

# OZONE LAYER DEPLETION

— THE INVISIBLE SHIELD UNDER THREAT —

UV RADIATION

OZONE LAYER  
(PROTECTS US FROM  
HARMFUL UV RADIATION)

DEPLETED  
OZONE LAYER

## CAUSES



CFCs



REFRIGERANTS



FOAM  
PROPELLANTS

## EFFECTS



SKIN CANCER



EYE DAMAGE



DAMAGE TO  
PLANTS & CROPS

PROTECT THE SHIELD. PROTECT LIFE.  
**OUR OZONE, OUR FUTURE.**

**Dronacharya**  
Year-Long Mentorship Programme

UPSC CIVIL SERVICES  
EXAMINATION & STATE PCS | 2027

Start From  
**15 April 2026**

**DRONACHARYA MENTORSHIP for  
UPSC and State PCS 2027**

**₹ 5,147** ~~₹40,147~~ **50% OFF**

**DRONACHARYA**  
YEAR-LONG MENTORSHIP PROGRAM  
FOR CSE 2026/27

Smruti Rajan Sir Avdhesh Sir Sudhanshu Sir

LIVE CLASS FREE CONTENT VIDEOS

**DRONACHARYA YEAR LONG  
MENTORSHIP PROGRAM FO...**

Extra ₹ 149 coupon  
discount

**₹ 17,999** ~~₹49,999~~ **10% OFF**

Strive Edge  
**UPSC AND STATE PCS  
ESSAY MASTERY COURSE**  
TRANSFORM YOUR ESSAY WRITING  
SKILLS FOR COMPETITIVE EXAMS

**COURSE BENEFITS:**

1. STRATEGIC APPROACH: LEARN OUR PROVEN METHODOLOGY FOR TACKLING ANY ESSAY TOPIC
2. CONTENT DEVELOPMENT: BUILD KNOWLEDGE REPOSITORY ACROSS DIVERSE TOPICS
3. STRUCTURED 3-MODULE PROGRAM COVERING FUNDAMENTALS TO ADVANCED TECHNIQUES
4. COMPREHENSIVE COVERAGE OF CONTEMPORARY ISSUES AND THEIR INTEGRATION

www.striveedgeias.in 7217630385 StriveIAS

VIDEOS FILES

**UPSC & State PCS Essay  
Mastery Course**

Extra ₹ 149 coupon  
discount

**₹ 1,000** ~~₹2,000~~ **50% OFF**

**JOIN: <https://pkrmej.courses.store/courses/702302>**

**6-MONTH DOUBLE  
QUESTION DAILY ANSWER  
WRITING PROGRAM**  
PROGRAM FOR UPSC  
MAINS 2026/27

**Daily Mode**  
2 questions per day (Mon-Fri)

**Weekly Mode**  
10 questions per week at your  
convenience

**Full Test Mode**  
Complete test every 14  
days

Strive Edge  
IAS ACADEMY  
**UPSC MAINS 2027**  
COMPREHENSIVE TEST SERIES

350+ Tests | 12 Months | Complete  
Syllabus Coverage

**MONTHLY ANSWER  
WRITING & EXPERT  
EVALUATION PROGRAM**  
FOR UPSC MAINS 2026/27

**Steady Daily Practice**  
2 answers daily (Mon-Fri)

**Weekly Batch Mode**  
10 answers per week in one go

**Test Format**  
Full-length test every fortnight

**1 MONTHS**

**6-MONTH SINGLE  
QUESTION DAILY ANSWER  
WRITING PROGRAM**  
FOR UPSC MAINS 2026/27

**Steady Daily Practice**  
1 question per day (Mon-Fri)

**Weekly Batch Mode**  
5 questions per week together

**Test Format**  
Half Full-length test every fortnight

**Strive for Success in Prelims (SSP)-2026**

COMPLETE TEST SERIES PROGRAM

Starts From - 5 JAN 2026

**PRICE ₹1499/- ONLY**

**PROGRAM HIGHLIGHTS**

- 52 Carefully Designed Tests
- UPSC-level MCQs with conceptual depth and (Previous Years Question)/PYQ-theme MCQs
- UPSC-level MCQs with Conceptual Depth
- Gradual Progression: Topic - Subject - Full Syllabus
- Exam-like Experience with Full Length Mocks



**PREMIUM INFOGRAPHIC EDITION**

Another Nipah death in Palakkad leads to alert in six Kerala districts

**The Hindu Highlight Daily Newspaper**

**₹ 318** ~~₹4,048~~ **70% OFF**

[Get this course](#)

**UPSC ALL PYQ**

**FROM 2013-2024**

www.striveedgeias.in 7217630385 StriveIAS

**All UPSC PYQ from 2013-2024**

**₹ 1** ~~₹4,000~~ **100% OFF**

[Get this course](#)

**ODISHA-SPECIFIC INFOGRAPHICS**

**Odisha Specific Daily Current Affairs Infographics**

**₹ 1** ~~₹4,000~~ **99% OFF**

**FROM DAILY HEADLINES TO MONTHLY ANALYSIS**

**ALL CURRENT AFFAIRS COVERED**

**Daily Current Affairs**

**₹ 1** ~~₹4,000~~ **100% OFF**

[Get this course](#)

**UPSC PRLIMS TEST SERIES PROGRAM FOR 2026**

**COURSE FEATURES**

- Test Schedule and proper timing to revise static and current Affairs
- All Questions are strictly as per the latest UPSC pattern
- All Test prepared by UPSC Interview appeared and multiple mains written faculties
- Podcast support on Sunday 8 pm

www.striveedgeias.in 7217630385 StriveIAS

**UPSC Prelims Test Series 2026**

**₹ 2,579** ~~₹5,079~~ **50% OFF**

2 Coupons Available [Apply here](#)

[Get this course](#)

**JOIN: <https://pkrmej.courses.store/courses/702302>**

**Free NCERT Test For UPSC**

www.striveedgeias.in 7217630385 StriveIAS

**FREE CONTENT TESTS**

**NCERT FREE TEST OF ALL SUBJECT**

Extra ₹ 99 coupon discount

**₹ 99** ~~₹999~~ **90% OFF**

**ODISHA-SPECIFIC CURRENT AFFAIRS**

**Odisha Specific Weekly Current Affairs**

**₹ 1**

[Get this course](#)

**CSAT PYQ**

**TESTS**

**UPSC CSAT PYQ Analysis & Mastery: 2011-2024**

Extra ₹ 98 coupon discount

**₹ 98** ~~₹4,000~~ **90% OFF**

# OZONE LAYER DEPLETION

Advanced UPSC Notes | Prelims + Mains | Environment & Ecology

## 1. INTRODUCTION

**Ozone Layer Depletion** refers to the gradual thinning of the ozone layer in the stratosphere caused primarily by anthropogenic emission of **Ozone-Depleting Substances (ODS)** such as CFCs, halons, and others.

The ozone layer exists in a dynamic equilibrium between:

- **Formation** — photochemical reactions
- **Destruction** — natural + chemical reactions

Human-induced chemicals have disturbed this equilibrium, leading to accelerated depletion.

**KEY RESULT: Increased penetration of harmful UV-B radiation → Adverse impacts on health, ecosystems, and climate**

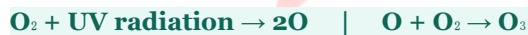
**CONTEMPORARY SHIFT: From 'global crisis' → 'controlled recovery with emerging risks'**

## 2. OZONE: NATURE, FORMATION & DISTRIBUTION

### A. Chemical Nature

- **Ozone (O<sub>3</sub>)** — triatomic allotrope of oxygen
- Highly reactive and thermodynamically unstable

### B. Formation Mechanism (Chapman Cycle)



Continuous formation & destruction maintain balance.

### C. Atmospheric Distribution

Layer	Location	Type
Stratosphere (10–50 km)	~90% Ozone	Good Ozone
Troposphere	~10% Ozone	Bad Ozone

### D. Importance of Ozone Layer

- **Protective Role:** Absorbs UV-B radiation (290–315 nm) — prevents DNA mutations, skin cancer, cataracts, ecosystem damage
- **Climatic Role:** Influences temperature gradient in stratosphere; affects global atmospheric circulation
- **Ecological Role:** Maintains biodiversity, supports agriculture & marine productivity

**Unit of Measurement: Dobson Unit (DU)**

## 3. MECHANISM OF OZONE DEPLETION

Ozone depletion occurs through **catalytic cycles involving halogen radicals**.

### A. Step-wise Mechanism

- **Step 1 – Photodissociation of ODS:**  $\text{CFC} + \text{UV} \rightarrow \text{Cl}$  (free radical)
- **Step 2 – Ozone Destruction Cycle:**
  - $\text{Cl} + \text{O}_3 \rightarrow \text{ClO} + \text{O}_2$
  - $\text{ClO} + \text{O} \rightarrow \text{Cl} + \text{O}_2$

**NET REACTION:  $\text{O}_3 + \text{O} \rightarrow 2\text{O}_2$**

### B. Key Concepts

- **Catalytic Nature:** Chlorine is regenerated — one Cl atom can destroy THOUSANDS of O<sub>3</sub> molecules!
- **Bromine Cycle:** ~100× more destructive than chlorine
- **Reservoir Compounds:** HCl, ClONO<sub>2</sub> act as inactive storage forms; converted into active radicals via PSCs

## 4. CAUSES OF OZONE DEPLETION

### A. Natural Causes (Minor)

- Nitrogen oxides (NO<sub>x</sub>), Hydrogen oxides (HO<sub>x</sub>)
- Volcanic eruptions, Methane oxidation

*Note: Natural causes lead only to TEMPORARY depletion*

### B. Anthropogenic Causes

ODS	Key Use	Depleting Agent	Significance
CFCs	Refrigeration, aerosols, foam	Chlorine	Lifetime: 40–150 yrs
Halons	Fire extinguishers	Bromine	100× > chlorine
Methyl Bromide	Pesticide	Bromine	High ODP
Nitrous Oxide (N <sub>2</sub> O)	Fertilizers, livestock, combustion	Nitrogen	<b>LARGEST ODS today!</b>

*Note : N<sub>2</sub>O is now the LARGEST ODS; VSLs (Very Short-Lived Substances) & illegal refrigerant trade are emerging concerns*

## 5. POLAR STRATOSPHERIC CLOUDS (PSCs)

### Formation

- Form at very low temperatures (~-80°C) in polar stratosphere

### Role in Ozone Depletion

- Convert **inactive chlorine** → **active radicals**
- Provide surface for **heterogeneous reactions**
- Accelerate ozone destruction cycles

*PSCs are the KEY reason for the severe Antarctic Ozone Hole*

## 6. THE OZONE HOLE

**Ozone Hole:** Region of severe **seasonal ozone depletion** — not complete disappearance!

ANTARCTICA (Severe)	ARCTIC (Less Severe)
<ul style="list-style-type: none"> <li>• Extremely low temperature</li> <li>• Strong polar vortex isolates air</li> <li>• High PSC formation</li> <li>• Peaks in OCTOBER</li> </ul>	<ul style="list-style-type: none"> <li>• Warmer conditions</li> <li>• Weaker polar vortex</li> <li>• Less PSC formation</li> <li>• Less severe depletion</li> </ul>

### Seasonal Cycle of Antarctic Ozone Hole

- **Winter:** PSC formation — chlorine stored
- **Spring:** UV returns → rapid ozone destruction
- **October:** PEAK depletion
- **Summer:** Vortex breaks — hole recovers

## 7. EFFECTS OF OZONE DEPLETION

### A. Human Health Effects

- **Skin Cancers:** Melanoma, Basal cell carcinoma, Squamous cell carcinoma
- **Eye Damage:** Cataracts, Photokeratitis
- **Immune Suppression** — reduces body's ability to fight infections
- **DNA Mutations** — direct UV-B damage to genetic material

### B. Terrestrial Ecosystem

- Reduced photosynthesis – growth abnormalities
- **Crop yield decline** – food security threat
- Biodiversity shifts – species vulnerability

### C. Aquatic Ecosystem

- **Damage to phytoplankton** – base of the marine food chain
- Reduced marine productivity
- Impaired larval development – fishery impacts

### D. Biogeochemical Cycles

- Alters carbon & nitrogen cycles
- Affects greenhouse gas balance

### E. Materials Damage

- Faster degradation of plastics, rubber, and paints

## 8. GLOBAL EFFORTS – INTERNATIONAL TREATIES

Treaty	Year	Key Features
Vienna Convention	1985	Framework agreement; first international recognition of ozone depletion threat
Montreal Protocol	1987	Legally binding; phased out ~98–99% ODS; Most Successful Environmental Agreement ever
Kigali Amendment	2016	Targets HFCs (high GWP gases); Aim: 80–85% reduction by 2047; Links ozone with climate change

**KEY FACT: Montreal Protocol is widely regarded as the MOST SUCCESSFUL international environmental agreement**

## 9. INDIA'S EFFORTS & POLICIES

### Achievements

- 99% ODS phased out – early compliance with global targets
- Active participant in Montreal Protocol & Kigali Amendment

### Key Policies

- **ODS Rules, 2000** – regulatory framework for ODS control
- **HCFC Phase-out by 2040** – gradual elimination of hydrochlorofluorocarbons

### Latest Updates (2024–25)

- **HCFC ban in new equipment: 2025**
- **Kigali phase-down from: 2028**

### Institutional Mechanism

- **Ozone Cell** – under Ministry of Environment, Forest and Climate Change (MoEFCC)
- Collaboration with UNDP for technology transfer

## 10. LATEST DEVELOPMENTS

### Recovery Timeline

Region	Expected Recovery
Global	~2040
Arctic	~2045

Region	Expected Recovery
Antarctic	~2066

- **2024–25:** Smaller ozone hole observed — early closure — indicates successful global action

**SUCCESS STORY: Ozone recovery is a rare example of global environmental cooperation working!**

### 11. OZONE–CLIMATE CHANGE NEXUS

- **ODS are also greenhouse gases** — dual impact on ozone & climate
- Ozone recovery affects temperature and wind circulation patterns globally
- **Kigali Amendment** — bridges ozone protection with climate change mitigation
- Stratospheric ozone changes can alter jet streams and rainfall patterns

### 12. EMERGING CHALLENGES

- **Nitrous Oxide (N<sub>2</sub>O) dominance** — not regulated under Montreal Protocol
- **Illegal ODS trade** — black market for banned refrigerants (e.g., CFC-11 resurgence)
- **Space launches** — rocket exhaust deposits chlorine at stratospheric altitudes
- **Climate feedback loops** — climate change may slow ozone recovery
- **VSLs** — Very Short-Lived Substances not yet fully regulated

### 13. WAY FORWARD

#### Policy

- Extend Montreal Protocol to regulate N<sub>2</sub>O
- Strengthen enforcement against illegal ODS trade
- Regulate emerging ODS (VSLs)

#### Technology

- Promote natural refrigerants — CO<sub>2</sub>, NH<sub>3</sub>, hydrocarbons
- Energy-efficient cooling systems — co-benefit for climate

#### Governance

- Integrate ozone + climate change frameworks
- Capacity building in developing nations

### 14. RECALL BOX

Key Term	Quick Fact
Dobson Unit (DU)	Unit to measure ozone concentration
Chapman Cycle	Natural O <sub>3</sub> formation mechanism
Montreal Protocol (1987)	Most successful environmental treaty
Kigali Amendment (2016)	Targets HFCs; climate + ozone link
PSCs	Key trigger of Antarctic Ozone Hole
N <sub>2</sub> O	Now the LARGEST ODS globally
Ozone Cell	India's nodal body — under MoEFCC
Antarctic hole peak	October every year
Antarctic recovery	Expected by ~2066