Ozone Depletion

The discovery of a major stratospheric ozone layer event (the ozone hole) over Antarctica in 1985 fueled interest in ozone depletion as a potential health and ecological threat related to increased solar ultraviolet radiation. Intensified research of this phenomenon followed and led ultimately to the strengthening of the Montreal Protocol, restricting or banning industrial production of chlorinated and brominated compounds causing the depletion.

Measurements of total-column ozone have been made for Over 40 years with the Dobson spectrophotometer. From this strong complement of ozone-measuring techniques, it has been possible to measure the decline in ozone over the past two decades at mid-latitudes of the northern hemisphere and the tropic and to characterize the dramatic ozone depletion over Antarctica.

Formation of Ozone

1. **In the stratosphere (Upper atmosphere).** In lower mesosphere, the atmospheric oxygen (O_2) absorbs UV radiation and photo dissociates into two oxygen atoms (O). These oxygen atoms combine with molecule oxygen of upper atmosphere, thereby producing ozone (O_3).
2. **In the troposphere (Lower atmosphere).** Automobile exhaust in the street and highways and exhaust of other internal combustion engines in the factories and in houses are probably the most important source of ozone. Thousands of tons of incompletely burned hydrocarbon and NO_2 (Nitrogen oxide) are released in the atmosphere daily by exhaust, in the presence of UV from sun. This NO_2 reacts with these instead of ozone and therefore ozone concentrations build up.

   Ozone is formed by photochemical reactions, followed by a three-body reaction :

   (Third body, Such as N_2 Or O_2)

The role of third body (M) is to absorb the excess energy liberated by the above reaction and thereby O_3 molecules are stabilized.

Importance

A layer of ozone in the stratosphere is a boon as it shields the passage of the dangerous solar ultraviolet rays to the earth. Ozone is acting as a protective radiation shield or natural sun glass for all living organisms on the earth. It strongly absorbs ultraviolet radiations from the sun in the region 220-330 nm and thereby protects the life on earth from severe radiation damage, such as DNA mutation and skin cancer. Thus only a small fraction of U.V radiation reaches the lower atmosphere and the earth's surface. Where the ozone shield not there, the consequences could be fatal for humankind. So, if humankind is to continue being able to walk around in the sunshine, then the stability of the ozone layer is essential. It is in this background that the appearance of the ozone hole becomes a matter of great concern. Studies with some 200 plant species have shown almost two-third of them to be susceptible. They include members of the bean, pea and cabbage

families. Among the visible harmful effects of exposure to high doses of ultraviolet radiation were reduced leaf size, stunted growth, poor seed quality and increased susceptibility to weeds disease and pests. A study by marine biologists in the seas around Antarctica showed that higher levels of ultraviolet radiation reduce algal productivity by 6-12 per cent. It also causes damage to various forms of aquatic larvae and other organisms.

Ozone in the Troposphere

Ozone (O_3) in the Troposphere is a green house gas and is considered to be a pollutant as it can rapidly remove vitamin E (which protects the skin) from the uppermost layer of skin and can cause corrosion problems, damage to vegetations and mutation in DNA, etc. Reports reveal, when Troposphere Ozone level reaches 50 ppb, plant growth reduces by about 15 per cent.

Creation of Ozone holes over Antarctica

In Layman's language "these are the pathches of the sky marked by extremely low concentration of ozone." Ozone Holes have been observed over Antarctica since 1970 in August and September. During these months, energized by the first-faint rays of sunlight Cl Chemistry destroys the ozone layer. Clouds of Polar Regions are formed by the condensation of nitric acid trihydrates and water of extremely cold temperature in the winter polar vortex. Stratospheric aerosol is served as nuclei for the development of PSCs (Pollar Stratospheric Clouds). These contains ice patricles which provide surface over which chlorine and other chemicals adhere, enabling them to attack ozone.

CFCs are the dominant source of chlorine in the atmosphere. Chlorofluro methane is used as a refrigerant and aerosol spray as a propellant. They are inert in the atmosphere but slowly diffuse into the stratosphere where they are subjected to ultraviolet radiation at about 200 nm generating Cl free radical. Cl immediately reacts with O_3

$$CFCl_{3(g)} \xrightarrow{uv} CFCl_{2(g)} + Cl_{(g)}$$

$$CF_2Cl_{2(g)} \xrightarrow{uv} CF_2Cl_{(g)} + Cl_{(g)}$$

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

$$ClO + O \longrightarrow Cl + O_2$$

$$ClO + NO_2 \longrightarrow Cl - O - N\begin{matrix}O\\ \diagdown\\ \diagup\\ O\end{matrix}$$

In the first step chlorine atoms are knocked off the CFC molecules by ultraviolet radiation. The highly reactive free chlorine atoms then attack ozone, breaking it down into an oxygen molecule and forming a substance called chlorine monoxide. This chlorine monoxide through further catalytic chain reactions releases more free chlorine atoms, which break down more ozone, and the chain continues. So efficient is the chlorine atom as an ozone destroyer that a single atom is enough to break down as many as 100,000 molecules of ozone before it drifts down into lower atmosphere and is washed away.

The detection of the 'Ozone hole' over Antarctica in 1985 attracted the attention of scientific community in the world. The U.S. immediately banned the use of CFCs in spray cans. Further in the year 1987, twenty-four nations of the world signed the Montreal Protocol, which aims at 35 percentage annually, efforts to produce chlorine-free substitutes have also started.

Causes of Ozone layer depletion

Ozone layer is depleted by reactions involving a variety of compounds reaching the Stratosphere. The important once are chlorofluorcarbons (CFCs). Halos (a combination of Bromine and Iodine), water vapour, nitrous oxide, methyl bromide, dichloromethane, carbon tetrachloride etc.

1. Chlorine nitrate has reduced catalytic cycles of Cl and NO_g for O_3 destruction, thereby lowering the overall O_3 depletion rates. It is estimated that for each chlorine atom released 100,000 molecules of ozone are destroyed.
2. Nuclear explosions produce a large quantity of NO_g, which directly enters the stratosphere. It is found that nuclear tests conducted by the USSR and the USA has reduced O_3 concentration by about 4 percentages. Such reduction definitely damages food production.
3. Atmospheric activities also play a significant role in the matter of NO_g load to the stratosphere. The supersonic aircraft (SST) fly in the stratosphere because of low air resistance, which is essential to maintain the speed of the supersonic. Their exhaust gases directly provide NO_g into the stratosphere.

   $N_2(g) + O_2 \rightarrow 2NO$

   The residence time of the gases in the stratosphere is of the order of a year or so. Because of this, there is no possibility of doubling of stratospheric concentration of NO_g. It leads to reduce O_3 concentration by about 40 per cent.

Ecological Impact

The loss of stratospheric ozone is now an established fact and there is genuine concern about its impact on humankind. Only recently have researchers turned their attention to finding out how humans, vegetation and aquatic ecosystems may be affected by ozone depletion. These effects are—

1. Direct exposure to ultraviolet radiation can damage the human immune system, cause cataracts and increase the incidence of skin cancer.
2. Studies with some 200-plant species have shown almost two-thirds of them to be susceptible. They include members of the bean, pea and cabbage families. Among the visible harmful effects of explosure to high doses of ultraviolet radiation were reduced leaf size, stunted growth, poor seed quality and increased susceptibility to weeds disease and pests.
3. A study by marine biologists in the seas around Antarctica showed that higher levels of ultraviolet radiation reduce algal productivity by 6-12 per cent. It also causes damage to various forms of aquatic larvae and other organisms.
4. The long-term effects of such changes could be catastrophic. For example, in Antarctic waters reduced productivity of photo plankton could affect krill–the tiny shrimp–like creatures that lie at the bottom of the Antarctic food chain. Krill would in turn affect fish, birds and marine animals including seals and whales that feed on them.
5. The global warming, depletion of ozone layer are some of the immediate threats to environment. The average global temperature during the 1980s exceeded that of any other decade since reliable temperature recording began a century ago and 1990 was the warmest year on record. The elevated concentration of greenhouse gases is responsible for rise in temperature. Troposphere O_3 is a greenhouse gas so it is also responsible for rise in temperature. This could lead to complex climatic changes including the rise in sea level. CFCs (Chlorofluorocarbons) are the dominant sources of chlorine in the stratosphere. It may be observed that from global point of view CO_2 is the most important greenhouse gas, which

constitutes 60-65 percentage in total trapping followed by methane. The contribution of CFCs in heat trapping is less but these gases also cause depletion of ozone layer along with others. The protective shield of ozone is depleting. Thus radiation absorbed by ozone layer is partly remitted to the earth's surface. The effect is that a phenomenon known as 'Greenhouse effect' heats up the earth's surface.