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ATMOSPHERIC OZONE LAYER DEPLETION AND ITS IMPACT

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Abstract

This study focuses on the ozone depletion substance (ODS), the impact and implication of the ozone layer depletion on human and wildlife and some suitable suggestion out of the challenges. Ozone is inextricably linked to the life-sustaining process. The biosphere of the Earth is protected by the ozone layer from harmful solar ultraviolet (UV) radiation. The loss of stratospheric ozone due to updrafts of ozone-depleting pollutants caused by both natural and human-caused processes may have catastrophic consequences, and this has become a source of significant concern in recent years. Ozone layer depletion has adversely impacted human: such as skin cancer, DNA damage, lung disease, eye disease, immunity suppression, etc. and also responsible for extreme climate event such as flooding, urban heat Island, sea water intrusion, drought, etc. Thus, increased UV radiation has negative consequences for human health, aquatic ecosystem, terrestrial plant, vegetation, tropospheric atmospheric composition, air equality, etc. Protecting the ozone layer also protect the world climate. Ozone layer recovery is highly dependent on reductions in CFCs and ODS. Some initiatives have been adopted across the global level: such as "Vienna convention" (1985) and "Montreal protocol" (1987) are the first major significant steps to protect the ozone depletion, which brought multiple experts ans stakeholders like the scientist, businessman and different government from across the world to negotiate which helped for international consensus that ozone depletion is a global challenge.

Keywords: *Ozone depletion, UV radiation, stratospheric ozone, global warming, Montreal protocol*

INTRODUCTION

Ozone, or three-atomic oxygen, is a colorless or slightly bluish triatomic molecule having the chemical formula O_3. Ozone is significantly rarer than regular oxygen. Just around 2 million of every 10 million air molecules are regular oxygen, while only 3 are ozone (Aggarwal & Rathi, 2013). At normal temperature and pressure (NTP), ozone in a column of the atmosphere would occupy a column of around 3 mm thick, whereas entire air would occupy an 8-kilometer-thick column. Even a small amount of ozone, however, plays an important role in the environment (Blokker & Rozema, 2005). Chemically, the ozone molecules in the lower and upper atmospheres are identical. They do, however, play extremely distinct roles in the atmosphere and have very varied effects on people and other living organisms (Cracknell & Varotsos, 2012).

In spite of being in such a small proportion, the ozone layer plays a significant role in climatology and life system of the earth. Thus, ozone layer is intimately connected with the life sustaining process. As a result, any ozone depletion will have disastrous consequences for the earth's life system. Ozone in the troposphere is increasing due to man-made pollutants. The depletion of tropospheric ozone is not only a matter of great concern for global warming, but it is also harmful for man and wildlife. The dual role of ozone in the atmosphere has resulted in the stratospheric ozone being renamed "good ozone" and tropospheric ozone being renamed "bad ozone" (Sharma

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& Andersen, 2002).

The major portion of the ozone layer, about 90%, lies in the stratosphere, it is found in the range of height between 10 and 50 km and about 10% of remaining ozone is found in the troposphere, a range ofheight is surface to around 10 km height. (Gleason, 2008) The stratospheric ozone layer, often known as the ozonosphere, has a peak ozone concentration of 20 to 30 km as shown in Figure 1. The ozonosphere absorbs all harmful solar ultraviolet (UV) light (240nm-300nm) and so works as a protective umbrella providing a beneficent environment for the living species to survive on the earth. If the atmosphere lacked an ozonosphere, all harmful UV light and highly energetic particles from space would reach the Earth's surface, causing harm to living beings (Cali & Palumbo, 1989).

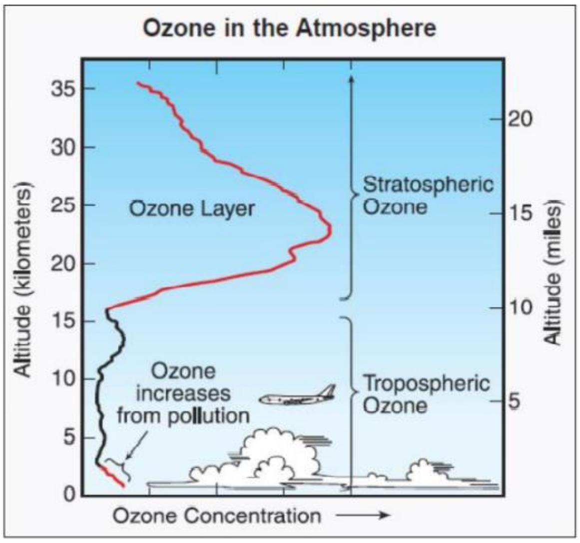
OBJECTIVES

The objectives of this paper are:

- To examine the concept and meaning of ozone layer depletion.
- Examine the cause of ozone layer depletion and its impact on life or living organisms.

OZONE LAYER

In actually ozone is not any kind of layer, but it is known as layer because the maximum particle of ozone is scattered between 20-30 km height in the atmosphere, region of this layer is called stratosphere. The concentration of ozone particle is around 10 parts per million in this layer. In the absence of the ozone layer, a lot of harmful ultraviolet solar radiation reached the earth's surface, causing the adverse effects on aquatic life, terrestrial life, vegetation and ecosystem. The concentration of ozone is measured in the unit of Dobson (DU). The biosphere of the Earth is protected by the ozone layer from harmful solar ultraviolet (UV) radiation. It does so by blocking out the sun's damaging UV radiation. Ozone molecules are constantly generated and destroyed in the stratosphere at any one time. The total amount of ozone, on the other hand, has remained largely constant.



Source: www.scienceschool.org

Figure 1. Vertical profile of ozone concentration in different atmospheric layer

Ozone is created in such a way that, when incoming ultraviolet solar radiation strike the oxygen atom, atom break into two parts. One of them its part combine with oxygen atoms and for a different atom which is known as ozone, all process is known as photolysis. Ozone is a product of photochemical reaction in the atmosphere. This approach was presented by Chapman in 1930, and his reaction schemes are as follows (Brasseur & Tyndall, 1999)

$$O_2 + h\nu_{uv} \rightarrow 2O$$
$$O + O_2 \leftrightarrow O_3$$
$$O + O + O \rightarrow O_3$$

Both natural and artificial activities have a significant impact on the ozone layer (Cracknell & Varotsos, 2012). According to the Chapman scheme, the principal cause of stratospheric ozone loss is photodissociation of ozone by UV light (Brasseur & Tyndall, 1999).

$$O_3 + h\nu \rightarrow O_2 + O$$
$$O_3 + O \rightarrow O_2 + O_2$$

The ozone layer's concentration can be compared to the depth of a stream at a certain location. The depth remains constant despite the steady flow of water in and out. While natural variations in ozone concentrations occur due to solar conditions, seasons, and latitude, these processes are well understood and predictable. Scientists have compiled records that span decades and show normal ozone levels over these periodic cycles. Each natural ozone decline has been followed by a recovery.

OZONE LAYER DEPLETION

Ozone layer depletion occurs mostly, when there is an unbalance between the rate of production and destruction of ozone, especially when destruction is very high as compare to production rate. The ozone depleting substances[1] (ODS) are the major causes of the ozone layer depletion, "which leads to global warming and cause of extreme climate changes through chemical and physical processes" (Kudoma & Tekere, 2020). Photochemical reactions and chemical interactions with various substances, including N, H, Br, and Cl in very small amounts spontaneously break ozone (Cali & Palumbo, 1989). Although natural events can cause temporary ozone depletion, the atmospheric release of ozone depleting substances: such as halocarbons, Bromo fluorocarbons (BFCs), chlorofluorocarbons (HCFCs) and chlorofluorocarbons (CFCs), have resulted in a significant reduction in the ozone layer (Aggarwal & Rathi, 2013). The ozone depletion potential (ODP)[2] is the measurement tool of the ozone layer depletion. It is commonly represented as CFC-11 equivalent in order to calculate the environmental impact potential (Niu, 2018). When CFCs and other ozone-depleting compounds are released into the atmosphere, they mix with it and eventually reach the stratosphere. Thus, the bromine and chlorine catalyze the depletion of ozone. This damage occurs at a faster rate than natural processes can produce ozone. The main element for the ozone layer depletion is chlorine and chemical reaction as follows (Larin, 2020).

$$\text{“}Cl + O_3 \rightarrow ClO + O_2$$
$$ClO + O \rightarrow O_2$$
$$O_3 + O \rightarrow O_2 + O_2\text{”}$$

Thus, when chlorine reacts with two atoms of ozone, replace the two-ozone atom into three atoms of oxygen and leaving the chlorine free to repeat this process up to 1,00,000 times, thus ozone layer depletion occurs.

[1] "ODS are mainly anthropogenic gases that destroy the stratospheric ozone once they reach the ozone layer" (Kudoma & Tekere, 2020)

[2] **ODP of a given substance is defined as the ratio of global loss of ozone due to the given substance to the global loss of ozone due to CFC-11 of the same mass (Niu, 2018).**

CHLOROFLUOROCARBON

CFCs are non-flammable and non-toxic. It's containing atoms of carbon, Florine, chlorine. Some "CFCs include CFC 114(dichloro-tetrfluoroethane- $C_2F_4Cl_2$), and CFC-115 (chloropentafluoroethane- C_2F_5Cl), CFC-11(trichlorofluoromethane- $CFCl_3$), CFC-12(dichloro-difluoromethane- CF_2Cl_2)" (Aggarwal & Rathi, 2013). CFCs are used in many industries such as refrigerator, air conditioners, in electronic circuit boards, in the production of foam and in cleaners as solvents.

ROCKET LAUNCHERS

Rocket Launchers are also the cause of ozone layer depletion. Rocket Launchers emitted a highly reactive trace-gas molecule, which is known radical dominate ozone destruction, even a single molecule of this gas can destruction up to 10,000 ozone molecules as a cause of ozone layer depletion. These molecules are more dangerous as compare to CFC molecule (Makhijani & Bickel, 1990).

NITROGENOUS COMPOUND

Nitrogenous compounds are emitted by man-made activities. NO, N_2O and NO_2 are Nitrogenous compounds, these are highly responsible for ozone layer depletion (Portmann & Daniel, 2012).

IMPACTS OF OZONE DEPLETION

Radiation with wavelengths less than 400 nm is particularly harmful to living organism. Because wavelengths shorter than 280 nm are virtually totally absorbed by the atmosphere, the UV-B (280 – 325 nm) and UV-A (315 – 400 nm) ranges are the only ones important to environmental biology (Koshy & Matta, 2006). In terms of radiant energy, the sunshine that reaches humans comprises only 0.5 percent UV-B radiation. The majority of the impacts of sunshine on living creatures are caused by this little amount of radiation. It is estimated that 1 percent decline in stratospheric ozone prompts 2 percent expansion in UV-B (Gao, Slusser, & Schmoldt, 2010) Consequently, an increase in UV-B causes the following effects on earth living organisms:

EFFECT ON HUMAN HEALTH

Ultraviolet radiation has deeply impacted on human health, due to penetration of solar UV-B, have a cause of many problems likely skin cancer, eye disease, DNA damage and lung disease. Evenly ultraviolet radiations are capable to damage of lens and cornea of the eyes. Thus, UV rays are responsible for photokeratitis, cataracts, and blindness. UV-B have badly affected the immune system of the body and causing a number of infectious diseases (Morrisette, 1995). According to one study, a 10 percent decline in stratospheric ozone is predicted to result in a 20–30 percent increase in skin cancer because UV rays can penetrate the thin skin more quickly, thin skinned people have a higher prevalence of skin cancer (Sharma S. , 1998). It is the primary cause of erythema (skin reddening), sometimes known as sunburn. It occurs between 1 and 6 hours after exposure and fades between 24 and 75 hours. Allergy, blistering, peeling, and inflammation are all symptoms.

As figure 2 depicts the ability of radiation to harm living organisms as a function of wavelength, referred to as action spectra (Mchenzie & Mathews, 1991). It has something to do with erythema induction (sunburn), DNA damage, and plant damage. Exposure of biological targets to UV light at various single wavelengths yields these data, which are normalized at 300 nm. They reveal that biological processes are most susceptible to the UV–B range, where air ozone has a significant impact on solar energy transmission. Snow blindness is another side effect of UV-B exposure, and it's thought to be one of the reasons in cataract formation. It is anticipated that a 1% decline in ozone would result in 100,000 more occurrences of cataracts – caused blindness over the world (Mchenzie & Mathews, 1991). Similarly, another negative impact of UV-A radiation is pigmentation, sometimes known as tanning.

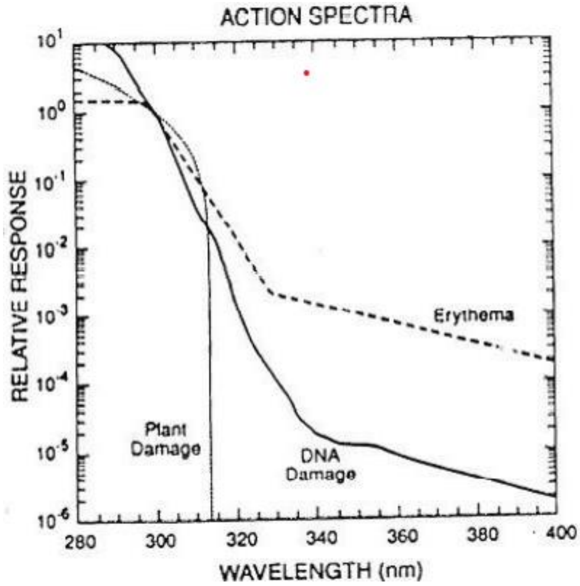


Figure 2: Action spectra for erythema induction, plant damage, and DNA damage (normalized to unity at 300 nm) between 280 and 400 nm (Mchenzie & Mathews, 1991)

EFFECTS ON TERRESTRIAL PLANTS

Ozone depletion has a negative impact on plants as well. It depletes forests and affects crop yields. UV-B can change the species composition of plant's and grasslands, which is also cause of changing the Bio- diversity in different ecosystems. UV-B radiation also could cause of changes in secondary metabolism and plant form, and so on. These changes can have badly affected the plant growth, pathogens and Bio-geo-chemical cycle (Stedman, 1991).

EFFECT ON AQUATIC ECOSYSTEM

The increased concentration or level of UV-B radiation can have badly affected the productivity of aquatic system (Albert & Mikkelsen, 2011). In the region of tropical and subtropical, ultraviolet radiation can affect the distribution of phytoplankton, which is the raw materials of aquatic food webs. According to reports, increased UV-B has resulted in a 6-12 percent decline in phytoplankton productivity in the marginal ice zone. UV-B can harm fish, shrimp, crabs, amphibians, and other creatures during their early stages of development (Albert & Mikkelsen, 2011). As a result, the most serious consequences are reducing reproductive capacity and hampered larval development.

GLOBAL WARMING

The principle components of ozone layer depletion are CFCs and oxides of nitrogen. These gases in the troposphere are additionally greenhouse gases. Due to these gases, the temperature of the earth increase continuously and it causes the global warming and it leads to extreme climate event: such as massive flooding, drought, urban heat Island, cyclone etc. If the earth temperature continues to rise at its current rate, the oceans are expected to overwhelm the number of islands in the not-too-distant future. Global warming has also adversely affected the glacier, weather, Earth's magnetism and gravitation, etc. (Bhattacharjee, 2010). Furthermore, increased UV radiation damage plastic and other materials.

SOME INITIATIVES TO PROTECT THE OZONE LAYER

"Vienna convention" (1985) and "Montreal protocol" (1987) have been adopted across the global level to achieve significant reduction in anthropogenic pollutant on the environment to protect the ozone depletion, which brought many of scientist, business class, environmental activist and different government from across the world to negotiate which helped for international consensus that ozone depletion is a global challenge. The "Montreal Protocol", which aims to "phase out the production and consumption of ozone-depleting substances (ODS)", has become one of the significant environmental success stories of the past century (Lickley & Solomon, 2020). It was the first international environmental treaty based on the "precautionary principle"[3] to be signed by all countries in the world, and it is often regarded as the UN's greatest environmental success to fill up the ozone hole. Without the "Montreal Protocol", the amount of bromine and chlorine in the atmosphere would have risen to dangerous levels, posing a threat to human life. Ultraviolet radiation would have resulted in millions more occurrences of eye damage, skin cancer, damaged the human immune system and lowered agriculture productivity (chipperfield & Bekki, 2017).

The initial "Montreal Protocol" (1987) only governed a few chemicals, but it was "Amended in London (1990), Copenhagen (1992), Montreal (1997), and Beijing (1999)" to include nearly 100 chemicals as shown in figure 3 (Porter & Andersen, 2013). It was also adjusted to ramp up the phase-out of various substances. The Amendment's impact of the "Montreal Protocol" is clearly shown in figure 3 as significant reduction in the ozone depleting substance in the atmosphere.

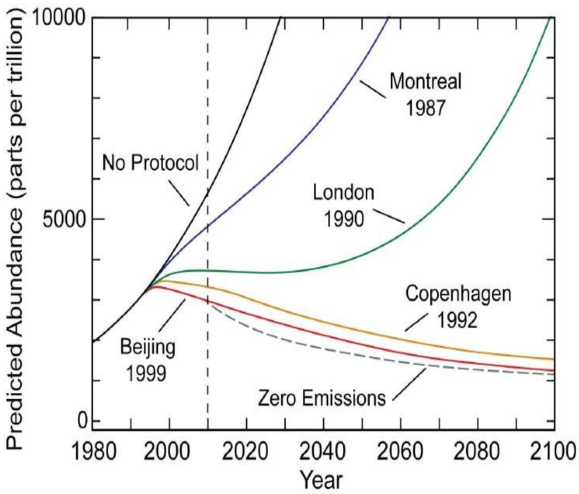


Figure 3 "Effect of Amendments to the Montreal Protocol since 1987 on reductions of predicted abundance of ozone depleting substances in the atmosphere" (Porter & Andersen, 2013).

However, despite global assertions of near-zero production since 2010, recent CFC-11

[3] "The precautionary principle allows urgent action to be taken in the absence of scientific consensus to avoid the risk of creating irreversible or intolerable harm to the community or the environment" (Porter & Andersen, 2013).

measurements show that emissions have grown, raising serious worries about future ozone recovery. (Lickley & Solomon, 2020). Thus, the future Ozone layer recovery is highly dependent on reductions in CFCs and ODS.

CONCLUSION

This paper has discussed the ozone layer depletion, the impact and implication of the ozone layer depletion on human and wildlife and some suitable suggestion out of the challenges. Continuously ozone layer depletion have highly critical situation of today. Chlorofluorocarbon is one of the major cause of ozone layer depletion. We should try to use some alternative materials so that we can protect the ozone layer: such as plastic film bubble wrap, non HCFC refrigerants and avoid the consumption of ozone depleting substance (ODS), minimize the use of air conditioners vehicles, proper timely air conditioners services, avoid using pesticide, chemical solvents, foam blowing agents, water from lakes etc. Ultraviolet radiation has adversely impacted on human health and cause of many problems likely skin cancer, eye disease, DNA damage and lung disease etc. So we should need to take some extra precaution to protect ourselves from these harmful gases: such as use full body clothes and sunglasses, especially during summer season and also use sun burn creams in the sensitive part of body such as face, skin etc and also use drinking water from clean water sources.

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