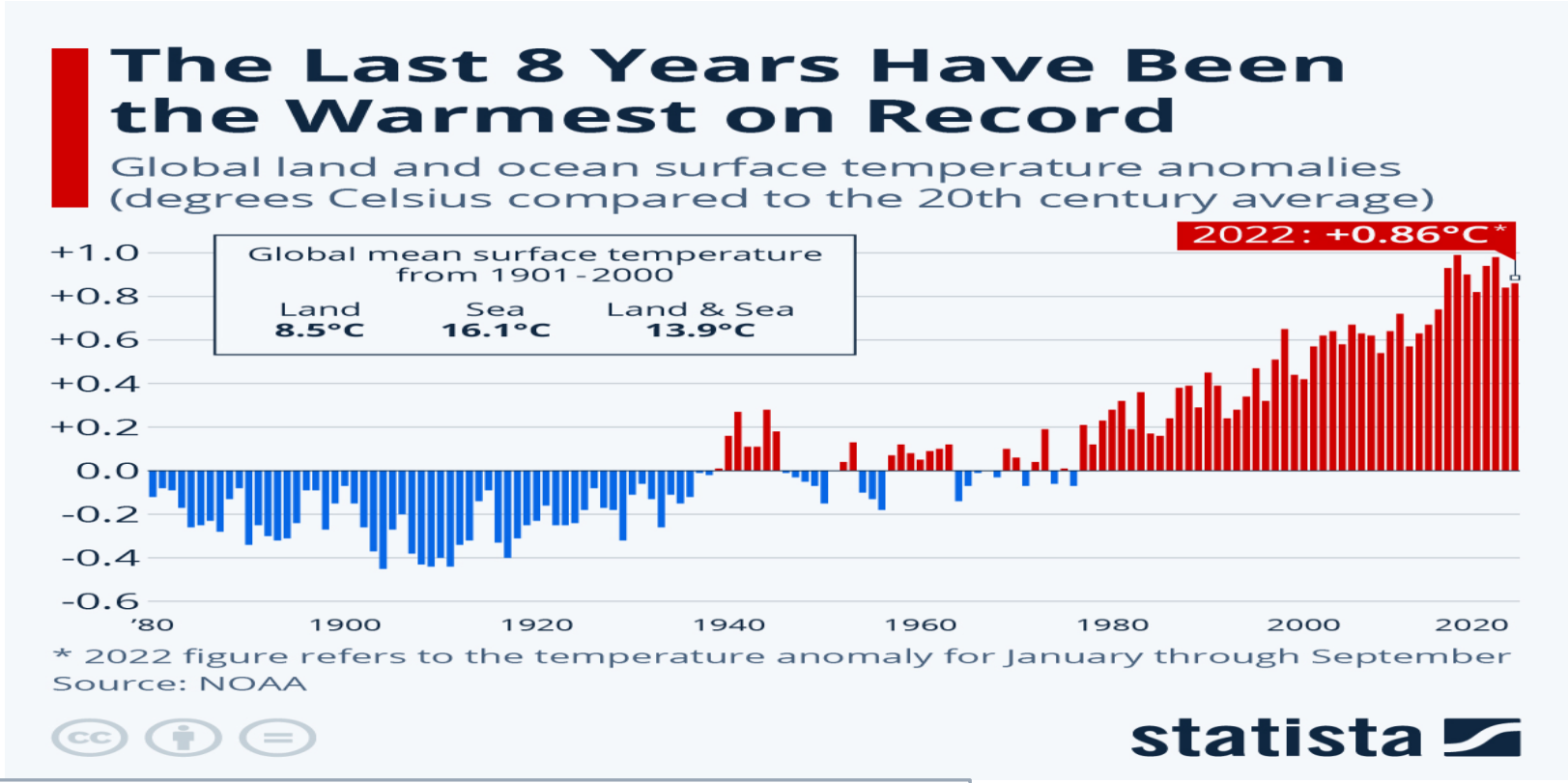
Clay Bottles to Bamboo Straws: 8 Products That Can Reduce Your Plastic Footprint

https://www.thebetterindia.com/179909/bengaluru-woman-eco-friendly-products-bare-necessities-india/

Bhubaneswar city administration urges employees to cycle to work once a week. Every Friday, the employees of BSCL, BDA and BMC will either cycle or walk to work to contribute towards a greener environment.

Read more at: https://www.hrkatha.com/practice/bhubaneswar-city-administration-urges-employees-to-cycle-to-work-once-a-week/

Global Warming



Source: National Oceanic and Atmospheric Administration

Definition

Global warming is the phenomenon of increasing average air temperatures near the surface of Earth over the past one to two centuries.

Long-term heating of Earth’s surface observed since the pre-industrial period (between 1850 and 1900) due to human activities, primarily fossil fuel combustion

For the last 40 years, we’ve seen the global annual temperature rise by 0.18 degrees Celsius, or 0.32 degrees Fahrenheit, per decade.

Term is not interchangeable with "climate change."

Solar radiation and reflection

The energy of the total incoming solar radiation at the top of Earth's atmosphere (the so-called "solar constant") amounts roughly to 1,366 watts per square metre annually.

Adjusting for the fact that only one-half of the planet's surface receives solar radiation at any given time, the average surface insolation is 342 watts per square metre annually.

For every 100 units of incoming solar radiation, roughly 30 units are reflected back to space by either clouds, the atmosphere, or reflective regions of Earth's surface.

This reflective capacity is referred to as Earth's planetary albedo, and it need not remain fixed over time, since the spatial extent and distribution of reflective formations, such as clouds and ice cover, can change.

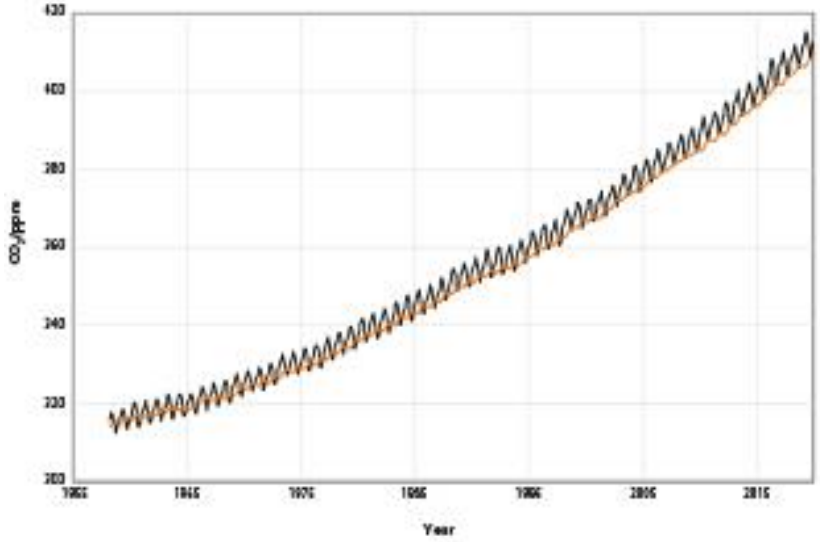
The 70 units of solar radiation that are not reflected may be absorbed by the atmosphere, clouds, or the surface. In the absence of further complications, in order to maintain thermodynamic equilibrium, Earth's surface and atmosphere must radiate these same 70 units back to space.

Earth's surface temperature (and that of the lower layer of the atmosphere essentially in contact with the surface) is tied to the magnitude of this emission of outgoing radiation according to the Stefan-Boltzmann law.

GHGs and warming

- Carbon dioxide concentrations in the atmosphere were roughly 280 **parts per million** (ppm) in 1750s

- By the end of 2022 they had risen to 419 ppm, and, if fossil fuels continue to be burned at current rates, they are projected to reach 550 ppm by the mid-21st century



- Doubling of carbon dioxide concentrations in 300 years.

https://royalsociety.org/topics-policy/projects/climate-change-evidence-causes/basics-of-climate-change/

Radiative forcing

Radiative forcing is a measure of the influence a given climatic factor has on the amount of downward-directed radiant energy impinging upon Earth's surface

Radiative forcing can be positive or negative

Factors other than GHG contributing to heat trap

- Water Vapour
- Aerosols
- Land use pattern

Water vapour

Water vapour is the most potent of the greenhouse gases in Earth's atmosphere, but its behaviour is fundamentally different from that of the other greenhouse gases.

The primary role of water vapour is not as a direct agent of radiative forcing but rather as a climate feedback—that is, as a response within the climate system that influences the system's continued activity.

This distinction arises from the fact that the amount of water vapour in the atmosphere cannot, in general, be directly modified by human behaviour but is instead set by air temperatures.

The warmer the surface, the greater the evaporation rate of water from the surface. As a result, increased evaporation leads to a greater concentration of water vapour in the lower atmosphere capable of absorbing longwave radiation and emitting it downward.

Aerosols

- The production of aerosols represents an important anthropogenic radiative forcing of climate
- Aerosols sometimes block—that is, reflect and absorb—a portion of incoming solar radiation, and this creates a negative radiative forcing.
- Most aerosols serve as condensation nuclei (surfaces upon which water vapour can condense to form clouds)
- Aerosols are second only to greenhouse gases in relative importance in their impact on near-surface air temperatures.

Land use pattern

- There are a number of ways in which changes in land use can influence surface temperature .
- The most direct influence is through the alteration of Earth's albedo, or surface reflectance.
- The replacement of forest by cropland and pasture in the middle latitudes over the past several centuries has led to an increase in albedo, which in turn has led to greater reflection of incoming solar radiation in those regions.
- This replacement of forest by agriculture has been associated with a change in global average radiative forcing of approximately –0.2 watt per square meter since 1750

Major findings and predictions

The IPCC (Intergovernmental Panel on Climate Change)’s Sixth Assessment Report (AR6), published in 2021, noted that the best estimate of the increase in global average surface temperature between 1850 and 2019 was 1.07 °C (1.9 °F).

An IPCC special report produced in 2018 noted that human beings and their activities have been responsible for a worldwide average temperature increase between 0.8 and 1.2 °C (1.4 and 2.2 °F) since preindustrial times, and most of the warming over the second half of the 20th century could be attributed to human activities.

The intermediate-emissions scenario, which assumed that emissions would stabilize by 2050 before declining gradually, projected an increase of between 2.1 and 3.5 °C (3.8 and 6.3 °F) by 2100.

Glaciers and global warming

Because of global warming, glaciers and sea ice melts at a faster rate.

As of now, Greenland ice is melting four times faster than in 2003.

In Arctic, 95% of the oldest and thickest ice sheets are already gone.

If the emission continue at this rate, whole Greenland glaciers will be disappeared by 2100

Arctic would be ice free in summer by 2040.

https://www.worldwildlife.org/pages/why-are-glaciers-and-sea-ice-melting#:~:text=Human%20activities%20are%20at%20the,sea%20and%20retreating%20on%20land.

Rise in sea level

The AR6 report also noted that the global average sea level had risen by some 20 cm (7.9 inches) between 1901 and 2018 and that sea level rose faster in the second half of the 20th century than in the first half.

Under the report's lowest-emission scenario, sea level would rise by 28–55 cm (11–21.7 inches), whereas, under the intermediate emissions scenario, sea level would rise by 44–76 cm (17.3–29.9 inches).

The highest-emissions scenario suggested that sea level would rise by 63–101 cm (24.8–39.8 inches) by 2100.

Rise in sea level may cause drowning of cities, destruction of coastal areas, frequent floods etc

https://www.britannica.com/science/global-warming/Surface-level-ozone-and-other-compounds

Rise in Ocean temperature

- The earth's ocean temperatures are getting warmer, too—which means that tropical storms can pick up more energy. In other words, global warming has the ability to turn a category 3 storm into a more dangerous category 4 storm.
- In fact, scientists have found that the frequency of North Atlantic hurricanes has increased since the early 1980s, as has the number of storms that reach categories 4 and 5.
- The 2020 Atlantic hurricane season included a record-breaking 30 tropical storms, 6 major hurricanes, and 13 hurricanes altogether, with increased intensity, increased damage and death.
- The United States saw an unprecedented 22 weather and climate disasters that caused at least a billion dollars' worth of damage in 2020.
- Rise in ocean temperature decreases DO (Dissolved Oxygen) in ocean, increases acidity and causes threat for marine life

Climate Change

https://climate.nasa.gov/

Climate change refers to long-term shifts in temperatures and weather patterns.

"a broad range of global phenomena created predominantly by burning fossil fuels, which add heat-trapping gases to Earth's atmosphere. These phenomena include the increased temperature trends described by global warming, but also encompass changes such as sea-level rise; ice mass loss in Greenland, Antarctica, the Arctic and mountain glaciers worldwide; shifts in flower/plant blooming; and extreme weather events."

Climate Change

- Change in precipitation
- Change in rainfall pattern
- Change in the wind speed
- Increased drought period
- Accidental wildfires
- Intensified natural calamities

Paris Agreement 2015

The Paris Agreement is a **legally binding international treaty on climate change**. It was adopted by 196 Parties at the UN Climate Change Conference (COP21) in Paris, France, on 12 December 2015. It entered into force on 4 November 2016.

Its overarching goal is to hold “the increase in the global average temperature to well below 2°C above pre-industrial levels” and pursue efforts “to limit the temperature increase to 1.5°C above pre-industrial levels.”

To limit global warming to 1.5°C, greenhouse gas emissions must peak before 2025 at the latest and decline 43% by 2030.

Impact of Paris Agreement

- The Paris Agreement works on a **five-year cycle** of increasingly ambitious climate action
- Since 2020, countries have been submitting their national climate action plans, known as **nationally determined contributions (NDCs)**. Each successive NDC is meant to reflect an increasingly higher degree of ambition compared to the previous version.
- With the Paris Agreement, countries established an **enhanced transparency framework (ETF)**. Under ETF, starting in 2024, countries will report transparently on actions taken and progress in climate change mitigation, adaptation measures and support provided or received.
- More and more countries, regions, cities and companies are establishing **carbon neutrality targets. Zero-carbon solutions** are becoming competitive across economic sectors representing 25% of emissions

Global Methane Pledge

Global Methane Pledge, a pact to collectively cut global emissions by at least 30% from 2020 levels by 2030. Scientists estimate the reduction could cut global temperature rise by 0.2% and help the world reach its target of keeping global warming under 1.5 degrees Celsius.

The pledge aims to catalyze global action and strengthen support for methane emission reduction initiatives.

Total 150 countries have joined as of 2022.

https://www.globalmethanepledge.org/

Carbon Footprint

Carbon footprint is the total amount of greenhouse gases (including carbon dioxide and methane) that are generated by our actions.

The annual per capita carbon footprint in the United States is 15 tons, one of the highest rates in the world.

Globally, the average carbon footprint is closer to 4 tons.

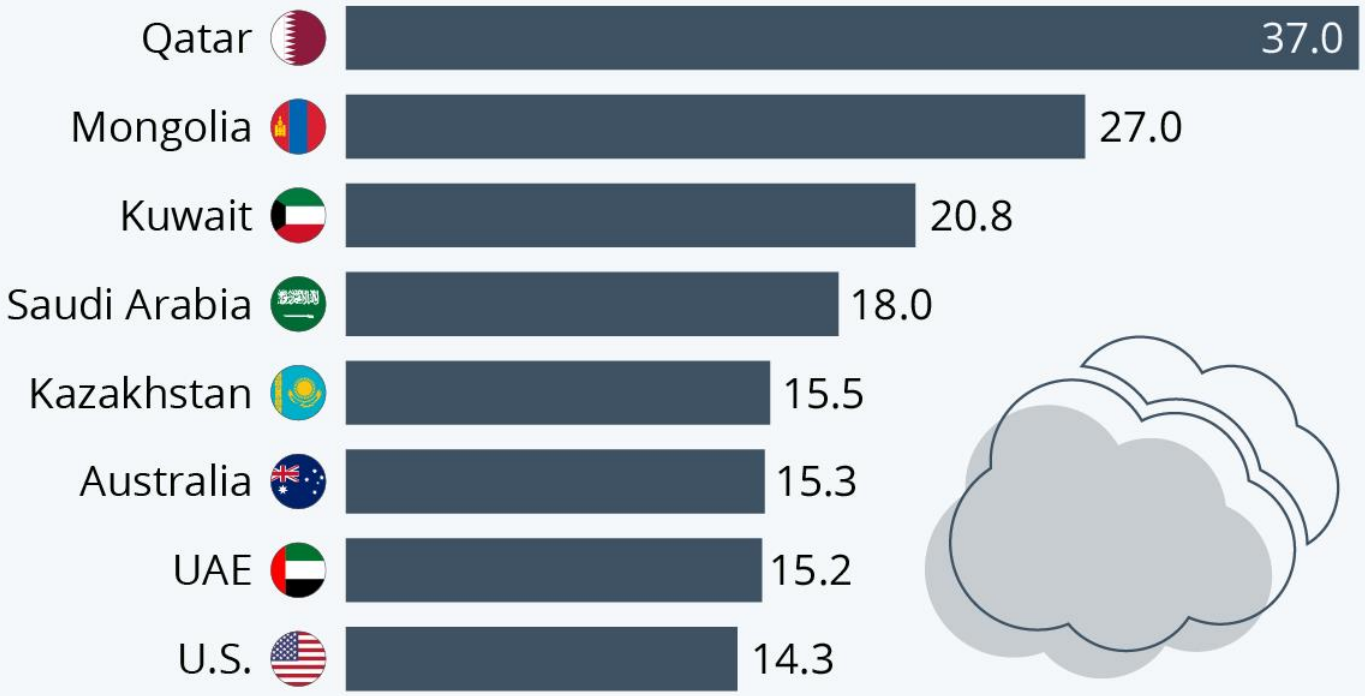
To have the best chance of avoiding a 2°C rise in global temperatures, the average global carbon footprint per year needs to drop to under 2 tons by 2050.

In India, per capita carbon footprint is 1.96 tons as on 2021.

https://offset.climateneutralnow.org/footprintcalc

The Countries Emitting the Most CO_2 per Capita

Countries with the highest annual per-capita CO_2 emissions (in tons)*



* only includes countries with two million inhabitants or more
2020 figures, latest available

Sources: UNFCCC/CDIAC/BP via Global Carbon Project, World Bank

Carbon neutral and Net zero

- Carbon neutrality is a state of net zero carbon (CO2) emissions.
- **Carbon neutral** means that any CO_2 released into the atmosphere from a company's activities is balanced by an equivalent amount being removed.
- **Net Zero** refers to the amount of greenhouse gases (GHGs) – such as carbon dioxide (CO_2), methane or Sulphur dioxide – that are removed from the atmosphere being equal to those emitted by human activity.
- **Bhutan is the only country in the world with negative carbon emission**

Carbon Credit Market

A carbon market allows investors and corporations to trade both carbon credits and carbon offsets simultaneously. This mitigates the environmental crisis, while also creating new market opportunities.

Carbon credits, also known as carbon allowances, work like permission slips for emissions. When a company buys a carbon credit, usually from the government, they gain permission to generate one ton of CO_2 emissions. With carbon credits, carbon revenue flows vertically from companies to regulators, though companies who end up with excess credits can sell them to other companies.

When one company removes a unit of carbon from the atmosphere as part of their normal business activity, they can generate a **carbon offset**. Other companies can then purchase that carbon offset to reduce their own carbon footprint.