Ozone Depletion, Montreal Protocol and Kigali Agreement

Ozone Depletion

Ozone(O_3) forms a layer in the stratosphere, between 10 to 50 km above the earth, thinner in the tropics (around the equator and denser towards the poles. The ozone layer in the upper atmosphere absorbs most of the harmful ultraviolet-B (UV-B) radiations from the sun. It also completely screens out the deadly UV-C radiation.

The ozone shield is thus essential to protect life on the earth.

Depleting the ozone layer allows UV-B to reach the earth.

The result would be increase in skin cancers, eye cataracts, weakened immune systems, reduced plant yields, damage to ocean ecosystems, reduced fishing yields, and adverse effects on animals.

Formation and destruction of zone in the stratosphere is explained by Chapman's Reaction.

Chapman Reaction: Natural process of formation and destruction of ozone in the stratosphere.

$$O_2 + h\nu \longrightarrow O + O \qquad \lambda < 240\ nm$$
$$O + O_2 \longrightarrow O_3$$
$$O_3 + h\nu \longrightarrow O_2 + O \qquad \lambda < 320\ nm$$
$$O + O_3 \longrightarrow 2\,O_2$$

In the stratosphere, ozone is destroyed and formed simultaneously, hence maintaining the balance.

The Antarctic hole was discovered by Dr. Joe C. Farman and his colleagues in British Antarctic Survey in the year 1985.

When CFCs (chlorofluorocarbons, used as a refrigerant and aerosol propellants), finally break apart in the atmosphere and release chlorine atoms, this causes that cause ozone depletion and the substance responsible are known as ozone depleting substances.

The CFCs are so stable and unreactive that they survive to reach the highest levels of the atmosphere, and become globally distributed in the stratosphere.

At these high altitudes, the intensity of ultra-violet radiation is so great that even the stable CFCs are split apart to release a chlorine atom.

$$CFCl_3 \xrightarrow{\text{UV radiation}} CFCl_2 + Cl$$
$$CF_2Cl_2 \xrightarrow{\text{UV radiation}} CF_2Cl + Cl$$

It is the atomic chlorine that does the damage, since it can react with ozone (O_3) to form oxygen.

$$Cl + O_3 \longrightarrow ClO + O_2$$

$$ClO + O_3 \longrightarrow Cl + 2O_2$$

$$\text{overall} \quad 2O_3 \longrightarrow 3O_2$$

The Cl atom is regenerated in this reaction, and so the breakup of only *one* CFC molecule can initiate the subsequent removal of *thousands* of ozone molecules. This has recently become a major cause for concern, since the ozone forms a vital protective layer in the upper atmosphere, shielding the Earth and all its plants and animals from the harmful effect of the sun's UV (ultra violet) radiation. Damage to the ozone layer would let more UV through to reach the planet's surface, leading to an increase in skin cancers in animals and humans, and damage to vegetation.

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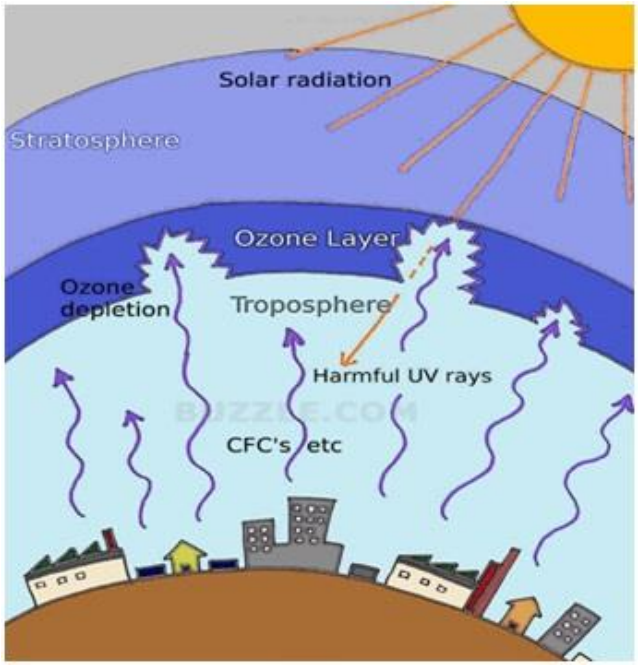
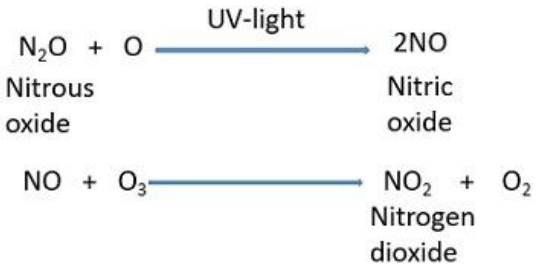


Fig: Ozone layer depletion

Nitrous oxide, like CFCs, is stable when emitted at ground level, but breaks down when it reaches the stratosphere to form other gases, called **nitrogen oxides**, that trigger **ozone**-destroying reactions. t is stable in the lowest level of the atmosphere, the troposphere, where it has a lifetime of about 100 years and acts like a greenhouse gas. When N_2O migrates up to the

stratosphere, it is converted to NO, which reacts with O_3 to produce NO_2 and O_2. NO_2 in turn reacts with O to re-form NO.



Nitrous oxide has a range of natural and human-made sources. The largest man-made source is agriculture, where the gas gets emitted after bacteria in soil break down the nitrogen in chemical fertilizers as well as in manure-based fertilizers. Nitrous oxide also comes from burning fossil fuels and from burning biomass.

What is Dobson Unit?

Dobson unit (DU) is the measure of the total amount of O_3 in an overhead column of the atmosphere. It is the measure of how thick the ozone layer at 0 degree Celsius with a pressure of 1 atmosphere above it.

0.01 mm thickness of the ozone layer = 1DU

Major Ozone Depleting Substances (ODS)

- Chlorofluorocarbons (CFCs)

It's billed as the most extensively utilized ozone-depleting substance because it attributes to more than 80% of overall ozone depletion. It was utilized as a coolant in home appliances like freezers, refrigerators and air conditioners in both buildings and cars that were manufactured prior to 1995. This substance is usually contained in dry cleaning agents, hospital sterilant, and industrial solvents. The substance is also utilized in foam products like mattresses and cushions and home insulation.

- Hydrofluorocarbons (HCFCs)

Hydrofluorocarbons have over the years served in place of Chlorofluorocarbons. They are not as harmful as CFCs to ozone layer.

- Halons

It's especially used in selected fire extinguishers in scenarios where the equipment or material could be devastated by water or extinguisher chemicals.

- Carbon Tetrachloride

Also used in selected fire extinguishers and solvents.

- Methyl Chloroform

Commonly utilized in industries for cold cleaning, vapor degreasing, chemical processing, adhesives and some aerosols.

Impacts of ozone depletion

- Damage to human health

If the ozone layer is depleted, it means humans will be overly exposed to strong UV light. Overexposure to strong UV light causes skin cancer, cataracts, sunburns, weakening of immune system and quick aging.

- Devastation to environment

Many crops species are vulnerable to strong UV light and overexposure may well lead to minimal growth, photosynthesis and flowering. Some of the crop species vulnerable to UV light such as barley, wheat, corn, oats, rice, broccoli, tomatoes, cauliflower just to name a few. Forests equally bear the brunt of ozone depletion.

- Threat to marine life

Certain marine life, especially planktons, is greatly impacted by exposure to strong ultraviolet rays. In the aquatic food chain, planktons appear high up. If planktons decrease in number due to ozone layer destruction, the marine food chain would be disrupted in many ways. Also, overexposure of sun rays could reduce the fortunes of fishers. On top of that, certain species of marine life have been greatly affected by overexposure to ultraviolet radiation at their early stage.

- Effect on animals

In domesticated animals, too much Ultraviolet radiation could also lead to skin and eye cancer.

- Impacts certain materials

Materials like plastics, wood, fabrics, rubber are massively degraded by too much ultraviolet radiation

Solutions to Ozone Depletion

- Discontinue using pesticides

Pesticides are great chemicals to rid your farm of pests and weeds, but they contribute enormously to ozone layer depletion. The solution to get rid of pests and weeds is to apply natural methods such as organic farming.

- Discourage driving of private vehicles

The easiest technique to minimize ozone depletion is to limit the number of vehicles on the road. These vehicles emit a lot of greenhouse gases that eventually form smog, a catalyst in the depletion of ozone layer.

- Utilize environmentally friendly products

Most household cleaning products are loaded with harsh chemicals that find way to the atmosphere, eventually contributing to degradation of the ozone layer. Use natural and environmentally friendly cleaning products to arrest this situation.

- Prohibit the use of harmful nitrous oxide
- The **Montreal Protocol** formed in 1989 helped a lot in the limitation of Chlorofluorocarbons (CFCs). However, the protocol never covered nitrous oxide, which is a known harmful chemical that can destroy the ozone layer. Nitrous oxide is still in use today. Governments must take action now and outlaw nitrous oxide use to reduce the rate of ozone depletion.

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Montreal Protocol (1987): The original Montreal Protocol was signed in **1987**, was the first step in international efforts to protect stratospheric ozone- depleting substances (ODS) as well as by moving up the date by which already controlled substance must phase out.

Under the original Montreal Protocol agreement (1987) developed countries were required to begin phasing out chlorofluorocarbons (CFCs) in 1993 and achieve a 50% reduction relative to 1986 consumption levels by 1998, under this agreement, CFCs were the only ODS addressed.

The Montreal Protocol on substances that deplete the O_3 layer was designed to reduce the production and consumption of ozone depleting substances in order to reduce their abundance in the atmosphere, and thereby protect the earth's fragile ozone layer. The original Montreal Protocol was signed in 16th Sept, 1987 and entered into force on 1st Jan 1989.

- It has 197 member parties to the protocol and become a first international treaty with complete ratification.
- Presently 96 chemicals are controlled by Montreal Protocol and phase out schedules.
- In 2009, the Montreal Protocol became the first UN treaty to achieve universal ratification demonstrating the world's commitment to ozone protection, and more broadly, to global environmental conservation.
- It has been observed that Montreal Protocol has resulted in phasing out of overall 98% of all ozone depleting substances. As most of the substances are potent GHG (green house gases) the protocol has delivered substantial climate benefits too.
- Outside the Polar Region the ozone layer has shown some initial signs of recovery. Assuming the continued compliance with the Protocol, Arctic ozone levels are expected to return to pre 1980 values around 2050.
- The Montreal Protocol is a most effective international environmental treaty to phase out the Ozone Depleting Substances (ODSs) from the atmosphere.

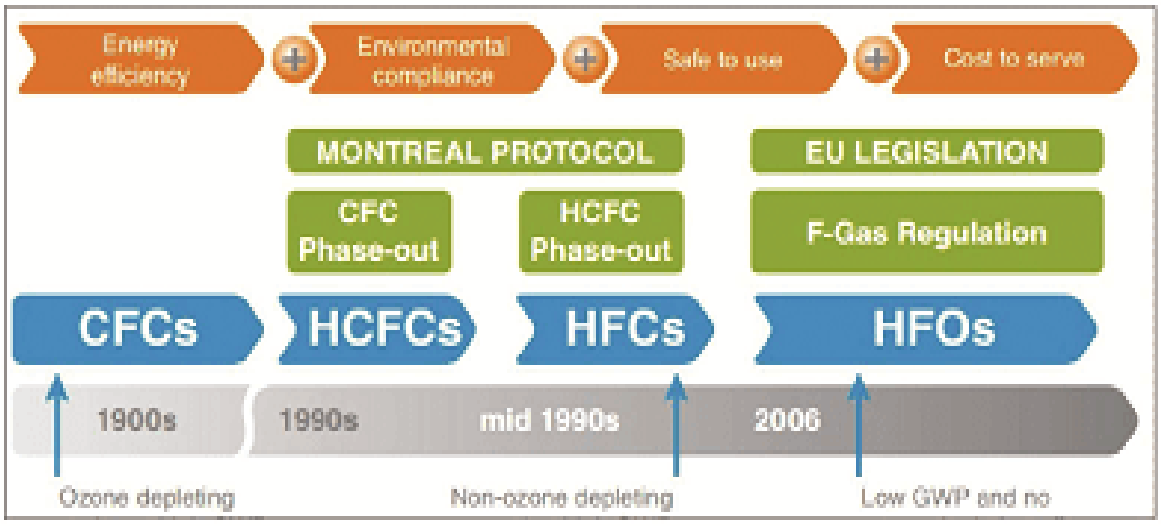

Fig: Transition of refrigerants

Note: HCFC (hydrofluorocarbon): Its Ozone depleting potential (ODP) is between 0.005-0.2

HFC hydrofluorocarbon: Absence of chlorine so it is not an ODS but a potent GHG.(GWP=11700)

What is ozone depleting potential?

Ozone depleting potential (ODP) is a measure of destructive effects of a substance compared to a reference substance. ODP of a chemical compound is the relative amount of degradation to ozone layer it can cause with trichlorofluoromethane (CFC-11) being fixed as 1 unit.

https://www.youtube.com/watch?v=vyItXoh4Vyo

Kigali Agreement

- In the 28th meeting of the Parties to the Montreal Protocol, negotiators from 197 nations have signed a historic agreement to amend the Montreal Protocol in Kigali, a capital city of a tiny African country, Rwanda on 15th October 2016.
- As per the agreement, these countries are expected to reduce the manufacture and use of **Hydrofluorocarbons (HFCs)** by roughly 80-85% from their respective baselines, till 2045.
- This phase down is expected to arrest the global average temperature rise up to 0.5° C by 2100.
- Kigali agreement is an amendment to Montreal Protocol.

- It is a **legally binding agreement** between the signatory parties with non-compliance measures.
- It came into effect from 1st January 2019 provided it is ratified by at least 20 member parties by then.
- It has shown a considerable flexibility in approach while setting phase-down targets for different economies accommodating their developmental aspirations, different socio-economic compulsions, and scientific & technological capabilities.
- It has divided the signatory parties into three groups-

1. **The first group** consists of rich and developed economies like USA, UK and EU countries who will start to phase down HFCs by 2019 and reduce it to 15% of 2012 levels by 2036.
2. **The second group** consists of emerging economies like China, Brazil as well as some African countries who will start phase down by 2024 and reduce it to 20% of 2021 levels by 2045.
3. **The third group** consists of developing economies and some of the hottest climatic countries like India, Pakistan, Iran, Saudi Arabia who will start phasing down HFCs by 2028 and reduce it to 15% of 2024-2026 levels till 2047.

   https://www.youtube.com/watch?v=Bw9P8X4sLHI

Why is Kigali Agreement significant?

- It strengthens the Paris Agreement which sets an ambitious target of restricting the rise in global temperature below 2^{O} Celsius, as compared to pre-industrial level.
- Unlike Paris agreement, it gives clear, concrete and mandatory targets with **fixed timelines** to the signatory parties to achieve their targets.
- It would prevent the emission of HFCs equivalent to 70 billion tons of CO_2.

New refrigerants after HFC would be like HFO which stands for hydrofluoro olefin, CO_2, ammonia (NH_3)