OZONE HOLE

Ozone Layer

- Over 91% of the ozone in Earth's atmosphere- present in the lower portion of the stratosphere from approximately 10 km to 50 km above Earth, though the thickness varies seasonally and geographically.
- Discovery of ozone layer - Charles Fabry and Henri Buisson(1913)- the French physicists.
- Exploration of its properties by G. M. B. Dobson.
- Dobson developed a simple spectrophotometer (the Dobson meter) that could be used to measure stratospheric ozone from the ground.
- Dobson established a worldwide network of ozone monitoring stations between 1928 and 1958 which continues to operate today.
- The "Dobson unit", a measure of the total amount of ozone in a column overhead, is named in his honor.

- **When the earth originated the primitive atmosphere was having reducing type of atmosphere.**
- **Obviously the first group of organisms the were anaerobes which did not require oxygen to survive. The condition existed on earth over 3000 million years ago.**
- **With evolution of the BGA, the primitive forms of plant life release of oxygen through the photosynthesis started which resulted in the buildup of oxygen in the atmosphere.**
- **It eventually led to the formation of the ozone layer in the upper atmosphere or stratosphere. This layer filters out incoming "cell-damaging" ultraviolet (UV) part of the spectrum.**
- **In this way, more advanced life forms began to evolve with the development of the ozone layer.**
- **Ozone is a form of oxygen. Normal oxygen which we breathe is colourless and odourless. Ozone, on the other hand, consists of three atoms of oxygen bound together (O3). Ozone is colourless and has a very harsh odour.**
- **Ozone is much less common than normal oxygen.**

- Out of 10 million air molecules, about 2 million are normal oxygen, but only 3 are ozone.
- Most ozone is produced naturally in the upper atmosphere or stratosphere.
- While ozone can be found through the entire atmosphere, the greatest concentration occurs at altitudes between 19 and 30 km above the Earth's surface. This band of ozone-rich air is known as the "ozone layer".
- Ozone also occurs in very small amounts in the troposphere. It is produced at ground level through a reaction between sunlight and volatile organic compounds (VOCs) and nitrogen oxides (NOx).
- Ground-level ozone is a component of urban smog and it is one of secondary pollutants which is harmful to human health.
- Even though both types of ozone contain the same molecules, their presence in different parts of the atmosphere has very different consequences.
- Stratospheric ozone blocks harmful UV-radiation.
- In contrast, ozone present in troposphere is simply a pollutant. It will absorb some incoming solar radiation, but it cannot make up for ozone losses in the stratosphere

Ozone hole

Technically, the term " OZONE HOLE" should be applied to regions where stratospheric ozone depletion is so severe that levels fall below 200 Dobson Units (D.U.), the traditional measure of stratospheric ozone.

- **Normal ozone Concentration is about 300 to 350 D.U [3].**
- **Such ozone loss now occurs every springtime above Antarctica, and to a lesser extent the Arctic, where special meteorological conditions and very low air temperatures accelerate and enhance the destruction of ozone loss by man-made ozone depleting chemicals (ODCs).**
- **During the period 1956-1970, the spring time O_3 layer thickness above Antarctica varied from 280 to 325 Dobson Unit.**
- **The thickness was sharply reduced to 225 DU in 1979 and to 136 DU in 1985.**
- **Later, the O_3 layer thickness continued to decline to about 94 DU in 1994.**
- **The ozone hole was first discovered in 1985 over Antarctica. The existence of ozone hole was also confirmed above Arctic in 1990.**

The Ozone Layer

- The ozone layer represents a region where most of ozone particles are scattered between 19 and 30 kilometers up in the stratosphere.
- The concentration of ozone in the ozone layer is usually under 10 parts ozone per million.
- In an unpolluted atmosphere the total concentration of ozone in the stratosphere remains relatively constant as there is a balance between the amount of ozone being produced and the amount of ozone being destroyed.
- At different temperatures and pressures i.e. at different altitudes within the stratosphere, the rate of formation and destruction varies. So, there is difference in amount of ozone within the stratosphere at varying altitude. Ozone concentrations are highest between 19 and 23 km .
- Most of the ozone in the stratosphere is formed over the equator where the level of sunshine striking the Earth is greatest.

It is transported by winds towards higher latitudes. Consequently, the amount of stratospheric ozone above a location on the Earth varies naturally with latitude, season, and from day-to-day.

- **Under normal circumstances highest ozone values are found over the Canadian Arctic and Siberia, whilst the lowest values are found around the equator.**

The ozone layer over Canada is normally thicker in winter and early spring, varying naturally by about 25% between January and July.

Weather conditions can also cause considerable daily variations.

Measuring Ozone Depletion:

The Dobson Unit (DU)-

It is the most common stratospheric ozone measurement unit.

A Dobson Unit measures the total amount of ozone in an overhead column of the atmosphere.

- **Dobson Units are measured by how thick the layer of ozone would be if it were compressed into one layer at 0 degrees Celsius and with a pressure of one atmosphere above it. Every 0.01 millimeter thickness of the layer is equal to one Dobson Unit.**
- **The average amount of ozone in the stratosphere across the globe is about 300 DU (or a thickness of only 3mm at 0°C and 1 atmospheric pressure!).**
- **When stratospheric ozone<200 DU it represents the beginnings of an ozone hole. Ozone holes commonly form during springtime above Antarctica, and to a lesser extent the Arctic.**

CAUSES OF OZONE DEPLETION

- **When the natural balance between the production and destruction of stratospheric ozone is disturbed and there is greater degree of destruction compared to its formation ozone layer thinning starts.**
- **M. Molina and S. Rowland in 1974 suggested that a group of compounds known as the chlorofluorocarbons (CFCs) were likely to be the main source of ozone depletion. Their idea was taken seriously only after the discovery of the ozone hole over Antarctica in 1985 by the Survey.**

Chlorofluorocarbons

- **Chlorofluorocarbons or CFCs are also known as Freon.**
- **CFCs are are non-toxic, non-flammable and non-carcinogenic. They contain fluorine atoms, carbon atoms and chlorine atoms.**
- **The 5 main CFCs are as follows:**
- **CFC-11 (trichlorofluoromethane - CFCl3),**
- **CFC-12 (dichloro-difluoromethane - CF2Cl2),**
- **CFC-113 (trichloro-trifluoroethane - C2F3Cl3),**
- **CFC-114 (dichloro-tetrfluoroethane - C2F4Cl2) and**
- **CFC-115 (chloropentafluoroethane - C2F5Cl).**

- **Uses of CFCs:**
  - **coolants in refrigeration and air conditioners,**
  - **as solvents in cleaners, particularly for electronic circuit boards,**
  - **as a blowing agents in the production of foam (for example fire extinguishers), and**
  - **as propellants in aerosols.**
- **Chlorofluorocarbons are not "washed" back to Earth by rain or destroyed in reactions with other chemicals. They simply do not break down in the lower atmosphere and they can remain in the atmosphere from 20 to 120 years or more.**

- **As a consequence of their relative stability, CFCs are instead transported into the stratosphere where they are eventually broken down by ultraviolet (UV) rays from the Sun, releasing free chlorine.**
- **The free chlorine atoms would then enter into a chain reaction, destroying ozone.**
- **The net result is that two molecules of ozone are replaced by three molecules of oxygen, leaving the chlorine free to repeat the process:**
- **Cl + O3 = ClO + O2**
- **ClO + O = Cl + O2**
- **Ozone is converted to oxygen, leaving the chlorine atom free to repeat the process up to 100,000 times, resulting in a reduced level of ozone.**
- **Bromine compounds, or halons, can also destroy stratospheric ozone. Compounds containing chlorine and bromine from man-made compounds are known as industrial halocarbons.**
- **Emissions of CFCs have accounted for roughly 80% of total stratospheric ozone depletion.**
- **Naturally occurring chlorine has the same effect on the ozone layer, but has a shorter life span in the atmosphere.**

- **Man-made CFCs are the main cause of stratospheric ozone depletion .**
- **CFCs have a lifetime in the atmosphere of about 20 to 100 years.**
- **Consequently one free chlorine atom from a CFC molecule can do a lot of damage, destroying ozone molecules for a long time.**
- **Although emissions of CFCs around the developed world have largely ceased due to international control agreements, the damage to the stratospheric ozone layer will continue well into the 21st century.**

Rocket Launches

- **The rocket launches would cause significant damage to Earth's stratospheric ozone layer in the decades to come, according to a new study by researchers in California and Colorado.**
- **Future ozone losses from unregulated rocket launches will eventually exceed ozone losses due to chlorofluorocarbons, or CFCs. The study concludes that with growth in the rocket launch market there would be increase in ozone-destroying rocket emissions.**
- **Highly reactive trace-gas molecules known as radicals dominate stratospheric ozone destruction, and a single radical in the stratosphere can destroy up to 10,000 ozone molecules before being deactivated and removed from the stratosphere.**

EFFECT OF OZONE LAYER DEPLETION

A. **Effects on Human and Animal Health:**

- **Increased penetration of solar UV-B radiation is likely to have significant impact on human health with potential risks of eye diseases, skin cancer and infectious diseases .**
- **UV radiation is known to damage the cornea and lens of the eye.**
- **Chronic exposure to UV-B could lead to cataract.**
- **UV-B radiation can adversely affect the immune system causing a number of infectious diseases.**
- **In light skinned human populations, it is likely to develop nonmelanoma skin cancer (NMSC).**
- **Experiments on animals show that UV exposure decreases the immune response to skin cancers, infectious agents and other antigens.**

B. Effects on Terrestrial Plants:

The increased UV-B radiation in natural ecosystem would change the species composition (mutation) which in turn, alters the bio-diversity in different ecosystems.

- The physiological and developmental processes of plants are affected by UV-B radiation.
- Scientists believe that an increase in UV-B levels would necessitate using more UV-B tolerant cultivar and breeding new tolerant ones in agriculture.
- UV-B could also affect the plant community indirectly resulting in changes in plant form, secondary metabolism, etc.
- These changes can have important implications for plant competitive balance, plant pathogens and bio-geochemical cycles.

C. Effects on Aquatic Ecosystems:

- **It is believed that increased levels of UV exposure would have adverse impacts on the productivity of aquatic systems.**
- **High levels of exposure in tropics and subtropics may affect the distribution of phytoplankton which form the foundation of aquatic food webs.**
- **A recent study has indicated 6-12 percent reduction in phytoplankton production in the marginal ice zone due to increases in UV-B.**
- **UV-B can also cause damage to early development stages of fish, shrimp, crab, amphibians and other animals, the most severe effects being decreased reproductive capacity and impaired larval development.**

D. Effects on Bio-geo-chemical Cycles

- **Bio-geo-chemical cycles can be affected by increased solar UV radiation which would alter both sources and sinks of greenhouse and important trace gases, e.g. carbon dioxide (CO_2), carbon monoxide (CO), carbonyl sulphide (COS), etc.**
- **These changes would contribute to biosphere-atmosphere feedbacks responsible for the atmosphere build-up of these gases.**

Other effects of increased UV-B radiation are as follows:

- **changes in the production and decomposition of plant matter;**
- **reduction of primary production**
- **changes in the uptake and release of important atmospheric gases;**
- **reduction of bacterioplankton growth in the upper ocean;**
- **increased degradation of aquatic dissolved organic matter (DOM), etc.**

- There would be effect of enhanced UV-B on aquatic nitrogen cycling due to inhibition of nitrifying bacteria and photodecomposition of simple inorganic species such as nitrate.
- It is going to affect the marine sulphur cycle also resulting in possible changes in the sea-to-air emissions of COS and dimethylsulfide (DMS), two gases that are degraded to sulphate aerosols in the stratosphere and troposphere, respectively.

E. Effects on Air Quality

- **Increased penetration of UV-B radiation due to reduction of stratospheric ozone increasse photo dissociation rates of key trace gases that control the chemical reactivity of the troposphere.**
- **It would increase both production and destruction of ozone and related oxidants such as hydrogen peroxide which are known to have adverse effects on human health, terrestrial plants and outdoor materials**.
- **Changes in the atmospheric concentrations of the hydroxyl radical (OH) may change the atmospheric lifetimes of important gases such as methane and substitutes of chlorofluoro carbons (CFCs).**

F. Effects on Materials

- **The increased level of UV radiation adversely affects**
  - **synthetic polymers,**
  - **naturally occurring biopolymers and**
  - **some other materials of commercial interest.**
- **UV-B radiation accelerates the photo degradation rates of these materials thus limiting their lifetimes.**
- **Typical damages range from discoloration to loss of mechanical integrity.**

G. Effects on Climate Change

- **Atmospheric ozone has two effects on the temperature balance of the Earth. It absorbs solar ultraviolet radiation, which heats the stratosphere.**
- **It also absorbs infrared radiation emitted by the Earth's surface, effectively trapping heat in the troposphere.**
- **Therefore, the climate impact of changes in ozone concentrations varies with the altitude at which these ozone changes occur.**
- **Reduction of stratospheric ozone has a cooling effect on the Earth's surface. On the other hand, the ozone increase in the troposphere has a warming effect on the Earth's surface.**

H. Effects on Ultraviolet Radiation

- **The depletion of the ozone layer leads to an increase in ground-level ultraviolet radiation, because ozone is an effective absorber of ultra-violet radiation.**
- **The Sun emits radiation over a wide range of energies, with about 2% in the form of high-energy, ultraviolet (UV) radiation.**
- **Some of this UV radiation (UV-B) is causes damage to living beings.**

INTERNATIONAL ACTIONS

- The first international action to focus attention on the dangers of ozone depletion in the stratosphere and its dangerous consequences on life on earth was focused in 1977 when in a meeting of 32 countries in Washington D.C. a World plan on action on Ozone layer with UNEP as the coordinator was adopted.
- An international convention was held in Vienna on March 22, 1985 which resulted in an international agreement in 1987 on specific measures to be taken in the form of an international treaty known as the Montreal Protocol on Substances.

A. Montreal Protocol

- On the basis of the Vienna Convention, the Montreal Protocol on Substances that Deplete the Ozone Layer was negotiated and signed by 24 countries and by the European Economic Community in September 1987.
- The Protocol called for the Parties to phase down the use of CFCs, halons and other man-made ODCs.
- The Montreal Protocol represented a landmark in the international environmentalist movement. For the first time whole countries were legally bound to reducing and eventually phasing out altogether the use of CFCs and other ODCs. Failure to comply was accompanied by stiff penalties.
- The original Protocol aimed to decrease the use of chemical compounds destructive to ozone in the stratosphere by 50% by the year 1999.

- The Protocol was supplemented by agreements made in London in 1990 and in Copenhagen in 1992, where the same countries promised to stop using CFCs and most of the other chemical compounds destructive to ozone by the end of 1995.
- Fortunately, it has been possible to develop and introduce compounds and methods to replace CFC compounds.
- In order to deal with the special difficulties experienced by developing countries it was agreed that they would be given an extended period of grace. An international fund was established to help the developing countries to introduce new and more environmentally friendly technologies and chemicals.

B. Australian Chlorofluorocarbon Management Strategy

It provides a framework for the responsible management and use of CFCs in Australia.

C. Environmental Protection (Ozone Protection) Policy2000 :

- It aims to minimize the discharge of ozone-depleting substances into the environment.

D. United Nations Environment Programme:

- It has published several assessments of the environmental effects of ozone depletion

- **E. Ultraviolet index forecast**
  The Bureau of Meteorology has developed a model to predict the amount of ultraviolet exposure. It is designed to help people minimize their exposure to dangerous levels of ultraviolet radiation.