Environmental Science: Theory into Practice-I

Lesson 1: Introduction to Environmental Studies

- **Introduction to Environment**
    - The term "Environment" is derived from the French word 'Environ', meaning 'surrounding'.
    - It encompasses **all living (biotic) and non-living (abiotic) components** present in nature.
    - The **Environmental Protection Act of 1986** defines environment as "water, air and land and the inter-relationship which exists among and between water, air and land, and human beings, other living creatures, plants, micro-organism and property".
    - Interactions between biotic and abiotic components form a **functional ecosystem** and support **sustainable life** on Earth.
    - The environment provides essential goods and services, such as clean air and water, food, fodder, medicines, raw materials, and tourism.
    - **Anthropogenic activities** and **unsustainable consumption** of natural resources have significantly degraded the

environment, highlighting the need for protection and environmental education.

- **Components of Environment**
  - Planet Earth is unique for its diversity of life, made possible by healthy interactions between biotic and abiotic components, facilitating energy flow and biogeochemical cycles.
  - The Earth is categorised into spheres representing solid (lithosphere), liquid (hydrosphere), and gaseous (atmosphere) phases.
  - **Lithosphere**:
    - Derived from Greek 'Lithos' (rock).
    - The outermost layer of the Earth's crust, representing the **land mass**.
    - Composed of rocks, soil, sediments, and minerals.
    - Features uneven geological structures like mountains, plateaus, valleys, and sea beds.
    - Site of **geological processes** (weathering, erosion, volcanic eruptions) and **biogeochemical cycles**.
    - Supports terrestrial ecosystems like forests, grasslands, and deserts.
  - **Hydrosphere**:
    - Derived from Greek 'Hydro' (water).

- Represents all **water masses** on the planet in solid (ice, glaciers), liquid (water bodies), and gaseous (water vapours) phases.
- Covers almost **three-fourths of Earth's surface**.
- **Oceans and seas** constitute marine ecosystems, holding 97% of total water (high salt concentration).
- The remaining 3% is **freshwater** in glaciers, rivers, lakes, ponds.
- Crucial for the **water cycle** and maintaining climatic, meteorological, physical, chemical, and biological functions.
- Oceans are the **largest carbon sinks**.

- **Atmosphere**:
  - Derived from Greek 'Atmos' (vapour).
  - A **thin sheet of gaseous mixture** enveloping Earth.
  - Density and pressure decrease with altitude.
  - **Composition of dry air**: Nitrogen (78.084%), Oxygen (20.946%), Argon (0.934%), Carbon Dioxide (0.040%), and trace gases.
  - **Layers of atmosphere** (stratified by temperature changes - lapse rate):

        - **Troposphere**: Lowest layer (0-11 km), largest percentage of air mass, temperature decreases with altitude, weather occurs here.
        - **Stratosphere**: 11-50 km, temperature rises due to **ozone (O3) layer** absorbing UV radiation (UV-B), crucial for life but depleting due to CFCs.
        - **Mesosphere**: 50-85 km, temperature decreases, low air density, contains O2+ and NO+ ions.
        - **Thermosphere**: 85-500 km, temperature increases rapidly due to ionic oxygen and other ions absorbing short-wave solar radiation, auroras occur here.
    - **Biosphere**:
        - Derived from Greek 'Bios' (life).
        - The **self-regulating overlapping region** of the atmosphere, lithosphere, and hydrosphere.
        - Life exists, is nourished, and flourishes through healthy interaction between biotic and abiotic components.
- **Environmental Education**
    - Gained global concern in the second half of the 20th century.
    - **UNESCO (1971) objectives**: Create awareness, impart knowledge, develop concern, motivate participation, acquire skills, and strive for harmony with Nature.

- **First intergovernmental conference** on environmental education: Organised jointly by UNESCO and UNEP in **Tbilisi, Georgia, in 1977**.
    - Goals: Foster awareness of interdependencies, provide opportunities for knowledge/values/attitudes/skills, and create new behaviour patterns towards the environment.
- **Categories of environmental education objectives**: Awareness, Knowledge, Attitudes, Skills, Participation.
- **In India**: Environmental education became compulsory at undergraduate levels in Indian universities due to a **Supreme Court ruling in 1991**.

- **Difference between Environmental Science and Environmental Studies**
    - **Environmental Studies**: A **multidisciplinary subject** that examines scientific, social, cultural, economic, political dimensions of the environment, its issues, challenges, and solutions holistically. It studies human-environment interaction at micro and macro levels.
    - **Environmental Science**: Strictly focuses on the **scientific aspects** of environmental problems and their tangible solutions. Environmental Studies, conversely, includes socio-economic, cultural, traditional, legislative, and historical dimensions in addition to scientific aspects.

- **Multidisciplinary Nature of Environmental Studies**
  - Environmental issues are complex, requiring expertise from various subjects.
  - **Environmental Impact Assessment (EIA)** case study illustrates this need:
    - **Life Sciences (Zoology and Botany)**: Assess biodiversity, endemism, and changes due to anthropogenic activities, and evaluate ecosystem goods and services.
    - **Earth Sciences (Geology, Geography, Geochemistry)**: Study geological/geographical terrain, soil/rock profiles, tectonic/seismic activity.
    - **Chemical Sciences**: Understand chemical processes, pollutant fate and effect on air, water, soil.
    - **Anthropology, History, and Archaeology**: Assess historical/archaeological importance, tribal populations, traditions.
    - **Social Sciences, Sociology, and Economics**: Assess socio-economic status of populations and project impacts.
    - **Law and Legal aspects**: Address legal aspects like land acquisition, relocation, rehabilitation.

        - **Mathematics, Computer Modelling, and Statistics**: Validate data, use models for predictions (e.g., meteorological).

- **Scope and Importance of Environmental Studies**
    - Offers a vast scope for professionals in various sectors.
    - **Career avenues**:
        - **Academics**: Teaching in schools, colleges, universities; dedicated departments and institutions (e.g., WII Dehradun, FRI Dehradun, IIFM Bhopal).
        - **Research & Development**: Understanding ecological mechanisms, developing cost-effective mitigation technologies.
        - **Industries**: Recruiting environmental engineers/scientists/experts to implement guidelines and mitigate degradation.
        - **Ministries and agencies**: Vacancies in national and international organizations (e.g., UNEP, IPCC, CITES, RAMSAR, USEPA).
        - **Non-governmental Organizations (NGOs) and Consultancy**: Working for environmental conservation (e.g., Bombay Natural History Society, IUCN, WWF, Wildlife Trust of India).

        - **Green Journalism**: Propagating environmental awareness through media.
        - **Environmental Legislation and Green Advocacy**: Legal experts for stringent provisions and effective implementation.
    - The subject addresses issues like pollution, biodiversity loss, global warming, energy demands, natural resource pressure, and offers solutions in fields like Environmental Education/Ethics, Ecosystems/Ecology, Natural Resources Management, Energy Efficiency/Audit, Renewable energy, Climate Change, Biodiversity Conservation, Pollution monitoring/mitigation, Population/Environment, and Waste management.
- **Important Landmarks In Environmentalism**
    - **1962**: Publication of **'Silent Spring' by Rachael Carson**, raising concerns about chemical fertilizers and pesticides.
    - **1970**: Publication of **'Limit to Growth' by the Club of Rome**.
    - **February 2, 1971**: **Ramsar Convention** came into existence to conserve wetlands globally; **World Wetlands Day** is observed on this date.

- **June 5-16, 1972**: **United Nations Conference on Human Environment** in Stockholm; **World Environment Day** celebrated on June 5th.
- **1973**: India started **Project Tiger**.
- **December 2-3, 1984**: **Bhopal Gas Tragedy**, worst industrial disaster.
- **April 26, 1986**: **Chernobyl Nuclear Disaster**.
- **1985**: **Vienna Convention**.
- **September 16, 1987**: **Montreal Protocol** signed to protect the Ozone layer.
- **1987**: **Concept of Sustainable Development** introduced by **Brundtland Commission Report ('Our Common Future')**.
- **1989**: **Inter-governmental Panel on Climate Change (IPCC)** formed to combat global warming.
- **1992**: **Agenda 21** adopted at **Earth Summit in Rio de Janeiro**; UN trio sister conventions (UNFCCC, UNCBD, UNCCD) signed.
- **1997**: **Kyoto Protocol** signed to curb greenhouse gas emissions.
- **2002**: **World Summit on Sustainable Development (Rio + 10)** in Johannesburg.

  - **November 30, 2015**: Government of India formed the **International Solar Alliance** during the Paris convention of UNFCC to promote solar energy.
- **Concept of Sustainability and Sustainable Development**
  - Historically, environmental conservation and economic development were seen as separate.
  - The **United Nations established the World Commission on Environment and Development (WCED)**, chaired by Gro Harlem Brundtland, in December 1983.
  - This **Brundtland Commission** submitted its report "Our Common Future" in 1987, introducing the concept of **Sustainable Development**.
  - **Sustainable Development** is defined as **"development that meets the needs of the present without compromising the ability of future generations to meet their own needs."**.
  - **Sustainability** (from Latin 'sustinere' meaning to hold up) is the long-term goal of making the entire world sustainable.
  - **Sustainable development** refers to the pathways to achieve this goal.
  - **Sustainable Development Goals (SDGs)**: Seventeen goals set as the '2030 agenda for sustainable development', adopted by UN members in 2015 as a blueprint for peace and prosperity.

- **Three Pillars of Sustainable Development**: Society, Environment, and Economy, which must harmonically interact.
  - **Environmental Sustainability**: Sustainable consumption of environmental goods and services; current over-exploitation exceeds replenishment rates. Examples of relevant SDGs: **Goal 6 (Clean Water and Sanitation)**, **7 (Affordable and Clean Energy)**, **13 (Climate Action)**, **14 (Life below Water)**, **15 (Life on Land)**. Mahatma Gandhi's quote, **"Earth provides enough to satisfy every man's need but not everyone's greed"**, highlights resource conservation.
  - **Social Sustainability**: Society with fair and equal opportunities, gender equality, good health, education, and public participation. Examples of relevant SDGs: **Goal 3 (Good Health and Well-Being)**, **4 (Quality Education)**, **5 (Gender Equality)**, **7 (Affordable and Clean Energy)**, **16 (Peace, Justice and Strong Institutions)**, **17 (Partnerships for the Goals)**.
  - **Economic Sustainability**: Equitable resource distribution, basic needs met, benefits without irreversible environmental loss. Examples of relevant SDGs: **Goal 1 (No Poverty)**, **2 (Zero Hunger)**, **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)**.

- The intersection of these three pillars creates a **bearable, equitable, and viable globe**, leading to sustainable development.

Lesson 2: Ecosystem: Concept, Structure, Pyramids and Succession

- **Concept of Ecosystem**
    - The **basic structural and functional unit of the environment**.
    - Involves the **constant interaction and exchange of materials and energy** between living (biotic) and non-living (abiotic) components to form a stable living community.
    - The study includes the structure, regulation, and role of each component.
    - The central theme of the ecosystem is **"energy flow"**.
    - Examples include terrestrial and aquatic ecosystems.
- **Structure of Ecosystem**
    - **Biotic Components**: Categorised by food-fed relationships.

- **Producers (Autotrophs)**: Organisms that can make their own food using carbon dioxide and water with sunlight and chlorophyll (e.g., green plants, algae, cyanobacteria).
- **Consumers (Heterotrophs)**: Organisms that depend on producers for energy.
    - **Primary Consumers (Herbivores)**: Eat autotrophs directly (e.g., grasshoppers, rabbits, goats).
    - **Secondary Consumers**: Eat herbivores (e.g., frogs, jackals, snakes).
    - **Tertiary Consumers (Carnivores)**: Top-level carnivores that eat secondary consumers (e.g., tigers, lions, vultures).
- **Decomposers (Saprophytes/Scavengers/Detritivores)**: Heterotrophic organisms that grow on dead and decaying materials, playing a crucial role in **biogeochemical cycles** (e.g., bacteria, fungi, earthworms).
- Examples of consumers in different ecosystems (Grassland, Forest, Desert, Pond/Lake, Marine) vary based on their food sources.

- **Abiotic Components**: Non-living factors (solids, liquids, gas).
  - **Climatic factors**:
    - **Light**: Essential for all living organisms. Plants use it for **chlorophyll production** and **photosynthesis**. Influences **plant distribution, physiology, temperature (and thus transpiration/water absorption), and stomatal movement**. For animals, it affects **metabolism, vision, pigmentation, reproduction, and circadian rhythm**.
    - **Temperature**: Affects physiological activity and growth of plants (e.g., desert vs. forest plants, summer vs. winter plants) and influences **thermal stratification** in aquatic ecosystems. For animals, it categorises them into **warm-blooded (endothermic)** and **cold-blooded (ectothermic)**, and influences **migration**.
    - **Water**: Indispensable for life, its amount determines the type of ecosystem. Essential for **photosynthesis, mineral circulation, and metabolic activity** in plants and animals.

Regulates body temperature and influences humidity/moisture.

- **Edaphic factors**:
  - **Soil**: A natural resource providing a platform for life. Its **fertility, quantity, and pH** (acidic, alkaline, neutral) determine vegetation and animal types. Contains **macro and micronutrients** vital for ecosystem sustenance. Soil **texture** (rocky, swampy) also dictates biotic factors.

- **Ecological Pyramids**
  - Graphical representation of relationships between organisms at various **trophic levels** in a food chain.
  - First designed by **Charles Elton**, hence called **Eltonian Pyramid or Food Pyramid**.
  - **Types**:
    - **Pyramid of Number**: Counts organisms at each trophic level. Producers are typically higher in number than consumers. Number of individuals decreases from bottom to top. Usually **upright** (e.g., Grassland, Aquatic), but can be **inverted** or **spindle-shaped** (e.g., Forest). The collective living organisms at each trophic level are called **standing crops**.

        - **Pyramid of Biomass**: Represents the total dry weight of organisms at each trophic level. Can be **upright** (Forest, Grassland) or **inverted** (Pond ecosystem).
        - **Pyramid of Energy**: Most important type. Shows the amount of energy transferred from lower to upper trophic levels, which **decreases at each step**. Follows the **10% rule**: only **10% of energy is transferred** to the subsequent upper trophic level. **Always upright** and cannot be inverted or spindle-shaped, irrespective of size, biomass, or number of organisms.
    - **Limitations of Ecological Pyramids**: Position of organisms may vary, no consideration for seasonal changes, role of detritivores not represented.

- **Ecological Succession**
    - Term coined by **Ragnar Hult (1885)**.
    - Defined by Clement as the **natural process where a locality is successively colonised by different groups or communities of plants**.
    - **Characteristics**: Orderly change in species/community, physical structure altered by biological factors, establishment of a stable ecosystem (climax community) maintaining equilibrium.
    - **Causes**:

        - **Initial Causes**: Destruction of existing habitat (e.g., soil erosion, floods, fire, deforestation, overgrazing, Jhum cultivation).
        - **Continuous Causes**: Changes in population composition due to migration (for safety, urbanisation, industrialisation, better life).
        - **Stabilizing Causes**: Climatic conditions, mineral availability, land fertility, continuous flow of food/energy.
    - **Order of basic processes**: Nudation → invasion → completion and coaction → reaction → stabilization.
    - **Types**:
        - **Primary Succession**: Begins on primitive substratum with no prior living factors (e.g., volcanic eruptions, rocky areas).
        - **Secondary Succession**: Begins where living matter previously existed but was damaged (e.g., by flood, fire, acid rain).
        - **Autogenic Succession**: Driven by biotic components, where the developing plant community changes conditions, creating an environment for a different community.

- **Allogenic Succession**: Caused by abiotic factors like volcanic eruptions, climate change, earthquakes, floods, drought.
- **Induced Succession**: Man-made process for human benefit (e.g., crop cultivation).
- **Autotrophic Succession**: Develops in inorganic-rich, organic-poor areas, dominated by plants.
- **Heterotrophic Succession**: Begins in organic-rich areas (e.g., forest litter, sewage), dominated by saprophytes (fungi, mushrooms).
- **Retrogressive Succession**: Succession goes backward due to heavy biological/biotic interferences (e.g., forest to shrubland/grassland/barren land due to deforestation/overgrazing).

Lesson 3: Ecosystem: Biogeochemical Cycles, Functions, Energy Flow and Productivity

- **Ecosystem Functions**
  - Includes interlinking of organisms, nutritional requirements, nutrient circulation, energy flow, and decomposition.
  - Explained under: Biogeochemical Cycle, Food chain and Food Web, Energy flow in the Ecosystem, and Productivity.

- **Biogeochemical Cycles (Nutrient Cycling)**
  - Involves the cycling of both biological and physical components underground and above ground.
  - Essential for forming and decomposing inorganic and organic compounds.
  - Also known as **nutrient cycles**; approximately forty elements are required by living organisms.
  - **Categories**: Atmospheric Nutrient Cycle and Edaphic Nutrients Cycle.
  - **Atmospheric Nutrient Cycle**:
    - **Water Cycle**: Driven by **solar radiation (15% of total reaching Earth)**. Plants absorb water from underground, use it for photosynthesis, and release some via transpiration. Water evaporates from water bodies and returns as rain.
    - **Carbon Cycle**: Carbon Dioxide is essential for **photosynthesis**, locking carbon into organic matter. Released by **respiration** of organisms. Earth's crust also releases carbon from mineralisation of marine organisms' skeletons. Burning fossil fuels, coal, and wood release CO2. Consumers obtain carbon via food, which returns to Earth's crust upon death and decay.

        - **Oxygen Cycle**: Simplest but vital cycle. Dry air contains **20.94% oxygen**. Required by all living organisms for respiration and associated with moisture content.
    - **Edaphic Nutrient Cycle**:
        - **Nitrogen Cycle**: Complex cycle.
            - **Nitrogen enters living organisms**: Pure nitrogen gas cannot be used by plants; only **Nitrate & Ammonium forms** are utilised.
            - **Nitrification**: Production of nitrates from nitrogen.
                - Non-Biological (Physical) fixation: Nitrogen combines with oxygen during lightning.
                - Artificial: Chemical fertilisers produced in industries.
                - Biological Nitrogen Fixation: Carried out by nitrogen-fixing organisms (blue-green algae, bacteria, fungi).
                    - Non-Symbiotic: Free-living in soil/water (e.g., Azotobacter, Anabaena, Nostoc).
                    - Symbiotic: Microorganisms living in root nodules of plants (primarily

legumes) form nodules to fix atmospheric nitrogen (e.g., Rhizobium). Converts nitrogen gas to ammonia, then amino acids (building blocks of DNA/RNA). Legumes are good biofertilisers.

    - **Ammonification**: Production of ammonia/ammonium compounds from decomposition of organic matter by bacteria (e.g., Nitrosomonas, Nitrosococcus).
    - **Nitrification**: Ammonium converted to nitrates; nitrates absorbed by plants, stored in humus, immobilised by bacteria, or reach water bodies.
    - **Nitrogen Gas back to the atmosphere (Denitrification)**: Denitrifying bacteria (e.g., Pseudomonas) convert nitrates to nitrites and then to gaseous nitrogen.
- **Sulphur Cycle**: Sedimentary cycle with reserve pool underground in rocks, minerals, and sulphates in sea sediments. Found as Hydrogen sulphide (H2S), Sulphur dioxide (SO2), and Sulphates (SO4). Enters living systems as soluble forms in soil, assimilated by plants for proteins/vitamins, passed to animals via food chain.

Organic sulphur decomposes to sulphate or H2S by aerobic bacteria; H2S converts to elemental sulphur by anaerobic bacteria, returning sulphur to soil. SO2 also released by burning fossil fuels (vehicular exhaustion).

- **Phosphorus Cycle**: More phosphorus in plants/animals than in abiotic systems. Abundant in rocks and natural deposits. Essential for DNA structure, coenzymes, and energy release. Plants absorb soluble phosphorus from soil; transferred to animals via food chain; returns to atmosphere via death/decay or animal excreta. Major loss of phosphorus to the sea.

- **Food Chain**
  - The **transfer of food energy** from plants through a series of organisms via repeated eating and being eaten.
  - **Process**: Plants (autotrophs/producers) make carbohydrates via photosynthesis. Heterotrophs (herbivores, carnivores) depend on autotrophs for food/energy. Forms a "Pray-Predator relationship" chain: Plants → Herbivores (Primary consumers) → Carnivores (Secondary/Tertiary consumers).
  - **Types**:
    - **Grazing Food Chain**: Starts with **living green plants** (e.g., Grass → Grasshoppers → Frogs → Snakes → Hawks).

    - **Detritus Food Chain**: Starts with **dead plants or animals**; does not depend on sunlight (e.g., dead plants/animals → scavengers → microorganisms).
  - Grazing and Detritus food chains operate independently but are parts of a single ecosystem and collectively complete the nutrient cycle. More energy is transferred in a grazing food chain.
- **Food Webs**
  - A **more complicated network of interconnected food chains** in nature.
  - When one species is absent, another replaces it to maintain the "to eat and to be eaten" system.
  - Plays a **significant role in the balance and stability of an Ecosystem**.
- **Energy Flow in an Ecosystem**
  - Aligned with the **first law of thermodynamics**: energy cannot be created or destroyed, only transferred.
  - Autotrophs fix solar energy; heterotrophs obtain energy from autotrophs. Energy is essential for all organisms' metabolism.
  - **Energy flow occurs in two models**:
    - **Single Channel Energy Flow Model**: Energy flows in a **one-way direction** as per the food chain. Longer food chains result in less energy reaching top carnivores.

        - **Y-Shaped Energy Flow Model**: Shows a **realistic, more complex picture** of energy flow, connecting grazing and detritus food chains. In a balanced ecosystem, little goes to waste as decomposers recycle nutrients, and decomposers can also be eaten by top predators (e.g., earthworms by hawks).
- **Productivity**
    - **Definition**: The **amount of organic matter (food) prepared by a plant**, or the rate of this production over time.
    - **Types**:
        - **Primary Productivity**: Associated with **autotrophs (green plants, photosynthetic microorganisms)**.
            - **Gross Primary Productivity (GPP)**: The **total rate of photosynthesis or food production**. Calculated as amount of CO_2 fixed per gram of chlorophyll per hour.
            - **Net Primary Productivity (NPP)**: The **remaining energy after respiration utilization**. **NPP = GPP – Respiration energy**.
        - **Secondary Productivity**: Energy stored at the **consumer level (heterotrophs)**. Ecologist Odum (1971) prefers "assimilation". It moves from one consumer level to another.

        - **Net Productivity**: The **storage of energy by consumers**, remaining after utilisation for respiration or other work. Can be measured as biomass.

- **Homeostasis**
    - **Definition**: The **"ability to maintain a constant internal environment in response to environment changes"**.
    - Natural ecosystems are capable of **self-regulation or self-maintenance**.
    - Odum (1971) defined it as the **tendency of a natural ecosystem to resist change and remain in equilibrium**, implying a balance between production, consumption, and decomposition.

Lesson 4: Ecosystem: Types and Services

- **Introduction**
    - Ecosystems vary greatly in size, from small water bodies to oceans, and from patches of woods to vast forests.
    - They can be **natural** or **anthropogenic** (human-created, like farmlands).
    - Broadly classified into **terrestrial and aquatic ecosystems**.
    - Ecosystems provide essential **products and services** that sustain mankind.

  - Exploitation of resources by the growing human population leads to ecosystem degradation, making preservation, conservation, and restoration vital.
- **Types of Ecosystems**
  - **Terrestrial Ecosystems**: Diversity influenced by climate and plant life forms (trees, shrubs, grasses).
    - **Forest Ecosystem**:
      - Consists of communities of plants, animals, microorganisms, and their non-living environment, collectively exchanging material and energy. Trees, shrubs, climbers, and ground cover are main components.
      - Pristine forests primarily exist in protected areas due to human expansion. Appearance and species vary with abiotic factors like temperature, rainfall, topography, and soil.
      - **Forest Types in India**: Broadly coniferous and broadleaved.
        - **Coniferous Forests**: Found in high-altitude Himalayas, snow-covered for months, temperatures below zero. Trees are tall with downward-sloping branches and needle-like leaves (e.g., Pine, Deodar). Animals include

wild goats, sheep, Himalayan black bears, snow leopards, hangul, and Himalayan brown bears.

- **Broadleaf Forests**: Further classified.
    - **Evergreen Forests**: Found in Western Ghats, North Eastern India, Andaman and Nicobar Islands, receiving high rainfall. Trees shed leaves year-round, appearing green. Dense canopy, high species richness (orchids, ferns), high diversity of mammals, reptiles, insects (e.g., tiger, leopard, Malabar pied hornbill, pygmy hog, lion-tailed macaque).
    - **Deciduous Forests**: Found in central highlands and Deccan peninsula with moderate rainfall. Trees shed leaves in a specific season and regain them at monsoon onset. Thick undergrowth due to light penetration (e.g., Teak, Sal, Ain). Animals include tigers, cheetal, barking deer, flycatchers, hornbills.

    - **Thorn and Scrub Forests**: Found in semi-arid and arid regions (low rainfall), sparse trees, surrounded by grasslands. Xerophytic plants with adaptations like small leaves, wax coating, deep roots (e.g., Babool, Khejdi, Ber). Fauna includes Blackbuck, chinkara, sambar, monitor lizards.
    - **Mangrove Forests**: Trees and shrubs in coastal-intertidal zones in tropics/subtropics. Grow in low-oxygen soil, with dense prop roots to withstand tides and accumulate sediment. Example: Sundarban in West Bengal. Stabilize coastlines and prevent erosion, ideal habitats for fish and other organisms.
- **Products & Services**: Direct consumption (fruits, medicine, fuel wood), raw materials (furniture, construction, medicines, industrial products), ecosystem services (air purification, climate regulation, soil erosion prevention).

    - **Threats**: Deforestation, forest fragmentation (urbanization, industrialization, intensive agriculture), overconsumption, invasive species.
    - **Conservation**: Afforestation, sustainable resource use, protected area networks.
- **Tundra Ecosystem**:
    - **Arctic tundra**: Extreme northern latitudes, snow melts seasonally.
    - **Alpine tundra**: Higher elevations of mountains, above tree line.
    - Characterised by long/severe winters, short summers, poor precipitation.
    - **Low species richness and primary productivity**.
    - Dominant vegetation: mosses, lichens, grasses, sedges; dwarf trees.
    - Animals: lemmings, voles, weasels, arctic foxes, snowy owls.
    - **Threats**: Oil/natural gas exploration, military use, **climate change (permafrost melt, replacement by coniferous trees)**.
- **Grasslands**:

- Landscapes dominated by grasses and small annual plants, in various climatic conditions.
- Known by different names globally: Prairies (U.S. Midwest), Pampas (South America), Steppes (central Eurasia), Savannas (Africa).
- Found where rainfall is insufficient for forests but too much for deserts.
- **Types**:
  - **Tropical Grasslands**: Warm year-round, dry and rainy seasons (e.g., Savanna in Africa). Animals: giraffes, zebra, rhinos, lions, hyenas, elephants.
  - **Temperate Grasslands**: Less rainfall than tropical, short grasses, growing and dormant seasons. Seasonal appearance due to flowering.
- **Examples in India**: Himalayan pasture belt, Terai (tall grasses interspersed with Sal forest), areas along thorn forests in western/central India and Deccan, Shola grasslands (Western Ghats, Nilgiris, Annamalai).
- **Human Use**: Pasturelands for cattle, source of fuelwood, habitats for pollinators.

        - **Degradation**: Overuse, overgrazing (due to increased demand for dairy, wool, meat), expansion of agricultural land.
    - **Desert Ecosystem**:
        - Receives **less than 12 cm of rainfall annually**.
        - **Examples in India**: Thar Desert (Rajasthan), Cold desert in Ladakh (high plateau of Himalayas), Great and Little Rann of Kutch (Gujarat – salt marshes during monsoon).
        - Vegetation: Sparse grasses, shrubs (e.g., Babool, Khair). Plants have xerophytic adaptations.
        - Fauna: Highly specialized insects, reptiles, desert cats, desert foxes, Indian wolves, Great Indian Bustard, Florican. Little Rann of Kutch is the only place for wild ass in India.
- **Aquatic Ecosystems**: Classified by salinity levels.
    - **Freshwater Ecosystems**:
        - **Lentic Ecosystems**: Stagnant water bodies (e.g., ponds, lakes).
            - **Pond Ecosystem**: Smallest and simplest. Many are seasonal, drying up and regrowing with monsoon. Organisms: algae, zooplankton, insects, snails, worms,

amphibians, crabs, fishes, floating weeds. Importance for water/biodiversity conservation. Threatened by industrial and agricultural pollution.

    - **Lake Ecosystem**: Larger, permanent ponds. Organisms: algae, microscopic animals, herbivorous/carnivorous fishes, bottom feeders (e.g., catfish). Similar importance and threats as ponds.

- **Lotic Ecosystems**: Running water ecosystems (e.g., streams, rivers).
    - **Streams and Rivers**: Streams are smaller than rivers. Open systems, exchanging nutrients/energy with larger areas. Current is a key ecological factor.
    - **Zones**: **Rapid zone** (fast current, firm/hard bottom, silt-free) and **Pool zone** (slow current, deep water, soft bottom due to sand/silt deposition). Different organisms adapted to each.
    - Rivers originate from glaciers, carry sediments, make soil fertile, and end in oceans. Provide water for drinking,

domestic, industrial, agriculture, and power generation.

        - **Threats**: Pollution from sewage/industrial/agricultural drains, destruction of floodplains and catchment areas.

- **Brackish Water Ecosystems**:
    - **Estuaries**: Where rivers meet oceans, intermediate salinity levels. Complex ecosystems of high productivity, with salt marshes and mud flats. Have both plankton and detritus-based food webs. Most fisheries depend on them.
- **Salt Water (Marine) Ecosystems**:
    - **Oceans**: Cover 70% of Earth's surface. Examples in India: Indian Ocean, Bay of Bengal, Arabian Sea. Extremely deep, with organisms at all depths. Salinity much higher than freshwater (3.5%). Water moves horizontally (waves from winds) and vertically (tides from gravitational forces).
    - **Communities**:
        - **Littoral Communities**: Coastal belts affected by waves/tides (e.g., oysters, branches, limpet, kelp).

- **Coral Reef Communities**: Formed by symbiotic relationship between coelenterate animals (forming calcium carbonate coral structures) and endozoic algae (dinoflagellates, providing food). Found in warm tropical/subtropical waters, huge species diversity/richness (sponges, molluscs, crabs, snails). In India: Gulf of Kutch, Andaman and Nicobar, Lakshadweep, Gulf of Mannar. World's largest is Great Barrier Reef (Australia).
- **Continental Shelf (Neritic) Benthos Communities**: Below littoral zone on bottom, light penetrates, diverse algal communities, fish, crustaceans.
- **Marine Surface Pelagic Communities**: Plankton and large swimming animals in open waters. Phytoplankton (dinoflagellates, diatoms) in surface due to light; Zooplankton (copepods), shrimp, arrow worms, comb jellies, tunicates.
- **Marine Deep Pelagic Communities**: Below lighted surface waters, heterotrophic, food

        from settling plankton and dead organic matter.
      - **Deep Open Benthos Communities**: Between continental shelf and deep oceans; light doesn't reach, only heterotrophic organisms and some bacteria.
    - **Importance**: Source of marine food, travel, goods transportation.
    - **Threats**: Water pollution (sewage, industrial), waste dumping, degradation of coral reefs due to climate change.

- **Ecosystem Services**
  - **Definition**: Direct and indirect benefits humans receive from nature, essential for basic Earth functioning and supporting life.
  - **Four main types**:
    - **Provisioning Services**: Materials and products from nature. Includes fruits, vegetables, crops, honey, fish, livestock, freshwater, fuelwood, timber, fibre, medicines, oil, natural gas, plant material for clothes, and genetic resources.
    - **Regulating Services**: Benefits from the maintenance of basic ecosystem functioning. Includes **purification of**

air and water, climate regulation, flood control, carbon storage, prevention of soil erosion, natural hazard regulation, pollination, pest control, and decomposition of waste by microbes. These processes ensure the ecosystem is functional, sustainable, and resilient.

- **Cultural Services**: Non-material benefits contributing to human progress and cultural advancement. Includes spiritual enrichment, intellectual development, recreation, aesthetic values, and creativity (art, music, architecture) from interacting with nature.
- **Supporting Services**: Processes essential for the sustenance of ecosystems and life. Includes **biogeochemical cycles, photosynthesis, creation of soils, and the water cycle**. These services underpin provisioning, regulating, and cultural services.

- **Ecosystem Preservation and Conservation**
  - **Ecological Restoration**: Process of **assisting the recovery of a partially or completely degraded ecosystem** to a former or perfect condition. Focuses on ecosystem health (air purification, carbon sequestration, water filtration), integrity (species composition, community structure), and sustainability (resistance/resilience to disturbance).

- **Rehabilitation**: **Returning degraded land to a fully functional ecosystem**, irrespective of its original state, but according to a prior land use plan. Examples: partial recovery of species diversity, reducing livestock grazing, natural vegetation growth.
- **Remediation**: Cleaning chemical contaminants from polluted ecosystems using physical and biological methods to protect human and ecosystem health.
- **Reclamation**: Restoring the biotic function and productivity of severely damaged land.
- **Mitigation**: Restoration, rehabilitation, or reclamation processes to reduce the effect of the source of degradation.

Lesson 5: Natural Resources: Land Resources

- **Introduction to Land Resources**
  - Land is a highly valuable resource, a mixture of inorganic and organic materials, sustaining life and providing resources.
  - Provides food, fibre, medicine, minerals, and services like agricultural productivity, biological diversity, and carbon sequestration.

  - Under threat due to **misuse and mismanagement** by humans, leading to degradation and pollution.
  - **Desertification** is an extreme case of land degradation in semi-dry regions, turning them barren.
- **Land Resources**
  - Includes aspects and functions of land that fulfill human needs (agriculture, mining, grazing, settlement).
  - **Categories**:
    - **Very stable resources**: Relief, geological formations, minerals.
    - **Moderately stable resources**: Soil, water.
    - **Very unstable resources**: Vegetation, biodiversity.
  - **Important Resources and Services from Land**:
    - **Minerals**: Pure inorganic substances found naturally in Earth's crust. **Non-renewable resources**. Include metallic (iron, copper, aluminium, lead, zinc), non-metallic (graphite, gypsum, clay, sand), and mineral fuels (coal, natural gas, petroleum). Crucial raw material for industries and national development. India is rich in certain minerals.
    - **Soil**: Outermost thin layer of Earth's crust, natural medium for plant growth, providing anchorage and nutrients. Complex mixture of organic and mineral

content, constantly formed by rock decomposition. A **renewable resource**. Topmost layer rich in organic matter is **humus**, the most fertile. Essential for human environment, supporting productivity, cycling biological resources, and acting as a buffer. Rich in microbial biodiversity and a major carbon reservoir. Major soil groups in India: alluvial, black, red, laterite, desert, and acid soil.

- **Agriculture**: Most dominant human use of land. Agricultural ecosystems cover nearly **40% of the land surface**. Total cultivable land: 4.4 billion ha, 1.6 billion ha currently cultivated. Dominant driving force for many developing economies, including India. Increased productivity due to fertilizers/pesticides has also **adversely impacted land**.
- **Natural Forest Products**: Materials derived from forests. Include timber, firewood, wood pulp, forage. Also **Non-Timber Forest Products (NTFPs)** like nuts, resins, medicinal plants, edible fruits, oils, bamboo, rattans. NTFPs have relatively less negative effects. Used globally for cooking, feeding animals, medicines, income generation, and cultural traditions. Significant source of revenue.

    - **Medicinal Plants**: Valuable natural resources, mainly from forests, used since prehistoric times. Tropical forests are immense sources of new pharmaceutical products. About 80% of developing countries depend on traditional medicinal plants for healthcare. Demand is rising.
    - **Forest-based Industries and Livelihood**: Significant role in economy and livelihood for millions. Source of raw materials for industries. Fuelwood/charcoal as main energy source for 2 billion people globally. Income from collecting/selling forest products, timber sales, furniture/handicraft making, industrial logging. Indirect contributions: soil nutrients, forage, crop pollination, erosion reduction, disaster protection. Estimated 1.5-2 billion people depend on forests for livelihoods; 200 million indigenous people almost fully dependent.
- **Land Cover and Land Use Change**
  - **Land Cover**: The **observed biophysical cover on Earth's surface** (vegetation, water, bare soil, urban infrastructure). Determined by field survey or satellite/aerial images. IGBP categorises into 17 classes. Global land area is **13.2 billion ha**. Distribution: 12% cultivated, 28% forest, 35% grassland/woodland.

  - **Land Use**: The **purpose the land serves** (e.g., recreation, wildlife habitat, agriculture). Distinct from land cover (e.g., grassland is cover, agricultural land is use).
  - **Land Use Change**: Conversion of terrestrial land surface for **anthropogenic uses**. Drastically altered land cover since human civilization. Increased demand for water, waste disposal, food, leading to unsustainable land use and degradation.
  - **Key drivers**: Forest cover/composition changes, cropland expansion, agriculture intensification, urban development, desertification.
  - **Major environmental impacts**: Climate Change, global warming, biodiversity loss, various pollutions, large-scale deforestation, land degradation, desertification, waste aggregation. These impact human health, well-being, and livelihoods.
- **Land Degradation**
  - **Definition**: **Deterioration of the productive capacity of land due to overexploitation by humans**.
  - Affects soil chemistry, soil biodiversity, and alters natural ecological processes.
  - Reduces supply of goods (food, timber, fuel).

  - **Major causes**: Deforestation, soil erosion, unpredictable weather, droughts/floods, modern agricultural practices, soil pollution, increasing urbanization.
  - A major challenge requiring urgent attention for ecosystem restoration, biodiversity, economic growth, and social structure.
- **Soil Erosion**
  - **Definition**: **Loss or removal of the top layer of soil** due to natural physical agents like wind, water, and gravity.
  - Topsoil is most fertile, so erosion reduces productivity and ability to support vegetation.
  - Soil formation is slow (1 cm in 200-300 years), so natural restoration takes long. Intense erosion destroys natural soil profile permanently.
  - **Causes**: Extensive cultivation, overgrazing, and deforestation expose topsoil to erosion.
    - **Natural/Anthropogenic reasons**:
      - **Slope of the Surface**: More common on hill slopes, worsened by vegetation removal.
      - **Soil Content**: Sandier soil more prone to erosion than clay-rich soil.

        - **Weather and climatic conditions**: High-intensity rainfall, floods, droughts (increasing with climate change).
        - **Deforestation**: Reduces tree roots that hold soil together.
        - **Extensive agriculture/Cultivation**: Chemical-intensive farming lowers soil organic matter, biodiversity, and water content, increasing erosion. Excessive irrigation.
        - **Overgrazing**: Exploitation of vegetation for cattle, exposing soil.
    - **Remedial measures (Soil Conservation)**:
        - **Erosion control technologies in farming**: No-tillage, low tillage, crop rotation, use of mulch cover.
        - **Adoption of terrace farming, contour farming**, and structures like windbreaks, live fences, sand fences.
        - **Reforestation**: Crucial as trees are natural soil binding agents.
- **Desertification**
    - **Definition**: An **extreme case of land degradation** where semi-dry regions become increasingly arid, leading to loss of water bodies, vegetation, and wildlife.

- Caused by both **anthropogenic activities** and **climate change**.
- A significant global ecological and environmental problem.
- **UNESCO** states that **one-third of Earth's drylands are threatened** by desertification.
- Impacts livelihoods of millions dependent on these drylands.
- Major problem: **Migration of people** to resource-rich cities, causing economic loss of cultivated land and burden on urban resources/pollution.
- **Process**: Land slowly degrades from deforestation, overgrazing, modern agriculture, urbanization, water mismanagement, groundwater exploitation, and wetland destruction; exacerbated by drought and erratic rainfall.
- **Consequences**: Loss of farmlands, increased hunger/poverty, social inequality, crowding/overpopulation in cities.
- **Prevention**: Integrated approach with multiple stakeholders, policies for better land/water management, awareness campaigns (especially farmers), support for local communities, promotion of sustainable agriculture.

- **Deforestation**
  - **Definition**: **Clearing or permanent removal of forest areas** for other uses.

- Root cause of land degradation, soil erosion, and desertification.
- Annual rate estimated at **1.3 million square km per decade** by FAO.
- Extensive in tropical regions.
- Leads to loss of trees (major carbon sink) and release of billions of tons of carbon from dead/decomposing trees, significantly impacting global warming and climate change.
- **Causes**:
  - **Agriculture and Plantations**: Most significant threat; conversion for human food needs. Direct cause of 80% of deforestation in tropical/subtropical regions. Industrial agriculture increased deforestation rates, impacted ecosystems, and caused biodiversity loss.
  - **Urbanization**: Result of increasing population, capitalism, globalization. Forests cleared for residential, industrial, commercial, and infrastructure projects (roads, railways). Leads to habitat degradation, loss, and fragmentation.
  - **Harvesting Wood for Use as Firewood and Timber**: Millions rely on fuelwood; increasing demand for timber from urbanization.

        - **Illegal Logging**: Common globally, for decorative and medicinal purposes, with huge markets in US/Europe.
        - **Forest Fires**: Millions of hectares destroyed annually, naturally (lightning, high temp, drought) or human-induced (unauthorized burning for farmland). Example: Australian bushfires released large amounts of greenhouse gases.
        - **Mining**: Major economic activity due to demand for metallic resources. Large-scale **open-pit mining** causes significant deforestation. Mining projects also require new roads, settlements, townships, clearing more forest. Causes large-scale deforestation, especially in tropical countries.

- **Impacts of Mining and Dam Building**
    - Both are essential drivers for economic growth but have devastating environmental and social impacts.
    - **Deforestation or Loss of vegetation**: Large-scale clearing for open-pit mining; huge tracts of forests submerged by large dams.
    - **Pollution**:
        - **Mining**: Air pollution (harmful gases from machinery, toxic gases from mines), water pollution (mine waste rock, tailings mixing with surface/underground water).

    - **Dams**: Air pollution during construction; source of **methane gas emissions (greenhouse gas)** from dead/decaying vegetation in reservoirs.
- **Land Degradation and Water Loss**:
    - **Mining**: Depletion of surface/groundwater due to extensive use in processing; groundwater withdrawal impacts distant streams/rivers. Open mines can lead to groundwater loss by evaporation, making areas barren and susceptible to desertification.
    - **Dams**: Siltation (increased sediment deposition in reservoirs, reducing water storage capacity), causes abrasion of turbines, reducing electricity generation.
- **Impact of Ecosystem and Biodiversity Loss**: Both cause deforestation, leading to habitat loss/fragmentation, affecting biodiversity. Dams submerge terrestrial ecosystems and impact aquatic ecosystems by obstructing/reducing water flow. Mines impact terrestrial and nearby aquatic ecosystems due to pollution.
- **Displacement of Local and Indigenous Communities**: Biggest social problem. Vulnerable communities often face injustice, not rehabilitated or compensated appropriately. Emotional upheavals, loss of traditional livelihoods, struggle to find similar conditions.

- **Health Problems and Social Issues**:
  - **Mining**: Mine workers exposed to toxic metals, wastes, poisonous gases, leading to health issues and fatal accidents.
  - **General**: Pollution from mines/dams affects nearby communities. Opens remote areas to developers, accelerating deforestation. Migration from other regions due to projects can increase social instability (unemployment, crime, resource shortage).

- **Steps for Sustainable Management of Land Resources**
  - **Afforestation**: Planting trees is a key way to overcome land degradation, soil erosion, and desertification. Improves air quality, mitigates global warming, creates habitats, provides products, dilutes natural disasters, and supports local communities.
  - **Forest Management**: Wise and sustainable management of existing forests. Governments need to enact and implement protective rules/policies and increase forest cover. Citizens and government must protect forests from illegal logging, invasive species, diseases, and overutilization. **Joint Forest Management** and **Social forestry** are successful models in India. Emphasize technology for threats.

- **Farming Methods**: Devise new methods to reduce pesticides, fertilizers, and excessive irrigation. Examples: **mixed farming, organic farming, Rice fish farming, developing nano-fertilizers, improving irrigation technology** (water conservation), use of mulch and manure, using a wide variety of seeds. These conserve soil fertility and improve agricultural output.
- **Water Management**: Water is vital for soil formation, fertility, and preventing erosion. Surface and groundwater must be regularly monitored; overutilization of groundwater must be addressed by coordinated efforts. Better irrigation technology, judicious crop management, understanding soil characteristics, and reducing surface water pollution are important.
- **Waste Management**: Develop effective solid waste management technologies and practices to reduce waste dumping and prevent non-biodegradable/toxic compounds from mixing into soil.

Lesson 6: Natural Resources: Water Resources

- **Introduction to Water Resources**

  - Earth is called the "blue planet" as water covers three-fourths of its surface.
  - Water is essential for life forms (60-70% of body weight) and ecosystem health.
  - Most Earth's water is **saline (97.5%)** and unsuitable for consumption, agriculture, or industries.
  - Only a small fraction of freshwater is accessible; most is frozen (glaciers, icecaps, 1.97%) or deep groundwater (0.5%).
  - Accessible freshwater is unevenly distributed, leading to water-related problems like interregional conflicts, competition between uses, health issues, and economic constraints.
  - Global freshwater use is increasing due to population expansion, human activities, and climate change. Per capita water availability has significantly dropped in India (e.g., 1816 m^3/year in 2001 to 1486 m^3/year in 2018).
- **Hydrological Cycle and Distribution of Water**
  - Water exists as solid (ice/snow), liquid (marine/freshwater), and vapour (water vapour/steam).
  - **Hydrologic cycle**: Continuous circulation of water from ocean to atmosphere to land and back to ocean. This process continually **renews the supply of freshwater on land**.

- **Distribution**:
  - **97.5% in oceans** (saline).
  - **1.97% frozen** (polar/glacial ice).
  - **0.5% groundwater**.
  - **0.03% in lakes, creeks, streams, rivers, and atmosphere**.
- **Groundwater**:
  - Water collected and stored in underground establishments.
  - Flows slowly through permeable sediments/rocks and discharges into rivers, wetlands, springs, or the ocean.
  - **Aquifers**: Underground reservoirs that hold groundwater.
    - **Unconfined aquifers**: Recharge area is directly above (permeable layers allow surface water to seep down). Upper boundary is the **water table**. Water table depth varies (e.g., far in deserts, intersects surface in wetlands/lakes/streams).
    - **Confined aquifers (Artesian aquifer)**: Groundwater storage between impermeable rock layers, often under positive pressure. Recharge area may be hundreds of kilometres away.

- Groundwater resources are generally considered **non-renewable** because they take hundreds to thousands of years to accumulate, with only a minor portion replaced annually. Confined aquifers recharge particularly slowly.

- **Water Resources of India**
    - India accounts for about **2.45% of the world's surface area** and **4% of the world's water resources**, but about **17.7% of the world's population**.
    - Water availability is decreasing due to increasing population.
    - **Sources of water in India**: Surface water (rivers, lakes, ponds), groundwater (wells, springs), and wetlands.
    - **Surface Water Resources**:
        - **12 major rivers**: Ganga, Yamuna, Indus, Brahmaputra, Cauvery, Godavari, Krishna, Mahanadi, Mahi, Narmada, Pennar, Tapi.
        - Mean annual flow: 1,869 cubic km. Only about **35% can be exploited** due to geographical/environmental constraints.
        - Precipitation in India has **high spatial variation** and is concentrated in the monsoon season.

    - Ganga, Brahmaputra, Indus have huge catchment areas. South Indian rivers are highly harnessed; Brahmaputra and Ganga basins are yet to be fully harnessed.
    - Other sources: Canals, ponds, lakes, tanks, wetlands (about 50% retained).
    - **Definitions**:
        - **Wetland**: Land covered with water for at least part of the year.
        - **Runoff**: Renewable, finite resource of precipitated water replenishing surface water.
        - **Drainage Basin**: Land area drained by a single river/stream.
        - **Watershed**: Land area draining snowmelt and rainfall into streams/rivers, varying in size.
        - **Groundwater**: Precipitation percolating into soil, accumulating above an impenetrable layer.
- **Groundwater Resources**:
    - India has about **432 cubic km of total annual replenishable groundwater**.
    - Ganga and Brahmaputra basins hold about 45% of total replenishable resources.
    - High utilisation in northwestern regions (Punjab, Haryana, Rajasthan, Tamil Nadu) and parts of South

India. Moderate utilisation in Bihar, Gujarat, Uttar Pradesh, Maharashtra, Tripura.
    - Utilisation has increased over time due to population growth, posing future water supply challenges.
  - **Lagoons and Backwaters**:
    - India has a vast coastline with many lagoons and estuaries.
    - **Lagoon**: Water body separated from larger bodies (e.g., river) by a natural barrier. Found in Kerala, Orissa, West Bengal. Water is usually **brackish**, used for fishing and irrigating specific crops (paddy, coconut).
    - **Backwater**: A water body or branch of a main river alongside it, backed up by an obstruction.
- **Water Demand and Utilization**
  - India is traditionally an agricultural country; agriculture provides livelihood for about two-thirds of the population.
  - Water demand increases dramatically with season and time due to population growth and lifestyle changes.
  - Conversion of agricultural land reduces open areas for groundwater recharging.
  - **More than 90% of India’s water demand is for agriculture**.

- **Multipurpose river valley projects** (e.g., Damodar, Bhakra-Nangal, Kosi, Hirakud, Nagarjuna Sagar, Narmada Valley, Indira Gandhi Canal) undertaken to meet agricultural needs.
- Agricultural sector has highest water utilisation.
- Water quantity and quality are global concerns. Asia has the **lowest availability of freshwater (3,000 m^3/person/year)**, leading to water stress from rapid population growth and poor management.

- **Emerging Water Resource Problems**
  - **Deterioration of Water Quality**:
    - Water quality refers to standard biological, chemical, and physical characteristics.
    - Mixing of foreign particles (microorganisms, agricultural, chemical, industrial, domestic wastes) pollutes water, making it unsuitable.
    - Pollutants dissolve or suspend in water, disturbing aquatic systems. Some seep into groundwater.
    - **Ganga and Yamuna are highly polluted rivers** in India.
  - **Enhanced Demand for Water for Irrigation**:
    - Needed due to spatial/temporal rainfall variability in India.

    - Large tracts (Deccan plateau, North-western India) are drought-prone.
    - Dry seasons necessitate irrigation.
    - Required for high-water-demand crops (sugarcane, rice, jute) and high-yielding crop varieties.
    - Increased agricultural productivity on irrigated land.
    - Major share of irrigation from **groundwater exploitation (tube wells, wells)**, leading to **depletion**.
  - **Increasing Water Conflicts**:
    - Water's indispensable nature and uneven distribution lead to inter-regional, international, inter-state, or inter-district disputes.
    - Examples: **Cauvery water dispute** (Karnataka vs. Tamil Nadu, Puducherry), **Krishna river water dispute** (Karnataka, Maharashtra, Andhra Pradesh), **Vamsadhara river water dispute** (Orissa vs. Andhra Pradesh).
    - **International disputes**: Indus water treaty (India vs. Pakistan), Middle East water conflict (Ethiopia, Sudan, Egypt, Jordan, Syria over Jordan, Nile, Tigris-Euphrates basins). Need resolution with understanding and impartiality.
  - **Flood and Drought**:

    - Countries with major monsoon rainfall (India, Bangladesh) prone to both.
    - **Floods**: Caused by heavy rainfall, overflowing rivers/lakes. Anthropogenic activities (e.g., destruction of floodplains) worsen floods. Interlinking rivers proposed as solution.
    - **Drought**: Annual rainfall lower than normal and less than annual evaporation. Affects about 80 countries in semi-arid/arid regions. Anthropogenic activities (deforestation, overgrazing, mining) lead to desertification and more drought-affected areas. Solutions: social forestry, wasteland reclamation, careful mixed cropping, indigenous knowledge.

- **Sustainable Water Management**
  - Crucial for sustainable development due to declining availability and increasing demand. Desalination is costly.
  - **Prevention of Water Pollution**: Rapid deterioration of water quality. Rivers are cleaner in hilly stretches, but polluted in plains by solid/liquid wastes, fertilizers, insecticides, industrial effluents. Pollutants enriched in summer. Monitored by CPCB and SPCB. Groundwater also polluted by heavy metals, fluoride, nitrates. Adherence to **Water**

(Prevention and Control of Pollution) Act 1974 and **Environment Protection Act 1986**; awareness creation.

- **Sustainable Water Use**: Using water in a way that supports human society indefinitely without undermining the hydrological cycle. Options: Utilising **reclaimed wastewater** for industries, household drain water for gardening, recycling water. **United Nations Environment Programme (UNEP)** launched **Integrated Water Resources Management (IWRM)** to promote coordination in managing water, land, and related resources.
- **Watershed Management**: Conservation and efficient management of surface and groundwater, especially in watershed areas. Involves storage and prevention of runoff for groundwater recharge (e.g., recharge wells, tanks, check dams). Objective: Balance natural resource utilisation and societal demand. Depends on **local community participation**. Government programmes in India: Haryali, Arvary Pani Sansad (Rajasthan), Neeru-Meeru (Andhra Pradesh). Awareness generation is essential.
- **Rainwater Harvesting**: Capturing and storing rainwater, also for **groundwater recharge**. Eco-friendly and cheap technique. Benefits: increases water availability, sustains groundwater table, improves groundwater quality (dilutes

contaminants), prevents flooding/soil erosion, arrests saltwater imposition in coastal areas. Government encourages it. Traditional practice in India (Kund/Tanka, ponds, lakes).

- **Dams and Their Role in Water Conservation**: Efficient for water management and irrigation. Several river valley projects (Sardar Sarovar Dam, Nagarjun Sagar Dam, Tehri Dam).
  - **Benefits**: Generation of hydroelectricity, irrigation, flood control, industrial/municipal water supply. Canal systems can transfer water over great distances (e.g., Indira Gandhi canal).
  - **Mismanagement problems**: Unequitable water distribution downstream, crops requiring heavy irrigation, sudden water release causes floods, disturbance of ecosystem.
  - Environmentalists (e.g., Sundar Lal Bahuguna, Medha Patkar, Chandi Prasad Bhatt) have opposed projects due to social, economic, and environmental problems.
  - **Cauvery Water Dispute Case Study**: Long-standing inter-State basin dispute originating in Karnataka and flowing through Tamil Nadu and Puducherry. River water almost fully utilised by upstream state. **Cauvery Water Dispute Tribunal (CWDT)** constituted in

1990. Interim order in 1991 for water release. Supreme Court verdict in 2018 allocated more water to Karnataka. **Cauvery Water Management Authority (CWMA)** and **Cauvery Water Regulation Committee (CWRC)** created to settle the dispute.

Lesson 7: Natural Resources: Energy Resources

- **Introduction to Energy**
  - Term "Energy" coined by **Thomas Young (1737-1829)**, applied to kinetic energy.
  - **Definition**: The "**ability/capacity to do work**".
  - **Two laws of thermodynamics**:
    - **First Law**: Energy cannot be created or destroyed, but can be transferred from one form to another.
    - **Second Law**: Some energy is always dissipated into an unavailable form (heat energy); no spontaneous 100% efficient transformation.
  - Energy is required by all living organisms for biochemical reactions and operations.
  - **99.8% of Earth's energy comes from solar radiation**. Solar energy fixed by plants becomes biomass.

  - Energy consumption indicates national development; disparities exist between developed and developing nations.
- **Growing Energy Needs**
  - An index of national development.
  - Energy derived from both **conventional and non-conventional resources**.
  - Global energy needs projected to be **50% higher by 2030** (average annual growth of 1.6%).
  - **India** is a fast-growing market, expected to contribute **18% of the global energy demand increase by 2035**.
  - India plans to increase renewable and nuclear power due to limited fossil fuel reserves.
  - **Fossil fuels** dominate current and projected energy supplies (expected to cater to over 80% of primary energy demand increase). Natural gas demand is rising due to power generation. Coal is the largest energy source, especially in China and India.
  - **Reasons for increase in worldwide energy demands**:
    - **Globalization**: Transportation is a large energy consumer (over 50% of liquid fuel), increased with globalization.
    - **Industrialization, especially in emerging markets**: Large-scale energy requirement in businesses/factories.

    Industrialization and urbanization multiply energy demand.
  - **Increasing wealth, especially in emerging markets**: Economic growth increases energy demand/consumption.
  - **Rapid growth of human population**: Puts heavy stress on all energy resources.

- **Sources of Energy**
  - A source provides sufficient usable energy for a long duration.
  - **Alternate sources of energy**: Alternatives to fossil fuels.
  - **Conventional mineral-based energy resources (fossil fuels) are exhaustible**. Coal reserves may last 200 years at present rate, or 65 years if use increases by 2% annually. India imports half its petroleum needs.
- **Renewable and Non-Renewable Sources of Energy**
  - Increased energy demands and environmental concerns from traditional sources compel a shift to sustainable energy.
  - **Renewable Energy Sources / Non-Conventional Energy Sources**:
    - **Definition**: Resources that can be **renewed/regenerated/replenished** within a given lifespan.

    - Stocks/reserves are **unlimited (inexhaustible)**.
    - **Non-polluting, environmentally clean, and socially relevant**.
    - **Examples**: Solar energy, wind energy, ocean energy, geothermal energy, urban waste, agricultural waste, energy plantations.
    - **Advantages**:
        - **Available in abundant quantity and free to use**.
        - **Low or zero carbon emissions** (green and eco-friendly).
        - Develops self-reliance, minimises dependence on other countries.
        - Can cost less than local electricity supply.
        - Helps in economic stimulation and job creation.
    - **Disadvantages**:
        - **High initial investment** to set up plants.
        - **Non-availability/unreliability** (e.g., solar only on sunny days, wind not always blowing).
        - May cause **loss of biodiversity and forest** (e.g., dams for hydroelectric energy).
        - Requires large storage space for batteries (solar).
  - **Non-Renewable Energy Sources / Conventional Energy Sources**:

- **Definition**: Resources accumulated over a long time that **cannot be quickly replenished** when exhausted.
- Stocks/reserves are **limited (exhaustible)**.
- **Not eco-friendly** as they cause environmental pollution.
- **Examples**: Coal, Petroleum, Natural gas, Nuclear fuels (uranium, thorium).
- **Advantages**:
    - **Cheaper and easy to use**.
    - Release a **great amount of energy from a small amount of resource** (e.g., uranium).
    - Coal is abundant.
    - Capacity to generate huge amounts of electricity in single location.
    - High calorific value.
    - Infrastructure is entirely developed.
    - Easy transportation of liquid or gaseous fuels.
    - Electricity by simple combustion process.
    - Highly stable.
- **Disadvantages**:
    - **Limited supply, will end one day**, prices will rise.

        - Release **toxic gases and atmospheric pollutants** (e.g., sulphur dioxide causing acid rain, greenhouse gases contributing to global warming).
        - Formation takes millions of years.
        - Mining causes **destruction of land and endangers miners' lives**.

- **Renewable Energy Types**
    - **1. Solar Energy**:
        - Sun is the ultimate energy source, driven by nuclear fusion. Earth receives 1.4 KJ/sec/m².
        - **Applications**: Photovoltaic energy, solar cookers, water heating systems, passive solar heating.
        - **Disadvantages**: Only during daytime/sunny days, unreliable, varies with location/time/weather, transmission barrier, high installation cost (panels, silicon, silver), DC to AC conversion increases cost, power stations expensive and produce less output than conventional, large land requirement, large/heavy batteries for night storage needing regular replacement.
    - **2. Wind Energy**:
        - High-speed winds possess kinetic energy, mainly driven by the sun.

- Captured by **windmills** (blades rotate electric generators, flour mills, water pumps).
- **Wind farms**: Clusters of windmills feeding power to the grid.
- Prominent areas: coasts, hilly regions, mountain passes, ridges, open grasslands.
- Minimum wind speed for satisfactory working: **15 km/hr**.
- Largest wind farm in India: near Kanyakumari (380MW).
- Second fastest-growing energy source since 1990, and cheapest.
- **Advantages**: Free, efficient with modern tech, can produce hydrogen, useful in remote areas, for power generation, pumping, domestic tasks, battery charging, revenue from tourism, land beneath can be farmed, low recurring cost.
- **Disadvantages**: Unreliability of wind, minimum speed required, unpredictability means need for backup systems, large number of turbines for sufficient electricity, interference with TV/microwave reception, large land requirement, **kills birds/migrating flocks**

(loss of biodiversity), unattractive, noisy, expensive land in optimum areas.

- **3. Hydroelectric Energy (Hydropower)**:
  - Electricity generated from the energy of falling/running water. Used since ancient times for irrigation, watermills, etc..
  - Most widely used, accounts for nearly **16% of global electricity generation**.
  - First hydropower station in India: Sidrapong, Darjeeling (1897).
  - Mini/micro hydel projects (3-15 MW) suitable for remote/hilly areas, avoid socio-economic/environmental problems of big dams.
  - **Applications**: Generating electricity, flood risk management, irrigation.
  - **Advantages**: Clean source, water for irrigation/drinking, non-polluting, long life, low operating/maintenance costs, not affected by inflation, flood control, constant electricity production once built, flexible operation based on demand, long-term energy source, no greenhouse gas production.
  - **Disadvantages**: Huge investment, high construction standards, **destruction of natural environment (large-**

scale flooding), submergence of forest/agricultural areas, water logging, siltation, **loss of biodiversity/fish population**, displacement of local people, socio-economic problems, increased seismicity, loss of prime agricultural land, altered water table, geological damage.

- **4. Hydrogen Energy**:
  - Burns in air to form water, liberating enormous energy (150 kJ/g). Highest calorific value, excellent fuel.
  - Clean fuel and energy storage medium.
  - Production: Thermal dissociation, photolysis, electrolysis of water; biological conversions from organic effluents.
  - **Advantages**: Used as fuel in spaceships (liquid hydrogen), generates electricity in fuel cells.
  - **Disadvantages**: Highly explosive and inflammable, requires safe handling, difficult to store and transport.
- **5. Ocean Energy**:
  - Oceans occupy over 70% of Earth's surface, acting as large solar collectors.
  - **Tidal Energy**: Produced by gravitational force of sun and moon. Requires several meters difference between high and low tide. Harnessed by **tidal barrage**

(seawater flows into/out of reservoir to turn turbines). Potential in India: 15,000 MW (Gulf of Cambay, Kutch, Sunderban deltas, Andaman & Nicobar, Lakshadweep, Odisha, Kerala, Tamil Nadu, Karnataka, Maharashtra coasts). Bay of Funday (Canada) has 5,000 MW potential. First modern tidal power mill: La Rance, France.

- **Ocean Wave Energy**: Operates on oscillating water column principle. India initiated a project at Vizhinjam Fishery Harbour, Kerala.
- **Ocean Thermal Energy**: Generated from temperature difference between warmer surface water and colder deeper layers (minimum 20°C difference) using OTEC power plants.
- **Advantages**: Free and clean, no greenhouse gases, shoreline protection, continuous electricity generation (tides are 24/7).
- **Disadvantages**: **Displacement of wildlife habitats**, destruction of ecosystem depending on tides, kills migrating fish, only harnessed in suitable wave/tidal flow areas (not inland), high recurring cost for salt-resistant parts, disrupts movement of marine animals/ships, intensity affected by extreme weather.

- **6. Geothermal Energy**:
  - Energy produced from **hot rocks inside the Earth**. High-temperature/pressure steam fields exist below surface, heat from radioactive materials via fission.
  - Comes out naturally as geysers (e.g., Manikaran, Sohana) or extracted by drilling.
  - Successful plants in USA, New Zealand.
  - **Advantages**: Lifetime energy resource (reusable), among the cleanest (doesn't burn fossil fuel), high heat source.
  - **Disadvantages**: Requires specific suitable spots (continuous/substantial steam), high capital for plant setup, high drilling/testing costs.
- **7. Biomass Energy**:
  - Organic matter from plants and animals (agricultural waste, crop residues, wood, manure, cattle dung, sewage).
  - **Types**:
    - **Agricultural and Industrial waste biomass**: Crop residues, bagasse, peanut hulls, cotton stalks, coconut shells, fishery/poultry waste, animal dung, human refuse. Brazil produces 30% electricity by burning bagasse. Used in rural India

for heat (dung cakes, wood). Open furnaces ("Chulhas") produce smoke and are inefficient (<8%). Improved smokeless chulhas used. Burning causes air pollution (smoke, ash), destroys nutrients.

  - **Energy Plantations**: Green plants trap solar energy via photosynthesis to produce biomass. Energy produced by direct burning or conversion to biofuels/burnable gas. Examples: sugarcane, sugar beet, sweet sorghum, aquatic weeds (water hyacinth), sea-weeds, carbohydrate-rich plants (potato, cereals), fast-growing trees.
  - **Petro-Crops**: Plants/algae rich in hydrocarbons that produce oil-like substances (e.g., oil palms, Euphorbias). Can be refined into gasoline or burnt directly in diesel engines.
- **Advantages**: Uses waste materials, cheap fuel source, doesn't emit additional CO2 (like fossil fuels), manufactures various fuels (biogas/biofuel/heat), reduces disposal costs, increases landfill life, negative fuel costs, reduces fossil fuel dependence.
- **Disadvantages**: Difficulty in gathering sufficient fuel, not available all year, biocrops may detract from food

production (shortages, increased prices), **emission of greenhouse gases and pollutants causing air pollution**.

- **Non-Renewable Energy Resources**
  - **Fossil Fuels**: Principally hydrocarbons, formed over centuries from once-living organisms. Types: Coal, Oil, Natural gas.
    - **Coal**: Formed during Carboniferous age (255-350 million years ago) from buried, partially decomposed vegetation. Most abundant fossil fuel (6,000 billion tonnes globally). Lifespan: 200 years (present rate), 65 years (2% increase).
      - **Types of Coal (by carbon content)**: Lignite (60-70%), Sub-bituminous (75-83%), Bituminous (78-90%), Anthracite (92-98%).
      - India's coal reserves unevenly distributed (eastern states, Central India). Indian coal generally not high heat capacity (5% of world's coal). Major coalfields: Bokaro, Jharia, Raniganj, Godavari valley, Singrauli. Anthracite only in J&K.
      - **Peat**: Precursor of coal, soft organic material (60% organic matter, 55-60% carbon, 30-35% oxygen).

    - Calorific values: Biogas (5000-5500 kcal/kg), Natural gas (13 kcal/g), Peat (5400 kcal/g).
- **Petroleum**: Lifeline of global economy, cleaner than coal. 67% of reserves in 13 OPEC countries (Saudi Arabia has 25%). World crude oil reserves estimated to last 40 years at present rate. India's first recovery from Makum, Assam. Oil fields in Digboi, Bay of Cambay, Bombay High, Godavari/Krishna/Cauvery/Mahanadi deltas. High demand, India imports.
- **Natural Gas**: Composed of methane (95%). Occurs with oil or independently. Cleanest fossil fuel. Easily transported via pipelines. Burns without smoke, high calorific value. Used for domestic/industrial purposes, power generation, raw material for petrochemicals/fertilizers. By-product of crude oil refining. 40% of total reserves in Russia, then Iran (14%), USA (7%). India's reserves with oil fields, new areas in Jaisalmer, Tripura, Mumbai offshore, Krishna-Godavari Delta.
    - **LPG (Liquefied Petroleum Gas)**: Domestic cooking fuel. Main content: odourless butane; propane/ethyl mercaptan added for smell.

Produced by converting petroleum to liquid under pressure. Cleaner burning than diesel.

- **CNG (Compressed Natural Gas)**: Substitute for petrol/diesel in vehicles. Used by Delhi DTC, reduced pollution. Cleaner than diesel, cheaper, readily available, lower carcinogenic potential, higher mileage (35-40 km/kg).

- **Nuclear Energy**:
  - High destructive value, non-renewable.
  - **Generation**:
    - **Nuclear fission**: Nucleus of heavy isotopes (e.g., Uranium-235) split by neutrons, releasing huge energy through a chain reaction.
    - **Nuclear fusion**: Heavier nucleus formed from two lighter element isotopes, releasing enormous energy at extremely high temperatures (1 billion °C).
  - Heat energy produced runs electric turbines.
  - **Components of a Nuclear Reactor**:
    - **Moderator**: Slows down fast neutrons (e.g., heavy water, graphite, deuterium, paraffin).
    - **Control Rods**: Boron or Cadmium rods.
    - **Coolant**: Removes heat from core.

- **Shielding**: Concrete walls (2-25m thick) to protect from radiation.
- **Nuclear Fuel**: Uranium-235.

- **Advantages**: Very few greenhouse gases (does not contribute to global warming), readily available technology, high electricity from small fuel amount, low operating costs, meets industrial/domestic needs, nuclear wastes may be reduced through reprocessing/recycling.
- **Disadvantages**: **High installation cost** (radiation containment), centralized power source, large infrastructure required, **high known and unknown risks**, long construction period, **finite fuel source** (Uranium may last 30-60 years), high expertise/skill needed for installation/operation, mining involves health/other catastrophes, huge water requirement, **disposing of spent fuel is a problem** (wastes last 200-500 years), target for terrorist activities, average reactor lifespan 40-50 years.

- **National Solar Mission (Case Study)**
  - Part of India's **National Action Plan on Climate Change (NAPCC)**, launched June 30, 2008.
  - Approved January 11, 2010.

- **Prime Objective**: Establish India as a **global leader in solar energy** by creating policy conditions for rapid diffusion.
- **Tremendous potential** due to high intensity and long duration of sunshine in India. Also permits **decentralized energy distribution**.
- **Three-phase approach**: Phase 1 (up to 2012-13), Phase 2 (2013-17), Phase 3 (2017-22).
- Revised ambitious target in June 2015: **1 lakh MW of grid-connected solar power by 2022**.
- **Purposes**: Long-term energy security and ecological security.
- **Environmental Impact**: Environmentally friendly (zero emissions), renewable, free, can be used in remote areas, long lifespan (30-40 years).

Lesson 8: Pollution: Air, Noise and Nuclear Pollution

- **Introduction to Pollution**
  - **E.P. Odum (1971)** defined pollution as an **alteration in the Physico-chemical and biological nature of air, water, and soil that ultimately affects the whole environment**.
  - It has hazardous impacts on living organisms (flora and fauna), environmental systems, and non-living material.

- Caused by **anthropogenic (man-made)** or **natural activities** (e.g., volcanic eruptions, forest fires, floods).
- Incomplete technology is a main cause of man-made pollution.

- **Sources of Pollution**
  - **1. Solid Wastes**: Domestic or industrial.
    - **Industrial wastes**: Glass fragments, leather pieces, rubber pieces.
    - **Domestic Wastes**: Combustible (leaves, paper), non-combustible (crockery, plastics, glass).
    - **Sewage**: Human and animal excreta, domestic effluents, detergents (solid faecal is called sludge).
    - **Agricultural Wastes**: Plant and animal residues, pesticides, fertilizers.
  - **2. Liquid Wastes**: Major sources of water and soil pollution.
    - **Industrial effluents**: From chemical factories, refineries, breweries, tanneries; contain acids, alkalies, oil, dissolved heavy metals; affect aquatic life and self-purification.
    - **Domestic wastes**: Inorganic (soap water, detergent) or organic (kitchen garbage, faecal water).
    - **Agricultural Runoff**: Carries residual fertilizers, pesticides, biocides.

- **3. Gaseous Wastes**: Common pollutants like carbon monoxide, sulphur oxides, nitrogen oxides, hydrogen sulphide released from industries and automobile exhausts. Most dangerous type, threatening life.
- **4. Energy Wastes**: Invisible pollutants like **heat and radioactive emissions**. Radioactive emissions are most hazardous, with far-reaching and damaging cumulative effects on genetic makeup.
- **5. Noise**: Unwanted sound above a certain level. Common sources: radios, traffic horns, public broadcasting systems, aeroplanes, supersonic jets. Can cause irreparable damage to ear drums/brain.

- **Classification of Pollution**
  - **1. Nature of Pollutants**:
    - **Biodegradable**: Substances naturally decomposed by microorganisms (e.g., organic waste, leaf litter).
    - **Non-biodegradable**: Substances not decomposed by natural processes (e.g., plastic waste, metallurgical waste).
  - **2. Components of Environment**: Air Pollution, Water Pollution, Soil Pollution, Radioactive Pollution, Noise Pollution, Thermal Pollution.
- **Management of Environmental Pollution**

- Requires a balanced and harmonious collaboration with nature.
- Goal: Manage environment for human happiness, health, enjoyment, and quality of life.
- Problems can be local, national, or international and must be managed accordingly.
- **Suggestions**:
  - **Environmental education** made compulsory from primary to university levels.
  - Mass awareness campaigns through media.
  - Formulation and strict enforcement of **quality standards**.
  - Sustainable approach through quality and impacting living/non-living systems.
- Air (atmosphere) is essential for life, making up nearly 80% of daily human intake by weight (16 kg/day).
- **Natural detergents for pollutants**: High mixing height and high wind speed (for dispersion), and high precipitation (rainfall acts as best scavenging agent).
- **Categorization of Air Pollutants**:
  - **A. Origin**:
    - **Primary air pollutants**: Have their own origin, direct emissions (e.g., oxides of nitrogen, sulphur,

carbon, volatile organic compounds (VOCs), particulate matter).

        - **Secondary air pollutants**: Derived from primary pollutants (e.g., Ozone (O3), Peroxy Acetyl Nitrate (PAN)).
    - **B. Chemical Composition**:
        - **Organic compounds**: Contain carbon and hydrogen (e.g., aldehydes, ketones).
        - **Inorganic compounds**: Mixed formations, no carbon and hydrogen (e.g., carbonates, nitrogen oxide).
    - **C. Kind of Matter**:
        - **Size-segregated particles**: Micrometre sizes (e.g., dust, aerosol, total suspended particulate).
        - **Gaseous air pollutants**: Oxides of nitrogen, sulphur, carbon, volatile organic compounds.
- **Types of Air Pollution**:
    - **Indoor air Pollution**: Anthropogenic sources (cooking fuel burning, coal burning, crop residue burning). Affects household women, common in developing nations.
    - **Outdoor air Pollution**: Major sources are vehicular and industrial emissions. Overpopulation and

industrialization are indirect contributors. Affects over 1,100 million people, mostly in cities.

- **Case Studies on Smog**:
  - **The London Smog, 1952**: Caused by wind speed fall, temperature inversions, high-pressure systems. Fog became "smog" (smoke + fog) from particulate emissions from coal combustion (industrial, domestic, locomotives). Resulted in paralysed city, PM up by 56x, SO2 by 7x, 8,000 deaths (bronchitis, heart disease). Led to **Clean Air Act of 1956**.
  - **The Los Angeles Smog, 1943**: Sulphur-laden sooty smog gave way to **photochemical smog** (initiated by nitrogen dioxides in sunlight reacting to form ozone). First evidenced in Los Angeles [328) from trees/plants, volcanic eruptions (sulphur dioxides), organic matter decomposition (CO2, methane).
- **B. Anthropogenic Sources**: Gasoline exhaust, industrial emissions, mining, cooking fuels, construction, fireworks.

- **Household works**: Coal combustion (smoke, soot, dust, CO, SO2, NOx); LPG burning releases fewer pollutants.
- **Gasoline Exhaust**: From vehicles (2/4-wheelers, heavy-duty), releasing NOx, SOx, VOCs, CO, O3, PM10, PM2.5, lead. Vehicles contribute ~70% of air pollution.
- **Industries**:
  - Chemical: SOx, NOx, VOCs, PM.
  - Coal Powered Plants: SO2, CO, NOx, PM.
  - Electroplating and Metallurgical: CO, CO2, NOx, PM, copper, lead.
  - Gasoline-fuel: Petroleum and diesel emit VOCs, NOx, SOx, CO, PM, O3.
  - Paper Manufacturing: PM10, PM2.5, SO2.
- **Agricultural Practices**: Chemical fertilizers (pesticides, herbicides).

- **Bhopal Gas Disaster (1984)**: Ghastliest industrial disaster. On Dec 2-3, 1984, **over 40 tons of Methyl Isocyanate (MIC) gas escaped** from Union Carbide Pesticide Plant in Bhopal, Madhya Pradesh. Instantly killed ~ radiative forcing. Sources: anthropogenic (crop residue burning, construction) and natural (sea salt spray, pollen, forest fires, dust storms). Block solar radiation (radiative heating), affect crop species, responsible for photochemical smog.

- **Volatile Organic Compounds (VOCs)**: Organic compounds with vapour pressure of 0.1mm Hg, vaporise at ≤25°C. Classes: non-methane hydrocarbons, aldehydes, ketones, aromatics. Max source from **natural sources (80%)** like trees/plants, and animal breath; rest (20%) anthropogenic (vehicular, industrial emissions, paints, mosquito repellents).
- **Persistent Organic Pollutants (POPs)**: Organic compounds adversely affecting human lives. Evaporate in tropics, travel by air to cooler regions, condense, then repeat in "hops" (long-range atmospheric transport, **'grasshopper or global distillation process'**). Highest concentrations in circumpolar nations. Arctic Council and UN/ECE LRTAP Convention monitor/identify. Remain Deeply penetrate lungs, settle in alveoli, most dangerous.
    - Sources: Vehicular/industrial emissions, construction, domestic, mining, religious activities. Symptoms: nausea, dizziness,

respiratory illness, asthma, lung inflammation, chest pain, lung cancer.

- **Chlorofluorocarbons (CFCs)**: Organic compounds with halogen groups, produced from methane/ethane ("freons"). Sources: refrigerators, propellants, cleaning solvents, disinfectants. Examples: HCFCs, R-12. Cause **ozone layer depletion**.
- **Other key pollutants**: Carbon monoxide (CO), Carbon dioxide (CO2), Sulphur dioxide (SO2), Polynuclear Aromatic Hydrocarbons (PAHs), Nitrogen Oxides, Peroxy Acetyl Nitrate (PAN). (Table 8.1 details sources and effects for each).

- **Air Pollution Control**
  - **A. Source Emissions - Industries**:
    - Encourage low-sulphur fuels, reduce benzene in gasoline (from 10% to 1% as per CPCB).
    - Exhaust hoods for solvent recovery.
    - Cost-effective instruments to reduce pollutants.
    - Removal of pollutants at source using devices: **Wet scrubbers** (remove pollutants from flue gas), **Electrostatic Precipitator (ESP)** (removes PM based on opposite charges), **Cyclone Separators**

(removes particles by centrifugal force, 10 microns or larger).

- Control for NOx: **Exhaust Gas Recirculation (EGR)**, **Catalytic converter**.
- Systems to Decrease VOC: **Gas Flare**, **Biofilters** (use living matter to trap biodegradable pollutants).

- **B. Source Emissions - Vehicles**:
  - **Eradication of old (over 15 years) vehicles** due to low efficiency/malfunctioning engines.
  - **Catalytic converters** convert noxious gases to less harmful ones.
  - Improvement in vehicular fuel quality (e.g., sulphur content reduced to 0.2% in diesel).
  - MTBE as gasoline additive to increase octane number.
  - **Unleaded petrol** recommended (especially in Delhi) to reduce lead emissions.
  - Use of **alternative fuels**: CNG, LPG, biodiesel, vegetable oils, ethanol, electric vehicles.
- **C. Legal and Policy Measures**:
  - **The Air Pollution Prevention and Control Act, 1981** and **Environmental Protection Act, 1986**.

    - **National Ambient Air Quality Standards (NAAQS)**: First suggested under 1981 Act. CPCB adopted 12 parameters (PM10, PM2.5, SO2, NO2, CO, NH3, O3, Pb, benzene, benzopyrene, arsenic, nickel). Programme called **National Air Monitoring Programme (NAMP)**.
    - **National Air Quality Monitoring Programme**: 610 stations in 227 cities (as of Jan 2019), supervised by CPCB, SPCB, DPCC, NEERI.
- **D. Greenbelt Development/Landscape Green Planning**:
    - Plant tolerant species (sinks) to absorb air pollutants and purify air.
    - Screen species by **Air Pollution Tolerance Index (APTI)** and plant around affected areas [345
- **Taj Mahal Issue (Case Study)**: Mathura Oil Refinery established in 1972. Environmentalists protested SO2 emissions causing acid rain (H2SO3, H2SO4), damaging white marble (yellowing/blackening). Committee concluded negligible SO2 increase (1-3 micrograms). **WHO recognised 'Taj Trapezium Zone' (TTZ)** (50 km radius) to protect the monument.

Burning coal/wood banned in TTZ; Supreme Court ordered solar power plant for TTZ.

- **Noise Pollution**
  - **Definition**: Unwanted and unpleasant sound released into the atmosphere, causing adverse effects.
  - Sound intensity measured in **decibels (dB)**.
  - **Sources**:
    - **Indoors**: Gadgets (mixture/grinder, vacuum cleaner), washing machines, coolers, ACs, radios, TV.
    - **Outdoors**: Factories, vehicles, aeroplanes, trains, loudspeakers, crackers.
  - **Effects of Noise Pollution**: Depend on intensity, frequency, periodicity.
    - **High-Intensity Sound (80-100 dB)**: From machinery, motorcycles, music systems. Causes emotional/behavioural changes, nervous tension, cardiovascular problems (heart disease, blood pressure), complete hearing loss, rise in blood cholesterol.
    - **Explosive Sound (>110 dB)**: From crackers, trains, motorcycles. Causes vomiting, severe concussions of inner ear, profound deafness.
    - **Loud and Sudden. Mild sound (~10 dB) from nature (bird songs) is necessary and pleasant.

- **Control of Noise Pollution**: Three ways: Eliminate noise at source, modify sound transmission path, provide receiver protection.
  - **1. Reduction in Industries**: Replace old machinery, relocate noisy generators, workers wear ear muffs/plugs, grow plants (Ashok, Banyan, Neem) around factories.
  - **2. Reduction of Community Noise**: Ban/restrict loudspeakers, prohibit high sound intensity crackers.
  - **3. Reduction of Traffic Noise**: Ban old noisy vehicles, restrict unnecessary horn blowing legally, develop 50-feet wide plantation strips along highways.
  - **4. Reduction of Aeroplane and Jet Noise**: Locate aerodromes far from residential areas, develop thick green belts around them.
  - **5. Planning of Cities and Housing System**: Develop well-planned cities to reduce noise from industries/highways, sufficient green belts in residential areas.
  - **6. Legal Control of Noise Pollution**: CPCB and SPCBs empowered to frame rules. Examples: Silence zones near hospitals/educational institutes, restricted sound amplifiers, effective silencers on vehicles,

restricted mid-night aircraft flights, legal handling of factory noises, promotion of soundless machinery, legal protocols for green belts.

- **Nuclear Pollution**
  - **Nuclear Hazard**: Potential risks from **exposure to radiation emanating from atomic nuclei**.
  - **Radioactivity**: Emission of energy from radioactive isotopes (e.g., Carbon-14, Uranium-235, Uranium-238, Radium-226).
  - Energy released as **alpha, beta, or gamma radiation**, with different tissue impacts. Alpha: highly ionising, low penetration; Beta: more penetration, cell damage/mutagenesis (used in radiation therapy); Gamma: high penetration, severe problems.
  - Used for sterilisation of medical/scientific equipment and food treatment.
  - Nuclear power plants can cause disasters with radiation fallout.
  - **Chernobyl Disaster (19 global anti-nuclear movement.
  - **Causes of Nuclear Pollution**:
    - **1. Nuclear accidents**: High energy/radiation in nuclear substances. Examples: Fukushima Daiichi, Chernobyl, Three Mile Island.

    - **2. Weapons of Mass Destruction (WMD)**: Atomic bombs/nuclear missiles (e.g., Hiroshima, Nagasaki in 1945); caused mental retardation, autism, increased cancer cases.
    - **3. Use of Radioisotopes**: Unstable atomic nucleus, emit energy/particles to become stable. Each has definite half-life and disintegration. Used in detectors, industrial activities. Uranium has high radiation. Carbon-containing radioactive material found in waterways from untreated sewage. Ingesting contaminated water is a risk.
    - **4. Mining**: Excavation of mineral ores exposes naturally occurring radioactive elements like Radium, Uranium, thorium, plutonium, radon, potassium, carbon, phosphorus.
    - **5. Radiation Tests**: For research and cancer treatment (chemotherapy).
    - **6. Cosmic Rays**: From outer space (e.g., gamma rays).
  - **Impact of Nuclear Hazards**:
    - Hazardous substances disperse or accumulate in living organisms, passing through food chain.
    - **Strontium-90**: Similar to calcium, deposited in bones; contaminated milk is a source.

    - **Tritium**: Used in nuclear power plants, half-life of 12.3 years, emits Beta particles. Acute, within days/weeks; physical crippling or immediate death.
        - **Long Range Effects**: Delayed; genetic changes, point mutation, chromosomal aberration, increased tumour/cancer incidence, shortening of lifespan, anaemia, haemorrhages.
- **Mitigation of Nuclear Hazards**:
    - **Safe disposal of nuclear waste** is priority. Burial in deep trenches.
    - **Delay and Decay**: Store radioactive waste in airtight containers, allow to decay deep underground.
    - **Concentrate and Contain**: Mix small amount of highly radioactive waste with concrete, solidify, dump deep in ocean/underground salt mines.
    - **Dilute and Disperse**: Release moderately/weakly radioactive waste after diluting with inert materials.
- **Protective Measures**:
    - Wear dark glass spectacles/goggles when handling UV lamps.
    - Visible light neutralises UV damage.

- Minimise nuclear fallout hazards by containment of high-level wastes (underground tanks, convert134, Caesium-137, strontium-90, Plutonium-238.

Lesson 9: Pollution: Water, Thermal and Soil Pollution

- **Introduction**
  - Water, soil, and thermal pollution are significant challenges.
  - Pollutants from natural and anthropogenic sources harm plants and human health.
- **Water Pollution**
  - **50% of all marine pollution** caused by sewage and wastewater discharge.
  - Annually, **400 billion tons of industrial waste** produced globally, mostly discharged untreated.
  - **Definition**: One or more substances building up in aquatic bodies to a limit that troubles life forms.
  - **Types of Water Pollution**:
    - **A. Based on water bodies**:
      - **Surface Water Pollution**: Affects huge oceans, lakes, rivers, streams (e.g., oil slicks from tankers).

        - **Ground Soft Water*: Little or no dissolved salts of magnesium and calcium.
        - **Hard Water**: High mineral content, primarily calcium and magnesium metal cations, sometimes bicarbonates and sulphates; unsuitable for use.
        - **Transboundary Pollution**: Pollution entering environment from one place but causing outcome far away (hundreds/thousands of miles), e.g., persistent organic pollutants, radioactive wastes across oceans/borders.
    - **Sources of Water Pollution**:
        - Approximately **33% from domestic sources**, 29% from agriculture/livestock, 27% from industry, 11% from other sources.
        - **A. Domestic**: Wastewater from households, 99.9% pure water, 0.1% pollutants (organic: food/vegetable waste, excreta; inorganic: phosphates/nitrates from soaps/detergents). Contains chemicals, drugs, papers, plastics.
        - **B. Agriculture**: Extensive use of **agrochemicals (fertilizers, pesticides)**. These chemicals move into water bodies via rainfall and groundwater leaching, Nobel Prize 1948) is highly penetrable, fat-soluble.

High doses: paresthesia, ataxia, dizziness, headache, nausea, restlessness. Chronic exposure: anorexia, anaemia, tremor. Potent carcinogens, damage liver/endocrine organs. * **Organophosphates**: Used in chemical warfare (e.g., Sarin, Tabun). Toxic effects are additive. Examples: malathion, parathion. * **Organo-carbamates**: Similar action to organophosphates but shorter duration, least toxic (e.g., Sevin, Baygon). Exposure causes salivation, lacrimation, convulsions. * **Biological Insecticides**: E.g., *Bacillus thuringiensis* (BT toxin) to kill larvae.

- **D. Industries**: Many located along river banks for convenience and effluent disposal. Effluents: acids, bases, dyes, paints, chemicals, detergents (form foam). Industrial waste: mercury, lead, cadmium, chlorides, fluorides, ammonia. Alters water pH, fatal to aquatic forms. Discharge of **superheated water** from thermal power plants, oil refineries, nuclear power plants leads to **thermal pollution**. High temperature reduces dissolved oxygen, harms/kills aquatic life.
  - **Mining Industries**: Extraction exposes heavy metals and sulphur. Rainwater leaches chemicals, causing **Acid Mine Drainage (AMD)** and heavy

metal pollution. Cyanide used in gold mines contaminates water. Mining Ca La Hague.

    - **Table of Major Water Pollutants and Impacts**: (Antimony, Mercury, Arsenic, Cadmium, Chromium, Lead, Nickel, Beryllium, Aluminium, Manganese). (Refer to original source for detailed impacts of each)

- **Impacts of Water Pollution**:
    - **1. Eutrophication**: **Enrichment of freshwater bodies by accumulation of nitrates and phosphates** (from sewage, fertilizers, organic matter). Predominantly in sluggish rivers, shallow lakes; affects over 500 coastal areas globally. Leads to **algal blooms** (discoloration, high density of pigmented cells, water becomes greenish). Rapid algal expansion increases decomposers, consuming dissolved oxygen and leading to **oxygen depletion**. Some algal blooms are harmful (e.g., dinoflagellates causing "red tide").
    - **2. Bioaccumulation and Biomagnification**:
        - **Bioaccumulation**: **Accretion of substances (pesticides, metals, organic compounds) in a living organism over time**. Occurs if chemical intake > utilisation/metabolism. Lipid-soluble compounds (DDT, tetra-ethyl lead) stored in

adipose tissues, causing acute poisoning upon release.

- **Bioconcentration**: Uptake and accumulation of chemical substance from water alone.
- **Biomagnification (Bioamplification / Biological magnification)**: **Amplification of a substance's concentration up the trophic level**. E.g., DDT entering In Toyama Prefecture, Japan. Characterized by severe pain in joints/vertebral column. Caused by **cadmium poisoning** from mining companies discharging cadmium into rivers. Consequences: softening of bones, kidney failure.
- **Chisso-Minamata Disease (Minamata Disease)**: Caused by **mercury poisoning**. Primary symptoms: ataxia (loss of muscular coordination), lack of sensation, muscle weakness, hearing/visual impairment. Extreme cases: insanity, paralysis, coma, death. Mercury can cross placenta, affecting fetus.
- **Blackfoot Disease (BFD)**: Endemic to southwestern Taiwan, caused by **arsenic toxicity**. Symptoms: coldness/numbness in extremities,

irregular claudication, severe systematic arteriosclerosis, gangrene-like symptoms.

- **Methemoglobinemia ('Blue Baby Syndrome')**: Excess nitrates from fertilizers enter human body via water, transform into nitrites, react with haemoglobin to form methemoglobin. of degradable matter. WHO recommended limit was 6 mg/l (no present limit).

- **2. Chemical Oxygen Demand (COD)**: Measures oxygen used for chemical oxidation of pollutants. Expressed in mg/l. Total measurement of all oxidizable chemicals. **Higher COD = higher pollution**. Faster than BOD (few hours), usable for waters too toxic for BOD test. Decomposition by powerful oxidant (potassium dichromate). COD value 1972, Basel Convention 1989, OSPAR Convention 1998, Nairobi International Convention on the Removal of Wrecks 2007). GOI legislations: **The Water (Prevention and Control of Pollution) Act, 1974** (amended 1988) and **The Water (Prevention and Control of Pollution) Cess Act, 1977** (amended 2003). BIS drinking water specifications (IS 10500-2012) exist.
- **Ganga Action Plan (GAP) (Case Study)**:

- River Ganga is culturally significant, designated National River of India (2008). 9th largest globally, 2nd largest in India (2,525 km).
- Over 600 km, especially between Kanpur and Patna, highly polluted. Receives 1300 million litres **Objectives**: Environmental improvements, sewage treatment, energy/manure production, pisciculture/aquaculture/irrigation with treated water, economic benefits to local population.
- GAP estimated huge discharge of toxic/domestic effluents from UP cities.
- Despite ₹20,000 crores spent, results insignificant. Projects subsidised by Netherlands, Japan. Now includes Yamuna and Gomti rivers (NGPRA granted ₹100 million).
- Technical experts (Himalayan (non-polluted), Upper (polluted by agrochemicals), **Delhi segment (Wazirabad to Okhla, 22 km, highly polluted due to Delhi effluent discharges)**. Eutrophicated segment (Okhla to Chambal, highly polluted with microbes, highest BOD), Mixed segment (Chambal to Allahabad, pollution decreases).

    - Delhi segment receives 1900 million litres sewage daily; only 1270 ml/day treated (partially) [417 work, problem remains serious. Barrages built in Delhi, Mathura, Agra for civic water supply and irrigation canals exacerbate pollution. Yamuna has become a "sewage Vahini".

- **Thermal Pollution**
  - **Definition**: Water pollution due to **heat**. Hot water enters water bodies adversely affecting plants and animals.
  - **Sources**: Industries, thermal power plants, nuclear power stations use large quantities of water as cooling agents, heating it. About 70% of heat in thermal power plants is lost as waste to cooling water, raising temperature 10-15°C. Sewage and industrial waste also raise temperature by 4-6°C.
  - **Effect on Aquatic Life**:
    - Small animals, phytoplankton, zooplankton, small fishes killed.
    - Cell walls severely damaged.
    - Adversely affects enzyme and metabolic activities.
    - Allow hot water to cool before discharge.
    - Use **cooling towers and fountains** for rapid cooling.
    - Construct large tanks/reservoirs to retain water longer.

        - Discharge hot water into **running water bodies** instead of stagnant ones.
- **Soil Pollution**
    - Soil is a natural medium of inorganic/organic nutrients with spontaneous recycling. Affected by atmospheric conditions, water content, microbial population.
    - ecal matter, urine, blood, slaughterhouse waste, dead animal bodies dumped indiscriminately. Excessive organic content creates hypertonic conditions, causing wilting/stunted plant growth.
        - **2. Anthropogenic Sources**:
            - **Domestic**: Household sewage (organic/inorganic pollutants, soaps, detergents).
            - **Agriculture**: Extensive use of **agrochemicals (fertilizers, pesticides)**. Leaches into water bodies, enters food chain, causing problems.
            - **Industries**: Eff formation/fertility).
        - Indiscriminate agrochemical use **destroys soil flora/fauna and soil properties**.
        - SO_2, SO_3, nitrogen oxides from atmosphere wash down as H_2SO_4, HNO_2, HNO_3 (acid rain), increasing **soil acidity** and creating unhealthy conditions for plant growth.

        - Dumping radioactive wastes is lethal to plants/microbial life, with far-reaching effects on humans.
    - **Control Measures for Soil Pollution**:
        - **1 into soil**.
        - **7. Sewage should be biologically treated and converted into manure** instead of uncontrolled release.

Lesson 10: Solid Waste Management and Case Studies

- **Introduction to Solid Waste**
    - **Waste**: Material or substance not useful after its process or use.
    - Generated from residential, industrial, commercial, or agricultural activity.
    - Can be paper, metal, glass composition: organic (51%), recyclables (17%), hazardous (11%), inert (21%).
    - **Waste segregation** is a basic problem; 40% of waste not collected, littering towns, entering drains/water bodies, choking and polluting environment. Unsegregated waste causes nuisance, pollution, spreads to nearby areas. Burning waste causes air pollution and releases global warming gases.
- **Types of Wastes**

- **1. E-waste (Electronic waste7]. Recovery/extraction leads to inhalation of toxic fumes and accumulation of harmful chemicals in water, soil, food.
- **2. Biomedical Waste (BMW)**: Waste generated during diagnosis, treatment of humans/animals, research, or testing.
  - **BMW Rules, 2016**: Improved collection, segregation, processing, treatment, and disposal.
  - Components: anatomical waste, soiled waste (plasters, bandages), medicines, chemical waste, discarded linen, syringes, needles, glassware.
  - Treated recycling rate. Majority ends up in oceans, affecting aquatic life.
  - Plastics cannot decompose; slowly break into **micro-plastics**, remaining for thousands of years.
  - **Plastic Waste Management Rules of 2016**: Specify **minimum thickness of 50 microns** for plastic use (for reuse/recycling). Promotes plastic use for **road construction, energy generation, oil formation**.
  - CPCB entrusted to set guidelines for thermoset plastics.1].
- **Reduce**: Start at household level by reducing commodity packaging, increasing durability, avoiding disposable/single-

use plastics, using jute/cloth bags, reducing paperwork (promoting e-mails/e-bills).

- **Reuse**: Promote reusing commodities (e.g., donating books, old clothes, electronics).
- **Recycle**: **Segregation of waste is paramount** (paper, metals, glass, plastics from organic waste). Recycled waste creates new products, saves resources (e.g., 1 ton recycled paper*

Incineration, Composting and Landfill

- **Incineration**: Waste treatment process where combustion occurs at **very high temperatures**, converting waste into ashes, gases, and heat. Considered a **waste-to-energy process** (like pyrolysis, gasification, anaerobic digestion). Used for **biomedical and hazardous waste**. Disadvantage: Release of **harmful gases like dioxins and furans**, causing severe health problems.
- **Composting**: Natural process using **microorganisms for decomposition of biodegradable waste** (organic, agricultural, kitchen waste). Requires aeration.
  - **Vermicomposting**: Uses **earthworms** (e.g., *Eisenia fetida*) to increase decomposition rate. Earthworms consume biomass and create **vermicasts**, which are rich in nutrients (N, P, K) and growth-promoting substances. Vermicompost is good for soil, free of pathogens and

weeds, reduces waste generation [44 (Case Study)**: One of the oldest and biggest landfill areas in Delhi NCR, over 30 years old and saturated. 65m high, filled with municipal waste. Releases greenhouse gases and leachate into soil. Over 3 million people live within 10 sq km radius. A major problem for global sustainable development goals.

- **Other Case Studies and Initiatives** (Some are repeats from Lesson 8/9, illustrating comprehensive coverage)
    - **The London Smog 1952**.
    - **Chernobyl Disaster**.
    - **Fukushima Disaster**.
    - **Indore: Global Model For Waste Management (Case Study)**: Named cleanest city in India (Swachh Survekshan 2019). Achieved **100% waste segregation at source** and successful organic waste management via composting. Success attributed to: **Information, Education and Communication (IEC)** for behavioural change; waste segregation at source and bulk; efficient collection and transportation; waste processing (wet waste to composting, hazardous/biomedical to incinerators, waste to bio-CNG for vehicles).

- **Swachh Bharat Abhiyan (Clean India Mission)**: Launched by PM of India on Oct 2, 2014. Largest cleanliness drive in India. Successful in creating awareness for cleanliness and discouraging open defecation by building toilets. Also raised health and sanitation awareness.
