

## Acid Rain & Ocean Acidification

### 1. Acid Rain (Acid Deposition)

#### 1.1 Meaning

- Acid rain refers to **precipitation with a pH < 5.6**
- Includes:
  - Rain
  - Snow
  - Fog
  - Mist
- Normal rainwater is slightly acidic due to **carbonic acid (CO<sub>2</sub> + H<sub>2</sub>O)**, but **not acid rain**

#### 1.2 Causes

- Emission of **acidic gases**:
  - **Sulphur dioxide (SO<sub>2</sub> / SO<sub>x</sub>)**
  - **Nitrogen oxides (NO, NO<sub>2</sub>, N<sub>2</sub>O collectively NO<sub>x</sub>)**
- Released mainly from:
  - Fossil fuel burning
  - Thermal power plants
  - Smelting industries
  - Vehicular emissions

#### 1.3 pH Scale (Prelims Favourite)

- Range: **0–14**
- **7 → Neutral**
- **<7 → Acidic**
- **>7 → Basic**
- Each unit decrease in pH → **10× increase in acidity**

#### 1.4 Gases Responsible for Acid Rain

Acidic Gases	Major Sources
SO <sub>x</sub>	Coal burning, smelting, fertiliser industry, volcanoes
NO <sub>x</sub>	Fossil fuels, power plants, lightning, biomass burning

#### 1.5 Types of Acid Deposition

##### A. Wet Deposition

- Acidic rain, snow, fog, mist

- Directly affects soil, crops, and lakes

### B. Dry Deposition

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- Acidic gases & particles settle on:
  - Buildings
  - Vegetation
  - Soil
- Washed down later by rain → **more acidic runoff**
- Nearly **50% acidity** comes via dry deposition

### 1.6 Chemistry of Acid Rain (Simplified)

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- I. Emission of SO<sub>x</sub> & NO<sub>x</sub>
- II. Sunlight forms photo-oxidants (e.g., ozone)
- III. Oxidation reactions occur
- IV. Formation of:
  - **Sulphuric acid (H<sub>2</sub>SO<sub>4</sub>)**
  - **Nitric acid (HNO<sub>3</sub>)**
- V. Acidic ions fall as wet/dry deposition

### 2. Harmful Effects of Acid Rain

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#### 2.1 On Human Health

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- Eye, skin, and respiratory irritation
- Aggravates:
  - Bronchitis
  - Emphysema
  - Lung cancer (indirectly)

#### 2.2 On Soil

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- Leaching of nutrients:
  - Calcium
  - Magnesium
  - Potassium
- Release of toxic metals:
  - Aluminium
  - Lead
- **Indian soils** → mostly alkaline → **better buffering capacity**

#### 2.3 On Aquatic Ecosystems

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- pH change kills:
  - Fish eggs
  - Amphibian larvae
- Heavy metals are released into water
- Microbial productivity declines

## 2.4 On Terrestrial Plants

- Leaf cuticle damage
- Reduced photosynthesis
- Metal toxicity through roots

## 2.5 On Microorganisms

- Shift from:
  - **Bacteria-dominated** → **Fungi-dominated soil**
- Slower decomposition
- Reduced soil fertility

## 2.6 On Buildings & Monuments

- Marble & limestone react with acids
- Causes:
  - Flaking
  - Black crust formation
- Example:
  - **Taj Trapezium Zone – “Marble Cancer”**

## 2.7 Acid Rain Regions

- **Global:**
  - Scandinavia
  - NE USA
  - Canada
  - NW Europe
- **India:**
  - First reported: **Mumbai (1974)**
  - NE India, coastal Karnataka, Kerala, Odisha, WB, Bihar

## 2.8 Control Measures

- Low-sulphur fuel
- Washed coal
- Use of natural gas
- **Buffering (Liming):**
  - CaO / CaCO<sub>3</sub> added to acidified lakes

## 3. Ocean Acidification

### 3.1 Meaning

- Ongoing **decrease in ocean pH**

- Due to the absorption of **atmospheric CO<sub>2</sub>**
- Called:
  - “**Evil twin of global warming**”
  - “**Other CO<sub>2</sub> problem**”

### 3.2 Chemical Process

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- I. CO<sub>2</sub> dissolves in seawater
- II. Forms **carbonic acid (H<sub>2</sub>CO<sub>3</sub>)**
- III. Produces:

- Bicarbonate (HCO<sub>3</sub><sup>-</sup>)
- Hydrogen ions (H<sup>+</sup>)
- IV. pH decreases → acidity increases

### 3.3 Major Contributors

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- Fossil fuel emissions
- Deforestation
- **Eutrophication:**
  - Plankton blooms → decomposition → CO<sub>2</sub> increase

## 4. Effects of Ocean Acidification

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### 4.1 On Marine Chemistry

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- Decrease in **carbonate ions (CO<sub>3</sub><sup>2-</sup>)**
- Difficulty in forming:
  - Calcium carbonate (CaCO<sub>3</sub>)

### 4.2 On Marine Life

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- Affects **calcifying organisms:**
  - Corals
  - Molluscs
  - Calcareous plankton
- Leads to:
  - Coral bleaching
  - Weak shells
  - Reduced growth

### 4.3 On Fisheries

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- Damage to the base of the food web
- Threatens:
  - Arctic fisheries
  - Commercial fisheries

### 4.4 On Climate Regulation

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- Oceans absorb ~1/3rd anthropogenic CO<sub>2</sub>
- Acidification reduces buffering capacity

### 5. Artificial Cloud Seeding

- Technique to induce rainfall
- Uses:
  - **Silver iodide**
  - Dry ice
- Encourages ice crystal formation in clouds

Aspire with Ram IAS