

Radiation Ecology & Global Environmental Changes

Radiation Ecology studies the effects of ionizing and non-ionizing radiation on the environment, ecosystems, and organisms. It also overlaps with global environmental changes that impact the Earth due to radiation-related and other human-induced activities.

- Ozone depletion
 - Acid rain
 - Greenhouse effect & global warming
 - Kyoto Protocol
 - Radioactive leakage
 - Environmental laws
-

I. Ozone Depletion

Ozone Layer:

- Located in the **stratosphere** (~10–50 km above Earth).
- Protects life by absorbing harmful **ultraviolet (UV-B)** radiation from the sun.

Causes of Ozone Depletion:

- **Chlorofluorocarbons (CFCs)** from aerosols, refrigeration, and ACs.
- Halons, carbon tetrachloride, methyl chloroform.

Process:

CFCs → UV exposure → release of chlorine → Cl breaks down ozone ($O_3 \rightarrow O_2$).

Effects:

- Increased UV-B exposure.
- Skin cancer, cataracts.
- Damage to crops, phytoplankton, and materials (e.g., plastics).

Control:

- **Montreal Protocol (1987)**: International treaty to phase out ozone-depleting substances (ODS).
-

II. Acid Rain

Definition:

Rainfall with **pH < 5.6**, formed when **sulfur dioxide (SO₂)** and **nitrogen oxides (NO_x)** combine with atmospheric water.

Sources:

- Burning fossil fuels (coal, oil).
- Vehicle exhaust.
- Industrial emissions.

Chemical Reactions:

$SO_2 + H_2O \rightarrow H_2SO_4$ (sulfuric acid)

$NO_x + H_2O \rightarrow HNO_3$ (nitric acid)

Effects:

- Acidification of lakes and soil.

- Damage to crops and forests (e.g., Black Forest in Germany).
- Corrosion of buildings and monuments.
- Leaching of toxic metals into groundwater.

Control:

- Scrubbers in smokestacks.
 - Use of low-sulfur fuel.
 - Clean energy alternatives.
-

III. Greenhouse Effect & Global Warming

Greenhouse Effect:

Natural phenomenon where greenhouse gases (GHGs) trap solar radiation, warming Earth's surface.

Major GHGs:

- Carbon dioxide (CO₂)
- Methane (CH₄)
- Nitrous oxide (N₂O)
- Water vapor
- Ozone (O₃)

Global Warming:

Enhanced greenhouse effect due to excessive human-induced GHG emissions, leading to **rise in Earth's average temperature.**

Sources of GHGs:

- Fossil fuel burning
- Deforestation
- Agriculture (e.g., paddy fields, livestock)
- Landfills

Impacts:

- Melting glaciers and rising sea levels
 - Extreme weather (heatwaves, floods, droughts)
 - Shifts in agriculture and ecosystems
 - Coral bleaching and biodiversity loss
 - Increased vector-borne diseases (malaria, dengue)
-

IV. Kyoto Protocol (1997)

Definition:

An international treaty under the **United Nations Framework Convention on Climate Change (UNFCCC)** that legally binds developed countries to reduce GHG emissions.

Key Points:

- Targets: Reduce emissions by **5.2% below 1990 levels** (by 2012).
- **Carbon credits** and **Clean Development Mechanism (CDM)** introduced.
- USA did **not ratify** the protocol.

Successor:

Paris Agreement (2015) – A broader, non-binding commitment from all countries to limit warming to **below 2°C**.

V. Radioactivity Leakage**Definition:**

Uncontrolled release of radioactive materials into the environment from nuclear power plants, weapons testing, or accidents.

Common Radioactive Substances:

- Iodine-131
- Cesium-137
- Strontium-90
- Plutonium-239

Examples of Major Nuclear Disasters:

1. **Chernobyl (Ukraine, 1986)** – Explosion and fire released massive radioactive material.
2. **Fukushima Daiichi (Japan, 2011)** – Earthquake and tsunami caused reactor meltdown.

Effects:

- Genetic mutations and cancer.
- Soil and water contamination.
- Bioaccumulation and biomagnification.
- Long-term ecological damage (up to centuries).

Control Measures:

- Safe reactor design.
 - Radiation shields and detectors.
 - Emergency response protocols.
 - International atomic energy regulations.
-

VI. Environmental Laws and Agreements**International Agreements:**

- **Montreal Protocol (1987)** – Ozone layer protection.
- **Kyoto Protocol (1997)** – GHG reduction.
- **Paris Agreement (2015)** – Climate action by all countries.
- **Stockholm Convention** – Restricts persistent organic pollutants.

Important Environmental Laws in Pakistan

- Pakistan Environmental Protection Act (PEPA), 1997
- Forest Act, 1927 (provincially amended)
- Punjab Wildlife Act, 1974
- Sindh Wildlife Protection Ordinance, 1972
- Balochistan Wildlife Protection Act, 2014
- Khyber Pakhtunkhwa Wildlife and Biodiversity Act, 2015
- National Conservation Strategy (NCS), 1992

- Climate Change Act, 2017
 - Hazardous Substances Rules, 2003
-

Conclusion

Radiation ecology and global environmental changes are deeply interconnected. Human-induced activities such as the burning of fossil fuels, use of harmful chemicals, and nuclear activities are pushing the planet towards **climate crisis, ozone depletion, and ecological instability**. Global cooperation and strict **environmental laws and protocols** are essential to protect the Earth's ecosystems and future generations.