



**UGC-NET**

**Environmental Science**

**National Testing Agency (NTA)**

**PAPER 2 || VOLUME 1**



# I UNIT

## Fundamentals of Environmental Sciences

### Definition, Principles, Scope, and Interdisciplinary Nature

#### Introduction

Environmental Science is a dynamic, interdisciplinary field that addresses the complex interactions between humans, ecosystems, and the Earth's physical systems. These topics are heavily tested in the exam, with questions ranging from basic definitions to applied scenarios involving Indian policies and global environmental challenges. This part focuses on the definition, principles, scope, and interdisciplinary nature of Environmental Science, providing a comprehensive, exam-oriented resource.

#### 1. Definition of Environmental Science

##### 1.1 What is Environmental Science?

Environmental Science is the systematic, scientific study of the environment, encompassing the interactions among its physical, chemical, and biological components, as well as the impacts of human activities on these systems. It aims to understand environmental processes, identify challenges like pollution and climate change, and propose sustainable solutions.

- **Core Components:**
  - **Physical Environment:** Includes the atmosphere (air), hydrosphere (water), and lithosphere (land), which provide the abiotic framework for life.
  - **Biological Environment:** Encompasses the biosphere, including ecosystems, species, and biodiversity, which represent the living components.
  - **Human Dimension:** Focuses on anthropogenic activities (e.g., industrialization, deforestation) and their environmental consequences, alongside policies, ethics, and societal responses.
- **Objective:** To foster a sustainable relationship between humans and the environment through research, education, and policy-making.
- **Scope of Study:** Ranges from local issues (e.g., urban air pollution in Delhi) to global challenges (e.g., climate change mitigation under the Paris Agreement).

##### 1.2 Evolution of Environmental Science

Environmental Science has evolved from early natural history studies to a modern, interdisciplinary discipline addressing complex environmental issues. Its development reflects growing awareness of human impacts on the environment.

- **Historical Context:**
  - **Ancient Civilizations:** Early societies, including those in India (Indus Valley, Vedic period), revered nature, with practices like sacred groves reflecting environmental stewardship.
  - **Industrial Revolution (18th–19th Century):** Rapid industrialization in Europe and North America led to deforestation, air pollution, and water contamination, prompting early conservation efforts.
  - **20th Century:**
    - **1962:** Rachel Carson's *Silent Spring* highlighted the dangers of pesticides like DDT, sparking the modern environmental movement.
    - **1970:** Establishment of Earth Day, raising global environmental awareness.
    - **1972:** United Nations Conference on the Human Environment (Stockholm) marked the first global environmental summit, leading to the creation of the United Nations Environment Programme (UNEP).
  - **21st Century:** Focus on climate change, biodiversity loss, and sustainable development, with agreements like the Kyoto Protocol (1997) and Paris Agreement (2015).

- **Indian Context:**
  - **Vedic Period:** Texts like the *Rigveda* and *Atharvaveda* emphasized harmony with nature, with deities representing natural elements (e.g., Vayu for air, Varuna for water).
  - **Colonial Era:** British exploitation of forests and resources led to environmental degradation, prompting early conservation laws like the Indian Forest Act (1865).
  - **Post-Independence:**
    - **1972:** Wildlife Protection Act protected endangered species and habitats.
    - **1986:** Environment Protection Act established a framework for environmental regulation.
    - **2006:** National Environmental Policy outlined sustainable development goals.
- **Global Milestones:**
  - **1948:** Formation of the International Union for Conservation of Nature (IUCN).
  - **1961:** Establishment of the World Wide Fund for Nature (WWF).
  - **1987:** Montreal Protocol addressed ozone-depleting substances.
  - **2015:** Adoption of the 17 Sustainable Development Goals (SDGs) by the United Nations.

**Table 1: Key Milestones in Environmental Science**

Year	Event	Significance
1865	Indian Forest Act	Early conservation law under British rule
1962	Publication of <i>Silent Spring</i>	Sparked global environmental awareness
1970	First Earth Day	Raised public consciousness about environmental issues
1972	Stockholm Conference	Established UNEP, global environmental governance
1986	Environment Protection Act (India)	Comprehensive environmental legislation
1997	Kyoto Protocol	First global agreement on greenhouse gas reductions
2015	Paris Agreement	Global commitment to limit warming to 1.5–2°C

### 1.3 Interdisciplinary Nature

Environmental Science integrates multiple disciplines to address environmental challenges holistically.

- **Natural Sciences:**
  - **Ecology:** Studies interactions among organisms and their environment (e.g., food webs, nutrient cycles).
  - **Chemistry:** Analyzes pollutants, atmospheric reactions (e.g., ozone formation).
  - **Physics:** Explores energy transfer, thermodynamics, and meteorology.
  - **Geology:** Examines Earth's structure, soil formation, and resource distribution.
- **Social Sciences:**
  - **Sociology:** Investigates human behavior, environmental awareness, and community responses.
  - **Economics:** Assesses costs of environmental degradation and benefits of conservation (e.g., cost-benefit analysis of renewable energy).
  - **Political Science:** Studies environmental policies, governance, and international agreements.
- **Applied Sciences:**
  - **Engineering:** Develops technologies for pollution control, renewable energy, and waste management.
  - **Remote Sensing and GIS:** Maps environmental changes, land use, and resource distribution.
- **Indian Examples:**
  - **Ecology and Sociology:** Chipko Movement combined ecological conservation with community activism.
  - **Chemistry and Engineering:** CPCB monitors air quality and develops pollution control technologies.
  - **Economics and Policy:** India's National Solar Mission balances economic growth with environmental sustainability.

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## 2. Principles of Environmental Science

Environmental Science is guided by core principles that provide a framework for understanding environmental systems and addressing challenges. These principles are ecological balance, interdependence, sustainability, and the systems approach.

### 2.1 Ecological Balance

- **Definition:** The dynamic equilibrium among living organisms, their environment, and abiotic factors, ensuring ecosystem stability.
- **Key Concepts:**
  - **Homeostasis:** Ecosystems maintain balance through self-regulating mechanisms (e.g., predator-prey dynamics).
  - **Carrying Capacity:** The maximum population an ecosystem can sustain without degradation.
  - **Trophic Levels:** Energy transfer through producers, consumers, and decomposers.
- **Mechanisms:**
  - **Negative Feedback:** Stabilizes ecosystems (e.g., increased CO<sub>2</sub> leads to more photosynthesis, reducing CO<sub>2</sub>).
  - **Positive Feedback:** Amplifies changes (e.g., deforestation reduces rainfall, worsening drought).
- **Examples:**
  - **Global:** Coral reef ecosystems maintain balance through symbiotic relationships (e.g., coral-zooxanthellae).
  - **India:** Overgrazing in Rajasthan disrupts ecological balance, leading to desertification.
- **Applications:**
  - Conservation projects like India's Project Tiger restore predator-prey balance.
  - Wetland restoration enhances nutrient cycling and biodiversity.
- **Indian Case Study:** The Keoladeo National Park (Bharatpur) faced ecological imbalance due to water scarcity, addressed through canal restoration.

**Table 2: Components of Ecological Balance**

Component	Description	Example
Homeostasis	Self-regulation of ecosystems	Predator-prey balance in forests
Carrying Capacity	Maximum sustainable population	Deer population in a grassland
Trophic Levels	Energy transfer through food chains	Grass → Deer → Tiger
Feedback Loops	Stabilizing or amplifying mechanisms	CO <sub>2</sub> -photosynthesis feedback

### 2.2 Interdependence

- **Definition:** The interconnectedness of all environmental components (biotic and abiotic), where changes in one affect others.
- **Key Concepts:**
  - **Ecosystem Services:**
    - **Provisioning:** Food, water, timber.
    - **Regulating:** Climate regulation, pollination.
    - **Cultural:** Recreation, spiritual value.
    - **Supporting:** Nutrient cycling, soil formation.
  - **Keystone Species:** Species critical to ecosystem function (e.g., bees for pollination, tigers for forest ecosystems).
  - **Food Webs:** Complex networks of trophic interactions.

- **Examples:**
  - **Global:** Deforestation in the Amazon reduces global carbon sequestration, affecting climate.
  - **India:** Declining vulture populations in India disrupted carrion decomposition, increasing disease risks.
- **Applications:**
  - Pollinator conservation enhances agricultural productivity.
  - Mangrove restoration protects coastal ecosystems and communities.
- **Indian Case Study:** The Sundarbans mangroves demonstrate interdependence, supporting biodiversity, fisheries, and storm protection.

### 2.3 Sustainability

- **Definition:** Meeting the needs of the present without compromising the ability of future generations to meet theirs, as defined by the Brundtland Report (1987).
- **Key Concepts:**
  - **Three Pillars:**
    - **Environmental:** Protecting ecosystems and resources.
    - **Economic:** Ensuring equitable growth and resource use.
    - **Social:** Promoting justice, equity, and education.
  - **Sustainable Development Goals (SDGs):** 17 UN goals (2015) addressing poverty, hunger, climate action, and more.
  - **Circular Economy:** Minimizing waste through reuse, recycling, and regeneration.
- **Examples:**
  - **Global:** Germany's Energiewende promotes renewable energy to reduce carbon emissions.
  - **India:** The National Solar Mission aims for 100 GW solar capacity by 2022, extended to 2030.
- **Applications:**
  - Organic farming reduces chemical inputs, preserving soil health.
  - Urban planning with green spaces enhances livability and reduces heat islands.
- **Indian Case Study:** The Swachh Bharat Abhiyan promotes sustainable waste management through composting and recycling.

**Table 3: Three Pillars of Sustainability**

Pillar	Focus	Example
Environmental	Ecosystem protection, resource conservation	Reforestation in Aravalli hills
Economic	Equitable growth, resource efficiency	Solar energy projects in Gujarat
Social	Equity, education, health	Environmental education in schools

### 2.4 Systems Approach

- **Definition:** Viewing the environment as a complex system of interacting components, analyzed holistically.
- **Key Concepts:**
  - **Holism:** Understanding the whole system, not just parts.
  - **Feedback Loops:**
    - **Positive:** Amplifies change (e.g., melting ice reduces albedo, increasing warming).
    - **Negative:** Stabilizes change (e.g., increased CO2 enhances photosynthesis).
  - **System Boundaries:** Defining the scope of study (e.g., a watershed, a city).
- **Examples:**
  - **Global:** Climate models use a systems approach to predict temperature changes.
  - **India:** The Ganga River Basin is studied as a system to address pollution and water flow.

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- **Applications:**

- Environmental Impact Assessments (EIAs) use systems modeling to predict project impacts.
- Urban planning integrates transport, waste, and energy systems.

- **Indian Case Study:** The National Action Plan on Climate Change (NAPCC) uses a systems approach, with eight missions addressing interconnected issues like water, energy, and agriculture.

### 3. Scope of Environmental Science

The scope of Environmental Science is vast, covering academic research, practical applications, policy-making, and societal impacts. It addresses environmental challenges at local, national, and global scales.

#### 3.1 Academic Scope

- **Disciplines Involved:** Ecology, climatology, hydrology, toxicology, sociology, economics, and more.
- **Research Areas:**
  - **Climate Change:** Studying causes (e.g., greenhouse gases), impacts (e.g., sea-level rise), and mitigation (e.g., carbon capture).
  - **Biodiversity Conservation:** Protecting species, habitats, and genetic diversity.
  - **Pollution Control:** Monitoring and mitigating air, water, soil, and noise pollution.
  - **Resource Management:** Assessing renewable and non-renewable resources.
- **Indian Institutions:**
  - **IITs and IISc:** Research on climate modeling, renewable energy.
  - **NEERI:** Studies on air and water pollution.
  - **TERI:** Focus on sustainable development and energy.
- **Examples:**
  - Research on Himalayan glacier retreat informs India's water security policies.
  - Studies on urban air quality in Delhi guide pollution control measures.

**Table 4: Academic Research Areas in Environmental Science**

Area	Focus	Indian Example
Climate Change	Causes, impacts, mitigation	Glacier studies in Himalayas
Biodiversity	Species and habitat conservation	Project Tiger
Pollution	Monitoring and control	Delhi air quality monitoring
Resource Management	Sustainable use of resources	Groundwater studies in Punjab

#### 3.2 Practical Applications

- **Environmental Management:**
  - **Waste Management:** Recycling, composting, landfill design, and waste-to-energy projects.
  - **Water Resource Management:** Watershed planning, rainwater harvesting, and desalination.
  - **Renewable Energy:** Solar, wind, hydropower, and bioenergy projects.
- **Technologies:**
  - **Remote Sensing:** Monitors deforestation, urban sprawl, and climate change.
  - **GIS:** Maps land use, biodiversity, and disaster risks.
  - **Bioremediation:** Uses microbes to clean contaminated soil and water.
- **Indian Examples:**
  - **Swachh Bharat Abhiyan:** Promotes waste segregation and composting.
  - **Namami Gange:** Cleans and conserves the Ganga River.
  - **Jal Jeevan Mission:** Ensures piped water supply to rural households.

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### 3.3 Policy and Governance

- **Role:** Formulating laws, regulations, and international agreements to protect the environment.
- **Key Policies:**
  - **Global:**
    - **Montreal Protocol (1987):** Phased out ozone-depleting substances.
    - **Paris Agreement (2015):** Aims to limit global warming to 1.5–2°C.
  - **India:**
    - **Environment Protection Act (1986):** Comprehensive environmental legislation.
    - **National Action Plan on Climate Change (NAPCC, 2008):** Includes eight missions (e.g., National Solar Mission, National Water Mission).
- **Institutions:**
  - **Ministry of Environment, Forest and Climate Change (MoEFCC):** Oversees environmental policies.
  - **Central Pollution Control Board (CPCB):** Monitors pollution and enforces standards.
  - **State Pollution Control Boards (SPCBs):** Implement policies at the state level.
- **Examples:**
  - India's ban on single-use plastics (2022) reduces plastic pollution.
  - The Green India Mission promotes afforestation and ecosystem restoration.

**Table 5: Key Environmental Policies**

Policy	Year	Objective
Environment Protection Act	1986	Comprehensive environmental regulation
NAPCC	2008	Address climate change through eight missions
Montreal Protocol	1987	Phase out ozone-depleting substances
Paris Agreement	2015	Limit global warming to 1.5–2°C

### 3.4 Societal Impacts

- **Environmental Awareness:** Educating communities about conservation, sustainability, and climate change.
- **Movements:**
  - **Global:**
    - **Greenpeace:** Campaigns against deforestation, whaling, and fossil fuels.
    - **Extinction Rebellion:** Advocates for urgent climate action.
  - **India:**
    - **Chipko Movement (1970s):** Protected forests in Uttarakhand through non-violent resistance.
    - **Narmada Bachao Andolan:** Opposed dam projects for environmental and social justice.
- **Examples:**
  - The “Beat Plastic Pollution” campaign (UNEP, 2018) raised awareness about plastic waste.
  - India's National Green Corps (Eco-Clubs) engages students in environmental activities.

## 4. Case Studies and Examples

### 4.1 Global Case Study: Silent Spring and the Environmental Movement

- **Context:** Rachel Carson's *Silent Spring* (1962) exposed the harmful effects of pesticides like DDT on ecosystems, particularly birds. It highlighted bioaccumulation and biomagnification, leading to widespread public awareness.

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- **Impact:**
    - Sparked the modern environmental movement.
    - Led to the ban of DDT in the USA (1972) and influenced global pesticide regulations.
    - Inspired the creation of the US Environmental Protection Agency (EPA).
  - **Relevance to Environmental Science:**
    - Demonstrates the interdisciplinary nature (ecology, toxicology, policy).
    - Emphasizes the role of awareness in driving environmental change.

#### 4.2 Indian Case Study: Chipko Movement

- **Context:** In the 1970s, villagers in Uttarakhand, led by women, hugged trees to prevent deforestation by loggers. The movement, rooted in Gandhian non-violence, spread across the Himalayan region.
- **Impact:**
  - Led to a 15-year ban on commercial logging in Uttarakhand (1980).
  - Inspired global forest conservation movements.
  - Highlighted the role of community action in environmental protection.
- **Relevance to Environmental Science:**
  - Reflects interdependence (forests support livelihoods, water cycles).
  - Demonstrates societal impacts and environmental awareness.

#### 4.3 Indian Case Study: National Action Plan on Climate Change (NAPCC)

- **Context:** Launched in 2008, NAPCC addresses climate change through eight missions, including National Solar Mission, National Water Mission, and Green India Mission.
- **Impact:**
  - Promotes renewable energy (e.g., 100 GW solar target).
  - Enhances water conservation and afforestation.
  - Aligns with global agreements like the Paris Agreement.
- **Relevance to Environmental Science:**
  - Illustrates the systems approach (integrating energy, water, and forests).
  - Highlights policy-making and sustainability.

#### 5. Potential Sample Questions

##### MCQ:

1. What is the primary objective of Environmental Science?

- (A) Promote industrialization
- (B) Study human-environment interactions
- (C) Focus on economic growth
- (D) Ignore ecological balance

*Answer: B*

*Explanation:* Environmental Science studies interactions between humans, ecosystems, and physical systems to promote sustainability.

2. **Assertion-Reason:**

Assertion (A): Sustainability is a core principle of Environmental Science.

Reason (R): It ensures resource availability for future generations.

- (A) Both A and R are true, and R explains A.
- (B) Both A and R are true, but R does not explain A.
- (C) A is true, R is false.
- (D) A is false, R is true.

*Answer: A*

*Explanation:* Sustainability focuses on resource conservation, and the reason correctly defines its goal.

### 3. Match the Following:

Principle	Example
A. Ecological Balance	1. Renewable energy adoption
B. Sustainability	2. Food chain stability
C. Interdependence	3. Pollination by bees
D. Systems Approach	4. Climate modeling
<i>Answer: A-2, B-1, C-3, D-4</i>	
<i>Explanation: Each principle is matched to a relevant example based on its definition.</i>	

## Structure and Composition of the Atmosphere

### Introduction

The atmosphere, a dynamic envelope of gases surrounding Earth, is a critical component of the planet's environmental systems. Understanding the **structure and composition of the atmosphere** is essential for grasping its role in climate regulation, weather patterns, and human-induced environmental changes. This topic is frequently tested in the exam, with questions covering atmospheric layers, gas compositions, greenhouse effects, ozone depletion, and air pollution, often requiring both conceptual clarity and applied knowledge.

### 1. Overview of the Atmosphere

#### 1.1 Definition and Importance

The **atmosphere** is a thin layer of gases enveloping Earth, held in place by gravity, extending from the surface to approximately 10,000 km. It plays a pivotal role in sustaining life by providing oxygen, regulating temperature, protecting against harmful solar radiation, and facilitating weather and climate systems.

#### • Functions of the Atmosphere:

- **Life Support:** Supplies oxygen (O<sub>2</sub>) for respiration and carbon dioxide (CO<sub>2</sub>) for photosynthesis.
- **Climate Regulation:** Absorbs and redistributes solar energy, maintaining Earth's temperature.
- **Protection:** Shields Earth from ultraviolet (UV) radiation via the ozone layer and from meteoroids through frictional burning.
- **Weather Systems:** Drives precipitation, wind, and storms through energy and water cycles.

#### • Significance in Environmental Science:

- Influences ecosystems, agriculture, and human health.
- Mediates global issues like climate change, air pollution, and ozone depletion.
- Critical for applications like weather forecasting, aviation, and satellite communication.

#### • Indian Context:

- The atmosphere affects monsoon patterns, vital for India's agriculture (e.g., 50% of India's farmland depends on monsoons).
- Urban air pollution in cities like Delhi and Mumbai highlights the need for atmospheric studies.

#### 1.2 Historical Understanding

• **Ancient Perspectives:** In India, Vedic texts like the *Rigveda* associated the atmosphere with deities like Vayu (wind) and Indra (rain), reflecting early awareness of its role.

#### • Scientific Advancements:

- **17th Century:** Evangelista Torricelli's barometer measured atmospheric pressure.
- **19th Century:** Discovery of atmospheric layers through balloon experiments.
- **20th Century:** Identification of greenhouse gases and ozone layer by scientists like Svante Arrhenius and G.M.B. Dobson.

• **Modern Era:** Satellite technology and remote sensing (e.g., ISRO's INSAT) enable precise atmospheric monitoring.

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## 2. Structure of the Atmosphere

The atmosphere is divided into five primary layers based on temperature, pressure, and composition: **troposphere, stratosphere, mesosphere, thermosphere, and exosphere**. These layers are separated by boundaries called “pauses” (e.g., tropopause).

### 2.1 Troposphere

- **Definition:** The lowest layer, extending from the Earth’s surface to 8–15 km (lower at poles, higher at equator).
- **Characteristics:**
  - **Temperature:** Decreases with altitude at  $\sim 6.5^\circ\text{C}/\text{km}$  (environmental lapse rate).
  - **Pressure:** Highest at sea level ( $\sim 1013$  mb), decreases with altitude.
  - **Composition:** Contains 75–80% of atmospheric mass, including water vapor, clouds, and pollutants.
- **Key Features:**
  - **Weather:** All weather phenomena (rain, storms, winds) occur here due to water vapor and convection.
  - **Tropopause:** Boundary with the stratosphere, where temperature stabilizes.
- **Environmental Role:**
  - Drives hydrological cycle through evaporation and precipitation.
  - Hosts air pollution (e.g., smog, particulate matter).
- **Indian Context:**
  - Monsoon clouds form in the troposphere, critical for India’s rainfall.
  - Delhi’s winter smog is confined to the troposphere due to temperature inversions.
- **Applications:**
  - Weather forecasting relies on tropospheric data (e.g., India Meteorological Department’s models).
  - Aviation operates within the upper troposphere.

### 2.2 Stratosphere

- **Definition:** Extends from the tropopause to  $\sim 50$  km.
- **Characteristics:**
  - **Temperature:** Increases with altitude due to ozone absorption of UV radiation.
  - **Pressure:** Low,  $\sim 1/1000$ th of sea-level pressure at top.
  - **Composition:** Dry, with high ozone ( $\text{O}_3$ ) concentration.
- **Key Features:**
  - **Ozone Layer:** Absorbs 90–99% of harmful UV radiation, protecting life.
  - **Stratopause:** Boundary with the mesosphere.
- **Environmental Role:**
  - Regulates Earth’s radiation balance.
  - Ozone depletion (e.g., Antarctic ozone hole) is a major concern.
- **Indian Context:**
  - India’s adherence to the Montreal Protocol reduced CFC emissions, aiding ozone recovery.
  - Stratospheric data informs climate models for India’s NAPCC.
- **Applications:**
  - High-altitude flights (e.g., jet aircraft) operate in the lower stratosphere.
  - Ozone monitoring via satellites (e.g., ISRO’s OCEANSAT).

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### 2.3 Mesosphere

- **Definition:** Extends from the stratopause to ~85 km.
- **Characteristics:**
  - **Temperature:** Decreases with altitude, reaching -90°C (coldest layer).
  - **Pressure:** Extremely low, ~1/100,000th of sea-level pressure.
  - **Composition:** Thin air, with trace gases and meteoric dust.
- **Key Features:**
  - **Meteor Burning:** Meteors burn up due to friction, producing shooting stars.
  - **Mesopause:** Boundary with the thermosphere.
- **Environmental Role:**
  - Minimal direct impact on surface environment but influences upper atmospheric dynamics.
- **Indian Context:**
  - ISRO's sounding rockets study mesospheric winds and temperatures.
- **Applications:**
  - Studies of noctilucent clouds (formed in mesosphere) aid climate research.

### 2.4 Thermosphere

- **Definition:** Extends from the mesopause to ~600 km.
- **Characteristics:**
  - **Temperature:** Increases sharply, reaching 1,500°C due to solar radiation absorption.
  - **Pressure:** Near vacuum, with sparse gas molecules.
  - **Composition:** Dominated by atomic oxygen (O), nitrogen (N<sub>2</sub>), and ionized particles.
- **Key Features:**
  - **Auroras:** Caused by charged particles interacting with gases.
  - **Ionosphere:** Overlaps with thermosphere, enabling radio communication.
  - **Thermopause:** Boundary with the exosphere.
- **Environmental Role:**
  - Absorbs high-energy solar radiation (X-rays, gamma rays).
  - Influences satellite orbits due to atmospheric drag.
- **Indian Context:**
  - ISRO's satellites (e.g., Chandrayaan) operate in the thermosphere.
  - Ionospheric studies support India's GPS system (NavIC).
- **Applications:**
  - Satellite communication and space exploration rely on thermospheric conditions.

### 2.5 Exosphere

- **Definition:** Outermost layer, extending from ~600 km to 10,000 km, merging with outer space.
- **Characteristics:**
  - **Temperature:** Extremely high but meaningless due to sparse particles.
  - **Pressure:** Virtually zero, resembling a vacuum.
  - **Composition:** Hydrogen (H<sub>2</sub>), helium (He), and occasional heavier molecules.
- **Key Features:**
  - **Transitional Zone:** Particles escape into space or are pulled back by gravity.
  - **No Defined Boundary:** Gradually fades into interplanetary space.
- **Environmental Role:**
  - Minimal direct impact but critical for understanding atmospheric escape.
- **Indian Context:**
  - Exospheric studies inform ISRO's deep-space missions (e.g., Mangalyaan).
- **Applications:**
  - Spacecraft design accounts for exospheric drag and radiation.

**Table 1: Characteristics of Atmospheric Layers**

Layer	Altitude (km)	Temperature	Key Features	Environmental Role
Troposphere	0–15	Decreases (~6.5°C/km)	Weather, clouds	Hydrological cycle, pollution
Stratosphere	15–50	Increases (ozone)	Ozone layer	UV protection, climate
Mesosphere	50–85	Decreases (-90°C)	Meteor burning	Upper atmospheric dynamics
Thermosphere	85–600	Increases (1,500°C)	Auroras, ionosphere	Satellite orbits, radiation
Exosphere	600–10,000	High (sparse)	Particle escape	Atmospheric escape

### 3. Composition of the Atmosphere

The atmosphere comprises **gases**, **aerosols**, and **particulates**, with distinct roles in environmental processes.

#### 3.1 Major Gases

- **Nitrogen (N<sub>2</sub>):** 78.08% of volume.
  - **Role:** Inert, dilutes oxygen, supports nitrogen cycle (e.g., fixation by bacteria).
  - **Environmental Impact:** Excess nitrogen from fertilizers causes eutrophication (e.g., algal blooms in Indian lakes).
- **Oxygen (O<sub>2</sub>):** 20.95%.
  - **Role:** Essential for respiration and combustion.
  - **Environmental Impact:** Depleted in polluted water bodies, affecting aquatic life.
- **Argon (Ar):** 0.93%.
  - **Role:** Inert, minimal environmental impact.
- **Carbon Dioxide (CO<sub>2</sub>):** 0.0407% (410 ppm, rising).
  - **Role:** Drives photosynthesis, regulates climate via greenhouse effect.
  - **Environmental Impact:** Increased CO<sub>2</sub> from fossil fuels causes global warming (e.g., India's coal plants contribute ~1.2 Gt CO<sub>2</sub> annually).

#### 3.2 Trace Gases

- **Methane (CH<sub>4</sub>):** ~1.8 ppm.
  - **Sources:** Wetlands, livestock, rice paddies, landfills.
  - **Impact:** 25 times more potent than CO<sub>2</sub> as a greenhouse gas.
  - **Indian Context:** Rice cultivation and cattle rearing contribute ~20% of India's CH<sub>4</sub> emissions.
- **Nitrous Oxide (N<sub>2</sub>O):** ~0.3 ppm.
  - **Sources:** Fertilizers, industrial processes.
  - **Impact:** 300 times more potent than CO<sub>2</sub>, depletes ozone.
- **Ozone (O<sub>3</sub>):** ~0.01–0.1 ppm (tropospheric), higher in stratosphere.
  - **Role:** Stratospheric ozone protects against UV; tropospheric ozone is a pollutant.
  - **Impact:** Ground-level ozone causes respiratory issues (e.g., Delhi's smog).
- **Chlorofluorocarbons (CFCs):** <1 ppb.
  - **Sources:** Refrigerants, aerosols (phased out under Montreal Protocol).
  - **Impact:** Deplete stratospheric ozone.

### 3.3 Aerosols and Particulates

- **Aerosols:** Tiny liquid/solid particles suspended in air (e.g., sulfate, nitrate, black carbon).
  - **Sources:** Volcanic eruptions, dust storms, industrial emissions, biomass burning.
  - **Impact:**
    - Reflect sunlight, cooling Earth (e.g., sulfate aerosols).
    - Absorb heat, warming atmosphere (e.g., black carbon).
    - Cause health issues (e.g., PM<sub>2.5</sub> in Delhi's air).
- **Particulates:**
  - **PM<sub>10</sub>:** Particles <10 μm, cause respiratory irritation.
  - **PM<sub>2.5</sub>:** Particles <2.5 μm, penetrate lungs, linked to cardiovascular diseases.
- **Indian Context:**
  - Biomass burning in Punjab and Haryana contributes to winter smog in northern India.
  - CPCB monitors PM<sub>2.5</sub> levels, with Delhi's annual average (~100 μg/m<sup>3</sup>) exceeding WHO limits (5 μg/m<sup>3</sup>).

**Table 2: Atmospheric Composition**

Component	Percentage/Concentration	Role	Environmental Impact
Nitrogen (N <sub>2</sub> )	78.08%	Nitrogen cycle	Eutrophication
Oxygen (O <sub>2</sub> )	20.95%	Respiration	Aquatic depletion
Carbon Dioxide (CO <sub>2</sub> )	0.0407% (410 ppm)	Photosynthesis, greenhouse	Global warming
Methane (CH <sub>4</sub> )	1.8 ppm	Greenhouse gas	Climate change
Ozone (O <sub>3</sub> )	0.01–0.1 ppm	UV protection, pollutant	Ozone depletion, health issues
PM <sub>2.5</sub>	Varies (e.g., 100 μg/m <sup>3</sup> in Delhi)	Air quality	Respiratory diseases

### 3.4 Physical and Chemical Properties

- **Physical Properties:**
  - **Density:** Decreases with altitude; densest in troposphere.
  - **Pressure:** 1013 mb at sea level, drops exponentially.
  - **Temperature:** Varies by layer (e.g., tropospheric lapse rate, stratospheric inversion).
- **Chemical Properties:**
  - **Reactivity:** Ozone reacts with CFCs, forming chlorine radicals that deplete O<sub>3</sub>.
  - **Photochemical Reactions:** UV radiation splits O<sub>2</sub> into atomic oxygen, forming O<sub>3</sub>.
  - **Acidity:** Acid rain forms when SO<sub>2</sub> and NO<sub>x</sub> react with water (e.g., Taj Mahal corrosion).
- **Indian Context:**
  - Acid rain in industrial areas (e.g., Korba, Chhattisgarh) damages crops and buildings.
  - Photochemical smog in Delhi results from NO<sub>x</sub> and VOCs under sunlight.

## 4. Human Impacts on the Atmosphere

### 4.1 Greenhouse Effect and Climate Change

- **Mechanism:** Greenhouse gases (CO<sub>2</sub>, CH<sub>4</sub>, N<sub>2</sub>O) trap infrared radiation, warming Earth.
- **Natural vs. Anthropogenic:**
  - Natural: Water vapor and CO<sub>2</sub> maintain Earth's temperature (~15°C vs. -18°C without).
  - Anthropogenic: Fossil fuel combustion, deforestation increase CO<sub>2</sub> and CH<sub>4</sub>.
- **Impacts:**
  - Global warming: 1.1°C rise since pre-industrial times (IPCC, 2023).
  - Extreme weather: Heatwaves, floods, and cyclones (e.g., 2023 Odisha cyclone).
- **Indian Context:**
  - India is the third-largest CO<sub>2</sub> emitter (~2.6 Gt/year), driven by coal power.
  - NAPCC's National Solar Mission aims to reduce emissions via renewables.

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## 4.2 Ozone Depletion

- **Mechanism:** CFCs release chlorine, which catalyzes O<sub>3</sub> breakdown in the stratosphere.
- **Impact:** Increased UV radiation, causing skin cancer and ecosystem damage.
- **Global Response:** Montreal Protocol (1987) phased out CFCs, leading to ozone hole recovery (projected full recovery by 2066).
- **Indian Context:**
  - India transitioned to HFCs under the Kigali Amendment (2016).
  - MoEFCC monitors ozone levels via ground stations and satellites.

## 4.3 Air Pollution

- **Sources:**
  - **Industrial:** SO<sub>2</sub>, NO<sub>x</sub>, and PM from factories.
  - **Vehicular:** CO, NO<sub>x</sub>, and VOCs from vehicles.
  - **Agricultural:** NH<sub>3</sub> from fertilizers, PM from stubble burning.
- **Impacts:**
  - Health: Respiratory diseases, ~1.7 million premature deaths in India annually (Lancet, 2020).
  - Environment: Acid rain, reduced crop yields.
- **Indian Context:**
  - Delhi's AQI often exceeds 300 (severe), driven by vehicles, industries, and stubble burning.
  - CPCB's National Clean Air Programme (NCAP) targets 20–30% PM reduction by 2024.

## 5. Applications of Atmospheric Studies

### 5.1 Climate Regulation

- **Role:** The atmosphere balances incoming solar radiation (shortwave) and outgoing infrared radiation (longwave).
- **Applications:**
  - Climate models predict temperature rises (e.g., IPCC's 1.5–4.5°C by 2100).
  - Carbon sequestration strategies (e.g., afforestation) reduce atmospheric CO<sub>2</sub>.
- **Indian Context:** Green India Mission promotes tree planting to sequester ~2.5 Gt CO<sub>2</sub> by 2030.

### 5.2 Weather Forecasting

- **Role:** Atmospheric data (pressure, temperature, humidity) inform weather predictions.
- **Applications:**
  - India Meteorological Department (IMD) uses satellites (e.g., INSAT-3D) for monsoon forecasts.
  - Early warnings for cyclones (e.g., Amphan, 2020) save lives.
- **Indian Context:** Accurate monsoon predictions support farmers in planning sowing and irrigation.

### 5.3 Air Quality Management

- **Role:** Monitoring pollutants (PM, NO<sub>x</sub>, SO<sub>2</sub>) guides mitigation.
- **Applications:**
  - CPCB's Air Quality Index (AQI) informs public health advisories.
  - NCAP funds cleaner technologies (e.g., scrubbers in power plants).
- **Indian Context:** Delhi's Graded Response Action Plan (GRAP) enforces measures like vehicle restrictions during high AQI.

**Table 3: Applications of Atmospheric Studies**

Application	Description	Indian Example
Climate Regulation	Balances radiation, reduces CO <sub>2</sub>	Green India Mission
Weather Forecasting	Predicts weather using atmospheric data	IMD's monsoon forecasts
Air Quality Management	Monitors and mitigates pollutants	NCAP, GRAP in Delhi

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## 6. Case Studies and Examples

### 6.1 Global Case Study: Ozone Hole Recovery

- **Context:** Discovered in 1985 over Antarctica, the ozone hole resulted from CFC emissions. The Montreal Protocol (1987) banned CFCs, leading to a gradual recovery.
- **Impact:**
  - Ozone hole area reduced from 29 million km<sup>2</sup> (2000) to 20 million km<sup>2</sup> (2023).
  - Full recovery projected by 2066 (WMO, 2022).
  - Reduced UV-related health risks (e.g., skin cancer).
- **Relevance:**
  - Highlights stratospheric ozone's role and human impacts.
  - Demonstrates global cooperation in environmental governance.

### 8.2 Indian Case Study: Delhi Air Pollution Crisis

- **Context:** Delhi's AQI frequently exceeds 300 (severe), driven by vehicular emissions, industrial pollutants, and stubble burning in Punjab/Haryana.
- **Impact:**
  - Health: ~1 million respiratory cases annually (AIIMS, 2022).
  - Environment: Reduced visibility, crop damage.
  - Economic: Losses of ~\$10 billion/year (World Bank, 2020).
- **Mitigation:**
  - NCAP targets PM reduction in 122 cities.
  - GRAP enforces measures like odd-even vehicle rules.
  - CPCB's SAMEER app provides real-time AQI data.
- **Relevance:**
  - Illustrates tropospheric pollution and health impacts.
  - Links to air quality management applications.

### 6.3 Indian Case Study: India's Monsoon and Tropospheric Dynamics

- **Context:** The Indian monsoon, driven by tropospheric heating and moisture, delivers 70–90% of India's annual rainfall (June–September).
- **Impact:**
  - Supports agriculture, contributing ~14% to GDP.
  - Variability causes floods (e.g., 2018 Kerala) or droughts (e.g., 2019 Maharashtra).
- **Mitigation:**
  - IMD's forecasts use tropospheric data from INSAT satellites.
  - National Water Mission (NAPCC) promotes water conservation.
- **Relevance:**
  - Highlights tropospheric weather processes.
  - Links to weather forecasting applications.

## 7. Potential Sample Questions

### MCQ:

4. Which atmospheric layer is responsible for auroras?  
(A) Stratosphere (B) Mesosphere (C) Thermosphere (D) Troposphere

*Answer: C*

*Explanation: Auroras occur in the thermosphere due to charged particle interactions.*

### 5. Assertion-Reason:

Assertion (A): The stratosphere contains the ozone layer.

Reason (R): Ozone absorbs UV radiation, increasing stratospheric temperature.

(A) Both A and R are true, and R explains A.

(B) Both A and R are true, but R does not explain A.

(C) A is true, R is false.

(D) A is false, R is true.

Answer: A

Explanation: The stratosphere hosts the ozone layer, and ozone's UV absorption causes temperature inversion.

### 6. Match the Following:

Gas	Role
A. Nitrogen	1. Greenhouse gas
B. Oxygen	2. UV protection
C. CO <sub>2</sub>	3. Respiration
D. Ozone	4. Nitrogen cycle
Answer: A-4, B-3, C-1, D-2	
Explanation: Each gas is matched to its primary environmental role.	

## Structure And Composition of the Hydrosphere

### Introduction

The hydrosphere, encompassing all water on Earth in its liquid, solid, and gaseous forms, is a cornerstone of environmental systems, driving climate, ecosystems, and human survival. The **structure and composition of the hydrosphere** covers water distribution, physical and chemical properties, the hydrological cycle, and human impacts like pollution and overexploitation. This topic is heavily tested, with questions on water resources, pollution, and India-specific issues like monsoon variability and groundwater depletion.

### 1. Overview of the Hydrosphere

#### 1.1 Definition and Importance

The **hydrosphere** is the total mass of water on Earth, including oceans, rivers, lakes, groundwater, glaciers, wetlands, and atmospheric water vapor. Covering ~71% of Earth's surface, it is essential for life, climate regulation, and socio-economic systems.

#### • Functions of the Hydrosphere:

- **Life Support:** Provides water for drinking, agriculture, and ecosystems (e.g., 97% of India's agriculture depends on water availability).
- **Climate Regulation:** Oceans store heat, moderating global temperatures; water vapor influences weather patterns.
- **Nutrient Cycling:** Transports nutrients (e.g., nitrogen, phosphorus) through rivers and groundwater.
- **Economic Role:** Supports fisheries, hydropower, and navigation (e.g., India's Inland Waterways Authority promotes river transport).

#### • Significance in Environmental Science:

- Addresses water scarcity, pollution, and climate change impacts (e.g., sea-level rise).
- Informs policies like India's National Water Mission (NAPCC) and global frameworks like SDG 6 (Clean Water and Sanitation).

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- **Indian Context:**

- Monsoons deliver 70–90% of India’s annual rainfall, shaping water availability.
- Overexploitation of groundwater in Punjab and Haryana threatens agricultural sustainability.
- Ganga River pollution highlights the need for hydrospheric studies.

### 1.2 Historical Understanding

- **Ancient India:** Vedic texts (*Rigveda, Atharvaveda*) revered water as sacred, with Varuna as the deity of oceans and rivers. Ancient systems like stepwells (e.g., Rani ki Vav, Gujarat) managed water resources.
- **Global Milestones:**
  - **17th Century:** Evangelista Torricelli’s studies on fluid dynamics laid foundations for hydrology.
  - **19th Century:** John Dalton’s work on evaporation and condensation advanced hydrological cycle understanding.
  - **20th Century:** Development of groundwater models and remote sensing (e.g., GRACE satellites) for water resource assessment.
- **Modern Era:** India’s ISRO satellites (e.g., Resourcesat) monitor water bodies, while global initiatives like the IPCC address water-climate linkages.

### 1.3 Components of the Hydrosphere

- **Oceans:** 97.5% of Earth’s water, covering 361 million km<sup>2</sup>.
- **Freshwater (2.5%):**
  - Glaciers/Ice Caps: 68.7% of freshwater, primarily in Antarctica and Greenland.
  - Groundwater: 30.1%, stored in aquifers.
  - Surface Water: 1.2% (lakes, rivers, wetlands).
- **Atmospheric Water Vapor:** <0.001% but critical for precipitation.
- **Indian Context:**
  - Himalayan glaciers (e.g., Gangotri) feed rivers like the Ganga and Brahmaputra.
  - India’s 7,517 km coastline supports marine ecosystems and fisheries.

**Table 1: Global Water Distribution**

Component	Percentage of Total Water	Volume (km <sup>3</sup> )	Role
Oceans	97.5%	1,338,000,000	Climate regulation, biodiversity
Glaciers/Ice Caps	1.74%	24,064,000	Freshwater storage, river flow
Groundwater	0.76%	10,530,000	Irrigation, drinking water
Surface Water	0.03%	374,000	Ecosystems, agriculture
Atmospheric Vapor	<0.001%	12,900	Precipitation, weather

## 2. Structure of the Hydrosphere

The hydrosphere is structured into distinct components, each with unique physical and ecological roles.

### 2.1 Oceans

- **Definition:** Vast bodies of saline water, covering 71% of Earth’s surface (Pacific, Atlantic, Indian, Southern, Arctic).
- **Characteristics:**
  - **Volume:** ~1.34 billion km<sup>3</sup>, 97.5% of total water.
  - **Depth:** Average 3.7 km, maximum 11 km (Mariana Trench).
  - **Salinity:** ~35 g/L (3.5%), varying by region (e.g., lower in coastal areas due to river inflows).
- **Physical Properties:**
  - **Temperature:** Surface 0–30°C, deep ocean ~2°C.
  - **Density:** 1.025 g/cm<sup>3</sup>, influenced by salinity and temperature.

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- **Environmental Role:**
    - Absorbs 90% of excess heat from global warming (IPCC, 2023).
    - Supports marine biodiversity (e.g., coral reefs, fisheries).
    - Drives thermohaline circulation, influencing global climate.
  - **Indian Context:**
    - Indian Ocean influences monsoon patterns via the Indian Ocean Dipole (IOD).
    - Overfishing in the Arabian Sea threatens marine ecosystems.
  - **Applications:**
    - Desalination plants (e.g., Chennai's Minjur plant) provide freshwater.
    - Marine protected areas (e.g., Gulf of Mannar) conserve biodiversity.

## 2.2 Rivers

- **Definition:** Flowing bodies of freshwater, transporting water and sediments to oceans or lakes.
- **Characteristics:**
  - **Volume:** ~2,120 km<sup>3</sup> globally, <0.01% of total water.
  - **Length:** Major rivers like the Ganga (~2,525 km) and Brahmaputra (~2,900 km).
- **Physical Properties:**
  - **Flow Rate:** Varies (e.g., Ganga's discharge: 38,000 m<sup>3</sup>/s during monsoons).
  - **Turbidity:** High in monsoon season due to sediment load.
- **Environmental Role:**
  - Supports riparian ecosystems (e.g., Sundarbans mangroves).
  - Transports nutrients, shaping soil fertility.
- **Indian Context:**
  - Ganga supports 400 million people but faces pollution (e.g., 3 billion liters/day sewage).
  - Namami Gange (2014) aims to clean the river by 2030.
- **Applications:**
  - Hydropower (e.g., Bhakra Dam on Sutlej).
  - Irrigation (e.g., Indira Gandhi Canal in Rajasthan).

## 2.3 Lakes

- **Definition:** Standing bodies of freshwater or saline water (e.g., freshwater: Dal Lake; saline: Chilika Lake).
- **Characteristics:**
  - **Volume:** ~87,000 km<sup>3</sup> globally, ~0.01% of total water.
  - **Surface Area:** Large lakes like Loktak (Manipur) cover ~287 km<sup>2</sup>.
- **Physical Properties:**
  - **Stratification:** Layers based on temperature/density (epilimnion, hypolimnion).
  - **Clarity:** Varies with algae and sediments.
- **Environmental Role:**
  - Regulates local climates (e.g., Bhopal's Upper Lake cools the city).
  - Supports biodiversity (e.g., Chilika's Irrawaddy dolphins).
- **Indian Context:**
  - Eutrophication in Dal Lake due to sewage and tourism.
  - National Lake Conservation Plan (NLCP) restores lakes like Powai (Mumbai).
- **Applications:**
  - Fisheries (e.g., Chilika produces 14,000 tonnes fish/year).
  - Tourism (e.g., Pangong Lake, Ladakh).

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## 2.4 Groundwater

- **Definition:** Water stored in underground aquifers, accessed via wells or springs.
- **Characteristics:**
  - **Volume:** ~10.5 million km<sup>3</sup>, 30.1% of freshwater.
  - **Recharge Rate:** Slow (years to centuries), depending on rainfall and geology.
- **Physical Properties:**
  - **Porosity:** Ability of rock to hold water (e.g., sandstone > clay).
  - **Permeability:** Ease of water flow (e.g., gravel > shale).
- **Environmental Role:**
  - Supplies 50% of India's irrigation water.
  - Maintains river base flow during dry seasons.
- **Indian Context:**
  - Overexploitation in Punjab (150% of sustainable yield) causes aquifer depletion.
  - Atal Bhujal Yojana (2020) promotes groundwater recharge.
- **Applications:**
  - Drinking water (e.g., 80% of rural India relies on groundwater).
  - Industrial use (e.g., textile industries in Gujarat).

## 2.5 Glaciers and Ice Caps

- **Definition:** Frozen water in glaciers, ice caps, and polar ice sheets.
- **Characteristics:**
  - **Volume:** ~24 million km<sup>3</sup>, 68.7% of freshwater.
  - **Location:** Himalayas, Antarctica, Greenland.
- **Physical Properties:**
  - **Density:** 0.917 g/cm<sup>3</sup> (ice vs. 1 g/cm<sup>3</sup> liquid water).
  - **Movement:** Glaciers flow under gravity (e.g., Gangotri retreats ~20 m/year).
- **Environmental Role:**
  - Feeds perennial rivers (e.g., Indus, Ganga).
  - Reflects sunlight, reducing global warming (albedo effect).
- **Indian Context:**
  - Himalayan glaciers melting at 0.5–1 m/year due to climate change.
  - National Mission for Sustaining Himalayan Ecosystem (NAPCC) monitors glaciers.
- **Applications:**
  - Hydropower (e.g., glaciers feed Tehri Dam).
  - Climate research (e.g., ice core studies).

## 2.6 Wetlands

- **Definition:** Transitional ecosystems with saturated soils (e.g., marshes, swamps, bogs).
- **Characteristics:**
  - **Area:** ~1.2 million km<sup>2</sup> globally, ~0.15 million km<sup>2</sup> in India (e.g., Sundarbans).
  - **Hydrology:** Seasonal flooding or permanent saturation.
- **Environmental Role:**
  - Filters pollutants, improving water quality.
  - Supports biodiversity (e.g., Keoladeo's migratory birds).

- **Indian Context:**

- Ramsar sites like Chilika and Sundarbans face threats from urbanization.
- National Wetland Conservation Programme protects 75 sites.

- **Applications:**

- Flood control (e.g., Kolkata's East Wetlands).
- Carbon sequestration (wetlands store 30% of soil carbon).

**Table 2: Hydrosphere Components and Characteristics**

Component	Volume (km <sup>3</sup> )	Physical Properties	Environmental Role	Indian Example
Oceans	1,338,000,000	Salinity: 35 g/L, Density: 1.025 g/cm <sup>3</sup>	Climate regulation	Indian Ocean monsoon
Rivers	2,120	Flow rate, turbidity	Nutrient transport	Ganga River
Lakes	87,000	Stratification, clarity	Biodiversity	Dal Lake
Groundwater	10,530,000	Porosity, permeability	Irrigation	Punjab aquifers
Glaciers	24,064,000	Density: 0.917 g/cm <sup>3</sup>	River flow	Gangotri Glacier
Wetlands	Varies	Saturated soils	Pollutant filtration	Sundarbans

### 3. Composition of the Hydrosphere

The hydrosphere's chemical composition includes water (H<sub>2</sub>O) and dissolved substances, varying by component.

#### 3.1 Chemical Composition

- **Water Molecule (H<sub>2</sub>O):**

- Polar structure enables solvent properties, dissolving salts and nutrients.
- pH: ~7 (neutral) in pure water, altered by pollutants (e.g., acid rain: pH 4–5).

- **Dissolved Substances:**

- **Salts:** Sodium (Na<sup>+</sup>), chloride (Cl<sup>-</sup>) dominate oceans (salinity: 35 g/L).
- **Nutrients:** Nitrogen (N), phosphorus (P) support aquatic ecosystems.
- **Gases:** Dissolved oxygen (DO, ~8 mg/L in freshwater), CO<sub>2</sub> (~0.5 mg/L).
- **Pollutants:** Heavy metals (e.g., lead, mercury), pesticides, nitrates.

- **Indian Context:**

- Ganga's high biochemical oxygen demand (BOD, ~30 mg/L vs. 5 mg/L standard) indicates pollution.
- Coastal waters near Mumbai have elevated heavy metals from industrial effluents.

#### 3.2 Salinity

- **Definition:** Concentration of dissolved salts, measured in g/L or parts per thousand (ppt).

- **Variation:**

- Oceans: 33–37 ppt (Indian Ocean: ~35 ppt).
- Estuaries: 0.5–30 ppt (e.g., Hooghly estuary).
- Freshwater: <0.5 ppt (e.g., Ganga upstream).

- **Factors:**

- Evaporation increases salinity (e.g., Arabian Sea).
- River inflows decrease salinity (e.g., Bay of Bengal).