SAVE THE OZONE SHIELD[φ]

David Tin Win [α] and Thandee Kywe [β]

Abstract

The earth is constantly bombarded by ultraviolet (UV) rays, which consist of two forms UVA and UVB, the latter being more potent. High UVB levels can affect human health, ecosystem productivity and global habitability. However a layer of ozone in the atmosphere, called the ozone shield, protects the earth. Over the years the ozone shield has been destroyed, and a hole has appeared that allows UVB to harm living organisms. The size of the ozone hole is increasing. The main ozone depleting substances, ODS, the chlorofluorocarbons (CFCs) are of anthropogenic origin. Global responses, such as the Montreal Protocol and the response by USA (the major ODS producer), to the threat are mentioned. Importance of individual response is also emphasized. Individual environmental ethics is fundamentally essential. Three ways of minimizing the release of CFCs are suggested. Benefits of reducing CFCs and some case studies of successful CFC elimination are cited.

[α] Ph.D. in Physical Chemistry , Strathclyde University, Glasgow, U.K. (1974).
Received scholarships from
(i) SIDA (Swedish International Development Agency) (1974). Certificate in Quantum Methods - Quantum Chemistry, Quantum Biology and Solid State Physics- Uppsala University, Sweden.
(ii) ADAB (Australian Development Assistance Bureau) (1985). Certificate in Chemistry Research Techniques (Environmental Chemistry), UNSW, Sydney, Australia.
Lecturer in the Faculty of Science and Technology, Assumption University of Thailand.
Author of several articles on Buddhism and Meditation,

[β] (i) Associate Degree in Business Administration, Howard Community College, Maryland, U.S.A. (2000). (ii) Currently studying for Business Degree at Notredame, Maryland, U.S.A.

[φ] This paper was originally intended as supplementary reading for Assumption University students

1. INTRODUCTION

Ozone depletion is one of the major atmospheric challenges traced to human technology. Environmental scientists have uncovered a serious problem for which there was no prior warning. Generally, knowledge of the workings of the atmosphere has been appallingly poor. This may lead to increase in ultraviolet light intensity all over the earth. As with global warming, there are skeptics who are not convinced that it is a serious problem.

However the long predicted degradation of the ozone layer was dramatically confirmed in 1985, when a team of British atmospheric scientists discovered a gaping “hole” in the layer over Antarctica. The ozone level there was 50% less than normal. Smaller but significant stratospheric decreases have been seen over some other areas of the Earth.

Subsequent research established that industrial chemicals are responsible for the observed depletions of ozone over Antarctica and play a major role in global ozone losses. CNN information released in September 2000, states that the size of the ozone hole reaches up to the tip of South America. On October 4, 2000, scientists at NASA’s Goddard Space Flight Center announced finding the largest ozone hole ever recorded, an area approximately three times the size of the United States, a 11.5 million square-mile hole - a severe thinning of Earth’s protective ozone layer.

2. NATURE AND IMPORTANCE OF THE OZONE SHIELD - OUR THREATENED OZONE LAYER 2

2.1 The Ozone Molecule

Ozone is a molecule made up of three oxygen atoms and has the chemical formula O_3. There are two important properties of ozone which have a direct impact on the environment. Firstly, ozone is a strong oxidant[*] and is capable of destroying organic tissues. This occurs in the troposphere, the atmospheric zone close to the earth. Thus troposhperic ozone is classified as an air pollutant.

Secondly, ozone has a strong absorption band in the ultraviolet (UV) region of the electromagnetic spectrum, or in simple terms it absorbs UV light. It therefore screens out UV radiation and prevents UV from reaching the earth. This occurs in the stratosphere, the atmospheric zone immediately above the troposphere and extends from 15 km to 50 km above the earth. Stratospheric ozone is therefore beneficial.

2.2 Ultraviolet Radiation

Sunlight contains visible (VIS) light and ultraviolet (UV) radiation,

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[*] chemicals which add oxygen or remove electron or increase the oxidation number of atoms

which are both electromagnetic waves[#]. Being waves the shorter the wavelength the higher the energy, $E \propto 1/\lambda$, where E is the energy and λ is the wavelength. UV having a shorter wavelength has a higher energy as compared to VIS. Again, UV is made up of two components UVA (λ = 320-400 nm) and UVB (λ = 280-320 nm). Thus UVB, with shorter wavelengths, is more energetic and potentially more harmful to living organisms.

On penetrating the atmosphere and being absorbed by biological tissues, UV radiation damages protein and DNA molecules at the surface of all living things. This is what is commonly known as sunburn. If the full amount of UV falling on the stratosphere, reaches earth's surface, it is doubtful that any life can survive; plants and animals will be cooked. Even the small amount , less than 1%, reaching earth is responsible for all the sunburns and more than 700,000 of skin cancer and precancerous ailments per year in North America, as well as the untold damage to plant crops and other life-forms. It is fortunate that over 99% of UVB is absorbed by ozone in the stratosphere. The ozone in the stratosphere protects life on earth from exposure to dangerous levels of ultraviolet light. It does so by filtering out (absorbing) harmful ultraviolet radiation from the sun. For this reason the stratospheric ozone layer is known as the ozone shield.

Ozone entering the stratosphere, resides there for a long time. This is because the temperature of the stratosphere gets hotter upwards. Consequently no air currents exist and there is little mixing so the residence time is very high. Also there is not much water vapor to destroy ozone, so the lifetime is very long.

2.3 Ozone Depleting Substances

Ozone depleting substances (ODS), such as the chlorofluorocarbons (CFCs), can destroy ozone. When they are emitted, they mix with the atmosphere and eventually rise to the stratosphere. There, the chlorine and the bromine they contain, catalyze the destruction of ozone. This destruction is occurring at a more rapid rate than ozone can be created through natural processes. Thus ozone is being depleted.

The degradation of the ozone layer leads to higher levels of UV reaching Earth's surface. This in turn can lead to a greater incidence of skin cancer, cataracts, and impaired immune systems, and is expected also to reduce crop yields, diminish the productivity of the oceans, and possibly to contribute to the decline of amphibious populations; the latter has been observed around the world.

[#] waves composed of electric and magnetic components

3.FORMATION AND BREAKDOWN OF THEVSHIELD[3] - WHAT CAUSES OZONE DEPLETION? WHO ARE THE CULPRITS?

The ozone shield lasts for a longtime if it is left alone. Unfortunately certain anthropogenic pollutants are causing it to break down.

3.1 Formation

Stratospheric ozone is the product of the action of UV on oxygen molecules, (O_2). The high-energy UV radiation first breaks the oxygen molecules into free oxygen atoms (O). These free atoms combine with molecular oxygen to form ozone.

$O + O_2 \rightarrow O_3$ ..... Ozone formation

$O_2 + UVB \rightarrow O + O$

3.2 Breakdown

The formation of ozone is accompanied by its destruction. Two processes cause ozone destruction and hence the breakdown of the ozone shield. Oxygen atoms break up ozone molecules by combining with ozone to form two oxygen molecules. UVB breaks up ozone into an oxygen atom and an oxygen molecule.

$O + O_3 \rightarrow O_2 + O_2$ ….. Ozone destruction

$O_3 + UVB \rightarrow O + O_2$ … Ozone destruction

3.3 Balanced Ozone Levels

Thus ozone is constantly being produced and destroyed in a natural cycle. This makes the overall amount of ozone essentially stable. This balance can be thought of as the height of the water column in a water fountain. Although individual water molecules are moving up and falling down, the height remains constant. The two opposing processes, water moving up under pump pressure and water falling under gravity's influence, produces a constant value: water height. This is dynamic equilibrium, as opposed to static equilibrium, seen in see-saws.

A more simple explanation is to think of the amount of ozone as the water level in a bucket with a small hole in the bottom and a hose adding water at the top. When the water is turned on, a balance point is reached where the amount of water in the bucket stays constant, even though the hose is adding water and the hole is removing it. The addition and removal are happening at the same rate, so the water level stays the same. Note that the hole in the bucket is not analogous to the Antarctic ozone hole (see below); the ozone hole is an area of severe depletion, but it is not a physical hole that drains away ozone.

Thus, while ozone production and destruction are balanced, ozone levels remain stable. The opposing formation and destruction processes cause a continual cycle of reactions and lead to a dynamic equilibrium. This was the situation until the past several decades.

3.4 Upsetting the Balance

Large increases in stratospheric chlorine and bromine, however, have upset that balance. In effect, they have added a siphon down-stream, removing ozone faster than natural ozone creation reactions can keep up. Therefore, ozone levels fall. Since ozone filters out harmful UVB radiation, less ozone means higher UVB levels at the surface. Increased depletion causes larger increases in incoming UVB. UVB has been linked to skin cancer, cataracts, damage to materials like plastics, and harm to certain crops and marine organisms. Admittedly, some UVB reaches the surface even without ozone depletion, but surely its harmful effects will increase as a result of this problem.

Because of seasonal changes in solar radiation, ozone concentration in the Northern Hemisphere is highest in summer and lowest in winter. Also ozone concentrations are generally high at the equator and diminish as latitude increases. However the presence of other chemicals in the stratosphere can upset normal ozone equilibrium and promote unsustainable reactions. The US national ambient air quality standards for criteria air pollutants set the standard value for ozone, averaged over one hour, at 0.12 ppm.

Can ozone be manufactured and added to replenish the depleted ozone and restore normal ozone equilibrium? To answer this, let us continue with the bucket analogy mentioned above. When a glass of water is poured into the bucket, the water just drains faster for a little while until the level returns to the previous depth. The balance is stable. That is because with more water in the sink, there is more pressure at the bottom, and the water drains faster. In the same way, if more ozone is dumped into the ozone layer, the destruction process will speed up a little bit until the amount of ozone returns to the stable point.

The other difficulty with simply manufacturing ozone is the prohibitive amount of energy required; which in nature this is provided by the sun. In fact, to produce the amount of ozone normally in the ozone layer, double the total annual U.S. electricity production will be needed. There is simply no way to create ozone fast enough, in large enough quantities, to replace the natural ozone production process.

3.5 Halogens in the Atmosphere

Chlorofluorocarbons (CFCs) or chlorinated-fluorinated hydrocarbons[*] are non-reactive, nonflammable and nontoxic. They are gases under the normal pressure of one atmosphere[#], but easily change into the liquid state

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[*] chlorine and fluorine atoms attached to a compound which contains hydrogen and carbon only

[#] equal to 101.3 kPa (kilopascal) in SI units or condense, under a modest pressure. The condensation process gives off heat and the CFC liquid becomes very cold. On vaporization heat is absorbed and the CFC becomes very hot. These attributes have induced widespread use of CFCs. Over a million tons per year was used in the eighties. Some of the main uses of CFCs are:-

- * Heat transfer fluid in refrigerators, air conditioners and heat pumps. Equipment breakdown or termination of usage generally lets CFCs escape into the atmosphere.[4]
- * Foaming gas in plastic foam production. CFCs are mixed into liquid plastic under pressure. When the pressure is released the CFC gases cause the plastic to foam. The CFCs escape into the atmosphere.
- * Cleaning solvent for computer parts. The spent CFCs escape into air.
- * Propellant in aerosol cans and sprays. The CFCs escape into air.

In 1972 Sherwood Roland and Mario Molina noticed James Lovelock's observation that the amount of CFCs present in the atmosphere was nearly equal to the total amount produced by industry. They made some studies and concluded that CFCs could be damaging the stratosphere ozone layer via the release of chlorine atoms (Cl) and predicted increased UV radiation and more skin cancer.

CFCs have been found to last 60 to 100 years in the troposphere; but in the stratosphere they will be exposed to intense UV radiation which will break them apart with the release of free chlorine atoms.

$$CFCl_3 + UV \rightarrow Cl + CFCl_2$$

Further photochemical breakdown[+] will release the remaining chlorine atoms of the CFCs. The free chlorine atoms then attack the stratospheric ozone to form chlorine monoxide (ClO) and molecular oxygen.

$$Cl + O_3 \rightarrow ClO + O_2$$

Moreover two chlorine monoxide molecules react to release more chlorine atoms and an oxygen molecule.

$$ClO + ClO \rightarrow 2Cl + O_2$$

The regenerated chlorine in this last step can breakdown more ozone. More and more ozone breaks down as chlorine is regenerated, over and over again, on and on continuously. Chlorine promotes ozone breakdown without itself being used up. Hence chlorine atom is a catalyst in the breakdown of ozone. Chlorine atoms are removed only very slowly from the stratosphere. They have very long lifetimes, ranging from 40 to 100 years. Because of this, each chlorine atom has the potential to breakdown 100,000 ozone molecules.

[+] breakdown caused by light, UV light in this case

Thus the CFCs are damaging due to their role as transport agents that continually move chlorine atoms into the atmosphere.

In 1978, the EPA became convinced that CFCs were a threat and banned their use in aerosol cans. Manufacturers quickly switched to non-damaging substitutes such as butane. However use of CFCs continued in other applications such as refrigerators and air conditioners.

According to atmospheric scientists, any substance transporting reactive halogens[*] to the stratosphere has the potential to deplete ozone. The chemicals most responsible for the destruction of the ozone layer are chlorofluorocarbons CFCs. As mentioned above they have long been widely used as coolants in refrigerators and air conditioners and as foaming agents, solvents, and aerosol propellants. Other ODS include carbon tetrachloride and methyl chloroform, important industrial solvents; carbon tetrachloride, feedstock for the production of chlorofluorocarbons; halons, fire retardants in fire extinguishers; and methyl bromide, which is used extensively as a soil fumigant and pesticide; and is thought to be responsible for 10% of stratospheric ozone loss. Bromine atom is 40 times more potent than chlorine atom in ozone destruction. Hydrogenated CFCs (HCFCs) with less halogen atoms and thus hopefully less potent, have many of the same uses as CFCs and are increasingly employed as interim for CFCs.

Hence the ozone depletion process begins when CFCs and other ozone depleting substances (ODS) leak from equipment. Winds efficiently mix the ODS and evenly distribute the gases. CFCs are extremely stable, and they do not dissolve in rain. After a period of several years, ODS molecules reach the stratosphere about 10 kilometers above the Earth's surface. Strong UV light breaks apart the ODS molecule. CFCs release chlorine atoms, and methyl bromide release bromine atoms. It is these atoms that actually destroy ozone, not the intact ODS molecule.

The issue with ODS is that they add chlorine and bromine to the ozone layer, which effectively destroys ozone. Thus, the stable point is lower than it used to be; this lowering of the stable point represents ozone depletion. Since making more ozone is out of the question, the solution is to reduce the hole in the bucket back to its natural size. The only way to do that is to remove the excess chlorine and bromine from the stratosphere. The only way to do that is to stop making CFCs and several other ODS. Several other measures have been proposed to accelerate the removal of chlorine and bromine from the stratosphere, but none are practical, and most can produce

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[*] group of elements consisting of fluorine, chlorine, bromine, iodine, astatine

unwanted side effects that are not understood very well.

Thus the actual ozone depleting chemicals are chlorine Cl and bromine Br atoms. They are produced from CFCs, so the source of ozone depletion is CFCs. The CFCs are released into the atmosphere by humans. Hence we are the culprits!

Remember every time you use your hair spray, your perfume spray; every time you drink a can of coke; every time you switch on the air-conditioner; or operate equipment like the fridge, you are guilty! Yes! We are guilty of ozone shield destruction, guilty of promoting famine, guilty of producing inhabitability, and guilty of causing ill health to ourselves. Shall we not be more careful?

Over a long period of time, stratospheric chlorine and bromine will combine with other chemicals and eventually fall back to Earth. The good news is that the stability works both ways. In the above bucket analogy, narrowing the hole allows the water inside to rise to a higher stable point. Similarly, by ending production of ozone depleters, natural processes are given the opportunity to remove excess chlorine and bromine. This will slow down the ozone destruction reactions to normal speeds, and the ozone production process will have the chance to restore the ozone layer to normal levels. Scientists expect that full compliance with the Montreal Protocol (see below) will heal the currently depleted ozone layer by about 2050.

4. THE EFFECTS OF OZONE DEPLETION - HOW IMPORTANT IS THE OZONE SHIELD?

4.1 The Connection between Ozone Depletion and UVB Radiation

Reductions in ozone levels will lead to higher levels of UV radiation reaching the Earth’s surface. The less ozone means less protection, and hence more UVB reaches the Earth. Studies have shown that in the Antarctic, the amount of UVB measured at the surface can double during the annual ozone hole (see below). Another study confirmed the relationship between reduced ozone and increased UVB levels in Canada during the past several years.

4.2 Effect on Human Health [5]

Three types of skin cancer are traced to UV exposure: basal cell carcinoma (BCC); squamous cell carcinoma (SCC); and melanoma. Most skin cancers are BCC (75% to 90%), slow growing and treatable. SCC accounts for 20% of skin cancers, this form can also be cured if treated early. However it metastasizes (spreads away from the source) more rapidly than BCC and thus is potentially fatal. Melanoma is the most deadly form of skin cancer. It easily metastasizes and is the form that causes the greatest mortality. A patch of skin or a mole that is changing size or color, or that is red and fails to heal is a sure sign of skin cancer.

In addition, UVB has been linked to cataracts. Even at normal ozone levels, all sunlight reaching the earth's surface contains some UVB. Thus it is always good to limit exposure to the sun. Ozone depletion will increase the amount of UVB and will consequently increase health risk.

4.3 Effect on Plants

Even by the amount of UVB in present-day sunlight, physiological and developmental processes of plants are affected by UVB radiation. Plant growth can be directly affected by UVB radiation despite the presence of mechanisms to reduce or repair these effects and a limited ability to adapt to increased levels of UVB. Indirect changes caused by UVB (such as changes in plant form, how nutrients are distributed within the plant, timing of developmental phases and secondary metabolism) may be equally, or sometimes more, important than damaging effects of UVB. These changes can have important implications for plant competitive balance, herbivory, plant diseases, and biogeochemical cycles.

4.4 Effect on Marine Ecosystems

Phytoplankton are the foundation of aquatic food webs. Phytoplankton productivity is limited to the euphotic zone, the upper layer of the water column in which there is sufficient sunlight for photosynthesis to support aquatic plants and thence other aquatic lifeforms, such as fish and shellfish. Many phytoplankton are capable of active movements that enhance their productivity and their survival. Both orientation mechanisms and motility in phytoplankton are affected by exposure to solar UVB radiation, and results in reduced survival rates for these organisms. Scientists have demonstrated a direct reduction in phytoplankton production due to ozone depletion-related increases in UVB. One study has indicated a 6-12% reduction in the marginal ice zone.

Solar UVB radiation causes damage to early developmental stages of fish, shrimp, crab, amphibians and other animals. Decreased reproductive capacity and impaired larval development are the most severe effects. Even at current levels, solar UVB radiation is a limiting factor*, and small increases in UVB exposure could result in significant reduction in the size of the population of animals that eat these smaller creatures.

4.5 Effect on Biogeochemical Cycles

Increases in solar UV radiation could affect terrestrial and aquatic biogeochemical cycles. This can alter

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* a critical factor which determines the population size of an organism

both sources and sinks of greenhouse and chemically-important trace gases e.g., carbon dioxide (CO2), carbon monoxide (CO), carbonyl sulfide (COS) and possibly other gases, including ozone. These potential changes would contribute to biosphere-atmosphere feedbacks that attenuate or reinforce the atmospheric buildup of these gases.

4.6 Effect on Materials [4]

Materials of commercial interest, such as synthetic polymers and naturally occurring biopolymers are adversely affected by solar UVB radiation. Although today's materials are somewhat protected from UVB by special additives, any increase in solar UVB levels will still accelerate their breakdown, limiting their useful lifetime outdoors.

5. THE OZONE HOLE [3]

5.1 Antartic Hole

The ozone hole is a well-defined, large-scale destruction of the ozone layer over Antarctica that occurs each Antarctic spring. The word "hole" is a misnomer; the hole is really a significant thinning, or reduction in ozone concentrations, which results in the destruction of up to 70% of the ozone normally found over Antarctica.

The science of the ozone hole is quite complex, but our understanding of the many factors that combine to create it has improved greatly since the first investigations in the 1980s. Unlike global ozone depletion which occurs all over the globe, the ozone hole occurs at the South pole, Antartica. Using several instruments, such as TOMS (Total Ozone Mapping Spectrometer) placed on instrument platforms of satellites such as NASA's *Earth Probe* and Japan's ADEOS (*Advanced Earth-orbiting satellite*); planes, and balloons, scientists have produced detailed graphs of the ozone hole.

The ozone hole was first discovered in 1985 by a team of British atmospheric scientists working in Antartica. In an area the size of the US, ozone levels were 50% less than normal. Scientists had assumed that ozone loss, if it occurred, would be slow, gradual and uniform over the globe. The hole came as a surprise. If it had occurred anywhere but the South Pole, the UV damage would have been extensive.

It is interesting to note that the hole would have been discovered earlier by NASA satellites monitoring ozone levels, if the computers had not been programmed to reject data showing a drop of 30% or more.

News of the ozone hole stimulated a great research effort. The hole has reappeared every spring in Antartica (autumn in US) and has been intensifying. A new low of 40% less ozone than the 1960 level was observed in the ozone hole of 1996, which extends over 10 million square miles, an area greater than all of North America.

A unique set of conditions is responsible for the ozone hole. In summer, atmospheric gases such as nitrogen dioxide (NO_2) and methane (CH_4) react with chlorine monoxide and chlorine to form chlorine Cl reservoirs, which are usually inert and therefore prevent ozone depletion.

When the Antartic winter arrives, a vortex like a whirlpool is created in the stratosphere and confines the gases within a ring of air circulating around the Antartic. The South Polar stratospheric clouds are formed during the extremely cold winter. These cloud particles provide surfaces on which chemical reactions occur and molecular chlorine (Cl) is released from the chlorine reservoirs.

When spring comes to the Antartic, the sun's heat breaks up the clouds, UV attacks molecular chlorine, releases free chlorine atoms and rapidly destroys ozone. Ozone poor air spreads all over the southern hemisphere. By the beginning of the Atlantic summer, the vortex breaks down and ozone -rich air returns to the area.

In summary, the 'ingredients' or conditions necessary for the destruction of ozone observed in Antarctica, are more or less the same for ozone loss in the Arctic stratosphere during winter.[6] The conditions are as follows:

- The polar winter forms the polar vortex that isolates the air within it.
- Cold temperatures form inside the vortex; and produce Polar Stratospheric Clouds (PSCs). The isolated vortex air makes the cold temperatures and the PSCs persist.
- Once the PSCs form, heterogeneous reactions take place and convert the inactive chlorine and bromine reservoirs to more active forms of chlorine and bromine.
- Ozone loss occurs only when sunlight returns to the air inside the polar vortex and allows the production of active chlorine and initiates the catalytic ozone destruction cycles, which result in rapid Ozone loss.

Shifting patches of ozone-depleted air have caused UV radiation increases of 20% above normal in Australia. Australian TV stations now report daily UV readings and warn people to stay out of the sun. Current estimates indicate that Queensland, where the ozone shield is thinnest, three out of four Australians are expected to develop skin cancer.

5.2 Artic Hole?

Although a winter ozone loss occurs over the Artic, the higher temperatures and weaker vortex formation have so far prevented ozone "hole" formation. If a "hole" does develop, it will be far more serious than that above the Antartic because ozone-depleted air will extend outward over highly populated regions of North America, Europe and Asia.

5.3 Hole over Other Regions?

A worldwide network of ozone-measuring stations sends data to the World Ozone Data Center in Toronto, Canada. Winter ozone losses of 5% to 15% occurring all over the temperate and tropical regions of both hemispheres have been recorded. Some ozone depletion during summer is also observed. No ozone hole has developed.

Two international organizations issue regular bulletins about the ozone hole as it develops each year: BAS and the World Meteorological Organization. The BAS site also explains why the ozone hole didn't occur in 1956, despite a widespread myth that it did. The University of Cambridge provides detailed explanations, with graphics, of the ozone hole and its history.

Although there is no ozone yet in the Northern hemisphere, nevertheless there is a thinning of the ozone layer which is getting serious attention. The EPA together with the National Oceanic and Atmospheric Administration and the centers for disease control has initiated a new "UV Index", which is in the form of daily forecasts of UV exposure, issued by the Weather Service. Satellite measurements of stratospheric ozone are combined with other weather patterns. The intention is to remind people of the dangers of UV radiation and prompt them to take appropriate action.

6. HUMAN ACTIVITIES

Chlorine and bromine are emitted to the atmosphere from both natural and human sources. These very stable man-made chemicals are not soluble in water and are not broken down chemically in the lower atmosphere. As mentioned above, they survive long enough to reach the stratosphere. The CFCs and carbon tetrachloride are relatively inert in the lower atmosphere (the troposphere) and move unscathed into the stratosphere where they are decomposed by intense sunlight, releasing chlorine to catalyze the destruction of ozone. Certain ozone-depleting chemicals (HCFC-22 and methyl chloroform) are more reactive in the troposphere and deliver less of their initial chlorine load to the stratosphere. Halons also are generally reactive in the troposphere and deliver only a fraction of their initial load of bromine to the stratosphere, but bromine as mentioned before, is 40 times more efficient at destroying ozone than chlorine.[6] Increasing attention is being focused on the ozone-depleting role of lead, which has three potentially major human sources (soil fumigation, biomass burning, and the exhaust of automobiles using leaded gasoline), in addition to a natural oceanic source.

U.S. production of ozone-depleting gases has declined significantly since 1988, and has now reached levels comparable to those of 30 years ago. Owing to international agreements for initial production decrease followed by phase out of CFCs and halons, total chlorine and bromine concentrations in the troposphere shall peak by 1996 and begin a slow decline soon thereafter. Concentrations are expected to peak in the stratosphere 3-5 years later. Since the ODS have long lifetimes, increasing ozone losses are predicted for the remainder of the decade, with gradual recovery by the mid-21st century.

7. STATE OF THE ENVIRONMENT[2]

Worldwide monitoring shows that stratospheric ozone has decreased over the past two decades or more. The average loss across the globe totaled about 5 % since the mid-1960s, with cumulative losses of about 10 % in the winter and spring and a 5 % loss in the summer and autumn over Antartica, and Australia.

An ozone hole has formed over Antarctica annually each austral spring (September/October), since the late 1970s. Up to 60 percent of the total ozone is depleted. Record low global ozone levels were recorded in 1992 and 1993. These lows were partly due to the volcanic eruption of Mount Pinatubo in the Philippines in 1991; the sulfate particles temporarily accelerated the ozone depletion caused by man-made chlorine and bromine compounds.

As expected from the increasing use of CFC substitutes, observations from several sites have revealed rising concentrations of these compounds in the atmosphere. These substitutes have short tropospheric lifetimes that tend to reduce their impact on stratospheric ozone as compared to CFCs and halons. However, some are potent greenhouse gases and can contribute to global warming.

The link between a decrease in stratospheric ozone and an increase in surface ultraviolet (UV) radiation at the Earth's surface has been strengthened during the last several years by simultaneous measurements of total ozone and UV radiation in Antarctica and the southern part of South America during the period of the seasonal ozone "hole". These measurements show that when total ozone decreases, UV increases. Furthermore, elevated surface UV levels in mid-to-high latitudes were observed in the Northern Hemisphere in 1992 and 1993, corresponding to the low ozone levels of those years. However, the lack of long-term monitoring of surface UV levels and uncertainties introduced by clouds and ground-level pollutants have precluded the unequivocal identification of a long-term trend in surface UV radiation.

8. RESPONSE [2]

8.1 International Agreements - What is being done globally?

Reacting to the environmental threat of ozone depletion, the United Nations under its Environmental Program (UNEP) convened a meeting in Montreal, Canada, in 1987. Nations of the world came together to create a global treaty, known as the Montreal Protocol, whereby it was agreed to scale back CFC production by 50% by 2000. The agreement entered into force in 1988. Currently 140 countries are parties to the Montreal Protocol. The parties to the Protocol decided on a timetable for countries to reduce and to end their production and consumption of eight major halocarbons. The Protocol also provides a ten-year delay in this timetable for those developing countries consuming less than 0.3 kilograms per capita.

The Montreal Protocol timetable was accelerated in 1990 and 1992. Amendments were adopted in response to scientific evidence that stratospheric ozone is depleting faster than predicted. As part of an effort to speed the phase-out of production and consumption of ozone-depleting chemicals, the parties to the Protocol decided to provide technology transfer and funds from industrial to developing countries. Under the accelerated schedule, the production of most controlled gases is to cease by 2000 (1990 amendment), 1996 (1992 amendment) in developed countries and 2010 in developing countries The developing countries, however, may receive residual production from industrialized countries not to exceed 15 percent of 1986 levels. Some individual governments have committed to even earlier phase-out deadlines.

Unfortunately, even with the ban, the quantities of CFCs already present in existing cars, refrigerators and air conditioners, released on normal breakdown of the units, will continue to contribute to atmospheric CFC levels for some years to come. On the positive side, atmospheric chlorine and bromine concentrations reached a peak in 1995 and are expected to decline to “safe” levels by 2050. [7]

8.2 United States Action

The U.S. is by far the major ODS producer, with du Pont Chemical Company being the most prominent. Environmental Protection Agency EPA under authority of the Amendments of 1990, issued regulations for the phasing out of ozone-depleting chemicals controlled under the Protocol through a marketable permit program. In addition, EPA established controls on refrigerant recycling and requirements to revise federal procurement specifications. Under the regulations, surplus or recycled substances can in general be stored to service existing machinery. Because of the importance of the ozone layer and the complexity of the chemical reactions affecting it, the condition of the ozone layer must continue to be monitored.

8.3 Individual Action - What can you do?

Individual environmental ethics or individual attitude and individual action, is all important. Individual action becomes a collective action when many individuals become aware of the problem and start the remedy process. You can start by minimizing the release of CFCs into the environment. How? There are three ways:-

ONE. Use the minimum possible amount of sprays, drink less cans.
Are you prepared to do so? Considering the dire consequences, you should.

TWO. Change to alternative material wherever possible. For example, since 1994, all automakers have started replacing CFC-12 air conditioner coolant by an alternative refrigerant HFC-134a, that does not contain chlorine. Which coolant is in your car?

THREE. Reduce unnecessary loss of refrigerant. If you continue using CFC-serviced equipment, perform preventive maintenance, fix leaks, and recycle. These are the key actions to minimize the need for additional refrigerant.

9. BENEFITS OF THE CFC PHASE-OUT

9.1 Protection of the Ozone Layer

Chlorofluorocarbon (CFC) phase-out is an important turning point in the recovery of the ozone layer. Currently, there is a depletion of approximately 5% at mid-latitudes, but if no action had been taken to limit CFCs, depletion at mid-latitudes would eventually have reached 20% or more. Because of the phase-out, CFCs are no longer accumulating in the atmosphere at an accelerating rate. Scientists predict that maximum CFC levels will occur before the turn of the century. If international agreements are adhered to, the ozone layer is expected to recover around 2050.

9.2 Reduced Health Risks

The phase-out of CFCs is expected to have health benefits over the next century, including reduced incidence of skin cancer and cataracts, decreased risks to human immune systems, and increased protection of plant and animal life from excessive UV exposure. A United Nations Environment Program (UNEP) study shows that a sustained 1% decrease in stratospheric ozone will result in about a 2% increase in the incidence of non-melanoma skin cancer, which can be fatal. With the successful phase-out of CFCs, EPA expects 295 million fewer cases of this form of skin cancer over the next century.

9.3 New Technologies

The CFC phase-out prompted research into alternative methods for cleaning applications in electronic assemblies and precision parts. Users often found that the need for chemicals during cleaning processes was reduced or even eliminated, while maintaining product quality and reducing costs. Precision ball bearings, medical devices, and sophisticated electronics components are now being produced using aqueous cleaning. New “no-clean” technologies eliminate the cleaning process altogether for printed circuit boards.

9.4 Energy Savings

The CFC phase-out provided an impetus to develop and invest in a new generation of energy efficient air-conditioning and refrigeration equipment. Electric utilities have acknowledged this benefit by providing financial incentives for installing energy-efficient equipment. Aside from substantial lifetime energy and dollar savings, equipment upgrades also improve occupant comfort, system reliability, and operation and maintenance.

The Air Conditioning and Refrigeration Institute has arranged a 44 % conversion or replacement of existing chillers (large scale air conditioning units for buildings) with equipment that uses non-CFC refrigerants. This conversion to more efficient equipment has reduced energy use by almost 7 billion kilowatt hours per year, amounting to $480 million annual savings for new equipment owners since January 1998.

9.5 Pollution Prevention

The energy savings from equipment upgrades mean that less fossil fuels are burned at the power plant, leading to reduced emissions of air pollutants including carbon dioxide (CO_2), nitrogen oxides (NO_x), and sulfur dioxide (SO_2), which are responsible for global warming and acid rain. Since 1998, chiller conversions and replacements are estimated to have avoided emissions of 4 million tons of CO_2, and 34,000 tons of SO_2. The reduction in SO_2 represents the annual emissions of one and a half large coal-fired power plants.

10.CASE STUDIES OF SUCCESSFUL CFC ELIMINATION

The CFC phase-out is a major component of the international effort to protect the stratospheric ozone layer. The phase-out relied on market forces to encourage development of CFC alternatives. This approach allowed CFC users to respond independently and creatively, often leading to improved technologies and cost reductions. The following are some examples.

10.1 Aerospace Guidance and Metrology Center (AGMC)

The AGMC is a critical repair facility for military navigation and guidance systems. The center once consumed more than 2 million pounds per year of CFC-based cleaning solvents, and it faced a daunting challenge in making the transition to non-ozone-depleting substances. Missile guidance systems are so sensitive that parts must fit with clearances of only one to five microns (millionths of a meter), and the most minute residue can affect a missile's target accuracy.

The AGMC developed The Ozone Depleting Chemical Elimination program, and initiated testing of alternatives. By shifting to more benign cleaning techniques, the AGMC has virtually eliminated dependence on ozone-depleting chemicals. Aerospace and electronics companies have praised AGMC's cleaning processes. In 1995 the center won the Ford Foundation "Innovations *in American Government"* award.

10.2 Food Packaging Industry

In 1988, the makers of disposable foam cartons and food packaging announced a nation-wide phase-out of CFC use in food service packaging foams. At that time, about one-third of foam products for food service were manufactured with CFCs. This initiative, which relied on the adoption of alternative foam blowing agents, marked the first time an industry voluntarily halted use of CFCs. Cooperation between government, business, and environmental groups made this initiative successful.

10.3 American Telephone & Telegraph (AT&T)

AT&T was the first U.S. company to set a goal of phasing out CFC use by the end of 1994, and actually succeeded in doing so by 1993. To achieve this goal, the company tested and developed CFC alternatives for its manufacturing operations. These include terpene-based solvents and aqueous spray defluxers for use in cleaning circuit boards.

AT&T was also proactive in encouraging developing countries to support the CFC phase-out. The company sent managers and technical experts to Hungary, Japan, Singapore, the former USSR, and other countries to demonstrate the new technologies. AT&T also played a leadership role in the creation of the International Cooperative for Ozone Protection (ICOLP), an industry and government partnership to promote the benefits of global cooperation in protecting the ozone layer.

10.4 J.C. Penney

The CFC phase-out presents an ideal opportunity for building owners to capture energy savings by upgrading and modernizing air conditioning and refrigeration systems. A J.C. Penney retail store in Cumberland, GA installed a smaller, more efficient air-conditioning and refrigeration system by implementing state-of-the-art lighting and other energy reduction measures. This generated annual energy savings of 25 percent, amounting to $66,500/year. J.C. Penney also earned a $35,000 rebate from Atlanta Gas Light Company to defray new equipment costs.

11. CONCLUSION

Ozone depletion and the ozone shield story is a remarkable episode in human history. From the first warnings in 1974 that something is happening in the stratosphere because of a practically inert and highly useful industrial chemical; through the development of the Montreal Protocol; and the final steps of CFC phase-out, the world has shown it can respond collectively and effectively to a clearly conceived threat. The scientific community played a critical role and they continue to influence the political process that has forged a response to the threat. There may be skeptics, but the strong consensus in the scientific community convinced the world's political leaders that action was clearly needed. This, in our opinion, is the most encouraging development towards forging of a sustainable society.

The most recent estimate made by a joint monitoring station at Cape Grim in Tasmania, Australia, run by Commonwealth Scientific and Industrial Research Organization (CSIRO) and Bureau of Metrology[8] states that the shrinking ozone hole over Antartica will be closed by 2050.

This demonstrates the positive effect of the Montreal Protocol and provides an additional impetus for the Kyoto Protocol that deals with curbing of greenhouse gases and controlling global warming.

But it must be remembered that whatever is being done by nations and communities cannot be really effective unless individual attitudes change and individual actions change.

So … please … please … save the ozone shield. Let us continue having a healthy life with enough food and enjoy a comfortable habitable environment! Let us live happily ever after!

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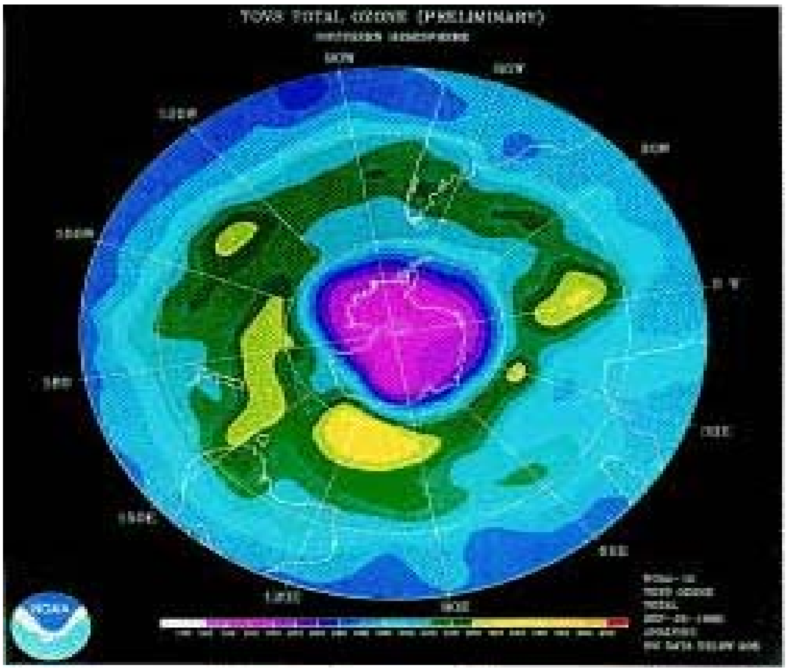

Figure1. The Ozone Hole. On October 4, 2000, scientists at NASA’s Goddard Space Flight Center announced finding the largest ozone hole ever recorded, a 11.5 million square-mile hole, an area approximately three times the size of the United States.

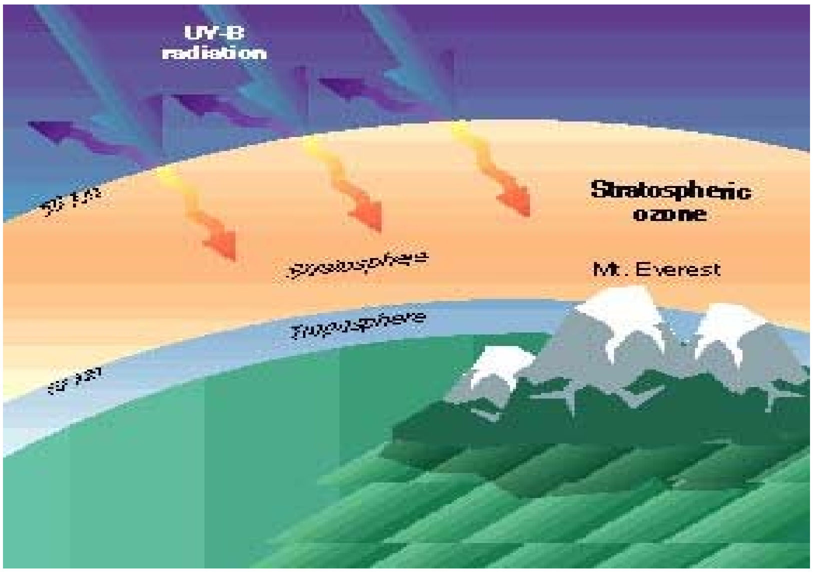

Figure 2. The Ozone Shield. Over 99% of UVB is absorbed by stratospheric ozone. This protects life on earth from exposure to dangerous levels of ultraviolet light. Thus the stratospheric ozone layer is known as the ozone shield.