UNEP
UNEP IE/PAC UNITED NATIONS ENVIRONMENT PROGRAMME
INDUSTRY AND ENVIRONMENT PROGRAMME ACTIVITY CENTRE

Protecting the Ozone Layer

Volume 5

Aerosols, sterilants, carbon tetrachloride and miscellaneous uses

United Nations Publication
Sales number: 92–III–D.9.
ISBN: 92–807–1356–6

First edition 1992

Protecting the

Ozone Layer

Volume 5

Aerosols, sterilants, carbon tetrachloride and miscellaneous uses

UNEP
INDUSTRY AND ENVIRONMENT
Programme Activity Centre (IE/PAC)
39-43, QUAI ANDRE CITROEN
75739 PARIS CEDEX 15, FRANCE
TEL: 33 (1) 40 58 88 50
FAX: 33 (1) 40 58 88 74
TELEX: 204 997 F

This document is published as part of UNEP IE/PAC's OzonAction programme, the programme created by UNEP to fulfil its obligations under the Interim Multilateral Ozone Fund for the Implementation of the Montreal Protocol. It was written, designed and produced by Words and Publications, Oxford, United Kingdom.

Contents

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. More than 80 countries are Parties to the Protocol.

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 a series of plain language reports that summarize the major issues surrounding CFC replacement for decision makers in government and industry. This is the fifth in the series prepared by UNEP IE/PAC; others cover refrigerants; solvents; foams; and halons for fire fighting.

Each of these 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. Those requiring more detailed information should refer to the 1992 reports of the UNEP Technical Options Committees (see Further Reading) on which this series is based.

Acknowledgements

This report is based on the *Report of the Aerosol Products, Sterilants, Miscellaneous Uses and Carbon Tetrachloride Technical Options Committee* (Nairobi, UNEP, 1992). Thanks are due to those members of the Committee who gave freely of their time to ensure that this publication, while written in plain language, reflects as accurately as possible the more detailed information available in the original report.

MEMBERS OF THE UNEP AEROSOL PRODUCTS, STERILANTS, MISCELLANEOUS USES AND CARBON TETRACHLORIDE TECHNICAL OPTIONS COMMITTEE

Nick Campbell, ICI Chemicals and Polymers, United Kingdom
Bill Dennis, Duke Medical Centre, United States
Donald Dunn, DuPont Chemicals, United States
Charles Hancock, MDT Corporation, United States
Anders Hansson, Astra Draco AB, Sweden
Leo Heileman, Institute of Marine Affairs, Trinidad/Tobago
Andrea Hinwood, EPA Victoria, Australia (Chair)
Katsuo Imazeki, Toyo Aerosol Co Pty, Japan
Montfort Johnsen, Montfort A. Johnsen & Associates, United States
Richard Knollys, Federation of European Aerosol Associations, United Kingdom
P. Kumarasamy, Kontrak Manufacture, Malaysia
Olle Matteson, Getinge, Sweden
Dr Robert Morrissey, Johnson & Johnson, United States
Geno Nardini, Precision Valve Corporation, Mexico
Dick Nusbaum, Pennsylvania Engineering, United States
Jose Pons Pons, Spray Química, Venezuela (Vice Chair)
Dr Ian Smith, Glaxo, United Kingdom
David Storey, Merck Sharp and Dohme, United Kingdom
Robert Suber, RJR Nabisco, United States
Chip Woltz, Linde, United States
Hua Zhangxi, Ministry of Light Industry, China

Executive summary

The use of ozone-depleting substances in industry increased significantly until about 1990. The result has been serious depletion of the ozone layer. New data have recently revealed that the hole in the Antarctic ozone layer which appears each spring is now larger than was originally calculated, and there is evidence of a similar hole beginning to form over the Arctic. The serious implications this has 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 more than 80 Parties. 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 should eventually allow the ozone layer to repair itself.

This volume deals with a number of different CFC uses: in aerosol products, as sterilants, and in a range of miscellaneous applications including food freezing, tobacco expansion, fumigation and cancer therapy. It also covers the use of carbon tetrachloride.

Of these applications, aerosol products consume the largest portion of CFCs: as much as 300 000 tonnes a year in 1986, a figure which had fallen to an estimated 115 000 tonnes by 1991. Substitutes for CFC aerosol products are readily available except where they are used to deliver drugs that are inhaled and in a few specialized industrial applications. CFC use in aerosol products is expected to be reduced to as little as 15 000 tonnes by 1995.

About 20 000 tonnes of CFCs are used each year to sterilize equipment. The most widely used sterilant is ethylene oxide, a substance that is toxic, mutagenic, a suspected carcinogen, flammable and explosive. To reduce these risks, ethylene oxide is mainly used in a mixture that contains 88 percent CFC-12 by weight. The alternatives include the use of undiluted ethylene oxide, steam, formaldehyde, and a mixture of ethylene oxide and carbon dioxide. These techniques will enable CFC use in sterilants to be substantially reduced worldwide, and to be phased out in developed countries no later than 1995.

Carbon tetrachloride is used as a feedstock in the production of CFC-11 and CFC-12, in the production of key pharmaceuticals and agricultural chemicals, and as a catalyst promoter in oil refineries. Use in the CFC industry will be progressively reduced as CFCs themselves are phased out. In the other applications, carbon tetrachloride is transformed or destroyed in the production process, a use that is allowable under the Montreal Protocol. Two remaining problems are the use of carbon tetrachloride as a solvent for materials being chlorinated, mainly in the production of chlorinated rubber, and as a process solvent in the pharmaceutical industry. Alternatives for these applications have still to be identified but these uses are expected to be phased out by 1997.

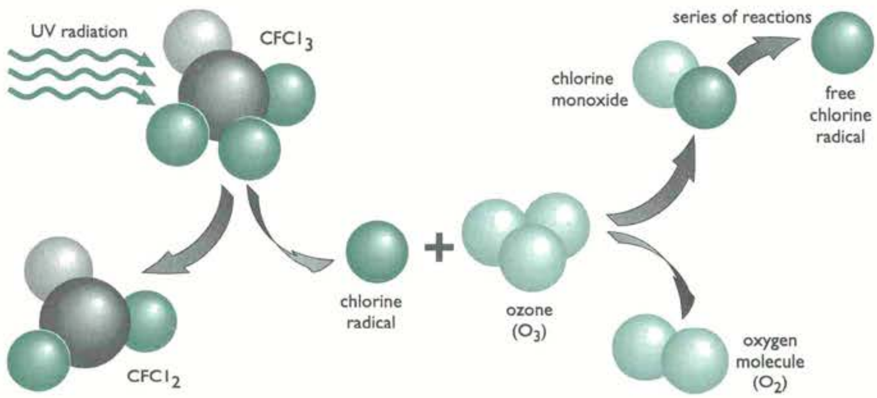
The miscellaneous uses of CFCs cover a wide variety of fields but use only small amounts of CFCs. They are therefore not covered in detail in this publication.

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



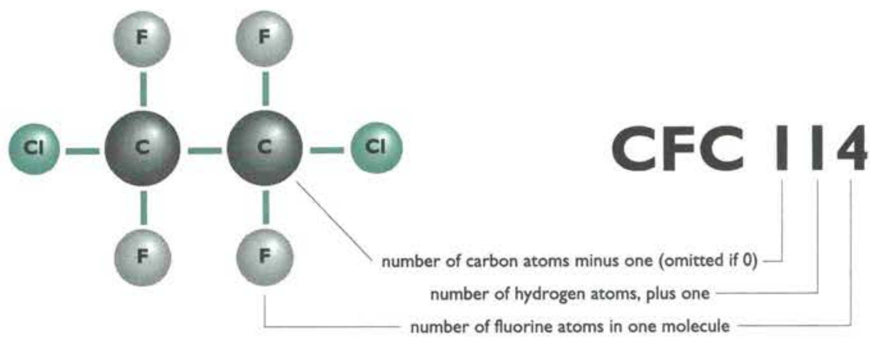
When gases containing chlorine, such as CFCs, are broken down in the atmosphere, each chlorine atom sets off a reaction that may destroy hundreds of thousands of ozone molecules.

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 per cent 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 F 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. R-502)

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 late 1992 there were more than 80 Parties to the Protocol, of which nearly 40 were developing countries.

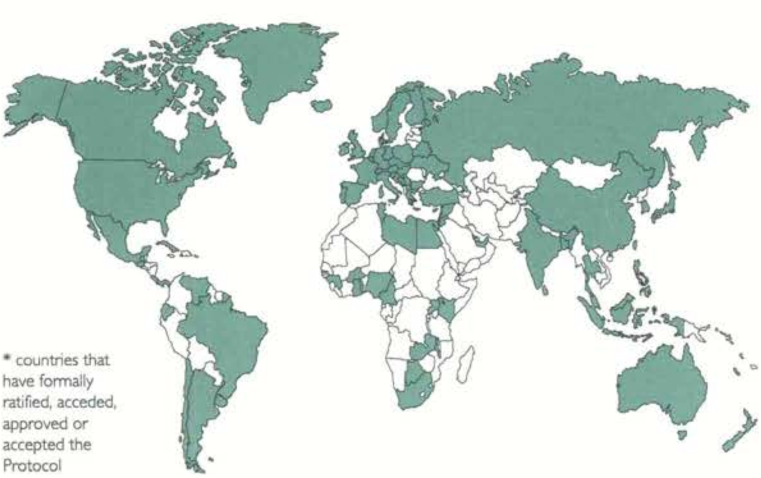
New scientific information soon made it clear that the original Protocol would not protect the ozone layer adequately. A revision made in London in June 1990 adopted supplementary control measures, and provided for technical and financial assistance to be given to signatories from developing countries. 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 per cent by 1995, by 85 per cent by 1997 and by 100 per cent 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.

Parties* to the Montreal Protocol, 31 July 1992



* countries that have formally ratified, acceded, approved or accepted the Protocol

Argentina
Australia
Austria
Bahrain
Bangladesh
Belarus
Belgium
Botswana
Brazil
Bulgaria
Burkina Faso
Cameroon
Canada
Chile
China
Costa Rica
Cuba
Cyprus
Czechoslovakia
Denmark
Ecuador
Egypt
European Community
Fiji
Finland
France
Gambia
Germany
Ghana
Greece
Guatemala
Guinea
Hungary
Iceland
India
Indonesia
Iran
Ireland
Israel
Italy
Japan
Jordan
Kenya
Korea, Rep. of
Libya
Liechtenstein
Luxembourg
Malawi
Malaysia
Maldives
Malta
Mexico
Netherlands
New Zealand
Nigeria
Norway
Panama
Philippines
Poland
Portugal
Russian Federation
Singapore
Slovenia
South Africa
Spain
Sri Lanka
Sweden
Switzerland
Syria
Thailand
Togo
Trinidad and Tobago
Tunisia
Turkey
Uganda
Ukraine
United Arab Emirates
United Kingdom
United States
Uruguay
Venezuela
Yugoslavia
Zambia

The Vienna Convention

The Montreal Protocol details how signatories should reduce their production and consumption of ozone-depleting chemicals. The principle that countries would agree internationally to take steps to protect the ozone layer was established in the Vienna Convention for the Protection of the Ozone Layer, signed by 21 states and the European Economic Community in March 1985. The Convention pledges parties to protect human health and the environment from the effects of ozone depletion, and two annexes provide for participating states to cooperate in research, observation and information exchange.

Requirements of the Montreal Protocol, as amended in London 1990

Name	*formula*	*ODP*	*reduction in production and consumption*
CONTROLLED SUBSTANCES *chlorofluorocarbons*			
CFC-11	$CFCl_3$	1.0	relative to 1986: 1995: 50 per cent 1997: 85 per cent 2000: 100 per cent
CFC-12	CF_2Cl_2	1.0	
CFC-113	$C_2F_3Cl_3$	0.8	
CFC-114	$C_2F_4Cl_2$	1.0	
CFC-115	C_2F_5Cl	0.6	
plus 10 other fully halogenated CFCs (*see below*)			
halons			relative to 1986: 1995: 50 per cent 1997: 85 per cent 2000: 100 per cent
halon 1211	$CBrClF_2$	3.0	
halon 1301	$CBrF_3$	10.0	
halon 2402	$C_2Br_2F_4$	6.0	
carbon tetrachloride	CCl_4	1.1	relative to 1989: 1995: 85 per cent 2000: 100 per cent
methyl chloroform	CH_3CCl_3	0.1	relative to 1989: 1993: levels frozen 1995: 30 per cent 2000: 70 per cent 2005: 100 per cent
NON-CONTROLLED TRANSITIONAL SUBSTANCES *hydrochlorofluorocarbons (HCFCs), such as*			substances with low ODPs, to be phased out by 2020 if feasible and not later than 2040
HCFC-22	$CHClF_2$		
HCFC-123	CF_3CHCl_2		
HCFC-141	$C_2H_3Cl_2F$		
HCFC-142	$C_2H_3ClF_2$		

plus 33 other HCFCs (*see below*)

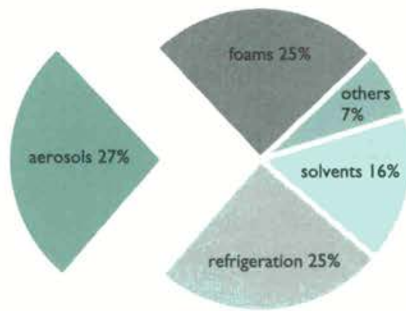
Note: The 1990 London Amendments added the following CFCs with an ODP of 1.0 to the list of controlled substances: CFCs -13, -111, -112, -211, -212, -213, -214, -215, -216 and -217. The following HCFCs (and their isomers) were made transitional substances, in addition to those shown by way of example above: HCFCs -21, -31, -121, -122, -124, -131, -132, -133, -151, -221, -222, -223, -224, -225, -226, -231, -232, -233, -234, -235, -241, -242, -243, -244, -251, -252, -253, -261, -262 and -271.

CFC use in aerosol products

Key facts

CFCs, until recently, were more widely used in aerosol propellants than in any other applications. But voluntary restrictions and legislation in both developed and developing countries has reduced use to only 38 percent of its 1976 value.

Aerosol propellants were first used in 1923 as a means of dispersing insecticides. An aerosol propellant must evaporate quickly and disperse the active ingredient effectively. Compressed gas is of limited use as a propellant since the gas pressure in the container falls as the container empties. Liquified gases do not suffer from this problem, and CFCs quickly became the preferred propellant in an industry that expanded rapidly after World War II. CFCs were widely adopted because they are not flammable, explosive or toxic, because they can be produced in a highly pure form and because they are good solvents. Today, more than 8000 million aerosol cans are produced annually—the equivalent of 300 000 every 20 minutes.



Aerosol product uses currently account for about 27 percent of all CFC usage but reductions are being rapidly introduced in most countries.

The products dispersed include lacquers, deodorants, shaving foam, perfume, insecticides, window cleaners, oven cleaners, pharmaceutical and veterinary products, paints, glues and lubricating oils. CFC-11 and CFC-12 are most widely used as propellants but CFC-114 is used to disperse products containing alcohol.

Use of CFCs in aerosol products

	aerosols produced (millions of units)		*% filled with CFC*	*CFC used (tonnes)*
	1986	*1990*	*1990*	*1990*
Argentina	123	86	14	1300
Australia	154	143	9	4500
Brazil	104	102	5	91
Canada	157	116	7	1000
China	20	48	80	4700
East Europe	140?	140	25	5000
EEC	2832	2913	10	17000
India	15	30	50?	500
Japan	408	570	1.4	3383
Mexico	47	60	5	300
Middle East	60?	120	8	1300
New Zealand	14	16	<2	400
South Africa	100	109	20	1500
South-east Asia	100?	100	20?	1400?
Soviet Union	448?	414	75	65000
Trinidad and Tobago	-	6	-	90
United States	2564	2920	5	11000
Venezuela	56	40	6	220

Notes: refill cans for refrigerators excluded; data from Trinidad and Tobago are preliminary

The fact that CFCs were both good propellants and good solvents accounted for many of their uses in aerosol products. An additional advantage in some products was the inflammability of CFCs: they can therefore sometimes be used as flammability depressants in aerosols in which other products are flammable.

CFCs are also the active ingredient in some aerosol products. They are used on their own, for example, in aerosol products designed to produce a chilling effect as a local anaesthetic, particularly in sports injuries. The chilling effect is also used to freeze pipes needing repair, remove chewing gum and identify electronic faults. They can also be used to remove dust from photographs, disks and tapes because they evaporate quickly, leaving no residues. And, finally, the sudden escape of CFCs from a small orifice is used to create noise in fog horns and alarm equipment.

In the mid-1970s, aerosol products accounted for 60 percent of all the CFC-11 and CFC-12 used worldwide. By the end of the decade, however, countries were beginning to ban or restrict the use of CFCs in aerosol products and after the introduction of the Montreal Protocol in 1987 CFC use in aerosol products began to decline rapidly. Overall consumption was about 300 000 tonnes in 1986 but was reduced to some 180 000 tonnes in 1989. Progress since then has been rapid; in 1991 only about 115 000 tonnes were used in aerosol products. The table below summarizes progress in the reduction programme.

How countries reduced CFC use in aerosol products

Australia: industry uses CFC propellants only in some medical products; manufacture, imports and sales banned from 1 January 1990 unless exemption granted.

Austria: CFC propellants not permitted after January 1990 except some medical and technical products.

Brazil: industry uses CFC propellants only in some medical products.

Canada: import, manufacture and sale regulated since 1 January 1990, with some exceptions until 1 January 1993.

China: production expected to increase to 23 000 tonnes of CFCs by 1996 but reduction plans are being made. Some plants have been converted to use hydrocarbon propellants instead of CFCs.

Denmark: except in industrial products, use banned 1 January 1987; with some exceptions, all uses banned 1 January 1990.

Egypt: use banned from 1 January 1991, and use has fallen from 1500 to 30 tonnes a year.

Finland: phased out by end 1991 except for medical and technical products where no substitutes available.

Germany: achieved a 90 percent reduction by 1988; further reductions planned.

Hungary: except medical products, use will be banned from 1993.

Japan: legislation on use of flammable propellants relaxed.

Mexico: first country to ratify the Montreal Protocol, reduced use by 80 percent between 1986 and 1990 by voluntary agreements with producers; eliminated nearly all aerosol uses by the end of 1991.

New Zealand: manufacture and import banned from 1 January 1990, except medical products.

Norway: banned 1 July 1991 with a few medical exemptions.

South Africa: voluntary cooperation of manufacturers has reduced 1990 use to 40 percent of 1988 use.

Sweden: banned 1 January 1989 with a few medical exemptions.

Switzerland: banned 1 January 1991 except for medical products which will be banned 1 January 1994 (exemptions can be granted).

Trinidad and Tobago: most aerosol product plants converted to hydrocarbons.

United Kingdom: achieved a 90 percent reduction by 1990.

United States: use banned since 1978, with further limitations on exemptions expected.

Venezuela: as for Finland, but from 1 July 1992.

CFC use in sterilants

ey facts

lixtures of CFC-12 and hylene oxide are widely used some countries for sterilizing edical equipment. Health nd safety regulations sewhere have led to the use alternatives such as steam, rmaldehyde and radiation. nese will make it possible to nase out the use of CFCs in erilants in developed ountries by 1995.

Ethylene oxide, mixed with CFC-12, is widely used as a medical sterilant. The CFC is used to reduce the flammability and explosive risk from ethylene oxide, and the most common mixture contains 88 percent CFC-12 by weight (commonly known as 12/88). Worldwide use of CFC-12 for this purpose is estimated at 18 000–20 000 tonnes a year, half of it in the United States. Since 1989, use has been reduced by 5000 tonnes.

Ethylene oxide penetrates packaging materials and destroys microorganisms within them, a highly useful property now that so many medical items are sold packaged and sterilized. Ethylene oxide is particularly useful for sterilizing objects that are sensitive to heat and moisture—such as catheters and medical equipment that uses fibre optics. The volume of equipment that is sensitive to heat and moisture has risen rapidly over the past few years with the advent of organ transplants and heart by-pass surgery.

However, since ethylene oxide is toxic, mutagenic and a suspected carcinogen (as well as being flammable and explosive), its use requires stringent safety precautions and is strictly regulated in some countries. This has led to widely differing sterilization practices in different countries. Nevertheless, 100 percent ethylene oxide can be used undiluted if equipment is correctly designed and it is operated by trained staff.

In the United States, most hospitals (which account for 30–40 percent of ethylene oxide use) use 12/88 for sterilization. Because of health and safety regulations, 12/88 is not used in many European hospitals except notably in Belgium and France. Germany and the Nordic countries tend to use steam and formaldehyde, and the latter is coming into favour in Eastern Europe and the Middle East. Italy and the United Kingdom tend to use undiluted ethylene oxide in hospitals, as do many manufacturers of medical devices and contract sterilization services.

A range of other alternatives is available, including the use of radiation. The use of CFCs in sterilants in developed countries is expected to be phased out by 1995 at the latest.

Countries using 12/88 sterilant in 1992

Angola
Argentina
Australia
Belgium
Canada
Chile
Colombia
Costa Rica
Côte d'Ivoire
Cuba
Czechoslovakia
Denmark
Ecuador
Egypt
Fiji
Finland
France
Germany
Greece
Guatemala
Hong Kong
Hungary
Indonesia
Iran
Iraq
Israel
Italy
Jamaica
Japan
Jordan
Kenya
Korea, Rep. of
Malaysia
Mexico
Morocco
Mozambique
Netherlands
Nigeria
Panama
Peru
Philippines
Poland
Portugal
Russian Federation
Saudi Arabia
Singapore
South Africa
Spain
Sweden
Switzerland
Taiwan
Thailand
Trinidad and Tobago
Turkey
United Arab Emirates
United States
Uruguay
Venezuela
Zambia
Zimbabwe

Carbon tetrachloride

Carbon tetrachloride—CCl_4, a controlled substance under the Montreal Protocol—is used as the basic chemical building block in the production of other CFCs, notably CFC–11 and CFC–12. It is used up in the process, so does not itself pose any threat to the ozone layer, even though the products of the reaction do. About 500 tonnes a year of carbon tetrachloride are also used in the production of fine chemicals, some pharmaceuticals and agrochemicals, and as a catalyst sweetener in the oil industry. All these applications result in the destruction of the original carbon tetrachloride, and are therefore allowable under the Montreal Protocol.

The largest use of carbon tetrachloride outside CFC production is probably as an inert solvent in chlorination reactions such as the production of chlorinated rubber. No substitutes have yet been identified for this application. However, the carbon tetrachloride is generally recycled, and in new plants recovery can be as high as 99.9 percent. Carbon tetrachloride is still used as a cleaning solvent in some developing countries; dry cleaning is dealt with in volume 2 of this series.

Carbon tetrachloride is also an 'involuntary' by-product of a number of important industrial processes, notably the production of chlorinated solvents and vinyl chloride. As much as 140 000 tonnes of carbon tetrachloride may be produced annually in this way. Most of it is recycled, destroyed in the production unit or used as a feedstock to produce other chlorinated compounds—processes permitted under the Montreal Protocol. However, trace levels of carbon tetrachloride do remain in the end products—generally about 10 parts per million. It is estimated that these by-products give rise to about 500 tonnes of carbon tetrachloride a year.

Worldwide production capacity for carbon tetrachloride is about 1 million tonnes a year, and in 1989 an estimated 750 000 tonnes were actually produced. In 1990, the United States produced 123 000 tonnes and Japan 52 000 tonnes of carbon tetrachloride—nearly all of it for CFC production. Production has declined as CFC uses have been curtailed, and 1990 production in the United States was little more than one-third that of 1988. Production is expected to decline further as CFC uses are phased out, with virtual elimination of the chemical in applications which result in its being dispersed in the atmosphere by 1997.

Because the bulk of carbon tetrachloride production is as a feedstock for CFC synthesis, an application that will disappear along with CFCs, carbon tetrachloride is not dealt with further in this publication.

Key facts

Carbon tetrachloride is a controlled substance under the Montreal Protocol.

Its main use is as a feedstock for the production of CFCs—a use that will disappear with the CFCs.

The second use is as a solvent in the chemical industry—no alternative is available but as much as 99.9 percent of the material can be recycled.

Small amounts are used in the production of some pharmaceutical and agricultural products, and in catalysis in the oil industry. They are destroyed in the process.

Miscellaneous uses

ey facts

here are many miscellaneous ses of CFCs in industry but one uses substantial amounts f CFC.

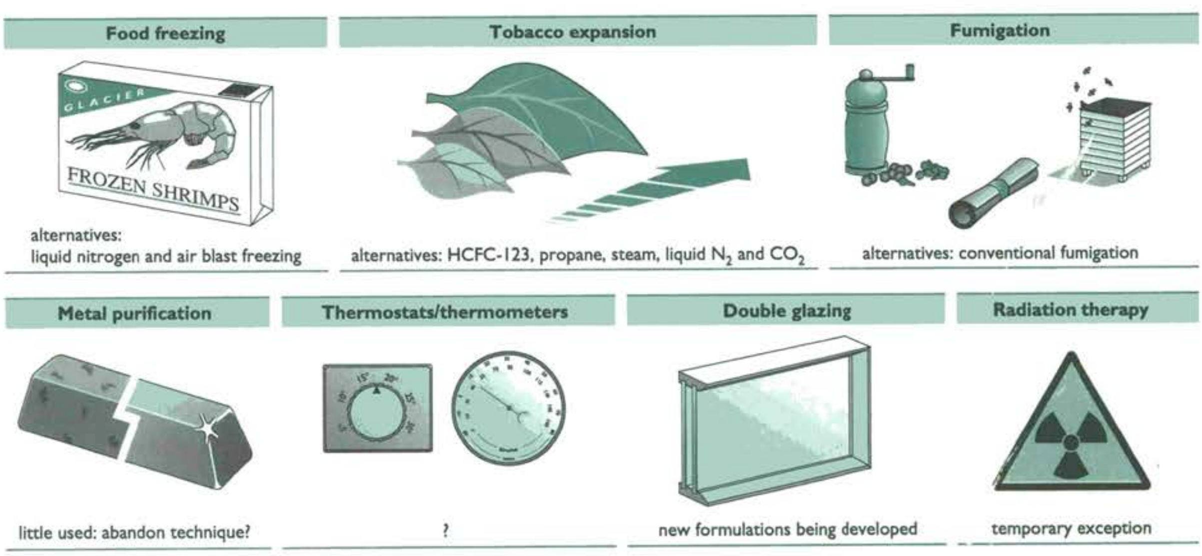
he two major consumers are he freezing of food and the xpansion of cured tobacco to rovide low tar cigarettes.

ubstitute chemicals and rocesses are available for nost miscellaneous uses.

phase out plans for CFCs are ccelerated, these substitutes ould be used or the processes bandoned. Temporary xemptions may be needed for ome low-volume uses such as aboratory analysis and adiation therapy machines.

CFCs are used in small amounts in many different ways in many different industries. The minor uses described below mostly consume insignificant amounts of CFC.

- Food is frozen through contact with liquid CFC-12, which boils at –30 °C at normal pressure. In 1986, 30 of these freezing units worldwide were consuming about 3400 tonnes of CFC-12 a year, mostly in the United States. Alternatives include freezing in liquid nitrogen and air blast freezing.
- CFC-11 is used to expand dried tobacco to its original size to provide low tar cigarettes—about 1100 tonnes a year are used in the United States and a further 700 tonnes elsewhere. Alternatives are under development; possibilities include using HCFC–123 instead of CFC–11, and using different processes based on propane, steam, nitrogen and, particularly, liquid carbon dioxide—a widely used and effective alternative.
- Fumigation with CFC/ethylene oxide mixtures is used to treat an assortment of objects, including spices, rare books and manuscripts, and beehives. By far the most significant use is for treating spices, which consumes about 180 tonnes of CFC-12 a year in the United States. Alternatives are available.
- Laboratory tests make use of CFC-113 and carbon tetrachloride as solvents but total use is very small.
- Leaks in pressure vessels are commonly detected using CFC-12 and a halide detector. A combination of HCFC–22 and nitrogen can be used instead.
- Wind tunnels are sometimes filled with CFCs because the velocity of sound is much lower in a CFC than in the air. This means that supersonic conditions can be reached with much lower circulation rates.
- Graphite rods used in nuclear reactors used to be purified in the United Kingdom by heating in a furnace filled with CFC–12. The process is no longer used though a similar one is used in the Middle East to refine aluminium.



- Refrigerator and central heating thermostats and thermometers make use of the rate at which CFCs expand as temperature rises to operate on/off switches and turn dials on rotary thermometers. About 1–10 grammes are used per unit.
- Double glazing sometimes uses a gas mixture that includes CFC–12 to lower thermal conductivity and increase transparency. New formulations are being developed.
- Linear accelerators used for radiation therapy make use of CFC–12 as a dielectric medium in the transmission of energy at radiofrequencies. Less than 2 tonnes of CFC are used annually in new equipment but some CFC–12 has to be replaced as a result of leakage. Sulphur hexafluoride is being tested as an alternative.
- Ice plugs are created in piping using CFCs to halt flow in the pipe during repairs. CFC–12 and halocarbon detectors are also used to check for leaks in new installations before filling. HCFC–22 and HCFC–152 are alternatives.
- Drug manufacture utilizes minor amounts of CFCs, for which substitutes are being developed. Because these substitutes must undergo rigorous testing, replacements may not be made before the end of the century.
- Solar tracking systems make use of CFC expansion to tilt solar panels towards the sun. Each unit uses 3–8 kg of CFC–12. HCFC–22 is a possible substitute and mechanically driven systems are also available. The latter, however, are more prone to wind damage and are less energy efficient since they utilize tracking motors.

Other minor uses of CFCs exist, in both developed and developing countries. Most could either be abandoned or switch to alternative substances and processes if CFC phase out plans are accelerated. A few very minor uses, such as laboratory analysis and radiation therapy, may require temporary exemption. Because the minor uses of CFCs are relatively unimportant, they are not considered further in this publication.

Laboratory analysis

temporary exeption

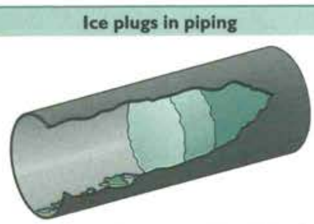
Leak testing

temporary exemption

Wind tunnels

little used: abandon technique?

Ice plugs in piping

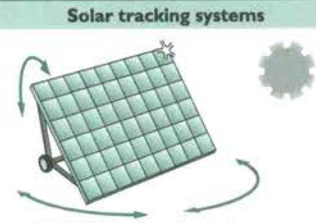


alternatives: HCFC-22 and HCFC-152

Drug manufacturing

substitutes by the year 2000

Solar tracking systems



HCFC-22 and mechanical systems

Aerosol products

CFCs are used in aerosol products as propellants, as solvents, as a means of reducing the flammability of the active ingredient, and as the active ingredient itself in aerosol products designed to chill and to produce noise. It follows that substitutes for CFCs must be chosen with these properties in mind, and that no single substitute can be used. The substitutes available for propellants, solvents and active ingredients are quite different.

Furthermore, there are two other ways of approaching the issue of eliminating CFCs from aerosol products. The first involves producing the aerosol in a different way. The second involves finding a substitute for the aerosol concept itself—such as the solid sticks used as deodorants. The range of possibilities is shown in the table below.

Substitutes for propellants

Hydrocarbons and dimethyl ether

The hydrocarbons propane, normal butane, isobutane and pentane are the most common substitutes for CFC propellants. They are cheap and efficient, but highly flammable. Operators can minimize risks by installing fire detection and extinguishing systems, reinforcing buildings to reduce explosion damage, and providing safety training. The average cost of converting a filling plant to hydrocarbons is about US$750 000. Hydrocarbons generally cost between one-third and one-fifth as much as CFCs, and the savings obtained soon pay back the costs of conversion. However, if the hydrocarbons need to be purified, costs may be considerably increased.

Dimethyl ether is used extensively, particularly in Europe, as a combined propellant and solvent replacement for CFCs. It is flammable, but can be used in certain aerosol filling plants if the usual safety procedures for flammable substances are followed.

Hydrocarbons and dimethyl ether share a major disadvantage: they are volatile organic compounds (VOCs) that take part in chemical reactions in the atmosphere in the presence of sunlight that result in the production of toxic ground-level ozone.

Aerosol products: currently available alternatives

alternative propellants	alternative solvents	alternative aerosol systems	alternatives to the aerosol
hydrocarbons (propane, butane, pentane)	water	bag-in-can systems	finger and trigger pumps
dimethyl ether	chlorinated solvents (methylene chloride, trichloroethylene, perchloroethylene, methyl chloroform)	piston-in-can systems	mechanical pressure dispensers
compressed gases (CO_2, NO_2, N_2O, air)		alcohols (isopropyl alcohol, ethanol and n-propanol)	sticks (for deodorants, anti-perspirants, insect repellants)
HCFC–22			rollers, brushes and cloths
HCFC–142b			powder inhalers, and nebulizers for pharmaceuticals
HFC–152a			

Compressed gas

If a coarse spray is acceptable, air, nitrogen, carbon dioxide and nitrous oxide can be substituted for CFC propellants. The main problem with these compressed gases is that as the container empties the pressure inside it falls dramatically, reducing the delivery rate, spray quality and perhaps even the quantity of spray dispensed. Attempts are being made to overcome this problem by redesigning the aerosol nozzle. It is hoped that this will increase the percentage of aerosol products using compressed gases (currently 7–9 percent of all products). Carbon dioxide can produce corrosion in the can if the formula and can specifications are not carefully chosen.

Carbon dioxide and nitrogen have the additional advantage of being non-flammable. Production costs for carbon dioxide aerosol products are lower than those for CFCs, and the costs of changing to carbon dioxide are comparable to those of changing to hydrocarbons.

HCFC-22

For some industrial and technical uses, non-flammable propellants are essential. HCFC-22 has been used in place of CFCs in these applications. HCFC-22 has also been used in some personal products, such as hair sprays and aerosol fragrances. By converting to HCFC-22, the industry has reduced its CFC use but, because HCFC-22 is an ozone-depleting substance, it is regarded only as a short-term alternative and consumption is unlikely to increase. The use of HCFC aerosol products is to be banned in the United States from 1 January 1994 (with some essential use exceptions).

Compounds under development

Propellant suppliers are developing new compounds to replace CFCs. HFC-134a and HFC-227ca are the only non-flammable fluorinated propellants being investigated, and both have an ODP of zero. HFC-134a is likely to replace CFC-12 in pharmaceutical inhalants and HCFC-22 in certain industrial products. HFC-134a will be widely available in the near future. HFC-227ca is being investigated for pharmaceutical inhalants, but will not be available for some time. HFC-143a is also being developed as a propellant in the United States. These substances are expected to be more expensive than CFCs.

Substitutes for solvents

Methyl chloroform is widely used as a solvent in aerosol products containing insecticides, and automotive and industrial products. It is non-flammable and reduces the flammability of substances in which it is used. In 1990 it was added to the list of substances to be phased out under the Montreal Protocol. In several countries, government regulations or voluntary agreements within industry are reducing methyl chloroform use. New regulations in the United States could reduce annual consumption from the 1990 level of 34 000 tonnes to 20 000 tonnes in 1995. There are no ideal replacements for methyl chloroform in aerosol products. The industry will have either to convert to more hazardous solvents such as hydrocarbons (which can require extensive plant modifications) or reformulate its products to ensure that their overall flammability does not increase.

Key facts

The aerosol products industry can reduce CFC usage by converting to alternative propellants, including:

- *hydrocarbons;*
- *dimethyl ether;*
- *compressed air, CO_2 or nitrous oxide; and*
- *HCFC-22.*

HFC-134a, which is non-flammable and has an ODP of zero, also has a large and sustained global warming potential and is thus a likely propellant only for metered-dose inhalents, in the future.

The only solvents available to replace methyl chloroform are hydrocarbons.

Some products can be redesigned to eliminate the use of propellant aerosols.

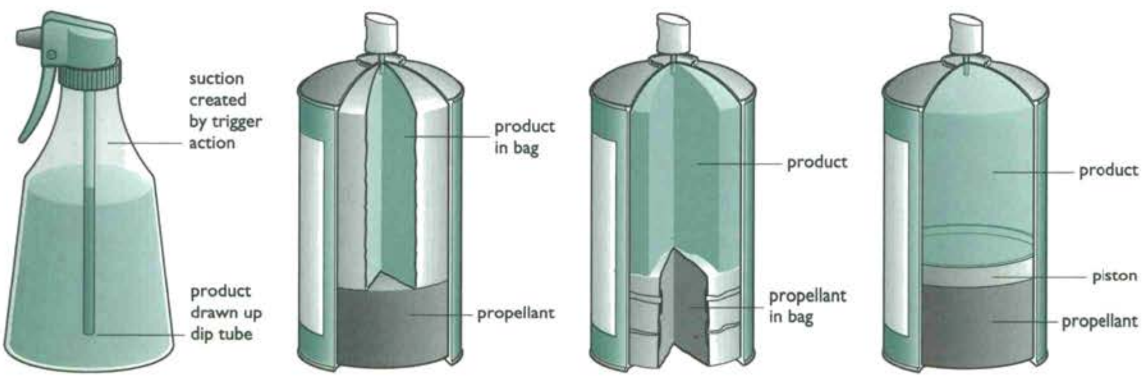
Alternatives to propellant aerosol products

A pump spray can be a useful alternative to some propellant aerosol products. The pump can be operated by a lever worked with a finger, or by a trigger that can be operated after pressure has been increased. Pump systems can be filled cheaply, without special equipment.

Another way of producing a spray is to separate the product and the propellant by a piston, an inner bag containing the product or an expanding bag containing the propellant. These systems deliver the product without propellant; although the propellant is ultimately released to the atmosphere, only small quantities are needed. Fluorocarbons, hydrocarbons and compressed gas can be used as the propellant. The system may cost twice as much as a normal aerosol product, and special filling machines are needed. The simplest device is one in which a flexible container, or a bag within it, is squeezed by hand.

The simplest of all alternatives is to market the product, if possible, as a solid stick, in a roll-on dispenser or as an impregnated cloth, brush or pad. While filling solid sticks is expensive, capital costs of roll-on dispensers are typically half those of an aerosol filling line.

Alternatives to propellant aerosol products



Potential problems

Specialized aerosol product uses

In some specialized uses of aerosol products, CFCs are difficult to replace. Propellants in medical aerosol products must be neither toxic nor flammable; and propellants and solvents in aerosol products used for many industrial purposes must be non-flammable and inert.

CFCs are used as propellants in inhalants for the treatment of asthma, and in medical aerosol products containing substances such as anaesthetics and antiseptics. Inhalant propellants are the most difficult to find substitutes for because propellants must conform to strict toxicity regulations and should not be flammable. CFC-11, CFC-12 and CFC-114 are used as propellants in medical inhalers, and possible alternatives include HCFC-141b, HFC-134a, HFC-227ca and hydrocarbons. None is ideal; they are undergoing extensive testing and the aerosol products may have to be reformulated to make them compatible with non-CFC propellants. CFC-free inhalers will therefore not be available before 1998, at the earliest. However, CFC-based inhalers are needed only by a proportion of patients with respiratory problems; many could use alternatives such as powder inhalers (common in Sweden and The Netherlands) and nebulizers. Medical aerosol products that are not inhaled could be converted to alternative propellants, dispensed by mechanical pump sprays or produced as powders.

CFCs are also widely used as propellants and solvents in aerosol products for lubricating, cleaning and fault-checking electrical equipment. Since 1989, most of these products have been converted to HCFC-22, and blends of HCFC-22 with dimethyl ether and methyl chloroform. However, it is difficult to find substitutes for some of them.

Cleaners and solvents are the main aerosol products used on electronic equipment. CFC-12, used as a propellant in these products, has now been replaced by HCFC-22. HCFC-123 and HCFC-141b are being evaluated as replacements for CFC-113, which is used as a solvent (see volume 2 of this series). Hydrocarbons have only a limited use on electronic equipment because they leave traces of petroleum oil on the circuit boards. Flammable substances are also unsuitable for safety reasons.

It is difficult to replace CFC-12 in aerosol products used to chill circuit boards and computer panels to locate breaks in the connections. These products have reduced the time needed to locate faults from several days to 5–10 minutes. HCFC-22 has been used as an alternative, and HCFC-124 and HFC-134a may be used in the future.

Implications for developing countries

In many developing countries the aerosol products industry is composed of multinational firms and small, local companies. These small companies may lack the capital and expertise to convert to CFC substitutes. Hydrocarbons are the most widely available alternatives to CFCs, but conversion involves extensive plant modifications and staff training. In developed countries, hydrocarbons are significantly cheaper than CFCs, but this may not be the case in developing countries. In addition, the supply and quality of alternatives such as propane and butane may be unreliable.

Many of the alternatives to hydrocarbons, such as HCFC-22, are expensive in developing countries. The introduction of CFC alternatives will therefore be much slower than in developed countries.

Accelerated phase out

Because most aerosol products are being converted to non-CFC propellants and solvents, an accelerated phase out of CFCs would not cause a serious shortage of these products. However, replacements for CFCs in medical inhalers are unlikely to be approved for use before 1999. An early phase out in 1997 could result in severe shortages in life-supporting medication for asthmatics.

Sterilants

Ethylene oxide mixed with CFC-12 (known as 12/88) is used to sterilize medical equipment. Hospitals, medical equipment manufacturers and commercial sterilizing facilities also use several other sterilizing substances and processes, which can be used in place of 12/88 sterilization. No single alternative process is suitable for sterilizing all medical equipment, but hospitals and manufacturers can use several methods to meet their needs. New sterilization substances are being developed as direct replacements for 12/88.

Key facts

Commercial sterilization plants can reduce CFC-12 use by converting from 12/88 to techniques based on 100 percent ethylene oxide, 10/90 and radiation. New HCFC mixtures will soon be available, but may be expensive.

For smaller units, such as those in hospitals, appropriate alternatives to 12/88 are a combination of steam, formaldehyde or ethylene oxide. HCFC/ethylene oxide drop-in replacements for 12/88 will soon be available.

Alternative sterilization processes

Steam sterilization

Steam sterilization is the least expensive of all sterilization methods and is widely used by equipment manufacturers and hospitals. This process is non-toxic, economical and safe, and can be used for all equipment that can withstand high humidity and temperatures up to 121 °C.

Steam sterilization can replace 12/88 in many of its uses, but cannot be used to sterilize medical equipment for technically advanced operations such as organ transplants. This equipment cannot withstand temperatures higher than 38–55 °C.

A change in normal hospital practice could increase the amount of equipment sterilized by steam. Hospitals usually keep surgical instruments in sets or trays according to the type of operation for which they are used, and these combined sets are sterilized with 12/88. If the two types of equipment were kept separately, it would be possible to sterilize the majority of equipment with steam, and only heat- and moisture-sensitive equipment with 12/88.

Formaldehyde

Formaldehyde has been used as a sterilant for many years. However, because it is toxic and a suspected carcinogen, its use is restricted in some countries, notably the United States. The most common formaldehyde sterilization process can be used on heat-sensitive equipment that cannot withstand the high temperatures of steam sterilization. Temperatures reach only 80–85 °C during formaldehyde sterilization, and in some countries, including Germany, equipment operating temperatures are as low as 60–65 °C.

It is cheaper to sterilize with steam than formaldehyde, and steam will therefore be the preferred alternative to 12/88 for heat-resistant equipment. Formaldehyde is cheaper than 12/88 and, where regulations allow, it is a viable alternative to 12/88 for the sterilization of heat-sensitive equipment.

Ethylene oxide

Although CFC-12 is used in 12/88 to reduce the flammability of ethylene oxide, undiluted ethylene oxide has been used as a sterilant for many years by hospitals and medical equipment manufacturers. Sterilization is usually carried out at atmospheric pressure, or below, to reduce the risk of fire and explosion. Safety precautions are also necessary during the storage and handling of ethylene oxide.

One hundred per cent ethylene oxide is widely used because the gas is widely available and cheap. However, each sterilizing unit costs about US$50 000, and the cost of conversion to 100 per cent ethylene oxide sterilization, particularly for large medical equipment manufacturers, is likely to be high. Safety regulations may require the relocation of sterilizing units, and this will add to the cost.

Because of the cost of ethylene oxide units and the associated safety risks, most hospitals have only small ethylene oxide units. Steam and formaldehyde are used for sterilizing most equipment, and ethylene oxide is used only for heat-sensitive equipment that cannot withstand sterilization by other methods. Sterilization is carried out at 37 °C for 5 hours, or 55 °C for 2 hours. Ethylene oxide, used in conjunction with another sterilization process, is a possible replacement for 12/88 in hospitals.

Techniques for reducing 12/88 use in hospitals

- *sterilizing heat-resistant equipment with steam;*
- *sterilizing heat-sensitive equipment with formaldehyde;*
- *using ethylene oxide sterilizers in units where this is safe and practical;*
- *recovering and recycling 12/88;*
- *using HCFC/ethylene oxide mixtures when they become available.*

Blends of ethylene oxide and CO_2

A mixture of 10 percent ethylene oxide and 90 percent CO_2 (known as 10/90) is sometimes a suitable alternative to 12/88. This mixture is not flammable, explosive or environmentally damaging; it is immediately available, and has a proven usage record. Its use, however, entails higher pressures than 12/88, and hence more expensive equipment.

However, there are problems. Because the vapour pressure of CO_2 is much higher than that of ethylene oxide, CO_2 gradually vaporizes within the sterilant cylinder and separates out from the liquid ethylene oxide. With successive use cycles, the proportion of ethylene oxide in the sterilant increases, and so does the flammability of the mixture. There is also a risk that the last few times the cylinder is used it contains only CO_2, and no sterilizing agent. One way to overcome these problems is to use cylinders that contain only a single charge of 10/90. The cost of conversion to a single charge cylinder system is minimal.

Mixtures of ethylene oxide and with 80 or 70 percent CO_2 are used in some countries. They can form explosive mixtures in air, and safety precautions are necessary to reduce operating risks.

Sterilization techniques: alternatives to 12/88

	cheaper than 12/88	*suitable for heat-sensitive equipment*	*non-toxic*	*non-flammable*	*comments*
steam	●		●	●	cheapest sterilization method
formaldehyde	●	●		●	use restricted in some countries
ethylene oxide		●	●		high conversion costs; safety procedures essential
10/90		●	●	●	operating problems
radiation		●	●	●	safety procedures essential
dry heat	●		●	●	sterilized equipment must be used immediately
ethylene oxide/ HCFC 124		●	●	●	drop-in replacement for 12/88 not yet available

Radiation

The use of radiation to sterilize medical products is increasing as governments regulate the use of ethylene oxide. Globally, half of all single-use medical products are sterilized by irradiation. Manufacturers usually have their own, on-site equipment for irradiation, whereas hospitals usually send equipment to specialized facilities for irradiation. Hospitals do not have their own facilities because of construction costs (US$4 million, on average) and the complexity of irradiation equipment.

Irradiation is a very reliable sterilization technique. Irradiated equipment can be released as sterile without holding it under quarantine to conduct sterility tests. However, radiation cannot be used to sterilize all equipment. Some products and packaging are irreversibly damaged by exposure to radiation, and only a small percentage could be redesigned to make them compatible with radiation.

Dry heat

Metal, and other items that can withstand temperatures up to about 190° C, can be sterilized by exposure to dry heat. A wide selection of equipment is available worldwide, and is cheap to buy, operate and maintain. Items sterilized by this technique must be used immediately because they are not protected by a sterilized package. Because of this, dry heat sterilization is a suitable technique for a small dental surgery, for instance, but not for a large hospital, where equipment is unlikely to be used immediately after it is sterilized.

New sterilization substances

New substances currently being developed could replace CFC-12 in 12/88 or be used as a substitute for 12/88 in some of its uses.

A number of the HCFCs and HFCs under investigation as replacements for CFCs could be used to dilute ethylene oxide. Suitable substances are good flame retardants; have low ODP, GWP and toxicity; are compatible with medical equipment; and blend with ethylene oxide.

In the early 1990s, chemical manufacturers in the United States began production of a mixture of ethylene oxide (8.6 percent) and HCFC 124 (91.4 percent), designed as a drop-in replacement for 12/88 in existing equipment. The performance of this product in sterilization systems, and its compatibility with medical equipment, is being investigated. These tests will take about two years to complete.

Ionized gas plasma could be a partial replacement for 12/88 in hospitals, and is undergoing field trials. Limited penetrating abilities preclude the use of many wrapping materials and may prevent use with items having long lumens such as flexible endoscopes. Tests have not yet determined whether the ionized gas plasma process could be scaled up for industrial sterilization.

Developing countries

Most developing countries have some hospitals using advanced medical techniques and equipment. A few developing countries have at least one commercial sterilization facility, and many countries have one or more hospital sterilization units. To reduce CFC use, commercial sterilization facilities are phasing out 12/88 and converting to other sterilization methods. Although 10/90 and ethylene oxide are available in developing countries, they are sometimes expensive and their supply can be unreliable. Because of this, hospitals are less willing to convert to alternative sterilization methods and many will continue to use 12/88 until 'drop in' replacements are available for existing equipment.

Governments in developing countries can take steps to minimize CFC use. Units using 12/88 should be identified and given assistance to convert to 100 per cent ethylene oxide or HCFC/ethylene oxide mixtures. Governments can also ensure that no new commercial facilities using 12/88 are built in the country; supply domestic chemical manufacturers with information on ethylene oxide production; provide commercial sterilization facilities with technical information and financial assistance to help them convert from 12/88; train personnel in commercial facilities and hospitals in ethylene oxide sterilization techniques; and encourage hospitals to choose non-CFC technology when purchasing new sterilizers.

Forecast of usage

If commercial sterilization facilities and hospitals convert to a combination of existing sterilization techniques, CFC use could be eliminated by 1996 in developed countries. In developing countries, 12/88 could be eliminated from commercial units by the same date, if financial and technical assistance is available. Hospitals in developing countries will continue to use 12/88 until drop-in blends are available.

Resources

The OzonAction Programme under the IMOF

The 1990 London Amendments to the Montreal Protocol created an Interim Multilateral Ozone Fund to help developing countries party to the Protocol meet the specified control measures. As one of the Fund's three implementing agencies, UNEP has responsibility for research, data gathering and an information clearinghouse function. In 1991 UNEP IE/PAC in Paris established the OzonAction Programme to discharge these duties. The programme includes three activities: information exchange, workshops/networking, and country programmes.

Information exchange includes an on-line information exchange system known as the OzonAction Information Clearinghouse (see box), the quarterly *OzonAction* newsletter, and a series of publications aimed at providing developing countries with technical and policy information needed to comply with the requirements of the Protocol. This document is part of that series.

Workshops/networking activities provide decision makers in government and industry with the latest scientific, technical and policy information on ozone-depletion control measures. The OzonAction Programme conducts a series of regional workshops, sponsors national information campaigns to help raise public awareness of the issues involved, and publishes technical papers, workshop proceedings and training manuals.

Country programmes are designed to help low CFC-consuming developing countries to establish their own baseline surveys, and draw up replacement and control strategies.

OzonAction Information Clearinghouse (OAIC)

The OAIC is an on-line data system that contains technical, policy and scientific information on a wide range of issues concerning the phase out of ozone-depleting substances. It contains:

- descriptions of alternative technologies and product listings for each use sector, including refrigeration and air conditioning;
- an international directory of experts;
- a database of technical literature abstracts, and information for ordering documents;
- descriptions of national and corporate policies and programmes to phase out ozone-depleting substances;
- a listing of workshops, conferences and meetings concerning ozone-depletion issues;
- bulletins containing news on phase-out initiatives.

In addition to providing information directly through these databases, the OAIC also refers users to more specialized information held by other organizations. The clearinghouse's electronic mail feature allows users to pose queries and exchange information with UNEP IE/PAC and with one another.

There is no charge for using OAIC. Anyone with a personal computer, a modem, and communication software can access the system via the methods indicated below.

Access via normal telephone lines
Set communication software to 1200 or 2400 baud, 8 data bits, 1 stop bit, no parity, emulated terminal to VT 100 (if necessary) and dial (33-1) 40 58 88 78.

Access via SprintNet™
Set communication software to same settings as above, and dial your local SprintNet™ access number. Once connected, type D<enter> if you are using 1200 baud, @D<enter> if you are using 2400 baud. If you are using an IBM PC, type <enter> when asked for a terminal identifier. At the system '@' prompt, type the OAIC access code: 76200604. Enter your SprintNet™ password when requested to do so.

Access via national packet switching networks (PSNs)
The OAIC can be accessed by numerous PSNs that connect with SprintNet™. Contact UNEP IE/PAC for more information (see inside front cover).

Contact points

American Hospital Association
840 North Lakeshore Drive
Chicago, IL 60675
United States
Tel: 1 312 280 6360
Fax: 1 312 280 5923

Asociación Española de Aerosoles
c/Balmes 189 dcha 5-2a
E-8006 Barcelona
Spain
Tel: 3 2186920
Fax: 3 4153012

Associação Portuguesa de Aerossois
Rúa Rosa Araújo, 49-B-2°
P-1200 Lisbon
Portugal
Tel: 1 570043
Fax: 1 577959

Association for the Advancement of Medical Instrumentation
3330 Washington Boulevard
Suite 400
Arlington, VA 22201-4598
United States
Tel: 1 703 525 4890
Fax: 1 703 276 0793

British Aerosol Manufacturers Association
King's Buildings
16 Smith Square
London SW1P 3JJ
United Kingdom
Tel: 71 828 5111
Fax: 71 834 8436

Chemical Manufacturers Association
2501 M Street, NW
Washington, DC 20037
United States
Tel: 1 202 887 1100
Fax: 1 202 887 1237

Comité Français des Aérosols
32 rue de Paradis
F-75484 Paris Cedex 10
France
Tel: 1 47 70 26 42
Fax: 1 47 70 34 84

European Council of Chemical Manufacturers Federations
Avenue E. Van Nieuwenhuyse, 4
B-1160 Brussels
Belgium
Tel: 322 676 7211
Fax: 322 676 7300

Federation of European Aerosol Associations
Square Marie-Louise, 49
B-1040 Brussels
Belgium
Tel: 322 238 9711
Fax: 322 231 1301

Health Industry Manufacturers Association
1200 G Street, NW
Washington, DC 20005
United States
Tel: 1 202 783 8700
Fax: 1 202 783 8750

Hellenic Aerosol Association
Souri Street Peristeri
GR-Athens
Greece
Tel: 57 41 4119
Fax: 57 41 4119

Industry Cooperative for Ozone Layer Protection
(ICOLP)
Suite 300, 1440 New York Avenue, NW
Washington, DC 20005
United States
Tel: 202 737 1419
Fax: 202 639 8685

International Aerosol Association
Waisenhausstrasse, 2
CH-8001 Zurich
Switzerland
Tel: 01 211 5255
Fax: 01 221 2940

Ozone Secretariat
c/o K. M. Sarma
United Nations Environment Programme
PO Box 30552
Nairobi
Kenya
Tel: 2542 521 928/9
Fax: 2542 521 930

Suomen Aerosoliyh
(Finnish Aerosol Association)
PO Box 073
SF-00131 Helsinki
Finland
Tel/Fax: 358 01 3451400

United Nations Development Programme
(UNDP)
1 United Nations Plaza
New York NY 10017
United States
Tel: 1 212 906 5042
Fax: 1 212 906 5365

United Nations Environment Programme
(UNEP)
PO Box 30552
Nairobi
Kenya
Tel: 2542 230 800
Fax: 2542 226 491

UNEP IE/PAC
39–43 Quai André Citroën
75739 Paris Cedex 15
France
Tel: 1 40 58 88 50
Fax: 1 40 58 88 74

World Bank
1818 H Street, NW
Washington, DC 20433
United States
Tel: 1 202 477 1234
Fax: 1 202 676 0483

Further reading

Brandberg *et al. Sterilisering med etylenoxid (EO).* På 4:e året i Göteborgs sjukvård, Sjukhuset, nr 2/1985, årgång 62.

'CFC Replacement, Are we Ready?' Deposition, Clearance and Effects in the Lung, Consensus Seminars on Issues of Aerosol Therapy. Davos, Switzerland, April 1991. *Journal of Aerosol Medicine*, Vol 4 No 3 1991.

Chest, *The Environmental Impact of Chlorofluorocarbon Use in Metered Dose Inhalers.* 100, No. 4 October 1991.

CMA reporting companies. Grant Thornton Report 1991. *Chlorofluorocarbons (CFCs) 11 and 12—Cumulative Production through 1979 and Annual Production and Sales for the Years 1980–1989.* CMA, Washington D.C., United States.

Figurama, Metal Box Aerosols, 1987.

Independent Committee on Smoking and Health. *Developments in Tobacco Products and the Possibility of 'Lower Risk' Cigarettes.* Second Report, page 7, 1979.

Midwest Research Institute. *Addenda to EPA Regulatory Impact Analysis Document, Miscellaneous Uses, vol III, part 5.* October 1987.

Midwest Research Institute. *Addenda to EPA Draft Regulatory Impact Analysis, vol III, part 6, Sterilants.* October 1987.

National Swedish Environmental Protection Board. *CFCs/Freons—Proposals to Protect the Ozone Layer.* Report 3410.

Radian, *Essential Aerosols Update.* EPA Contract No. 68-02-4288, January 1989.

UNEP. *Report of the Aerosol Products, Sterilants, Miscellaneous Uses and Carbon Tetrachloride Technical Options Committee*, 1992.

USEPA. *Future Concentrations of Stratospheric Chlorine and Bromine.* USEPA, 1989.

Glossary

CFC	chlorofluorocarbon
carcinogen	causing cancer in animals and humans
compressed gas	a high pressure propellant that behaves like a gas inside the aerosol
DME	dimethyl ether
GWP	global warming potential
HCFC	hydrochlorofluorocarbon
HFC	hydrofluorocarbon
hydrocarbon	organic substance made of hydrogen and carbon
mutagenic	causes mutation
ODP	ozone-depletion potential
OAIC	OzonAction Information Clearinghouse
ozone	gas formed from three oxygen atoms
propellant	a liquid or gas inside an aerosol product that provides pressure to expel the contents
VOC	volatile organic compound—constituents will evaporate at temperature of use, and may react photochemically with atmospheric oxygen to produce toxic and smog-producing tropospheric ozone
12/88	a mixture of ethylene oxide and CFC-12 in the proportion 12:88 percent
10/90	mixture of ethylene oxide and CO_2 in the proportion 10:90