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Protecting the

Ozone Layer

Volume 2

Solvents, coatings and adhesives

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Foreword

In 1974, Sherwood Rowland and Mario Molina of the University of California claimed that the man-made chemicals known as chlorofluorocarbons (CFCs) were damaging the stratospheric ozone layer. Subsequent research supported the theory, and it is now established that the stratospheric ozone layer—which protects the earth from dangerously high levels of ultraviolet radiation from the sun—is being destroyed by human activity. Ozone-depleting substances are used in the manufacture of thousands of products.

The Montreal Protocol on Substances that Deplete the Ozone Layer was drawn up under the guidance of the United Nations Environment Programme (UNEP) in September 1987. The Protocol identified the main ozone-depleting substances, and set specific limits on their production levels in the future. By 1991, 71 countries had ratified the agreement.

It is intended that the Protocol be continually updated, as necessary. In June 1990 the Parties to the Protocol met in London to consider the implications of new scientific evidence that showed that the ozone layer was being depleted even faster than originally thought. The London meeting agreed to phase out the consumption and production of CFCs and halons by the year 2000, and to control certain other chemicals.

Signatories to the Montreal Protocol agreed to reduce and eliminate CFC usage even though substitutes and alternative technologies were not yet fully developed. Industries and manufacturers are starting to replace CFCs with less damaging substances, but a major obstacle in the conversion process is a lack of up-to-date, accurate information on issues relating to CFC substitutes and CFC-free technology.

The London Amendments to the Protocol acknowledged the financial and technical help that developing countries would need, and set up the Interim Multilateral Ozone Fund (IMOF) to provide them. UNEP was charged with specific responsibilities for implementing the IMOF, and it created an OzonAction Programme within UNEP's Industry and Environment Programme Activity Centre (IE/PAC) to carry out information exchange and training, and to act as an information clearinghouse.

One of the most important jobs of this programme is to ensure that all those who need to know understand clearly the issues involved in replacing CFCs and how to obtain the information and assistance they may need to do so. Hence the publication, in English, French and Spanish, of six plain language reports that summarize the major issues surrounding CFC replacement for decision makers in government and industry. This is the second in the series prepared by UNEP IE/PAC; others cover refrigerants; foams; aerosols and sterilants; and halons for fire fighting.

Each of these five publications summarizes the current uses of ozone-depleting substances within an industrial sector, the availability of CFC substitutes, and the technological and economic implications of converting to CFC-free production. A sixth volume summarizes the overall situation, provides examples of successful conversion to CFC-free technologies, and explains how to apply for assistance from the IMOF. Those requiring more detailed information should refer to the 1992 reports of the five UNEP Technical Options Committees (see Further Reading) on which this series is based.

Acknowledgements

This report is based on the *UNEP Solvents, Coatings and Adhesives Technical Options Report* (Nairobi, UNEP, 1992). Members of the Committee (see list below) gave freely of their time to ensure that this publication, while written in plain language, reflects accurately the much more detailed information available in the original report.

Thanks are also due for the assistance that was provided by Mr Steve Andersen, Chairman of the UNEP Scientific Options Committee on Solvents, and by the Industry Cooperative for Ozone Layer Protection.

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Executive summary

Until 1990 the use of ozone-depleting substances in industry has increased significantly and has led to the depletion of the ozone layer observed by scientists in the 1980s. New data have revealed that the hole in the Antarctic ozone layer which appears each spring is larger than was originally calculated, and there is evidence of a similar hole beginning to form over the Arctic. The serious implications for life on earth and human health have resulted in global action to protect the stratospheric ozone layer.

This action is contained in the Montreal Protocol which was developed under the guidance of the United Nations Environment Programme (UNEP) and by 1992 had 76 signatories. It aims first to limit, then to phase out completely the production and consumption of the man-made substances that have contributed to ozone depletion. If implemented, this action will prevent further damage to the ozone layer and—eventually—repair most of the damage already done.

The main ozone-depleting solvents in use today are CFC-113 and methyl chloroform. CFC-113 is a fully halogenated chlorofluorocarbon with a relatively high ozone-depletion potential. It is used because of its non-corrosive properties, chemical inertness, non-flammability, low viscosity and low surface tension. Its use is regulated under the Montreal Protocol and is due to be phased out by the year 2000. Methyl chloroform has also been used as a solvent; although its ozone-depletion potential is lower, it was included in the 1990 London revisions to the Montreal Protocol and its use is to be phased out by the year 2005. Carbon tetrachloride is now no longer used as a solvent in most developed countries because of its toxicity and potential carcinogenicity, but it is used as a feedstock to produce CFCs, and as a solvent in developing countries. Its use has been regulated under the protocol and must be phased out by 2000.

There is no one substitute for ozone-depleting solvents. Ozone-safe solvents and alternative technologies (or both) can be used, or the cleaning step eliminated by redesigning the production process. The substitutes being developed include organic solvents; the hydrochlorofluorocarbons HCFC-225ca, -225cb, -123 and -141b; alcohols such as isopropanol; solvent blends; and water with saponifiers. Alternative technologies include aqueous and semi-aqueous cleaning; no-clean options, such as using low-solids fluxes and pastes in electronics which eliminate the need for post-flux cleaning; and ice-particle and plasma cleaning. Improved conservation and recovery practices could initially reduce the emissions of CFC-113 and other ozone-depleting solvents by up to 90 percent, and in many cases could be implemented at minimal cost. Conservation measures include retrofitting and redesigning equipment, and introducing better operator, handling and storage practices.

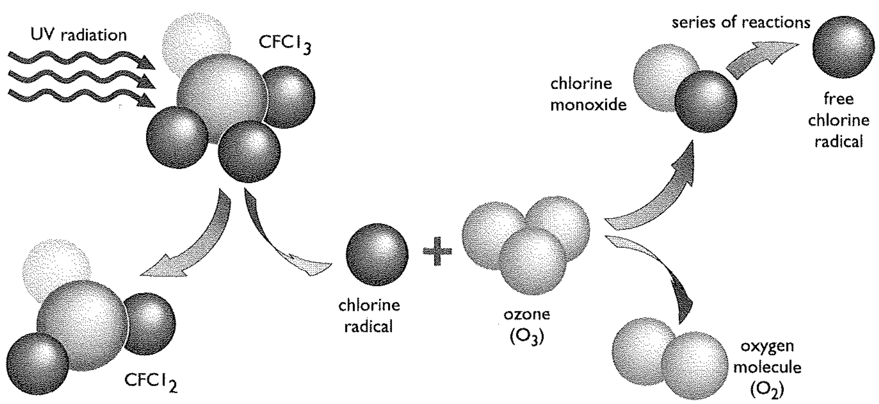
UNEP's Technical Options Committee is confident that the adoption of conservation and recovery measures, coupled with the use of alternative cleaning solvents and technologies, can phase out all uses of ozone-depleting solvents as early as 1995 in developed countries.

The science of ozone depletion

Ozone is a naturally occurring gas found in the earth's atmosphere that absorbs certain wavelengths of the sun's ultraviolet radiation. Ozone concentrations vary with altitude, peaking in the stratosphere approximately 25–30 km from the earth's surface. This concentration of the gas is known as the ozone layer, and it reduces the intensity of certain wavelengths of ultraviolet radiation reaching the earth's surface. High doses of ultraviolet radiation at these wavelengths can damage the human eye, cause skin cancers, reduce rates of plant growth, upset the balance of ecosystems, accelerate the degradation of plastics and, by suppressing the efficiency of the body's immune system, increase the risks of disease.

Solar radiation breaks down many of the gases in the stratosphere that contain chlorine and bromine. Chlorine and bromine radicals can then set off a destructive chain reaction,

Effects of CFCs on stratospheric ozone



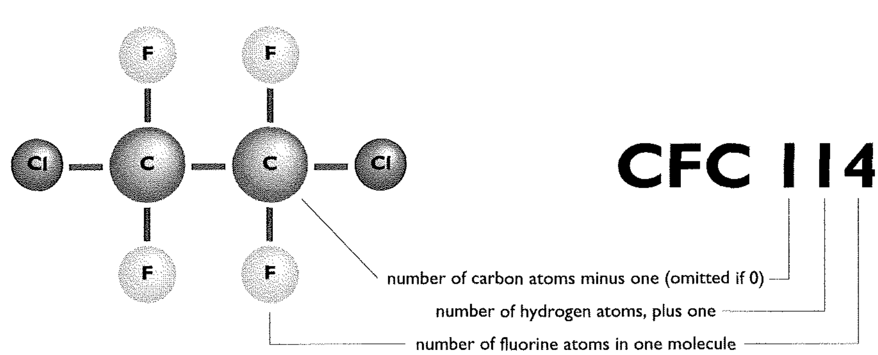
When gases containing chlorine, such as CFCs, are broken down in the atmosphere, each chlorine atom sets off a reaction that may destroy hundreds of thousands of ozone molecules

breaking down other gases in the stratosphere, including ozone. Ozone molecules are broken down into oxygen and chlorine monoxide (see above), thus reducing the concentration of atmospheric ozone. A single chlorine or bromine radical is left intact after this reaction, and may take part in as many as 100 000 similar reactions before eventually being washed out of the stratosphere into the troposphere.

During the past few decades, CFCs have been released into the atmosphere in sufficient quantities to damage the ozone layer. The largest losses of stratospheric ozone occur regularly over the Antarctic every spring, producing substantial increases in ultraviolet levels over Antarctica. A similar, though weaker, effect has been found over the Arctic. There is now evidence that ozone levels decrease by several percent in the spring and summer in both hemispheres at middle and high latitudes; they also fall during the winter at these latitudes in the southern hemisphere. Levels of ozone damage were generally higher during the 1980s than the 1970s.

How CFC Nomenclature Works

CFC numbers provide the information needed to deduce the chemical structure of the compound. The digit far right provides information on the number of fluorine atoms, the digit second from the right provides information on hydrogen atoms, and the digit on the left provides information on carbon atoms. Vacant valencies are filled with chlorine atoms. Adding 90 to the number reveals the numbers of C, H and Fl atoms more directly.



Note: 1. All spare valencies filled by chlorine atoms
2. Different isomers are indicated by a suffix of lower case letters
3. Bromine atoms are indicated by a suffix B plus number of atoms
4. Hundreds number = 4 or 5 for blends (e.g. R502)

The second environmental impact of a gas is its contribution to global warming. Global warming potential (GWP) is related to the ability of a gas to absorb infrared radiation. GWP is an estimate of the atmospheric warming resulting from the release of a unit mass of gas, in relation to the warming resulting from the release of the same amount of carbon dioxide. Global warming, unlike ozone depletion, is not covered by the Montreal Protocol.

CFCs make a substantial contribution to global warming but there are indications that this effect is offset globally by the cooling that results from the destruction of ozone by CFCs in the lower stratosphere.

Fully halogenated chlorofluorocarbons (CFCs) contain only chlorine, fluorine and carbon, and have a high ODP. Similar compounds which are not fully halogenated, and contain hydrogen in addition to chlorine, fluorine and carbon, are called hydrochlorofluorocarbons, or HCFCs. The presence of hydrogen in HCFCs reduces their persistence in the atmosphere, and they have a less destructive effect on the ozone layer than CFCs. They are nevertheless classified as transitional substances under the Montreal Protocol, and their use is likely to be controlled in the future.

Chemicals containing fluorine, carbon and hydrogen, but no chlorine or bromine, are known as hydrofluorocarbons, or HFCs. The HFCs currently being developed as CFC substitutes do not damage the ozone layer, but may contribute to global warming.

Blends containing a combination of CFCs, HCFCs and HFCs have been developed for specific applications. Their ODPs are lower than that of the CFCs they contain—though they are more damaging to the environment than both HCFCs and HFCs.

The Montreal Protocol

The Montreal Protocol, developed under the management of the United Nations Environment Programme in 1987, came into force on 1 January 1989. The Protocol defined the measures that Parties must take to limit production and consumption of the controlled substances, originally five CFCs and three halons. In early 1992 there were 76 Parties to the Protocol, of which nearly 40 were developing countries.

New scientific information soon made it clear that the original Protocol would not protect the ozone layer adequately. A revision made in London in June 1990 adopted supplementary control measures, and provided for technical and financial assistance to be given to signatories from developing countries. The London revisions introduced controls on 10 more CFCs, carbon tetrachloride and methyl chloroform, and set deadlines for the elimination of the controlled substances.

The Montreal Protocol—and the Vienna Convention from which it was born (see box right)—are the first global agreements to protect the atmosphere.

How regulation works

Each of the controlled chemicals is assigned an ODP in relation to CFC-11, which is arbitrarily given an ODP of 1. These values are used to compute an indicator of the damage being inflicted on the ozone layer by each country's production and consumption of controlled substances. Consumption is defined as total production plus imports less exports, and therefore excludes recycled substances. Thus the relative ozone depletion effect of CFC production is computed by multiplying the annual production of each controlled CFC by its ODP. These totals are added together to produce an indicator of potential ozone damage. Parties are required to reduce this total by 50 percent by 1995, by 85 percent by 1997 and by 100 percent by the year 2000 (in relation to 1986 figures). Developing countries have a 'grace period' of 10 additional years in which to meet these requirements.