IJNRD.ORG ISSN : 2456-4184
INTERNATIONAL JOURNAL OF NOVEL RESEARCH AND DEVELOPMENT (IJNRD) | IJNRD.ORG
An International Open Access, Peer-reviewed, Refereed Journal

OZONE LAYER DEPLETION: CAUSES, EFFECTS AND SOLUTIONS

Hussain Ahmed Barbhuiya, Assistant Professor, Department of Physics
Moinul Hoque Choudhury Memorial Science College, Hailakandi, Assam, India
Email-hussainbarbhuiya9@gmail.com, Ph No-9435179512

Abstract:

The ozone layer is a fragile shield of gas located in the stratosphere, approximately 10 to 50 kilometers above Earth's surface. It plays a critical role in protecting life on Earth by absorbing the majority of the sun's harmful ultraviolet (UV) radiation. However, over the past few decades, this protective layer has been thinning—a phenomenon known as ozone layer depletion. Ozone layer depletion has posed a serious threat to human health and the environment since its discovery in the late 20th century. As a result of widespread international concern and scientific understanding, significant efforts have been made to mitigate this environmental crisis. This paper explores the causes, consequences and key strategies & actions that have been instrumental in reducing ozone-depleting substances (ODS) and promoting the recovery of the ozone layer.

Key word: Ozone, UV Radiation, Ecosystem, Climate Change,

1. Introduction:

First theoretical explanation of how ozone is formed and destroyed in the stratosphere studied by Sydney Chapman in 1930 and published *"A Theory of Upper Atmospheric Ozone". He demonstrated* that ozone absorbs **ultraviolet radiation**, especially UV-B and UV-C and established the fundamental role of ozone in protecting Earth from UV radiation. Key milestone for protecting ozone layer signed in 1987 as Montreal Protocol as major environmental success story to phase out the production and consumption of ozone-depleting substances (ODS), especially **CFCs**, **Halons**, and **other related chemicals**.

The ozone layer is composed primarily of ozone (O_3) molecules, which consist of three oxygen atoms. This layer is most concentrated in the lower portion of the stratosphere and is vital for shielding life on Earth from UV-B and UV-C radiation. Without this layer, increased levels of UV radiation would lead to higher rates of skin cancer, cataracts, and other health and environmental problems.

2. Causes of Ozone Layer Depletion:

(a) Chlorofluorocarbons (CFCs)-CFCs are synthetic compounds once widely used in refrigeration, air conditioning, aerosol sprays, and foam-blowing agents. When released into the atmosphere, they rise slowly to the stratosphere, where UV radiation breaks them down, releasing chlorine atoms. A single chlorine atom can destroy over 100,000 ozone molecules.

UV rays break CFCs, releasing chlorine atoms **(Cl)**. - **Cl_3F + UV light → Cl + CCl_2F**

Free chlorine atoms react with ozone **(O_3)-** **$Cl + O_3 \rightarrow ClO\bullet + O_2$**

The chlorine monoxide (ClO) then reacts with another O atom:-**$ClO\bullet + O \rightarrow Cl\bullet + O_2$**

The chlorine atom is free again, ready to destroy more ozone.

(b) Halons and Other Ozone-Depleting Substances (ODS)-Halons, used in fire extinguishers, along with other substances such as carbon tetrachloride and methyl chloroform, also contribute to ozone depletion by releasing bromine and chlorine atoms into the atmosphere. The uses of ODS and their Ozone-Depleting Substances (ODS) are human-made chemicals that damage the ozone layer by releasing halogen atoms (mainly chlorine and bromine) when they reach the stratosphere. These atoms break down **ozone (O_3)** molecules, thinning the protective layer that blocks harmful UV radiation.

ODS Name	Main Use(s)	Ozone-Depleting Element
Hydrochlorofluorocarbons	Transitional refrigerants replacing CFCs	Chlorine (less damaging than CFCs)
Halons/Brominated hydrocarbons	Fire extinguishers (especially in aircraft, data centers)	Bromine
Carbon Tetrachloride	Solvent, cleaning agent in industry	Chlorine
Methyl Chloroform	Degreasing agent for metals	Chlorine
Methyl Bromide	Pesticide/fumigant for crops and soil	Bromine

(c) Nitrous Oxide- Agricultural activities that release nitrous oxide also contribute to ozone layer depletion. Though less destructive than CFCs, nitrous oxide is now the leading ozone-depleting emission due to reductions in CFC use.

Nitrous oxide is a significant ozone-depleting substance **(ODS)** — and in fact, it is now the largest ozone-depleting emission still being released into the atmosphere. Nitrous oxide is emitted at ground level**,** mainly from agriculture and slowly rises into the stratosphere (similar to CFCs). In the stratosphere, N_2O is broken down by UV radiations **s**ome of it breaks into harmless nitrogen and oxygen, but a portion reacts with *excited oxygen atoms (O)*, forming nitric oxide (NO). NO reacts with ozone (O_3) in a catalytic cycle, similar to chlorine. The reaction is $NO + O_3 \rightarrow NO_2 + O_2$ again $NO_2 + O \rightarrow NO + O_2$.

3. Effects of Ozone Layer Depletion:

A. Increased UV Radiation-

UV radiation (Ultraviolet radiation) is a type of electromagnetic radiation that comes mainly from the sun. UV Radiation and Ozone Depletion are closely linked because the ozone layer in Earth's stratosphere acts as a protective shield that absorbs most of the Sun's harmful ultraviolet (UV) radiation—especially UV B and UV C**,** which are the most dangerous to living organisms. Ozone depletion leads to higher levels of UV radiation reaching the Earth's surface, increasing the incidence of skin cancer, sunburns, and cataracts in humans. It also affects animals, particularly those in marine ecosystems. Increased UV radiation causes: skin cancers and cataracts in humans, DNA damage in animals and plants, Reduced phytoplankton growth (base of aquatic food chains) and Slower crop growth and reduced agricultural productivity.

B. Environmetal Impact-

The environmental effects of ozone layer depletion are wide-ranging and serious, because increased ultraviolet (especially UVB) radiation at Earth's surface harms living organisms, ecosystems, and natural processes. Here's an in-depth look at the environmental consequences:

C. Effects on Terrestrial Ecosystems-

Plant - The Growth and development of Plants are affected by UV radiations such as UVB radiation can damage plant DNA, proteins, and cellular structures, It affects photosynthesis by damaging chloroplasts, reducing plant productivity, Some crops show reduced yield, such as soybeans, wheat, and rice also UVB can alter flowering times, leaf structure, and nutrient cycles, which may disrupt plant-pollinator relationships.

Forest - Forest Ecosystems are affected due to UV radiation such as Young seedlings and certain tree species are more sensitive to UVB, Altered growth patterns in trees can affect forest structure, biodiversity, and carbon sequestration capacity

Aquatic- Aquatic ecosystem largely depends on Phytoplankton and Zooplankton. Phytoplankton are microscopic, photosynthetic organisms that live in aquatic environments—**oceans, seas, and** freshwater bodies. They are often called the "grass of the sea" because they function like land plants: they use sunlight, carbon dioxide (CO_2), and nutrients to produce energy through photosynthesis**.** Zooplankton is tiny animal-like organism**'s** key part of the **aquatic food chain.** UV B damages the DNA of Phytoplankton and restrains photosynthesis, leading to reduce growth and reproduction and disruption of the marine food chain.

Effects on Animals-UVB can cause eye damage (cataracts, retinal lesions) in wild animals. It affects immune function in birds, amphibians, and mammals, making them more vulnerable to disease. Eggs laid by Amphibians (frogs, salamanders) in shallow water are exposed to UV B impact in developmental deformities and reduced hatching success

D. Ecosystem Imbalances –

Even small shifts in UV exposure -especially increases in UVB radiation can significantly alter species interactions in ecosystems. This is because UV radiation affects individual organisms in different ways, and those effects ripple through food webs and ecological relationships. Altered predator-prey dynamics due to increased UV radiation (especially UVB) is one of the most critical ways that ozone layer depletion can destabilize ecosystems. When UV levels change, they don't affect all organisms equally—some species are more sensitive than others. This uneven impact can disrupt the delicate balance between predators and their prey. Increased UVB radiation can significantly alter how organisms compete for resources like light, nutrients, food, and habitat. These changes occur because UV doesn't affect all species equally, giving some an advantage and pushing others to decline or adapt. Spread of invasive species better adapted to UV. When UV levels rise, some invasive species especially those with greater UV resistance gain a competitive edge and can expand rapidly, disrupting ecosystems.

E. Climate Change-

Although ozone layer depletion and climate change are caused by different processes, they are closely connected and influence each other in complex ways. Both are serious environmental issues with global impacts on health, ecosystems, and weather patterns. Climate change mainly driven by Green House Gases GHGs by taping heat in the troposphere leading to global warming and changing climate patterns. Some ODS are also potent greenhouse gases. The relationship between ozone depletion and climate change is complex but interconnected.

4. Global Response and Recovery:

A. The Montreal Protocol-

Montreal Protocol adopted in 1987, the ODS Substances that Deplete the Ozone Layer is an international treaty designed to phase out the production and consumption of ODS. It is considered one of the most successful environmental agreements in history, with universal ratification by all UN member states.

B. Vienna Convention (1985)-

This foundational agreement laid the groundwork for international cooperation on ozone protection. It provided the scientific framework that led to the Montreal Protocol (UNEP, 2020).

C. Recovery Progress-

Thanks to the Montreal Protocol, ozone-depleting emissions have significantly declined. According to the United Nations, the ozone layer is on track to recover by the middle of the 21st century, with the Antarctic ozone hole expected to return to 1980 levels by around 2060.

D. Scientific Monitoring and Research-

Ongoing atmospheric monitoring by organizations such as NASA, NOAA, and the World Meteorological Organization (WMO) has been essential in tracking the effectiveness of mitigation efforts. These studies show measurable improvements in ozone concentrations and a decline in the size of the Antarctic ozone hole (WMO, 2022).

E. Role of Individuals-

Though global treaties and industry shifts are primary drivers, individuals can also help mitigate ozone depletion by properly servicing and disposing of appliances like refrigerators and AC units, avoiding illegal ODS-based products, spreading awareness about ozone protection and support and advocate for policies that protect the environment.

5. Conclusion:

Ozone layer depletion remains a critical environmental issue, but it also represents a success story of global cooperation and environmental action. While the ozone layer is slowly recovering, continued vigilance and commitment are essential. By understanding its importance and supporting sustainable practices, we can ensure that this vital shield remains intact for future generations. The mitigation of ozone layer depletion is a global success story rooted in international cooperation, technological innovation, and informed public action. Policies like the Montreal Protocol have not only reduced harmful emissions but have also set a precedent for addressing other global environmental issues. With sustained commitment and adaptive strategies, the ozone layer is expected to fully recover soon in near future.

6. References:

- EPA. (2023). *Ozone-depleting substances*. United States Environmental Protection Agency. https://www.epa.gov/ods
- Intergovernmental Panel on Climate Change (IPCC). (2021). *Climate Change 2021: The Physical Science Basis*. Cambridge University Press.
- Ravishankara, A. R., Daniel, J. S., & Portmann, R. W. (2009). Nitrous oxide (N_2O): The dominant ozone-depleting substance emitted in the 21st century. *Science*, *326*(5949), 123-125. https://doi.org/10.1126/science.1176985
- United Nations Environment Programme (UNEP). (2020). *Environmental Effects of Ozone Depletion and Its Interactions with Climate Change: Progress Report, 2020*. *https://ozone.unep.org*
- World Health Organization (WHO). (2021). *Ultraviolet radiation and health*. https://www.who.int/news-room/fact-sheets/detail/ultraviolet-(uv)-radiation
- World Meteorological Organization (WMO). (2018). *Scientific Assessment of Ozone Depletion: 2018*. https://www.wmo.int/pages/prog/arep/gaw/ozone_2018.html
- World Meteorological Organization (WMO). (2022). *Scientific Assessment of Ozone Depletion: 2022*. https://public.wmo.int