ENVIORNMENTAL POLLUTION II - DEPLETION OF THE OZONE LAYER

Energy for all the process taking place in our planet Earth is provided by the sun. Energy is transmitted from one place to another by three methods, conduction, convention and radiation. Of these, conduction and convention need a medium for the transmission of energy. Radiation does not require a medium for energy transmission. The solar energy reaches the Earth by radiation which does not need a medium. The radiation that carry energy from the Sun to the Earth are known as electromagnetic radiations.

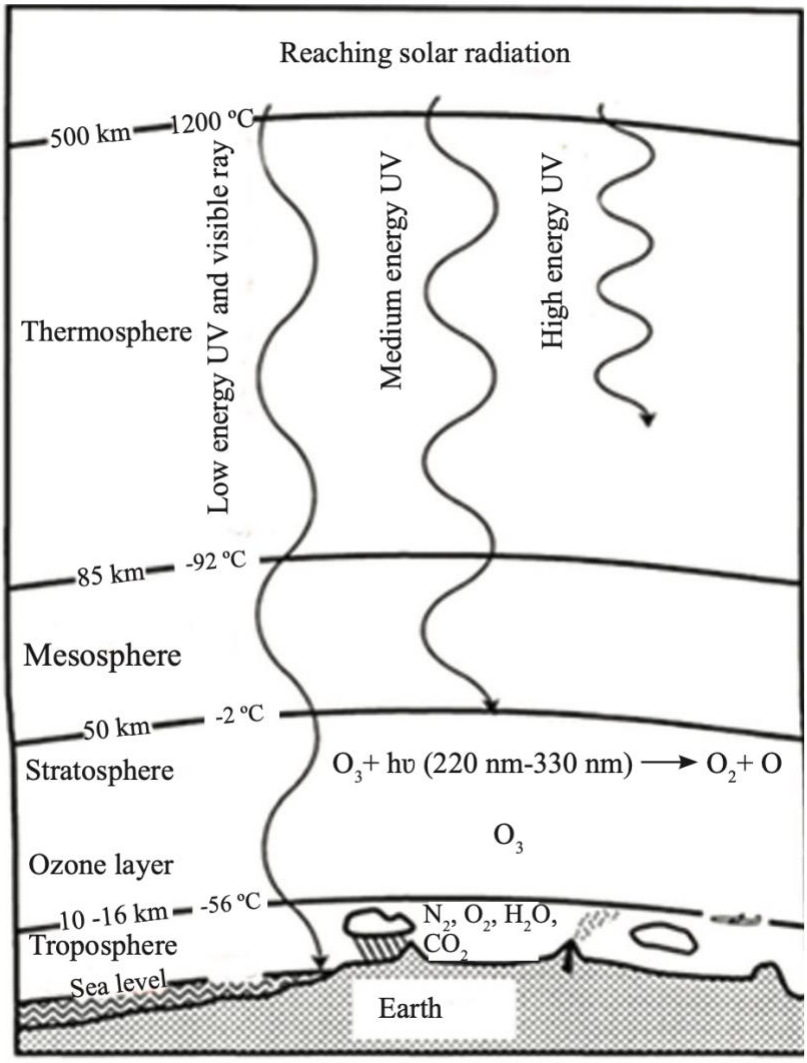
Electromagnetic radiations are classified according to the energy in them. That is as X-rays, ultraviolet rays, visible rays, infrared rays, micro waves and radio waves. Table indicates the properties of various electromagnetic waves.

Electromagnetic waves	Mean wave length	Mean frequency/ s^{-1}	Mean energy/ $kJ\ mol^{-1}$
Radio waves	1 cm	3×10^{10}	1.2×10^{-2}
Micro waves	1 mm	3×10^{11}	1.2×10^{-1}
Infared waves	10 μm	3×10^{13}	12
Visible waves	500 nm	6×10^{14}	240
Ultraviolet waves	250 nm	1.2×10^{15}	479
X ray	1 nm	6×10^{17}	1.2×10^{5}

Of these X-rays and ultraviolet rays are highly energetic.

Energy is transmitted from the Sun to our planet Earth mainly in the form of ultraviolet rays, visible rays and infrared rays.

Illustrates the nature of the solar rays reaching the Earth and their intensity.



Figure, reveals that most of the UV rays have been eliminate before they reach the Earth's surface. It is because the absorption of those rays by the gas molecules in the upper strata of the atmosphere while the solar rays travel to the Earth's surface across the atmosphere.

Stratification of the atmosphere

The atmosphere is divided into several layers. This stretches from the Earths surface to about 15 km upwards. A greater percent (about 99%) of the atmospheric gases is found in this region.

The region from 15 km to 50 km from the Earth's surface is . The percentage of gases here is very low and ascending the layer, the temperature increases.

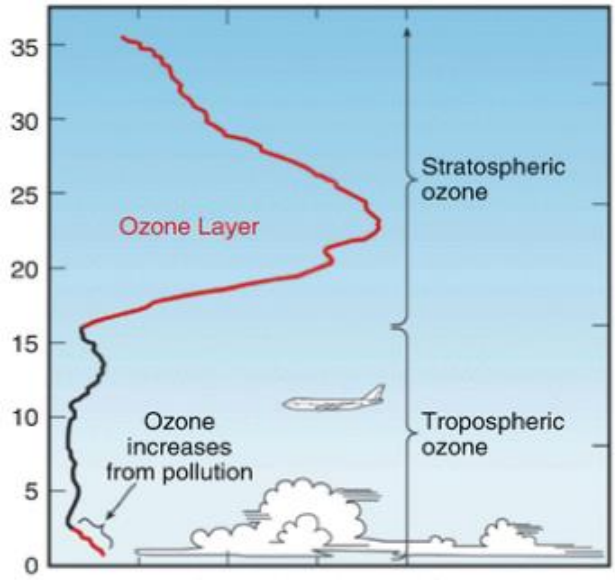
It is the region above 50 km from the Earth's surface. Amount of gases in this region is extremely small and the temperature is very high.

A sub-zone in the stratosphere is referred to as the ozone layer. This extends from 20 km to about 35 km from the Earth's surface. This is called ozone layer because most of the naturally occurring ozone gas in the Earth (around 95%) is found in this region.

A greater part of the UV rays received from the Sun is spent to maintain the ozone gas in the ozone layer in the stratosphere. Therefore most of the harmful UV radiations coming from the Sun does not reach the Earth's surface. In other words, the ozone layer protects us from being exposed to higher energy UV rays by acting as a filter to them. This phenomenon is vital for the survival of life on the Earth. It is important for the maintenance of the life as much as the existence of water and an optimum temperature.

Functioning of the ozone layer

When higher energy UV rays coming from the Sun reach the stratosphere, they decompose oxygen gas and produce atomic oxygen.



As this atomic oxygen is very reactive it reacts with another oxygen molecule forming ozone.

In the ozone layer when the rates of breaking and making of ozone like this become a dynamic equilibrium sets in maintaining a fixed amount of ozone in this region. i.e. the following equilibrium exists in the ozone layer.

As UV rays coming from the Sun are absorbed in maintaining this equilibrium, the entry of those harmful rays to the Earth's surface is prevented.

Depletion of the ozone layer

The ozone level in the ozone layer was continuously measured from 1950 with the aid of weather balloons.

Generally the ozone level in the ozone layer does not remain constant every day. It changes to some extent with the temperature of the environment, seasonal changes and geographical factors. But a gradual decrease of it was observed annually since 1970. This continuous decrease in the ozone level in the ozone layer is, called ozone layer depletion. Depletion of ozone layer is a serious environmental problem.

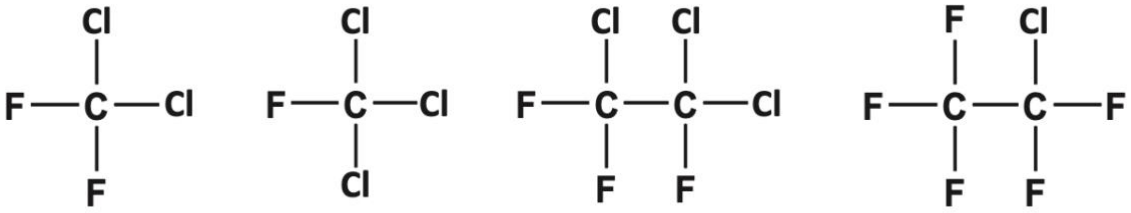
The ozone layer prevents the entry of harmful UV rays to the Earths' surface. Because of the depletion of ozone layer in upper levels more harmful UV rays reach the Earth's surface. Exposure of the Earth's inhabitants more to the harmful UV rays causes various complications in them.

Causes for ozone layer depletion

Of these the natural causes are temporary and the damage made is recovered in a short period of time.

The most severe and non-reversible damages to the ozone layer are brought by the human. This is caused by the volatile compounds released to the atmosphere by man.

The main class of compounds which contributes to ozone layer depletion is chlorofluorocarbons. These are derivatives of hydrocarbons with one or two carbon atoms. Of these, all the hydrogen atoms are replaced by chlorine or fluorine.



Freon 12 **Freon 11** **Freon 113** **Freon 115**

All CFCs are synthetic compounds and not found in nature. Mainly they have the following industrial applications.

How CFCs and other compounds damage the ozone layer

We should remember that none of the above compounds react directly with ozone.

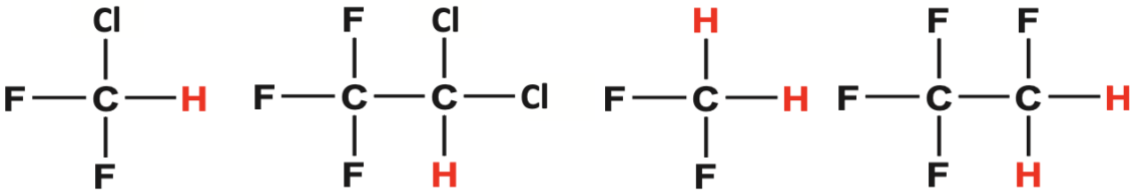
The main adverse effect of ozone layer depletion is the entrance of high energy, harmful UV rays in high intensity to the Earth's surface. A greater amount of such UV rays gains admission to the Earth's surface after the degradation of the ozone layer than that reached to the Earth's surface before its degradation.

Listed below are such unfavourable effects.

Measures to be taken to protect the ozone layer

As CFC is the main destroyer of the ozone canopy its production and usage should be stopped. Action has already been taken in this regard and the Montreal Convention ended the production of CFCs from about 1996. At present alternative gases are being used for the industrial applications for which CFCs were used.

HCFC (Hydrochlorofluorocarbon) was the first alternative gas used for CFCs. This molecule is very much similar to CFC and the only difference was presence of a hydrogen atom in addition to chlorine and fluorine atoms.



HCFC 22 (a) HCFC 123 (b) HFC 32 (c) HFC 134 a (d)

Though HFC gas does not harm the ozone layer HFC, CFC and HCFC all are very powerful greenhouse gases. The global warming potential (GWP) of these gases is thousand times the GWP of carbon dioxide.

Despite the fact that the above gases occur in the atmosphere in very small concentrations (ppt), they can contribute considerably to increase global warming because of their very high GWP values. HFC is a good alternative for the ozone layer depletion. But its use is questionable because it contribute to another global environmental issue, the global warming. This has prompted the global community to use cooling gases that do not damage the ozone layer and contribute little to global warming.

Greenhouse gases and their GWP values

Greenhouse gases and their GWP values

Gas	GWP value
CO_2	1
CH_4	22
N_2O	310
HFC 23	11700
HFC 134a	1300
CFC 12	10600
HCFC 22	1700

unsaturated hydrofluorocarbon. HFO is structurally similar to HFC and has a double bond. As compounds with double bonds are more reactive, HFO compounds decompose faster in the lower atmosphere and get removed. Thus their contribution to global warming is very low.

If so, have a look over the town from a fairly tall building in an afternoon. You will be able to see a less transparent, brown coloured mist above the relevant buildings. On less windy days with a clear sky this could be seen in areas close to towns like Pettah, Borella, Kaduwela and Kandy. Though somewhat rare in Sri Lanka this is a dreadful common place in towns like New Delhi, Mumbai, Culcutta, Shanghai, Beijing and Kuala Lumpur.

What is the reason that gives rise to this kind of a less transparent, browny haze in afternoons? The complex photochemical process leading to this phenomenon is called photochemical smog. Photochemical smog means the lowering of the transparency of the atmosphere due to scattering of solar rays by chemical substances formed by the interaction of several environmental pollutants, fine particles and droplets of water.

Chemical pollutants causing photochemical smog and their sources

Two types of chemical pollutants contribute to the photochemical smog.

Unburned hydrocarbons.

Inside the engine,

Chemistry of the photochemical smog

The photochemical smog is a result of a series of complex chemical reactions happening in the lower atmosphere under the influence of sunlight. But to make the study facile, the reactions occurring in the photochemical smog can be simplified as follows.

Nitric oxide gas released from internal combustion engines is subjected to further oxidation in the atmosphere producing nitrogen dioxide. This NO_2 when exposed to solar rays, get decomposed forming atomic oxygen.

In addition to these, $^{\bullet}OH$ free radicals and ozone which is formed by atomic oxygen react with volatile hydrocarbon forming alkyl and peroxyalkyl free radicals. These alkyl ($R^{\bullet}$) and peroxyalkyl ($ROO^{\bullet}$) free radicals react with NO_2 and O_2 producing harmful volatile short chain aldehydes, peroxyacetyl nitrate (PAN) and peroxybenzyl nitrate (PBN).

Aldehydes produced are subjected to polymerization forming small particles suspended in air. Large particles are formed by these small particles by the deposition of dust, water vapour etc. on them. These particles scatter sunlight reducing the transparency and it appear like a mist in the lower atmospere. Photochemical smog is the only state of pollution visible to our naked eye.

Adverse effects of the photochemical smog