Action on Ozone

2000 Edition

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Ozone Secretariat
United Nations Environment Programme

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Foreword

Imagine a world without the treaties designed to protect the Earth's stratospheric ozone layer.

Production and consumption of industrial chemicals such as chlorofluorocarbons (CFCs) and halons would be climbing steadily, bringing products such as refrigerators, air conditioning, aerosol sprays, insulating and furniture foams into the homes and vehicles of hundreds of millions of families around the world.

Part of the attraction of these substances is their stability; they do not break down easily under heat, or pressure, or chemical reactions. But this very stability means that when they are released into the atmosphere, they survive to diffuse up into the stratosphere. In this world without the treaties, concentrations of these chemicals reach five times today's value and nine times the value now projected for 2050.

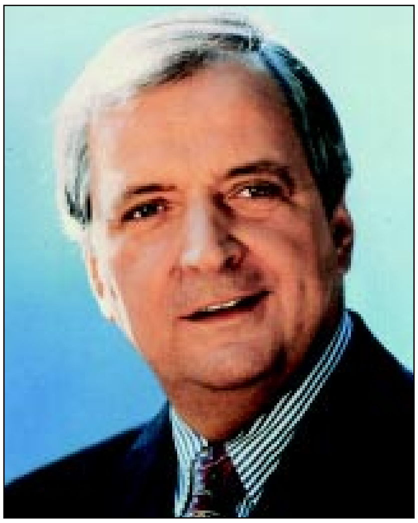
High in the atmosphere, these chemicals are finally broken apart by solar radiation and in turn react with and destroy the planet's protective layer of ozone. By 2000, ozone levels have fallen by 50% of pre-industrial levels north of the tropics, and by 70% southwards.

Without the stratospheric ozone layer to stop it, an ever-rising intensity of ultraviolet radiation penetrates to the planet's surface by 2050, double current levels in the north and quadruple in the south. Skin cancers, eye damage and immune system suppression are rife in those who expose their bodies to the sun. Walking in the open air cannot be risked without sunscreen and sunglasses; sunbathing is banned.

This is the world as it might have been, without the ozone treaties – the 1985 Vienna Convention for the Protection of the Ozone Layer and the 1987 Montreal Protocol on Substances that Deplete the Ozone Layer. The international regime created by these two agreements – revised, and made more effective, on no less than five occasions over the last decade – is saving the world from that alternative.

This is the fourth edition of *Action on Ozone* produced by UNEP. And although the depletion of the Earth's ozone layer has now reached record levels – thanks to the last seventy-five years of production and use of ozone-damaging chemicals – this is the first edition in which we can say it is now at its peak. The scientific evidence clearly shows the beginnings of a fall in the concentrations of the dangerous chemicals in the lower atmosphere – which is now being translated into a similar fall in the stratosphere, where the ozone is destroyed. The ozone layer is predicted to start to recover in the next one or two decades, and should be restored to full health by the middle of the new century.

It is one of UNEP's proudest achievements to have led the international effort to protect the Earth's ozone layer. The Montreal Protocol, which was negotiated under our aegis, has, rightly, been regarded as a model for other international environmental agreements. It has proved a flexible and adaptable regime. It has helped to bring together scientists, industrialists and governments, with their different but essential viewpoints. It has dealt effectively with the different needs of industrialised and developing countries in meeting a common threat. There is much that can be learned from the story of the ozone regime of value to other areas of international environmental action, including biodiversity, desertification and climate change.



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We must remember, however, that although the fight is being won, there is still much to be done in the field of ozone protection. Although there is still some scope for tightening the control schedules for the remaining ozone-depleting substances, in order to hasten the recovery of the ozone layer, the ozone regime, as it continues to evolve, is facing new and different challenges. Implementation of the control measures in developing countries, who met their first targets under the Protocol just last year; cases of non-compliance; evasion of the controls through illegal trade: all pose new threats to the health of the ozone layer and to the planet beneath it.

We can be proud of our achievements. We can learn lessons, and continue to adapt and innovate. And we can continue to meet these challenges, so that we all may strive for a better life for the peoples of the world.

Klaus Töpfer
Executive Director, UNEP

1928: The first CFCs (CFC-11 and -12) are developed in the US, initially to be used as coolants for refrigeration. Beginning in the 1960s, consumption grows rapidly in developed countries, encouraged by the versatile and favourable properties of CFCs: stable, non-toxic, non-corrosive and non-flammable.

1970: A scientific paper points out the possibility that nitrogen-oxides from high-flying supersonic aircraft and from fertilizer applications might deplete the ozone layer.

1. The Shield in the Sky

All life on Earth depends on the existence of a thin shield of a poisonous gas high in the atmosphere: the ozone layer.

Ozone is a molecule made up of three oxygen atoms. It is an extremely rare component of the Earth's atmosphere; in every ten million molecules of air, only about three are ozone. Most of the ozone (90%) is found in the upper atmosphere (the stratosphere), between 10 and 50 kilometers (6–30 miles) above the Earth's surface. This 'ozone layer' absorbs all but a small fraction of the harmful ultraviolet radiation (UV-B) emanating from the sun. It therefore shields plant and animal life from UV-B, which in high doses can be particularly damaging.

Ozone depletion

Any damage to the ozone layer therefore allows more UV-B radiation to reach the surface of the Earth. Throughout the 1970s and 1980s, scientists began first to suspect, and then to detect, a steady thinning of the layer. This was accompanied by increases in the amount of UV-B reaching the surface. In northern hemisphere mid-latitudes (25–60°, i.e. north of the tropics but south of the polar regions), UV-B levels are now about 7% higher than twenty years ago in the winter and spring, and about 4% higher in the summer and autumn. In southern hemisphere mid-latitudes, UV-B levels are about 6% higher all the year round. UV-B radiation has increased dramatically nearer the poles, particularly in the spring – 22% higher in the Arctic and 130% higher in the Antarctic relative to values in the 1970s. The next chapter explains why this damage to the ozone layer is occurring.

Moderate exposure to UV-B poses no dangers; indeed, in humans it is an essential part of the process that forms vitamin D in the skin. But higher levels of exposure have potentially harmful effects on human health, animals, plants, micro-organisms, materials and air quality.

In humans, long-term exposure to UV-B is associated with the risk of eye damage, including severe reactions such as 'snowblindness', cancer and cataracts; UV-B radiation can cause effects on the immune system, but may be both adverse and beneficial. Increases in UV-B are likely to accelerate the rate of photoaging, as well as increase the incidence (and associated mortality) of melanoma and non-melanoma skin cancer, basal cell and squamous cell carcinoma with risk increasing with fairness of the skin. The risk of the more serious melanoma may also increase with UV-B exposure, particularly during childhood; melanoma is now one of the most common cancers among white-skinned people.

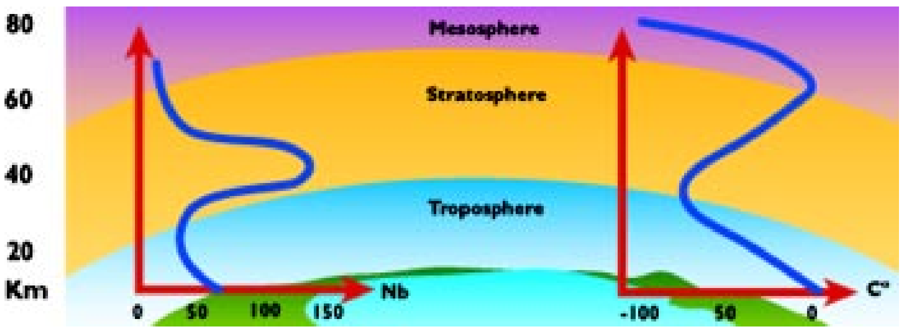


Fig. 1.1 The thin layer of ozone in the stratophere is at its thickest between about 20-40 km up. It also accumulates near the ground in the troposphere, where it is a troublesome pollutant.

1974: Two scientific papers suggest that CFCs emitted to the atmosphere will diffuse to the upper atmosphere and be broken down to release chlorine atoms, which will catalytically destroy ozone molecules. Nitrogen oxides emitted by high-flying supersonic aircraft are also suggested as a potential cause of ozone depletion.

1975: UNEP's Governing Council launches a programme of research on risks to the ozone layer; in the United States, a federal task force concludes that atmospheric release of CFCs is a 'legitimate cause for concern' and that uses of CFC-11 and -12 might have to be restricted. The National Academy of Sciences (NAS) launches an assessment of human impact on the stratosphere.

Report of the UNEP Enviromental Effects Assessment Panel (1998) and Dr. Sasha Madronich

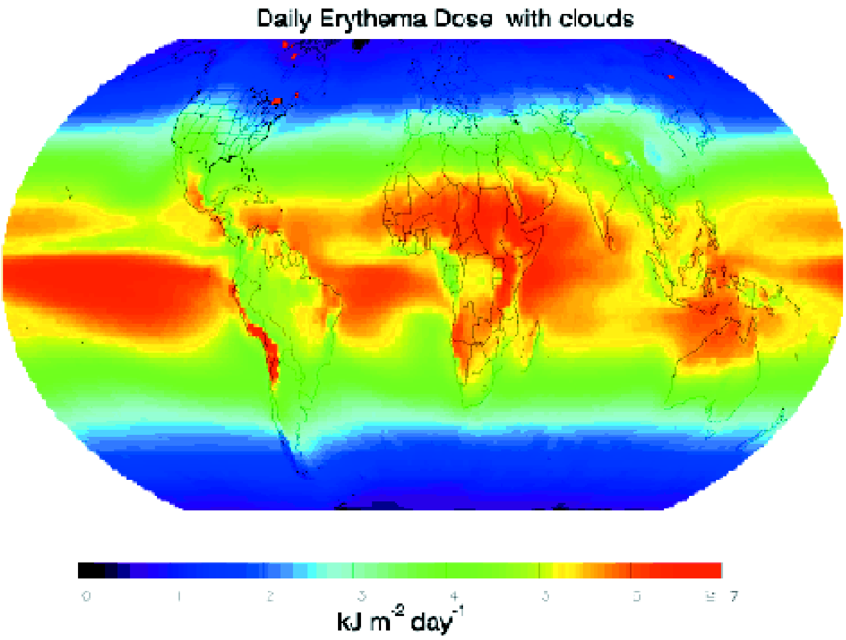


Fig. 1.2 Daily erythemal (skin-reddening) UV radiation with clouds. Significant progress has been made in recent years in utilizing satellite-based measurements of cloud cover as well as atmospheric ozone, to derive estimates of surface UV radiation levels.

Animals are subject to similar effects of increased UV-B levels. Squamous cell carcinoma associated with ambient solar exposure has been reported in cattle, horses, cats, sheep, goats and dogs. In addition, marine life is particularly vulnerable to UV-B, a matter of some concern as more than 30% of the world's animal protein for human consumption comes from the sea. Recent studies continue to demonstrate that solar UV-B and UV-A have adverse effects on the growth, photosynthesis, protein and pigment content and reproduction of phytoplankton, thus affecting the food chain. Plant growth may also be directly reduced by UV-B radiation (though responses vary a good deal depending on species), harming crop yields and quality, and various effects in forests. Effects of increased UV-B on emissions of carbon dioxide and carbon monoxide and on mineral nutrient cycling in the terrestrial biosphere have been confirmed.

Dr. Donat Häder, member of the Enviromental Effects Assessment Panel

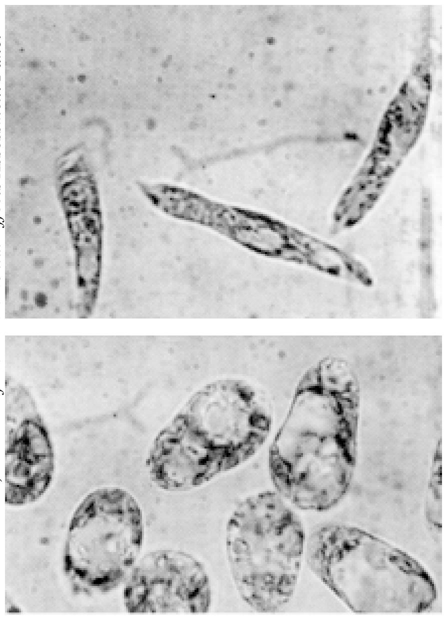


Fig. 1.3 Euglena gracilis is a green flagellate organism which occurs in freshwater habitats and is common in lakes, ponds and rivers; Above: these organisms have a spindle form and swim in their elongated form. Below: After UV irradiation the cells twist and turn and then become rounded and cannot swim.

Synthetic materials such as plastics and rubber, and naturally occurring materials such as wood, paper or cotton, are affected by UV-B; the damage caused ranges from discoloration to loss of mechanical strength. Increases in UV-B may limit the lifetimes of these materials and require more expensive production processes.

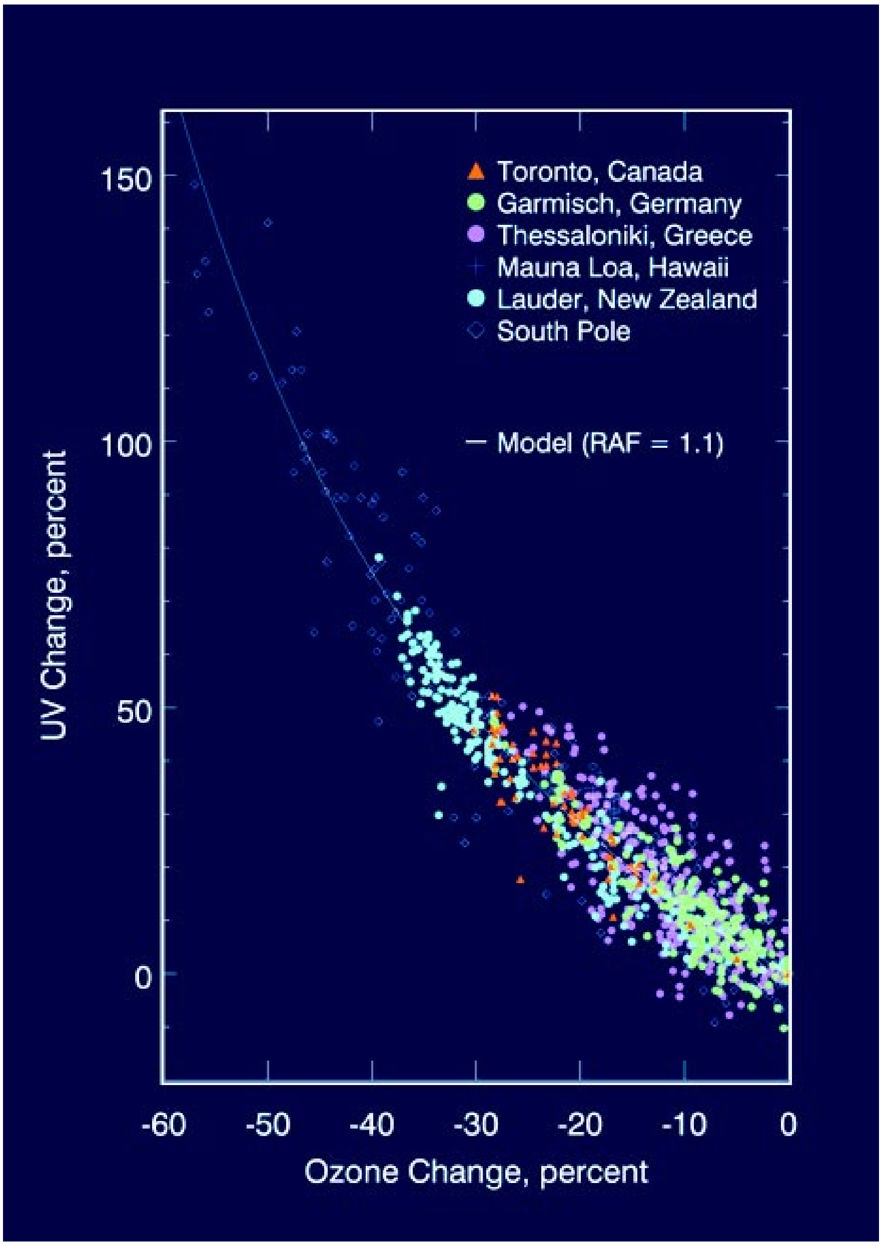
Finally, reductions in stratospheric ozone and the accompanying increases in UV-B radiation interact with other sources of pollution and environmental change. Increased levels of UV-B change the chemical activity of the troposphere, the lower region of the atmosphere. In

1977: 32 countries agree to a UNEP-brokered World Plan of Action on the Ozone Layer designed to stimulate research; UNEP establishes the Coordinating Committee on the Ozone Layer. The US Government requires warning labels on CFC-containing aerosols and announces its intention to phase out most CFC use as aerosol propellants. U.S.NAS estimates that continued release of CFCs to the atmosphere will deplete the ozone layer by 14%.

1978: Developed countries attend an international meeting on CFC regulation and recommend a significant reduction in CFC use in aerosols as a precautionary measure.

areas already suffering from pollution such as vehicle exhausts, concentrations of ozone (which at this level is a pollutant, causing irritation to eyes and lungs) tend to increase.

There are also complex interactions between ozone destruction and climate change. UV-B induced destruction of stratospheric ozone in recent years has led to a cooling of the lower stratosphere, masking to a certain extent the effects of the growing emissions of greenhouse gases. On the other hand, increases in tropospheric ozone contribute to global warming. In addition, the build-up of greenhouse gases in the atmosphere tends to reduce the frequency of sudden stratospheric warming in the northern hemisphere, adding to the severity of Arctic winters, which increase ozone loss (see next chapter).



Report of the UNEP Enviromental Effects Assessment Panel (1998)

Fig. 1.4 UV change versus ozone change. Dependence of erythemal ultraviolet (UV) radiation at the Earth's surface on atmospheric ozone, measured on cloud-free days at various locations, at fixed solar zenith angles. Solid curve shows model prediction with a power rule using RAF=1.10.

1979: A number of developed countries start to impose legal controls on CFC-11 and -12 production or use; in the United States, the NAS estimates eventual ozone depletion of 16.5%, or up to 30% if CFC production and release continues to grow, and calls on the US Government to lead a world effort to control CFCs.

2. The 'Holes' in the Layer

Miracle substances

Concern began to be expressed in the early 1970s that the Earth's ozone layer was vulnerable to damage by the release of chemicals known as halocarbons, compounds containing chlorine, fluorine, bromine, carbon and hydrogen. The most common ozone-depleting substances (ODS) were thought to be the family of chlorofluorocarbons, or CFCs, first produced in Belgium in 1892, and found, by General Motors chemists in the US in 1928, to be an effective refrigerating fluid. Stable and non-toxic, cheap to produce, easy to store and highly versatile, CFCs proved themselves an immensely valuable range of industrial chemicals. They came to be used as coolants for refrigeration and air conditioning, for blowing foams, as solvents, sterilants and aerosol propellants. Major new uses were found for CFCs each decade, and world production, concentrated largely in the USA and western Europe, doubled roughly every five years until 1970.

As scientific knowledge developed,