DP IB Environmental Systems & Societies (ESS): SL

Your notes

Stratospheric Ozone

Contents

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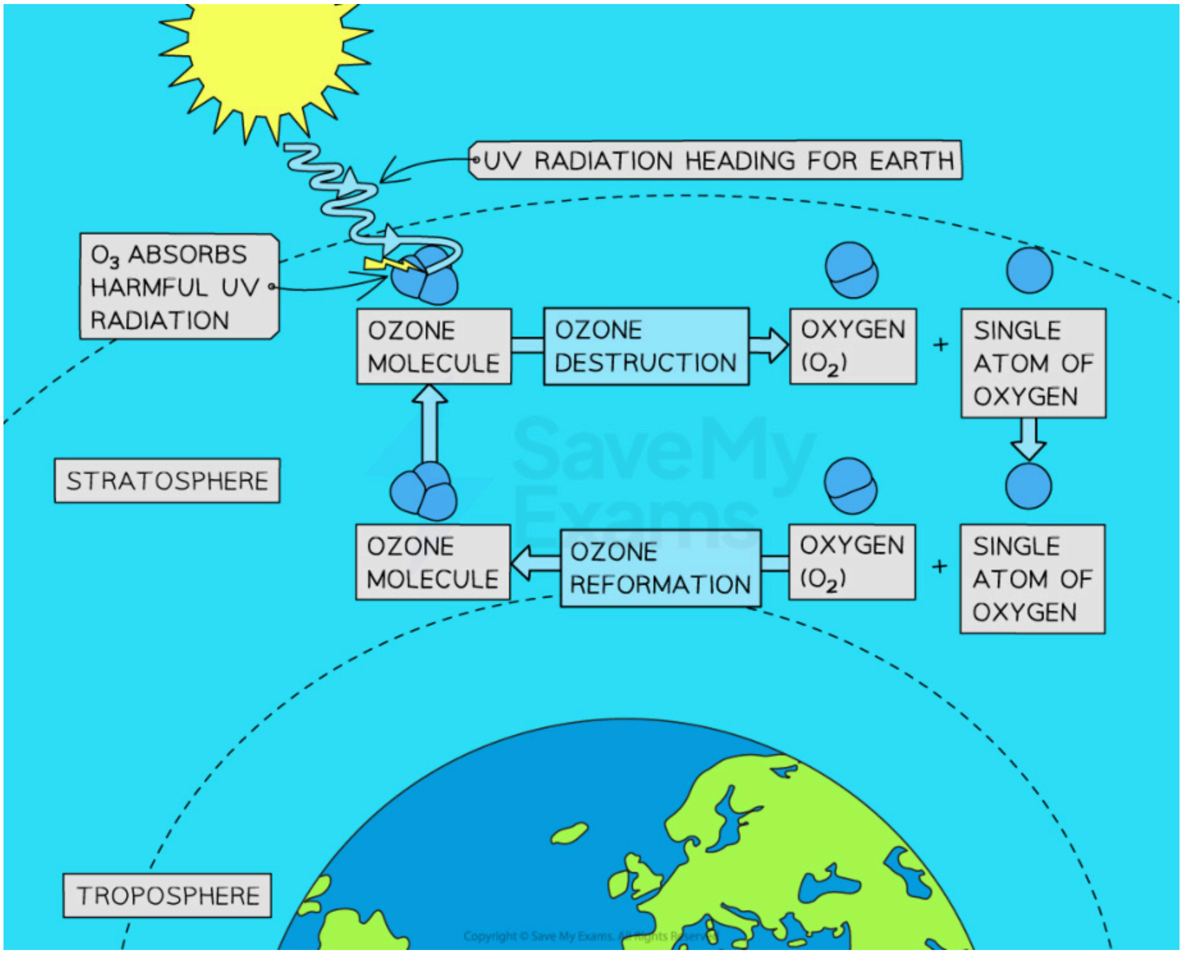
UV Radiation & Ozone

- 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**

- 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

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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

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

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  - 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

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

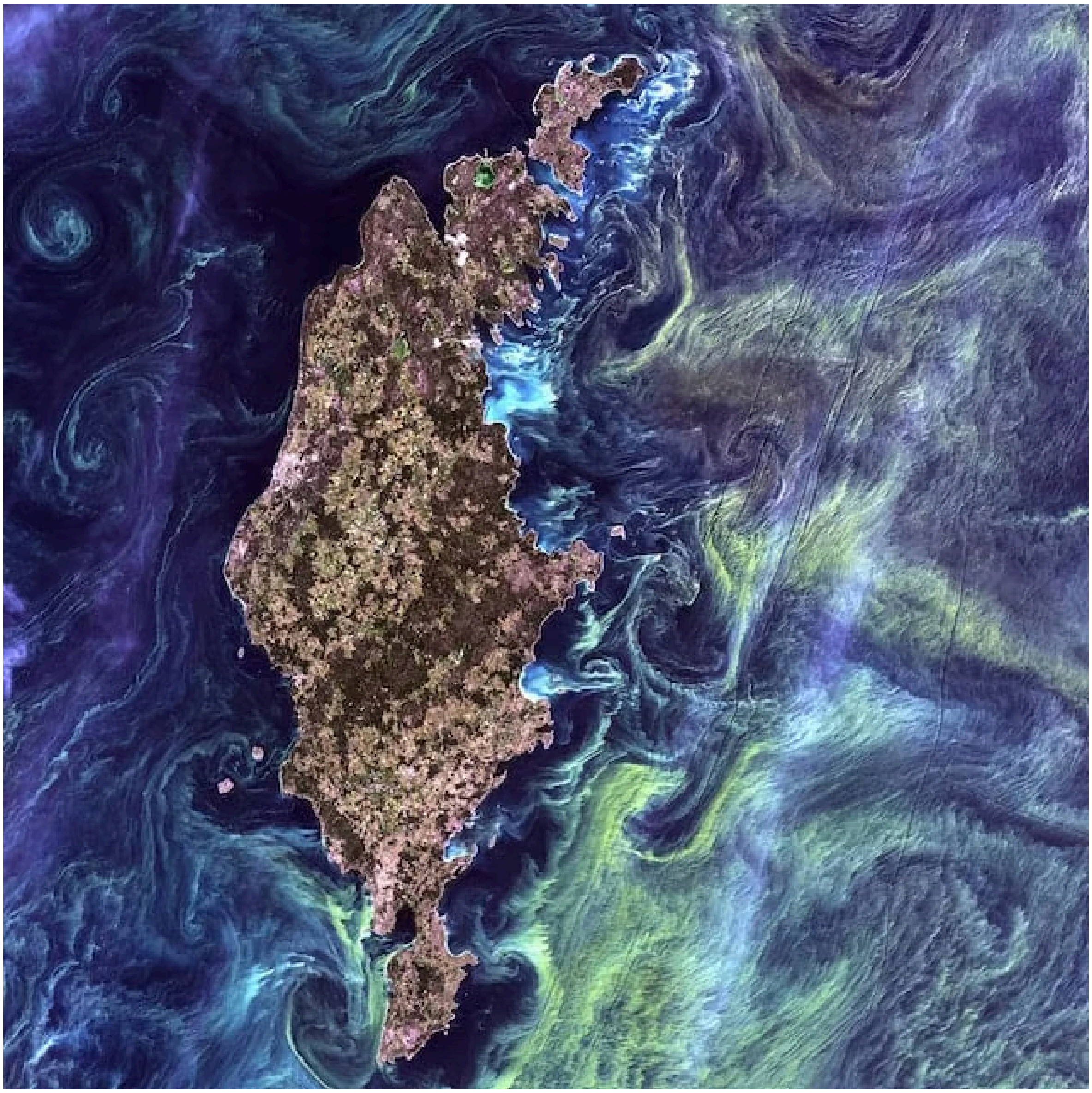

Photo by USGS on Unsplash

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

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- 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

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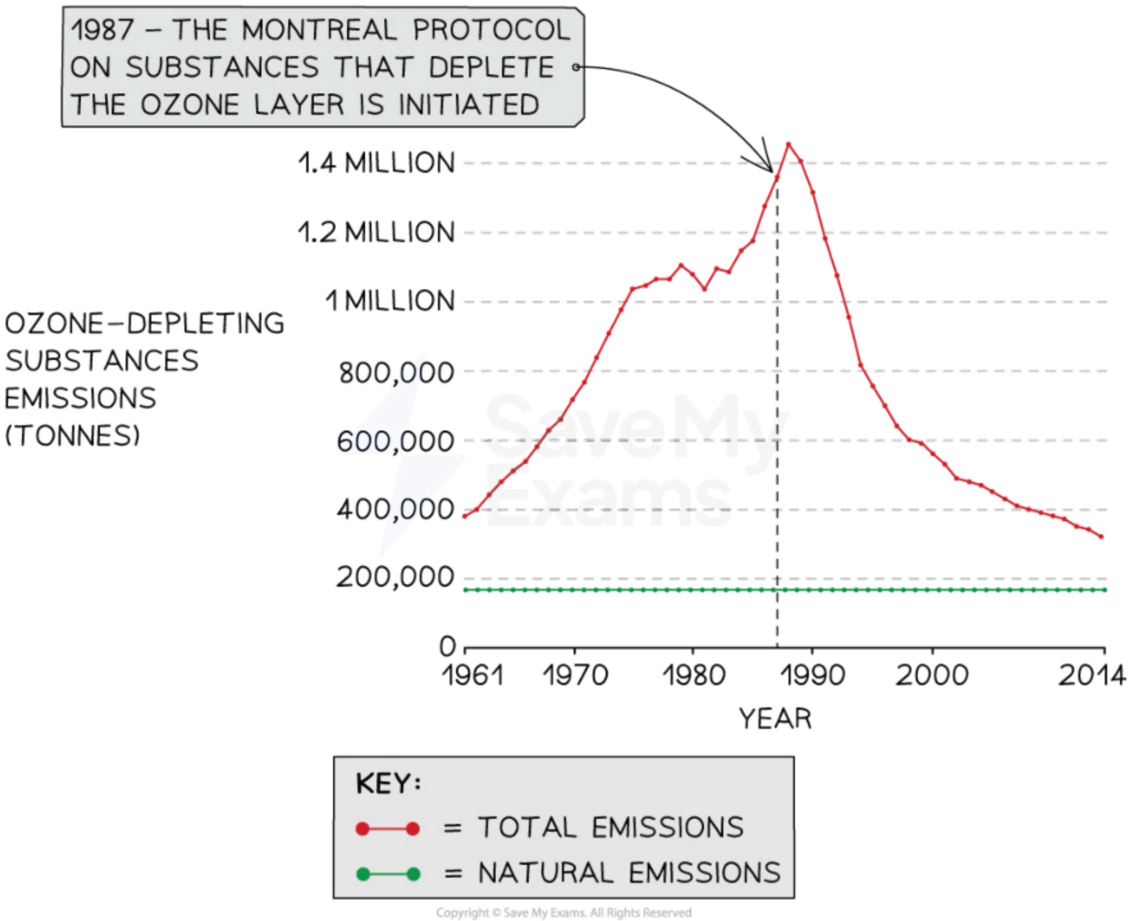
- Through research, monitoring, and dissemination of information, UNEP has helped educate governments, industries, and the public about the importance of ozone layer protection
- UNEP has been actively involved in the creation and evaluation of international agreements aimed at **reducing** the use of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

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    - 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