Academic Voices
A Multidisciplinary Journal
Volume 8, No. 1, 2018
ISSN: 2091-1106

OZONE LAYER DEPLETION: A GLOBAL CONCERN

Shiva Kant Dube

Department of Geography, TU, Thakur Ram Multiple Campus, Birgunj, Nepal

Email: shivakant.dube@gmail.com

Abstract

The distribution of ozone in the stratosphere is a function of altitude, latitude and season. It is determined by photochemical and transport processes. The ozone layer is located between 10 to 50 km above the earth's surface and contains 90 percent of all stratospheric ozone. Under normal conditions, stratospheric ozone is formed by a photochemical reaction between oxygen molecules, oxygen atoms and solar radiation. The ozone layer is essential to life on earth, as it absorbs harmful ultraviolet-B radiation from the sun. In recent years the thickness of this layer has been decreasing, leading in extreme cases to holes in the layer. Measurements carried out in the Antarctic have shown that, more than 95 percent of the ozone concentrations found at altitudes between 15 to 20 km and more than 50 percent of total ozone are destroyed. The main cause of ozone layer depletion is the increased stratospheric concentration of chlorine from industrially produced CFCs i.e. chlorofluorocarbons. Thus, the effective implementation of commitments made in national conventions, international treaties and global cooperation would help to safeguard this protective shield and earth's umbrella.

Key words

Stratosphere; photochemical reaction; protective shield; biological furnace; blast furnace

Introduction

Those events or accidents, whether caused by natural processes or human factors, are called extreme events which occur very rarely and aggravate natural environmental processes to cause disaster for human society. Environmental hazards may be defined as those extreme events either natural or man-induced, which exceed the tolerable magnitude within or beyond certain time limits, make adjustment difficult, result in catastrophic losses of property, income and lives and become the headlines of different news media at world level (Strahler & Strahler, 1976).

Singh describes that hazards are generally taken to be the processes, both natural and anthropogenic, which cause an accident/extreme event or danger whereas 'disaster' is a sudden adverse or unfortunate extreme event which causes great damage to human beings as well as plants and animals. Disasters occur rapidly, instantaneously and indiscriminately. It, therefore, becomes obvious that environmental hazards are the processes whereas the environmental disasters are the results or responses of environmental hazards. It may be mentioned that environmental disasters are always viewed in terms of human beings. The intensity of environmental disaster is weighed in terms of the quantum of damages done to the human society (as cited by Dube, 2015).

Ozone layer depletion is one of those global issues caused due to anthropogenic or natural or by both factors. This paper incorporates the introduction of ozone, ozone layer, ozone layer depletion, causes, effects and solution measures including conclusion.

Ozone is a colorless gas; it is relatively simple molecule, consisting of three oxygen atoms bound together. The stratospheric ozone layer mostly concentrated between 12 to 50 km considered as protective shield and earth's umbrella because it prevents ultra-violet radiation from reaching to the earth surface. Thus the presence of ozone layer in the stratosphere is of vital significant for all biota (biological community) including, plants, animals and human beings in the biosphere. In the absence of this layer no life is possible because all the ultra-violet rays of the sun will reach on the earth's surface consequently, the temperature of the earth and lower atmosphere will rise to such an extent that the "Biological furnace" of the biosphere will turn into a "Blast furnace" (Singh, 2015).

Ozone is a bluish gas that is formed by three atoms of oxygen. The form of oxygen that humans breathe in consists of two oxygen atoms, O_2. When found on the surface of the planet, ozone is considered a dangerous pollutant and is one substance responsible for producing the greenhouse effect. The highest regions of the stratosphere contain about 90 percent of all ozone. In recent years, the ozone layer has been the subject of much discussion and rightly so, because the ozone layer protects both plant and animal life on the planet. The fact that the ozone layer was being depleted was discovered in the mid-1980s. The main cause of this is the release of CFCs, chlorofluorocarbons. Antarctica was an early victim of ozone destruction. A massive hole in the ozone layer right above Antarctica now threatens not only that continent, but many others that could be the victims of Antarctica's melting icecaps. In the future, the ozone problem will have to be solved so that the protective layer can be conserved (Rayamane, 2011).

Ozone is defined as three atoms of oxygen or merely a triatomic form of oxygen and it is expressed as O_3 which is faintly blue irritating gas with the characteristics of pungent odor. Ozone is a strong oxidizing agent which can at higher concentration decompose with an explosion.

It may be pointed out that ozone is present at almost all altitude in the atmosphere and within this highest concentration of ozone is between the altitude of twelve to thirty five (12 to 35) km in the stratosphere. This zone of ozone is called ozonosphere or ozone layer or stratospheric ozone layer. The ozone gas is unstable because it is created as well as destroyed or disintegrated. In other words the creation and destruction of ozone gas is gradual and continuous natural process. The oxygen molecules (O_2) are broken up and separated in the atmospheric layer by ultra-violet solar radiation or by an electric discharge in oxygen or air during thunderstorms in the troposphere ($O_2 = O+O$). These separated oxygen atoms (O) are then combined with oxygen molecules (O_2) and thus ozone ($O_2+O= O_3$) is formed (Singh, 2015). Symbolically

$$O_2 \xrightarrow{UV} O + O$$

Then,

$$O_2 + O \xrightarrow{UV} O_3$$

which is ozone gas.

Fig. 1 The ozone layer and ozone hole

Depletion of Ozone Layer

There has been much ‘hue and cry’ about the depletion of stratospheric ozone in the last 4-5 decades and the issue now has assumed a global dimension because the problem of ozone depletion and its adverse consequences have threatened the existence of all forms of life in the biosphere. The presence of ozone layer is very crucial and significant for plants and animals in general and human beings in particular because it provides a protective shield against the exposer of ultra violet radiation and by absorbing unwanted ultraviolet rays to reach and allowing only those radiation wave to reach the earth surface which are essential for the maintenance of life on the planet earth (Singh, 2003).

The first conscious effort to sound warning about the depletion of ozone layer was made by M. Molina and S. Rowland of the University of California on 1974/75. They predicted the accumulation of man-made ozone destroyer chemical CFCs in the atmosphere of the earth and rapid rate of depletion of ozone because of the presence of these chemicals. On the other hand the efforts to collect information and data of the variations in ozone layer based on satellite monitoring on regular basis started by the USSR in 1967. The sharp decline in ozone layer during 1960 was attributed to the discharge and transport of nitrous oxides caused numerous nuclear tests carried out by USSR, USA, France and other countries in the atmosphere. The British Atlantic Survey Team headed by Josheph Forman provided first hand evidence of ozone layer or ozone depletion over the Antarctica in 1985. He reported 40 percent loss in the spring time ozone layer in the atmosphere over the Antarctica. Similarly, the formation of ozone hole in the ozone layer over the Antarctica was founded by British Climatologist in 1985 (Singh, 2015).

In 1976 the United States National Academy of Sciences released a report concluding that the ozone depletion hypothesis was strongly supported by the scientific evidence. Scientists calculated that if CFC production continued to increase at the going rate of 10% per year until 1990 and then remain steady, CFCs would cause a global ozone loss of 5 to 7% by 1995, and a 30 to 50% loss by 2050. In response the United States, Canada and Norway banned the use of CFCs in aerosol spray cans in 1978. However, subsequent research, summarized by the National Academy in reports issued between 1979 and 1984, appeared to show that the earlier estimates of global ozone loss had been too large. Crutzen, Molina, and Rowland were awarded the 1995 Nobel Prize in Chemistry for their work on stratospheric ozone (Wikipedia).

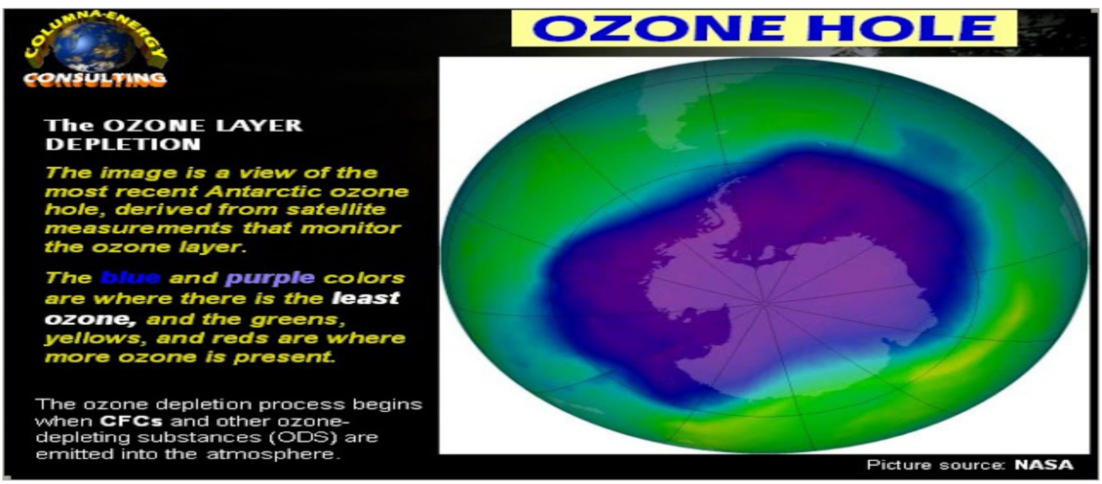


Fig. 2 The ozone layer and ozone hole

Causes of ozone layer depletion

In the beginning, there was various controversy thinking about the causes of ozone depletion but now a consensus has been reached that the main culprit of ozone depletion are halogenated gases called CFCs, hallons and nitrogen dioxides. It may be pointed out that the CFCs are neither toxic nor flammable at ground level but when these gases reach stratosphere they become potent destroyer of ozone layer through a set of chemical reactions. These synthetic chemicals are widely used as propellants in spray can dispenser, as fluids in air conditioner and refrigerator, as blowing agents in foams and industrial solvents. Some amounts of CFCs are also produced by combing, cosmetic goods and other substances (Singh, 2015).

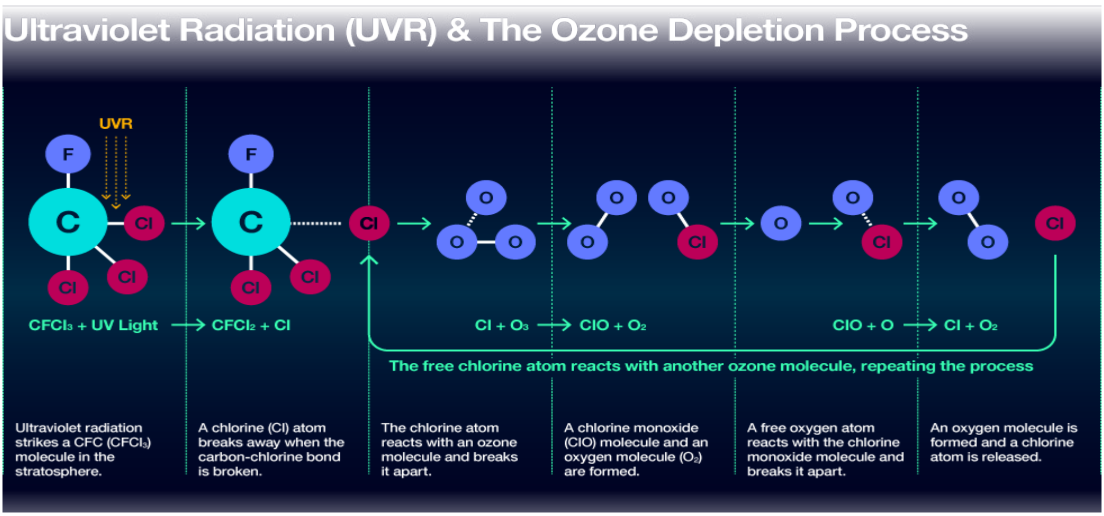


Fig. 3 Ultraviolet radiation and the ozone depletion process

Only a few factors combine to create the problem of ozone layer depletion. The production and emission of CFCs, chlorofluorocarbons, is by far the leading cause. Many countries have called for the end of CFC production because only a few produce the chemical. However, those industries that do use CFCs do not want to discontinue usage of this highly valuable industrial chemical. CFCs are used in industry in a variety of ways and have been amazingly useful in many products. Discovered in the 1930s by American chemist Thomas Midgley, CFCs came to be used in refrigerators, home insulation, plastic foam, and throwaway food containers. Only later did people realize the disaster CFCs caused in the stratosphere. There, the chlorine atom is removed from the CFC and attracts one of the three oxygen atoms in the ozone molecule. The process continues, and a single chlorine atom can destroy over 100,000 molecules of ozone (Singh, 2015).

The amount of atmospheric ozone is measured by 'Dobson Spectrometer' and is expressed in **Dobson Units (DU).** One DU is equivalent to a 0.01 mm thickness of pure ozone at the density it would possess if it were brought to ground level (1atm) pressure. Normally over temperate latitudes its concentration is about 350 DU, over tropics it is 250 DU whereas at sub-polar regions (except when ozone thinning occurs) it is on an average 450 DU. It is because of the stratospheric winds which transport ozone from tropical towards polar regions (Kaushik & Kaushik, 2018).

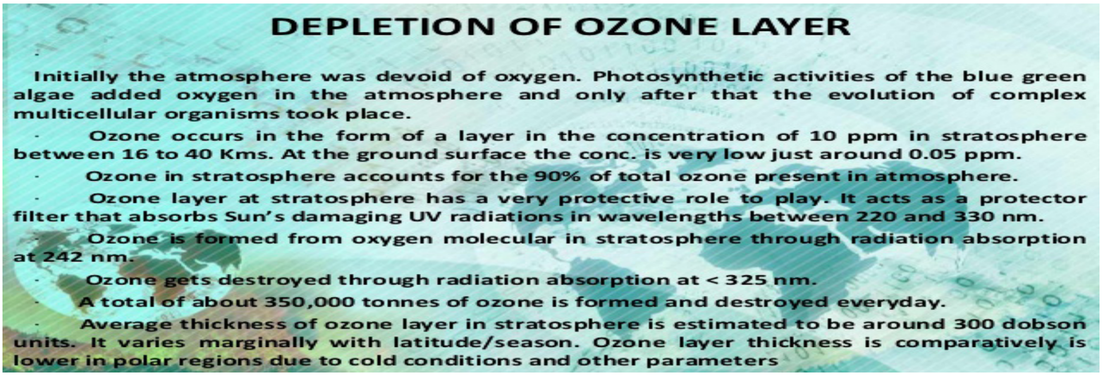
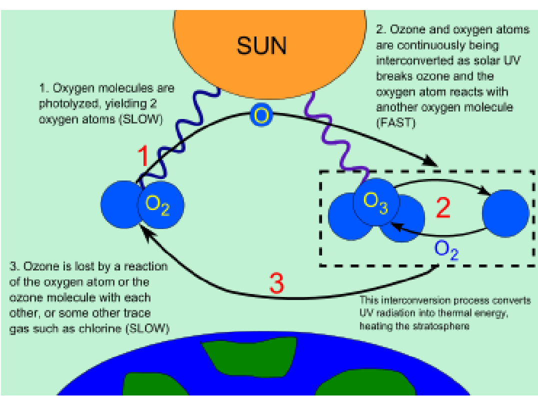


Fig. 4 Depletion of ozone layer

In 1974, Sherwood Rowland and Mario Molina followed the path of CFCs. Their research proved that CFCs are entering the atmosphere, and they concluded that 99% of all CFC molecules would end up in the stratosphere. Only in 1984, when the ozone layer hole was discovered over Antarctica, was the proof truly conclusive. At that point, it was hard to question the destructive capabilities of CFCs. Even if CFCs were banned, problems would remain. There would still be no way to remove the CFCs that are now present in the environment. Clearly though, something must be done to limit this international problem in the future (Rayamane, 2011).



Source: Wikipedia

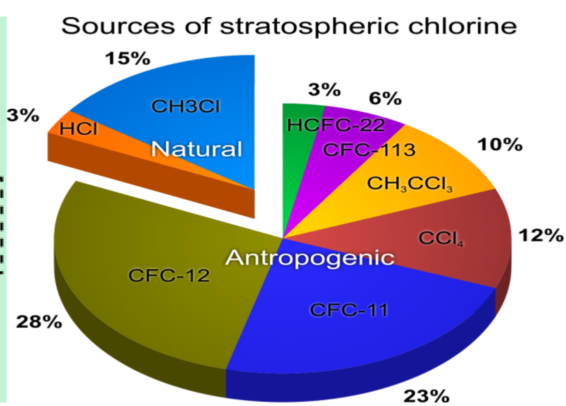


Fig. 5 Ozone formation and depletion cycle and sources of stratospheric chlorine

Effects of ozone layer depletion

The increased ultraviolet rays due to depletion of ozone layer would raise the temperature of the earth surface and lower atmosphere. This would trigger a chain of effects and counter effects which could adversely affect the life in the biosphere (Singh, 2008). Some of the major effects of ozone layer are;

- Ultraviolet radiation (UV) can cause skin burns, skin cancer, breast cancer and lungs cancer.
- It may damage the genetic materials which will induce eye cancer, among the cattle including eye sight problem in human beings.
- It will reduce the crop production and productivity.
- It will bring about significant changes in the climate including greenhouse effect.
- UV radiation effects plants, proteins and causes chlorophyll and mutation.
- The depletion of ozone layer leads to mass damages of plants from terrestrial and aquatic habitat.
- It badly effects the marine food chain and ultimately effects aquatic and other lives

Even minor problems of ozone depletion can have major effects. Every time even a small amount of the ozone layer is lost, more ultraviolet light from the sun can reach the earth. Every time 1% of the ozone layer is depleted, 2% more UV-B is able to reach the surface of the planet. UV-B increase is one of the most harmful consequences of ozone depletion because it can cause skin cancer. The increased cancer level caused by exposure to this ultraviolet light could be enormous. The EPA estimates that 60 million Americans born by the year 2075 will get skin cancer because of ozone depletion. About one million of these people will die. In addition to cancer, some research shows that a decreased ozone layer will increase rates of malaria and other infectious diseases. According to the EPA, 17 million more cases of cataracts can also be expected. The environment will also be negatively affected by ozone depletion. The life cycles of plants will change, disrupting the food chain. Effects on animals will also be severe, and are very difficult to foresee.

Oceans will be hit hard as well. The most basic microscopic organisms such as plankton may not be able to survive. If that happened, it would mean that all of the other animals that are above plankton in the food chain would also die out. Other ecosystems such as forests and deserts will also be harmed. The planet's climate could also be affected by depletion of the ozone layer. Wind patterns could change, resulting in climate changes throughout the world (Rayamane, 2011).

Due to ozone depletion harmful U.V. Rays such as UV_B Radiation reaches to earth which leads harmful effects on animals, plants, aquatic life as well as on human beings.

- Effects on Aquatic system: Affects phytoplankton, fish, and larval crabs. Decrease in amount of phytoplankton increase in CO2 in the atmosphere which contributes the global warming.
- Effects on Materials: Degradation of paints and plastics.
- Effects on Climate: Global Warming (Increasing the average temperature of the earth's surface (Wikipedia).

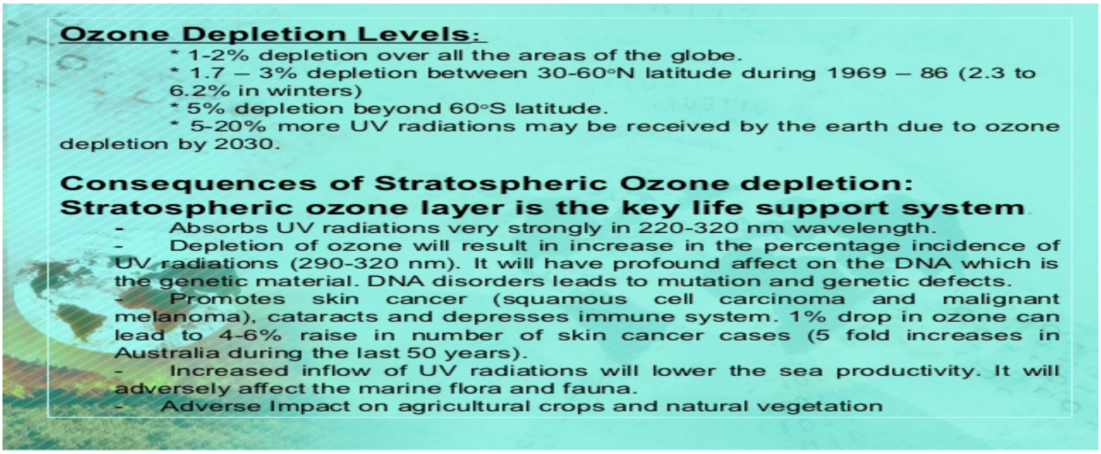


Fig. 6 Ozone depletion levels and its consequences

Solution of ozone depletion

The discovery of the ozone depletion problem came as a great surprise. Now, action must be taken to ensure that the ozone layer is not destroyed. Because CFCs are so widespread and used in such a great variety of products, limiting their use is hard. Also, since many products already contain components that use CFCs, it would be difficult if not impossible to eliminate those CFCs already in existence. The CFC problem may be hard to solve because there are already great quantities of CFCs in the environment. CFCs would remain in the stratosphere for another 100 years even if none were ever produced again. Despite the difficulties, international action has been taken to limit CFCs. In the Montreal Protocol, 30 nations worldwide agreed to reduce usage of CFCs and encouraged other countries to do so as well. However, many environmentalists felt the treaty did "too little, too late", as the Natural Resources Defense Council put it. The treaty asked for CFC makers to only eliminate half of their CFC production, making some people feel it was inadequate.

Fig. 7 International cooperation for ozone layer protection

By the year 2000, the US and twelve nations in Europe have agreed to ban all use and production of CFCs. This will be highly significant, because these countries produce three quarters of the CFCs in the world. Many other countries have signed treaties and written laws restricting the use of CFCs. Companies are finding substitutes for CFCs, and people in general are becoming more aware of the dangers of ozone depletion. Ozone depletion damage gets much worse when the stratosphere is very cold. This has been the case the past two years, causing extensive ozone depletion. This past winter, ozone depletion reached the most severe levels ever recorded over the Northern Hemisphere. Western United States ozone levels also continue to drop 3-4 percent per decade. Even if all our efforts to stop harmful emissions are successful, the ozone layer is not expected to being recovery until around 2020 at the earliest. Under the auspices of United Nations Environment Programme (UNEP), Governments of the World, including the United States have cooperatively taken action to stop ozone depletion with the "The Montreal Protocol on Substances that Deplete the Ozone layer", signed in 1987 (Rayamane, 2011).

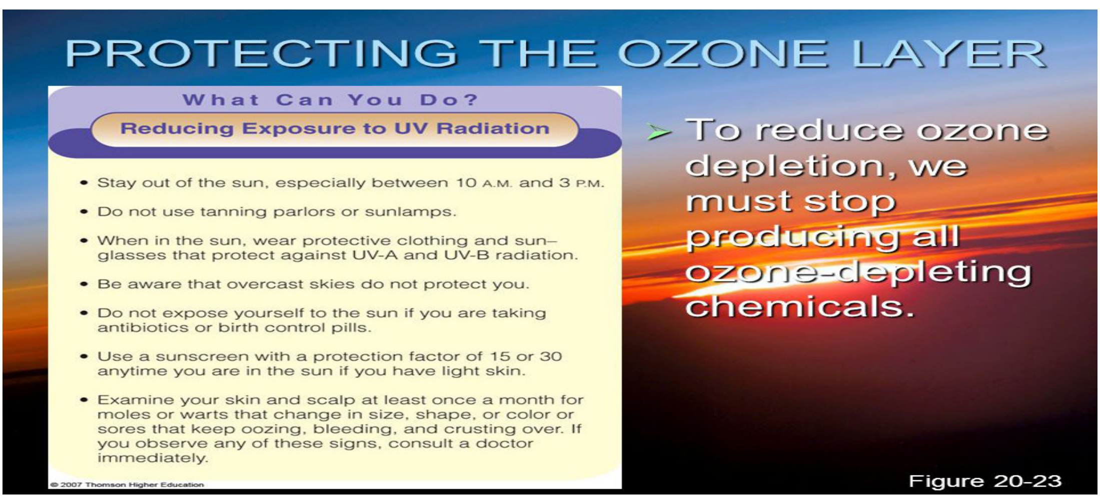


Fig. 8 Suggestive measures to protect ozone layer

Conclusion

Ozone is defined as three atoms of oxygen or merely a triatomic form of oxygen and it is expressed as $O_{3.}$ Ozone is a colorless gas; it is relatively simple molecule, consisting of three oxygen atoms bound together. The stratospheric ozone layer mostly concentrated between 12 to 50 km considered as protective shield and earth's umbrella because it prevents ultra-violet radiation from reaching to the earth surface. Thus, the presence of ozone layer in the stratosphere is of vital significant for all biota (biological community) including, plants, animals and human beings in the biosphere.

The highest concentration of ozone is between the altitude of twelve to thirty five (12 to 35) km in the stratosphere. This zone of ozone is called ozonosphere or ozone layer or stratospheric ozone layer. The ozone gas is unstable because it is created as well as destroyed or disintegrated. In other words the creation and destruction of ozone gas is gradual and continuous natural process.

Initially there was various controversy thinking about the causes of ozone depletion but now a consensus has been reached that the main culprit of ozone depletion are halogenated gases called CFCs, hallons and nitrogen dioxides. The amount of atmospheric ozone is measured by 'Dobson Spectrometer' and is expressed in **Dobson Units (DU).**

The increased ultraviolet rays due to depletion of ozone layer would raise the temperature of the earth surface and lower atmosphere. This would trigger a chain of effects and counter effects which could adversely affect the life in the biosphere. Thus, the effective implementation of commitments made in national conventions, international treaties and global cooperation would help to safeguard this protective shield and earth's umbrella.

Acknowledgements

The author is thankful to Prof. Dr. A.S. Rayamane, Department of Geography, Bangalore University, Bangalore, India and Prof. Dr. HridayLalKoiral, Department of Geography, Tribhuvan University, Nepal for their invaluable support and inspiration to finalize this manuscript. Thanks are also due to Mr. Shreyash for his kind help in typing the manuscript.

References

Dube, S. K. (2015). Earthquake in Nepal: A Miserable environmental hazard visited by nature. *Academic Voices A Multidisciplinary Journal*, vol. 5, no. 1, 2015, 56-66.

Gurung, J. B. (2064 BS). *Concept of environmental education for grade XII*. Kathmandu: MK Publishers and Distributors, Nepal.

Kaushik, A. & Kaushik, C. P. (2018). *Perspectives in environmental studies*. New Delhi: New Age International (P) Limited, Publishers, India.

Rayamane, A.S. (2011). *Environment, Agriculture and Food Security in India*. Bangalore: Janapragathi Press, India.

Sharma, P. K. & Bhatta, B. (2008). *Environmental Education.* Kathmandu: Bhundipuran Publication, Nepal.

---------------- (2011). *Environmental Education.* Kathmandu: Bhundipuran Publication, Nepal.

Singh, S. (1999). *Physical Geography*. Allahabad: Prayag Pustak Bhawan, India.

----------- (2003). *Environmental Geography*. Allahabad: Prayag Pustak Bhawan, India.

----------- (2008). *Environmental Geography*. Allahabad: Prayag Pustak Bhawan, India.

Singh, S. (2015). *Environmental Geography*. Allahabad: Pravalika Publications, India.

Strahler, A. N. & Strahler, A. H. (1976). *Geography and Man's Environment.* New York: John Willey.

National Research Council. (1982). *Causes and Effects of Stratospheric Ozone Reduction: An Update*. Washington, DC: The National Academies Press. Retrieved on 15th November, 2018 from https://doi.org/10.17226/319.