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Component-I (B) - Description of Module

Items	Description of Module
Subject Name	**Geography**
Paper Name	Climatology
Module Name/Title	**OZONE DEPLETION: CAUSES AND IMPACTS**
Module Id	8
Pre-requisites	
Objectives	• describe the distribution of ozone, • explainthe process of ozone depletion and cycle of ozone formation, • identify the ozone depleting substances and their

	sources, • explain the mechanism of ozone hole formation over the Antarctica, • highlight the impact of ozone depletion. • describe the steps taken as remedial measures to overcome the problem of ozone depletion.
Keywords	

Contents

Introduction

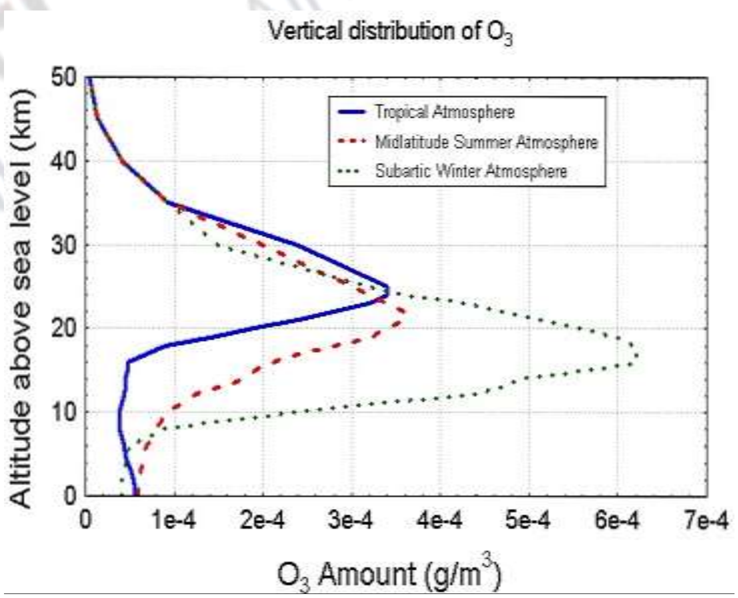
Ozone layeris a vital component of our atmosphere. Instratosphere,it acts as a protective layer as it absorbs the harmful ultraviolet radiation and does not allow it to reach the earth's surface.Therefore, the presence of the ozone layer is essential factor in the life environment. Ozone is a very reactive molecule and with the help of a catalyst it is easily reduced to the more stable oxygen. The ozone destroying catalysts are natural as well as manmade. The primary cause of ozone depletion is the trace gases mainly chlorine and bromine, from anthropogenic sources.The depletion of ozone layer was discovered for the first time by Farman in 1985. It wasestablished that, ozone 'hole' has occurred in the ozone layer over Antarctica.In 1987, the Montreal protocol set legally binding controls on the production and consumption of gases associated with ozone depletion.The outcome of this response is decline in the total abundance of CFCs in the atmosphere and trend of gradual healing of ozone layer.In this module, discussion and deliberation on the causes and impacts of ozone depletion are aimed at.

Ozone

Ozone is a rare gas made up of three atoms of oxygen.You have already studied the composition and structure of earth's atmosphere. You are well aware that the contribution of ozone in the constitution of the atmosphere is very little. Overall its share is just three per every 10 million molecules. Moreover, the distribution of ozone in atmosphere is highly uneven. In troposphere, ozone represents less than one part per 100 million molecules. Still, ozone is a very significant component of atmosphere. It is found concentrated mainly in stratosphere at the height range of 10 to 50 km (Figure 1).Its concentration is much higher in the low latitudes but much lower in the high latitudes. The maximum is just a few km above the tropopause.

Ozone gas is predominantly found in stratosphere and has also a limited presence in the troposphere. Near surface, ozone is undesirable because it is a pollutant. It results into photochemical smog and green house effect resulting into global warming. Here ozone exists as a by-product of photochemical processes between sunlight and pollutants, particularly nitrogen oxides from vehicular exhausts. It is regarded toxic when presence is above sixty parts per billion. It has harmful effects on plant growth as well as causes respiratory problems.

Figure 1. Vertical Distribution of Ozone



Source:http://cimss.ssec.wisc.edu/wxwise/ozone/O3vert.gif

In the stratosphere it is formed through the interaction of the shorter, ultra-violet part of the solar radiation and oxygen molecules, which consist of two atoms of oxygen. Ozone is dominantly concentrated at the height range of 15 and 35 km from surface. The solar ultraviolet radiation breaks-up the oxygen molecules at altitudes above 30 km (i.e. $O_2 \rightarrow O + O$). Theseseparated atoms of oxygen (O + O) when join individually with other oxygen molecules ozone is formed as following:

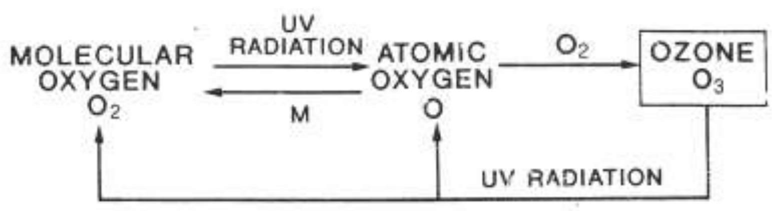
$O_2 + O + M \rightarrow O_3 + M$

Here, M represents the energy and momentum balance provided by collision with a third atom or molecule. Ozone is formed due to the collision of a single atom of oxygen (O) and a molecule of oxygen (O_2). This collision requires the presence of a third, neutral molecule to act as a catalyst. The catalyst allows the interactions without being consumed in this process.

This type of three-body collisions is exceptional at 80 to 100 km above surface, due to very low density of the atmosphere. At height, below 35 km majority incoming ultraviolet radiation gets already absorbed at higher levels. Therefore, ozone is dominantly formed in the height range of 30 to 60 km, where such collisions are more likely.

Sydeny Chapman (1930) discovered the basic physical and chemical processes resulting into the formation of ozone in stratosphere. The ultraviolet radiation breaks an oxygen molecule (O_2) into two oxygen (O) atoms. These atoms then join with other oxygen molecules to create ozone. Ozone is dissolved when an oxygen atom and an ozone molecule rejoin to give two oxygen moleculesi.e. $O + O_3 \rightarrow 2O_2$(Figure 2). In the 1950s, David Bates and Marcel Nicolet proved that various free radicals, especially hydroxyl (OH) and nitric oxide (NO), could catalyze this recombination reaction, depleting the overall amount of ozone. These free radicals are present in the stratosphere. They maintain the natural balance by reducing the overall amount of ozone. It is estimated that in the absence of these free radicals the ozone layer would have thickness twice of the present layer.

Figure 2. Ozone Formation (Chapman Cycle, Oxygen ↔ Ozone)



Source: Barry, R.G. and Chorley, R.J. (1998), P-5.

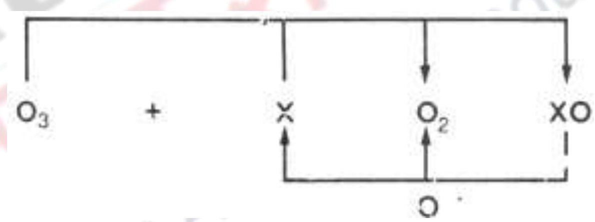
The Chapman cycle (oxygen ↔ ozone) results into filtering of the harmful ultraviolet solar radiation. Therefore, it works as a protective layer; it absorbs harmful radiation and restricts it to reach the surface. In addition, it helps to trap the weather conditions within the lower atmosphere i.e. troposphere by creating an inversion of temperature in the stratosphere.

Ozone Depletion: Process and Causes

Ozone is a very reactive molecule and with the help of a catalyst it is easily reduced to the more stable oxygen. The ozone destroying catalysts are natural as well as manmade. Ozone can be destroyed by a number of free radical catalysts such as (i) OH (hydroxyl) -the odd hydrogen atoms and OH come from the dissociation of water vapour, molecular hydrogen and methane (CH_4); (ii) nitric oxide –ozone is destroyed in stratosphere due to the presence nitrogen oxides (NO_x, i.e. NO_2 and NO). The source gas of theNO_x is nitrous oxide (N_2O) - it is produced by combustion, supersonic jets and fertilizer use; (iii) Chlorine and (iv) Bromine (Figure 3).Anthropogenic activities have sharply increased the levels of chlorine and bromine.

A single chlorine atom has the capability to interact with thousands of ozone molecules in catalytic cycle before it is finally removed. On a per atom basis, the efficiency of bromine is far more than chlorine to destroy ozone, but its abundance is much less in the atmosphere. Therefore, both chlorine and bromine are the major contributors in overall ozone destruction. The increase in abundance of chlorine and bromine during the decades of 1970-90 is reflected in the observed decrease of stratospheric ozone over the Antarctica and other parts. A simplified illustration is given to show ozone destruction below:

Figure 3: Ozone Destruction Process (where X is any ozone-destroying species, e.g. OH, NO, CR, Br)



Source: Barry, R.G. and Chorley, R.J. (1998), P-5.

The depletion of ozone in the stratosphere due to human activities is a serious global environmental problem. The major offending chemicals are Freons, synthetic compounds containing carbon, fluorine and chlorine atoms. Compounds of this class are also known as *halocarbons*. The popular alternate name for these is*chlorofluorocarbons*, or CFCs. They are versatile compounds that are chemically stable, odorless, nontoxic, noncorrosive, and inexpensive to produce. CFCs, carbon tetrachloride (used in fire extinguishers and solvents), alternates of CFCs - hydrochlorofluorocarbons (HCFCs) and methyl chloroform are the chief chlorine containing gases. These gases are used in many applications such as – refrigeration, air conditioning, foam blowing, aerosol propellants and cleaning of metals and electronic components (Table 1).Methyl chloroform is used in industries for cold cleaning, vapor degreasing, chemical processing, adhesives and aerosols.

The most important source halogen gases for bromine are the halons and methyl bromide. Halons are used to extinguish fires. Methyl bromide, used as an agricultural fumigant, is another significant source of bromine to the atmosphere. Methane and nitrogen oxide, which react in stratosphere to form water vapour and reactive hydrogen and nitrogen oxides, respectively have ozone depletion capabilities.The emission of oxides of nitrogen by supersonic jet planes is also destructive for ozone layer.

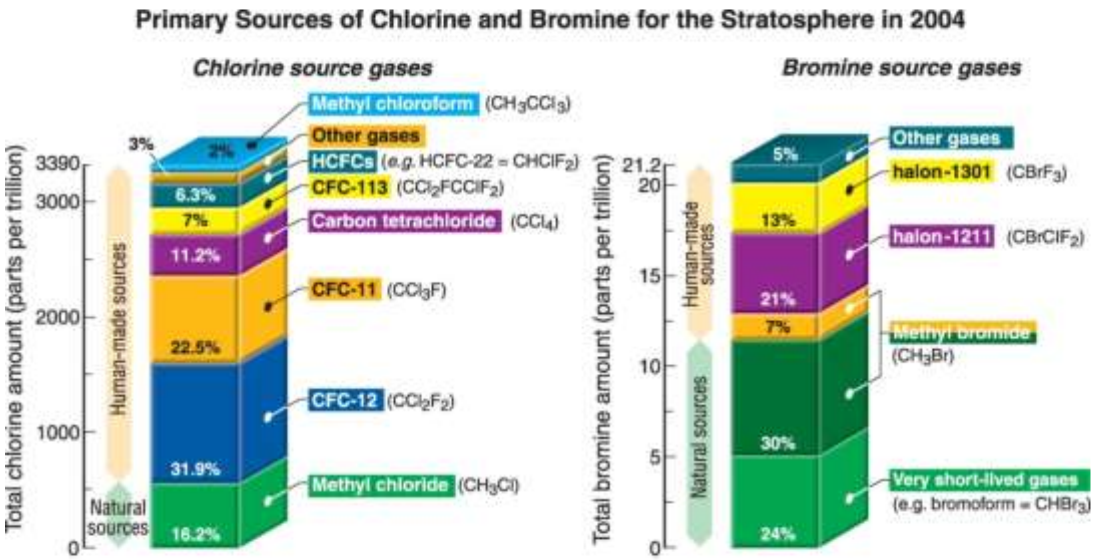
Table 1: Common Chloroflurocarbons and Halons

Compound (chemical formula)	Ozone Depletion Potential[a]	Atmospheric Lifetime (Years)	Major Uses
CFC-11 ($CFCl_3$)	1.0	64	Rigid and flexible foams, refrigration
CFC-12 (CF_2Cl_3)	1.0	108	Air conditioning, refrigeration, rigid foam
CFC-113 ($C_2F_3Cl_3$)	0.8	88	Solvent
Halon-1211 (CF_3BrCl)	3.0	25	Portable fire extinguishers
Halon-1301 (CF_3Br)	10.0	110	Total flooding fire extinguisher systems
HCFC-22 ($HCCIF_2$)	0.05	22	Air conditioning

Source: Oliver, J.E and Hidore, J. (2003), P-366. ([a]Ozone-depleting potentials represent the destructiveness of each compound in relation to CFC-11, which is given value of 1.0)

There are a few halogen source gases present in the stratosphere that have large natural sources. Methyl chloride contributes about 17 per cent of the chlorine currently into the stratosphere. Likewise, about 30 per cent of the bromine is contributed by natural source methyl bromide (Figure 4). These gases are emitted by oceanic and terrestrial ecosystems. Sunspot cycle shows that global total ozone levels vary by 1 to 2 per cent between the maximum and minimum. Volcanoes can emit some chlorine containing gases. In addition, volcanic sulphur and particulate matter emissions reduce solar transmission and ozone abundance. Sunspots and volcanic eruptions bring only short term changes in ozone abundance. Therefore, the main causes of ozone depletion are anthropogenic.

Figure 4. Natural and Anthropogenic Sources of Chlorine and Bromine in Stratosphere



Source:**https://www.esrl.noaa.gov/csd/assessments/ozone/2006/images/Q7-1HighRes.jpg**

There was no concern about the negative consequences of nitrous oxide and CFCs until three scientists, Paul Crutzen, F.S. Rowland, and Mario Molina, studied the relationship. In 1970, Crutzen highlighted that emissions of nitrous oxide (N_2O), from increased use of fertilizers and supersonic aircrafts could deplete ozone in the stratosphere, where due to photochemical process it is converted into nitric oxide (NO). In 1974, Rowland and Molina concluded that, like N_2O, the CFCs under ultraviolet radiation in stratosphere would be dissociated and released chlorine atoms will destroy ozone layer. This way they alerted the world through their research work that CFCs were probably reducing the average concentration of ozone in the stratosphere.

Later on, when in 1995 ozone hole formation was reported, Dr Rowland expressed his frustration and stated, "What's the use of having developed a science well enough to make predictions, if in the end all we are willing to do is stand around and wait for them come true. Unfortunately, this means that if a disaster is in the making in the stratosphere we are probably not going to avoid it." In 1995, scholarsCrutzen, Rowland and Molina, were awarded the Nobel Prize in chemistry for their pioneering research work on ozone depleting substances.

They discovered that molecules of ozone depleting substances like CFCs drift upward and reach the ozone layer in stratosphere. In stratosphere, CFCs in photochemical process absorb ultraviolet radiation and get decomposed, releasing chlorine. These released chlorine atoms in a complex series of reactions attack molecules of ozone. In a series of chain reactions large numbers of ozone molecules are converted into ordinary oxygen molecules. The chlorine atoms basically interact with ozone molecules by acquiring one oxygen atom to constitute chlorine monoxide (CIO) and leaving behind an oxygen molecule (O_2). As the molecule of chlorine monoxide encounters a single oxygen atom, the oxygen "breaks up" the chlorine monoxide, acquires its oxygen atom and chlorine is released back to indulge in further destruction of ozone in stratosphere. These reactions are chain reactions. In this manner, through chain reactions each chlorine atom that reaches the stratosphere is able to destroy thousands of molecules of ozone resulting into ozone depletion. The simplified reactions are following:

(i) $O_3 + Cl \rightarrow ClO + O_2$ (chlorine acting as the catalyst)

$O + ClO \rightarrow O_2 + Cl$

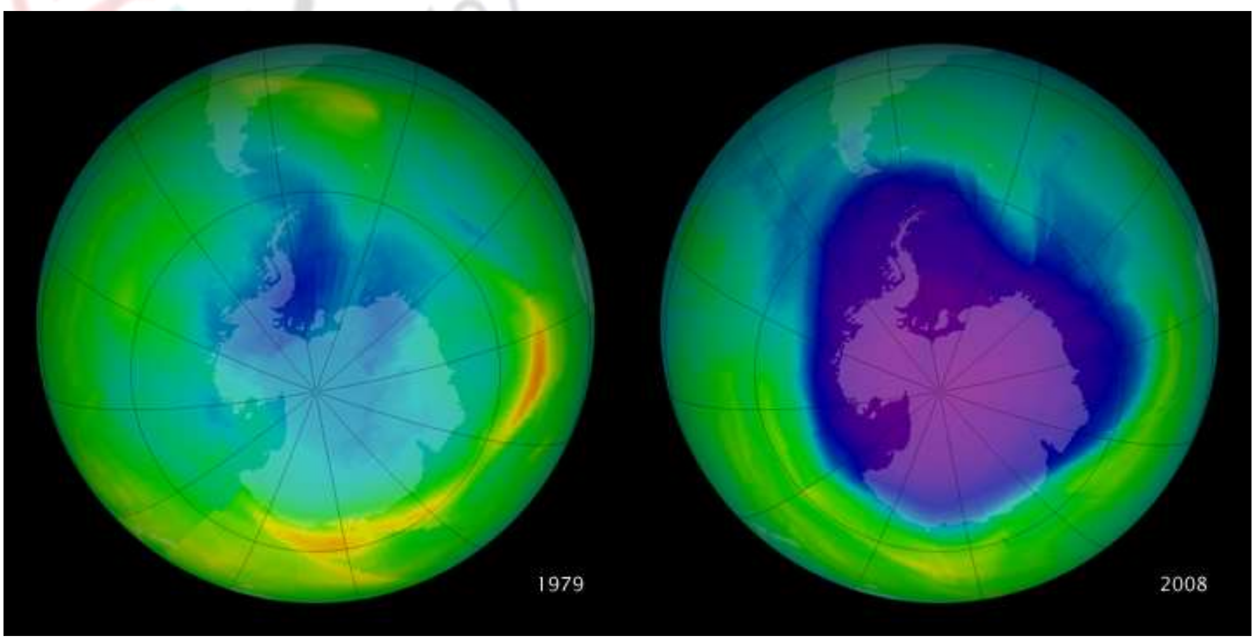
(ii) $O_3 + NO \rightarrow NO_2 + O_2$ (with nitrous oxide acting as the catalyst)

$O + NO_2 \rightarrow O_2 + NO$

The Antarctica Ozone Hole

The first significant data based on scientific observations about the depletion of ozone layer was presented by Farman and his British Antarctic Survey team in 1985. This team on factual basis established that ozone 'hole' has occurred in the stratospheric ozone layer each spring since 1977 over Antarctica. They observed that for the period 1977-84, the abundance of ozone depleted by 40 per cent during spring season of southern hemisphere. Basically ozone hole is not like a 'hole in the windshield'. The ozone does not disappear in a particular part entirely nor is the depletionin the form of uniform thinning of layer. Therefore, the term holeis representative of more of a depression or decline in quantity. The ozone hole covers about 90 per cent of Antarctica and has also expanded over the adjoining oceans. It extends over an area of about 26 million square km. i.e. about the size of North America (Figure 5).

Figure 5: Ozone Holeover Antarctic



Source:http://noair-rors.weebly.com/uploads/5/1/4/5/51453091/288240858.png

The ozone hole develops during the Antarctic spring from September to early December. It is most extensive in October. During this time strong westerly winds start to circulate around the continent and a polar vortex gets established. Due to lack of sunlight temperature decreases and polar vortex traps and chills air to around below -80^{0}C. These temperatures form polar stratospheric clouds (PSCs). These clouds provide surface for reactive chlorine compounds for chemical reactions leading to ozone depletion.

The role of sun light in ozone depletion is most significant. In winter, PSCs are most abundant but due to absence of sunlight chemical reactions don't take place. During the spring, as the sun comes out, photochemical reactions start along with melting of PSCs. The released CIO drives the ozone hole formation mechanism. At the end of spring season (Mid December) due to warming, polar vortex breaks down, the PSCs are destroyed and air flows from lower latitudes restrict the enhanced ozone depletion and ozone hole closes.The depletion of ozone is measured in terms of reduction in the total column ozone above a point on the earth's surface and it is observed with the help of the Total Ozone Mapping Spectrometer (TOMS) and measured in Dobson Units (DU).

The Arctic Hole

Kerr (1988) reported that ozone layer depletion is also going on in the Arctic atmosphere. In the Arctic stratosphere, the ozone abundance is more variable than in the Antarctic. The maximum depletion is up to 30 per cent and it is in winter and spring, when the lowest temperatures prevail in stratosphere. Later on it was reported that the background ozone levels have depleted in northern hemisphere to about 15 per cent and the trend was observed over the Mediterranean Sea and the southern United States also. This is of special significance because the northern hemisphere is more densely populated as compared to southern hemisphere and mid-latitude zone is dominated by developed countries. The seriousness and required responses are reflected in the follow up conferences and meetings of the Montreal Protocol.

Impact of Ozone Depletion

Ozone layer by filtering the harmful ultraviolet radiation functions as a protective shield. In case the ultraviolet radiation reaches the surface with full intensity, it will severely damage the animal tissues and destroy the exposed bacteria. Hence, the presence of the protective ozone layer in stratosphere is essential factor in the life environment. As a consequence of ozone depletion earth surface is exposed to increased ultraviolet radiation. The scholars have estimated that 1 per cent decrease in ozone in stratosphere results into about 2 per cent increase in ultraviolet radiation on surface.

Health of Biotic Life: The increased ultra violet radiation due to ozone depletion can cause damage to human health, ecosystems and global climate (Table 2).Ozone depletion intensifies all of the effects of ultraviolet radiation on health of human beings and other organisms. In addition, increase in ultraviolet radiation at surface results into increase in tropospheric ozone. Ozone concentration in lower part of troposphere is a health risk for human beings and other organisms.

Ozone because of its intense oxidant properties, it is toxic in nature. Juvenile and senile age groups and persons with asthmatic and other respiratory difficulties are more vulnerable.

Greenhouse Effect: Near surface, ozone is produced due to photochemical decomposition of NO_2 by ultraviolet radiation into NO and O. Reaction of atomic oxygen with molecular oxygen results into formation of ozone. Ozone formation takes place here, mainly because of interaction of ultraviolet radiation with combustion gases from vehicular exhausts. Ozone introposphere acts as a greenhouse gas and contributes in global warming. Therefore, ozone depletion on one hand results into global warming andon the other hand in cooling of stratosphere.

Skin Tanning and Cancer:One of the predicted effects of increased ultraviolet radiation is a significant increase in the incidences of skin cancer. The most common skin cancers, basal and squamous cell carcinomas are strongly associated with exposure to ultraviolet radiation. During the decade of the 1990s, scientists in New Zealand discovered that due to depletion of stratospheric ozone concentration,harmful ultraviolet radiation increased substantially. By 2000, peak sunburning ultraviolet levels were nearly 12 per cent more as compared with the levels 10 years earlier in New Zealand. Hence, ozone depletion results into increased incidences of sunburns. The fair-skinned and persons exposed for longer durations have higher vulnerability for sunburn and skin cancer.

Reduction in Human Immune System: The increase in harmful ultraviolet radiation has negative impact of the human immune system. It will be reflected in increased vulnerability to infections and diseases. More exposure to ultraviolet radiation also promotes cataracts. In cataract, the clouding of the eye lens not only reduces vision but may also result into blindness if not treated properly. Epidemiological studies have shown a positive correlation between ocular cortical cataracts and ultraviolet B exposure. To counter the threat of ultraviolet radiation, school children in Australia are motivated to use protective hats and sunglasses and also suggested to avoid bright sunlight.

Effect on Crop Yield: The increased ultraviolet radiation has significant effects on plants and animals. One of the major concerns is that the crop yield and quality will be affected negatively. This quantitative and qualitative loss will intensify food insecurity. Exposure of bacteria to additional ultraviolet radiation affects them adversely because of their sensitivity for this type of radiation. Bacteria help in nitrogen fixation and maintenance of soil fertility for economically significant crops. For instance, rice plants for nitrogen depend on cyanobacteria present in their root system. Therefore the production of economically significant crops will decrease.

Effect on Aquatic Life: The additional ultraviolet radiation has potential to eliminate certain forms of aquatic life mainly in the upper layer of water bodies such as oceans, streams and lakes. Some scientists have highlighted the risk of destruction of the microscopic plants, phytoplankton, due to exposure to ultraviolet radiation in waters surrounding the Antarctica. The phytoplankton represents the base of the food chain in marine ecosystems. Therefore, phytoplankton and zooplankton destruction will result into destruction of marine life. On the basis of measurements scholars have concluded that the increase in ultraviolet radiation reduces photosynthesis linearly. The productivity was reported to be declined by a minimum between 6 to 12 per cent.

Table 2: Impact of Ozone Depletion

Human Health	▪ Increase in number and intensity of sunburning cases. ▪ Increase in eye cataracts and blindness ▪ Increased risk for skin cancer (especially basal, squamous cell carcinomas, and malignant melanoma). ▪ Suppression of immune system and increased risk for infections and diseases. ▪ Positive impact can be reduction in vitamin D deficiency.
Food and Forest	▪ Declined yields and quality of plant products. ▪ Declined seafood supplies due to reduced phytoplankton. ▪ Reduced forest productivity for ultraviolet sensitive tree species.
Wildlife	▪ Increased eye cataracts in some species. ▪ Decline in population of ultraviolet radiation sensitive aquatic species. ▪ Reduced phytoplankton and zooplankton. ▪ Increased sunburning of animals. ▪ Ecological imbalances due to decline in primary production.
Air Pollution and Materials	▪ Increased acid deposition. ▪ Increased photochemical smog in lower troposphere. ▪ Degradation of outdoor paints and plastics. ▪ Toxic ozone risk for asthma and respiratory problems.
Global Warming	▪ Increase in tropospheric ozone, CFCs and decreased marine uptake of carbon dioxide from atmosphere by phytoplankons. ▪ Stratospheric cooling due to ozone depletion because less ultra violet radiation will get absorbed.

Measures to Check Ozone Depletion

In 1976, on the basis of scientific evidences a few countries like United States, Canada, Sweden, Denmark, and Norway banned the use of CFCs in aerosol spray cans. The majority of European countries did not ban CFCs in aerosol sprays. After this ban by these few countries, CFCs production initially declined worldwide. But as CFCs continued in use as refrigerants, solvents, propellants and fire extinguishers, there level by 1986 returned back to the its level of 1976.

In 1985, British Antarctic Survey scientists, Farman, Gardiner and Shanklin, on the basis of scientific evidences discovered ozone hole formation over the Antarctica. Taking into consideration the sharp decline in levels of ozone and associated exposure to ultraviolet radiation, scientists and politicians agreed for some positive measures to address the problem. In response to the global threat of ozone depletion and consequent impact on the life environment in 1985 the Vienna Conference was convened by UNEP (United Nation Environment Programme). Members of 43 nations participated in the Vienna Convention for the Protection of Ozone Layer. The motive of the conference was to promote monitoring, research and sharing of information for the protection of ozone layer to avoid its adverse implications.

In 1987, the Montreal Protocol on substances that deplete ozone layer was signed by the representatives from 43 countries. The participants decided to freeze production of CFCs at 1986 levels by reducing CFCs production by 50 per cent by 1999. In response to ozone depletion trend over the Antarctica and other parts of the world, this protocol was strengthened at a meeting in London (1990). The participants decided to total phase out of CFCs and halon by 2000 by MDCs (More Developed Countries) and by 2010 by LDCs (Less Developed Countries). The phase out date was preponed to 1996 in a meeting at Copenhagen in 1992.

The Montreal Protocol set legally binding limitations on the consumption and production of gases depleting ozone. Over the period of time substitutes were developed and the Montreal Protocol was strengthened and enhanced many times. More than 190 countries have ratified the treaty, including India.

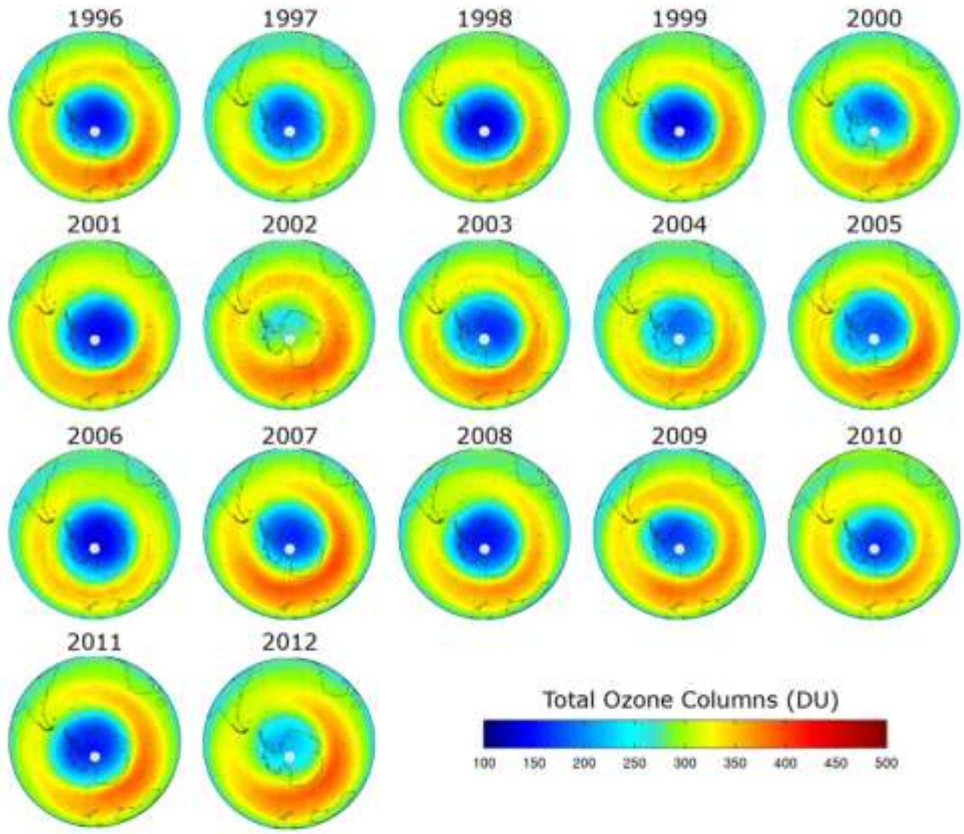
The Montreal Protocol shows a quick and positive international response to a global environmental threat. The outcome of this response is decline in the total abundance of CFCs in the atmosphere. The U.S. Environmental Protection Agencyhas reported that over most of the world the ozone layer has not depleted thinner since 1998. The scholars have projected that between 2060 and 2075, the level of ozone depleting gases will be at the level that existed before the formation of the Antarctic ozone hole.

The hydro chlorofluorocarbons (HCFCs) andhydro fluorocarbons (HFCs) have replaced CFCs. The HFCs do not have chlorine or bromine and therefore, do not result into ozone depletion but they are potent greenhouse gases.An ozone-safe refrigerant known as “Greenfreeze” is in use as an alternative to CFCs.

The Montreal Protocol and use of substitutes and alternatives of CFCs reflect positive results. The ozone levels have stabilized and trends of recovery have been observed (Figure 6). In 2012, UNEP report stated that in the last decade global ozone, including polar areas, showed no depleting trend. The scholars have projected that ozone layer will recover to its pre-1980 levels by some time before the middle of this century and in polar areas by 2060-2075 (Figure 7). Studies have reported a gradual trend towards “healing” of ozone layer in 2016.

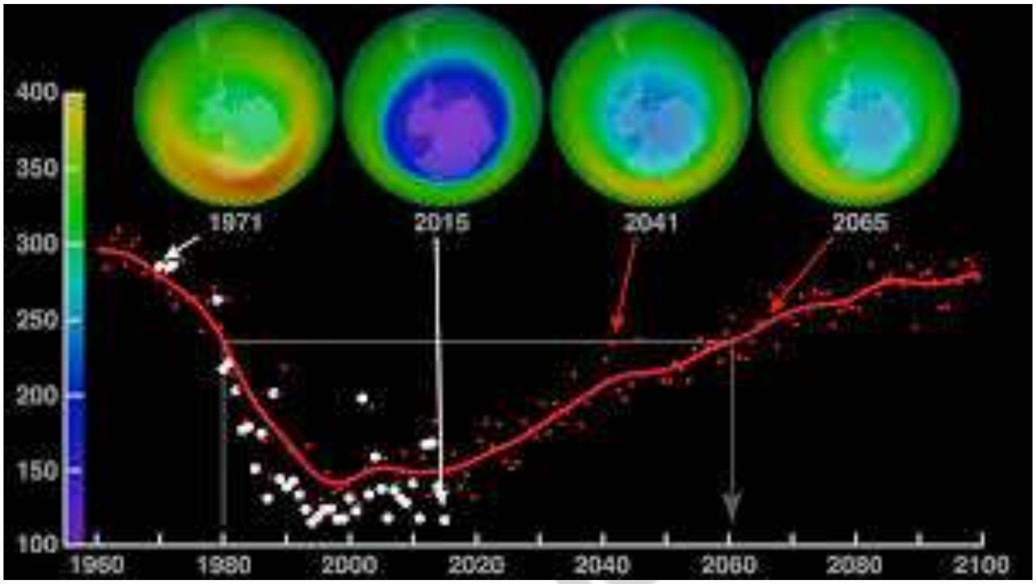
The Montreal Protocol and development of alternatives and substitutes of CFCs has shown positive results.Ozone levels stabilized in the 1990s following the Montreal Protocol, and have started to recover. The UNEP report (2007) showed that the hole in the ozone layer was recovering and the smallest it had been for about a decade. The 2010 report found, "Over the past decade, global ozone and ozone in the Arctic and Antarctic regions is no longer decreasing but is not yet increasing. The ozone layer outside the Polar Regions is projected to recover to its pre-1980 levels some time before the middle of this century. In contrast, the springtime ozone hole over the Antarctic is expected to recover by 2060 –2075). A gradual trend toward "healing" was reported in 2016.

Figure 6: Ozone Hole Trend, 1996-2012.



Source:http://mygoodplanet.com/wp-content/uploads/2016/07/South_Pole_ozone.jpg

Figure 7. Projected Ozone Hole Recovery



https://en.wikipedia.org/wiki/Ozone_depletion#/media/File:Ozone_hole_recovery.jpg

Summary and conclusions

Ozone layeris a very significant component of our atmosphere. It acts as a protective layer as it absorbs the harmful ultraviolet radiation and does not allow it to reach the earth's surface.Therefore, the presence of the ozone layer is essential factor in the life environmentof our planet. In stratosphere, oxygen ↔ ozone cycle operates as Chapman cycle. Ozone is a very reactive molecule. It is easily reduced to more stable oxygen form with the help of catalysts. The ozone destroying catalysts are natural as well as manmade.

Ozone can be destroyed by a number of free radical catalysts such as - OH (hydroxyl), nitrogen oxides (NO_x, i.e. NO_2 and NO), Chlorine and Bromine. Anthropogenic sources have dramatically increased the levels of chlorine and bromine. Over the decades, many uses were developed for Chlorofluorocarbons (CFCs), including as coolants for air conditioning and refrigeration equipment, cleaning solvents for electronic components, propellants for aerosol sprays, and production of certain plastic foams. Halons used as fire retardants result into ozone depletion. The emission of oxides of nitrogen by supersonic jet planes is also destructive for ozone layer.

Crutzen (1970) and Rowland and Molina (1974) pointed out that emissions of nitrous oxide and CFCs have capacities to destroy ozone. The first significant data about the depletion of ozone layer was presented by Farman (1985), the leader of British Antarctic Survey team. He established that, ozone 'hole' has occurred in the stratospheric ozone layer over Antarctica each spring for the period 1977-84. The ozone abundance declined by about 40 per cent during each spring in this period.Later on ozone depletion was also reported over Arctic and northern hemisphere mid-latitudes.

Ozone depletion results into increase in ultraviolet radiation reaching the earth's surface. The increased ultra violet radiation due to ozone depletion can cause damage to human health, ecosystems and to the global climate.Ozone depletion would magnify all of thenegative effects of ultraviolet radiation on human health such as sunburns, skin cancers, and cataracts. The effects of additional ultra violet radiation on animal and plant life are also important. There is serious concern that crop yield and quality will be adversely affected.

In 1987, the Montreal Protocol set legally binding controls on the production and consumption of gases associated with ozone depletion.Montreal Protocol represents a positive international response to a global environment problem. As a result of the action, the total abundance of ozone depleting gases in the atmosphere has started to decrease recently and a healing trend is visible.