

DP IB Environmental Systems & Societies (ESS): SL



Stratospheric Ozone

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Your notes

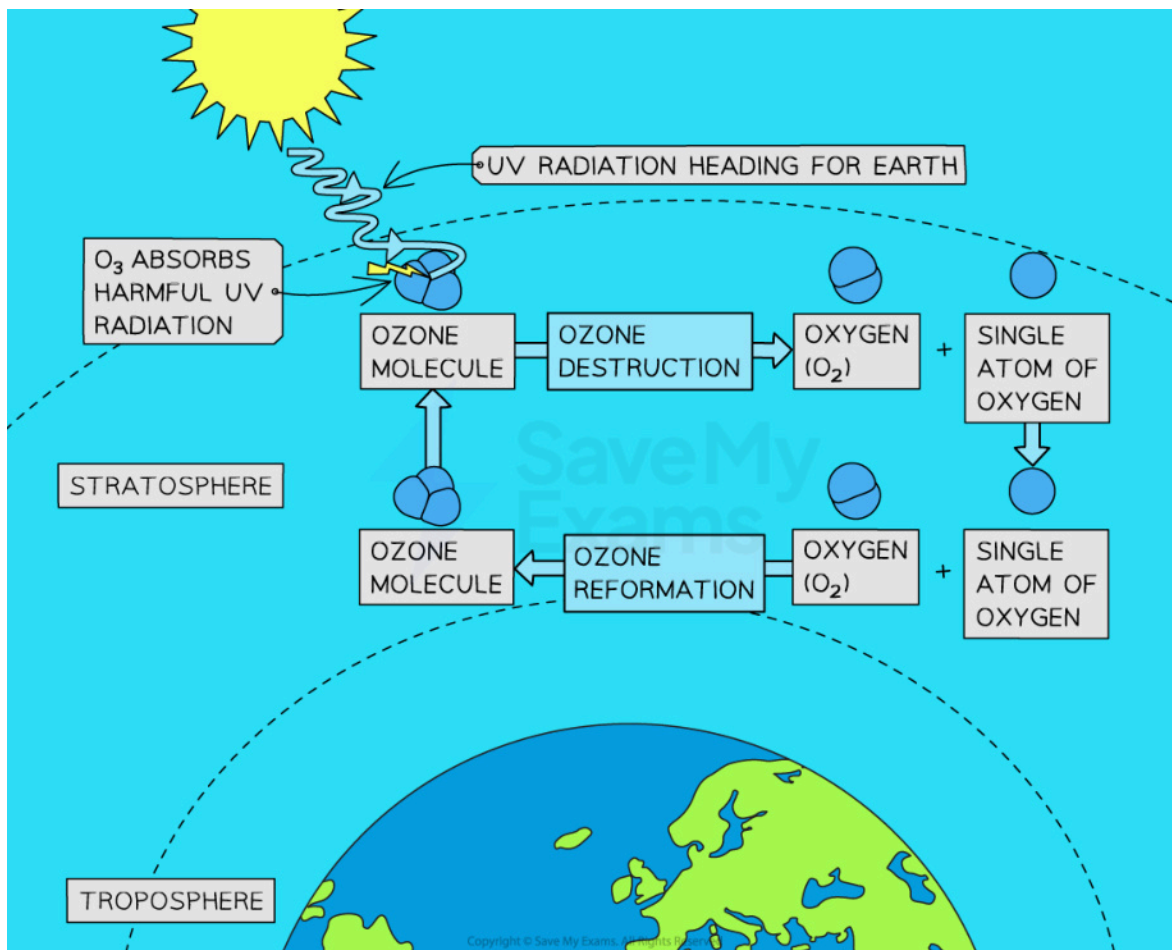
UV Radiation & Ozone

UV Radiation & Ozone

- UV radiation is a form of electromagnetic radiation emitted by the Sun
- It is invisible to the human eye and is characterised by having shorter wavelengths than visible light

Ozone

- Ozone is a molecule composed of three oxygen atoms (O_3)
 - It is primarily found in the Earth's **stratosphere**, a layer of the atmosphere located approximately 10 to 50 kilometres above the Earth's surface
- Ozone plays a crucial role in **protecting life on Earth** by **absorbing** a significant portion of the Sun's **harmful UV radiation**
- When UV radiation from the Sun interacts with ozone molecules, some of the ozone **absorbs** the energy and **breaks apart**, resulting in the formation of an oxygen molecule (O_2) and a free oxygen atom (O)
 - This process of ozone destruction occurs naturally in the stratosphere due to the presence of UV radiation
 - However, under normal conditions, the free oxygen atom (O) can combine with another oxygen molecule (O_2) to form ozone (O_3) again
 - This ozone destruction and reformation creates a **dynamic equilibrium** in the stratosphere, where there is a **continuous cycle** of ozone molecules being broken apart and reformed
 - This dynamic equilibrium ensures that the concentration of ozone in the stratosphere remains relatively **stable** over time, as the rate of the forward reaction equals the rate of the backward reaction in the system, so the concentrations of the **reactants** and **products** remain relatively **constant**



Ozone destruction and reformation creates a dynamic equilibrium in the stratosphere - there is a continuous cycle of ozone molecules being broken apart and reformed

Ozone Depleting Substances (ODSs)

- Ozone-depleting substances (ODSs) are chemicals that cause **stratospheric ozone depletion** by breaking down ozone molecules
- ODSs, including **halogenated organic gases** like chlorofluorocarbons (CFCs), are commonly used in various human activities and products:

Aerosols

- ODSs such as CFCs were previously used as propellants in aerosol products like sprays, foams, and **deodorants**



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- When released into the atmosphere during spraying, these substances can eventually reach the stratosphere and contribute to ozone depletion

Gas-blown plastics

- ODSs were also used as blowing agents in the production of foamed plastics
- These agents help create air pockets within the plastic material, making it lightweight
- However, during the **manufacturing** process or **disposal** of these products, ODSs can be released into the atmosphere

Pesticides

- Some pesticides, particularly those containing methyl bromide, a halogenated compound, have been used in agricultural practices for soil fumigation
- When applied, these substances can **volatilise** and enter the atmosphere, where they can contribute to ozone depletion

Flame retardants

- Certain flame retardants, including polybrominated diphenyl ethers (PBDEs), contain halogen atoms and have been used in various products to reduce their flammability
- When these products **degrade** or are **disposed** of, the halogenated compounds can be released into the atmosphere

Refrigerants

- ODSs were widely used as refrigerants in cooling systems, such as air conditioners and refrigerators
- The most well-known examples are the **chlorofluorocarbons** (CFCs) and **hydrochlorofluorocarbons** (HCFCs)
- When these refrigerants **leak** or are **improperly disposed** of, they can reach the stratosphere and contribute to ozone depletion
- **Halogen** atoms (e.g. **chlorine** and **bromine**) from ODSs enter the stratosphere through these various human activities
- Once in the stratosphere, these atoms can undergo a **repetitive cycle** of ozone destruction
 - The released halogen atoms react with ozone molecules, breaking them apart and reducing the concentration of ozone in the stratosphere
 - After the ozone molecules are destroyed, the halogen atoms can be **regenerated** and participate in further ozone-depleting reactions, perpetuating the cycle
 - This repetitive cycle of ozone destruction by halogen atoms increases the overall depletion of ozone in the stratosphere, resulting in an increasingly **thinner** ozone layer

- With a thinner ozone layer, more ultraviolet radiation from the Sun can penetrate the Earth's atmosphere, reaching the surface and potentially causing harmful effects on living organisms



Your notes



Your notes

Biological Effects of UV Radiation

Biological Effects of UV Radiation

UV Radiation Effects on Humans

- Ultraviolet radiation from the **Sun** can have damaging effects on human **living tissues**
 - When excessive UV radiation reaches the surface of the Earth, it can lead to various health issues by damaging cells and tissues

Cataracts

- Prolonged exposure to UV radiation can contribute to the development of cataracts
- Cataracts cause **clouding** of the **lens** in the eye, leading to blurry vision and eventual vision loss if left untreated

UV radiation effects on cells

- UV radiation has the potential to induce **mutations** in **DNA** during cell division
- When skin cells are exposed to UV radiation, it can lead to genetic alterations and mutations, which can disrupt normal cell growth and increase the risk of developing **cancer**

Skin cancer

- UV radiation is a major risk factor for the development of **skin cancer**
- UV rays can damage the DNA in skin cells, leading to uncontrolled cell growth and the formation of cancerous **tumours**
- Prolonged or intense exposure to UV radiation, especially without proper **protection**, increases the risk of developing skin cancer



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Photo by [Dimitris Chapsoulas](#) on [Unsplash](#)

Measures such as wearing sunscreen with a high sun protection factor (SPF), using sunglasses that block certain UV rays, seeking shade during peak sun hours, and wearing protective clothing can help reduce the risk of UV-related health issues

Sunburn

- When the skin is exposed to excessive UV rays, it triggers an **inflammatory response** as a defence mechanism
- Sunburned skin becomes red, painful, and may blister, indicating damage to the skin cells

Premature skin ageing

- Chronic exposure to UV radiation accelerates the **ageing** process of the skin
- It can cause the breakdown of collagen and elastin fibres, leading to wrinkles, sagging skin, and the development of age spots
- Protecting the skin and eyes from excessive UV radiation is crucial to minimise the harmful effects

- Measures such as wearing sunscreen with a high sun protection factor (SPF), using sunglasses that block certain UV rays, seeking shade during peak sun hours, and wearing protective clothing can help reduce the risk of UV-related health issues
- Regular skin examinations and eye check-ups can help detect any potential UV-related damage or abnormalities early on, allowing for timely intervention and treatment



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Effects on Biological Productivity

- Exposure to increased ultraviolet radiation can have significant effects on biological productivity, particularly on photosynthetic organisms such as **phytoplankton**, which play a crucial role in **aquatic food webs**
 - Phytoplankton convert sunlight, carbon dioxide, and nutrients into organic matter through **photosynthesis**
- Increased UV radiation damages photosynthetic organisms, such as phytoplankton, by causing DNA damage and inhibiting photosynthesis
 - When exposed to increased UV radiation, phytoplankton may experience **reduced photosynthetic activity and growth**, leading to a decrease in primary productivity in aquatic ecosystems



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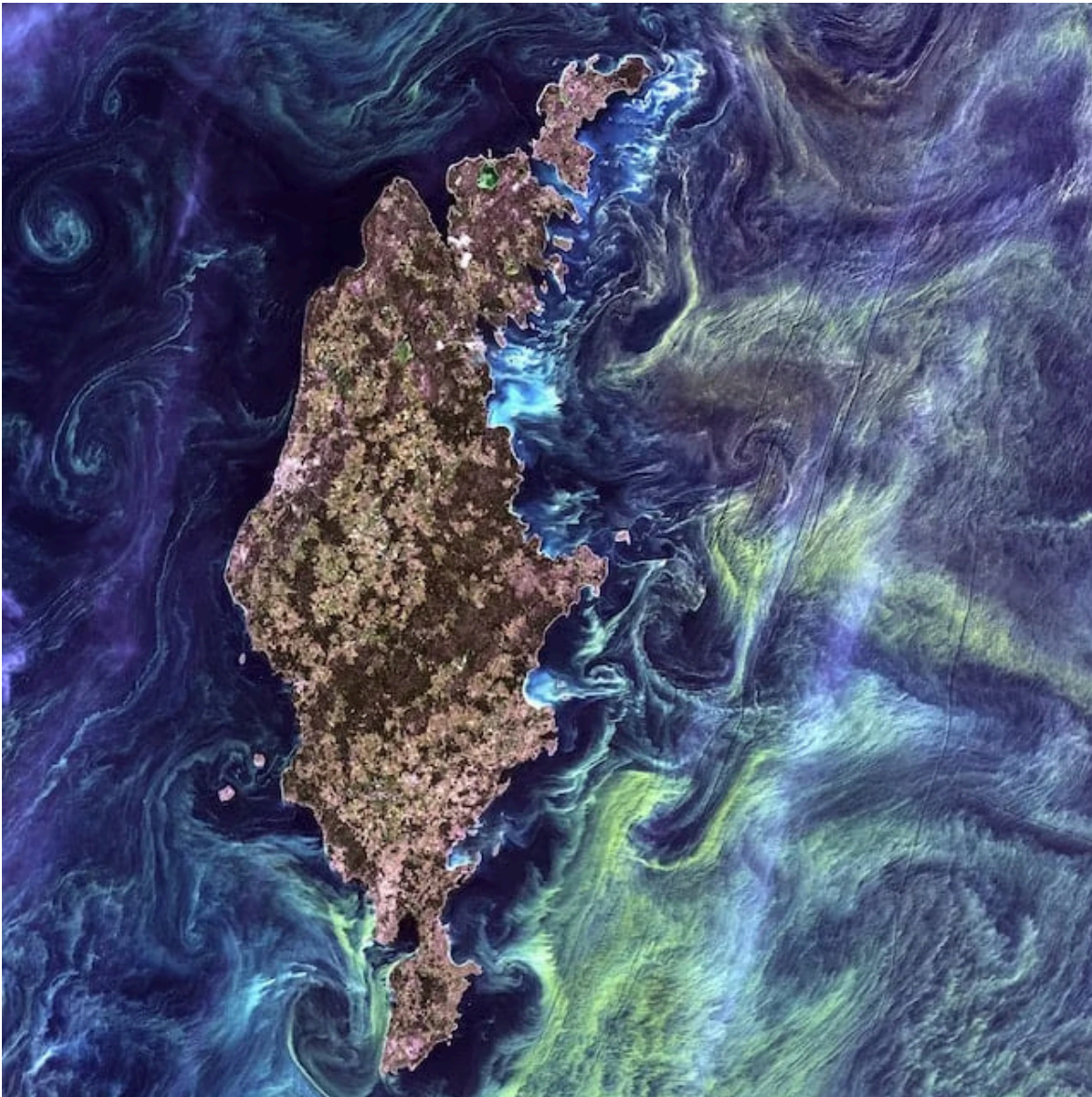


Photo by [USGS](#) on [Unsplash](#)

A population explosion, or bloom, of green phytoplankton, which form the first link in nearly all ocean food chains, can be seen from above swirling in the dark water around Gotland, a Swedish island in the Baltic Sea

- Phytoplankton play a vital role in **nutrient cycling**
 - They absorb nutrients from the water, convert them into biomass, and serve as a food source for other organisms

- Reduced phytoplankton populations due to UV radiation damage can disrupt nutrient cycling processes, leading to imbalances and nutrient **deficiencies** in the ecosystem
- Reduced phytoplankton productivity can have cascading effects on **higher trophic levels** in aquatic ecosystems
 - **Zooplankton**, which feed on phytoplankton, may experience decreased food availability, affecting their growth and reproduction
 - This, in turn, can impact higher-level consumers, such as **fish** and **marine mammals**, which rely on phytoplankton and zooplankton as a food source
- Changes in phytoplankton productivity disrupts overall ecosystem dynamics and **stability**
- The **depletion of the ozone layer**, which filters harmful UV radiation, increases the impact of UV radiation on aquatic ecosystems
- Mitigating human activities that contribute to ozone depletion is therefore crucial for preserving the health and productivity of photosynthetic organisms and maintaining balanced aquatic ecosystems



Your notes



Your notes

Reducing Ozone Depletion

Reducing Ozone Depletion

Reducing the Manufacture and Release of Ozone Depleting Substances

- **Recycling refrigerants** is an effective method to minimise the release of ozone-depleting substances during the disposal and handling of refrigeration and air conditioning equipment
 - This involves the proper collection, purification, and **reuse** of refrigerants from old or discarded refrigeration and air conditioning systems and **minimises** the need for **new production**
 - Fridges with ODS refrigeration can be replaced with 'green freeze' technology that uses propane and/or butane
- Developing **alternatives to gas-blown plastics**, which use ozone-depleting substances as foaming agents, helps in reducing their production and usage
- Finding **alternatives to halogenated pesticides**, which contain ozone-depleting substances, reduces their release into the environment during agricultural practices
 - By promoting the use of alternative pesticides that are effective and environmentally friendly, the reliance on ozone-depleting substances can be eliminated
 - For example, **organic methods of pest control** can be used instead of methyl bromide
- Developing **non-propellant alternatives** for aerosols reduces the reliance on ozone-depleting substances for product dispensing mechanisms
 - By exploring innovative technologies and utilising non-harmful propellants, the release of ozone-depleting substances can be eliminated or minimised
 - For example, pump-action sprays can be used instead of propellant aerosols or alternatives to aerosols can be used - for example, soap bars rather than shaving foam

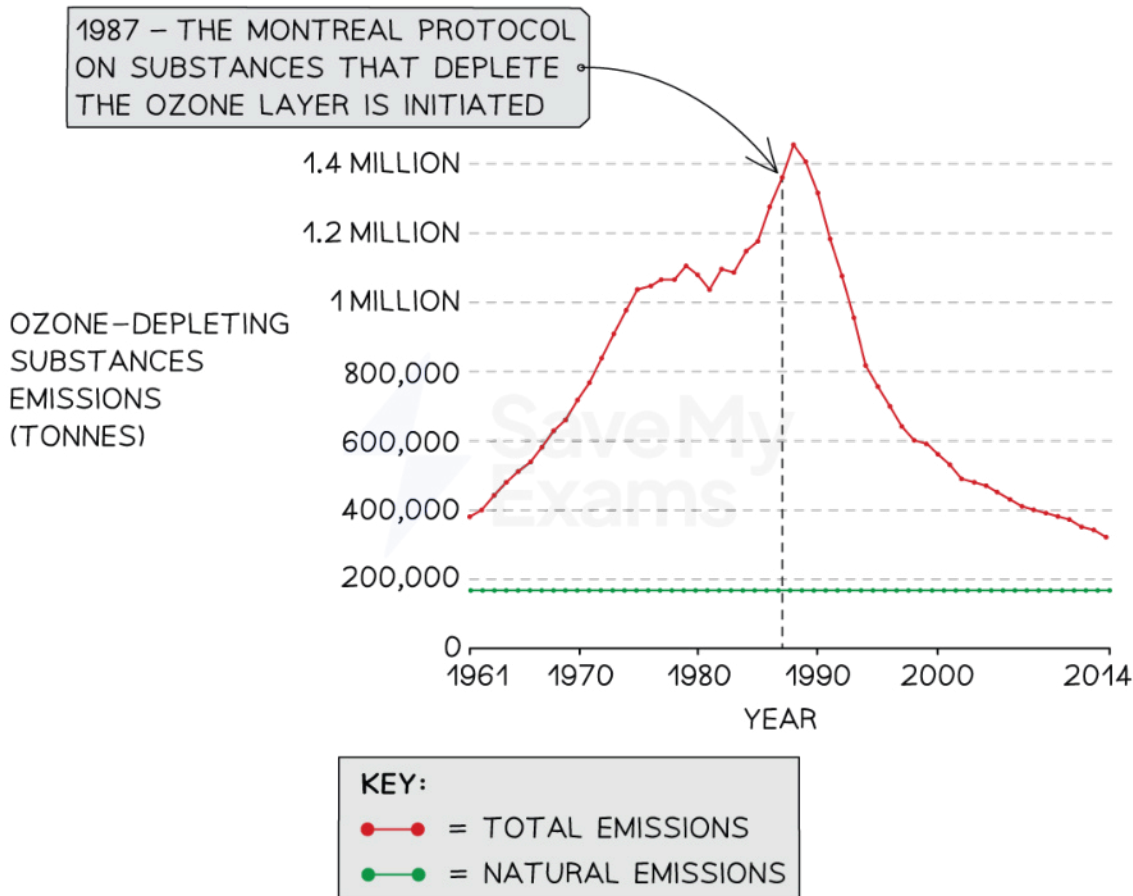
The Role of UNEP

- The United Nations Environment Programme (UNEP) has played a critical role in the **protection** of the **stratospheric ozone layer** through its efforts in providing information and creating **international agreements**
- UNEP has been instrumental in raising awareness about the depletion of the ozone layer, its causes, and the associated environmental and health impacts



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- Through research, monitoring, and dissemination of information, UNEP has helped educate governments, industries, and the public about the importance of ozone layer protection
- UNEP has been actively involved in the creation and evaluation of international agreements aimed at **reducing** the use of **ozone-depleting substances**



The Montreal Protocol on Substances that Deplete the Ozone Layer, initiated in 1987, played a crucial role in reducing the production, use and emissions of ozone-depleting substances (note that natural sources of halogen gases, which deplete stratospheric ozone, include biological activity in terrestrial and aquatic ecosystems)

- The **Montreal Protocol on Substances that Deplete the Ozone Layer**, initiated in 1987 under the guidance of UNEP, is a landmark international agreement
 - It has been updated and strengthened through subsequent amendments, reflecting the evolving scientific understanding and technological advancements
 - 24 countries initially signed the initial Protocol and the total now stands at **197 countries**

- Largely as a result of this, emissions of ODSs have **rapidly fallen** from around 1.5 million tonnes in 1987 to around 400 000 tonnes in 2010
- UNEP hopes to end production of all HCFCs by 2040
- The **illegal market** for ozone-depleting substances poses a significant challenge to the effectiveness of ozone protection efforts
 - UNEP recognises the need for consistent **monitoring** and **enforcement** to tackle this issue
 - By collaborating with national authorities, customs agencies, and other relevant stakeholders, UNEP works towards curbing the illegal trade of ozone-depleting substances and ensuring **compliance with international regulations**
- **National governments** play a crucial role in implementing the agreements made under the direction of UNEP
 - In response to the Montreal Protocol, governments have enacted **national laws** and **regulations** to decrease the consumption and production of halogenated organic gases, such as chlorofluorocarbons (CFCs)
 - These measures help enforce the reduction targets and promote the **transition to ozone-friendly alternatives**
 - The collective efforts of UNEP, governments, industries, and other stakeholders are vital in achieving the goals of ozone layer protection, mitigating the illegal trade of ozone-depleting substances, and fostering global cooperation for a sustainable future



Your notes