Topic 6 Content

- 6.1 The Earth's Atmosphere
- 6.2 Causes and Effects of Climate Change
- 6.3 Management Strategies of Climate Change
- **6.4 Stratospheric Ozone**

If we do not act soon, anthropogenic environmental changes will bring serious harms to the future. We have a moral obligation to avert harms to the future, so as to leave a world as rich in life and possibility as the world we inherited. Therefore, we have a moral obligation to act, and act now.

By whom?

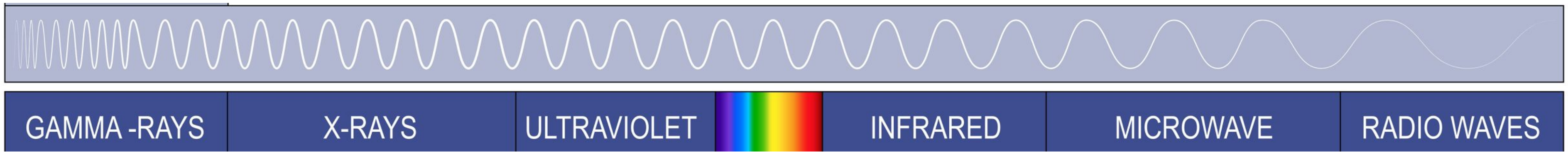
6.4.1 – 6.4.2 Learning Objectives

1. Summarise solar radiation and outline the UV radiations that can pass through and absorbed by the stratospheric ozone
2. Describe the impacts of UV radiation
3. Describe the ozone layer and ozone equilibrium
4. Outline ozone depletion substances (ODSs)
5. Evaluate the strategies managing ozone depletion

Electromagnetic Radiation

Gamma radiation

- Shortest wavelength and highest energy
- Primarily from radioactive decay of atomic nuclei.



Radio waves

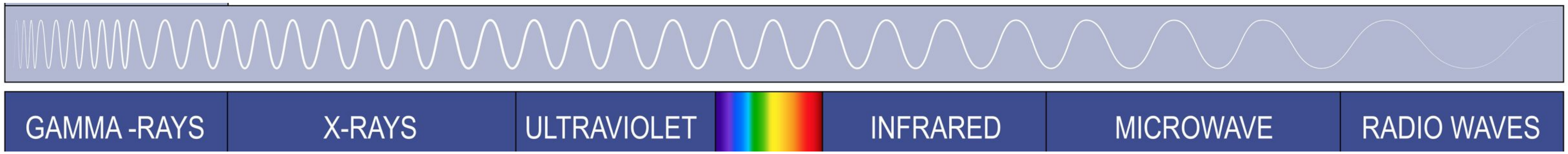
- possess long wavelengths and low frequencies.
- primarily used in communication technologies, including television, radio, and satellite transmission.
- Radio waves travel efficiently through the atmosphere and pose no known harm to human health.

Electromagnetic Radiation

Gamma radiation
- Shortest wavelength and highest energy
- Primarily from radioactive decay of atomic nuclei.

Visible light
- Wavelengths: 400 – 700 nm
- Essential for photosynthesis and to life on Earth.

Infrared (IR) radiation
- wavelengths longer than visible light (approximately 700 nm to 1 mm).



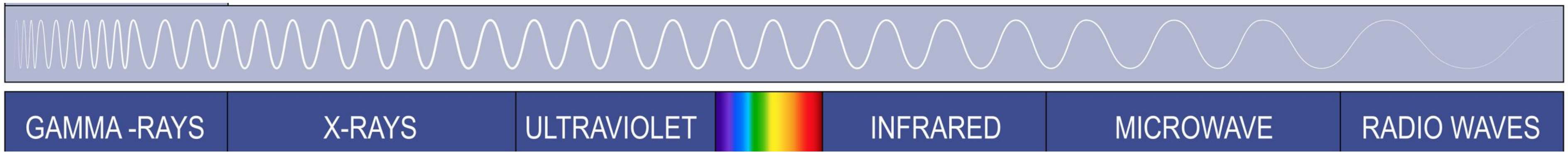
Radio waves
- possess long wavelengths and low frequencies.
- primarily used in communication technologies, including television, radio, and satellite transmission.
- Radio waves travel efficiently through the atmosphere and pose no known harm to human health.

Electromagnetic Radiation

Gamma radiation
- Shortest wavelength and highest energy
- Primarily from radioactive decay of atomic nuclei.

Visible light
- Wavelengths: 400 – 700 nm
- Essential for photosynthesis and to life on Earth.

Infrared (IR) radiation
- wavelengths longer than visible light (approximately 700 nm to 1 mm).



Ultraviolet (UV) radiation
- wavelengths shorter than visible light, spanning approximately 10 to 400 nm.
- UVA (315–400 nm) contributes to vitamin D synthesis but can also cause sunburn and cataracts.
- UVB (280–315 nm) is capable of inducing DNA damage, while
- UVC (100–280 nm) is largely absorbed by atmospheric ozone before reaching the Earth’s surface.

Radio waves
- possess long wavelengths and low frequencies.
- primarily used in communication technologies, including television, radio, and satellite transmission.
- Radio waves travel efficiently through the atmosphere and pose no known harm to human health.

Effects of UV

Outline the harmful and beneficial effects of UV on the following:

1. Photosynthetic organisms
2. Human health
3. Scientific research

Effects of UV Radiation

Damaging Effects

- Aquatic ecosystems produce over 50% of Earth's biomass
- UV radiation coudd urioencing mypaneture productivity of phyoJ" ondu
- Suppression of the human immune system
- Cataract formation in eyes
  - Worldwide, 15 million people areon blu die cantarats are nol.or cataracts
- Skin cancers caused primarily by UV exposure from sun or artificial sources suc
  - In 2020, over 1.5 million new cases of skin cancer were diagnosed
  - Over 120,000 skin cancer-associateo deaths were reported
- In New Zealand, the dangleuear forcence

Beneficial Effects

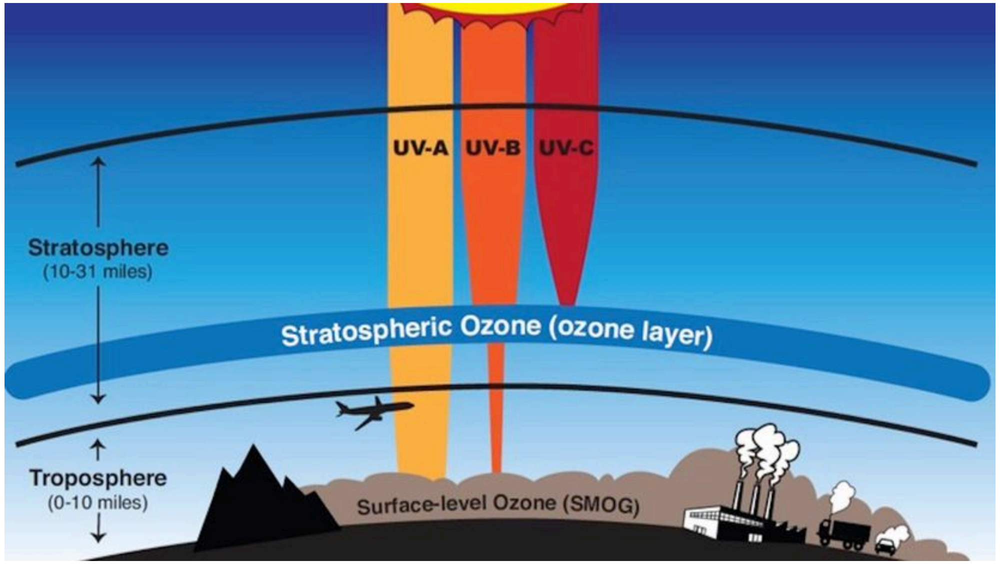
- In animals, and humans, UV radiation stimulates the production of vitamin D
  Vitamin D deficiency causes rickets, a condition where a child's bones are a short of calcium and so too soft to support the body
- Used as a sterilizer. becaust it lnt pathogenic bacteria
- Used as an air and water purm
- Industrial uses in lasers, viewing old scripts, forensic analysis, lightrin
- Inceustrial uses in weatter report in summer includes isolines to show burn times

Impacts of UV

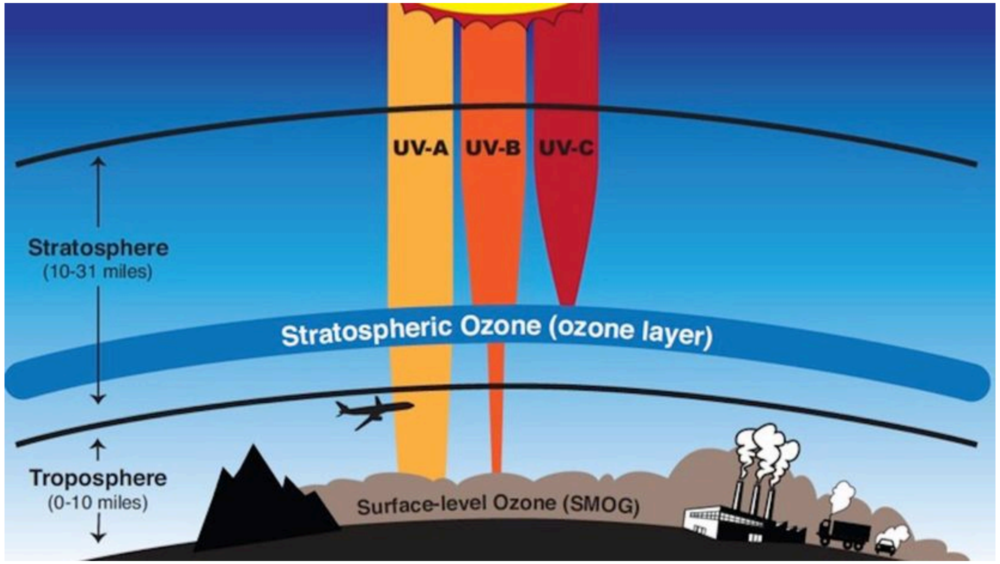
Type of UV Radiation	Characteristics	Penetration	Effects on Organisms / Uses
UV-A	• Comprises ~95% of terrestrial UV radiation • Has the longest wavelengths among UV types	• Penetrates deeply into the skin (reaches the middle layer) • Passes through glass and clouds	• Causes wrinkles and premature skin ageing • Can contribute to skin cancer with prolonged exposure
UV-B	• Comprises ~5% of terrestrial UV radiation • Has shorter wavelengths than UV-A	• Penetrates only the top layer of skin • Blocked by glass	• Causes skin redness and burns • Damages DNA, strongly linked to melanoma cancers • SPF 30+ sunscreen helps deflect UV-B • Partially absorbed by stratospheric ozone (which protects Earth)
UV-C	• Has the shortest wavelengths (and highest frequencies)	• Completely absorbed by the ozone layer — does not naturally reach Earth's surface	• Used artificially for disinfection (e.g., tertiary water treatment) • Emitted by lasers and welding • Extremely harmful to living cells if directly exposed

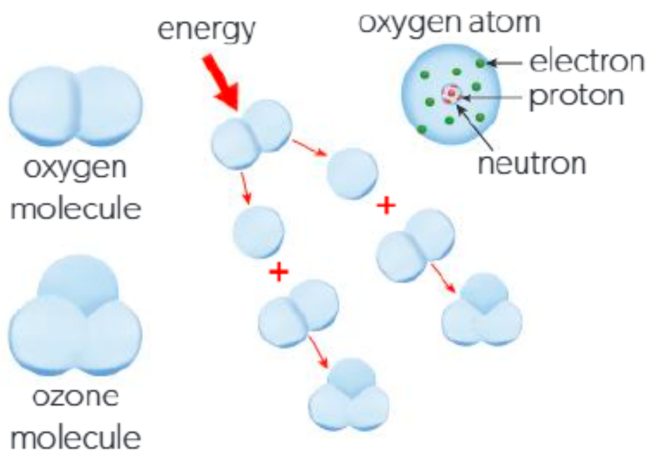
Stratospheric Ozone

Outline ozone cycle

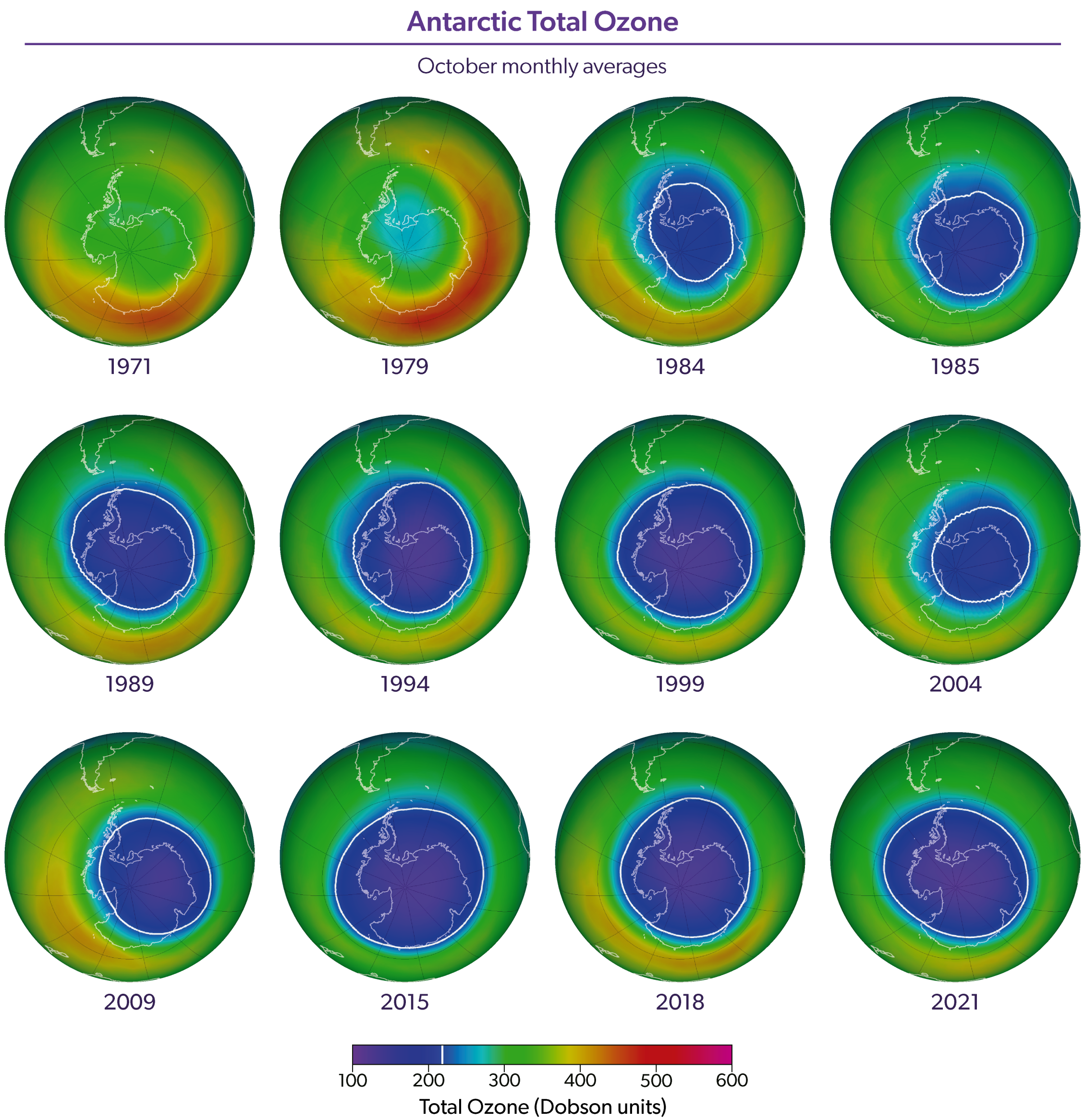


Stratospheric Ozone





Evidence of ozone depletion



ODSs

Substance Type	Contains Chlorine?	Contains Hydrogen?	Ozone-Depleting Substance (ODS)?	Greenhouse Gas (GHG)?	Environmental Impact / Notes
CFCs (Chlorofluorocarbons) – phased out	✅ Yes	❌ No	✅ Yes	✅ Yes	Strongly deplete the ozone layer; highly stable in the atmosphere; banned under the Montreal Protocol.
HCFCs (Hydrochlorofluorocarbons) – phased out	✅ Yes	✅ Yes	✅ Yes (less than CFCs)	✅ Yes	Transitional substitutes for CFCs; still deplete ozone but to a lesser extent; being phased out globally.
HFCs (Hydrofluorocarbons)	❌ No	✅ Yes	❌ No	✅ Yes	Do not harm the ozone layer, but are potent greenhouse gases that contribute to climate change; regulated under the Kigali Amendment.

The Action of ODSs

- All ODSs are human-made.
- CFCs (chlorofluorocarbons) were developed in the 1930s as safe, stable, and non-reactive compounds.
- They were used as:
  - Aerosol propellants
  - Blowing agents for plastic foams
  - Pesticides
  - Flame retardants
  - Refrigerants, replacing toxic and flammable alternatives
- At ground level, CFCs are chemically stable.
- In the stratosphere, UV radiation breaks them down, releasing chlorine atoms.

The Action of ODSs

- These chlorine atoms:
  - React with ozone (O_3), destroying it.
  - React with oxygen atoms (O), preventing ozone formation.
- The chlorine atoms are regenerated, enabling a chain reaction that destroys many ozone molecules.
- One chlorine atom can destroy thousands of ozone molecules.
- Replacing CFCs in aerosols and foams was easy, but finding new refrigerants was difficult.
- HCFCs (hydrochlorofluorocarbons) replaced CFCs:
  - Non-toxic and non-flammable
  - Still ozone-depleting and greenhouse gases (GHGs)
  - Some have a GWP up to 2,000× CO_2
  - Shorter atmospheric lifetimes than CFCs, so less damaging
- CFCs persist up to 100 years, so recovery of the ozone layer takes decades.

Strategies for Reducing Ozone Depletion

Management Strategies

Strategy for reducing pollution	Example of action
Altering the human activity producing pollution	Replace gas-blown plastics
	Replace CFCs and HCFCs with carbon dioxide, propane, or air as a propellant
	Replace aerosols with pump-action sprays
	Replace methyl bromide pesticides (but most gases that can be used to replace CFCs are GHGs)
Regulating and reducing the pollutants at the point of emission	Recover and recycle ODSs from refrigerators and AC units
	Legislate to have fridges returned to the manufacturer and coolants removed and stored
	Capture ODSs from scrap car AC units
Clean up and restoration	Add ozone to or remove chlorine from the stratosphere — not practical, but it was once suggested that ozone-filled balloons be released

Individual Action

- Public campaigns raised awareness about CFCs in aerosols.
- Consumers stopped buying CFC-based spray products.
- Manufacturers switched to ozone-friendly alternatives.
- 1975: *Johnson & Johnson* banned CFCs globally.
  - Demonstrated how individual and consumer choices can drive change.

The Montreal Protocol (1987)

- Led by the United Nations Environment Programme (UNEP).
- UNEP's roles:
  - Negotiates treaties (e.g., Montreal Protocol)
  - Monitors effectiveness and compliance
  - Disseminates information globally
- The Montreal Protocol:
  - Regulates production, trade, and use of ODSs (mainly CFCs and halons).
  - Controls substances containing chlorine or bromine.
  - Substances with only fluorine (like HFCs) are not ODSs.
- Widely recognized as the most successful international environmental treaty.
- Rapid response due to public and scientific pressure.
- 197 countries signed the agreement.
- Key commitments:
  - Freeze production/consumption at 1986 levels by 1990
  - Reduce usage significantly by 2000
- 7 later amendments strengthened the treaty.
- Allowed LICs (Low-Income Countries) longer timelines for compliance.

Timeline

Year / Period	**Event**
1970s	CFCs identified as ozone-depleting; USA & Sweden ban aerosol uses (1974).
1985	British Antarctic Survey discovers ozone hole.
1987	Montreal Protocol signed; 30+ nations agree to halve CFCs by 2000.
2006	Largest ozone hole recorded by NASA & NOAA.
2007	Agreement to phase out **HCFCs by 2030**.
2012	25th anniversary of the Montreal Protocol.
2019	**Kigali Amendment** ratified to phase down **HFCs by the 2040s**.

Significance and Success of the Montreal Protocol

- Without the ban, by 2050, global ozone depletion could have rendered much of Earth uninhabitable.
- Three main reasons for rapid action:
  - Clear and immediate threat to human health (UV exposure).
  - Satellite images made the ozone hole visible and real.
  - Viable substitutes for ODSs were available.
- The Protocol is:
  - The best example of global environmental cooperation.
  - A demonstration of the precautionary principle.
  - A model of multidisciplinary collaboration.
  - Economically flexible, allowing varied phase-out schedules.
  - The first treaty with strict monitoring and enforcement.

Current Challenges

- CFCs remain in the atmosphere for decades:
  - Chlorine levels peaked in 2005.
  - Expected to return to pre-ODS levels by ~2050.
- Some LICs still produce limited HFCs.
- Illegal trade in ODSs persists.
- The Antarctic ozone hole forms annually and closes in summer.
- Volcanic eruptions can cause short-term ozone losses.
- Nitrous oxide (N_2O):
  - A GHG and ODS
  - Not covered by the Montreal Protocol
  - Emissions increasing due to fertilizer use
- 2020–2022 data show little ozone improvement due to:
  - Unexpected CFC-11 emissions
  - Cooling of the stratosphere from climate change
  - Hunga Tonga–Hunga Ha'apai eruption (2022)

Formative

- Outline the role of the stratospheric ozone [1]
- Explain 2 negative effects of UV on phytoplankton and human [4]
- Outline the ozone cycle process [2]
- Evaluate Montreal Protocol in managing ozone depletion [9]

Formative

- Outline the role of the stratospheric ozone [1]

Absorbs UV-B and UV-C and prevent the UV from entering the earth or reaching the Earth's surfaces

Formative

- Explain 2 negative effects of UV on phytoplankton and human [4]

Phytoplankton:

- Destroys DNA of phytoplankton and causes the death of cells
- Reduces the ability to photosynthesise hence no energy in cells and later, the ecosystem

Humans

- Destroys DNA of skin cells which results in melanoma cancer
- Denatures protein in the eye and becomes whitish protein that causes cataracts

Formative

- Outline the ozone cycle process [2]

$O2 \rightarrow O. + O.$

$O. + O2 \rightarrow O3$

$O3 \rightarrow O2 + O.$