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Characterization of chemical processes involved in ozone depletion

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ABSTRACT

The earth's carrying capacity to support human life has been overstretched by increasing need to meet food requirements, consumption of resources; amount of waste generation and choice of technologies. These activities release into the atmosphere, chemical constituents of varied concentrations. When these chemicals enter into the atmosphere, they are subjected to various transformations that yield products or intermediates that tend to alter atmospheric chemical balance. In recent years, the global problem of ozone depletion has underscored the danger of overstepping earth's ability to absorb waste products. This study therefore, focuses on the various chemical reactions involved in ozone depletion and the effects of ozone layer depletion on plant, animals, materials and climate.

***Keywords*:** Atmosphere; ozone; depletion; processes and effects

1. INTRODUCTION

It takes no stretch of imagination to see that human species are agents of earth proportion. In our effort to make the earth yield more food for ourselves, we constantly diminish earth's ability to sustain life of all kinds. The earth's capacity to support humans is determined by our most basic food requirements, levels of consumption of resources, by the amount of waste generated, technology choices and our success at mobilizing to deal with major threats.

One of the global problems that has of late underscored the danger of overstepping the earth's ability to absorb waste products is ozone depletion on daily basis, waste products are constantly emitted into the atmosphere through natural and anthropogenic activities carried out on the earth. Some of these waste products destroy the ozone layer.

Ozone is a triatomic molecule which is blue in colour and has a characteristic pungent smell. Under average condition, at ground level, each cm of air contains about 0.1 % of ozone (Santra 2012). It occurs in significant amount (710 ppm) in the lower stratosphere. High level of ozone is generally observed during hot, still sunny, weather where air mass has previously collected emission of hydrocarbons (NO_x).

Ozone destructions are also dependent on geographical locations. For example, 4 % of ozone destruction is in the tropics, 9 % in the temperate zones and 14 % in the Polar Regions (Bhatia, 2006). The decrease in rainfall level and increasing draughts in the world indicate that ozone depletion and global warming has taken place.

The aim of this study is focus on the characterization chemical processes involved in ozone layer depletion. The specific objective is to explain the various effects of ozone layer depletion on humans, plants, materials and animals.

2. FORMATION OF OZONE

The formation of ozone in the troposphere is contributed by two sources:

A) Downward movement from the stratosphere
B) Direct photochemical production within the troposphere

2. 1. Downward Movement

The NO_x from stratosphere abstract energy in the UV radiation range < 430 nm from the sun light and dissociated to give NO and reactive oxygen atom (O^*). The reactive oxygen atom then reacts with oxygen gas at the troposphere to produce ozone molecule

$$NO_2{}^* + hv = NO^* + O^*$$

$$O^* + O_2\ tm = O_3 + m$$

3. DIRECT PHOTO CHEMICAL PRODUCTION OF OZONE

Above 50 cm (60-80 cm), molecule oxygen, O_2 absorbs energy at < 240 nm, and dissociates to form atomic oxygen (O^*).

$$O_2 \xrightarrow[240\ nm]{hv} O^* + O$$

Molecular oxygen (O_2) in upper stratosphere absorbs UV radiation (<240nm) to form ozone

$$O_{2(g)} + O^* + M \xrightarrow{hv} O_3 + M$$

(0 nm)

The presence of ozone in the atmosphere shields living being on earth from the ecological harmful effects.

High level of ozone destroys rubber due to its weak 0-0 bond and affects bronchial function and w toxic to plant and vegetation due to production of harmful intermediates (oxidants).

4. OZONE DEPLETION CHEMICAL PROCESSES

Ozone depletion is simply the destruction of ozone layer in the stratosphere. The relative concentration of NO_2 and O_3 determine whether the destruction or generation of ozone takes place (Naranyanan, 2009).

In general, there are three principal ways of ozone (O_3) depletion:

- Hydrogen system (OH System)
- Nitrogen system (NO_2 system)
- Chlorine system ($CFCl_3$ w CF_2Cl_2 system)

5. OH SYSTEM

This system destroys only 10 % of O_3 and the reaction occur above 40 km over the earth crust. Water vapour in the atmosphere react with the oxygen atom (O^*) produced by photochemical dissociation to yield hydroxyl group. The hydroxyl in turn, reacts with ozone to form water and oxygen molecule.

$$H_2O_{(g)} + O^* (ID) = 2OH$$

$$^*OH + O_3 = HO_2^* + O_{2(g)}$$

$$H_2O_{(g)} + 3O^* = 2\ ^*OH + O_2$$

Net: $O^* + O_3 = 2O_{2(g)}$

This can as well be formed from oxidation of methane (CH_4).

$$CH_{4(g)} + O^* (ID) = HO^* + {}^*CH_3$$

6. NITROGEN SYSTEM (NO_2 SYSTEM)

Sixty percent ozone destruction occurs through N_2O system. The N_2O produced by bacterial action of micro organism in ocean and soil (denitrification) diffuses upwards from troposphere to stratosphere where its reacts with O^* in the presence of light to produce NO, which then destroys ozone. The detailed reaction is expressed below:

$$NO_2 + O^* (ID) = 2NO^*$$

$$N_2O + O^* (hv) = N_2 + O_2$$

$$NO^* + O_3 = NO_2^* + O_2$$

$$NO_2 + O^* = NO^* + O_2$$

Net: $O_3 + O = 2O_2$

7. CHLORINE SYSTEM ($CFCl_3$ or CF_2Cl_2 SYSTEM)

Neutral chlorine contributes only very little to ozone destruction. The main sources of chloro species are chloro fluoro carbons, (CFCs) from fire extinguisher, perfumes, air conditioners, aluminum industries and plants that produce rubber. These compounds are inert in the troposphere but become disassociated in stratosphere.

$$CFCl_3 + CF_2Cl_2 \xrightarrow[180\text{-}220\ nm]{hv} Cl_{2(g)}$$

$$Cl_2 \xrightarrow{hv} Cl^* + Cl^*$$

$$Cl^* + O_3 = ClO^* + O_{2(g)}$$

$$ClO^* + O^* = Cl^* + O_2$$

Net: $O + O_3 = 2O_{2(g)}$

8. EFFECTS OF OZONE LAYER DEPLETION

Correlation between the attendant increase in UV-B and estimated ozone loss may affect rate of skin cancer. Experts suggested that every 1 % decrease of ozone column will result in 3 % rise in incidence of non-melanoma. Besides, enhanced levels of UV-B has the direct harmful effects on humans in the following ways below:

- It suppresses the body immune responses
- It causes damage to the eyes, especially in the development of cataracts.

9. TERRESTIAL PLANTS

Plants are mostly adapted to some level of visible radiation. But two thirds have been found to be sensitive to UV-B radiation (Narayanan, 2009) sensitive plants show reduced growth and smaller leaves unable to photosynthesize as efficient as others. Such plants are affected as

- They yield small amount of seeds or fruits
- They show changes in chemical composition, which affects food quality
- Upset the delicate balance in natural ecosystem thus changing the dissolution and balance of plants.

10. CLIMATE

Ozone cycles through its round of creation and destruction. The overall absorption of radiations is dumped as heat in the stratosphere. Any depletion of stratospheric ozone is predicted to cool the region, hence changes the temperature structure of the atmosphere to some extent.

11. CONCLUSION

Natural and anthropogenic activities on earth are constantly emitting chemical wastes into the atmosphere. These chemical wastes in the atmosphere undergo various chemical processes that tent to produce intermediates that ultimately lead to ozone formation and destruction. Ozone molecule in the atmosphere no doubt serves the purpose of blanketing the earth surface from the harmful effects UV radiations. However, its depletion through various chemical process stated in this study, has greatly impacted negatively on humans, animals, plants and climate. The understanding of the source of chemical wastes that destroy ozone layer and cascade of chemical processes involved in ozone depletion become apt and imperative in the choice of technologies to be employed in monitoring and remediation of atmosphere ozone depletion.

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