MONTREAL PROTOCOL

ON SUBSTANCES THAT DEPLETE

THE OZONE LAYER

UNEP

Technology and Economic Assessment Panel

Part I: Essential Use Nominations
Part II: The MBTOC April 1997 Progress Report to TEAP and Miscellaneous Methyl Bromide Issues
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April 1997 Report
Volume I

UNEP
APRIL 1997 REPORT OF THE TECHNOLOGY AND ECONOMIC ASSESSMENT PANEL

VOLUME I

Montreal Protocol
On Substances that Deplete the Ozone Layer

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PART I:	**ESSENTIAL USE NOMINATIONS**
PART II:	**THE MBTOC APRIL 1997 PROGRESS REPORT TO TEAP AND MISCELLANEOUS METHYL BROMIDE ISSUES**
PART III:	**TOC PROGRESS REPORTS AND SPECIFIC PROGRESS ISSUES** **POSSIBLE APPLICATIONS OF HCFCS** **EXECUTIVE SUMMARIES OF VOLUME II REPORTS**
PART IV:	**PROGRESS ON THE RESTRUCTURING OF THE TECHNOLOGY AND ECONOMIC ASSESSMENT PANEL** **TEAP MEMBERSHIP BACKGROUND INFORMATION** **CONTACT INFORMATION FOR TEAP MEMBERS AND TOCS**

April 1997 Report, Volume I

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Volume I

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UNEP APRIL 1997 REPORT OF THE TECHNOLOGY AND ECONOMIC ASSESSMENT PANEL

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INTRODUCTION

The Seventh Meeting of the Parties (Vienna, December 1995) and the Eighth Meeting of the Parties (Costa Rica, November 1996) took a number of decisions which request actions by the UNEP Technology and Economic Assessment Panel (TEAP). Responses of the TEAP to several of the 1995 requests can be found in its March and June 1996 reports; some are presented in this report.

The April 1997 TEAP report provides the responses from TEAP on:

a. The following decisions taken at the Eighth Meeting in 1996:

Decision VIII/9 — *"Essential Use nominations for Parties not operating under Article 5 for controlled substances for 1997 through 2002"*
In accordance with Decision VII/34(5) the essential use nominations are dealt with in Volume I, Part I of this report. Part I also addresses the issues mentioned under DecisionVIII/9, paragraphs 6,7 and 9.

Decision VIII/10 — *"Promotion of industry's participation on a smooth and efficient transition away from CFC-based MDIs"*
As a follow-up to the study given in the TEAP June 1996 report (Part III, Sections 1/2), a more elaborate study is given in Volume II, Part I of this report. An Executive Summary of this report is also given in Volume I, Part III of this April 1997 report.

Decision VIII/11 — *"Measures to facilitate a transition, etc."*

Decision VIII/12 — *"Information gathering on a transition, etc."*
Responses to both decisions can be found in Volume II, Part I of this April 1997 report. The Executive Summary is also given in Volume I, Part III of this report.

Decision VIII/13 — *"Uses and possible applications of hydrochlorofluorocarbons (HCFCs)"*
Subsequent to the response by the TEAP in its June 1996 report, a response to this decision is given in Volume I, Part III (Section 2) of this report.
It contains a list with possible applications of HCFCs and elaborates on available HCFC alternatives.

Decision VIII/14 — *"Further clarification of the definition of "bulk substances", etc."*

Decision VIII/15 — *"Control of trade in methyl bromide with non-Parties"*
These issues are dealt with in this 1997 report, Part III, Sections 2 and 4.

Decision VIII/16 *"Critical agricultural uses of methyl bromide"*
This issue is addressed under Part II, Section I of this 1997 report (a first report addressing Decision VII/29 was already presented in the TEAP June 1996 report, Part IV, Section 1.0).

Decision VIII/17 *"Availability of halons for critical uses"*
This issue is addressed under Part III, Section 1 (1.0) "Halons TOC", of this 1997 report, Volume I.

b. The following decisions taken at the Seventh Meeting in 1995:

Decision VII/8 *"Review of methyl bromide controls"*
In this Decision the TEAP was requested to prepare a report to the Ninth Meeting of the Parties to enable them to consider further adjustments to the control measures on methyl bromide. This report is contained in Volume I of the TEAP 1997 report, Part II.

A Methyl Bromide Task Force has also prepared a report on the economic feasibility of alternatives to methyl bromide. This assessment report is given in Volume II of the 1997 report; the Executive Summary is also presented in Volume I, Part III.

Decision VII/10 *"Continued use of controlled substances as chemical process agents after 1996"*
In 1995, Parties decided to further consider this issue and to take decisions in 1997, following recommendations by the TEAP.

The report by the Process Agent Task Force (PATF) under the TEAP is given in Volume II of this 1997 report; the Executive Summary is also presented in Volume I, Part III.

Decision VII/34 *"Countries with Economies in Transition"*
The Decision VII/34, paragraph 5d, the Parties requested the TEAP to update or supplement its report on the status of implementation of the Protocol in CEIT countries by 31 March 1996. Updates of the work by the Task Force on CEIT Aspects were presented in the TEAP March 1996 and June 1996 reports. The Task Force has conceived a final report after the Eighth Meeting of the Parties in 1996. Copies of this report were already forwarded to all Parties by the Ozone Secretariat in January/February 1997.

Decision VII/34 *"Progress and development in the control of substances"*
In Decision VII/34 (c) the TEAP was requested to report on progress and developments in the control of substances each year. Progress reports of the different TOCs can be found in Volume I, Part III, Section 1.0 of this report. Some of the TOC reports give a summary of their functioning with respect to the preparation of the 1998/99 assessment reports. Others, particularly, the foam sector, give a first short assessment of the status of technology to date and feasible options.

A progress report on the use of flammable refrigerants is presented by the TOC Refrigeration, AC and Heat Pumps in Volume II of this 1997 report. The Executive Summary is given in Part III of Volume I.

Decision VII/34 *"TEAP organisation and functioning"*

TEAP reported on progress towards improved geographical balance and other structural adjustments in its March and June 1996 reports.

Part IV (Volume I) of this 1997 report presents further information on the restructuring of the TEAP and its TOCs. This part of the report takes into account the issues mentioned in Decision VIII/19 by the Parties at their Eighth Meeting.

Part IV (Volume I) of this 1997 report also elaborates on paragraph (e)(iv) of Decision VII/34 regarding background and financing of TEAP members.

The TEAP 1997 report also contains information on a number of miscellaneous issues, which are considered by TEAP to be important for consideration by the Parties. Some of the contributions contained in this report have also been transferred to the TEAP Internet Site (http://www.teap.org).

MONTREAL PROTOCOL

ON SUBSTANCES THAT DEPLETE

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Technology and Economic Assessment Panel

PART I: ESSENTIAL USE NOMINATIONS

April 1997 Report

Montreal Protocol
On Substances that Deplete the Ozone Layer

UNEP Technology and Economic Assessment Panel

PART I: ESSENTIAL USE NOMINATIONS

April 1997 Report

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1 ESSENTIAL USE NOMINATIONS

1.1. REVIEW OF ESSENTIAL USE NOMINATIONS FOR MDIs

The adjustments adopted at Copenhagen by the Fourth Meeting of the Parties to the Montreal Protocol mandated a phaseout of production and consumption of CFCs, carbon tetrachloride, 1,1,1-trichloroethane and other fully halogenated controlled substances by January 1 1996, with the ability of Parties to designate uses agreed by them to be essential. Decision IV/25 of the Fourth Meeting set the criteria and the procedure for assessing an essential use and requested each Party to nominate uses it considered essential to the Secretariat, at least nine months prior to the Sixth Meeting of the Parties to the Protocol to be held in 1994. This decision also requested the Technical Options Committees to consider and make recommendations on the nominations.

Only nominations requesting specific production/consumption exemptions for a specific time period were to be assessed by the Technical Options Committee.

1.1.1 Decision IV/25

Essential Use nominations are considered for exemptions on an annual basis. Exemptions granted for more than one year (if any) are still subject to the review provisions described in paragraph 5 of decision IV/25. Therefore, Parties which are given multiple year exemptions should update their nomination annually to facilitate that review.

The criteria for essential use set by Decision IV/25 has two important elements. Each Party should demonstrate that:

1. *The proposed CFC use is necessary for the health, safety or the functioning of society (encompassing cultural and intellectual aspects); and*

   There are no available technically and economically feasible alternatives or substitutes that are acceptable from the standpoint of environment and health; and

2. *Production and consumption if any, of a controlled substance should be permitted only if:*

   All economically feasible steps have been taken to minimise the essential use and any associated emission of the controlled substance; and

   The controlled substance is not available in sufficient quantity and quality from existing stocks of banked or recycled controlled substances, also bearing in mind the Article 5(1) countries need for controlled substances.

1.1.2 Review of Nominations

The review by the Technical Options Committee Aerosols, Sterilants, Miscellaneous Uses and CTC was conducted as follows. Three members of the Technical Options Committee independently reviewed each nomination. Members prepared preliminary reports which were forwarded to the chair. The results of these assessments were considered by the full committee and this report drafted. For nominations where some divergence of view was expressed, additional expertise was sought.

Concurrent with the evaluation being undertaken by the Technical Options Committee, copies of all nominations were provided to each member of the Technology and Economic Assessment Panel. Panel members were able to consult with other appropriate individuals or organisations in order to assist in the review and to prepare the Panel's recommendations to the Parties.

Basis for Review (as per Essential Uses Handbook 1994)

The basis for consideration of requests for consumption/production exemptions, after production phaseout, was Decision IV/25 of the Parties, taken at the fourth meeting of Parties in Copenhagen. To address the requirements of Decision IV/25, the following list of information was to accompany each nomination. The Parties were requested to:

i) Provide details of the type, quantity and quality of the controlled substances that is requested to satisfy the use that is the subject of the nomination. Indicate the period of time and the annual quantities of the controlled substance that are requested, the historical basis for the quantity requested.

ii) Provide a detailed description of the use.

iii) Explain why this use is necessary for health and/or safety, or why it is critical for the functioning of society.

iv) Explain what alternatives and substitutes have been employed to reduce the dependency on the controlled substance for this application.

v) Explain what alternatives were investigated and why they were not considered adequate.

vi) Describe the measures that are proposed to eliminate all unnecessary emissions. At a minimum, this explanation should include design considerations and maintenance procedures.

vii) Explain what efforts are being undertaken to employ other measures for this application in the future.

viii) Explain whether the nomination is being made because of national or international regulations require use of the controlled substance to achieve compliance. Provide full documentation including the name, address, phone and fax number of the regulatory authority requiring use of the controlled substance and provide a full copy or summary of the regulation. Explain what efforts are being made to provide a full copy or summary of the regulation. Explain what efforts are being made to change such regulations or to achieve acceptance on the basis of alternative measures that would satisfy the intent of the requirement.

ix) Describe the efforts that have been made to acquire stockpiled or recycled controlled substance for this application both from within the nation and internationally. Explain what efforts have been made to establish banks for the controlled substance.

x) Briefly state any other barriers encountered in attempts to eliminate the use of the controlled substance for this application.

1.1.3 Committee Evaluation and Recommendations

Nominations were assessed against the above guidelines as developed by the Technology and Economic Assessment Panel in 1994. Further information was requested where nominations were found to be incomplete.

The Aerosols, Sterilants, Miscellaneous Uses and CTC Technical Options Committee reviewed all of the submitted nominations for a production exemption. Production in this context includes import of ozone depleting substances for the purposes of manufacture.

Nominations from Article 5(1) Parties are not required since paragraph 7 of Decision IV/25 clarified that essential use controls will not be applicable to such Parties until the phaseout dates apply to them. Therefore these were not considered.

The following Parties nominated essential use production exemptions.

Country	**Nominated Uses**	**Year/s**		
Australia	MDI (asthma/COPD)		1998	1999
European Community	MDI (asthma/COPD)			1999
Hungary	MDI (asthma/COPD)		1998	1999
Russia	MDI (asthma/COPD)		1998	
South Africa	MDI (asthma/COPD)			1999
USA	MDI (asthma/COPD)			1999
	Sterile Aerosol Talc	1997†	1998	1999
	Leuprolide		1998	

† Emergency request per Decision VIII/9 for transfer of an essential use allocation from previously approved 1997 quantities.

1.1.4 Observations on the Process

Nominations received for 1998/1999 again varied in completeness. Many countries had to be asked for additional information and some, again, relied heavily on international materials as substantiation for their nomination, without providing adequate national information.

Some applications had significant omissions making it difficult for the TOC to make a recommendation. All Parties are encouraged to exercise greater diligence in the assessment of essentiality and to provide detailed rationale for all nominations.

The TOC does not anticipate receiving any further applications for new products containing CFCs. However, if any were to be submitted in future years, considerably more detail would be needed for the TOC to make a full assessment than was provided for aerosolised sterile talc and leuprolide in 1997.

Vague statements of commitment toward reformulation efforts are not sufficient for the TOC to make evaluations, and Parties are encouraged to determine whether companies are truly undertaking reformulation research/development and/or seeking licensing arrangements consistent with Decision VIII/10(1).

The TOC notes that it did not receive nominations for 1998/9 from some Parties who have applied in previous years (e.g. Switzerland, Canada, Poland and Israel).

Future Considerations

Under Decision VIII/10 (1), Parties will request individual companies applying for essential use allocations in 1998 to provide information on research and development initiatives on alternatives to CFCs. The Parties will also request applicants to demonstrate education and outreach efforts to facilitate the transition to non-CFC alternatives. The TOC encourages Parties to share detailed information on these efforts in their nominations.

Under Decision VIII/9 Parties are also required to begin detailed reporting under the accounting framework for essential uses, other than laboratory and analytical applications. Parties are encouraged to report this data from 1996 and 1997 in nominations submitted in January 1998 to enable the TOC to better fulfil its obligations under Decision IV/25 .

1.1.5 Recommendations

Individual Country Summaries

<u>Australia</u>

Year:		**1998**	**1999**
Tonnages:	CFC-11	35	49
	CFC-12	85	120
	CFC-114		5
Specific Usage:	MDIs for asthma and COPD		

Recommendation: Recommend exemption

Comments: Australia requested an increment of 120 tonnes of CFCs to supplement the amount granted in 1996 for 1998, and requested an exemption of 174 tonnes for 1999. The TOC notes that the 1996 use in Australia was 245 metric tonnes versus the allocation, approved by the Parties, of 278 tonnes. Furthermore the allocation for 1997 is 194 tonnes and in 1998 the requested addition makes a total of 223 tonnes. Thus in 1997, it appears that Australia might have a shortfall in its allocation, without use of stockpiles, increase use of alternatives or importation of CFC MDIs.

The TOC recommends approval of the additional 120 tonnes, (total allocation 223 tonnes), for 1998 and the total of 174 tonnes for 1999. However if significant reduction of CFC use is achieved in 1997, the TOC urges Australia to try and maintain reduction in subsequent years, despite the increased allocation being requested.

<u>**European Community**</u>

Year:		**1999**
Tonnages:	CFC-11	1690
	CFC-12	2857
	CFC-113	19
	CFC-114	434

Specific Usage: MDIs for asthma and COPD

Recommendation: Recommend exemption

Comments: The TOC welcomes the reduction for 1999 on previous years and the commitment to review this figure in 1998 with a view to further reduction in the light of regulatory approval of CFC-free alternatives.

<u>**Hungary**</u>

Year:		**1998**	**1999**
Tonnage:	CFC-11	6	3
	CFC-12	2.25	3
	CFC-113	0.23	0.23
	CFC-114	1.7	3

Specific Usage: MDIs for asthma and COPD

Recommendation: Recommend exemption

Comments:	The nomination from Hungary provides information to substantiate the nominated volumes. The volume for 1998 and 1999, 10 and 9.23 metric tonnes respectively are comparatively small and well in line with previous need and allocations.		

Russia

Year:		**1998**	
Tonnage:	CFC-11	226	
	CFC-12	226	
Specific Usage:	MDIs for asthma/COPD		
Recommendation:	Recommend exemption		
Comments:	The TOC welcomes the application from the Russian Federation. Volumes and use seem appropriate. However, inadequate information to justify the nomination was provided. The amount of CFC required is the same as for 1997. In future Russia is encouraged to complete their nominations as outlined in the Essential Use Handbook.		

South Africa

Year:			**1999**
Tonnages:	CFC-11		69
	CFC-12		174
	CFC-114		3
Specific Usage:	MDIs for asthma and COPD		
Recommendation:	Recommend exemption		
Comments:	Note that South Africa was the only country to increase essential use nomination (by a small amount, 14 tonnes over 1998). This seems justified on the basis of enhancement of health care systems and the likelihood of export to neighbouring countries. Further nominations are encouraged to include accounting framework to help clarify this.		

USA

MDIs

Year:		**1998**	**1999**
Tonnages:	CFC-11		1085.3

	CFC-12	2539.7
	CFC-114	280.8

Specific Usage: MDIs for asthma and COPD

Recommendation: Recommend exemption

Comments: The TOC welcomes the reduction for 1999 on previous years. The requested quantities in the US nomination are approved with the following proviso.

The TOC noted the continued approval of new products which contain CFCs.

Although the US practice of submitting some individual company requests increases transparency, some individual company applications omitted or had insufficient detail on information required under the Essential Use Nomination criteria. It would be helpful if the US could ensure that individual company applications were more complete.

Sterile Aerosol Talc

Year:		**1997**	**1998**	**1999**
Tonnages:	CFC-12	3	5	7

Specific Usage: Sterile Aerosol Talc

Recommendation: Unable to recommend

Comments: The TOC found it difficult to make a firm recommendation on this nomination. The nomination is inadequate as it does not provide sufficient information to allow a decision on essentiality.

The submission states that sterile talc aerosol is manufactured in France. The source of CFC used to manufacture this product is undefined. There is no statement as to whether talc can be formulated in non-CFC containing formulations although it has been reported to the TOC that an HFC formulation may be available outside the US.

The TOC agreed that talc insufflation is unequivocally effective for treatment of malignant pleural effusion. The majority of TOC physicians favoured the limited availability of talc formulated as a CFC containing aerosol because of (i) an asserted benefit of sterility in this product and (ii) potential compromise of patients needs if this formulation was not available. A minority considered the dry powder insufflation method which has been in use for many years as effective and safe and a possible adequate alternative.

The Secretariat may wish to grant the emergency request for 1997 and Parties may wish to consider a one year exemption for 1998. Further data is needed at the beginning of 1998 to justify essentiality for 1999. See for further information under Section 2.1.

Leuprolide

Year:		**1998**
Tonnages:	CFC-11	0.167
	CFC-12	0.444
Specific Usage:	MDI for inhalation of leuprolide for endometriosis.	
Recommendation:	Unable to recommend	
Comments:	Leuprolide has not yet been approved for marketing. Injectable forms and nasal spray of analogues are available. The reported reduction in side effects, such as modest change in bone mineral density has not been fully substantiated as a unique benefit. Based on the available data it is not possible to accept leuprolide as an essential use therapy.	

1.1.6 Review of 1996 Authorised Essential Uses (Decision VII/28 (2a))

The TOC has reviewed the issue of the essentiality of MDIs for asthma and COPD, and concluded that they remain essential for patient health until an adequate range of technically and economically feasible alternatives are available.

The TOC reminds Parties of Decision VIII/9 (9) that requests accounting framework details for 1996 and 1997 for all Parties with exemptions for these years by 31 January 1998. The TOC welcomes the accounting framework details for 1996 already provided by Australia, Canada and Poland.

1.2 REVIEW OF AN ESSENTIAL USE NOMINATION FOR A STERILE TALC APPLICATION

The product does not satisfy the Essential Use criteria because alternative medical procedures are globally available. However, TEAP recommends that the Secretariat allow an emergency exemption for use of 3 (three) tonnes of CFC for 1997 only in order to give the possibility to hospitals to make the transition to traditional, non-aerosol, talc administering technologies (insufflation). If the United States applies for an emergency exemption for 1998, they should apply early with far better documentation of the therapeutic advantage of aerosolised talc compared to traditional treatments and the availability of either non-CFC aerosol formulations or insufflation. TEAP and its TOC Aerosols, Sterilants, Miscellaneous Uses and CTC are currently unable to recommend either emergency or essential use exemptions for 1998 and 1999.

2.1 REVIEW OF AN ESSENTIAL USE NOMINATION SUBMITTED BY THE RUSSIAN FEDERATION FOR REFRIGERATION - AIR CONDITIONING

An essential use nomination from the Russian Federation was received in February 1997 which requested 5455 tons of CFCs for the servicing of refrigeration and air conditioning equipment. The request mentioned in particular 60 million domestic refrigerators, 1.6 million units in the commercial sector, 280,000 units in the industrial refrigeration units, and air conditioning equipment in defence systems.

The unanimous conclusion from the TEAP and its TOC is that the Essential Use request cannot be further evaluated nor recommended since the application does not provide the necessary data.

The review was conducted by the TOC Refrigeration, AC and Heat Pumps, particularly the TOC section co-chairs who are responsible for the sectors addressed in the request by the Russian Federation.

The basis for consideration of the request was Decision IV/25 which asks for information including (see also Section 1.1.2):

1. details of the type and quantity of the chemicals;
2. a detailed description of the use;
3. an explanation of why it is necessary for health and safety, or why it is critical for the functioning of society;
4. an explanation of what alternatives and substitutes have been employed to reduce dependency;
5. an explanation of what alternatives were investigated that were not considered adequate;
6. a description of all measures proposed to eliminate unnecessary emissions (amongst which design considerations and maintenance procedures);
7. a description of the efforts made to acquire stockpiled or recycled controlled substance both from within the nation and internationally.

The TOC noted that there are clear options for reducing refrigerant demand other than following the Russian Federation essential use request which implies a more or less ”conservative” approach. Specifically the Russian Federation could apply

- *better maintenance and minimisation of leaks:*
  The nomination does not specify whether better maintenance procedures are applied or whether systems are made more tight to reduce refrigerant losses.
- *recover and recycling of refrigerant:*
  The nomination does not contain information regarding recovery and recycling during maintenance and disposal. This would substantially reduce the demand for new refrigerant.
- *retrofit of equipment:*
  The nomination does not contain any information on retrofits either planned or underway. This particularly applies to retrofits to HCFCs and HFCs which are readily available for commercial and industrial refrigeration.

The nomination also did not indicate whether they could use refrigerant from stockpiles and/or to use recycled refrigerants. The TOC would further like to emphasise that production in the Russian Federation has not been phased out (non-compliance as dealt with by the Montreal Protocol Implementation Committee) and that it is impossible to judge whether stockpiles have been or are being built up. Furthermore, the existence of substantial recycling capacity has already been reported by the Russian Federation. Parties may also wish to consider the fact that recycled CFCs from the Russian Federation have been offered repeatedly on the international market during 1995-96. Parties may therefore also wish to consider that a better domestic control of the flow of recycled quantities of controlled substances may eliminate the need for further production of CFC-refrigerants in the Russian Federation.

On the basis of the above, the unanimous conclusion from the TEAP and its TOC is that the Essential Use request cannot be further evaluated nor recommended since the application does not provide the necessary data. It can be inferred from the essential use request that no substantial efforts are planned to reduce demand via known technical procedures.

The TEAP and its TOC are of the opinion that a replacement strategy, including recovery and recycling and retrofits, can be developed during the years 1998-99 when it is expected that the Russian Federation will continue to be in non-compliance; this would eliminate the need for new CFC refrigerant.

3.1 REVIEW OF AN HALON ESSENTIAL USE NOMINATION SUBMITTED BY THE RUSSIAN FEDERATION

An Essential Use request for 255 tonnes of halon-2402 for 1998 was received from the Russian Federation. The TEAP and its HTOC recommend that the Parties grant the Essential Use request by the Russian Federation for this amount of halons for 1998.

The Essential Use nomination submitted by the Russian Federation in 1997 was reviewed by the Halons Technical Options Committee. The HTOC received additional information from the Russian Federation and was therefore able to assess progress made over the last two years. It was noted that the actual amount of halon-2402 produced in 1996 was lower than the amount granted, mainly due to economic difficulties within the Russian Federation, but also thanks to increasing efforts for recycling halon-2402.

The Halon Technical Options Committee maintains that a halon replacement strategy, as explained in the nomination two years ago and reconfirmed by the information provided by the Russian members, offers the most realistic opportunity to reduce or eliminate the need for further production. The HTOC upholds its request, that the Russian Federation provide a progress report on an annual basis. The Russian Federation has submitted in the framework of its country programme a country sub-programme for halon to the Global Environment Facility, GEF. The Halons Technical Options Committee believes that technical assistance and financial support from the GEF to the Russian Federation will be required to achieve the goals outlined in the programme submitted.

The TEAP and its HTOC recommend that the Parties grant the Essential Use request by the Russian Federation for 255 tonnes of halon-2402 for 1998.

4.1 SUMMARY AND FINDINGS FOR THE 1996 ODS USE IN MANUFACTURING SOLID ROCKET MOTORS

The Technology and Economic Assessment Panel and its Solvents Technical Options Committee find that the manufacturing of solid rocket motors for United States Space Launch Vehicles continues to qualify as essential under the Montreal Protocol criteria and that the quantities granted are adequate to meet the anticipated needs. Furthermore, the Solvents TOC finds that research, development, and implementation of new technology to replace ODSs is proceeding as rapidly as possible and that the United States and its applicants are taking required actions to utilise existing supplies of ODS and to minimise use and emissions. An effort to further accelerate phaseout for the Space Shuttle ODS adhesive uses has suffered a serious setback due to hot gas penetration in field joints of the solid rocket motors on the June 1996 launch of the Space Shuttle Columbia. However, no additional ODS is requested at this time and no adjustments in the Essential Use Exemption for solid rocket motors are necessary.

4.1.1 Importance of Space Exploration

The Space Shuttle provides access to space for payloads, scientists, and other specialists. The expendable launch vehicles provide access to space for payloads requiring heavy lift capabilities but not requiring experts on-board. The payloads carried on these vehicle are valuable and important to space exploration, national security, and earth environmental science.

Scientific data from space programs is used by scientists throughout the world. Titan vehicles were used for the Vela satellites (provided information on solar flares and other radiation); Helios satellites (providing scientific data on solar atmospheres, solar winds and electromagnetic radiation); and for the inter-planetary Viking Spacecraft to Mars and Voyager Spacecraft to Jupiter, Saturn, Uranus and Neptune. The Cassini spacecraft--co-sponsored by European Space Agency, France, Germany, Italy, the United Kingdom, and others--provides close proximity study of Saturn. The Space Shuttle has launched numerous earth-observation satellites, including many used to verify that ODSs deplete the ozone layer and to track recovery of the ozone layer resulting from the controls of the Montreal Protocol. Other important payloads already launched include the Hubble Space Telescope, numerous life sciences and microgravity/space manufacturing platforms, and the International Space Station preparation missions/MIR dockings. Future Space Shuttle missions include additional Spacelab life sciences/microgravity experiments; retrieval of the Long Duration Exposure Space Flier; as well as the continuing construction, operation, and utilisation of the International Space Station.

Solid rocket motors are also used for the successful positioning of communication satellites used for global television and telephone communications and for positioning of critical weather and earth science satellites.

4.1.2 Progress on Eliminating ODS

There has been significant progress in the elimination of ozone depleting substances from solid rocket manufacture. By 1993, the Titan program reduced 1,1,1-trichloroethane use from 1,232 to 602 metric tonnes and reduced CFC-113 use from 99 to 14 metric tonnes. Since 1993, the program has eliminated all but 16 metric tonnes per annum--a 99 percent reduction of the original quantity used.

The Space Shuttle has eliminated 90 percent of previous applications including preservation, storage and transportation of metal hardware; most vapour degreasing of refurbished and production hardware; and cleaning of propellant mix and cast tooling. The remaining 10 percent of use is for rubber activation, critical hand-cleaning, and bond preparation of the rocket motor segments as they are manufactured. It was a failure of a field joint where ODSs are used under the essential use exemption that caused the loss of the Space Shuttle Challenger, the death of its human crew, and the loss of its scientific cargo.

4.1.3 Space Shuttle Phaseout Setback

The NASA Space Shuttle program recently experienced a serious setback in its efforts to safely phase out the use of Ozone Depleting Substances (ODSs) currently allowed under terms of the Essential Use Exemption. Specifically, during the June 20, 1996 launch of the Space Shuttle Columbia, hot exhaust gases penetrated into the insulation ”J” joint of all three field joints on both solid rocket motors. Any gas penetration is a cause for concern for the flight reliability of the shuttle and the safety of the crew; penetrations in six separate locations increases the severity and significance appreciably.

The ongoing investigation suggests that the most likely cause of the gas penetrations was the first time use of a new ODS-free adhesive and a new ODS-free hand-wipe cleaning agent in the assembly of the rocket motor set. The new adhesive had been carefully screened, had passed extensive laboratory tests, and had been verified in a full-scale ground test. This analysis and testing did not indicate any potential for the thermal barrier anomaly that was experienced on Space Shuttle Columbia.

Because the Space Shuttle Atlantis’ rocket motor set was assembled using the same ODS-free materials, the launch to the Russian Space Station Mir was delayed from July 31, 1996 until September 16, 1996. The postponement was required to allow Atlantis to be refitted with rocket motors that were assembled using the original, flight-proven adhesive and cleaning agents containing methyl chloroform (1,1,1-trichloroethane). The rocket motors using ODS adhesives did not experience gas penetration. NASA is continuing research and development for all remaining ODS use and will continue to implement alternatives in applications that do not jeopardise flight safety.

4.1.4 Sources of ODS for Essential Uses

Limited amounts of newly-produced ODS on hand in January 1996 and ODS produced under terms of the essential use exemption are being utilised for essential uses. It is not technically feasible to recycle used solvents to necessary standards of purity for these essential uses.

4.1.5 Remaining Essential Uses

There are four remaining critical uses of 1,1,1-trichloroethane (methyl chloroform) used for manufacture of expendable solid rocket motors which affect the stability and integrity of the critical bond lines in the solid motors. Critical bond lines ensure that insulators remain intact during the burn of the solid motors. The four essential uses are 1) the application of a tackifier for the insulator to composite bond on the solid motors, 2) the tackifier to apply the breather cloth in order to cure the insulator, 3) preparation of the isolator surface to bond the propellant to the insulator and 4) an additive to disperse the curing catalyst for the propellant. The Space Shuttle requires ODS for rubber activation, critical hand-cleaning, and bond preparation of the rocket motor segments as they are manufactured.

4.1.6 Research, Development, and Implementation Continues

Research continues to find substitutes for all remaining critical ODS uses in the manufacture of solid rocket motors. Emerging technology includes pelletised CO_2, reformulated adhesives and preparation cleaners, and new aqueous methods to eliminate methyl chloroform in sizing carbon graphite fibres.

Country	Category	Chemical	Year	Nominated Tonnes	Use	TEAP Action	Approved Amount/NONE(N)	Adjustments	Adjustments Notes
AUSTRALIA	AEROSOL	CFC-11	1998	35.00	MDI/COPD	RECOMMENDED			
AUSTRALIA	AEROSOL	CFC-12	1998	85.00	MDI/COPD	RECOMMENDED			
AUSTRALIA	AEROSOL	CFC-11	1999	49.00	MDI/COPD	RECOMMENDED			
AUSTRALIA	AEROSOL	CFC-12	1999	120.00	MDI/COPD	RECOMMENDED			
AUSTRALIA	AEROSOL	CFC-114	1999	5.00	MDI/COPD	RECOMMENDED			
EUROPEAN U	AEROSOL	CFC-11	1999	1,690.00	MDI/COPD	RECOMMENDED			
EUROPEAN U	AEROSOL	CFC-12	1999	2,857.00	MDI/COPD	RECOMMENDED			
EUROPEAN U	AEROSOL	CFC-113	1999	19.00	MDI/COPD	RECOMMENDED			
EUROPEAN U	AEROSOL	CFC-114	1999	434.00	MDI/COPD	RECOMMENDED			
HUNGARY	AEROSOL	CFC-11	1998	6.00	MDI/COPD	RECOMMENDED			
HUNGARY	AEROSOL	CFC-12	1998	2.25	MDI/COPD	RECOMMENDED			
HUNGARY	AEROSOL	CFC-113	1998	0.23	MDI/COPD	RECOMMENDED			
HUNGARY	AEROSOL	CFC-114	1998	1.70	MDI/COPD	RECOMMENDED			
HUNGARY	AEROSOL	CFC-11	1999	3.00	MDI/COPD	RECOMMENDED			
HUNGARY	AEROSOL	CFC-12	1999	3.00	MDI/COPD	RECOMMENDED			
HUNGARY	AEROSOL	CFC-113	1999	0.23	MDI/COPD	RECOMMENDED			
HUNGARY	AEROSOL	CFC-114	1999	3.00	MDI/COPD	RECOMMENDED			
RUSSIA	AEROSOL	CFC-11	1998	226	MDI/COPD	RECOMMENDED			
RUSSIA	AEROSOL	CFC-12	1998	226	MDI/COPD	RECOMMENDED			
SOUTH AFRIC	AEROSOL	CFC-11	1999	69.00	MDI/COPD	RECOMMENDED			
SOUTH AFRIC	AEROSOL	CFC-12	1999	174.00	MDI/COPD	RECOMMENDED			
SOUTH AFRIC	AEROSOL	CFC-114	1999	3.00	MDI/COPD	RECOMMENDED			
U.S.A.	AEROSOL	CFC-11	1999	1085.3	MDI/COPD	RECOMMENDED			
U.S.A.	AEROSOL	CFC-12	1999	2,539.70	MDI/COPD	RECOMMENDED			
U.S.A.	AEROSOL	CFC-114	1999	280.80	MDI/COPD	RECOMMENDED			
U.S.A.	AEROSOL	CFC-12	1997	3.00	AEROSOL TALC	UNABLE TO RECOMMEND			
U.S.A.	AEROSOL	CFC-12	1998	5.00	AEROSOL TALC	UNABLE TO RECOMMEND			
U.S.A.	AEROSOL	CFC-12	1999	7.00	AEROSOL TALC	UNABLE TO RECOMMEND			
U.S.A.	AEROSOL	CFC-11	1998	0.17	MDI/LEUPROLIDE	UNABLE TO RECOMMEND			
U.S.A.	AEROSOL	CFC-12	1998	0.44	MDI/LEUPROLIDE	UNABLE TO RECOMMEND			
RUSSIA	HALONS	HALON-2402	1998	255.00	FIRE PROT.	RECOMMENDED			
RUSSIA	REFRIGERANTS	CFC-12	1998	4,600.00	SERVICE EQUIP.	UNABLE TO RECOMMEND			
RUSSIA	REFRIGERANTS	CFC-115	1998	15.00	SERVICE EQUIP.	UNABLE TO RECOMMEND			
RUSSIA	REFRIGERANTS	CFC-13	1998	50.00	SERVICE EQUIP.	UNABLE TO RECOMMEND			
RUSSIA	REFRIGERANTS	CFC-12	1998	790.00	DEFENSE EQUIP	UNABLE TO RECOMMEND			
RUSSIA	REFRIGERANTS	CFC-113	1998	150.00	DEFENSE EQUIP	UNABLE TO RECOMMEND			
RUSSIA	REFRIGERANTS	MC	1998	200.00	DEFENSE EQUIP	UNABLE TO RECOMMEND			
RUSSIA	SOLVENTS	CT	1998	1,000.00	DEFENSE/AVIATION	UNABLE TO RECOMMEND			

ANNEX IV

REPORTING ACCOUNTING FRAMEWORK FOR ESSENTIAL USES OTHER THAN LABORATORY AND ANALYLTICAL APPLICATIONS

A	B	C	D	E		F (D+E)	G (C-F)	H 1	I (H+F)	J	K	L	M (I-J-L)
Year of essential Use	Ozone Depleting Substance	Amount exempted for year of essential use	Amount acquired by production	Amount acquired for essential uses by imports	Countries of Manufacture	Total acquired for essential use	Authorized but not acquired	On hand start of year	Available for use in current year	Used for essential Use	Quantity contained in exported products	Destroyed	On hand end of year
AUSTRALIA													
1996	CFC-11	72.5	0	68.52	Netherlands	68.52	3.98	2.317	70.837	69.697	12.531	0	1.14
1996	CFC-12	183.7	0	18.29	Spain	180.76 ,	2.94	3.242	184.002	173.282	35.457	0	10.72
				162.47	Netherlands								
1996	CFC-114	3.3	0	3.23	Spain	3.23	0.07	0.572	3.802	1.908	1.157	0	1.894
TOTAL AUSTRALIA		**259.5**	**0**	**252.51**		**252.51**	**6.99**	**6.131**	**258.641**	**244.887**	**49.145**	**0**	**13.754**
CANADA													
1996	CFC-11	152	0	39	USA	39	113	11	50	42	0	0	8
	CFC-12	337	0	85	USA	85	252	16	101	84	0	0	17
	CFC-114	70	0	5	USA	5	65	2	7	0	0	0	7
TOTAL CANADA		**559**	**0**	**129**		**129**	**430**	**29**	**158**	**126**	**0**	**0**	**32**
POLAND													
1996	CFC-11	330	0	276.4	*	276.4	53.6	75.4	351.8	253.1	51.8	0	98.7
1996	CFC-12	330	0	253.2	**	253.2	76.8	74.2	327.4	252.8	82.4	0	74.6
1996	CFC-114	40	0	21.7	***	21.7	18.3	5.8	27.5	20.7	6.9	0	6.8
TOTAL POLAND		**700**	**0**	**551.3**		**551.3**	**148.7**	**155.4**	**706.7**	**526.6**	**141.1**	**0**	**180.1**

* Spain, The Netherlands, United Kingdom

** The Netherlands, United Kingdom, Spain, Russian Federation

*** The Netherlands, United Kingdom

2 MANAGEMENT OF CFC SUPPLIES FOR MDIs

2.1 Introduction

Adequate supplies of CFCs to meet patient demand until non-CFC alternatives are available have to be provided. These are currently being met through Essential Use allocations and existing stockpiles. However, as non-CFC alternatives become available and rationalisation across CFC suppliers and CFC MDI manufacturers occurs, there will be a need to carefully manage supplies. Parties may wish to monitor existing stockpiles, and consider the benefits of transfer of Essential Use authorisations between Parties and periodic campaign production to ensure a smooth transition.

2.2 Flexibility in the Transfer of Essential Use Authorisations between Parties

At their Eighth Meeting, Parties granted a request to transfer an essential use authorisation from one Party to another on a one-time basis. This Decision ensured an uninterrupted supply of CFCs to a Party where the CFC MDI manufacturer had chosen to rationalise production outside that Party. The TOC believes this one-time transfer could serve as a model for similar situations provided:

- both Parties agree to the transfer;
- total production volume does not increase; and
- the intended use does not change.

The Parties may wish to consider the advantages of a decision allowing for flexibility in transfer without previous approval by the Parties, but with subsequent approval at a Meeting of the Parties provided these conditions are met.

2.3 Implications of Campaign Production of CFCs for MDIs

With the phaseout of other CFC uses an imbalance between the capacity of the plants that still produce CFCs and the demand they have to meet could occur. To operate a CFC unit efficiently it is necessary to run it above a minimum capacity, therefore, the CFC producer will be forced to run it intermittently in what is called a "campaign" whereby a large CFC manufacturer produces sufficient amount of CFC over a relatively short period (e.g. 1-6 months) to service the needs of multiple MDI manufacturers for a longer period.

An imbalance may however not materialise if the CFC plants are kept operating above the minimum capacity to meet basic domestic needs of Article 5(1) countries. If needed, change from a continuous operation to a campaign operation cannot be accomplished overnight. A preliminary estimate that 17-19 months would be required to complete a CFC stockpile through campaign production (see Volume II of this report, Appendix 2). Thus, if campaign productions were ever required, up to 2 years advance notice to producers would be needed.

Given the current schedule for final phaseout of CFC-based MDIs, campaign production probably will not be needed except possibly at the end of the CFC MDI transition to provide for a final stockpile of pharmaceutical grade CFCs to meet special patient needs.

The TOC also wishes to advise the Parties of possible implications of campaign production, as follows:

- If campaigns are not allowed, some CFC manufacturers may find continued production non-viable. A reduction in the number of CFC manufacturers would result in a higher risk of interruption to availability of CFC MDIs in case of catastrophic loss, plant failure, product quality etc.

- Each MDI manufacturer has in their product registration an identified, registered source of CFCs. If that source changes, then the registration dossier has to be changed for each product. The sole manufacturer(s) of campaign bulk CFC will have to be qualified to produce pharmaceutical-grade CFC by the national regulatory bodies. These processes could take at least 2 years.

- Article 5(1) country manufacturers which meet appropriate national specifications, may be a potential future source of CFCs. However, the same specification and registration processes would be needed as indicated above. No Article 5(1) manufacturer currently supplies a Non-Article 5(1) MDI manufacturer.

- Stockpiling of campaign produced CFC is necessary, therefore, the implications of long-term storage as discussed below in section 3.3 have to be considered.

- There is a potential for a monopoly as fewer manufacturers will be willing to produce CFCs.

2.4 Existing Stockpiles

The TOC previously stated that bulk storage of CFCs necessary for MDIs was not technically feasible as an alternative to essential use production. The TOC continues to believe that stockpiled CFCs are insufficient to meet the quality and quantity of CFCs necessary to meet patient needs. In 1996 the TOC had no data to confirm that long term bulk storage maintains pharmaceutical quality. Quality is now being monitored on a routine basis. Currently, there is about 2 years experience indicating acceptable stability. Prior to 1996 a number of drug manufacturers established strategic stockpiles of CFCs (estimated at 3-12 months of use in production) as contingency against uncertainties in the Essential Use process, and unforeseen disruption in Essential Use supplies (catastrophic plant failures, contamination of supplies, shifts in market share etc.).

Reporting under the Accounting Framework will enable Parties to assess the size of existing stockpiles and determine whether these stockpiles represent a reasonable amount for contingencies. Whilst the Committee believes stockpiles of reasonable size are sensible and represent a safeguard of public health needs, excessive stockpiles could be utilised to prolong CFC MDI manufacture against the spirit of the Montreal Protocol, and act as an impediment to the transition to CFC-free alternatives. The TOC could investigate this issue further in 1998 with information provided through the Accounting Frameworks.

MONTREAL PROTOCOL

ON SUBSTANCES THAT DEPLETE

THE OZONE LAYER

UNEP

Technology and Economic Assessment Panel

PART II: THE MBTOC APRIL 1997 PROGRESS REPORT TO TEAP AND MISCELLANEOUS METHYL BROMIDE ISSUES

April 1997 Report

Montreal Protocol
On Substances that Deplete the Ozone Layer

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- **1.0 CRITICAL AGRICULTURAL ISSUES AND PRE-SHIPMENT AND QUARANTINE USE EXEMPTION**
- **2.0 POTENTIAL TRADE MEASURES IN RELATION TO METHYL BROMIDE CONTROL**
- **3.0 METHYL BROMIDE ESSENTIAL USE PROCESS ELABORATION**
- **4.0 METHYL BROMIDE: MARKET-BASED MEASURES**
- **5.0 TEAP COMMENTS ON METHYL BROMIDE**

April 1997 Report

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THE MBTOC APRIL 1997 PROGRESS REPORT TO TEAP AND MISCELLANEOUS METHYL BROMIDE ISSUES

CONTENTS

1 EXECUTIVE SUMMARY

This report reviews progress towards adoption or development of alternatives to methyl bromide (MeBr) in both Non-Article 5(1) and Article 5(1) countries. This information is provided in part fulfilment of the request of the Parties under Decision VII/8 and partly to provide annually update information to the Parties through TEAP as required by Decision VII/34.

The report follows the organisation of the MBTOC 1994 Assessment Report. Parties are referred to this Assessment Report for detailed discussion of the various alternatives and substitutes considered here. Only areas of change and progress are discussed here.

The question of alternatives to methyl bromide is complex. In many situations approaches are available which achieve the same technical aim as methyl bromide treatment. These may be either by direct substitution (e.g. metham-sodium treatments), not-in-kind (e.g. crop rotation) or integrated systems involving multiple actions in a rational combination. In all of these cases, the end process leads to the removal of the need for methyl bromide.

In order to reduce the task to manageable proportions for the purposes of a response to Decision VII/8, the Committee has analysed in detail only alternatives to uses that consume a substantial quantity of methyl bromide globally. These represented 65% of 1992 global MeBr use as a soil fumigant and the major other use (post-harvest grain protection). Treatment of dried fruit and nuts, and flour mills was also considered.

It is recognised that this inventory of uses excludes from consideration many low volume uses of MeBr which are nevertheless most important to particular local or national economies. However, by covering alternatives to the major uses, it is likely that most low volume uses and alternatives will also be covered (Quarantine and Pre-shipment uses excluded).

It should be noted that usage patterns of methyl bromide or its alternatives may change as a result of the introduction of new varieties of crops. Some modern high yielding varieties, for example of tomatoes and strawberries, may be particularly susceptible to pathogens thus requiring additional protection against pests. Some modern cultivars have been bred in the expectation that a soil treatment with an effective soil disinfectant will be used so as to realise their full potential. A consequence of restriction of methyl bromide use will be that plant breeders will need to consider breeding cultivars better adapted to other systems of management.

For soil treatments, there is wide agreement that integrated pest management (IPM) systems are needed to replace methyl bromide-based strategies since no single alternative is currently or likely to become available. Site-specific IPM treatment programs combine two or more methods selected from biological, cultural, physical, mechanical and chemical methods.

Soilless culture is a method in which plant growth substrates provide an anchoring medium that allows nutrients and water to be absorbed by plant roots. One of the purposes of using this system is to avoid soilborne pathogens. The methodology of culturing on different kinds of substrates is broadly available, mostly for protected agriculture. In protected cultivation, it is efficient, performs consistently, and increases yields.

Crop rotation is the planting of successive crops that are non-host, less suitable host, or trap crops for the target pathogens. Fallow consists of temporarily taking land out of production to reduce soil pest populations. Both these techniques are in widespread use and can be very effective for the management of soilborne pests. Rotation crops must be selected carefully, to avoid those that may reduce the population of particular pests, while increasing the level of other pests. Such crops must also be selected to consider not only suitability as a non-host crop, but also crop production system economics.

When feasible, use of cultivars resistant or tolerant to soilborne pests constitutes a cornerstone component of an integrated pest management system. There are resistant or tolerant cultivars available for many specific pests or pest strains.

Grafting is used with excellent efficacy to control pathogens such as root nematodes, *Fusarium*, and *Verticillium* (vegetable crops), and *Phytophthora* (fruit trees, citrus) can be as effective as resistant varieties when resistant rootstocks are available.

In most cases biological control agents act as protectants against root infection. Their activity may be enhanced when combined with other strategies. Organic amendments such as composts, sewage, by-products from agriculture, forest and food industries may be used to control certain soilborne pests in various crops. Their application will be localised and dependent on reliable sources of raw materials for conversion into useful formulations.

Soil solarisation involves the trapping of solar radiation under clear plastic sheeting to elevate temperatures of moist soil to lethal levels for soilborne pests. Of all the physical methods, it is widely perceived as having high potential as an alternative for methyl bromide. It is most successfully used on heavier soils within arid or semiarid areas with intense sunshine and minimal rainfall, although also may be effective under some humid conditions and with sandy soils.

Biofumigation is the amendment of soil with organic matter that release gases that kill or control pests. This may be combined with covering of soil with plastic or any appropriate system for the purpose of trapping solar energy and raising soil temperatures. This technique is receiving attention in numerous countries and could be especially important in Article 5(1) countries where a low technology solution is appropriate.

Steaming for soil pasteurisation is a well established and effective technique for soilborne pest control and is used extensively in Non-Article 5(1) countries, and some also in Article 5(1) countries, for bulk soil, in greenhouses, and for nursery beds and small-scale field operations. Energy-efficient steaming techniques are now available.

No single chemical provides an alternative to preplant uses of methyl bromide in terms of consistency and efficacy against a broad spectrum of pests, although there are a number of chemicals available which are equal or superior to methyl bromide against limited pest complexes. Combinations and/or rotations of chemical alternatives have achieved broad spectrum pest control and yields approaching those obtained with methyl bromide. Additionally, combinations of chemical alternatives with non-chemical alternatives, e.g. solarisation, have shown some promise but require further study.

Research aimed at reducing the emissions of methyl bromide from fumigation operations is ongoing. This includes:

- new or improved practices to better contain methyl bromide during fumigation, which both reduce leakage and enable use of lower methyl bromide dosages, and
- the development of technologies to reduce emissions after space or commodity fumigation by recovering methyl bromide for recycling or destruction.

Improvements have been made in the quality of the plastics used for soil fumigation to make them virtually impermeable. Such plastics have been available for over ten years but have been subject to detailed research recently to further identify how well they perform. Dosage reductions of up to 50% under certain conditions are possible without affecting performance or crop yield. Associated emission reductions could be even greater, but will vary depending on application and tarping techniques. Potential for dosage reductions will be lower in USA than in most other countries as lower dosages are already in use. Commercial use of methyl bromide recovery technologies following commodity or structural fumigation is still limited to a few operations in California and to some small operations in Europe.

Although technologies that lead to reduced methyl bromide use such as better containment and recycling can assist Parties in meeting their obligations to reduce consumption during the phaseout period, the Protocol's focus on reducing usage rather than reducing emissions does not provide a marked incentive for investment in research or capital equipment for emission reduction for commodity fumigation. Nevertheless these technologies are important as they have the potential to reduce emissions from exempt uses such as quarantine treatments.

In the area of alternatives to MeBr for durable crops, there have been few novel concepts since the 1994 MBTOC report. There has been considerable increase in the use of phosphine as a replacement and work on new methods of applying and distributing phosphine have advanced to the commercial stage. A new compound, methyl phosphine, which is active against phosphine-resistant pests, is under investigation in the UK. Research on controlled atmospheres has also progressed for use on grain stored in silos, and alone or in combination treatments with other control components for dried fruit and nuts. Test have also been conducted on the use of CO_2 under high pressure in chambers for museum artefacts, and a new technique employing heat in conjunction with controlled humidity is now in commercial use. Many new compounds are being tested such as methyl iodide, carbonyl sulphide, and methyl isothiocyanate for use on timber products. Irradiation of some wooden products and forage crops have found use as quarantine treatments in Australia.

With regard to Decision VII/8 there are a number of alternatives for MeBr uses on durable commodities which could be or are available and most have been tested under commercial conditions, both in Non-Article 5(1) and Article 5(1) countries. In general the alternatives are technically effective but there are implementation issues to be overcome for some specialised MeBr uses. For grain pests the commercially available alternative treatments identified, either individually or as components of a system, include phosphine, controlled atmospheres, chemical protectants, inert dusts and irradiation. For dried fruits and nuts the alternative treatments identified were phosphine, oxygen deficient atmospheres, low temperature, irradiation and granulosis virus. In addition several alternatives were identified for the treatment of artefacts.

Of the alternatives for durables, phosphine on grain currently has the highest potential to replace most of the remaining MeBr uses in both Non-Article 5(1) and Article 5(1) countries. However, there are aspects to be considered before further extending phosphine use in view of increased pest resistance, regulatory questions relating to health and safety, corrosivity, length of treatment and ineffectiveness at low temperature. Logistical and facility problems related to long treatment times and the need for tightly sealed enclosures may make it difficult to expand the use of phosphine as a replacement to MeBr in some Article 5(1) countries.

Article 2H provides exemptions for quarantine and pre-shipment treatments (QPS) because of concerns that loss of approved treatment would severely curtail international trade. At the time the exemptions were introduced there were no apparent alternatives. Almost all of the treatments of perishables with MeBr will currently fall under this exemption. However, some countries are scheduled to ban all MeBr uses, including those for quarantine. Such schedules, coupled with the need to develop treatments that maintain or improve the quality and/or shelf life for commodities currently treated with MeBr, are encouraging the development of QPS treatments. Information on progress on alternatives for QPS remains very important.

The difficulty of developing QPS treatments for perishables should not be underestimated as most treatments are generally complex, require substantial time to refine to a stage where they kill pests without affecting the marketability of the commodity (often specific varieties), and may require repetition of specific experiments in each importing country prior to regulatory approval. In order to preserve the quality and market life of perishable commodities, specific treatments are often of short duration.

Despite these difficulties, MBTOC has identified more than 97 examples where non-MeBr quarantine treatments for perishables have been approved. A number of these treatments existed prior to 1994. In the past three years, QPS treatments utilising the systems approach, pest free zones, combination treatments, chemical dips and irradiation have been implemented. However, these recent approvals account for a minority of exports requiring non-MeBr treatments. Furthermore, there is currently no approved substitute for methyl bromide treatment immediately on arrival for imported perishable commodities infested with pests of quarantine importance. This use is regarded as most important for protecting the agriculture of many countries around the world from the introduction of exotic pests.

Additional treatments are under development with potential implementation in the next 2-5 years including those based on the systems approach, heat, electron beam and gamma irradiation, high pressure water treatment, and controlled atmospheres in combination with heat or cold storage. Current research includes efforts on the following potential alternatives which are now in various stages of development: heat treatment for sweet potatoes and root crops, irradiation and alternative fumigants for cut flowers, physical disinfestation of citrus and a systems approach for avocado.

Historically, the mutual acceptance of a new QPS protocol by trading partners has taken 2-15 years because of extensive data requirements demonstrating minimal risk of accidentally importing a damaging pest. Some countries are considering accepting a new quarantine security approach which takes account of packing, distribution and inspection activities that mitigate against pest infestation. This approach increases opportunities for researchers to implement treatments less harmful to the commodity as alternatives to MeBr. Many of the alternatives are pest and commodity specific.

Since the 1994 MBTOC Assessment report, several techniques and materials have either been introduced or trialed for full site structural fumigations of flour mills or similar premises.

A combination of phosphine, carbon dioxide and heat has been used commercially in several locations in the USA and Canada. A cylinder based formulation of phosphine in liquid carbon dioxide has been tested and is commercially available in some countries. A transportable phosphine generator which can produce large volumes of pure phosphine has been developed by a Chilean company and used in a mill treatment. This method, as with phosphine in cylinders, has potential to reduce the treatment time for phosphine fumigations. The use of heat for disinfestation is being adopted by some food production facilities in some countries. Use of advanced IPM systems in some countries has led to reduction of frequency or apparent elimination of full-site methyl bromide treatments.

Sulfuryl fluoride has largely replaced methyl bromide in the USA for the fumigation of dry wood termites, but use for other wood boring insects is restricted because of the need for high dosages. The use of heat combined with humidity control for treatment against woodboring insects is currently being trialed in Germany and the UK.

Since the 1994 MBTOC Report, there has been increased use of alternatives to methyl bromide in Article 5(1) countries, and a number of Article 5(1) countries have decreased overall usage of this fumigant. However, methyl bromide use in other Article 5(1) countries has increased or remained stable. The decrease in the use of methyl bromide has resulted from the use of alternatives such as: 1) solarisation, chemical pesticides, and soil amendments as part of an integrated pest management (IPM) system for soil treatment; 2) phosphine for grain treatment; 3) vapour heat for perishable commodities; and 4) sulfuryl fluoride for structures. The increase in use of methyl bromide has been due to the slow transfer of technology, delayed development and adoption of alternatives, and pest resistance issues.

UNEP-IE has conducted a number of regional seminars for Article 5(1) countries concerning the phase out of methyl bromide and the alternatives to this fumigant. The methyl bromide industry has also held a number of seminars in several Article 5(1) countries. These seminars and other factors may have contributed to the methyl bromide use trends noted in this report.
An area of concern is the potential of methyl bromide use in Non-Article 5(1) countries for agricultural production to move to Article 5(1) countries in the future. This may occur when methyl bromide is phased out in the Non-Article 5(1) countries, and production of the agricultural crop associated with methyl bromide use is transferred to an Article 5(1) country where methyl bromide is available.

In order to facilitate increased use of alternatives in Article 5(1) countries, substantial efforts will be needed for the evaluation of efficacy of alternatives (field testing), and as collaborative research projects. MBTOC notes the significant commitment and financial support under the Multilateral Fund for the implementation of the Montreal Protocol towards these goals.

2 INTRODUCTION

This report reviews progress towards adoption or development of alternatives to methyl bromide in both Non-Article 5(1) and Article 5(1) countries. This information is provided in part to fulfil the request of the Parties under Decision VII/8 and partly to provide annually update information to the Parties through TEAP as required by Decision VII/34.

The report follows the organisation of the MBTOC 1994 Assessment Report. Parties are referred to this Assessment Report for detailed discussion of the various alternatives and substitutes considered here. Only areas of change and progress are discussed here.

Methyl bromide use continues in Non-Article 5(1) countries under an annual consumption level under the Protocol frozen at 1991 levels, while it is not yet controlled in Article 5(1) countries. However, in the latter, average actual consumption in the years 1996, 1997, 1998 are to be used as a baseline for future calculations for a freeze in 2002. Consumption during the period under review here will thus have an important influence in future Article 5(1) potential consumption.

Under Decision VII/8 the Parties called upon TEAP to consider the viability of possible substitutes and alternatives to methyl bromide, and to examine the extent to which technologies and chemicals identified as alternatives and/or substitutes have been tested under full laboratory and field conditions, including field tests in Article 5(1) countries and have been fully assessed, inter alia, as to their efficacy, ease of application, relevance to climatic conditions, soils and cropping patterns, commercial availability, economic viability and efficacy with respect to specific target pests.

TEAP then tasked MBTOC to consider whether alternatives identified in the 1994 Assessment Report have been evaluated under laboratory and field conditions for their efficacy, ease of application, relevance to climatic conditions, soils and cropping patterns. This report contains the response of MBTOC to this task. The EOC is charged with providing information on economic viability of the alternatives.

The question of alternatives to methyl bromide is complex. In many situations approaches are available which achieve the same technical aim as methyl bromide treatment. These may be either by direct substitution (e.g. vapam sodium treatments), not-in-kind (e.g. crop rotation) or integrated systems involving multiple actions in a rational combination. In all of these cases, the end process leads to the removal of the need for methyl bromide.

Additionally, there are approaches that lead to a reduction in methyl bromide emissions to the atmosphere, though they still rely on methyl bromide as a component of the system. These include reduced dosage rates or frequency of application, use of virtually impermeable sheeting, adding equipment capable of capturing any methyl bromide emitted from a treatment, combining methyl bromide with other materials (e.g. chloropicrin) or other measures (e.g. solarisation).

In order to reduce the task to manageable proportions for the purposes of a response to Decision VII/8, the Committee has analysed in detail only alternatives to uses that consume a substantial quantity of methyl bromide globally. The alternatives are those presented in the MBTOC 1994 Assessment or the update thereto and that are at an advanced stage of research or are being implemented somewhere. Alternatives to methyl bromide for following crops/commodities/structure were covered. These represented 65% of 1992 global MeBr use as a soil fumigant and the major other use (post-harvest grain protection). Treatment of dried fruit and nuts, and flour mills was also considered (Table 2.1).

Table 2.1 *Proportion of 1992 methyl bromide global agricultural use represented by crops/commodities/structure considered in this report with respect to Decision VII/8.*

Crop/commodity/structure	**% of 1992 global use**
tomatoes	22
strawberries	13
grain (post harvest)	8
melons/cucurbits	7
cut flowers	6
nursery crops	6
tobacco seedbeds	5
perennial crop planting	5
flour mills	2
dried fruit and nuts	0.8

It is recognised that this inventory of uses excludes from consideration many low volume uses of MeBr which are nevertheless most important to particular local or national economies. However, by covering alternatives to the major uses, it is likely that most low volume uses and alternatives will also be covered (Quarantine and Pre-shipment uses excluded).

It should be noted that usage patterns of methyl bromide or its alternatives may often change as a result of the introduction of new varieties of crops. Some modern high yielding varieties, for example, of tomatoes and strawberries, may be particularly susceptible to pathogens, thus requiring additional protection against pests. Indeed some modern cultivars with desirable yield and quality characteristics have only been bred in the expectation that a soil treatment with an effective soil disinfectant will be used so as to realise their full potential. A consequence of restriction of methyl bromide use will be that plant breeders will need to consider breeding cultivars better adapted to other systems of pest management. In addition, the ‘fit’ of new cultivars in the whole production system will have to be assessed. It is understood that this is already in progress, at least for strawberries.

3 EMISSION REDUCTION AND RECOVERY AND RECYCLING

3.1 Introduction

Research aimed at reducing the emissions of methyl bromide from fumigation operations is ongoing. This includes new or improved practices to better contain methyl bromide during fumigation so that there will be less leakage and potential for reduced methyl bromide dosage, as well as the development of technologies to reduce emissions after fumigation by recovering methyl bromide for recycling or destruction. Better application technology for soil fumigation is beginning to be adopted, most notably in the USA. Commercial use of recovery technologies for commodity or structural fumigation is still limited to a few operations in California and to some small operations in Europe.

Although technologies that lead to reduced methyl bromide use such as better containment and recycling can assist parties in meeting their obligations to reduce consumption during the phaseout period, the Protocol's focus on reducing usage rather than reducing emissions does not provide a marked incentive for investment in research or capital equipment for emission reduction in commodity fumigation. Such technologies will be important as they have the potential to reduce emissions from exempt uses such as quarantine.

3.2 Emission Reduction by Reduced Utilisation and Better Containment

3.2.1 Virtually Impermeable Films (VIF)

From 1993 a detailed multi-national research programme has been carried out in Europe looking at the benefits of using virtually impermeable films (VIF) for soil fumigation (Anon. 1996).

VIF films have been available commercially for more than 10 years, but interest in their use has intensified recently in response to the curtailing of MeBr supplies. VIF is a gas-tight film which is virtually impermeable to methyl bromide. This contrasts with the polyethylene sheeting, typically used to contain methyl bromide in soil fumigations now. Polyethylene is quite permeable to methyl bromide and significant loss to atmosphere occurs directly through the sheeting. VIF films are multi-layer laminates with outer layers of low density polyethylene and a barrier layer of polyamide or ethylene vinyl alcohol (EVOH). The research programme has given information on the efficacy of reduced dosages using VIFs compared with standard treatments against a variety of pathogens in different crops, comparing the effective dosage achieved in the different combinations by monitoring MeBr concentrations at different depths in different soil types, the edge effect, mass balance, bromides in the soil, plant growth parameters, yield and quality, laboratory tests of permeability of many different films and follow-up of upscaled treatments in commercial applications.

Dosage reductions of up to 50% under certain conditions are possible without affecting performance or yield. Associated emission reductions are likely to be even higher, but will vary depending on application and tarping techniques. The potential to reduce dosages for soil fumigations in the U.S. compared with many other countries will be less because dosages there are already lower (see MBTOC 1994 Assessment Report, p.124), but there is scope for emission reduction from the better containment offered by increased introduction of VIF. Additional research has occurred in a wide number of locations that verify the effectiveness of this method of emission reduction.

A concern expressed by some is that there may be increased levels of bromide ion remaining in the soil because of the greater quantity of methyl bromide remaining in contact with the soil. Some bromide could leach into ground and surface water. This problem, if it does occur, will be very specific to each location and will be minimised where lower methyl bromide doses can be used. Research on the neutralisation of methyl bromide such as by use of absorbent tarping (see below) is still at an early stage.

Based on these comprehensive research studies (Anon. 1996), the following conclusions were made:

- Plastic films containing an EVOH or polyamide layer proved to be excellent barrier and impermeable to MeBr. In the laboratory, the diffusion rate of MeBr through VIF was more than 1000 times less compared with PE. In the field an improvement factor of 2-3 was observed.

- By using VIF in the field, it was feasible to significantly reduce the emission to the atmosphere by applying dosages reduced up to 50% of the recommended dosage while keeping the same efficacy of pathogen control to considerable depths, and growth, yield and quality of crops at least as good as standard treatments.

- VIF retained MeBr in the soil for longer periods as compared with the standard treatment. The resultant Concentration-Time Products (CTP) from the reduced dosages under VIF were similar or higher at all depths to those for the full dosage applied under standard polyethylene film. (CTP is a value which indicates the control potential of MeBr.)

  Emission of MeBr to the atmosphere during fumigation occurs from MeBr permeation through the sheeting and from leakage from the edges of the sheeting (edge effect). From work done in the UK, Belgium and Israel, the total emission reduction achieved is the combined result of lower dosage (30-50%) and improved non-permeable films, which give a total reduction of more than 70% compared with polyethylene sheeting where more than 70% of the applied dose of MeBr was emitted.

- A further reduction of emissions can be achieved by better sealing (deeper placement, adding water) of the edges. The edge effect is more of a problem in strip fumigation. In using VIF, high concentrations of MeBr are retained under the film for at least 5 days (the recommended exposure time for VIF fumigation) which gives rise to a higher breakdown of MeBr to inorganic bromides - about 15% per day according to UK results. Thus, a further reduction of MeBr emission is achieved.

- The potential for dosage optimisation (reduction) varies from location/crop to other locations and crops. There are locations where no further dosage reduction is possible.

- A further reduction of dosage can be achieved when MeBr is combined with solarisation in locations with appropriate climatic conditions. This proved to be as effective as the standard treatment or a reduced dosage using VIF (e.g. see Anon. 1996).

- The present cost of VIF is about 2.5 times higher than standard polyethylene film, which makes the treatment more expensive. The costs of fumigation with VIF break even at application rates of about 750 kg/Ha. A reduction in VIF cost is expected when commercial use and production increases begin.

- Long-term beneficial effects were observed in semi-commercial and commercial trials in Israel for two seasons indicating another source of emission reduction where the frequency of treatments can be decreased by the use of VIF films.

The ultimate cost of using VIF has not yet been developed because the system is not fully developed and large scale production of the films has not yet occurred. A further reduction of the plastics cost is expected once demand increases. The following table (Table 3.1) gives a breakdown of fumigation cost at various methyl bromide dosages and compares a standard treatment and a treatment using 50% of the currently used dosage with VIF.

3.2.2 Improved Application Methods

Improved application techniques for soil fumigation that bury edges of tarps has reduced the escape of methyl bromide. Improved injection techniques and the use of hot gas results in a more uniform dispersion of methyl bromide in the soil, slows the upper movement and facilitates greater mineralisation (conversion to bromide) of methyl bromide thus reducing emissions.

Table 3.1 *Comparison of costs per hectare for standard and VIF covered soil fumigations (M. Spiegelstein, pers. Comm.)*[e]

	Standard treatment[a] (polyethylene film)			New treatment (VIF film[c] & 50% MeBr dose)			
dosage (kg/Ha)	Film[b] cost (US$)	MeBr cost[d] (US$)	Total cost (US$)	Film cost (US$)	MeBr cost[d] (US$)	Total cost (US$)	Cost difference (US$)
500	600	1150	1750	1505	575	2080	(+) 330
600	600	1380	1980	1505	690	2195	(+) 215
700	600	1610	2210	1505	805	2310	(+) 100
800	600	1840	2440	1505	920	2425	(-) 15
900	600	2070	2670	1505	1035	2540	(-) 130

Notes:
a A MeBr dosage of $50 g/m^2$ and a film weight of 350 kg/Ha has been assumed.
b Polyethylene price is based on an average price of US$1.70/kg
c VIF price is based on an average price of US$4.30/kg.
d Cost of MeBr is based on an average price of US$2.30/kg. Prices may vary in different regions according to returnable/non-returnable, market, packaging etc.
e The calculation does not take into account other components like labour, glue, etc. which are common to both situations.

3.3 Emission Reduction by Recovery after Fumigation followed by Recycling or Destruction

3.3.1 Activated Carbon

The UK method using activated carbon for recovering methyl bromide from bubble fumigation operations for subsequent disposal (or emission to the atmosphere) at a remote site is well developed and in regular use. Further research is being carried out on methods of disposal or recovery of the captured methyl bromide.

A large scale trial of an activated carbon recovery system in a flour mill and silo in Germany was carried out in 1994. Of 1,260 kg of methyl bromide applied to the mill, 565 kg was available for recovery at the end of the fumigation treatment. Of this, only 325 kg was able to be adsorbed and of that only 180 kg was available for reuse. The recycling process was very slow which resulted in the mill being out of action for longer than normal.

3.3.2 Activated Carbon/Condensation

A plant in California USA which recovers methyl bromide from cotton fumigation has been in regular use since December 1993. This use is from vacuum chambers where the potential discharge occurs when the vacuum is released at the end of fumigation and after each of the air washes. The plant apparently meets the local air quality requirements. Access to the plant is restricted and no data has been supplied to quantify the level of recovery or recycling.

3.3.3 Ozone Treatment/Activated Carbon

A plant was installed in late 1996 at another cotton fumigation site in California USA. It uses ozone to destroy the methyl bromide in the discharge and air washes from a vacuum chamber. Activated carbon is used to scrub any residual traces of methyl bromide from the discharge air stream. At the date of writing, two monitored trials had been carried out and in excess of 90% of methyl bromide emissions have been destroyed. The plant is large and has a significant electrical power requirement for the ozone lamps and the blowers.

3.3.4 Activated Carbon/Thermal Destruction

A process to control emissions has been developed on a laboratory scale by the USDA in California (Leesch, 1997). Plans are now under way to test the process on a pilot scale in both a $14m^3$ chamber and from the slip streams of commercial fumigation systems. The process is based on using activated carbon to capture the methyl bromide and then transferring the exhausted activated carbon to a remote site where it is reactivated and the methyl bromide destroyed thermally. A methyl bromide producer is also involved and initial thoughts are to sell methyl bromide at a price which includes the cost of capture and destruction.

3.3.5 Adsorption onto Zeolite

Large scale trials carried out at the Port of San Diego in 1995/96 were unsuccessful because of the suspected creation of hydrobromic acid (HBr), possibly by the interaction of methyl bromide and water vapour in the recirculating air during the recycling stage of the process. Apart from the introduction of an undesirable compound, there was evidence of corrosion to some internal components of the plant. The trials at San Diego have been abandoned. However, a similar smaller recovery plant has been installed and successfully commissioned at a fumigation facility in Chile. Recoveries of more than 94% of the methyl bromide from the fumigation chamber and recycling rates of 87% were achieved. At the time of preparation of this report, approval had not been received from USA authorities for the quarantine treatment of grapes using recycled methyl bromide.

3.3.6 Improved Solid Adsorbents

Further development work has been carried out in Japan on MBAC which is a mixture of activated carbon and special amines. A granular and a sheet product have been developed for use in adsorbing the methyl bromide which is slowly emitted after a fumigation treatment (Kawakami & Soma, 1995). Efforts are now being made to develop domestic markets for the product.

3.3.7 Condensation

A pressure/cooling condensation process is in use in California USA to recover methyl bromide where it is in a highly concentrated form in the vent gas lines from cylinder filling.

3.3.8 Direct Catalytic Destruction

Research is being carried out in Japan on the catalytic decomposition of methyl bromide. Promising recent results from using new Mn/Cu-zeolites indicate that satisfactory levels of destruction can be obtained at lower temperatures than previously and minimise the production of CO. This research is still at an early stage of development.

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4 ALTERNATIVES TO METHYL BROMIDE FOR SOIL TREATMENT

4.1 State of Alternatives by Major Crop (Decision VII/8)

In its consideration of Decision VII/8 MBTOC recognised two categories of alternatives to methyl bromide:

- direct alternatives;
- indirect alternatives.

A direct alternative is one that has replaced methyl bromide in some use area. An indirect alternative is one which is effective for one or more of the pests or weeds currently controlled by methyl bromide on a particular crop but has not achieved widespread use as a direct replacement at this time. Note that these definitions do not correspond with the familiar in kind/not-in-kind categories. They are needed to distinguish procedures which have actually replaced some methyl bromide use from ones which have technical potential to do so, but have not been subject to comparative tests or implementation as an alternative.

Indirect alternatives will usually require local testing and optimising before full commercial acceptance as a replacement. In general, the definition of an ‘alternative’ follows the MBTOC 1994 Assessment Report where a technology demonstrated in use in one part of the world was considered to be an alternative technically, unless there were obvious constraints to the contrary. However, some strategies have not been intensively studied and thus the transferability of these alternatives cannot always be assumed.

As in the 1994 Assessment Report, MBTOC limited its considerations to questions of technical feasibility with regard to alternatives, with economic aspects considered in detail by the EOC.

Examples of direct replacements of methyl bromide are relatively limited at this time. They include use of steam and natural and artificial substrates for greenhouse tomato, cut flowers and strawberry production in Europe, and integrated pest management systems for cut flower production in Colombia. All of the crops produced with methyl bromide are produced commercially without methyl bromide in some regions of the world, although not necessarily to the same level of profitability.

The attention of the Parties is drawn to the difficulty of providing simple descriptions of alternatives, as the appropriateness of a given alternative or alternative system is dependent on a variety of factors, including social infrastructure, climate, market, pest level and presence, land availability and soil type and condition. The complex interaction of these factors requires choice of best alternatives to be made on a case-by-case basis. It is inappropriate to attempt to provide the level of detail required to make this analysis for all cultural systems currently using MeBr. Nevertheless, there are some practices which have widespread applicability, though not necessarily producing the same yield/profitability as methyl bromide and which may need local optimisation to perform to their full potential.

Furthermore, to successfully replace methyl bromide use, many of the alternative processes identified by MBTOC must be used in combination. Methyl bromide has activity against fungi, nematodes, insect pests, weeds, and weed seeds. All of these areas of activity are important in some cultural systems and situations. Some alternatives only have a limited spectrum of activity. Thus, for instance, chloropicrin is an excellent fungicide but lacks activity against some nematodes and weeds, and additional measures are needed to provide a full alternative system. However, some combinations and/or rotations with chemical alternatives have achieved broad spectrum pest control and yields approaching or exceeding those obtained with methyl bromide.

The table below (Table 4.1) provides a broad overview of methyl bromide alternatives in use or as indirect replacements. This is organised by major crop with an indication of level of development of use for each identified process. Further detail on the constraints and characteristics of particular technologies are given in Section 4.2.

Table 4.1 was compiled from published literature and specialist knowledge of MBTOC experts. It is for the purposes of illustration of some of the regions where given alternatives are in use, and does not intend to present a comprehensive overview. It is not comprehensive. The ratings given as to degree of adoption are also only approximate, with assessment of adoption level differing between individual experts and also often for different parts of a country.

Table 4.1 includes discussion of alternatives for perennial crops. Development of treatments for perennial crops present special experimental problems. The crops are often of high value but slow to come into production. They may then have a productive life exceeding 10 years. Additionally, early growth may not be a good indicator of later productivity (Stirling et al. 1995). There are few comparative studies between methyl bromide treatment and a potential alternative and more are urgently needed to establish relative efficacy of alternatives.

Table 4.1 *- Examples of alternatives in use, replacing methyl bromide or controlling one or more pests or weeds currently controlled in some situations by methyl bromide, with indications of degree of development and adoption of the technique. Ratings of scale of applications - see footnote.*

CUCURBITS

	Treatment	**Region**
Non-Chemical	Resistant Varieties	Non-Article 5(1) countries(4) Article 5(1) countries (4)
	Grafting	Non-Article 5(1) countries (3) Egypt (3), Jordan (3), Lebanon (3), Morocco (3), Tunisia (3)
	Solarisation	Non-Article 5(1) countries (2-3) Brazil (2), Egypt (2-3), Jordan (3), Morocco (2-3), Syria (2-3), Tunisia (2-3)
	Steam (protected cultivation)	Brazil (2), Europe (4), US (2)
	Biological Control	Brazil (3), Europe (3), Mexico (2), Morocco (2), US (2-3)
	Biofumigation	Non-Article 5(1) countries (3), Brazil (2), Mexico (2)
	Soilless Culture (protected cultivation)	Brazil (2), Egypt (2-3), Europe (4), Jordan (2-3), Lebanon (2-3), Morocco (2-3), US (2-3)
	Crop Rotation	Universal (4)

[continued:]

Chemical	Chloropicrin	Non-Article 5(1) countries (3), Zimbabwe (3)
	1,3-D	Non-Article 5(1) countries (3-4) Costa Rica (3-4), Honduras (3-4), Mexico (3-4) Morocco (3-4)
	Metham sodium	Non-Article 5(1) countries (3-4) Brazil (2), Costa Rica (3-4), Egypt (3-4), Jordan (3-4), Lebanon (3-4), Mexico (3-4), Morocco (3-4), Tunisia (3-4)
	Other specific soil treatments (e.g. Ethotrop, Aldicarb, Carbofuran, Oxamyl, Fenamiphos)	Non-Article 5(1) countries (3-4) Brazil (3-4), Costa Rica (3-4), Egypt (3-4), Jordan (3-4), Lebanon (3-4), Morocco (3-4), Syria (3-4), Tunisia (3-4)

[continued:]

CUTFLOWERS

	Treatment	Region
Protected Cultivation	Steam	Brazil (2), Colombia (4), Europe (4), US (2)
	Solarisation	Non-Article 5(1) Countries (2-3)
		Jordan (1-2), Lebanon (3-4), Morocco (2-3)
	Biocontrol	Non-Article 5(1) countries (1-2)
	Substrates	Brazil (3), Canada (4), Europe (4), Morocco (1), Tanzania (2-3), US (2-3)
	Organic Amendments (compost, etc.)	Universal (4)
	Crop Rotation/Fallow	Universal (4)
	Resistant Varieties	Universal (3-4)
	Biofumigation	Non-Article 5(1) Countries (1-2)
	Metham sodium	Non-Article 5(1) Countries (2-4)
		Jordan (2-3), Lebanon (2-3), Morocco (2-3)
Open Field	MITC generators (dazomet, metham sodium)	Non-Article 5(1) countries (2-4)
		Brazil (3), Costa Rica (3), Egypt (2-3), Jordan (2-3), Lebanon (2-3), Morocco (2-4) Tunisia (2-4)
	1,3-D	Non-Article 5(1) countries (2-4) Colombia (3-4)
	Chloropicrin	Non-Article 5(1) Countries (3-4)
		Zimbabwe (3)
	Organic Amendments (compost, etc.)	Universal (4)
	Crop Rotation/Fallow	Universal (4)
	Resistant Varieties	Universal (2-4)
	Solarisation	Non-Article 5(1) countries (2-3)

[continued:]

NURSERY CROPS (VEGETABLES AND FRUIT)

Treatment	Region
Steam (protected cultivation)	Widespread (4)
Steam (open field)	Denmark (3)
Solarisation	Widespread (3-4)
Biocontrol	Canada (3), Germany (3), Israel (3), Mauritius (3), Netherlands (3), Switzerland (3), UK (3)
Substrates (protected cultivation)	Brazil (4), Canada (4), Chile (4), Denmark (4), Germany (4), Israel (4), Mexico (4), Morocco (4), Netherlands (4), Spain (4), Switzerland (4), UK (4), US (4), Zimbabwe (4)
Soil Amendments (compost, etc.)	Widespread (4)
Crop Rotation/Fallow	Widespread (4)
Resistant Varieties	Widespread (3) including Egypt, Jordan, Lebanon, Morocco, Tunisia
Grafting	Widespread (4)
Biofumigation	Brazil (3), Israel (3), Mexico (3), US (3)

[continued:]

PERENNIAL CROPS (REPLANT)

	Treatment	Region
Banana	Soil Amendments	Universal (3-4)
	Biological Control	Canary Is. (1), Brazil (2)
	Biofumigation	Canary Is. (1)
	Solarisation	Canary Is. (1), Morocco (1)
	Substrates	Canary Is. (4)
	Chloropicrin + 1,3-D	Costa Rica (1)
	1,3-D	Costa Rica (3-4)
	Metham sodium	Costa Rica (1-2), Egypt (1-2), Lebanon (1-2), Morocco (1-2)
	Dazomet	Costa Rica (1-2), Egypt (1-2), Morocco (1-2)
	Crop rotation	Brazil (2)
	Resistant cultivars	Brazil (2)
Perennial Vines	Biological Control	Australia (1-2)
	Substrates	Canary Is. (2-3)
	Grafting	Universal and pest specific (4)
Nuts	Substrates	US (1)
	Grafting	Universal and pest specific (4)

[continued:]

Stone & Pome Fruits	Biological Control	US, (crown gal) (1-3)
	Grafting	Universal, very specific to soil pests (2-4)
	1,3-D	Spain (3-4),US (3-4) stone fruit only
Citrus	Biological Control	Florida (root weevil) (4)
	1,3-D	Florida (3), Spain (3)
	Solarisation	Spain (1), US (1)
Roses	Biological Control	Morocco (crown gal), (1-3), US (1-3)
	Resistant Varieties	Universal (3-4)
	Grafting	Universal (3-4)
	Substrates	Belgium (4), Denmark (4), Greece (1-2), Italy (1-2), Morocco (1-2), Netherlands (4), Spain (1-2), US (1-2)
	1,3-D	Egypt (2-3), France (2-3), Greece (2-3), Italy (2-3), Jordan (2-3), Lebanon (2-3), Morocco (2-3), Portugal (2-3), Spain (2-3), Tunisia (2-3), US (2-3)
	Metham sodium	Egypt (2-3), France (2-3), Greece (2-3), Italy (2-3), Jordan (2-3), Lebanon (2-3), Morocco (2-4), Portugal (2-3), Spain (2-4), Tunisia (2-4), US (2-3)
	Dazomet	Egypt (2-3), France (2-3), Greece (2-3), Italy (2-3), Japan (3), Jordan (2-3), Lebanon (2-3), Morocco (2-3), Portugal (2-3), Spain (2-3), Tunisia (2-3), US (2-3)
	Solarisation	Israel (4)
	Steam (protected cultivation)	Belgium (4), Netherlands (4)

[continued:]

STRAWBERRIES (RUNNER AND FRUIT PRODUCTION)

Treatment	Region
Steam	Non-Article 5(1) countries (1)
Solarisation	Non-Article 5(1) countries (2-3)
Biocontrol	Non-Article 5(1) countries (1), Japan (2-3)
Substrates	Indonesia (3), Malaysia (3), Netherlands (4), UK (3), US (1-2)
Organic Amendments (compost, etc.)	Universal (4)
Crop Rotation/Fallow	Universal (4)
Resistant Varieties	Denmark (4), Japan (3), Mexico (1), Spain (1), UK (1), US (1)
Biofumigation	US (1)
Metham sodium	Egypt (3), Jordan (3), Lebanon (3), Morocco (3-4), Netherlands (4), Spain (4), Tunisia (3-4), UK (2), US (2)
Dazomet	Egypt (3), Jordan (3), Lebanon (3), Morocco (3), Netherlands (4), Spain (4), Tunisia (3), UK (3), US (2)
1,3-D	Netherlands (4), Spain (2), UK (3), US (2)
Chloropicrin + 1,3-D	US (2)
MeBr/Chloropicrin mixtures & reduced usage MeBr	Australia (4), Italy (4), Mexico (3-4), Spain (3-4), US (3-4)
Chloropicrin	Japan (3), UK (3), US (1-2)

[continued:]

TOMATO & PEPPER

	Treatment	Region
Protected	Steam	Belgium (4), Netherlands (4), UK (3), US (1)
	Solarisation	Egypt (1-2), Japan (3), Jordan (1-2), Lebanon (1-2), Morocco (2-3)
	Substrates	Brazil (2), Belgium (4), Canada (3), Denmark (4), Morocco (2-3), Netherlands (4), Spain (2-3), UK (3), US (2-3)
	Biofumigation	Southern Europe (1-2)
	Metham sodium and dazomet	Egypt (3), Europe (3-4), Jordan (3), Lebanon (3), Morocco (3), Tunisia (3), US (2-3)
Open Field	Solarisation	Egypt (1-2), Israel (3-4), Japan (3), Jordan (1-2), Lebanon (1-2), Morocco (1-2), Spain (1-2), Tunisia (1-2), US (1-3)
	Biocontrol	Brazil (2), Israel (1-2), Mexico (2), US (1-2)
	Substrates	Canary Island (2-3)
	Organic Amendments (compost, etc.)	Universal (1-2)
	Crop Rotation/Fallow	Universal (3-4)
	Resistant Varieties	Article 5(1) countries (4), Japan (4), Spain (4), US (4)
	Grafting	Egypt (1), Japan (4), Jordan (1), Lebanon (1), Morocco (1), Spain (1), Tunisia (1), US (1)
	Biofumigation	Brazil (2), Mexico (2), US (1-2)
	Metham sodium	Australia (4), Brazil (4), Costa Rica (4), Egypt (4), Japan (3), Jordan (4), Lebanon (4), Mexico (4), Morocco (4) Spain (4), Tunisia (4), US (3), Zimbabwe (4)

Dazomet	Brazil (2), Europe (3-4), Japan (3), Morocco (3), US (2)
1,3-D	Costa Rica (3-4), Honduras (3-4), Italy (3-4), Japan (3), Mexico (3-4), Morocco (1-2), Spain (3-4), US (3-4)
Chloropicrin	Costa Rica (3-4), Honduras (3-4), Japan (3-4), Mexico (3-4), US (3-4), Zimbabwe (3-4)
Chloropicrin/methyl bromide mixtures	Australia (3), Japan (3)

[continued:]

TOBACCO SEEDLINGS

Treatment	Region
Dazomet	Brazil (3-4), India (2-3), Japan (3), Malawi (2-3), South Africa (2-3), Thailand (2-3), USA (3-4)
Dazomet + EDB	Zimbabwe (2)
Brush burning + 1,3-D	Malawi (3), Zambia (3), Zimbabwe (3)
Biocontrol (*Trichoderma*)	Malawi (4), Zambia (3), Zimbabwe (4)
Biofumigation	Australia (2), South Africa (3), USA (3), Zimbabwe (3)
Soil solarisation	Brazil (2), Zimbabwe (2)
Soilless culture	Brazil (3-4), South Africa (3-4), USA (3-4), Zimbabwe (2)
Chloropicrin	Japan (4)
Methyl isothiocyanate	Japan (3)
Chloropicrin with 1,3-D or methyl bromide	Japan (3)

Footnotes:

(a) Region. Examples of regions using the alternative in part or full replacement of the effect obtained by methyl bromide in production of the nominated crop. This list provides examples only and is not comprehensive. The alternative may or may not be economically competitive with methyl bromide use.

(b) Numerals in brackets, e.g. (1), refer to the most advanced degree of development of the alternative in a region. Ratings correspond to the following levels:

(2) = under experimental investigation (laboratory)
(3) = under experimental investigation (field trials)
(4) = limited commercial use
(4) = widespread commercial use.

4.2 Alternatives - Scope of Use and Recent Developments

The 1994 MBTOC Assessment Report identified a wide range of procedures that in particular circumstances can act individually or in combination to replace or reduce the need for methyl bromide treatments. Advances in their use are summarised below. These are arranged as in the 1994 Report, with the addition of the emerging technique of ‘biofumigation’ which was not discussed in that report.

4.2.1 Non-Chemical Alternatives

4.2.1.1 Integrated Pest Management

Integrated pest management (IPM) utilises pest monitoring techniques, establishment of pest injury levels and a mix of strategies and tactics to prevent or manage pest problems in an environmentally sound and cost-effective manner. Site-specific treatment programs combine two or more methods selected from biological, cultural, physical, mechanical, and chemical methods.

There is wide agreement that some IPM systems are needed to replace methyl bromide-based systems since no single alternative is currently or likely to become available. The success of these efforts is exemplified by containerised conifers in Canadian nurseries, and fresh market tomatoes in northern Florida and the Canary Islands, and replanting of apples in Australia, among others.

4.2.1.2 Soilless Culture and Plant Growth Substrates

Soilless culture is a method in which plant growth substrates provide an anchoring medium that allows nutrients and water to be absorbed by plant roots. Requirements of the method include the substrate, and systems for water and nutrient movement, decontamination, and sanitation, and can be applied at various levels of technological complexity. Recirculated or discharged irrigation water requires disinfection to remove certain pathogens (e.g. *Pythium, Phytophthora*, bacteria) if they become established. One of the purposes of using this system is to avoid, rather than control, soilborne pathogens.

Substrates include rock wool, tuff stone, clay granules, solid foams (e.g., polyurethane), glass wool, peat, coconut granules, volcanic stones, and pine bark. Soilless culture is used with numerous crops, including tomatoes, strawberries, cut flowers, melons, cucurbits, nursery-grown vegetable transplants, and tobacco seedlings. At this stage, most of the substrate culture occurs within covered agriculture (e.g., plastic greenhouses or tunnels in mild climates, and glass greenhouses in cold climates). There are examples of open field operations under suitable climatic conditions. Substrates of different types are used in several regions of the world, including some Article 5(1) countries.

The methodology of culturing on different kinds of substrates is broadly available; it is efficient, performs consistently, and increases yields. Where the substrates are locally available, feasibility studies are needed to determine whether the methodology is applicable.

4.2.1.3 Crop Rotation

Crop rotation is the planting of successive crops that are non-host, less suitable host, or trap crops for the target pathogens. It is one of the oldest and most reliable methods used in agriculture. However, it should be noted that additional land may be required to achieve the same production as at present achieved with methyl bromide.

Fallow consists of temporarily taking land out of production to reduce soil pest populations by denying them hosts or substrate for their development, and exposing them to adverse environmental conditions.

The efficacy of crop rotation and fallow is dependent on the life history and other characteristics of the pathogens. For example, some pathogens are long-lived (e.g., microsclerotia of *Verticillium dahliae*, chlamydospores of *Fusarium*, oospores of *Phytophthora*); some subsist as saprophytes in competition with the soil flora and fauna; and some (e.g., *Verticillium*) have a wide host range.

Rotation crops must be selected carefully, because a particular crop may reduce the population of particular pests, while increasing the level of other pests. Such crops must also be selected to consider not only suitability as a non-host crop, but also crop production system economics.

Research should continue to develop suitable rotation crops for pest control.

4.2.1.4 Grafting

Grafting is a method that consists of using resistant rootstocks for susceptible annual (e.g., tomatoes, cucurbits) and perennial (e.g., fruit trees, citrus, grapes) crops to control soilborne pathogens.

Grafting is used with excellent efficacy to control pathogens such as root nematodes, *Fusarium*, and *Verticillium* (vegetable crops), *Phytophthora* (fruit trees, citrus). Grafting can be as effective as resistant varieties when resistant rootstocks are available. For example, resistant rootstocks for cucurbits include *Cucurbita ficifolia* and *Benincasa carifera*. For tomatoes, various wild species of *Lycopersicon* are used. Rootstocks used for citrus include sour lemon for the control of *Phytophthora* diseases and *Poncitrus trifoliata* for the citrus nematode, *Tylenchulus semipenetrans*. Some nematode-resistant rootstocks for grapes and fruit trees are available. Grafting has been tested in some Article 5(1) countries such as Morocco, Tunisia, Lebanon, Egypt, Jordan, and Cyprus.

Rootstock resistance may break down with the emergence of new races and under some environmental conditions (e.g., high temperature, salinity). However, it may be possible to regulate temperature by cultural practices (e.g., watering and mulching).

4.2.1.5 Soil Amendments

Organic amendments such as composts, sewage, by-products from agriculture, forest and food industries may be used to control certain soilborne pests in various crops. Their application will be localised; dependent on reliable sources of raw materials they will be converted into useful formulations.

Soil amendments including softwood and hardwood barks reduce the incidence of many soil-borne pathogens such as damping-off caused by *Pythium ultimum* under greenhouse and open field conditions. The addition of chitin into the soil suppresses *Rhizoctonia solani* and additionally may reduce nematodes. Chitin amendments to soil are also known to increase beneficial soil populations of actinomycetes. In addition, compost improves physical soil properties such as soil water-holding capacity, infiltration, aeration, permeability, soil aggregation, and micronutrient levels, and supports microbial activity.

Methods based on composting are by definition regionalised, and effort should be made to develop composts from inexpensive, locally available materials. The degree of efficacy vis-a-vis the soil borne pathogens will also vary regionally; compost that controls a pathogen in one region may not do so in another region. The method has been tested in some Article 5(1) countries such as Morocco, Chile, and Brazil.

4.2.1.6 Biofumigation

Biofumigation is the amendment of soil with organic matter that releases gases which kill or control pests. This may be combined with covering of the soil with plastic or any appropriate system for the purpose of trapping solar energy and raising soil temperatures. The technique can result in the selection of specific beneficial microflora. An example of biofumigation is the incorporation into soil of residues of some brassicas and various Compositae. These give off volatile chemicals, such as methyl isothiocyante and phenethyl isothyocianate, which have herbicidal, fungicidal and/or nematocidal properties.

Potential disadvantages of biofumigation are not clearly defined at present. They may include release of phytotoxic compounds, lack of available organic amendments, and additional waiting time required for breakdown of the amendments.

There is active research in biofumigation in many crops not currently utilising methyl bromide as part of the production process, but the process is now being extended to methyl bromide-using areas. Preliminary results utilising a brassica biofumigation for tobacco seedbeds in Australia have shown responses similar to that from methyl bromide. This technique is receiving attention in numerous countries and will be especially important in Article 5(1) countries where a low technology solution is appropriate.

4.2.1.7 Solarisation

Soil solarisation is the trapping of solar radiation under clear plastic sheeting to elevate soil temperature of moist soil to levels lethal to soilborne pests. Soil solarisation is presently used at least to a limited extent in over 40 countries. It is most successfully used on heavier soils within arid or semi-arid regions with intense sunshine and minimal rainfall, but with slightly changed technology is effective on sandy soils too. With appropriate technology it may also be effective under humid conditions (Chellemi et al. 1997). Of all the physical methods, it is widely perceived as having high potential as an alternative to methyl bromide.

Soil solarisation has demonstrated a relatively broad spectrum of pest control activity. There are however some important pests (e.g. root-knot nematode, nutsedge, some wilt pathogens) which are not consistently controlled by solarisation alone. To address this limitation, soil solarisation is most effective when implemented as a component of an IPM system, i.e., used in combination with other chemical and non-chemical pest control methods eg. soil amendments, crop residues (biofumigation), reduced rates of soil fumigants, etc. New technologies are also in use or under development that enhance or broaden areas of potential use (e.g. to shorten the treatment period or expand its use into cooler climates or subtropical areas with high rainfall). Such technologies include sprayable mulches, double layers of plastic, gas impermeable plastic, plastic bag solarisation, soil amendments and cover crops, biological inoculants, and solar-heated irrigation water.

Trials in southern Europe have shown that a substantial reduction in methyl bromide use is possible when applied in conjunction with solarisation (Anon. 1996).

4.2.1.8 Steam

Steaming is the introduction of water vapour (>100°C) into soil to elevate soil temperatures to levels lethal (70°-80°C) to soilborne pests. Soil temperature and treatment duration determine whether complete elimination (sterilisation) or only partial removal of soil microflora (pasteurisation) occurs. Previous research has demonstrated the undesirable effects of soil sterilisation (pathogen recolonisation, release of heavy metals, and phytotoxic materials). Therefore soil pasteurisation is preferred.

Steaming is a well established and effective technique for soilborne pest control and is extensively used for bulk soil or small scale field treatments within greenhouses and some small scale nursery plant operations. Energy-efficient steaming techniques are now available. Steaming is an alternative to methyl bromide soil fumigation for small scale, open field production of cut flowers, for some protected culture production systems, bulb and cut flowers, and woody fruit and ornamental plants. The use of steam has yet to be demonstrated to have practical utility where large open areas are to be treated and sequential plantings or planting date adjustments are inflexible or cannot be economically implemented. Expanded use of steam for large scale, open field production systems will require technological improvements. It is currently dependent on fossil fuels for generation.

4.2.1.9 Biological Control

Biological control of root pests utilises native soilborne non-pathogenic, bacteria, and fungi that compete for space and nutrients or are antagonistic in some manner toward pathogens on root surfaces or the area immediately surrounding the root. In most they act as protectants against root infection. It is also found that some non-pathogenic root associations induce systemic resistance (ISR) to root pathogens (Winterbottom et al., 1996). Inoculation with non-pathogenic *Fusarium* to inhibit attack on sweet potato plants is in commercial use in Japan (Ogawa and Komada, 1984).

There is a large body of literature available describing many species of organisms antagonistic to plant pathogens and research on utilising antagonists to control plant pathogens has been going on for more than a century (MBTOC, 1994, pp71-72). Biological control agents are generally highly specific and could provide some level of overall disease management only if used with other disease control strategies, i.e., fumigation, steam, or solarisation. Integrated crop management (ICM) strategies using biological control as part of a disease control arsenal holds greater promise as a control tactic than biologicals alone (Winterbottom, 1990). It is most effective when combined with chemical means of control or genetic resistance where the plant's period of susceptibility is short and/or under cultural circumstances where inundation with microbial agents offer a distinctive competitive advantage over pathogens. Protection of roots against pathogens in field grown crops requires that biologicals grow in the rhizophere near the root tip, the site of infection by most root pathogens, during periods of susceptibility. This area of research is still emerging.

With a crop such as strawberry that develops new primary roots every 3 to 4 weeks during the crop season means that protection must be continuous. These requirements for crop protection may be met someday as more is learned about rhizophere/rhizoplane ecology and different means of biological control, such as ISR, but expectations currently for biological alone are unrealistic for strawberry, a crop exposed to a wide variety of pathogens with different environmental requirements over long periods of vulnerability.

4.2.1.10 Resistant Cultivars (Varieties)

Production of resistant cultivars involves systematic genetic modification of germplasm by incorporating specific gene(s) for resistance or tolerance and the selection for horticulturally acceptable types in environments that identifies superior individuals.

The use of plant breeding to select and develop crop cultivars resistant or tolerant to pests/pathogens is as old as agriculture. Its use as an alternative to pre-plant soil fumigation is limited by the time and resources, both genetic and financial, required for developing multiple-resistant cultivars with appropriate commercially acceptable quality and yield.

When feasible, breeding cultivar resistant or tolerant to soil borne pathogen/pests is the optimum control method in integrated pest management systems, because of the relatively low environmental impact of this option. There are resistant (tolerant) varieties for most crop species today. These include resistance to root-knot nematodes or to phytopathogenic fungi in genera such as *Phytophthora, Fusarium, Verticillium, and Sclerotinia.* New resistant varieties to individual pests can be developed for some crops within in 5 to 15 years depending on crop species and genetic resources (research commitment).

There are limitations to what can be done through plant breeding even with the recent advances in molecular techniques. It is difficult to develop multiresistant cultivars. Most fields are infested with a multiplicity of major and minor plant pathogens. The use of cultivars resistant to only a limited number of pathogens results in increased severity of disease caused by pathogens that the cultivar is susceptible. Even for a single pathogen, cultivars may be resistant to a narrow spectrum of races within the pathogen's genome. This can result in the appearance of "new races" through selection by the use of these resistant cultivars. Some resistant genes are unstable in unfavourable environmental conditions, e.g. high soil temperatures, high salinity and may limit the efficacy of resistant plants. Finally, resistant cultivars can be integrated within crop rotation systems (integrated crop management i.e. ICM) to enhance pathogen suppression.

There are currently no cultivars of strawberries which have both sufficient resistance to withstand one or more of the soil pathogens limiting strawberry production, and also have acceptable yields and cultural traits for intensive cropping systems.

4.2.2 Chemical Alternatives

4.2.2.1 Introduction

No single chemical provides an alternative to preplant uses of methyl bromide in terms of consistency and efficacy against target pests. Therefore, combinations of chemicals and/or other pest control methods will be necessary. Some combinations have already been shown effective. Additional research over multiple growing seasons, locations and pest pressures is underway to determine required application rates and procedures for preplant soil treatments. Factors affecting costs include direct costs of the alternative, labour inputs and decreased efficacy against target pests. In many cases depth of soil penetration, poor dispersion of the chemicals under various conditions and narrow effective temperature ranges result in inconsistent control. Although total yield may not be impacted adversely by an alternative chemical, the quality and production patterns can be affected.

4.2.2.2 Chloropicrin

Chloropicrin adequately controls most soilborne fungi, root destroying insects and fruit marring organisms such as slugs, snails and earwigs, but provides little or no control of nematodes or weeds. Only recently have systematic long term experiments been initiated to evaluate the efficacy of chloropicrin alone as a preplant soil fumigant. Regulatory and trade restrictions could compromise its future use. Research is underway with chloropicrin to focus on development of combination treatments with other materials and practices which provide both weed and nematode control.

In some strawberry production areas in California where the viability of the industry is dependent on high value, early season fruit, clear plastic mulch is used to increase soil warming, and, in turn, enhance plant growth and yield. This practice would be discontinued if chloropicrin was used alone due to its inability to control weeds, resulting in a 5 to 10% reduction in growth and yield.

Chloropicrin/methyl bromide mixtures have successfully replaced pure methyl bromide in the Australian strawberry industry in response to reduced supplies of methyl bromide.

4.2.2.3 1,3-dichlorpropene (1,3-D)

With current use practices, 1,3-D alone provides effective control of nematodes and insects and suppresses some weeds and pathogenic fungi. Accelerated degradation of 1,3-D by soil micro-organisms after repeated application of the material has been demonstrated in rare instances resulting in variable yield. Further, 1,3-D in air and shallow groundwater has been reported. Water contamination could be a concern if 1,3-D is not applied properly or in areas where there is a high water table. In the United States, new EPA regulatory actions will result in additional restrictions limiting application rate, geographical areas of use, as well as imposing costly requirements for personal worker safety equipment in the field.

Research is underway with 1,3-D in the United States to focus on development of combination treatments with other materials and practices which provide weed and nematode control.

4.2.2.4 Ethylene Dibromide (EDB)

EDB is a liquid fumigant that is an effective nematocide with some activity against arthropods, but with little activity against weeds and soilborne pathogens. It has been banned in most countries because of environmental and health effects. Where EDB is still permitted, it is being tested in combination with other chemicals.

4.2.2.5 Metham Sodium

Metham sodium is a liquid preplant soil chemical and is effective for controlling arthropods, some weeds and soilborne pathogens, principally fungi, and a limited number of parasitic nematode species. Recent studies using injection methods of application have shown that metham sodium does not provide consistent control due to non-uniform distribution in the soil. Control failure has also been attributed to a build-up of micro-organisms that may result in increased degradation of the chemical. As a result, preplant soil treatment with metham sodium presents problems with consistency of yield. It does not disperse well in the soil and requires water for good movement and efficacy. Research is underway to improve chemical dispersion systems and to develop combination treatments.

4.2.2.6 Dazomet

Dazomet is a granular preplant soil chemical and has been reported to control weeds, nematodes and fungi. Recent data indicate that treatment with dazomet does not always provide consistent control due to non-uniform distribution in soil. Dazomet requires mechanical distribution in the soil for good movement and efficacy. Research with dazomet is underway to improve chemical dispersion systems, chemical formulations, methods of application and combination treatments.

4.2.2.7 Combination of Chemicals and Other Systems

Combinations and/or rotations of chemical alternatives have achieved broad spectrum pest control and yields approaching those obtained with methyl bromide. These include 1,3-D + chloropicrin in strawberries (California), 1,3-D + chloropicrin + the herbicide pebulate in tomatoes (Florida) and EDB + dazomet in tobacco (Zimbabwe). A combination of 1, 3-D + MITC (Vorlex ®) was previously identified as a potential alternative, but is no longer available and not currently being tested.

Combinations of chemical alternatives with non-chemical alternatives, notably solarisation, have shown some promise but require further study. Examples include metam sodium or 1,3-D + chloropicrin in combination with solarisation or gas impermeable plastic mulches. Studies are being conducted to evaluate additional combinations and to optimise ratios of chemicals and improved methods of application. Where feasible, combination of methyl bromide and solarisation appear particularly promising with field trials in southern Europe and Israel giving good pest control with methyl bromide reduced by 50% or more (Anon. 1996).

4.2.2.8 Other Chemicals

There are numerous pesticides that provide control of specific pests, and combinations of these chemicals may provide a broader spectrum of control than the individual chemicals. Many of these chemicals are mentioned in the 1994 MBTOC report.

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5 ALTERNATIVES TO METHYL BROMIDE FOR FUMIGATION OF DURABLES

5.1 Introduction

There are a number of alternatives for methyl bromide (MeBr) uses on durable commodities which could be or are available. Most have been tested under commercial conditions in both Article 2 and Article 5(1) countries. In the two years since the issue of the MBTOC report there has been considerable research in Article 2 countries on various important durable commodities including grain, dried fruit and nuts, timber and museum artefacts.

The fumigant phosphine is a leading contender in the search for MeBr replacement technologies for durable commodities. There are drawbacks to further extending its use in view of increased pest resistance, regulatory questions relating to health and safety, corrosivity and ineffectiveness at low temperature. Logistical and facility problems related to long treatment times will make it difficult to expand the use of phosphine as a replacement to those uses of MeBr in Article 5(1) countries where rapid action is essential.

This report presents developments on grain as a significant use area of MeBr. Also considered were dried fruits and nuts, a minor use area with a significant input into a wide variety of food industries, and museum artefacts which have immense cultural and economic significance. The few developments in another significant MeBr use area, timber, have not been considered because these are exempted from the phase out timetable as quarantine procedures. There are other important MeBr use areas within the category of durables (for example, processed foods) that are not included in this response to Decision VII/8 because there has been no progress in the identification of alternatives.

5.2 Scope of Alternatives and their Adoption (Decision VII/8)

5.2.1 Control of Grain Pests with Phosphine

Phosphine has been in widespread use as a fumigant of grain for over 40 years, and is a viable alternative to MeBr, particularly at higher temperatures. It is an extremely good penetrant and is effective against pests at low concentrations. Some insect and mite stages require long exposures (5 to 28 days) for control, particularly at low temperatures. MeBr treatments can be carried out within 24 hours under most conditions and so tend to be used where time is critical such as at the point of export or import. In situations such as ports where facilities cannot remain idle for the time that may be required for a phosphine fumigation, considerable reworking of commercial practices may be needed before MeBr can be replaced and a more rapid disinfestation technique such as heat or irradiation may be more appropriate.

Phosphine has been used for many years in almost all Article 5(1) countries and continues to replace MeBr where this is practicable. Insect resistance to phosphine, however, is becoming more widespread, particularly in Article 5(1) countries, mainly due to faulty applications. Some pests have developed mechanisms to actively exclude the gas or to reduce the sensitivity of active sites. However, the resistance problem can be overcome by increasing the treatment exposure period under well sealed conditions. New technology is becoming available to extend fumigation periods using continuous dosing systems. Phosphine can replace most of the methyl bromide currently used in this application.

5.2.2 Control of Grain Pests by the Use of Controlled Atmospheres, Carbon Dioxide, Nitrogen or Inert Atmospheres Generated by Combustion

Carbon dioxide atmospheres of 60% or higher, or atmospheres containing less than 1% oxygen are effective against all stored-product pests, but has limited potential as an MeBr alternative. Long exposures are required, especially at low temperatures (for example, 4-8 weeks at 15°C) and a very high degree of sealing needs to be maintained for the treatment enclosure. Either category of atmosphere may be more suitable to recommend for use depending on local supply, economics, main target pest and local equipment. Some transfer of controlled atmosphere technology has occurred for treatment of bagged rice with CO_2 in South East Asia, but lack of technical infrastructure, equipment and its maintenance is hampering widespread adoption in some other Article 5(1) countries.

5.2.3 Control of Grain Pests using Chemical Protectants/ Inert Dusts

These products are generally applied to bulk grain and thus have limited potential to replace MeBr use. They are ineffective against hidden stages of internal feeding insects like *Sitophilus granarius* and *Rhyzopertha dominica*, but kill these pests when they emerge from the grain kernels as adults. The development of resistance is a major biological constraint on the long term use of particular protectants. There is, thus, a continuous need for the development of new protectants, but this is constrained by the small market (in terms of product volume) for use on stored grain.

Protectants were formally used as a corrective or prophylactic treatment world wide. Usage has declined because of insect resistance, health and safety concerns as well as market/consumer acceptance of residues. Another limitation is registration of compound(s) in different countries. Generally, this control technique is not suitable for use as a rapid disinfestation procedure, which is the major area of use of MeBr, though admixture of infested grain is sometimes practised and may give satisfactory results especially when using more volatile compounds (e.g. dichlorvos). Inert dusts, including diatomaceous earth, as grain protectants have continued to receive some attention and there have been both positive and negative results. Some types of diatomateous earth products have been in widespread use in grain storage for several years as a component of a non-chemical IPM system of grain management which reduces the need for MeBr treatments. Tests in Germany have shown that there is poor efficacy against weevils at 15% moisture content and above. New dusts continue to be developed and approved that are effective at lower application levels and thereby prevent the grain quality from being reduced.

5.2.4 Control of Grain Pests by Irradiation

Irradiation has been shown to be effective in some grain applications but has limited potential for replacement of MeBr. It is currently commercially used for bagged grain in Indonesia, and in smaller applications in other Article 5(1) countries (eg. China and Thailand). The logistics of moving large amounts of grain to the irradiation site is a constraint unless the irradiator is placed at a common point of movement such as a port. Irradiation has been used for bulk grain at a port, but currently there are no bulk grain irradiators in operation. A point treatment, similar to MeBr, irradiated grain is subject to re-infestation. This exacerbates the logistical problem. Irradiation might be used in combination with some other technology.

5.2.5 Control of Pests in Dried Fruits and Nuts using Phosphine

Phosphine is currently used for fumigation of a significant portion of almonds, pistachios, dates, figs, prunes and raisins world-wide. It has already replaced MeBr where practical. Problems have been encountered with off-flavours in walnuts. Compared to 24 hours or less for MeBr, fumigation will take 5 to 28 days, depending on temperature and humidity. Phosphine cannot be applied effectively below 10°C against dried fruit pests. As with MeBr, and particularly because of the longer exposures, use of the fumigant requires well sealed facilities. Insect resistance may be a problem, particularly when poorly applied over a continuous period of time. In the presence of moisture, phosphine may be corrosive to copper and copper-containing alloys.

5.2.6 Control of Pests of Dried Fruits and Nuts using Oxygen Deficient Atmospheres

Factors which will limit the use of oxygen deficient atmospheres to replace MeBr include long treatment times, higher equipment costs, increased energy requirements and increased equipment maintenance. Results of laboratory studies published in refereed journals show the efficacy of controlled atmosphere and the influence of gas levels, relative humidity and temperature on exposure requirements for storage pests. The technique has been field tested in the USA. All insect species were controlled by a 0.5% oxygen atmosphere. In many countries use of low oxygen atmospheres is exempt from registration.

5.2.7 Control of Dried Fruit and Nut Pests using Irradiation

Irradiation is technically efficacious and does not cause food quality problems in dried fruit and nuts, except for walnuts at dosages reaching 0.9 kilogray. There are many factors limiting the implementation of irradiation as a replacement for MeBr. Treated insects may survive for some time after treatment. The economics of commercial facilities would improve if adequate volumes of other commodities were available to the facility throughout the year. The possibility of having to retreat stored product, re-infested under current storage procedures, also poses logistical problems, and a significant barrier if the product has to be transported to the irradiator. Some governments restrict the use of irradiation.

Improvements in storage facilities or combining irradiation with preventative treatments may be necessary. Product handling procedures and the high initial capital cost of irradiators, make this technology difficult to implement. Although laboratory tested in several Article 5(1) countries (eg. Pakistan, Algeria, Syria) this technique in not in commercial use for these commodities. Food labelling requirements may be a constraint in some countries.

5.2.8 Control of Indianmeal Moth in Stored Products using Granulosis Virus (GV)

The granulosis virus is a baculovirus infectious only to Indianmeal moth and a few closely related insect species, and thus has limited potential as a replacement for MeBr. It has been tested as a long-term protectant for bulk and packaged commodities (walnuts, almonds, raisins, wheat, corn and peanuts) where these moths are a particular problem. Production and formulation methods have been patented, but the GV is not registered as an insecticide. Primary use of the virus would be as a protectant while the commodities are in marketing channels where its use has been studied most extensively. It has also been tested as a protectant for commodities in bulk storage, and can be expected to protect commodities for periods in excess of six months. One of the impediments to commercialisation is its specificity to Indianmeal moth and a few very closely related species. The virus can be applied as a dust or spray. It has no known effect on commodity quality.

5.2.9 Disinfestation of Artefacts

There are existing and potential alternatives to MeBr in this use area. Several techniques have been researched for the treatment of museum and cultural artefacts, including use of modified atmospheres, low oxygen treatments or CO_2, low temperature and heat treatments with controlled humidity. Modified atmosphere treatments are in use in some Non-Article 5(1) countries.

5.3 Recent Advances in Development of Alternatives

5.3.1 Grain and Legumes

There have been further developments in research on the alternative fumigant phosphine. For storage and pre-shipment treatments, phosphine is increasingly being used in some countries because of better application methods and gas distribution systems in conjunction with the use of less permeable sheeting and improved sealing techniques for longer containment of gas. Additionally, a new on-site generating machine for phosphine has been field tested in Germany, Argentina and Chile and is commercially available.

A cylinder-based formulation of phosphine in liquid carbon dioxide has been tested and is commercially available. In contrast to phosphine generated from pellets, the formulation offers simultaneous application and immediate release of carbon dioxide and phosphine together, reducing risk of reaction with air and introducing the possibility of maintaining a fixed concentration of phosphine. Exposure times may be slightly reduced and a reduced dose of phosphine may be permitted, which may reduce the corrosive potential against certain metals. As no water vapour is required to release the gas, the use of phosphine can be extended to very dry commodities.

Research is also in progress on controlled atmospheres (CA) of different types. Nitrogen supplied as liquid nitrogen *is* in use at port facilities in Australia and nitrogen pressure swing adsorption (PSA) generators for grain in bins in Germany. Carbon dioxide is used to a limited extent commercially for bulk grain disinfestation in Australia. Research is in progress on the use of a propane combustion system for treatment of grain in bolted metal bins in the UK, on the use of carbon dioxide for silos in elevators in Canada, and for silos in Kenya where there is a local supply from volcanic sources and technology has been transferred up to the development of training programmes.

In Japan regulatory approval has been established for the use of carbon dioxide to control insects other than *Sitophilus* spp. and *Trogoderma granarium*. A new compound, methyl phosphine is under investigation in the UK which acts selectively against phosphine resistance strains. In the People's Republic of China there has been a slight increase in the use of methyl bromide on grains to deal with phosphine resistant strains.

Inert dusts as grain protectants have continued to receive some attention and there have been both positive and negative results. A particular diatomaceous earth product has been used as a component of a non-chemical IPM grain management system for many years in some countries, reducing the need for MeBr treatments. Tests in Germany have shown that there is poor efficacy at 15 % moisture content or greater against weevils. Research by Agriculture Agri-Food Canada revealed the importance of diatom type in determining the efficacy of the dusts, and regulatory approval for application of 100 ppm has been given for a new product following satisfactory efficacy trials.

Some bagged rice continues to be irradiation disinfested in Indonesia before storage under government contract. The main method of long term protection of milled rice in the large Indonesian parastatal system is with carbon dioxide under sealed storage, avoiding the need for MeBr fumigation.

Research on biological control has continued in Germany and Denmark on the use of the egg parasitoid *Trichogramma* for control of moths, the main cause of MeBr fumigations in a number of storage situations. In Canada there is an active promotional program for pest management for grain post-harvest by a system of preventative steps during storage starting from the farm to the point of export without the use of MeBr.

5.3.2 Dried Fruits and Nuts

The past two years have seen a tendency to replace MeBr by phosphine for treatment of dried fruits and nuts (except walnuts) in different parts of the world. Continuing research on IPM activities include the combinations of granulosis virus, cold, heat and controlled atmosphere. Research is also in progress on carbonyl sulphide and on natural enemies. At present no non-methyl bromide quarantine treatments have been approved for these products.

In Australia carbon dioxide disinfestation of packed sultanas has been demonstrated under full scale commercial conditions both in storage stacks and when containerised for export. Also almonds are commercially stored in bulk under low temperature after disinfestation with nitrogen in Australia.

5.3.3 Beverage Crops

There have been no recent developments other than cocoa beans which are increasingly being treated with phosphine instead of methyl bromide.

5.3.4 Herbs and Spices

In the USA about 30,000 tonnes are now treated with irradiation and the trend is for further increase of this proportion. World-wide, approximately 25% of the spices that require treatment are irradiated. Another technique for treating spices in Germany is the use of carbon dioxide in chambers under high pressure. In Denmark phosphine or carbon dioxide have gained increased use on herbs and spices where insects rather than pathogens are the targets for treatment.

5.3.5 Tobacco

Phosphine resistance in the cigarette beetle *Lasioderma serricorne*, a major stored tobacco pest, has been detected and is under investigation in the UK. Phosphine is now widely used in preference to MeBr for disinfestation of stored tobacco but high resistance levels may lead to reconsideration of MeBr use unless other procedures are developed.

5.3.6 Artefacts

A commercial technique employing heat and humidity to disinfest museum artefacts has been field tested in Germany, Austria and the UK.

CA with humidified nitrogen in a carefully constructed gas tight enclosure can control all stages of museum insect pests after purging to bring oxygen levels down to about 1%. The introduction of a proprietary oxygen scavenger can bring oxygen levels down further to 0.05 % and hold them there for 30 days.

In Denmark fumigation of museum artefacts and historic buildings with MeBr has now ceased and is substituted by spot treatment with chemical pesticides and occasionally heat treatment. Cooling techniques are also used as appropriate for smaller objects. A method optimising cooling treatments by consideration of insect supercooling points has been proposed and methods of diagnosing probability of pest presence have been improved to prevent unnecessary treatments and save costs. A new method of optimising heat treatment while lowering the risk of physical damage by controlling humidity is under development.

5.3.7 Logs, Timber, Bark and Wood Products

New developments include the adoption of phosphine to treat bamboo in transit to forestall MeBr quarantine treatments in Japan, and work in Germany on carbonyl sulphide, methyl iodide and sulfuryl fluoride. In Germany and Japan a mixture of phosphine with sulfuryl fluoride and a method to use methyl isothiocyanate to control fungi in timber are being researched. It is reported from Japan that improved sealing methods using less permeable films have achieved a saving of 5% MeBr use.

Collaborative research has been conducted on irradiation in Russia with the United States to provide a quarantine treatment for logs transported from Siberia to the US.
If successful this would present an alternative to MeBr treatment. Some wood products are commercially irradiated on arrival in Australia as a quarantine treatment.

5.3.8 Other Products

There have been no reported developments for treatments of seed stocks, dried fish, sea food nor dried meat.

In Australia irradiation is used for trade in forage crops between Australia and New Zealand under quarantine procedures. Disinfestation of pet foods is increasingly carried out in Germany and France by use of carbon dioxide under high pressure in chambers.

6 ALTERNATIVES TO METHYL BROMIDE FOR FUMIGATION OF PERISHABLES

6.1 Introduction

Under the Protocol there are no controls on quarantine and pre-shipment (QPS) uses in recognition that loss of approved treatments would severely curtail international trade if alternatives were not commercially available. The volume of MeBr used for QPS treatments of perishable commodities e.g., fresh fruit, vegetables, cut flowers and nursery stock, is estimated at less than 8% of total consumption (MBTOC 1994; TEAP 1995), with about 90% of this released to the atmosphere. However, MeBr is used mostly on economically important perishable exports and, for those countries that cannot allow exemptions for QPS, alternative treatments to MeBr for perishables are still urgently required.

Almost all treatments of perishables with MeBr could be exempt from control under Article 2H, except in some countries scheduled to ban all MeBr uses including QPS. These schedules, coupled with the need to develop treatments that maintain or improve the quality and/or shelf life of commodities currently treated with MeBr, are encouraging the development of QPS treatments. In addition, most QPS treatments are commodity and pest specific leading to a range of potential solutions requiring evaluation. Moreover, new quarantine treatments based on MeBr are still being developed and submitted for approval e.g., apples from Tasmania to Japan for codling moth control, confirming that the use of MeBr as post-harvest treatment may actually increase while other pre-harvest uses continue to decline.

As QPS treatments are used mostly for valuable export commodities. They are generally complex and require much time to refine to a stage where they kill pests without affecting the marketability of the commodity (often specific varieties). In order to preserve the quality and market life of perishable commodities, specific treatments are often of short duration. New treatments may require repetition of specific experiments in each importing country prior to regulatory approval. Therefore, information on progress remains important for considering their potential as treatments for perishable commodities.

Alternatives available are summarised in Table 1 (MBTOC 1994). The number of cases where alternatives have been approved and implemented by various countries is summarised in Table 2 which now exceeds 97 examples. Many of these existed prior to 1994 when the MBTOC last reported QPS for perishables. They represent only a small percentage of quarantine treatments world-wide, and each proposed treatment requires evaluation on a case-by-case basis.

Furthermore, there is currently no approved substitute for methyl bromide treatment immediately on arrival for imported perishable commodities infested with pests of quarantine importance. This use is regarded as most important for protecting the agriculture of many countries around the world from the introduction of exotic pests. Without such a treatment, the onus must be placed on the exporting country to ensure freedom from quarantine pests.

Also reported here are examples of disinfestation treatments implemented since MBTOC (1994), and those with potential for implementation within the next 2-5 years. While most examples are 'new' treatments rather than replacements for 'existing' ones based on MeBr , they serve to illustrate the investment in a range of commercial options to avoid further QPS dependency on MeBr.

6.2 Alternatives Implemented

6.2.1 Systems Approach

The systems approach is based on a reduction of key pests at various stages of the pre- and post-harvest chain. Brazil has recently accepted a 'Systems Approach' for apples exported from the United States (J. Thaw, USDA-APHIS, pers. comm. 1997).

Avocados from Mexico exported to 19 North-eastern states in the USA certified free of avocado seed weevil, avocado seed moth, avocado stem weevil, fruit fly and other hitchhikers based on field surveys, trapping and field treatments, field sanitation, host resistance, post-harvest safeguards (e.g., tarpaulins on trucks, screened packhouses), packhouse inspection and fruit cutting, winter shipping only and port of arrival inspection (Firko 1995; Miller et al. 1995).

The 'Systems Approach' for control of major quarantine pests often exceeds the security level required by some countries and could become more prevalent as a substitute for MeBr in the future. However, both exporting and importing countries need to be involved in the development of mutually-agreed pre- and post-harvest measures required for phytosanitary security if this methodology is to gain even wider acceptance internationally.

6.2.2 Pest Free Zones

Japan has accepted a range of horticultural products including grapes and kiwifruit from southern Chile based on freedom from Mediterranean fruit fly (Ceratitis capitata) (Anon. 1996).

6.2.3 Heat Treatment

Vapour heat has been accepted as a quarantine treatment for sweet potato weevil potentially infesting Japanese sweet potatoes shipped to the mainland from the southern islands of Japan (Anon. 1995a).

A review of heat-based treatments for disinfestation of perishable commodities has recently been published (Anon. 1996a).

6.2.4 Combination Treatments

Inspection combined with a heat treatment is a Proposed Rule (USDA-APHIS 1996) for interstate transport of lichi free of fruit fly from Hawaii to the mainland USA.

A mixture of MeBr, phosphine and carbon dioxide was registered for use in Japan for controlling arthropods intercepted on cut flowers (Anon 1995b). The MeBr dose was two-thirds less with the gas mixture than when used alone (Kawakami et al. 1995). No injury was observed on chrysanthemums and orchids which are sensitive to MeBr fumigation.

6.2.5 Chemicals Dips

Insecticidal dip is one of the most common post-harvest treatments for cut flowers (Hara 1994) and likely to become even more widespread as an alternative to MeBr in the future. Fluvalinate a synthetic pyrethroid, is registered for use on cut flowers in the USA, and its use has been recommended for tropical foliage plants imported into the US (Osborne 1986).

Reduction of field populations of pests followed by post-harvest insecticidal treatment must be cost effective, the insecticide must reach pests often well-hidden in plant parts, phytotoxicity must be avoided, operators must be well protected, and insecticide disposal must minimise environmental problems.

6.2.6 Irradiation

Disinfestation by irradiation for fruit flies is a Proposed Rule (USDA-APHIS 1996) for export of Hawaiian papaya (up to 250 Gy), litchi and carambola to the US mainland.

6.2.7 Research Close to Implementation

These treatments could be implemented within 2-5 years:

- Control of pests in sweet potato and root crops using an heat treatment (Hansen and Sharp 1992);
- Disinfestation of a range of pests intercepted on 17 species of cut flowers imported by Japan such as lily, orchid and carnation at an absorbed dose of 0.4 kGy (Hayashi and Todoriki 1996) using electron beam irradiation;
- Radiation-based disinfestation of litchi, orchids, mango, fresh herbs and ornamental plants of insects and mites of quarantine importance (Anon 1996b);
- Reduction of scale insects on citrus in the USA using a high pressure post-harvest wash (Walker et al. 1996), but scale insect removal may not be sufficient for some countries to accept it as a quarantine treatment;
- In-transit, controlled atmosphere (CA) (high CO2, low oxygen) combined with cool-storage disinfestation of table grapes exported from the USA to Australia (Mitcham et al. 1995, 1996);
- Heat treatment of apples, pears and cherries using forced hot air for disinfestation of codling moth, combined with a controlled atmosphere and post-harvest cool-storage to reduce the duration of the heat treatment (Neven 1995);

- A low-oxygen treatment developed by the United States Navy to preserve the quality of leafy vegetables uses a CA in shipping containers while in transit to Guam (Gay et al. 1994). Although not yet supported by entomological research, this treatment has also substantially reduced the number of occasions treatment was required on arrival for quarantine pests; and

- Controlled atmosphere mixtures of oxygen, nitrogen and carbon dioxide gases applied in-transit for controlling fruit flies in citrus, mango, avocado and other fresh fruit shipped from California and Texas to other parts of the USA (Anon. 1996c).

6.2.8 MeBr Decrease

Preventative treatments carried out prior to shipment that do not use MeBr have reduced its use in specialised cases for pests intercepted in the destination country. It is important that shippers be made aware of such treatments because more widespread use will reduce MeBr consumption. For example, bamboo stems loaded in sea containers are imported by Japan from Taiwan and fumigated with aluminium phosphide in-transit. As a result, both MeBr fumigation for live pests in Japan and delays in marketing are reduced.

6.2.9 Alternatives for Quarantine Security

Historically, the mutual acceptance of a new QPS protocol by trading partners has taken 2-15 years because of extensive data requirements to Probit 9 security level (equivalent to 99.9968% mortality) demonstrating minimal risk of accidentally importing a quarantine pest. The USA is considering accepting a new approach to replace Probit 9. This would involve a sliding scale based on pest risk combined with packing, distribution and inspection activities to mitigate against pest infestation of the commodity (Anon 1997). Reducing the treatment acceptance criterion while still maintaining quarantine security increases the opportunity for researchers to identify treatments less harmful to the commodity as alternatives to MeBr.

__Table 6.1__ Alternative quarantine techniques, with examples of approved applications for fresh fruit, vegetables and cut flowers (Source: Compiled from MBTOC 1994: 222-226)

Procedure or treatment	**Examples of approved quarantine applications**
Cold treatments	• Grapes & kiwifruit from Chile to Japan
	• Citrus from Israel, South Africa, Florida (USA) to Japan
	• Cherries from Chile to USA
	• Apples from Chile, Mexico, Israel, Italy, France, Spain, South Africa to US
	• Citrus from 23 countries to USA
	• Peaches, apricots and plums from Morocco to USA
Heat treatments	• Mangoes from Taiwan to Japan
	• Papaya from Hawaii to Japan and USA
	• Narcissus bulbs to Japan and USA
	• Tomatoes, zucchini, squash eggplant, bell peppers to USA
Certified pest-free zones or pest-free periods	• Melons from a region of China to Japan
	• Squash from Tasmania to Japan
	• Cucurbits to Japan and USA
	• Nectarines from USA to New Zealand
Systems approach (IPM)	• Immature banana to Japan
	• Avocado
Pre-shipment inspection and certification	• Certain cut flowers from Netherlands to Japan
	• Apples from Chile and New Zealand to USA
	• Nectarines from New Zealand to Australia
	• Green vegetables to many countries
Physical removal of pests	• Root crops are accepted by many countries if all soil removed
	• Hand removal of certain pests from cut flowers to USA
Controlled atmospheres	• Apples from Canada to California.
Pesticides, fumigants, aerosols	• Cut Flowers from New Zealand to Japan
	• Asparagus to Japan
	• Tomatoes from Australia to New Zealand
	• Cut flowers from Thailand and Hawaii
	• Bulbs to Japan
Irradiation	• Plums
	• Garlic
Combination treatments	• Soapy water and wax coating for cherimoya from Chile to USA
	• Vapour heat and cold treatment for lychees from Taiwan to Japan
	• Pressure water spray and insecticide for certain cut flowers to USA

Table 6.2 *Number of known cases where countries have approved an alternative quarantine technique for perishable commodities (or groups of similar commodities)*

Alternative procedure or technique	**Number of cases where a country has approved an alternative quarantine treatment**
Systems Approach	4
Pest-free zones or periods	7
Pre-shipment inspection	many
Cold treatments	61
Heat treatments	11
Controlled atmospheres	1
Modified atmospheres	nil
Physical removal of pests	many
Combined treatments	4
Fumigants other than MeBr	5
Chemical dips	4
Total	>97

Source: Compiled from MBTOC 1994 and this report.

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7 ALTERNATIVES TO METHYL BROMIDE FOR FUMIGATION OF STRUCTURES AND TRANSPORT

7.1 Introduction

In preparing this response the same basis for analysis as agreed for the 1994 report was used, which are as follows:

Structural fumigation is a pest management technique that uses a fumigant on either an entire structure or a significant portion of a structure. The structure may contain raw agricultural commodities, raw products in process or finished food products awaiting delivery to distribution points. Fumigation is utilised whenever the infestation is so widespread that localised treatments may result in re-infestation or when the infestation is within the walls or other inaccessible areas.

Methyl bromide is currently used as a structural fumigant in three types of facilities: food production and storage (mills, food processing, distribution warehouses), non food facilities (dwellings, museums) and transport vehicles (trucks, ships, aircraft, railcars). Target pests include stored product pests (mites, beetles, moths) cockroaches, silverfish, psocids, flies, spiders; wood destroying insects (termites, beetles); and rodents.

7.2 Alternatives for Fumigation of Structures (Decision VII/8)

7.2.1 Phosphine, Carbon Dioxide and Heat

This combination is currently being used in the USA and Canada in full scale trials. Tests to date show it to be efficient against the main mill pests, but further data is required to measure efficacy under a wider range of conditions and against a full range of mill pests. Development of resistance from less than fully efficient treatments is an unquantified risk.

Application requires a very high skill level and is labour intensive. Risk of corrosion damage has not yet been defined. This process may be limited in use by climatic conditions affecting corrosion risk, and also by carbon dioxide availability in some parts of the world. Registration requirements and additional insurance requirements in some countries will affect commercial uptake. It is currently estimated to cost a minimum of 50% more than a comparable methyl bromide treatment. It has not been tested in Article 5(1) countries.

7.2.2 Phosphine from Metallic Phosphides

Phosphine generated in situ from metallic phosphides is rarely used commercially for structural fumigation and is unlikely to be used in the future because of corrosion risk and the potential for resistance development by insects. These are greater when phosphine is used alone due to the higher concentrations or longer exposures required. This method was used annually as a structural fumigant in Mauritius. This resulted in damage to electrical circuits and no further treatments have been undertaken. Phosphine generated from metallic phosphides is produced slowly and unevenly and the concentration produced is impossible to control with any precision. This should be improved in the future by the use of phosphine generators currently being developed in Chile and Australia.

7.2.3 Phosphine in Cylinders with Carbon Dioxide

Cylinder-supplied phosphine provides potential for lower dosages and more accurate application of phosphine than other phosphine producing methods. However, corrosion risk and potential for resistance development remain but some of the risks may be reduced using this method. Currently this product requires registration in most countries and has not yet been used either commercially or in field trials in structures. The cost of phosphine supplied in cylinders is currently 4 to 5 times more expensive than when it is liberated from metallic phosphides. This method has not been tested in Article 5(1) countries.

7.2.4 Heat

Heating is currently used commercially for insect control in some food production facilities in the USA and some other countries; this method has been used for many years in some buildings. Efficacy against stored product insects is acceptable if the temperature requirements are met, but methyl bromide is occasionally used as an emergency measure where heat treatments fail to achieve the required degree of control. Application is relatively simple and safe but the risk of structural damage and additional insurance requirements may limit the use of this method. Climatic conditions do not limit this method but it is more economical in warmer climates. It has not been tested in Article 5(1) countries.

7.2.5 Heat and Humidity

A combination of heating with controlled humidity is currently being used in commercial field trials for the treatment of wood boring insects in Germany and the UK. Small scale trials are planned to take place in food production buildings shortly. Efficacy against wood boring insects is proven and the efficacy of heat treatment against stored product insects is also proven provided the required temperature is achieved and maintained. Application requires highly a skilled workforce and is labour intensive. The control of humidity in direct proportion to the heat used provides the opportunity for shorter exposure times and lower energy input. No registration is required but high capital cost and the level of skill required may delay uptake by industry. It has not been tested in Article 5(1) countries.

7.2.6 Cold Temperature (Using Ambient Climatic Conditions)

Cold is currently used for insect control in parts of Canada and other countries with suitable climates. It is very effective where temperatures can be reduced by using ambient conditions to a low enough level to eradicate infestation. Application is simple with low risk to workers and there are no registration requirements, however it is only applicable in very limited climatic conditions. In the right location it is economical. It may already be used in Article 5(1) countries with appropriate climates.

7.2.7 Sulfuryl Fluoride

Sulfuryl fluoride is currently used as an alternative fumigant to methyl bromide against dry wood termites and the efficacy for this use is well proven. For wood boring beetles the dose required is up to 10 times that required for dry wood termites because of sulfuryl fluoride's poor ovacidal properties. Efficacy against stored product insects (SPI) is less well developed and research is underway in Europe. Application is similar to methyl bromide. The mammalian toxicity of sulfuryl fluoride is similar to methyl bromide. Field trials in buildings in Germany are taking place in locations where food is not present. This product has not been registered in most parts of the world. Sulfuryl fluoride is used for control of dry wood termites where the cost of a treatment is approximately the same as methyl bromide but when used against wood boring insects the cost is about five times more due to the extra quantity of gas required. For stored product insect control more development work and efficacy information is needed to allow it to be used commercially. It has not been tested in Article 5(1) countries.

7.2.8 Modified Atmospheres (MA)

This treatment consists of either using low oxygen atmospheres (less than 1%) or high carbon dioxide atmospheres (greater than 60%). It has been used in field trials in buildings in Germany and the Netherlands and is being used for certain localised container and truck quarantine fumigations in Australia. It has the potential to be used for the treatment of rodents in aircraft. Application in most situations requires that extremely gas tight conditions are maintained for a long period. It is commonly available but will require registration in some countries. Treatment is likely to be 3 - 5 times more expensive than with methyl bromide for small short exposure treatments (e.g. containers or aircraft for rodents). From the field trial data available for buildings costs are likely to be 10 times or even greater than for methyl bromide. It has not been tested in Article 5(1) countries.

7.2.9 Hydrogen Cyanide (HCN)

Hydrogen cyanide is currently used in a few countries for the de-ratting of ships (in Singapore it is a mandatory method) as it is very rapid and effective in this situation. It has been used previously for mill fumigation but today most registrations have expired and are unlikely to be renewed due to public perception and toxicity concerns. Application is quite difficult due to the high toxicity, water solubility and high flammability. HCN is not commercially available in most countries and is unlikely to be so for the reasons given above. Treatment is likely to be twice the cost of a methyl bromide fumigation. It is not used in Article 5(1) countries.

7.2.10 Integrated Pest Management

The most advanced systems that have been developed and are currently used in food production plants have been demonstrated to provide effective control for a number of years in a number of countries. There is no evidence yet available that indicates that the necessity for localised spot treatments or full site eradication (using fumigants or heat for example) will be eliminated entirely even with the most effective system. IPM applications are relatively labour intensive and requires a high level of ongoing training of all people involved. It has the potential of being adapted to suit any geographic or climate location. IPM is widely commercially available provided access to the necessary training, suitable methods, and localised or full site treatments are available. It may be either more expensive or less expensive than a system dependent on methyl bromide fumigation and it appears that this will vary according to the location and the acceptable level of infestation. It is used world-wide with varying degrees of complexity.

7.2.11 Liquid Nitrogen (Rapid Generation of Sub-Zero Temperatures)

Liquid nitrogen has primarily been limited to the control of drywood termites. It has been used in the U.S. for several years with limited success. It is confined to wall void treatments, not for full sites and is dependent on a thorough inspection of the pest location and the containment area. Deprivation of oxygen has been a concern for workers when leakage occurs. Some damage to water pipes has occurred. Not tested in Article 5(1) countries.

7.2.12 Microwave

The use of microwaves has primarily been limited to the control of drywood termites. It has been used in the U.S. for several years with limited efficacy. As a localised treatment its success is dependent on a thorough inspection and the evenness of the microwaves to avoid hot and cold spots. There is concern about the health risks because of the difficulty of shielding microwaves. Some damage to properties has occurred because of overheating of the target area. Not tested in Article 5(1) countries.

7.3 Recent Advances in Development and Use

7.3.1 Substitute and Alternatives for Pests other than Wood Destroying Insects

7.3.2 IPM programs

In some countries (eg Canada, UK, Denmark and Australia) more advanced IPM programs have been instituted so that the frequency of full-site treatments have been reduced or apparently eliminated.

7.3.3 Phosphine in Cylinders

The use of cylinderised phosphine and carbon dioxide requires registration in most countries.

7.3.4 Phosphine, Heat and Carbon Dioxide

Phosphine, heat and carbon dioxide in combination has been trialed in the USA and Canada.

This process may be limited because of prevailing conditions affecting corrosion. The development of insect resistance to phosphine continues to be a concern because of the lower concentrations and reduced exposure times. More research needs to be done to quantify the risk of resistance and corrosion.

7.3.5 Sulphuryl Fluoride

Research is ongoing for stored product insects. Registration in at least one European country (Germany) is under consideration for facilities where no food or feed is present.

7.3.6 Carbonyl Sulphide

Carbonyl sulphide has not yet been registered.

7.3.7 Heat

The use of heat in some food production facilities in some countries (USA and Canada) has increased and the frequency of methyl bromide fumigations has been reduced. A research project is underway in Denmark to optimise heat treatment. The parameters of the project include low temperatures, short exposure, low energy consumption, reduction of physical damage with acceptable insect mortality.

The use of heat and humidity is currently being trialed in Germany and the UK.

7.3.8 Substitutes and Alternatives for Wood Destroying Insects

The use of sulfuryl fluoride is increasing and registrations are being considered in additional countries (Germany). Development of new wood preservatives has allowed for the discontinued use of chrome and arsenic based compounds in Denmark. Improvement of cooling techniques for moveable objects has taken place in Denmark.

7.3.9 Transport

In the Nordic countries methyl bromide will no longer be allowed for fumigation of ships and aircraft from 1998 including for quarantine. Treatment in ships will be carried out against rodents by using traditional pest control techniques or in extreme situations by using hydrogen cyanide or sulfuryl fluoride. In aircraft, treatment will be by traditional rodent control techniques.

8 ARTICLE 5(1) (DEVELOPING COUNTRIES) ISSUES

8.1 Introduction

This is an update to the 1994 MBTOC Report and provides new information beyond the findings and the general conclusions enumerated in that report. It is based on the best information available. This report seeks to establish whether or not there has been a noticeable change in use of methyl bromide and alternatives in Article 5(1) Countries.

This report contains four sections discussing changes in trends and data. The first section discusses trends in both methyl bromide use and the adoption of alternatives noted since the 1994 MBTOC report; the second section lists increases in the use of alternatives to methyl bromide in Article 5(1) Countries; the third section is an update on methyl bromide use in Article 5(1) Countries; and fourth section discusses country specific information as available. This information was obtained from MBTOC members and the 1995 UNDP Regional surveys which took place in English-speaking Africa, Latin America and the Caribbean, and South East Asia and the Pacific.

8.2 Trends Since 1994 of Methyl Bromide Use and Adoption of Alternatives

Since the 1994 MBTOC Report, a number of Article 5(1) Countries have decreased overall methyl bromide usage, and an increase in the use of alternatives has been noted. Specifically, methyl bromide use decreased in Brazil, Chile, Colombia, Peru, Venezuela, the Philippines, Thailand, and Zimbabwe. However, there have also been instances of increased use of this fumigant in some countries (China, Uruguay, Malaysia, Vietnam, Egypt, Kenya, and Morocco). Uganda reintroduced the use of methyl bromide in 1995. Use did not change significantly in Fiji, Indonesia, Ethiopia, Malawi, Mozambique, and Tanzania. Methyl bromide use is summarised in tables (8.6.1 to 8.6.3) and figures (8.6.1 to 8.6.3) shown in section 8.6. In addition information on China and Morocco is shown in section 8.4.

Factors which have contributed to an increase in methyl bromide in a particular country should be identified and addressed. For example, the development of insect resistance to phosphine can be a significant problem, as in China where methyl bromide use has increased over the past two years because of pest resistance issues in grain storage. However, strategies to overcome or avoid insect resistance are well documented and in use (Taylor and Gudrups, 1996). In general, methyl bromide use in other Article 5(1) is decreasing for the disinfestation of grain, with phosphine as the main cost-effective replacement.

Since the 1994 MBTOC Report was issued, educational, informational and public awareness programs regarding the methyl bromide issues and alternatives have been held in most Article 5(1) Countries. UNEP-IE has conducted regional seminars in English-speaking Africa, Latin America, and South East Asia and the Pacific concerning the adoption alternatives to methyl bromide. In addition, the National Ozone Offices, Governmental and Non-Governmental Organisations, Bilateral and Multilateral Agencies, and implementing agencies of the Multilateral Fund (UNEP, UNDP, UNIDO and World Bank) have held workshops and public campaigns regarding methyl bromide issues and alternatives. The methyl bromide industry has also held a number of seminars directed toward government officials in a number of Article 5(1) countries. These seminars and public awareness efforts as well as other impacting factors may have contributed to the use trends of methyl bromide and alternative noted in this report.

An area of concern is the potential of methyl bromide use in Non-Article 5(1) countries for agricultural production to move to Article 5(1) countries in the future. This may occur when methyl bromide is phased out in a Non-Article 5(1) country, and production of the agricultural crop dependant upon methyl bromide is transferred to an Article 5(1) where methyl bromide is available. In this case, it is possible that the amount of methyl bromide used in that Article 5(1) country may increase. Nevertheless, under this scenario, the situation may be counter balanced by consumers in Non-Article 5(1) countries who may exert influence against importation of agricultural products form Article 5(1) products which have been treated with methyl bromide. It is important that where a significant increase in methyl bromide use in Article 5(1) Countries is noted, careful consideration should be given to the above concerns to ascertain if indeed this is related to a transfer of a crop traditionally dependant upon methyl bromide. Hence, continued monitoring of methyl bromide use in Article 5(1) is a critical aspect of this issue.

The current status of the use of alternatives to methyl bromide on crops grown in Article 5(1) countries is shown in tables in section 8.5. Alternative soil pest control methods have been developed and are in commercial use for the major crop uses in Article 5(1) countries including cut flowers, tomatoes, strawberries, tobacco seed-beds, peppers, curcurbits and nursery crops. These alternatives have now been adopted in a variety of soil types, climates and regions.

The various alternatives and techniques which are in use or being introduced for soil uses include soil amendments, solarisation, resistant varieties, crop rotation, bio-controls, cover crops, composting and pesticides. Examples of alternatives include conventional seed trays for tobacco seed-beds in countries such as Zimbabwe and Brazil; solarisation for curcurbits in Brazil, Jordan and Morocco; steam for cut flowers in Brazil and Columbia; and soil-less cultures for strawberries in Indonesia and Singapore. Trials on a number of alternative methods are currently being conducted in some Article 5(1) countries including steam and CO_2 fumigation in Kenya. A low-cost method that shows promise is biofumigation, the tilling in of crops that give off volatile chemicals that suppress soil-borne pathogens.

Solarisation is an alternative to methyl bromide which is already used in a number of Article 5(1) countries for controlling soil pests. This pest control tool can be more widely adopted where climatic and soil conditions allow. This technique can be used in combination with other pest control methods in an integrated pest management (IPM) system. This has now been evaluated in tropical areas with success, proving effective in controlling pests and giving yields similar to fields treated with methyl bromide.

Integrated pest management strategies employing a combination of these techniques have also been successfully adopted for various crops and in certain regions in Article 5(1) countries. Examples of IPM systems which involve the use of cultivation practices and selected pesticides for strawberries are used in Zimbabwe and Guatemala. Mixed cropping with marigold (*Tagetes* spp.) is practised to control nematodes on vegetable fields in India, Kenya and Vietnam.

Phosphine remains the major alternative to methyl bromide for disinfesting commodities in most Article 5(1) countries. However, methyl bromide is still in use and especially where treatment has to be completed rapidly because of time constraints.

The potential use of CO_2 as an alternative to methyl bromide has been successfully demonstrated in fumigation of stored grains in bag stacks in Zimbabwe. This technique is already widely used in Indonesia and is under trial in Kenya for silo bins.

It is important to recognise that many of the pest management practices that are being used in one Article 5(1) country or region can be applied or modified for use on other crops or in other Article 5(1) countries or regions. Information sharing between Article 5(1) countries, technology transfer and farmer education and training must continue to promote the adoption of these alternatives in other countries and regions.

It is apparent that significant work still needs to be done to enhance confidence in and augment the adoption of alternatives to methyl bromide in Article 5(1) Countries. In particular, it is critical that future efforts continue to focus on field testing (on-farm demonstrations), the evaluation of efficacy, as well as the essential elements of technology transfer program which will ensure the adoption of alternatives. Field demonstrations, farmer education and training are integral components of these technology transfer efforts. Significant technical assistance and financial support, under the provisions of the Montreal Protocol, are critical to achieve these goals.

8.3 Country Specific Information

8.3.1 China

Methyl bromide use patterns, in tonnes, are shown in Table 8.3.1.1.

Table 8.3.1.1

Use	1991	1992	1993	1994	1995	Total	Average
quarantine	500	524	455	362	335	2,176	435
soil	17	24	53	92	341	527	105
post-harvest	35	31	18	10	19	113	23
structural	8	10	10	3	7	38	8
Total	550	589	536	467	722	2854	

8.3.2 Egypt

The UNDP Regional Survey (1995) indicated that Egypt continues to be the largest consumer of methyl bromide for commodity (cereals) disinfestation in Africa. (Table 8.6.3)

8.3.3 Jordan

Methyl bromide consumption in Jordan has dropped from about 900t in 1992 to 300t in 1996 largely as a result of adopting solarisation to replace methyl bromide in production of tomatoes, eggplant, cucumber, peppers and strawberries.

8.3.4 Kenya

Trials have been conducted in Kenya to evaluate the potential for fumigating cereal grains in vertical silos with CO_2 with a successful demonstration of disinfestation of maize (Brice et al. 1997). The local availability of the gas from a volcanic source was a major cost-effective factor in causing a successful outcome and a workable technique was established.

8.3.5 Malaysia

In Malaysia, 55.8 tons of methyl bromide were used in 1995 (Table 8.5.2).

8.3.6 Mexico

Approximately 10 million tonnes of grain are fumigated annually in Mexico; 25% of this is treated with methyl bromide and 75% is treated with phosphine. The total quantity of methyl bromide used by the official organisations ANDSA (national stores) and BORUCONSA (rural stores) to fumigate grain is reported to be approximately 100 tonnes per year; this quantity has not varied substantially in the last five years. It is also reported that no reductions in the usage of methyl bromide for commodity disinfestation are currently taking place.

An additional use of methyl bromide is for the fumigation of imported grain in ships. The large grain importations in recent years, varying from 4-6 million tonnes per year, due to poor harvests, have increased the number of quarantine treatments conducted. This has had a significant effect on the total methyl bromide usage. Application of methyl bromide for quarantine fumigations conducted on ships is reported to be at the relatively high rate of 57-60 g/m^3. However, information on the exact quantity of methyl bromide used for this purpose is currently not available.

8.3.7 Morocco

In Morocco, the quantities of methyl bromide utilised for quarantine purposes are very low compared to pre-plant soil use (Table 8.4.6.1).

Table 8.3.5.1 *- Methyl bromide Use Pattern in Morocco (in tonnes)*

Use	1992	1993	1994	1995
Quarantine	0.29	0.25	0.3	0.28
Soil	870	930	1,000	1,500

Methyl bromide is used in combination with chloropicrin (98:2) as a pre-plant fumigant. Use of chloropicrin alone is not permitted. The pre-plant rates of methyl bromide used for soil treatments vary from $70 g/m^2$ to $100 g/m^2$, primarily for greenhouse soil used in the production of vegetables, strawberries and bananas. In 1995, 1,500 tons of methyl bromide was used to fumigate about 2,300 hectares. Whole field fumigation is utilised for banana production, and strip fumigation is used for strawberry and vegetables (tomato, curcurbit) production. Strip fumigation, which is widely used in Morocco, has reduced methyl bromide use by 66% compared with full field application.

8.4 New Information on the Use of Alternatives in Article 5(1) Countries

The following section is composed of tables based on methyl bromide use. Each table contains a list of alternatives to methyl bromide which have been reported to be in use since the 1994 MBTOC Report, listed by crop, alternative, and the country. This section is intended to provide current information not only on the use of alternatives to methyl bromide, but also to stimulate communication on available alternatives between countries. Effectiveness of the following alternatives is not discussed, as this information was not available at time of drafting.

Table 8.4.1 *- Use of Alternatives on Soil-Borne Pests in Article 5(1) Countries*

Crops	**Alternatives**	**Countries**	**Comments**
bananas	nemacur, mocap	Philippines	registered for use
broccoli	cultural practices and pesticides	Guatemala	widely used
cumin	solarisation	India	limited use due to cost constraints and degradation of plastic tarp material
cumin	soil amendments	India	widely used for soil improvement
curcurbits	soil solarisation	Morocco	limited use based on nematode populations
curcurbits	soil solarisation	Jordan	limited use
curcurbits	soil & agricultural material solarisation	Brazil	recently introduced in green houses
curcurbits	grafting	Morocco	recently introduced for melon
curcurbits	resistant varieties	Morocco	widely used for melons
curcurbits	soil chemical pesticides	Morocco	limited use based on pest populations
curcurbits	soil-less culture (volcanic stones, rock wool, pearlite, oak bark)	Morocco	recently introduced for vegetable crops on limited acreage
cut flower seed beds	steam	Brazil	limited use because of cost issues
cut flowers	compost and steam	Colombia	cost effective
cut flowers	steam	Brazil, China, Kenya, Thailand	limited use because of cost issues, in an experimental state
cut flowers	Tagetes extract	Kenya	limited use because of lack of land for rotation
cut flowers	crop rotation	Kenya	limited use because of lack of land for rotation
cut flowers	Tissue culture to produce pathogen free plants	Kenya	limited use due to cost and expertise required - used for Statice, chrysanthemum

Crops	Alternatives	Countries	Comments
fruit tree nurseries	solarisation	Egypt	used only during hot season
lettuce	soil substitutes (grain hulls)	Chile	limited use
paprika	floating seed trays	Zimbabwe	limited use
paprika	directing sowing	Zimbabwe	limited use, but expected to increase
paprika	dazomet	Chile	widely used
peppers	dazomet	Chile	widely used
cut flowers	dazomet	Kenya	registered for use, limited use due to cost issues
cut flowers	metam sodium and dazomet	Brazil	widely used
cut flowers	steam and soil amendments	Colombia	widely used
cut flowers	dazomet	Malaysia	registered for use, widely used
tobacco seed beds	dazomet	Malaysia	registered for use, widely used
roses	biocontrol of *Agrobacterium tumefascens* with *A. radiobacter*	Morocco	used mainly for the production for grafted plants in nurseries
snow peas	cultural practices and pesticides	Guatemala	widely used
strawberries	straw and solarisation	Philippines	widely used
strawberries	resistant varieties	Morocco	used on large scale for some soil borne pathogens
strawberries	soil solarisation	Morocco	used at a limited scale with low nematode populations
strawberries	cultural practices and pesticides	Guatemala	widely used
strawberries	soil amendments	Zimbabwe	limited use, but accepted by growers
strawberries	soil & agricultural material solarisation	Brazil	recently introduced
strawberry seed beds	solarisation	Egypt	used in hot season
sugarcane	biocontrol: fungal pathogen, Beauveria	Mauritius	no data available
tobacco seed beds	floating seed trays	Zimbabwe	experimental
tobacco seed beds	floating seed trays	Brazil	recently introduced, use expected to increase

Crops	Alternatives	Countries	Comments
tobacco seed beds	substrate: pine bark, rice hulls, vermiculite, & manure	Brazil	recently introduced, use expected to increase
tobacco seed beds	pine bark substrate	Zimbabwe	experimental
tobacco seed beds	steam	Thailand	limited use due to cost issues
tobacco seed beds	selected cover crops	Zimbabwe	widely used
tobacco seed beds	resistant cultivars	Zimbabwe	used for root knot nematode
tobacco seed beds	composting	China	limited use
tobacco seed beds	1,3-D dazomet	Zimbabwe	widely used
tobacco seed beds	*Trichoderma harzianum*	Philippines, Zimbabwe	used as part of an IPM program for control of *Fusarium* and *Rhizoctonia*
tobacco seed beds	solarisation	Brazil	experimental
tobacco seed beds	dazomet, metam sodium	Brazil	recently introduced
tomatoes	soil substitutes (grain hulls)	Chile	limited use
tomatoes	soil & agricultural material solarisation	Morocco	for the control of fusarium and verticillium wilt and *Didymella* stem canker
tomatoes	cultural practices and pesticides	Guatemala	widely used
tomatoes	resistant cultivars	Mexico	widely used
tomatoes	soil solarisation	Jordan	no data available
tomatoes	soil & agricultural material solarisation	Brazil	recently introduced
tomatoes	grafting	Morocco	recently introduced by some farmers for nematode control
tomatoes	resistant varieties	Morocco	widely used

Crops	Alternatives	Countries	Comments
tomatoes, broccoli, snow peas, peppers, banana	IPM (cultivation practices and pesticides)	Chile, Mexico, Guatemala, Indonesia, Costa Rica	cost effective
tomatoes, peppers	substrate	Zimbabwe	trials being conducted
tomatoes, curcurbits, cut flowers, strawberries	cultural practices (crop rotation, flooding, sanitation, composting)	Article 5(1) Countries	widely used
tomatoes	soil amendments	Senegal	widely used
tomatoes, curcurbits (greenhouse)	Integrated Disease Management of soil borne pathogens	Article 5(1) Countries	widely used
tree nurseries	crop rotation	South Africa	widely used in conjunction with methyl bromide in a 3 yr rotation cycle

__Table 8.4.2__ - Use of Alternatives on Durable Commodities in Article 5(1) Countries

Crop	Alternative	Countries	Comments
black pepper	phosphine	Malaysia	registered for use and widely used - storage
coconut products	phosphine	Philippines	registered for use; mostly used for exports
coffee	phosphine	Vietnam	registered for use and widely used
grain (rice)	CO_2	Indonesia, Philippines, Vietnam	currently being introduced
grain (barley)	premixed CO_2 & phosphine	Cyprus	currently being introduced
grain	controlled atmosphere	China	adopted and use expected to increase
grain	phosphine	Article 5(1) Countries	use continues to increase
grain	hermetic sealing/storage	Philippines (rice), Cyprus (barley)	technology available for adoption
pulses	irradiation	Indonesia, Thailand	Indonesia - limited commercial use Thailand - experimental use
rice	nitrogen gas	Thailand	commercial experimental use
rice	irradiation	Indonesia, Thailand	experimental use
timber	heat	China	limited use
timber	sulfuryl fluoride	China	use increasing, but trials still needed
tobacco	phosphine	Philippines, Indonesia, Zimbabwe	use increasing
wheat	CO_2	Kenya	experimental in silos

__Table 8.4.3__ - Use of Alternative on Perishable Commodities in Article 5(1) Countries

Crop	Alternative	Country	Comments
apples	wax coating	Chile	widely used
citrus	wax coating	Chile	widely used
lychee fruit	vapour heat	China	limited use
stone fruit	double inspections	Chile	widely used

__Table 8.4.4__ - Use of Alternatives on Structural Pests in Article 5(1) Countries

Crop	Alternative	Country	Comments
grain mills	cold CO_2 + phosphine	Argentina	experimental
empty containers	sulfuryl fluoride	China	limited use

8.5 Methyl Bromide Use in Article 5(1) Countries

Tables 8.5.1 to 8.5.3, and the corresponding Figures 8.5.1 to 8.5.3, contain information derived mainly from the 1995 UNDP Regional surveys which were conducted in English-speaking Africa, Latin America and the Caribbean, and South East Asia and the Pacific. The information on the Philippines has been updated, and data for Morocco, China, India, and Mexico was compiled by MBTOC members.

8.6 Conclusion

Although methyl bromide continues to be used in Article 5(1) countries for certain economically important agricultural products, use is decreasing in a number of these countries. However, use of methyl bromide in some Article 5(1) countries has increased. It continues to be important that alternatives to methyl bromide for use in Article 5(1) countries are economically viable.

Since the 1994 MBTOC Report, significant progress has been made in the adoption of alternatives. For example, solarisation is now an accepted alternative for controlling soil pests and is already in use in a number of countries. For commodity use, phosphine is now accepted as the standard fumigant for controlling stored grain pest where time is not a constraint. It should be noted that some Article 5(1) countries have adopted many of the low-technology/low-cost alternatives listed in the 1994 MBTOC Report.

It is important that applied research and field demonstration projects, as well as training programs on alternatives continue so as to allow Article 5(1) countries to decrease the reliance on methyl bromide. To address these issues, a follow-up program is of immediate priority to ensure those Article 5(1) countries that are in a stage of evaluating and/or adopting alternatives are encouraged to proceed in the use of alternatives. It is essential that the monitoring of methyl bromide use and adoption of alternatives, as well as technology transfer and information exchange continue. Further assistance will continue to be required to implement alternative pest control methods which are cost-effective, affordable, environmentally sound, and safe to users.

To reiterate the conclusions of the 1994 MBTOC Report, alternatives to methyl bromide will need to be country-specific, crop-specific, and pest-specific. Additional efforts to develop substantial programs involving on-farm research, technology transfer, training and infrastructure strengthening are imperative.

8.7 References

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Table 8.5.1 - Methyl bromide use in Latin America 1990-1994 (metric tonnes)

Country	1990	1991	1992	1993	1994	Total	Average
Argentina	190	285	349	356	284	**1,464**	**293**
Brazil	684	940	1,147	1,144	388	**4,303**	**861**
Chile	336	256	319	300	199	**1,410**	**282**
Colombia	29	98	121	102	72	**422**	**84**
Mexico			1,265	1,244	1,525	**4,034**	**1,345**
Peru	24	25	26	10	11	**96**	**19**
Uraguay	4	6	10	10	18	**48**	**10**
Venezuela	1	27	88	23	3	**142**	**28**
Total	**1,268**	**1,637**	**3,325**	**3,189**	**2,500**	**11,919**	

Figure 8.5.1 - Five year trend in methyl bromide use in Latin America

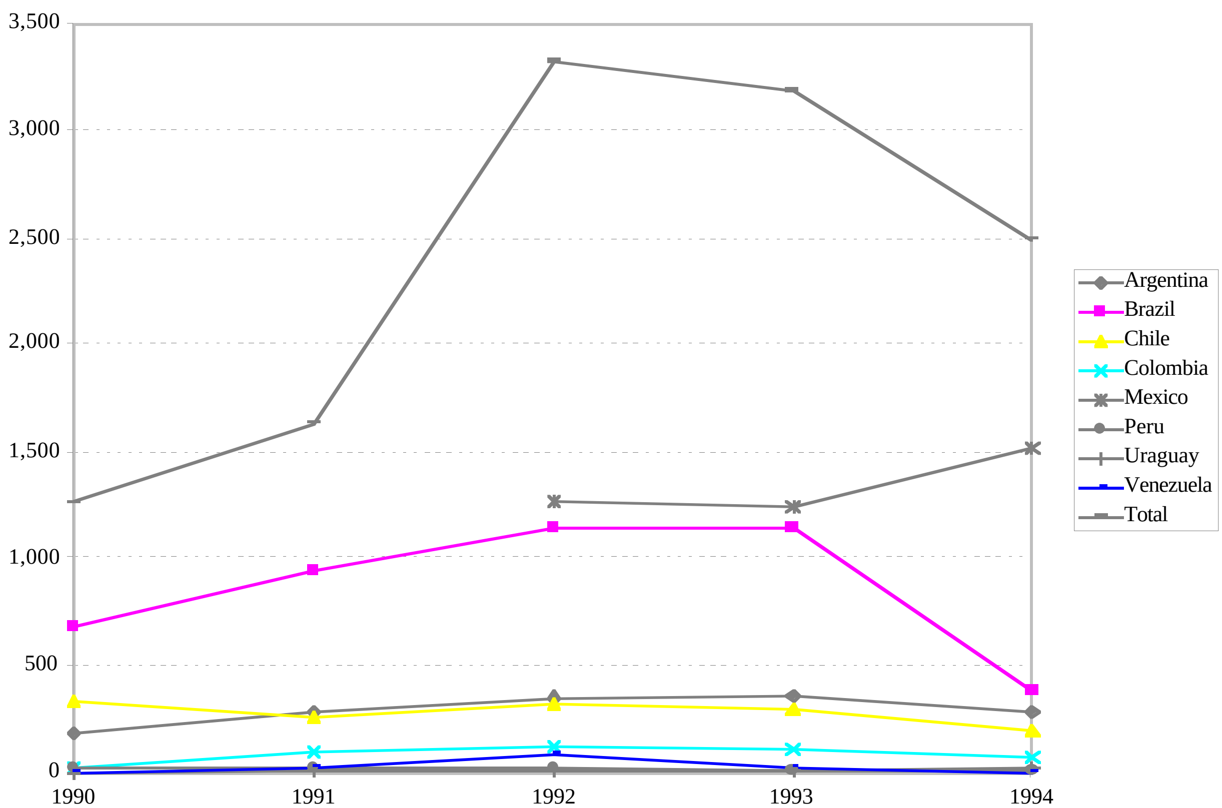


Table 8.5.2 - Methyl bromide use in Asia 1990-1994 (metric tonnes)

Country	1990	1991	1992	1993	1994	Total	Average
China		550	589	536	467	**2,142**	**536**
Fiji	3	2	5	4	4	**18**	**4**
India	166	235	240	162	170	**973**	**195**
Indonesia	217	105	270	220	255	**1,067**	**213**
Malaysia	24	34	52	58	89	**257**	**51**
Philippines	124	133	104	108	63	**532**	**106**
Thailand	680	708	658	964	590	**3,600**	**720**
Viet Nam	50	50	74	85	108	**367**	**73**
Total	**1,264**	**1,817**	**1,992**	**2,137**	**1,746**	**8,956**	

Figure 8.5.2 - Five year trend in methyl bromide use in Asia

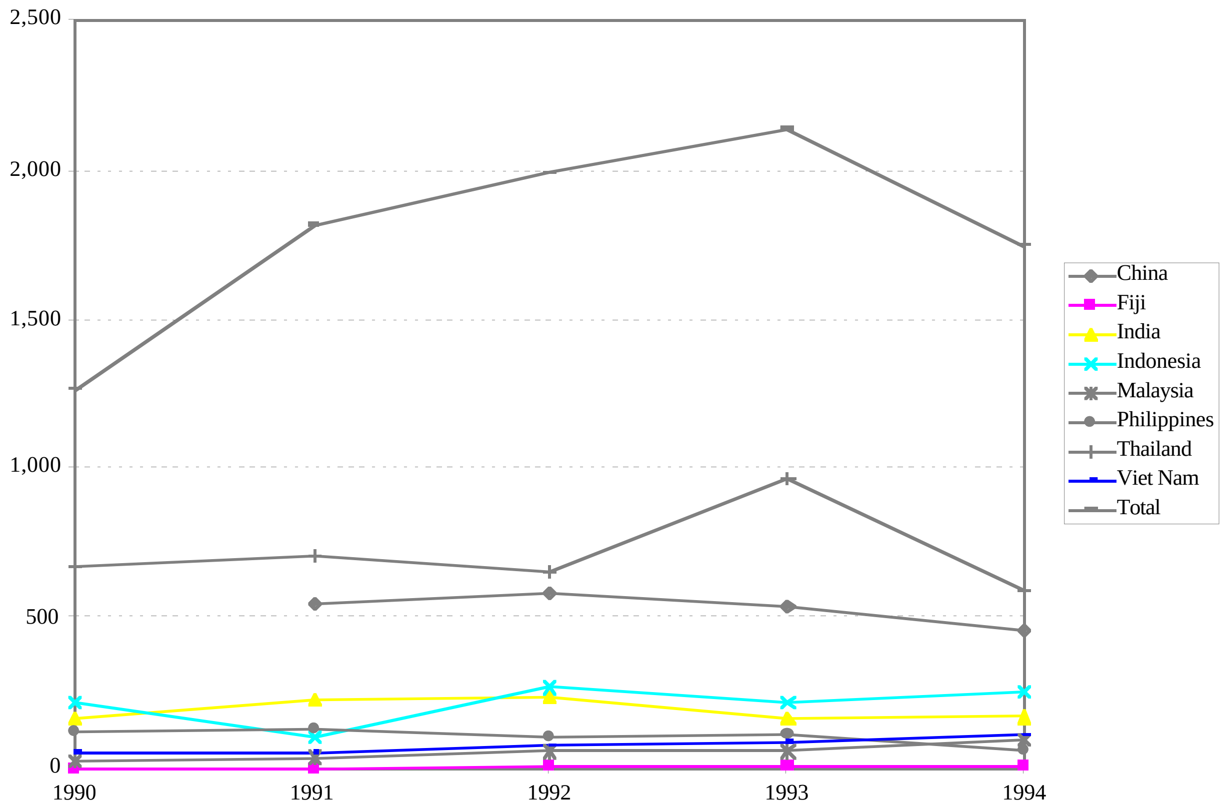
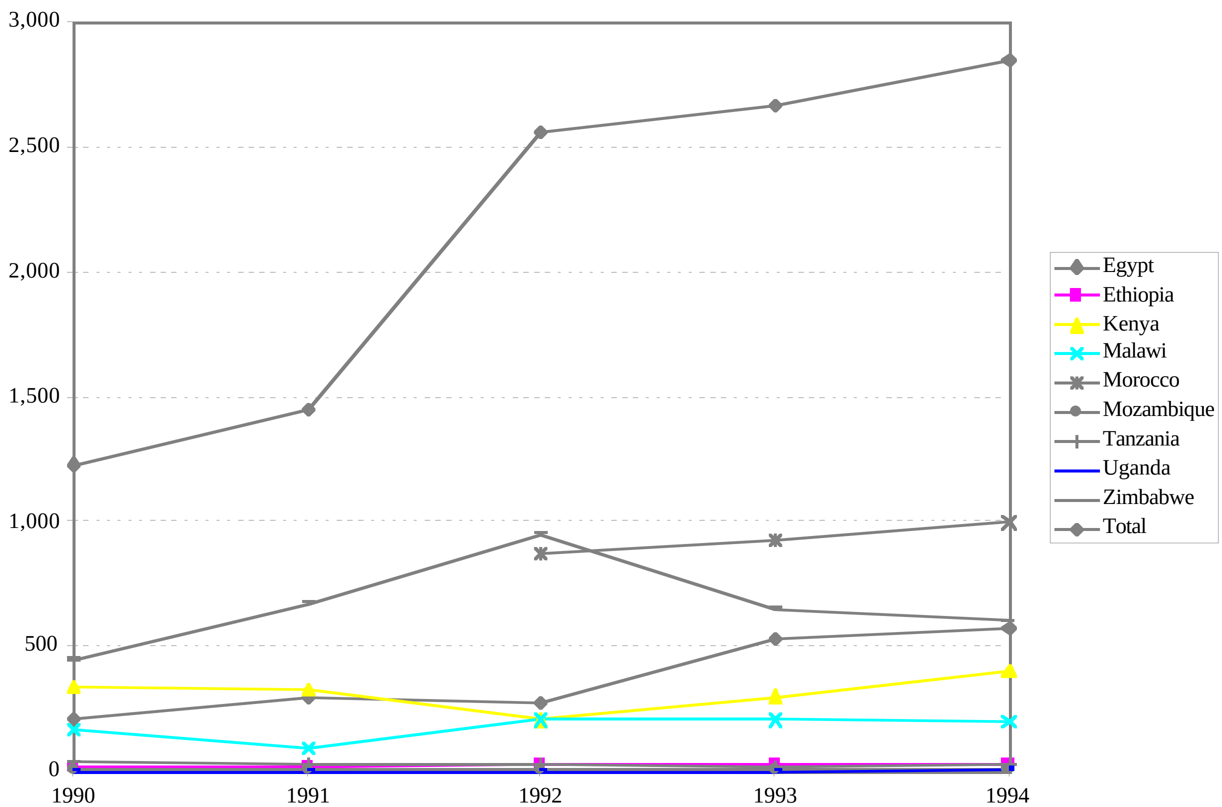


Table 8.5.3 - Methyl bromide use in Africa 1990-1994 (metric tonnes)

Country	1990	1991	1992	1993	1994	Total	Average
Egypt	214	301	272	531	572	**1,890**	**378**
Ethiopia	20	14	28	27	30	**119**	**24**
Kenya	340	331	204	300	400	**1,575**	**315**
Malawi	170	91	207	204	200	**872**	**174**
Morocco			870	930	1,000	**2,800**	**933**
Mozambique	9	11	6	6	8	**40**	**8**
Tanzania	37	27	26	24	26	**140**	**28**
Uganda	0	0	0	0	10	**10**	**2**
Zimbabwe	444	676	953	650	604	**3,327**	**665**
Total	**1,234**	**1,451**	**2,566**	**2,672**	**2,850**	**10,773**	

Figure 8.5.3 - Five year trend in methyl bromide use in Africa



9 RECENT CONFERENCES AND REVIEWS ON METHYL BROMIDE AND ALTERNATIVES

9.1 Introduction

Restrictions on methyl bromide and its phaseout scheduled under the Protocol has generated a large number of conferences, meetings and workshops relating to methyl bromide and alternatives. References to a selection of printed documents and publications that have become available to MBTOC subsequent to the 1994 MBTOC Assessment Report are given below. These give a substantial number of primary studies on alternatives.

These publications provide a valuable database for further study of the details of many methyl bromide alternatives. Attention is drawn particularly to the proceedings of the Annual International Research Conference on Methyl Bromide Alternatives and Emission Reductions, Orlando, 1996 (Anon., 1996a) and of previous meetings in the series.

9.2 Publications

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1 CRITICAL AGRICULTURAL USES AND QUARANTINE AND PRE-SHIPMENT USE EXEMPTION

1.1 Introduction

Decision VIII/16 requested TEAP to provide further elaboration on possible definition and modalities for implementation of a "critical agricultural use" (CAU) exemption in relation to the controlled substance, methyl bromide. TEAP has previously submitted to the Parties a discussion on potential CAU and implementation thereof (TEAP Report, June 1996, p. 113).

It has been argued that some methyl bromide uses may be held to be "critical" and there are presently no acceptable alternatives to some of these critical uses. These uses may not be covered post phaseout by the existing Quarantine and Pre-shipment exemption (QPS) of Article 2H and may also not be covered under the existing essential use exemption applying to ODS generally. Parties may wish to consider measures which incorporate the unique features of methyl bromide into the exemption framework for uses held to be "critical."

In the 1996 TEAP Report listed the following particular uses and properties of methyl bromide that distinguish it from other ODS and should be considered in developing concepts of a critical use system:

1. Some countries require registration of alternatives and substitutes to methyl bromide.
2. There are a large number of locality-specific methyl bromide uses.
3. There may be a necessity to revert to methyl bromide in the event of failure of an alternative e.g. development of pest resistance to an alternative or the emergence of a new pest.
4. There are specific physical constraints e.g. soil type and climate, that affect the efficacy of alternatives.
5. Some uses of methyl bromide are urgent, sporadic or unforeseen, e.g. due to sudden pest outbreaks requiring emergency treatment.
6. There is a significant use of methyl bromide in intra country trade. If alternatives were not available, loss of methyl bromide is likely to be disruptive.

The Parties have already provided a set of criteria that could be considered under Dec VII/29. This reads in part: "In recommending suitable modalities and criteria, the Technology and Economic Assessment Panel may take into consideration:

(a) Whether alternative practices or substitutes exist that are commercially available and efficacious;
(b) The relative costs and benefit of alternative practices and substitutes to allow the Parties to assess their economic viability, taking into account the scale of application and the individual circumstances of particular uses;
(c) Whether a Party has demonstrated that all economically feasible actions are being taken to minimise use and any associated emissions from the approved exemption, and that continued efforts are being made to evaluate and develop alternatives to the use of methyl bromide for this application;

(d) The feasibility of placing a cap on the total percentage of baseline production and consumption permitted under an essential use for any particular country; and
(e) A range of alternative decision-making and implementation processes."

TEAP and MBTOC have noted additionally that the term "critical agricultural use" appears targeted at critical application of methyl bromide to soil but to exclude applications to non-agricultural structures and commodities. It may not have been the intention of the Parties to exclude these uses from consideration of essential use.

1.2 Recent Developments Impacting Potential CAU

At the Eighth meeting of the Parties Decision VIII/9(10) established an additional provision for emergency use of an ODS. The Decision reads:

To allow the Secretariat, in consultation with the Technology and Economic Assessment Panel, to authorise, in an emergency situation, if possible by transfer of essential-use exemptions, consumption of quantities not exceeding 20 tonnes of ODS for essential uses on application by a Party prior to the next scheduled Meeting of the Parties. The Secretariat should present this information to the next Meeting of the Parties for review and appropriate action by the Parties.

TEAP notes that this provision is particularly appropriate to providing emergency authorised supplies of methyl bromide to control sudden, unforeseen pest outbreaks for which alternatives are not available. An important aspect of methyl bromide use is that it may be required at short notice in agricultural and non-agricultural situations and that the current essential use process requires too long a lead time to provide appropriate supplies of methyl bromide.

TEAP noted that methyl bromide is stable in storage in steel cylinders, held under dry conditions, and there is thus potential for at least limited stockpiling to cope with usage, either emergency or routine, post phaseout where alternatives are still under development or registration.

1.3 Modification of Essential Use Criteria

In the 1996 TEAP report a number of potential CAU modalities were presented. These were:

1. Modification of the essential use process and criteria to accommodate additional special requirements of methyl bromide.
2. Provision of some emergency use approval system.
3. Provision of a 'positive list' of applications of methyl bromide deemed 'critical' by the Parties.
4. Provision of a 'negative list' of applications of methyl bromide. This would be all applications of methyl bromide deemed <u>not</u> critical by the Parties.

TEAP continues to favour the first option, modification of essential use criteria, and to not recommend options 3 and 4 on the grounds that these would impose a heavy administrative burden and there is substantial potential that particular uses would either be missed, with a positive list, or permitted despite availability of alternatives with a negative list. The recent Decision VIII/9(10) removes the need to further consider option 2, provided the response time of the Secretariat and TEAP is appropriately rapid for such an emergency request.

TEAP notes that post phaseout, provided QPS or other exemptions are maintained, there should be continued production, albeit in limited quantities and possibly increased cost, of methyl bromide, so supplies for emergency use would still be available.

TEAP continues to support changes to essential use criteria deemed necessary to cope with the particular needs of methyl bromide. Suggested changes to essential use criteria as set out in Decision IV/25 were given in TEAP's 1996 Report. These were as given in bold italic text below:

(1) to apply the following criteria and procedure in assessing an essential use for the purposes of control measures in Article 2 of the Protocol:

(a) that a use of a controlled substance should qualify as "essential" only if:
- *(i) it is necessary for the health* ***(encompassing national food supply)*** *safety or is critical for the functioning of society (encompassing* ***economic****, cultural and intellectual aspects); and*
- *(ii) there are no available technically and economically feasible alternatives or substitutes that are acceptable from the standpoint of environment and health.*

(b) that production and consumption, if any, of a controlled substance for essential uses should be permitted only if:
- *(i) all economically feasible steps have been taken to minimise the essential use and any associated emission of the controlled substance;*
- *(ii) the controlled substance is not available in sufficient quantity and quality from existing stocks of banked or recycled controlled substances, also bearing in mind the developing countries need for controlled substances; and*
- *(iii)* ***it is demonstrated that a concerted effort is being made to evaluate, commercialise and secure national regulatory approval of alternatives and substitutes.***

There is no persuasive reason known to TEAP why methyl bromide should be treated differently from other ODSs.

1.4 Processes Currently Exempt and Control of their Emissions

Under Article 2H quarantine and pre-shipment uses are presently exempt from control. These constitute a significant unregulated use of methyl bromide with potential for continuing growth. QPS exemptions are estimated to cover more than 10% of global methyl bromide use. Most of the methyl bromide applied in QPS situations is now emitted to atmosphere when the commodity is aired after treatment.

Parties may wish to consider some requirement that methyl bromide must be used in well-contained situations fitted with recapture devices (scrubbers and the like). At present, recapture is encouraged under the Protocol (Decisions VI/11(1c) and VII/6), but there is little incentive to fit recapture devices. Such devices are costly and savings in the quantity of methyl bromide used do not repay the investment. Most contained methyl bromide treatments are commodity treatments (durable or perishable). About half of this use is covered under the QPS exemption. However, the technology exists to reduce emissions from such treatments from 80% or more to 5% or less of the material used. There is active research and commercialisation in this area, driven by local emission regulations, not ozone layer consideration.

Parties may wish to consider some form of appropriately controlled incentive to encourage the use of emission reduction devices. A process which allowed continued application of methyl bromide for certified low-emissive use in well contained situations, would open the way for removal of the anomalous QPS exemption and bringing emissions from these treatments under control of the Protocol.

A benefit of such an allowance would be that methyl bromide use for pre-shipment and quarantine applications would be allowed to continue while ozone layer damage from currently highly emissive applications would be avoided.

2 POTENTIAL TRADE MEASURES IN RELATION TO METHYL BROMIDE CONTROL

2.1 Introduction

TEAP in its 1995 report discussed the prospects and problems associated with potential methyl bromide trade control measures. Methyl bromide is the only controlled substance under the Protocol which does not have restrictions in place with regard to trade between Parties and non-Parties.

2.2 Products containing methyl bromide

- Decision VIII/14 clarified that all trade in methyl bromide is trade in bulk. Such pesticide products are typically well-labelled and subject to simple border controls;
- No other materials in trade that contain methyl bromide are known to TEAP, except as a residue from fumigation;
- Some commodities treated post-harvest retain detectable levels of methyl bromide for some time (several days) after treatment, thus making some detection of use possible;
- Most of the goods produced or protected with the aid of methyl bromide do not contain detectable methyl bromide as an intact molecule.

In summary, except for controls on trade of methyl bromide in bulk, TEAP does not regard it as feasible or useful for goods to be screened; this screening would be done to detect intact residues of methyl bromide to indicate that they are "products made with and containing". In the absence of a testing procedure, other options as set out below will need to be applied.

2.3 Products made with but not containing methyl bromide

- Some crops grown with the aid of methyl bromide soil treatment contain enhanced bromide levels. However,
    1. treated soil may be leached to remove bromide ion for food crop production;
    2. there are highly variable natural levels of bromide in soil, high in volcanic areas, leading to uncertainty as to origin of high bromide level and difficulty in being conclusive that a crop was grown with aid of methyl bromide; and
    3. the crop may have picked up bromide from a soil treatment for a previous crop.
- Post-harvest treatments may elevate the bromide content, particularly if carried out repeatedly. Increases from a single dosage may be similar to the variability in natural levels of the chemical.

Therefore, enhanced bromide is an unreliable indicator of methyl bromide use and alternative means of tracking methyl bromide use is required, if trade measures are to be applicable.

However, technical and administrative options to control trade are feasible and include:

- Certification by the shipper or other authority that methyl bromide was not used;

- Quarantine records of prescribed treatment without methyl bromide;
- Field inspection by national authorities; and
- Controlled sales records of methyl bromide use.

3 METHYL BROMIDE ESSENTIAL USE PROCESS ELABORATION

Parties asked TEAP to further elaborate on the options for a special essential use exemption for methyl bromide. TEAP believes that the options for an essential use exemption already presented are fully workable and can be successfully implemented at the time of the methyl bromide phaseout. For administrative efficiency and equity with other essential ODS uses, TEAP prefers that methyl bromide be accommodated within the existing structure by making the slight changes in criteria as recommended in the June 1996 TEAP report.

At the time of the phaseout, Parties may wish to consider the option of eliminating the global exemption for pre-shipment and quarantine and relying solely on the essential use process including the provision for emergency exemptions by the Secretariat after consultation with the TEAP.

Parties might also consider the advantages of requiring users of methyl bromide under the current exemption, to limit emissions to a small fraction, say 5% of use, within a short time frame. This reduced level of emissions is technically feasible but is not undertaken because costs are higher and the Protocol completely exempts pre-shipment and quarantine uses, regardless of unnecessary emissions.

One reason the essential use exemption was developed was to allow an early phaseout of ODSs with "safety valve" in case essential uses emerged. Since 1994 the Essential Use process has proven to function well. Parties can schedule an early methyl bromide phaseout and depend on the essential use process.

4 METHYL BROMIDE: MARKET-BASED MEASURES

4.1 Introduction

The TEAP was requested to report on possible uses of market-based measures to allow for greater flexibility in implementing the requirements for limitations on methyl bromide (Decision VII/29, paragraph 4). Market-based measures operate through their influence on market prices (e.g., taxes and subsidies) and on other factors that influence the purchasing decisions of producers and consumers (e.g., Eco-labelling and other information on product standards).

4.2 Taxes on Methyl Bromide Production and Imports

As the market demand for methyl bromide is met by imports in most countries, taxes can be used to raise domestic market prices as a means of reducing the domestic use and encouraging technical innovation. The extent of such reductions depend on the percentage change in the quantity demanded relative to the percentage change in the market price (the price-elasticity). To the extent that the input cost of methyl bromide is low relative to total production costs, the price elasticity will be low thereby making it difficult to use this market-based measure effectively. As the recognition and availability of technically and economically feasible alternatives increases, the price elasticity of methyl bromide will increase thereby increasing the potential effectiveness of an import tax per unit of methyl bromide imported.

4.3 Domestic Product Taxes

The market prices of goods produced using methyl bromide could be driven up to discourage demand by imposing specific product taxes. This measure requires a means of differentiating between those products which have been produced or treated with methyl bromide from those not produced or treated with methyl bromide, and a certification process to ensure the proper implementation of such a tax.

4.4 Subsidies

Subsidies could be used during the transition to cost-effective alternatives to reduce the production costs of crops grown using alternatives as a means of accelerating the phasing out of methyl bromide. These measures could be applied to reduce the cost of equipment purchases, technical assistance and other inputs to production processes.

4.5 Eco-labelling

The purchasing decisions of consumers can also be influenced by product information on the environment effects of producing, using and disposing of specific products. Eco-labelling systems are widely used. Those Parties that are not yet using Eco-labelling systems to promote the objectives of the Montreal Protocol might consider the benefits of adding such a market-based measure to their ozone protection policies.

5 TEAP COMMENTS ON METHYL BROMIDE

Conclusions

TEAP finds that it is technically feasible to phase out approximately 75% of non-QPS (non-Quarantine and Pre-Shipment) methyl bromide use by 2001, provided that current emergency and routine essential use provisions are modified and made applicable to methyl bromide. TEAP finds no compelling technical or economic reasons why Non-Article 5(1) and Article 5(1) countries could not pursue similar phaseout schedules.

5.1 Background

TEAP notes that most methyl bromide is used in soil fumigation, as a pre-plant treatment. In Article 5(1) countries it is used principally for production of high-value export crops for developed country markets, with some application to disinfest grain and other durable commodity stocks post-harvest. The proportion of methyl bromide used for soil and post-harvest treatment varies widely between different Article 5(1) countries. In Non-Article 5(1) countries it is used principally for production of high-value crops, with some post-harvest use and also for disinfestation (fumigation) of structures such as flour mills.

While methyl bromide users face some challenges to find and implement alternatives, TEAP notes that these challenges are no more difficult than challenges already solved by other sectors. For solvents, refrigerants, foams, aerosols and halons, ODSs provided adequate performance across a wide range of applications. The alternatives in these other sectors are more numerous and are more tailored to specific situations. Methyl bromide is similar in that it is a wide spectrum biocide which provides adequate performance across a range of application scenarios. TEAP also notes that a high degree of variability exists with biological systems, and a high degree of skill may be required for selecting and applying alternatives. This situation is also similar to other sectors in that application of alternatives relative to the ODS itself has required a higher skill level and education and training for the user community.

Each industry and consumer sector faced with reducing and ultimately phasing out ODSs has gone through the same economic and technical transition, which included the following elements:

- Initial assessments predict low rates of technical feasibility and high economic costs
- New technologies emerge and alternative proven technologies are re-evaluated
- Early innovators attempt transition, often with poor results and high costs
- National regulation forces increased innovation and technologies are optimised
- Best technologies are perfected, optimised, and mass produced
- Costs decline and performance approaches or exceeds ODS benchmarks

In the case of methyl bromide, these transition steps have been slowed down relative to other uses of ODS because some portions of the industry have opted to concentrate their efforts on saving methyl bromide instead of directing efforts and resources to a vigorous search for alternatives. However, in other portions of the industry, some leadership companies, industry associations, and nations have proceeded with research, development, and implementation. As a result, methyl bromide uses are declining in many places and for many applications.

5.2 Methyl Bromide Use Trends

Methyl bromide use has decreased in some Article 5(1) countries as a result of local efforts and technology co-operation through UNEP and bilateral projects and because of health concerns over its toxicity to workers. Alternate technologies to methyl bromide have been put in place without loss of productivity and quality of high-value crops previously dependent on methyl bromide.

- In Brazil, tobacco growers are pursuing technically and economically feasible alternatives they believe can be utilised in the near future. They have announced their commitment to protect the environment. The government of Brazil has identified alternative technologies and is confident in the near-term phaseout.
- Food processing facilities are reporting pest control without methyl bromide and at substantial savings.
- Florida tomato growers are decreasing methyl bromide use at affordable costs.
- Jordan has reduced their use from 900 to 300 metric tonnes per year.

By contrast, other countries have seen some very large increases in methyl bromide use.

- China increased its use from 467 metric tonnes in 1994 to 722 metric tonnes in 1995, which was largely driven by a threefold increase in the use for soil fumigation in one year.
- Vietnam increased its use by over 30% between 1993 and 1994.
- Malaysia increased its use from 58 to 89 metric tonnes between 1993 and 1994.
- Morocco increased its use from 930 to 1,500 metric tonnes between 1993 and 1995 (due to an increased use on soils).

At these rates of increase, the Article 5(1) countries which are increasing use have the potential to completely overwhelm progress made elsewhere in the world within a relatively short period of time. This is occurring despite the fact that dosage decreases of up to 50% are possible under certain conditions simply by optimising applications without affecting performance or yield.

Soil fumigation is the only methyl bromide growth area in both Article 5(1) and Non-Article 5(1) countries, with the exception of quarantine and pre-shipment (QPS). Virtually all perishables, about half of all durables and some structural and transport use is for QPS. World-wide, over 18% of the 1992methyl bromide use is estimated to have been excluded from control by the QPS exemption. The quantity of methyl bromide used for QPS is also increasing.

The MBTOC has not gathered comprehensive data on 1995 or 1996 production or consumption. However, it is reported (UNIDO, 1996, “methyl bromide manufacturers” estimates) that 1995 global market for methyl bromide was 75,279 tonnes. No indication was given whether or not this figure includes feedstock uses. 1992 usage was estimated (MBTOC, 1995) at 72,975 tonnes based also on manufacturer’s data, including feedstock uses. These figures suggest a continuing increase in global methyl bromide consumption. TEAP notes that estimates of 1995, 1996, and to the extent possible, 1997 methyl bromide production and consumption figures will be important to providing the Parties with an assessment of the progress toward compliance with the existing control measures and identification of areas which require further effort.

TEAP notes that since the 1994 MBTOC Report was issued, UNEP-IE, National Ozone Offices, Governments and Non-Governmental Organisations, and Implementing Agencies of the Multilateral Fund have conducted conferences, workshops and other informational programs in Article 5(1) countries. These seminars may have contributed to the reduced methyl bromide use experienced in several countries. The methyl bromide industry has also conducted independent seminars directed toward government officials in a number of Article 5(1) countries. These efforts may contribute to the use trends, both positive and negative, which are noted in the MBTOC report.

5.3 Alternatives to Methyl Bromide

On a crop basis, approximately 35% of all methyl bromide use is for growing tomatoes and strawberries. Post-harvest protection of grain, timber and other durables represent another 13% of use. On an application basis, 75% of use is for soil fumigation, 13% for durables, 9% for perishables and 3% for structures. Table 4.1 of the MBTOC report (as contained in this TEAP report, Volume I) describes a wide range of alternatives at various stages of maturity for virtually all methyl bromide applications. Integrated Pest Management (IPM) is a rational strategy for significantly reducing methyl bromide usage. Under IPM, biocides are only applied when they are needed and the IPM approach supports beneficial ecosystems. By contrast, in most cases where methyl bromide is currently applied it indiscriminately destroys pathogens, weeds, other pests and also beneficial organisms. While Table 4.1 lists individual treatments, they are usually most effective in combinations tailored to local conditions.

The MBTOC report presents early evidence of innovation and the first stages of optimised commercial alternatives. In many cases the costs are currently higher than for methyl bromide. This is not unexpected; the comparison is between the system (methyl bromide) in use, optimised to local conditions, and an alternative which is applied without the benefit of experience and adaption. Thus, these costs are expected to decline. Uses with the highest cost of methyl bromide replacement are often for highly profitable luxury products.

One of the largest and most technically challenging methyl bromide uses is for the production of large, mild-flavoured strawberries produced in California and marketed world-wide. California strawberry growers have been particularly slow to make necessary investigations and investments in alternatives and substitutes. So far, they have been hesitant to accept the successful Netherlands methyl bromide-free steamed artificial soil technique, they have rejected the Mexican field flooding technique, and have not shifted production to locations where pests can be controlled without methyl bromide. In addition, TEAP notes that investments in research and development for methyl bromide alternatives appear to be significantly less than those made by other sectors, such as foams, halons, solvents and refrigerants.

5.4 Small and Medium-Sized Enterprises

The TEAP notes that the methyl bromide sector includes many small and medium-sized enterprises. This is a similar situation to other sectors, which are also characterised by large numbers of small and medium-sized enterprises. These other sectors have experienced similar costs of transition and based on an evaluation of the wide range and efficacy of methyl bromide alternatives, the TEAP concludes the methyl bromide sector is not unduly affected when compared to other sectors and because the agricultural sector is globally organised for technology co-operation. Like other sectors which have successfully phased out, a change of attitude is required regarding alternative technologies, and an end by methyl bromide advocates to activities that discourage alternatives.

5.5 Control Scenarios for Methyl Bromide

TEAP considered the following:

- the objectives of the Protocol were fulfilled by adoption of environmentally sound non-ODS technology in place of ODS use and that the replacement did not necessarily have to be at lower cost/high profitability than the ODS use.

- there are a substantial number of alternative technologies available for soil fumigation which do not depend on methyl bromide. While adoption of particular alternatives or combination thereof needs to be considered on a case-by-case basis to provide a local optimum solution, this is a normal process in agriculture, and is achievable in a limited time frame.

- there is proven technology (VIF films) for improving the containment of methyl bromide in soil fumigations. This is demonstrated to allow reduction of up to 50% in dosage rates. MBTOC noted that in the USA the potential for reduction may be less as improved technologies such as deep injection are already practised. TEAP concluded that, despite the technologies prevailing in the USA, similar reductions could be achieved, and where not, alternatives would be adopted if methyl bromide supplies were further controlled.

- VIF technology is a transitional technology which could be applied in those methyl bromide soil sectors which did not consider the alternatives acceptably efficacious or cost-effective. The use in perennial crop replants may be one such sector, where trailing of alternatives may be a protracted undertaking.

- economic studies show a decreasing predicted impact of a switch to alternatives.

- there will inevitably be costs associated with a transition away from methyl bromide in those industries that currently use it, but in areas such as the Netherlands, where the change is complete, some alternatives have been shown to be more cost-effective than methyl bromide.

- that much methyl bromide use on durables and perishables is covered by the QPS exemption under the Protocol.

- that in the absence of “technology forcing” through methyl bromide controls, use would continue and there would be little incentive to convert to alternative systems. It is possible that methyl bromide use may become further entrenched.

- that there has been extensive development of substrate systems for protected cultivation and seedling production. These provide technically feasible alternatives to much of the methyl bromide use.

- with the notable exceptions of some tobacco and vegetable seedbed treatments, most Article 5(1) use of methyl bromide in soils is usually carried out by or on behalf of large, technically advanced concerns and transnationals with links to Non-Article 5(1) countries. While it may be difficult to conduct effective IPM programs as methyl bromide replacements in some Article 5(1) countries, suitable personnel can be recruited by local concerns or multinational partners in Article 5(1) countries, at least as a short term measure.

- the difference in baseline used for usage calculations for methyl bromide between Non-Article 5(1) countries (1991) and Article 5(1) countries (average 1995-98), builds in an allowance for the circumstances of Article 5(1) countries.

- proposed demonstration projects under the Multilateral Fund and other agencies, address the major non-QPS uses of methyl bromide in Article 5(1) countries. With these and various bilateral and local projects completed there will be a good basis for substantial reductions in methyl bromide use, once the required infrastructure is in place.

On the basis of these considerations and on the assumption that conversion to VIF technology, improved methyl bromide use, and containment, and adoption of substrate and other technologies for protected cultivation could be made and resourced rapidly if the incentive was provided through reduced methyl bromide supplies, TEAP presents the following calculations for consideration.

Scenario for Further Methyl Bromide Controls at 2001 (metric tonnes)

Area of Use	**Use in 1992* (tonnes)**	**QPS use** (tonnes)**	**non-QPS use (tonnes)**	**% reduction of non-QPS*****
Soils	55,074	0	55,074	80%
Durables	9,457	6,931	2,523	80%
Perishables	6,268	6,268	0	-
Structures	9,457	435	1,739	50%
Totals	**72,975**	**13,635**	**59,337**	**79%**

* *As given in MBTOC 1994 Assessment, Table 3.1, scaled to correspond to total usage of 72,975 tonnes, as given in Table 2.3, MBTOC 1994 Assessment.*

** *Calculated on the basis that the following would be covered by current QPS exemptions - all of use on “perishables”, 20% of use in structures and transport, all timber fumigation, 50% of post-harvest grain treatment and 20% post-harvest treatment of dried fruit and nuts.*

*** *Based on 60% use of alternatives for soil fumigation, plus 40% transitional technologies leading to a 50% reduction in MeBr use, such as improved application, including VIF technologies, reduced frequency of use and application as a component of mixtures with other chemicals,; 50% reduction in use in structures through use of alternatives and reduced frequency of use; 80% use reduction in “durables” treatment through adoption of alternatives (principally phosphine use).*

This scenario gives a weighted average reduction of 79% of non-QPS global methyl bromide usage. This is based on 1992 use figures. Taking into account that the baselines for Article 5(1) and Non-Article 5(1) countries differ (average of 1995-98 annual consumption and 1991 usage respectively), and that circumstances differ between countries so that the degree of difficulty of reduction varies, TEAP suggests it is technically reasonable to discount this figure and suggests a figure of 75% non-QPS global reduction is feasible.

Based on the wide range of cost effective alternatives being successfully applied to a wide range of applications and local conditions in both Non-Article 5(1) and Article 5(1) countries, the TEAP finds no compelling technical or economic reasons that Non-Article 5(1) and Article 5(1) countries could not pursue similar phaseout schedules, if an essential or critical use process, technology co-operation and financing were available. Programs to popularise alternatives, demonstrate application techniques and verify efficacy in Article 5(1) countries would be important elements to realise full penetration of available alternatives. There are several demonstration projects currently under consideration by the Multilateral Fund.

Uses of methyl bromide for durables - except as covered by QPS exemptions - can be almost completely phased out over a short time period using available technically and economically feasible alternatives. While pest control costs may increase slightly in the short term, these are well within the range of costs borne by other sectors during the transition period. In addition, TEAP notes that based on economics of end products and the proportion of the final cost represented by pesticide use, little, if any, additional cost change would be the result for the final product.

The essential use nomination process has been shown to be an effective mechanism to provide ODS supplies for essential uses post phaseout. The recent Decision providing the Secretariat, after consultation with TEAP, the latitude to grant emergency essential use quantities for later confirmation by the Parties provides further mechanisms for ensuring short notice critical situations can be accommodated. Further, methyl bromide is a stable gas stored in cylinders and can be stored during transition periods or as emergency supplies for use in the event pests resistant to an alternative emerge, or other pests break out where methyl bromide use is judged vital.

TEAP recognises that there is little time available if controls are enacted in order to meet a 2001 schedule. This corresponds to three annual harvests in the northern hemisphere. Such a schedule would require rapid conversion to alternatives and considerable development of infrastructure and supply systems associated with alternative technologies (e.g. increased production and implementation of substrate systems, increased production of VIF films).

TEAP bases the suggested reduction scenario on the alternatives presented by the MBTOC in the response to Decision VII/8 (herewith) and the MBTOC 1994 Assessment report, together with considerations presented by the Task Force organised by the EOC in its current report to TEAP herewith.

On the basis of the calculations and considerations above, TEAP affirms that a global reduction of 75% of methyl bromide consumption by 2001 is a technically and economically feasible reduction step for this important ODS.

5.6 Conclusions

TEAP finds that it is technically feasible to phase out approximately 75% of non-exempt methyl bromide use by 2001, provided that current emergency and routine essential use provisions are modified and made applicable to methyl bromide. TEAP finds no compelling technical or economic reasons that Non-Article 5(1) and Article 5(1) countries could not pursue similar phaseout schedules.

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MONTREAL PROTOCOL
ON SUBSTANCES THAT DEPLETE
THE OZONE LAYER

UNEP

Technology and Economic Assessment Panel

PART III: TOC PROGRESS REPORTS AND
SPECIFIC PROGRESS ISSUES
POSSIBLE APPLICATIONS OF HCFCS
EXECUTIVE SUMMARIES OF VOLUME II REPORTS

April 1997 Report

Montreal Protocol
On Substances that Deplete the Ozone Layer

UNEP Technology and Economic Assessment Panel

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TOC PROGRESS REPORTS

AND SPECIFIC PROGRESS ISSUES

1 TOC PROGRESS REPORTS AND SPECIFIC PROGRESS ISSUES

1.1 TOC AEROSOLS, STERILANTS MISCELLANEOUS USES AND CTC

At the Seventh Meeting of the Parties to the Montreal Protocol in Vienna in December 1995, the Parties requested the TEAP and its Technical Options Committees under Decision VII/34 5b(ii-iv) and 5d) to keep the Parties to the Montreal Protocol informed of any important new technical and economic developments on a year- to- year basis.

The following sections summarise the findings of the Aerosols, Sterilants, Miscellaneous Uses and CTC Technical Options Committee in March 1997.

1.1.1 Aerosol Products

World-wide Use of CFCs in Aerosol Products

For aerosol products, other than MDIs, there are no technical barriers to global transition to alternatives. The major issue remaining for Parties to address is the use of CFCs in Article 5(1) countries and CEIT. Some significant reductions have been achieved in recent years, and some additional reductions can be expected in the near future. The TOC believes that 1996 CFC consumption in the aerosol sector was less than 24,000 metric tonnes in Article 5(1) countries and CEIT countries excluding MDI use and some pharmaceutical products.

Comprehensive CFC consumption data for aerosol products is difficult to obtain. However the best estimate of regional break down of quantities for 1996 is as follows:

1996 CFC Consumption in non-MDI Aerosols (metric tonnes)

Russian Federation	8,600
China	7,700
Indonesia	1,500
Ukraine	1,200
Other CEIT	1,000
ASEAN and Indian Subcontinent Countries	1,700
Middle East, Africa	800
Latin America	600
Total	**23,100**

Since the 1996 Report, significant reductions have occurred due to the completion of two of the three large projects approved in China (Shanghai and Tianjin - the project at Guangdong is not yet completed). A large reduction in aerosol fillings in the Russian Federation was due to a new high excise tax on ethanol which is used as a solvent in aerosol products. This tax resulted in a dramatic reduction in the number of cosmetic aerosols filled, and a corresponding reduction of CFC propellant use of approximately 4,000 metric tonnes. This reduction, however, is likely to be temporary. Additional reductions are due to ongoing phaseout projects in several countries, such as Bangladesh, Jordan, Malaysia, Sri Lanka, Thailand, Uruguay, Vietnam.

Final Phaseout

In the near-term additional phaseout of CFC consumption will result mainly from the implementation of already approved projects (especially the large China and Russian Federation projects).

The phaseout of the remaining CFCs in the aerosol sector is dependent upon the availability of hydrocarbon propellants (HAPs) . Where HAP supplies were available at reasonable cost transition out of CFCs has already taken place. It is worth mentioning that HAP, being liquefied gases, cannot be transported long distances without a heavy penalty on price due to their high flammability.

Construction of suitable HAP plants under the MLF are contingent on a corresponding volume reduction in CFC production. Usually the HAP supplier is neither a CFC manufacturer nor an aerosol producer. Furthermore, there is no link between aerosol product manufacturers and CFC producers. Neither the HAP manufacturer nor the aerosol manufacturer is in a position to guarantee the reductions in CFC production that the MLF is requesting to fund HAP projects. Consequently although there are no technical barriers to transition, it is difficult to predict when final phase out in the aerosol sector will occur.

Article 5(1) and CEIT Countries

Some reduction in CFC usage has already occurred in Article 5(1) and CEIT countries. The phaseout of CFCs for aerosols in these countries is related to:

- inadequate supply of hydrocarbon propellants
- financial costs of retrofitting to handle flammable propellants
- need for technical assistance

Where the cost of CFCs is in the same range of hydrocarbon propellants there is little incentive to change. This is the case in India, ASEAN countries, and some other countries where aerosol grade HAP propellants are not available.

Hydrocarbons are the principal substitutes for CFCs used in aerosols. A HAPs plant may be a simple facility that consists of storage tanks for crude propane and butane, storage tanks for purified propane and butane, and several towers with molecular sieves; or it may be a much more complicated facility that uses the petrochemical process of hydrogenation to saturate undesired olefin molecules. The type of process required depends entirely upon the quality of feedstock available. Transport and safety equipment is also needed.

Non-availability of suitable quality hydrocarbon in many cases continues to thwart efforts to replace CFCs. Risks associated with haphazard conversions to hydrocarbons makes it obligatory for governments to develop suitable monitoring procedures to ensure safe practices including proper design, management and use of prescribed filling equipment, hydrocarbon storage and handling facilities. Indeed when considering the conversion of CFCs to hydrocarbons, the problems facing small aerosol fillers operating in congested areas in Article 5(1) countries need to be resolved.

In the Russian Federation the preferred substitute is also HAPs. In 1996 CFC use was reduced to 8,600 metric tonnes due to several factors that included a new high excise tax on the use of ethanol, continued depressed economic conditions, and some reformulation efforts to use blends of HAPs and CFCs. It is expected that in 1997 CFC use will increase above 1996 levels. Negotiations between the World Bank/GEF and the Russian Government resulted in the approval of seven projects to phaseout CFC use in the aerosol sector. Of these, six require the use of HAPs and one uses pump sprays. Since GEF funding of these projects has not become available, it is not expected that significant reductions of CFC consumption will occur before 1999. Therefore acceleration of the implementation of these approved projects becomes particularly important.

Sources of suitable HAPs must be available in Article 5(1) countries and CEIT to achieve significant conversion from CFCs and to prevent a growth in HCFC use. Financial and technical assistance must also be provided to aerosol fillers to convert to hydrocarbons. If these conditions were met, a very substantial decrease in CFC use could be achieved by the year 2000. The TOC is concerned that these conditions are not currently being met. The potential exists for continued consumption and emission in excess of 10,000 metric tonnes of CFCs in aerosol products, other than MDIs, in future years, if sources of suitable HAPs are not available to remaining users.

Estimated Future Use of HCFCs

Use of HCFCs in aerosols is prohibited in many European countries and severely restricted in the USA. In the USA only HCFC-141b is allowed as a solvent where there are no technically feasible alternatives due to health or safety considerations.

There are two possible factors that could affect the utilisation of HCFCs in aerosols. First, if electronic cleaners convert from CFC-113 to HCFC-141b it is estimated that the consumption of HCFC-141b could be between 2,000-4,000 metric tonnes per year. Formulators should be aware that HCFC-141b is a more aggressive solvent than CFC-113 and can damage some materials.

Some Russian Federation enterprises have indicated that they may use blends of HCFC-21 and HCFC-22 to reformulate products that should not be flammable. However, this use is currently not anticipated to be very large.

In Article 5(1) countries HCFCs will be limited in their use by cost considerations.

1.1.2 Metered Dose Inhalers

CFC-containing metered dose inhalers (MDIs) are inexpensive, reliable and effective therapy for respiratory diseases such as asthma and chronic obstructive pulmonary disease (COPD). MDIs generally use CFC-12 as a propellant and most use CFC-11 and CFC-114 either alone or in a mixture to suspend or dissolve medication.

Within the category of aerosol products, MDIs for asthma and COPD are recognised as the most difficult to substitute and have been granted essential use exemptions for the production of the CFCs required for their manufacture in Non-Article 5(1) countries.

The prevalence of asthma and chronic obstructive pulmonary disease (COPD) is increasing world-wide. There are at least 300 million people with asthma world-wide and there may be comparable numbers with COPD. Evidence now confirms that asthma prevalence is increasing as urbanisation of developing countries continues. Currently, some 500 million MDIs are used annually world-wide, using approximately 10,000 tonnes of CFC.

There is international consensus that primary treatment of these diseases should be by the inhaled route. This permits treatment to be delivered quickly and efficiently to the airways, with minimal risk of adverse reactions. Therapy necessitates regular treatment, often with more than one drug.

As a consequence of the above factors, there remains a requirement for inhaled medications such as the CFC-containing MDI.

Status of Introduction of Alternatives

Dry Powder Inhalers (DPIs) are continuing to be introduced by a number of companies into many countries. There is good evidence that the previously noted trend of increased DPI usage continues but since overall inhaled therapy has increased further, they have not reduced the sales of MDIs. Penetration of DPIs into a market depends on health professional and patient acceptance and on cost. There still remains several DPIs which are not available in some countries e.g. USA and Japan.

The figures below illustrate respectively:

- by drug category, the percentage of the MDI and DPI market shared by each device in approximately 54 Party states world-wide;

- the usage of MDIs and DPIs in treatment months from October 1995 through September 1996 in 19 Party states where inhaled therapies are most widely prescribed.

These figures have been provided by the International Pharmaceutical Aerosol Consortium (IPAC).

New Therapy (oral) Two novel oral compound (leukotriene modifiers) for the treatment of asthma have been approved by the regulatory authorities in some countries. These may be of value to a small number of those with asthma, but is highly unlikely that these will be a substitute for the current effective inhaled preventative therapy. For the reasons outlined in the 1994 Technical Options Committee Report, overall use of inhaled medication is increasing because of increased disease prevalence. World Health Organisation/US National Heart, Lung and Blood Institute (WHO/NHLBI) Guidelines in asthma management also encourage the inhaled route as the preferred method of administering medicine. The mainstay of therapy for asthma/COPD is likely to remain therapy administered by the inhaled route.

Alternative technologies, e.g. portable handheld nebulisers, are also being evaluated.

MDIs Reformulated Without CFCs

MDIs remain the dominant inhaled delivery system in most countries and for all categories of drugs. HFC-134a and HFC-227 have been approved as propellants in MDIs.

In March 1995 the first approval for a CFC-free MDI was granted to 3M's Airomir™, a salbutamol product reformulated with HFA-134a propellant. By March 1997, over thirty five countries had approved Airomir™ (Proventil™-HFA in the USA) for use, and approval was being sought in a number of additional countries.

Additional companies have submitted applications to market CFC-free inhalers in a number of countries. Approvals are anticipated in the coming year.

It is anticipated that at least two salbutamol CFC-free MDIs will be available in a number of countries by the end of 1998. Since salbutamol MDIs are estimated to comprise half the total global use of MDIs the potential exists for a significant reduction in consumption of CFCs in 1999. This is dependent on regulatory approval, reimbursement approval, patient/physician uptake, and subsequent early phaseout of CFC inhalers.

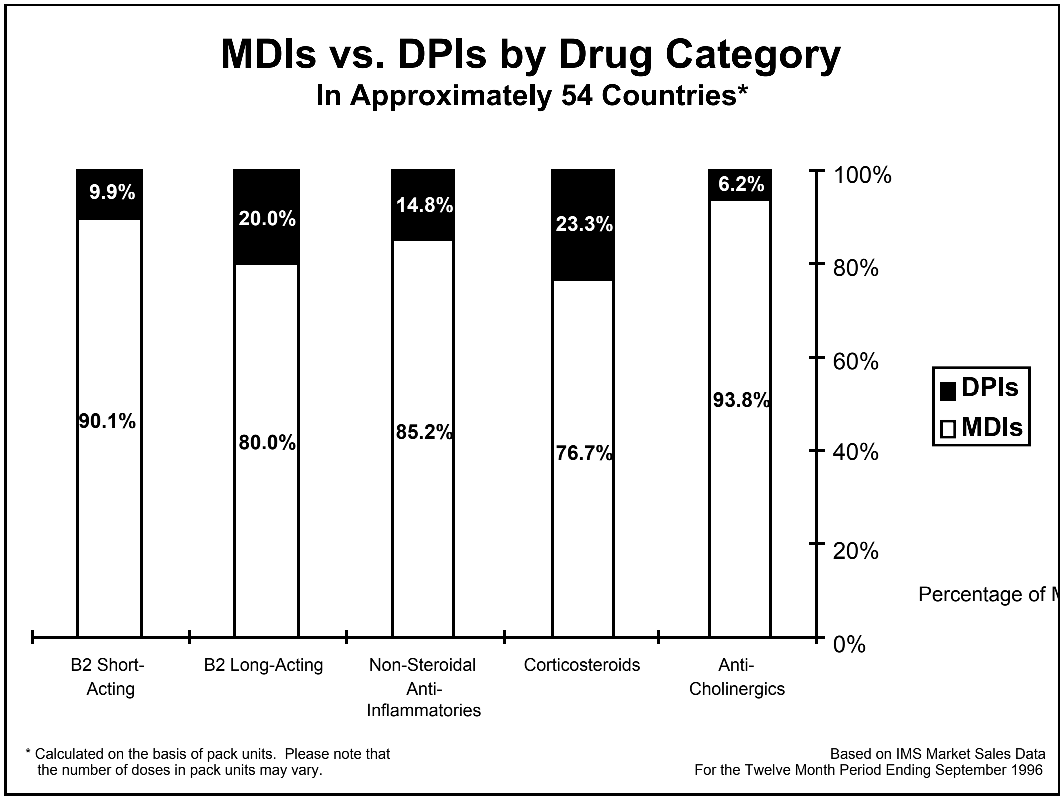
Reformulation efforts for the remaining inhaled medications is well advanced with HFC-134a and HFC-227.

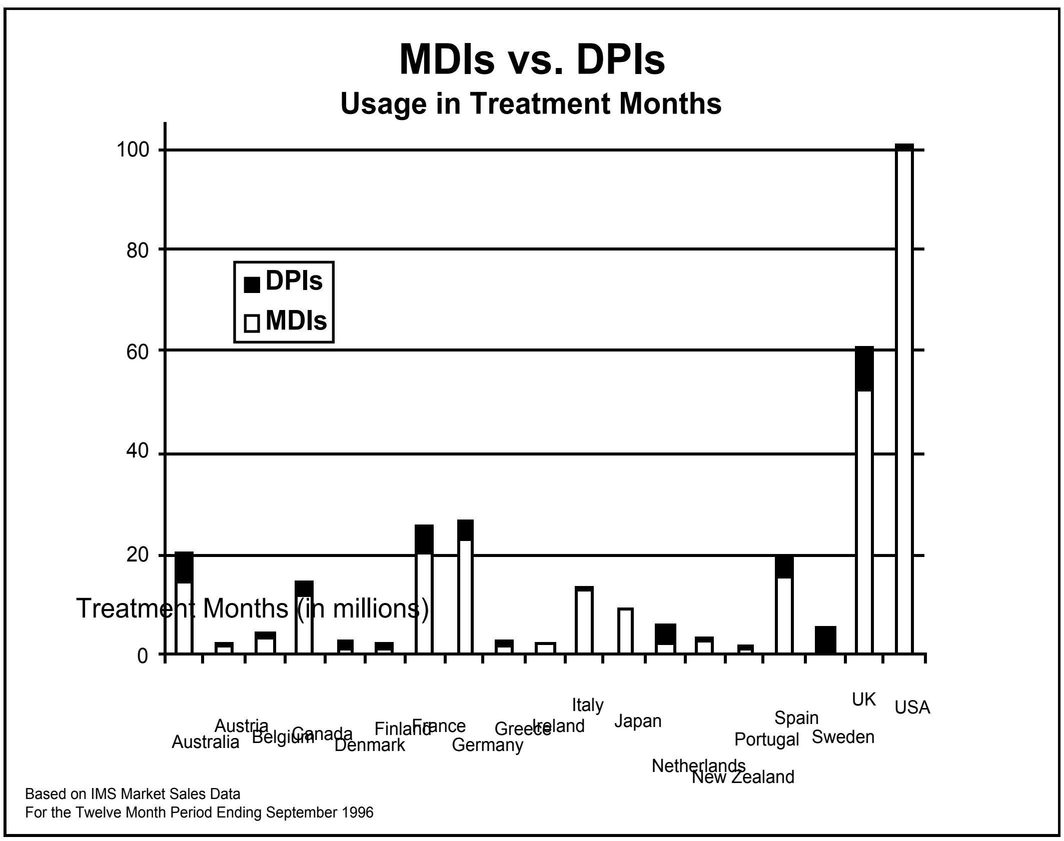
The figures below illustrate projected timetables for the first launch of HFC MDI products in the European Union (in any one member state) and for the launch of HFC MDI products in the United States from 1996 to 2005, showing a best possible scenario and a scenario with some reasonable delay (figures provided by IPAC from data collected through industry surveys undertaken during 1996). The different scenarios reflect the uncertainties of the issues described above but in either case a substantial number of reformulated CFC-free MDIs will be available in the next 5 years (note, in the figure, an "HFC MDI product" represents a single dosage of a single brand).

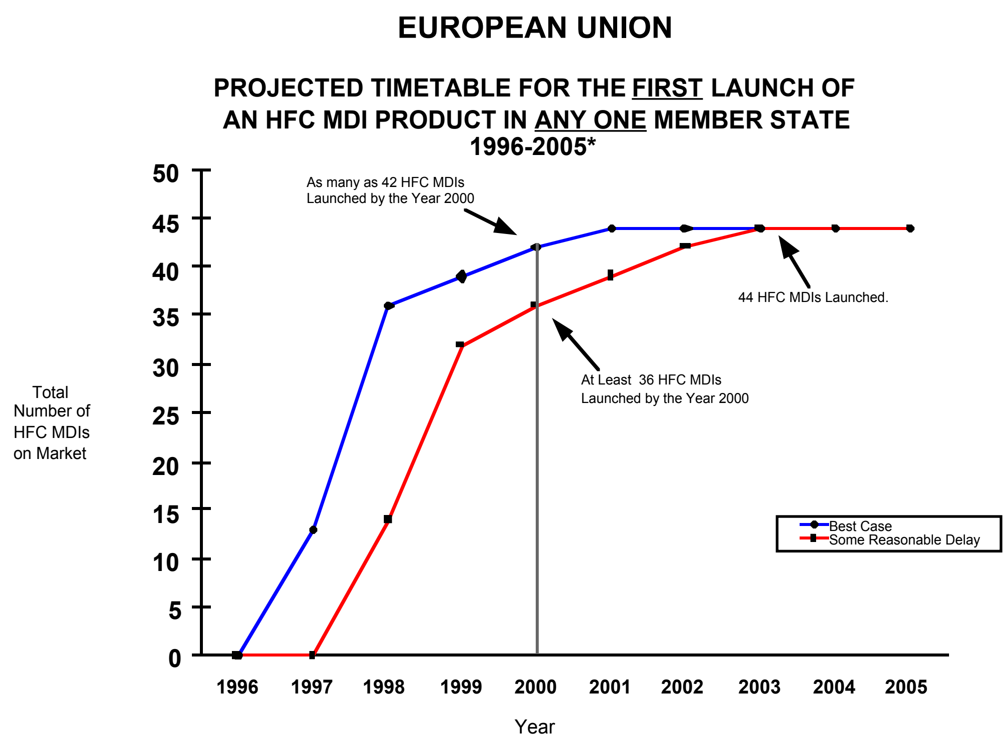
Education and Training

To facilitate patient and physician utilisation of the reformulated products, education and training are required. Options currently employed and planned include:

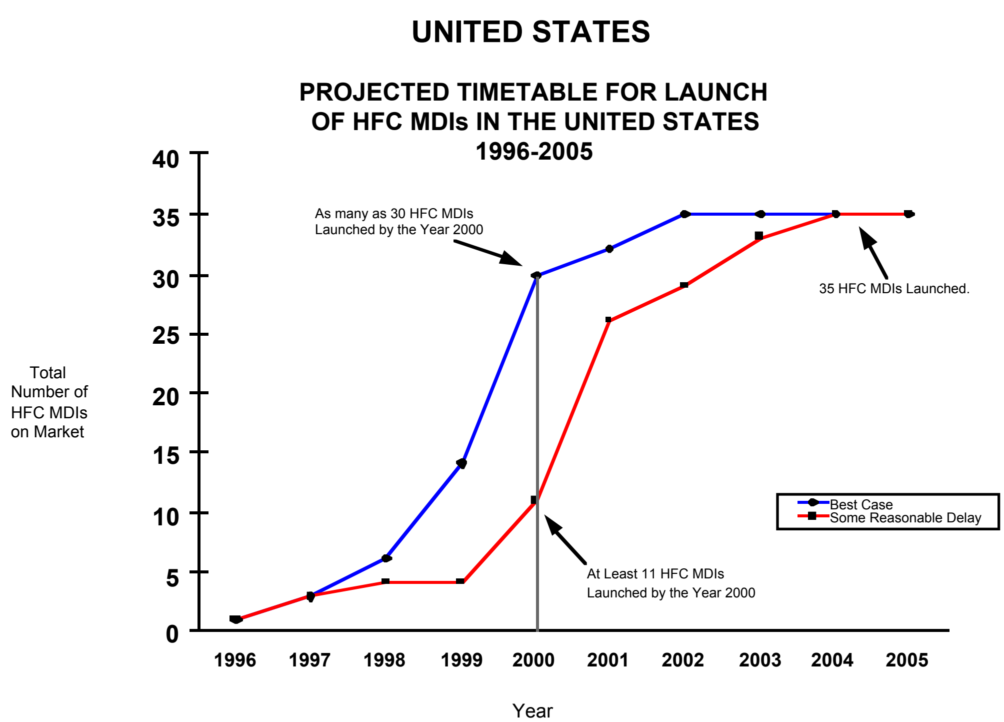
- Professional Associations - through medical journals, reports, newsletters and conferences. The TOC welcomes national initiatives such as the professional/pharmaceutical collaboration embodied in the National Asthma Education and Prevention Programme in the USA.


MDIs vs. DPIs by Drug Category
In Approximately 54 Countries*
9.9%
20.0%
14.8%
23.3%
6.2%
90.1%
80.0%
85.2%
76.7%
93.8%
100%
80%
60%
40%
20%
0%
Percentage of M
DPIs
MDIs
B2 Short-Acting
B2 Long-Acting
Non-Steroidal Anti-Inflammatories
Corticosteroids
Anti-Cholinergics
* Calculated on the basis of pack units. Please note that the number of doses in pack units may vary.
Based on IMS Market Sales Data For the Twelve Month Period Ending September 1996


MDIs vs. DPIs
Usage in Treatment Months
100
80
60
40
20
0
DPIs
MDIs
Treatment Months (in millions)
Australia
Austria
Belgium
Canada
Denmark
Finland
France
Germany
Greece
Ireland
Italy
Japan
Netherlands
New Zealand
Portugal
Spain
Sweden
UK
USA
Based on IMS Market Sales Data
For the Twelve Month Period Ending September 1996



*Note: One HFC MDI product was launched in 1995.



- Treatment guidelines issued by the country's medical authority which document the advantages and drawbacks of different forms of therapy and recommend specific forms of care for specific patient groups. All countries with guidelines continually review and revise their nations guidelines and many now include reference to the CFC/MDI issue. During 1995 the US National Heart Lung and Blood Institute (NHLBI) and WHO introduced a Global Initiative on Asthma (GINA). This is educationally active within Non-Article 5(1) and Article 5(1) countries and is likely to be one appropriate body through which to increase international awareness of this subject.

- Medical Symposia where international leaders in the respiratory care field gather. Here physicians, medical researchers and pharmaceutical development experts can present, discuss and evaluate the advances and latest development of alternative treatment. During 1996 many more symposia were held where alternatives and current research efforts were discussed and examples include the European Respiratory Society, the American Thoracic Society and the American Academy of Allergy and Immunology. In the US the National Asthma Education Programme is in discussion with the American Lung Association regarding increasing awareness of the CFC/MDI issue, and other initiatives are taking place elsewhere.

- Promotional Material and Media Coverage Advertising and promotional material placed in medical journals and circulated to physicians by pharmaceutical companies. Also articles in popular media promote awareness in the public of new products. There is a need for further publicity by means of television and newspapers.

- Pharmaceutical Industry Education of the medical profession, support of medical symposia, reprint of pertinent articles and reports and information sheets to patients are strategies to help to inform both professionals and the public of developments and alternatives. The International Pharmaceutical Aerosol Consortium (IPAC) developed a brochure for health professionals entitled "Moving Towards CFC-free Metered Dose Inhalers".

- Medical Literature Articles appearing in the medical journals inform professionals of developments, and several were published during 1994-1996, many written by members of the TOC.

- Support Groups which provide information, seminars and programmes aimed at both the general community and through schools, sporting groups etc., e.g. National Asthma Campaign (Australia), Asthma Society of Canada. The United Kingdom National Asthma Campaign has produced a fact sheet to help prepare patients for changeover of their inhalers.

The amount of educational activity being undertaken varies from country to country and should involve increasing awareness of DPIs as well as the reformulated MDI products. As more alternatives become available it is essential that a more active patient strategy is developed. This will involve concerted effort by the industry, and by health professional associations and national health authorities working together with patient support associations (e.g. National Asthma Campaigns and Asthma Foundations). For countries without patient support associations it is possible that the NHLBI/WHO Global Initiative (GINA) may be able to have available suitable literature for copying in the same way as they do with their current patient booklet, or add transition information to the GINA page on the Internet (http://www.ginasthma.com).

Professional bodies and patient associations are most likely to address this issue if governments take a lead in highlighting the importance of the subject. These educational activities are likely to cost money and responsibility and adequate funding need to be identified if a successful transition is to occur.

Increasing numbers of medical symposia are scheduled for 1997/8, culminating in a World Asthma Meeting in December 1998. This is supported by the major world respiratory organisations (European Respiratory Society, European Society for Asthma, Allergy and Immunology, American Thoracic Society, Asia-Pacific Society of Respirology, American Academy for Asthma, Allergy and Immunology, International Union Against Tuberculosis and Infectious Disease WHO/GINA). This meeting will highlight issues surrounding the safe transition to non-CFC treatments. The TOC encourages UNEP to actively support the 1998 World Asthma Meeting.

Asthma and COPD Treatment in Article 5(1) and CEIT Markets

Prevalence of asthma fluctuates from country to country, but the condition is diagnosed world-wide. The guidelines for its treatment and management by oral inhalation are accepted by the medical community. However, cost considerations may have restricted the use of inhaled therapy. As economies expand it is expected that MDI consumption in Article 5(1) and CEIT markets will continue to grow.

Article 5(1) countries and CEIT satisfy their MDI technology needs in the following manners:

Imports as Sole Source:

Countries such as Ecuador, Tunisia and Guatemala import all MDIs. No technology transfer is necessary.

Multinational Local Production:

Countries such as China and India (Glaxo Wellcome, Astra), Indonesia (Schering Plough) Brazil (Glaxo Wellcome, Boehringer de Angelli, and others), and Mexico (Glaxo Wellcome). depend in part upon multinational companies that locally manufacture MDIs. Each company has its own technology. However, many of these countries also rely on imports to supply domestic needs for the full MDI product range.

Independent Local Production:

Companies such as Lek (Slovenia), Exacerbazi (Turkey), Micropharm (Ukraine), CIPLA (India) and SINE (China) are independent companies which have adopted CFC-based technology.

Technology Transfer to the Article 5(1) and CEIT Countries

Most intellectual property protection concerning MDIs with CFCs has expired, and this technology has been widely copied without compensation. In contrast, there is very extensive world-wide intellectual property protection in place concerning the new HFC MDIs, and it may be necessary to acquire and compensate innovators for the use of these technologies unless local producers can develop novel manufacturing technologies and formulations.

In those countries where multinational companies are already operating, adoption of CFC-free technologies should take place as soon as possible. Parties may wish to add this commitment to the Code of Conduct approved at the Eighth Meeting of the Parties to encourage phaseout of CFCs.

Independent local producers may be able to obtain the necessary technology under licensing agreements. Financial assistance to obtain this technology will be necessary. Furthermore the availability and incremental cost of the non CFC propellants and other unique components of CFC-free MDIs are to be considered.

1.1.3 Sterilisation

By the beginning of 1997, CFC-12 use in Non-Article 5(1) countries for 12/88 sterilant gas had virtually disappeared, as final inventories were depleted. There remain no technical barriers to the phase out of CFCs in sterilisation.

Global consumption of CFC-12 in this sector has decreased from 20,000 metric tonnes in 1991 to less than an expected 500 metric tonnes in 1997. It is anticipated that virtually all CFC-12 use in this sector will be discontinued by 1999.

HCFCs are important as transitional products in both Non-Article 5(1) and Article 5(1) countries for hospital sterilisation. The only barrier to the final conversion from CFCs to HCFCs remains cost. Where CFCs remain relatively inexpensive and there is no regulation to require conversion, there is no incentive for the final conversion from CFCs to HCFCs.

Global consumption of HCFCs in 1996 for sterilisation was 2,900 metric tonnes and estimated global consumption of HCFCs for 1997 is 3,100 metric tonnes. The projected global usage for HCFCs is expected to peak at no greater than 3,400 metric tonnes and then decline after the year 2000 as HFC replacements and new technologies replace HCFCs.

1.1.4 Miscellaneous Uses

Ozone-depleting substances have been used in a variety of miscellaneous uses including tobacco expansion and laboratory and analytical uses amongst others. This report evaluates the current status of use of controlled substances and alternatives and reports progress on the availability of alternatives for laboratory and analytical uses. For other miscellaneous uses there have been no further developments as to alternatives. Further information will be provided in the 1998 report of the Aerosols, Sterilants, Miscellaneous Uses and CTC Technical Options Committee.

1.1.5 Carbon Tetrachloride

Carbon tetrachloride (CTC) is a heavy, colourless liquid at normal temperatures and pressures (boiling point 77°C). It is non-flammable, miscible with most organic liquids and is a powerful solvent. CTC is the most toxic of the chloromethanes (10 ppm by volume in air threshold limit as a maximum safe concentration for daily 8hr exposure). It is harmful if swallowed, inhaled or absorbed through the skin and its vapour decomposes on contact with flame or very hot surfaces to give off phosgene and other toxic products. CTC vapour or mist is irritating to the skin, eyes, mucous membranes and upper respiratory tract. Exposure can cause stomach pains, vomiting, diarrhoea, nausea, dizziness and headaches, and damage to the eyes, liver and kidneys.

CTC is an easily manufactured chemical which is widely available. Because of its relevance to the ozone layer, CTC has been extensively reviewed in the Report of the Aerosols, Sterilants, Miscellaneous Uses and Carbon Tetrachloride Technical Options Committee 1994. Specific applications of CTC have been investigated by the Process Agents Working Group in 1995 and are further elaborated upon by the Process Agents Task Force (PATF) in 1997; review can also be found in the Report of the Laboratory and Analytical Uses Working Group. Inadvertent Emissions and Process Losses were discussed in the 1994 Report of the Technical and Economic Assessment Panel (TEAP).

This large number of studies reflects the multiple nature of CTC uses. To better understand the role of this chemical it is important to keep in mind that CTC can be:

- Used as a feedstock for other chemicals. In the 1997 Report of the Process Agents Task Force (PATF), feedstock is defined as:

  "*A controlled substance that undergoes transformation in a process in which it is converted from its original composition except for insignificant trace emissions as allowed by Decision IV/12*."

- Used as a process agent. The 1997 Report of the PATF recommends that Parties consider process agent to be defined as:

  "*A controlled substance that because of its unique chemical and/or physical properties, facilitates an intended chemical reaction and/or inhibits an unintended chemical reaction*.

  Controlled substances are typically used in chemical processes as process agents for at least two of the following unique chemical and/or physical properties:

  1.) Chemically inert during a chemical reaction

  2.) Physical properties, e.g.

  - boiling point

  - vapour pressure

  - specific solvency

  3.) To act as a chain transfer agent

  4.) To control the desired physical properties of a process, e.g.,

  - molecular weight

  - viscosity

  5.) To increase plant yield

  6.) Non-flammable/non-explosive

  7.) To minimise undesirable by-product formation

Note 1: *Refrigeration, solvent cleaning, sterilisation, aerosol propellants and fire-fighting are not process agents according to this definition.*

Note 2: *Parties need not consider use of ODS for foam blowing, tobacco puffing, caffeine extraction, or fumigation because these uses are already covered in other Decisions and/or by Technical Options Committee Reports.*"

- Used as a solvent. This includes simple solvent extraction such as caffeine extraction and palm oil extraction, and cleaning applications such as metal degreasing and textile spotting. These uses should be discontinued to protect the ozone layer as well as to safeguard the health and safety of people using CTC where safer alternatives exist.

- Used in miscellaneous applications such as fire extinguishers, as grain insecticide fumigants, and as an antihelminthic agent (especially for the treatment of liver fluke in sheep).

- Used as a laboratory chemical.

- Produced inadvertently in some important industrial processes.

The distinction between these uses is not always clear cut and therefore makes it difficult to provide global data on both CTC production and consumption. Further information is required in some areas and where available will be presented in the next Report of the Aerosols, Sterilants, Miscellaneous Uses and Carbon Tetrachloride Technical Options Committee.

The remainder of this progress report will cover feedstock, solvent, miscellaneous and laboratory uses. The role of CTC as a process agent has already been studied extensively in the 1997 PATF Report.

Recent atmospheric measurements have demonstrated that the atmospheric levels of carbon tetrachloride are falling (Simmonds *et al*., *Atmospheric Environment*, 30 (23), pp 4041-4063, 1996). There are a number of possible reasons for this reduction:

- Reduction in the use of CTC as a feedstock to produce CFC-11 and CFC-12 in Non-Article 5(1) countries and CEITs resulting in a reduction in emissions during the manufacturing processes.

- Improvements in containment technologies in process agent applications in Article 2 countries.

- Reductions in the use of CTC in process agent and other applications in CEITs.

These reductions could be partially offset by increased use and emissions of CTC in some Article 5(1) countries. However, the TOC believes that the degree of CTC emissions varies significantly from country to country depending on the type of process, use and emission control techniques.

CTC Production and Consumption

CTC is normally produced by the high temperature chlorination of propylene or methanes, known as chlorinolysis. Other starting materials have been used. Most production facilities to manufacture CTC alone have closed in Non-Article 5(1) countries. Some facilities can produce CTC and perchlorethylene as joint products - these latter facilities can usually be tuned to produce either 100% perchlorethylene or 100% CTC by recycling within the plant.

The global production data for CTC are hard to obtain and difficult to interpret due to the dual nature of CTC as a feedstock and as a final product. It is possible to estimate the total CTC production for CFC production by using the following formula:

CFC-11 produced x 1.14* = CTC consumed

CFC-12 produced x 1.30* = CTC consumed

(*) These figures are average values and for guidance only

By using data provided by the Alternative Fluorocarbon Environmental Acceptability Study (AFEAS) Production, Sales and Atmospheric Release of Fluorocarbons through 1995, Alternative Fluorocarbons Environmental Acceptability Study 1997, it is possible to make the following estimates (in tonnes).

Production of CTC as feedstock for CFC manufacture (metric tonnes)

Year	CTC	CFC-11	CTC	CFC-12	Total CTC
1993	167,729	147,131	279,063	214,664	446,792
1994	68,665	60,232	173,680	133,600	242,345
1995	37,259	32,683	107,669	82,822	144,928

The AFEAS data includes production in all Non-Article 5(1) countries, plus their subsidiaries in Article 5(1) countries, and exclude CEIT countries. Traditionally, AFEAS data have not included countries such as the CEIT countries, India and China. However, unofficial data for the Russian Federation indicates that in 1995 31,082 tonnes of CTC were manufactured and 28,596 were used as feedstock, the remainder being exported. Figures for 1996 indicate a 40% reduction in CTC manufacture for the Russian Federation from 1995. The only other country of the former USSR which produced CTC in the last 2 years was the Ukraine which manufactured about 9,000 metric tonnes. In 1995, China used as feedstock 52,400 tonnes of CTC of which 30,500 tonnes were produced domestically. Other non-feedstock uses in China amounted to 459 metric tonnes. For India, it is estimated that an additional 25,000 tonnes of CTC were used for CFC manufacture in 1995. From this data it can be estimated that approximately 240,000 metric tonnes of CTC were produced for the manufacture of CFCs in 1995.

Using 1995 data provided by the UNEP Ozone Secretariat, it is possible to extrapolate feedstock volumes of CTC from the figures that Parties reported for CFC production. Non-Article 5(1) countries declared that approximately 131,000 tonnes of CFC were produced in 1995 and Article 5(1) countries reported 107,000 tonnes of CFC production for the same year. From these figures, the TOC estimates a total CTC requirement for CFC production of 285,000 tonnes in 1995. This latter figure is approximately 20% higher than the figure calculated from the AFEAS and other data presented above and probably reflects the absence of data for some countries that do not report to AFEAS. Given 1995 was the last year that Non-Article 5(1) countries were allowed normal manufacture of CFCs, the TOC believes that a substantial reduction could be expected for 1996 in Non-Article 5(1) countries.

The main use of CTC is that of feedstock for the production of CFC-11 and CFC-12. It can be estimated that about 95% of CTC production is used in this manner. The other major recognised use is as process agents. In its 1997 report, the Process Agent Task Force has estimated that production of carbon tetrachloride for process agent use is approximately 10,000 tonnes in Non-Article 5 and Article 5(1) countries for 1995.

Other uses of CTC, such as metal and textile cleaning and fumigants have been described in previous reports of the Aerosols, Sterilants, Miscellaneous Uses and Carbon Tetrachloride Technical Options Committee (1991, 1994). Alternatives already exist for the majority of these uses, and are widely available as discussed in the 1994 UNEP Solvents, Coatings and Adhesives Technical Options Report. The TOC will investigate these other uses of CTC in more detail for its 1998 report.

1.2 THE ECONOMIC OPTIONS COMMITTEE

This brief report covers the activities of the Economic Options Committee (EOC) from April 1996 to April 1997. No full meetings of the EOC were conducted during this period.

EOC members have taken part in tasks assigned by the Parties to the Technology and Economic Assessment Panel. Suely Carvalho, a co-chair of TEAP and EOC member, Robert Van Slooten, co-chair of the EOC and a TEAP member, and Sergio Oxman, an EOC member, were members of the Replenishment Task Force which prepared the report to the Parties on the "1997-1999 Replenishment of the Multilateral Fund"; and were also the co-chairs of the Methyl Bromide Task Force of the Economic Options Committee in 1997. Anil Markandya, a member of the EOC, also served as a member of the Methyl Bromide Task Force of the EOC.

The work of the Replenishment Task Force was underway by April 1996 and was completed at the Eighth Meeting of the Parties in San Jose, Costa Rica. During this period there were a number of working meetings with the members of the Executive Committee, the Secretariat of the Multilateral Fund, representatives of the Implementing Agencies, members of a number of delegations to Open-Ended Working Parties and the Eighth Meeting of the Parties.

The Methyl Bromide Task Force of the EOC met in Bangkok during 17-28 February in parallel with the 17-21 February meeting of the Methyl Bromide Technical Options Committee. The report of the Task Force was reviewed during the 7-11 April 1997 meeting of the TEAP in Brugge, Belgium. The report forms part of the TEAP Report to the Ninth Meeting of the Parties in Montreal, Canada in September 1997 (the Executive Summary is given in Volume I of this report).

A position of co-chair of the EOC remains open. Efforts are underway to fill this position with an economic expert from an Article 5(1) country and re-structure the EOC according to decisions approved by the Parties in 1996 (see for further information Part VI, Section 1.0).

1.3 THE RIGID AND FLEXIBLE FOAMS TOC

Key Conclusions

- All CFC use in this sector was eliminated by 1996 in Non-Article 5(1) countries (except for some CEIT countries).
- Zero ODP alternatives are the substitutes of choice in many applications including packaging, cushioning (flexible) and certain rigid thermal applications.
- No single solution has emerged from transition. Choices must be retained to allow optimal solutions for given applications, producer-specific and country-specific circumstances.
- In several markets and for certain applications HCFCs are necessary for rigid thermal insulating foams until other long term zero-ODP solutions are proven.
- Given the availability of zero-ODP substitutes for other foam applications, it is unlikely that there will be expanding use of HCFCs in Article 5(1) or Non-Article 5(1) countries beyond thermal insulation applications.
- No transition barriers unique to Article 5(1) countries have been identified.

1.3.1 Status of CFC and HCFC Use

CFC use in Non-Article 5(1) countries was eliminated in 1996. For Article 5(1) countries a CFC phaseout in this sector is technically feasible around the year 2000 provided that Multilateral Fund projects are implemented without delay and zero-ODP alternatives are commercially available.

In several markets and for certain applications HCFCs are necessary for rigid thermal insulating foams until other long term zero-ODP solutions are proven. Given the availability of zero-ODP substitutes for other foam applications, it is unlikely that there will be expanding use of HCFCs in Article 5(1) or Non-Article 5(1) countries beyond the insulation applications.

1.3.2 Status of Zero-ODP Substitutes

Zero-ODP alternatives are currently the substitutes of choice in many foam types and applications. The major zero-ODP applications are:

polystyrene, polyolefin and polyurethane for packaging with CO2 (water and injected), hydrocarbons and HFC-152a;

flexible polyurethane for cushioning with methylene chloride and liquid CO2;

polyurethane and polystyrene rigid insulation foams where energy efficiency and fire safety requirements can be met with hydrocarbons, HFC-134a and CO2 (water and injected); and

polyurethane integral skin with CO2 (water), HFC-134a and hydrocarbons.

1.3.3 HCFC Replacements

Potential next generation HFC replacements for HCFC-141b continue development for thermal insulating polyurethane and phenolic foams. Although not yet commercialised, technical evaluations show these substitutes are non-flammable and have an equivalent thermal insulation value of currently used HCFCs. Most toxicological testing has been completed for the leading next generation HFC candidate (HFC-245fa) and commercialisation is expected to begin around 2000. For polystyrene and polyolefin insulating foam, the most likely long term candidates are CO2 and HFC-134a.

Considerable technical resources are also being devoted to optimising current hydrocarbon formulations used for polyurethane and phenolic foams, especially in reducing the density and in improving mechanical properties and insulation performance over a wide temperature range of product use. For construction foam applications it is not yet possible to meet fire safety requirements in all markets with hydrocarbon blowing agents.

The transition out of HCFCs is being hampered by the continued uncertainty over the long-term acceptability of HFCs due to potential climate impacts. The foam industry is, however, working to clarify net (direct and indirect) impacts using the Total Equivalent Warming Impact (TEWI) method.

1.3.4 Issues in Article 5(1) Countries

No major technical barriers have been identified for the phaseout of CFCs used in Article 5(1) Countries for foam products. CFC-11 continues to be widely available and is generally much cheaper to use than the currently available alternatives. Another factor constraining a more rapid phaseout is that very few alternatives are manufactured in Article 5(1) Countries. Given the advantage of using existing equipment with next generation HFCs, once the uncertainties in price and availability are clarified these substitutes may serve as a cost-effective replacement in Article 5(1) Countries.

Many Article 5(1) Countries are transitioning from CFCs to materials that are relatively more hazardous for various foam applications. Consistent use of safe practices for flammable or toxic materials during storage, production and transportation continues to be of some concern.

1.3.5 Rigid Polyurethane Foams

a. Overview

The use of CFCs in the manufacture of polyurethane rigid foams were completely replaced in almost all Non-Article 5(1) Countries by the end of 1995 (end 1994 in the European Union). Only some CEIT countries failed to meet this deadline. There are currently many phaseout projects in progress in these countries using funds from the Global Environmental Facility (GEF). In Article 5(1) Countries CFC replacement is underway and several projects supported by the Multilateral Fund have been completed.

In terms of technology the main choices have been either HCFC-141b or hydrocarbons (cyclopentane or pentane isomers). There are several issues and considerations which are common across the applications and geographic regions:

> <u>HCFCs</u> - HCFC-141b has been used in more than 80% of the cases where an HCFC route has been chosen. These cases cover virtually every application, the main ones being appliances in North America, Japan and several Article 5(1) Countries and building/construction in all regions. HCFC-141b is chosen because it offers a thermal conductivity/insulation performance almost equivalent to that given by CFC-11 and does not require significant changes to existing processing equipment. In several markets and for certain applications HCFCs are necessary for rigid thermal insulating foams and transportation safety foams until other long term zero-ODP solutions are proven. There has been a foam density, and thus cost, increase particularly in appliance and boardstock applications of about 10%. There has also been some HCFC use to avoid problems resulting from inadequate dimensional stability (e.g. shrinkage) which affects the mechanical performance of the foam in building applications, especially in areas with extreme cold weather conditions. Density and dimensional stability issues have been

addressed, in some instances, by co-blowing with HCFC-22.

Other than HCFC-141b there has been relatively minor use of the HCFC-142b/HCFC-22 blend (particularly in sandwich panels) and HCFC-22.

Hydrocarbons - The main uses are cyclopentane in domestic appliances in Europe and in both GEF and MLF projects and of iso or n-pentane in building/construction applications in Europe. Considerable technical resources are being devoted to optimising current formulations in order to improve mechanical properties and insulation performance over a wide temperature range of product use. Progress has been made in reducing the density increase from CFCs in appliance formulations, and in improving dimensional stability in boardstock formulations.

Non-HC Zero ODP Options - Despite relatively poor insulating properties, there has been some renewed interest in HFC-134a for sandwich panels and appliances because it is non-flammable and is currently available. The properties of 100% CO_2 formulations have not made any significant advances.

There is a very high level of interest and expectation for next generation HFCs which are now under development. The next generation HFCs are expected to have comparable energy efficiency properties to HCFC-141b, and also be non-flammable. They are also potential "drop-in" replacements for existing equipment which uses HCFC-141b when it is phased out in Non-Article 5(1) Countries beginning in 2003. For long term these next generation HFCs are viewed as the only potential viable alternatives to hydrocarbons. In the last two years greater quantities of the new HFCs have been available for foam evaluations and toxicology testing. Common issues for next generation HFCs are higher costs in use, commercialisation timing and impact on climate change. Climate impacts of use of HFCs in insulating foam are being evaluated by total equivalent warming index (TEWI) analysis.

The leading candidate is HFC-245fa which has been proven to be a technically feasible replacement for HCFC-141b in several applications. Toxicology testing is underway and results of 90 day exposures suggest the material will have no toxicity issues. Initial commercial production by one company is expected by fourth quarter 1999. Other candidates include HFC-365mfc, and possibly HFC-236ea. Commitment to commercialise either HFC-365mfc or HFC-236ea is unconfirmed.

b. Rigid Polyurethane Applications

Appliances - The main replacements for CFC-11 have been HCFC-141b and cyclopentane. The former is used in domestic appliances in North America, Japan, Europe (about 10% of appliances), Korea and in some Article 5(1) Countries where energy consumption is a major concern for either domestic or export markets. It is also being used extensively in commercial units and in domestic units when the small scale of production makes conversion to hydrocarbons not economically viable.

Cyclopentane, and in some cases, mixtures with pentane isomers are used throughout Western Europe, Australasia and in several lines in Japan. Conversion is in progress or production is underway in some facilities in Eastern Europe, Russia and the Ukraine, Korea, and many Article 5(1) Countries including China, Thailand, Indonesia, Argentina, and Malaysia. Partial conversion to HCFC-141b and cyclopentane is also underway in some appliance facilities in Brazil.

There is only minor use of other options.

Further development of HCFC-141b-based formulations has been mostly to achieve lower stable densities for better performance (energy efficiency) and cost reduction. The optimisation routes have included the use of 10-20% of HCFC-22 to increase cell gas pressures.

Additional development of cyclopentane-based formulations has allowed cost savings by minimising the density increase (compared to CFC-11-based formulations) from an initial level of up of 15% down to 7% or less. This has been achieved by formulation optimisation and the use of cyclo/iso pentane mixtures or iso/n-pentane mixtures. The latter can give a density only marginally above those with CFC-11 and can be especially suited to freezer applications where the operating temperature is lower and the thermal conductivity penalty relative to cyclopentane is of the order of 0.5 mW/mK.

Next generation HFCs are being extensively evaluated by potential suppliers, foam system suppliers and by appliance industry consortia. Whilst formulations have yet to be optimised the energy consumption of cabinets based on HFC-245fa is comparable to those using HCFC-141b. Whilst the future economics of the use of HFC-245fa is not known there will be balancing factors compared to HCFC-141b because the stable foam density will be lower and it does not need a specific plastic liner to prevent solvent attack.

There is renewed interest in HFC-134a as a safeguard against the non-availability of next generation HFCs and to avoid the cost of conversion to handle flammable HCs.

In terms of alternative products, the vacuum panel picture has evolved. Silica-based panels have not significantly expanded their market and the glass-fibre based panels are no longer in production. Whilst panels based on open/fine celled rigid polyurethane foams have been further developed and implemented in some product lines, and are being extensively evaluated by several additional appliance manufacturers. Vacuum panels have the advantage of weight/density coupled with increasingly proven performance. They offer, typically, a 20% reduction in energy consumption or a 25% increase in internal volume. Overall current usage of vacuum panels has been limited to niche market segments due to the high cost of panels. Panels supplement but do no replace standard foam insulation, and they may find greater utility as more stringent energy regulations spread across the markets.

Other Appliances - These applications include water heaters, commercial refrigerators and freezers, picnic boxes (coolers), flasks and thermoware and refrigerated containers.

There have been no significant changes since the 1994/95 TOC Report. A range of HCFC technologies is used with HCFC-141b in those, for example, commercial refrigerators and freezers and refrigerated containers, where high insulation requirements must be met. CO_2 (water) is used when the opposite is the case and where foam thickness can be increased, for example, in water heaters. Pentane isomers and cyclopentane is used in water heaters and commercial refrigerators and freezers, especially in Europe.

For many applications next generation HFCs are expected to be used, especially HFC-245 fa, when they are commercially available.

Boardstock/Flexible-Faced Lamination - The CFC replacement technologies are almost entirely HCFC-141b in all regions except for considerable n-pentane being used in Europe.

Some early foams made with HCFC-141b and hydrocarbons in place of CFC-11 experienced dimensional stability problems associated with density and the reduction of cell gas pressure in use conditions. Progress has been made, especially in some markets, toward overcoming these problems. Changes in many basic raw material components and improved processing techniques have allowed production of HCFC-141b polyisocyanurate-formulation boardstock with no density penalty when compared with foams meeting the same specification when produced with CFC-11.

For the future, the next generation HFCs, particularly HFC-245fa, and hydrocarbons are seen to be the main alternatives after HCFC-141b is phased out in Non-Article 5(1) Countries. Next generation HFCs are not yet proven, and it is not yet known whether fire performance constraints using hydrocarbons can be overcome in all markets. The production cost structures whilst using HFC alternatives will be critical factors affecting their wide scale use. Raw material costs can have a major impact on the unit volume cost of boardstock products. However, improved performance properties, particularly thermal resistance, may offset the increased cost. There is very little boardstock production in Article 5(1) Countries.

Sandwich Panels - The main alternative used is HCFC-141b but there is more use of gaseous HCFC-142b/HCFC-22 blends and HCFC-22 than in most other applications and this has also led to the use of HFC-134a in several discontinuous and continuous production lines. Some lines in Europe, particularly in Germany, Finland and the Netherlands, are in production with pentane.

As in the case of boardstock, many manufacturers are viewing the next generation HFCs as potential long term replacements for HCFC-141b with relevant issues as cited before.

Spray Foam - In this application CFC-11 has been mainly replaced by HCFC-141b but, in addition and particularly in Western Europe, suppliers are also offering water blown systems. The latter has a thermal conductivity up to 50% higher than with HCFC-141b and a significant (20-30%) increase in foam density. Water-blown systems result in a significant economic penalty and are unable to be used to meet all fire regulations.

Due to outdoor applications and higher flammability risks, the next generation HFCs are expected to be long-term replacements for HCFC-141b.

Rigid Slabstock (Bunstock and Box) Foam - The main CFC replacement is HCFC-141b. A small number of European producers have switched to a pentane isomer but the processing conditions, including the high temperature exotherm, has limited the application of this option.

As in the other building/construction sectors, next generation HFCs are viewed by many as long-term options.

Pipe-in-Pipe/Preformed Pipe - For the pipe-in-pipe application the European producers have switched to either cyclopentane or water-blown formulations. Elsewhere the main alternative is HCFC-141b with the next-generation HFCs seen as the longer term option. Both hydrocarbons and HCFCs are being considered in China.

One Component Foam - This technology favours a gaseous blowing agent and the HCFC-142b/HCFC-22 blends have been used in some markets. Flammable gases such as propane, butane and dimethyl ether (DME) are used either singly or in combination. HFC-134a is also now widely used and may take a dominant position. HFC-134a is also being combined with HFC-152a or DME and some hydrocarbons.

c. Rigid Polyurethane - Issues in Article 5(1) Countries

CFC-11 continues to be widely available and is much cheaper to use than the currently available alternatives. Another factor constraining a more rapid phaseout is that very few alternatives are manufactured in Article 5(1) Countries. Given the advantage of using existing equipment with next generation HFCs, once the uncertainties in price and availability are clarified these substitutes may serve as a cost-effective replacement in Article 5(1) Countries.

Many Article 5(1) Countries are transitioning from CFCs to hydrocarbons for various applications. Consistent use of safe practices for flammable materials in handling and use of flammable substances continues to be of concern.

1.3.6 Polyurethane Integral Skin Foam

Automotive Safety--As of 1996, North America completely converted to HFC-134a or H_2O blown systems. Conversion from HCFC-22 went smoothly, although skin formation is not as good. In some limited applications conversion has been made to n-pentane blown systems (i.e. instrument panels for heavy trucks). In Europe, although some HCFC-141b is still used (predominantly in CEIT countries), conversion to zero-ODS systems is occurring rapidly. Most production is currently using n-pentane, H_2O or HFC-134a systems. In the Russian Federation, CFC-11 is still being used for these applications. In Asia, CFC-11 (China) and HCFC-141b (India) blown systems are still used for integral skin. In Japan, nearly all production has changed to H_2O blown systems. HFC-134a is also used in some countries in Asia.

This application is in the middle of a technological change with the expectation that CO2 (water)-based technology will eventually be widely used. However, the market does not uniformly have confidence that current formulations are suitable in all cases, especially with respect to skin quality. Consequently, there may be some limited ODS use. In addition, CO2 (water)-based technology is not yet commercially available in all markets. In the interim, HFC-134a and pentane are used in addition to CO2 (water).

Shoe Soles--North America converted to HFC-134a or all H_2O blown formulations for both polyether and polyester polyol based systems. Some limited conversion to n-pentane and acetone systems have also occurred. N-pentane systems give excellent skin properties and good processability. Europe has converted to all H_2O blown systems, with some HFC-134a being used in polyether polyol based systems. In some CEIT countries (e.g. Russian Federation), CFC-11 is still used in polyether polyol based systems. Some countries in Asia are still utilising CFC-11 or HCFC-141b blown systems. Systems without blowing agents are also being sold to customers in Asia, whereby the system user independently chooses the blowing agent.

Rigid Integral Skin (i.e. computer housings, skis etc.)--These applications have completely converted to all H_2O blown systems. In some cases in Europe, t-butanol is used as the blowing agent.

1.3.7 Flexible Polyurethane Foam

a. HCFC Overview

There is currently no or negligible use of HCFCs in this application. The use of HCFCs in the manufacture of flexible foam is (i) not attractive from a cost standpoint, and (ii) not necessary from a technical standpoint.

b. Zero-ODP Alternatives

With an abundant array of commercially developed ODS free technologies for the manufacture of flexible PU foam, there is no technical barrier to make the transition to an ODP free product. Some non-technical barriers may slow the transition including (i) existing or emerging regulatory restrictions, mainly related to the emission of organic compounds and (ii) the capital costs required to make the transition.

ODS phaseout technologies for flexible polyurethane foams are frequently specific to the three sub-categories: slabstock, box and moulded.

Liquid Carbon Dioxide (LCD) Technology--The most outstanding development in the replacement of CFCs in flexible foams is the rapid emergence agent. Three equipment manufacturers have introduced and installed full scale machinery capable of producing flexible PU foam--slabstock as well as moulded. The technology has not been applied to box foam.

LCD technology for slabstock is based on (pre) mixing liquefied carbon dioxide in the polyol--which requires low temperature and elevated pressure, followed by mixing with the other components, controlled decompression and laydown of the foam mixture. While all suppliers use similar LCD storage, mixing and metering devices, they differ in the design of the--very critical--laydown device.

Currently 15-20 slabstock units are using LCD technology with about 20 more in planning or in construction stages. The technology is being used not only to replace CFCs but also methylene chloride. Methylene chloride is the primary replacement technology but is in several countries under regulatory scrutiny and faces restrictions in allowable emission rates as well as in human exposure. LCD technology has proven to be commercially viable for a significant variety of foam grades in the 15-35 kg/m3 density range. Each LCD foam manufacturing system faces challenges specific to its equipment design and the desired product range, which include:

- Achievement of relatively high hardness at low densities;
- Control of pinholes to a level consistent to non-LCD processes; and
- Production of foams using raw materials with solid particles such as calcium carbonate, melamine, graft polyols and pigments.

The application of LCD in flexible mouldings is less critical in decompression and laydown. LCD is premixed in the polyol or in the isocyanate. This application has not seen a similar rapid development as in slabstock. The current major CFC replacement technology--the use of water-based formulations--does not face any regulatory restrictions and requires lower investment. In addition, the largest use of flexible mouldings is in automotive seats, an application that requires intensive product scrutiny before product changes are allowed. It is expected that LCD will act in this application as an option to reduce densities while maintaining acceptable product properties.

Any flexible foam producer considering the use of LCD must evaluate the current alternatives in light of the product mix that is being produced. One system may be more suited to a certain product than the others. This can only be determined by a thorough analysis and understanding of the offered alternatives.

The use of LCD as an auxiliary blowing agent to produce flexible polyurethane foam will continue to grow in popularity related to its benign environmental nature--no ODP, no GWP impact. The main barrier--high investment costs--limits its economical use to plants that consume in excess of 20 tonnes CFCs/year, but the cost structure is still developing and may improve.

Low Index Technology--The so called “low index” technology, in which the use of certain additives is combined with lower TDI indexes, has also recently received increased attention with the introduction of two new additive systems that are claimed to allow up to 70% CFC--or methylene chloride--replacement. The lower TDI product density is achieved through the increase of water--which is the principal blowing agent producer in all of flexible PU foams. The technology may have good chances in the production of box foam, where no LCD technology is offered.

c. Flexible Polyurethane Foam - Issues in Article 5(1) Countries

There are no technical barriers to transitioning to zero-ODP alternatives in flexible foams. A number of facilities have completed transition. Over 50 additional facilities have completed plans to transition to methylene chloride or LCD technology.

1.3.8 Extruded Polystyrene Sheet

There is no technical nor economic justification for the use of CFCs or HCFCs in Non-Article 5(1) and Article 5(1) Countries for extruded polystyrene sheet foam. CFCs and HCFCs are banned in all Non-Article 5(1) Countries in this highly emissive non-insulating application. In Article 5(1) Countries, alternative blowing agent technologies using either CO_2 or hydrocarbons are readily available and transferable.

1.3.9 Extruded Polystyrene Board

a. HCFC Overview

HCFCs remain essential transitional blowing agents for extruded polystyrene insulation boards in most parts of the world because of their contribution to the overall insulation performance of the product. Nonetheless, transition to zero-ODP alternatives has begun in some countries. The European plastic foam insulation industry has pledged to the European Commission to phase out HCFCs by 2004.

b. Zero-ODP Alternatives

Since the last TOC report no further technical solutions for zero-ODP options have been announced. The alternatives remain:

a) CO_2 either alone or with non-halogenated organic co-blowing agent; and
b) HFC's 134a and 152a - where HFC-134a is the preferred option because it offers improved thermal resistance.

Geographically, transition zero-ODP alternatives is not uniform. In Europe, the CO_2 - blown foam is, in spite of the current disadvantages of higher density and lower insulation performance, gradually increasing its market acceptance in the traditional extruded polystyrene applications where the performance properties like moisture resistance and compressive strength are as significant as thermal insulation value.

Whilst public authority purchasing policies have had considerable influence in countries like Germany, Austria, Switzerland, the Netherlands and the Scandinavian region, in most other regions economic viability and market needs are dictating the pace of the implementation of the CO_2 technology.

HFC-134a and -152a technology is being used in Sweden by one producer and is being actively considered by many others globally. However, due to their potential to contribute to climate change use of HFCs are of concern even though most of the blowing agent is retained in the foam and only gradually released over decades. The Swedish EPA has proposed that as of January 1998 the use of HFCs as foam blowing agents be banned.

In North America, there are no signs of a move out of HCFC-142b/ethyl chloride formulations because of technology barriers in producing a North American product mix, meeting industry insulation standards and the general acceptability of HCFCs.

In Japan, where HCFC-141b is not produced, near-zero ODP formulations have already been in existence for some time covering the lower insulation value sector of the market. Blowing agents are ethyl or even methyl chloride (phased out on toxicity grounds in W. Europe and N. America), and hydrocarbons such as butane and isobutane. For high performance insulation applications HFCs are being seriously considered.

There are extruded polystyrene applications which have dimensional constraints which require the maintenance of high performance insulation. In such areas, unless there is a further breakthrough in CO_2 technology, HFC-134a will remain the sole zero-ODP alternative. For these applications, any bans or restrictions of HFC use due to climate change concerns could slow the transition to zero-ODP alternatives.

1.3.10 Polyolefin Foam

a. HCFC Overview

Except for minor use for thermal insulation or automotive safety cushioning applications, HCFCs are not used in polyolefin foams. Many Non-Article 5(1) Countries have banned HCFC use for this sector. Most Article 5(1) Countries are expected to be switching directly from CFCs to zero ODP alternatives.

b. Zero-ODP Options

Since the 1994/5 TOC Report, no new zero-ODP substitute technologies or products have been identified. The alternatives remain:

Hydrocarbons (primarily isobutane, n-butane mixtures); and
HFC-152a or HFC-134a usually in mixtures with hydrocarbons or CO2.

There has been considerable conversion of sheet and plank products globally to hydrocarbon alternatives (primarily isobutane, n-butane and mixtures).

c. Problem Areas/Barriers For Transition

Hydrocarbons
Flammability and safety continue to be the primary concerns. This has been highlighted by several incidents, in North America and Asia (Thailand, Singapore, Malaysia) involving explosions with serious injury during unloading on transport containers and fire during welding of a case containing foam. Areas that need to be carefully controlled are production storage, handling, shipping and customer use. Some manufactures have invested significant capital in their processes to reduce/eliminate pockets of high blowing agent concentration and/or spark minimising equipment/devices. Investment would likely include explosion proof equipment. Product containing flammable blowing agents should only be shipped in well-ventilated trucks or containers. Patented technology has been developed to help minimise flammability and safety concerns. This technology involves accelerated curing and in some cases perforation of the foam to reduce blowing agent levels to where safety concerns are minimised for storage, handling shipping and customer use.

Hydrocarbons are also classified as volatile organic compounds and local emission limits must be followed, where they exist. Meeting these regulations would likely add significantly to costs to convert some existing factories where best available technology (BAT) must be applied.

HFC-152a
This product continues to be difficult to use to produce large cross-section polyolefin foam. It has higher LFL (lower flammability limit) than isobutane (3.7% vs. 1.8%) but similar low energy of ignition and must be handled much like a hydrocarbon. The relatively higher cost of this material makes it difficult for manufacturers to be cost competitive in many markets.

HFC-134a
HFC-134a is even more difficult to use than HFC-152a. Its main benefit is that it is non-flammable and some manufacturers have opted for its use (blends with hydrocarbons or ethyl chloride) to balance flammability and safety concerns. The cost of HFC-134a has dropped due to increased supply, however, it still remains an expensive alternative when compared to hydrocarbons. CO2 has been considered as a cost reducer in HFC formulations, but its use (due to its fast exudation rate from polyolefin foams) make HFCs more difficult to implement during manufacture.

d. Issues / Successes in Article 5(1) Countries

Conversions from CFCs have been primarily to hydrocarbons based on utility, availability and economic viability.

1.3.11 Phenolic Foam

a. Market Penetration of HCFCs

With only a few exceptions, the use of HCFC-141b has dominated the phenolic foam sector following the phase-out of CFC use in Non-Article 5(1) Countries. In Europe, the use of continuously laminated phenolic foam products is growing strongly and is supported by steadily increasing sales of discontinuous block foam. In contrast, the use of phenolic foams in North America continues to decline, primarily because of technology difficulties and a market which does not fully differentiate the superior fire properties. As of today, the estimated use of HCFCs in the phenolic sector is between 1250-1500 metric tonnes world-wide.

b. Zero-ODP Alternatives

In the 1994 report, the key zero-ODP options for this sector were defined as next generation HFCs and hydrocarbons. In the intervening period more attention has focused on HFC-245fa than on other HFCs in view of the potential commitment of manufacturers to this product. However, significant development work on phenolic foams using this blowing agent has still not been possible owing to the very limited availability of samples. Of course, the eventual commercial price of the material will be an additional critical factor to the industry.

End-product fire performance continues to be the chief concern for closed cell hydrocarbon phenolic foams and the uncertainties surrounding the European efforts to harmonise fire regulations only serve to heighten this. Additional concerns are also arising from strengthening VOC legislation in certain parts of Europe and North America which are pressuring existing hydrocarbon users in related industries. A significant additional factor in the selection of hydrocarbons as a blowing agent for phenolic foam remains their poorer thermal efficiency. Current estimates show a 14-20% reduction in thermal efficiency over existing HCFC-141b blown foams and this is likely to be transferred also to the HFC comparison. Obviously, such thermal efficiency differences are at their most influential in applications where thickness is restricted, but even under conditions of constant thermal resistance (i.e. thicker sections of poorer insulants), factors such as weight, cost and embodied energy come into consideration.

c. Problem Areas/Barriers to Transition

The transition out of HCFCs is undoubtedly being hampered by the continued uncertainty over the future availability of appropriate next generation HFCs. Potential manufacturers of these materials are also being confronted by legislative proposals which restrict or ban HFC use due to potential climate impacts. This is particularly the case in Europe, where the major phenolic foam market exists. The foam industry in general, and the phenolic foam industry in particular, believes decisions in this area should not based on the specific global warming potentials of the blowing agents but on the overall comparative environmental benefits achieved with HFC blown foams. The calculation of Total Equivalent Warming Impact (TEWI) remains the most important parameter in making such comparisons and work is on-going to develop this data ahead of the Kyoto Conference on Climate Protection in late 1997.

d. Issues/Successes in Article 5(1) Countries

Although indigenous hydrocarbon based technologies have been identified for at least the last 2 years, most of those phenolic foam manufacturers historically-using CFCs have not yet made the change. It is difficult to judge whether the main reason arises from short-comings in the locally developed technologies or lack of funding. However, it is clear that further attention is required to facilitate phase-out of CFCs in these countries.

1.4 HALONS TOC

1.4.1 Introduction

In the past year the HTOC has concentrated on responding to requests from the Parties concerning the availability of halons and evaluating the possibility of surplus halon that could be destroyed. This is a complex issue and the work providing a thorough response to Decision VIII/17 continues. Parties may wish to refer to the 1991 HTOC assessment report which provides an explanation on the methodology used by the HTOC to estimate halon stocks. The methodology will be refined to reflect the experience gained since 1991 and the data that will be provided by Parties.

In addition, HTOC has started work on the 1998 Assessment Report. In the course of this work, the HTOC will focus on the achievements made to date as well as the range of issues that Parties have raised since the last assessment. The 1998 assessment report will therefore put more emphasis on regulatory aspects and upcoming policy issues where Parties have expressed a need for further technical information.

Past reports have always included valuable information of particular to the fire protection community. This information has now been transferred to the TEAP-Internet-site (http://www.teap.org), where it is readily available to the public. HTOC believes, that disseminating up-to-date technical information via this means of communication can serve as a worthwhile contribution to the provision of timely technology transfer. This will also allow the HTOC assessment process to focus on information of more specific interest to policy makers.

1.4.2 Assessing Achievements to Date

Production in Non-Article 5(1) countries, with the exception of some limited production of halon-2402 in Russia for essential uses, ceased as of January 1994. A major contribution to the production phaseout achievement were the proactive efforts of major users and some governments to establish halon banking and recycling programs.

Currently, recycled halon-1301 is being used to recharge existing installations after fires and supply new systems for critical applications. Virtually no new halon-1301 fire protection systems are being installed in non-critical applications. This has been made possible because alternatives are now available for most applications. Fire protection research efforts to identify and commercialise alternatives for remaining halon-1301 applications continues with strong support from the fire protection industry, major users and some governments. HTOC would also like to acknowledge the significant contribution by those governments that assisted with toxicology evaluation of the new alternatives.

Emissions resulting from testing of halon-1301 systems and training with halon-1211 fire extinguishers have been virtually eliminated. As well, service losses and other losses during the normal life of installations have been reduced significantly by improved housekeeping procedures, improved training of service personnel and other emission control measures. The objectives of the Protocol were shared by the fire protection community and strong efforts to implement measures that helped the protection of the ozone layer have been incorporated into fire protection technical standards and fire protection codes.

The existing installed base of halon-1301, referred to as the halon bank, is being carefully managed in most Non-Article 5(1) countries and some Article 5(1) countries. Management procedures have been established, allowing an orderly transfer of halons from decommissioned systems to critical uses. This has primarily been accomplished by national programs established by the fire protection industry and users with critical needs and assisted in some cases by national governments. There are still existing needs where no alternative solution is either technically possible or economically feasible. A such banking schemes are vital to meet these critical needs without an essential use production exemption.

This process also ensures that halon continues to have an asset value and thus encourages sustainable management of existing halons. HTOC is of the firm opinion, that maintaining a commercial value for the installed halon encourages efforts to further reduce emissions as the value of existing halon continues to increase.

Production of halon-1211 portable fire extinguishers ceased when production of halon-1211 was curtailed. In most cases halon-1211 fire extinguishers have been left in service, however, if used on a fire they are not recharged. In general, multipurpose dry powder has been accepted by the market as an acceptable alternative to halon-1211. For special cases where a clean agent, capable of extinguishing fires involving wood, paper and plastic is deemed to be of great importance, HCFC based alternative streaming type fire extinguishants are now being offered where allowed.

As a result of all the above mentioned steps, no essential use exemptions in the halon sector have been necessary with the exception of the special case of halon-2402 in the Russian Federation. In the Russian Federation, a national program has been developed and provided that the necessary funding will be made available, production of halon-2402 could be phased out completely in the near future.

1.4.3 Outstanding Issues

HTOC is of the opinion that ongoing production in Article 5(1) countries is the most important issue to be dealt with in the immediate future. Production of halon-1211 in Article 5(1) countries is growing and has reached a level of nearly 10,000 tonnes, the equivalent of the global halon-1211 production in 1984. A focus of attention on this problem and possible solutions is necessary. Several Parties have expressed interest in using recovered halon-1211 from Non-Article 5(1) countries to offset new production of halon-1211 in Article 5(1) countries. However there are difficult technical and commercial issues that must be considered in evaluating the viability of such an approach. HTOC will carefully evaluate its technical feasibility.

The concept of banking requires further clarification and explanation as confusion appears to remain widespread. The term "halon bank" is used to describe the total available amount of halon, that in existing equipment (the installed base - the greatest quantity) plus the halon reclaimed from decommissioned systems (a smaller quantity used to supply short term needs). It is therefore not a physical bank in the traditional meaning of the word but rather a managed inventory. HTOC will undertake additional efforts to communicate the concept and clarify the functioning.

Concern has been raised over the effect of delayed release of this halon inventory. HTOC will address these questions and has established information exchange with the Science Panel. The HTOC is of the opinion that banking efforts resulting in a careful management of the installed halon will result in lower emissions. Wise management mitigates the need for essential use production to satisfy critical uses and establishes programs that would also be suited to manage environmentally sound disposition of excess stocks should alternatives for critical uses become available at some future date.

Certain critical uses still have no proven alternative (e.g. aircraft, combat vehicles and explosion inerting situation). HTOC will furthermore provide information on the differences between new-built- vs. retrofit-situations. Major research efforts are still needed for solutions and it is recognised, that such projects are under way. Many applications are confronted with prohibitive costs in the latter situation.

For halon-1211, most is in small fire extinguishers, widely dispersed over many locations within a country. Both tracking and collecting this material appears to be especially difficult. Management programs for halon-1211 have not been well established as yet due to the difficulties posed by trying to collect the small, widely dispersed quantities involved even though the total may be significant.

HTOC recognises that special problems exist for CEITs. A special case is the fact that many CEITs have halon banks that are too small to justify individual recycling facilities. Advice will have to be developed for solutions based on a regional approach. Parties may also wish to advise GEF to concentrate on such solutions.

1.5 TOC REFRIGERATION, AIR CONDITIONING AND HEAT PUMPS

1.5.1 Key Developments

The following is a brief summary of key developments.

- CFC use in new products in Non-Article 5(1) countries (except for some CEIT countries) has ceased. Certain amounts of CFCs are still being applied in servicing where prices are strongly dependent on the geographical region.
- Main alternatives in new equipment consist of HFCs, hydrocarbons and ammonia; in certain sectors the hydrocarbon option is increasingly being applied.
- In several sectors HCFCs are necessary since no long-term zero-ODP solutions are proven (e.g. HCFC-123 in chillers).
- Retrofits from CFCs (HCFCs) to hydrocarbon options are being promoted without taking into account an integrated safety approach; further research and development is needed before this can be considered an "overall" valid option.

1.5.2 Progress in the operation of the TOC

This section describes the progress made in the preparation of the 1998 Assessment Report by the TOC Refrigeration, Air Conditioning and Heat Pumps. The TOC has taken a number of decisions in two meetings, which were held in Aarhus, Denmark (September 1996) and Washington D.C. (October 1996).

The 1998 Assessment Report will follow the structure of the 1994 Assessment Report. It will consist of a large number of self-supporting sections on the various sub-sectors. A section on refrigerant data and properties - in fact an update of the 1994 Section - will be annexed to the report. Section Chairmen and members were defined in the 1996 Aarhus meeting. The outline of the different sections is being discussed and information is currently being collected. Several sections will address flammable and non-flammable refrigerant options, for both new products and for retrofits, as well as not-in-kind options. Special attention will be given to the Article 5(1) country developments.

The number of Article 5(1) and CEIT members in the TOC has been increased to 15, while the total membership has been decreased. Membership, as well as technical issues, will be further discussed in a TOC meeting which will be held 9-10 June 1997 (Paris). Further meetings are planned in Baltimore, November 1997 and in India, at the beginning of 1998. The latter will be in conjunction with a workshop/conference which will be organised by the Article 5(1) Co-chair of the TOC.

Since the flammable refrigerant option is the subject of many discussions at present, particularly for domestic refrigeration but also for other sectors, the 1996 Aarhus meeting decided to establish a sub-committee which should report on the flammable refrigerant options, the maturity of each of the options and the safety aspects involved. In discussions with the Sub-committee, the TOC Co-chairs also established a Task Force which should report on the specific aspects in domestic refrigeration. The report of the Sub-committee - which includes the report of the Task Force - was reviewed and was finalised in the course of 1997; it addresses only flammable options, where the full 1998 Assessment Report will deal with all options. This Sub-committee report has also been reviewed by the Technology and Economic Assessment Panel and forms part of the 1997 TEAP Report. In fact, it can be considered as a Technical Progress Report for 1997 by the TOC Refrigeration, Air Conditioning and Heat Pumps (see for the Executive Summary, Volume I, Part III).

1.6 SOLVENTS TOC

1.6.1 Introduction

The Work Programme (WP) was formulated and finalised at the Solvents TOC (STOC) meeting held in Washington in October 1996 (Appendix 1) for the 1998 Assessment. The WP takes into consideration the directives of the Parties as well as tasks which are essential to further the contributory efforts of TEAP in general.

Furthermore, it is the aim of STOC to delegate its work to as many members as possible and to intensively encourage members from Article 5(1) countries in the participation of its work. It is suggested that Article 5(1) countries shall be assisted in the phaseout programmes through identification and introduction of appropriate alternative technologies to them. To achieve these objectives, technology transfer shall be prioritised through exchange of information, direct workshop, training, on-site visits and increased attention of the implementing agencies to the needs of Article 5(1) countries.

The WP focuses on the need of the Article 5(1) countries to have a choice of alternative materials and technologies which are less capital and cost intensive and simpler to put into operation. Many industrial organisations in Non-Article 5(1) countries have gone through this exercise and are constantly rationalising the processes without ODS. This experience is strongly concentrated within users industries and STOC aims to enlist strong support from these. In this context the STOC's mode of functioning has been so devised that this support from Non-Article 5(1) countries is maintained and intensified through a focused sub-sectorial approach. Five Working Groups have been established which cover almost all applications in the industrial sector.

1.6.2 Highlights of STOC Activities

a. Regional UNEP ODS Officers Network Meeting in Brunei

This network meeting took place 13 - 16 August 1996. The STOC was represented by two TOC members (Mr. B. Ellis and Mr. M. Malik) with the objective of obtaining information on regional issues and problems in ODS elimination and their incorporation into TOC's Work Programme. The co-chair informed the meeting on the tentative Work Programme and requested the participants to make use of the services offered by the TOC. Network officers were requested to assist TOC in enlisting suitable members from the region.

One of the primary needs of the Network-Officers is to identify the ODP of products sold in the market under different trade names. In this respect the first solvents specific draft titled as "The STOC Ready Reference of Ozone Depleting Solvents" was distributed to all STOC members in October 1996. In between, an updated draft incorporating comments from members has been circulated. It is expected that these tasks shall be concluded towards the middle of 1997.

b. STOC Meeting in Washington, October 23/24, 1996

The meeting deliberated on its current Work Programme and topics which came under discussion are as follows:

- Technical description of solvents alternatives on standardised format
- Soldering with reliability and problems with low solid fluxes
- Critical uses by Swedish Military
- Military standards prescribing ODS
- Remaining possible essential uses in aviation
- Fingerprint inks
- Essential use Nominations

The work on these topics is being pursued further.

c. UNEP Sourcebook Solvents, Coatings and Adhesives

The work on the 1996 “Update” of the Sourcebook is progressing satisfactorily. The “Update” draft entailing contributions from several authors shall be discussed at the forthcoming STOC meeting (April 1997). It is expected that soon after the meeting the final draft shall be available for comments by those members not participating at the meeting. The work is to be concluded by the end of June 1997.

d. Status on NASA - Thiokol RSRM and Titan - ODS Elimination Programmes

Both organisations gave extensive reviews during the Washington meeting on their respective programmes and documents covering these were distributed to the TOC members. The presentations on RSRM and Titan ODS Elimination Programmes provided in depth a justification for the further use of the ODS in critical applications.

The cause of the RSRM problem experienced in June this year is still being investigated. NASA was requested to inform STOC on the findings of their investigation.

Discussion on these topics revealed that the introduction of ODS free solvents for some applications may be a long way off and financial and resource constraints also contribute towards this situation.

1.6.3 Developments in ODS Alternatives

a. Suspect Solvent Alternatives:

STOC has become aware of certain solvents which are being marketed aggressively by some suppliers with erroneous information with regard to their ODP. The solvents identified are Chlorobromomethane CBM - (CH_2ClBr) and its derivative Borothene with their ODP 0,05 and 0,044 respectively as calculated by the University of Cambridge. For CBM this figure is nearly twice that of HCFC-225 and roughly half that 1,1,1-trichloroethane which are both controlled substances. The sales publicity claims Borothene as an efficient solvent for precision cleaning and degreasing operation, for removing resin flux in soldering operations. Borothene is claimed as an acceptable substitute for the following chemicals previously used in these operations:

Isopropyl Alcohol	1,1,1-Trichlorethane	Blended HCFCs
Methyl Ethyl Ketone	HCFC-141b	Acetone
HCFC-225	Trichloroethylene	CFC-113
1,2,2 Trifluoroethane	Methanol	Toluene
N-Methyl Pyrrolidone	1,1,2-Trichlorethane	HFEs
Ethyl Alcohol	Methylene Chloride	

Another series of compounds based on o-propyl bromide (nPB) - CH_3 CH_2 CHBr) with ODP 0,03 as given by the supplier (Abermarle Inc.) is being marketed in some countries.

The STOC recommended that a mechanism be found by which new class of materials with an ODP comparable with those of controlled substances be prevented in coming to usage in industrial applications (see also a draft proposal as annex to this STOC report).

b. Rain Repellent Compound (Rainboe Replacement)

For aircraft windshields at least one aircraft manufacturer (OEM) has made a considerable breakthrough in operating without a CFC-113 containing rain repellent. Approval from the FAA[1] for operation without a rain repellent was obtained. As an optional enhancement for improved visibility in heavy rain, the use of hydrophobic coatings has been approved and instructions to deactivate or remove Rainboe repellent systems are scheduled for release in 1997 for operators who wish to implement this change.

On this issue, the STOC co-chairs shall contact other OEMs in the near future.

Annex

UNREGULATED OZONE DEPLETING SOLVENTS

The STOC recommends to the TEAP that chlorobromomethane, by virtue of its declared ODP of 0.05, as determined by the University of Cambridge, and n-propyl bromide, by virtue of its declared ODP of 0.03, as determined by its manufacturers, Albemarle Inc., be considered urgently by the Parties to the Montreal Protocol . As these substances or products containing them are being aggressively marketed, the STOC wishes to draw attention to the urgency of a rapid decision, so that prospective users are discouraged from investing in cleaning methods where the solvents may not be available in longer than the short term. It is also suggested that the Executive Committee of the Multilateral Fund be advised that methods using such substances are not recommended. Furthermore, in view of the history of introduction of new ODS or for new applications of non-regulated ODS, the STOC suggests that the Parties may wish to consider a mechanism to present future marketing of similar products. There are a considerable number of non-regulated substances that may be used as solvents with probable ODPs in the range of 0.01 to 0.025 (see also Section 1.9 in Part III of this report).

[1] Federal Aviation Administration

1.7 STATUS OF MILITARY PROGRESS IN PHASING OUT ODSs

Military organisations have used ODS in many of the same applications as the commercial sector, and in others which are unique to a military setting. A number of Non-Article 5(1) and some Article 5(1) countries have provided information to TEAP regarding their uses and efforts to find alternatives, however many nations remain silent on their military uses. A more extensive discussion of continuing military uses of ODS, efforts at finding alternatives, and long term prognosis for continued ODS needs will be included in the full 1998 TEAP Assessment report.

1.7.1 NATO Activities to Promote Technology Transfer

Two workshops were held on the Military Role in Implementing the Montreal Protocol, the first in 1991 in Williamsburg, VA, USA, and the second in 1994 in Brussels, Belgium. Participation included nations outside NATO such as Russia, China and other CEIT and Article 5(1) countries. NATO also issued a statement to the Executive Director of UNEP supporting the London Amendments accelerating the phaseout following the 1991 workshop.

1.7.2 Non-Article 5(1) Military Assistance to Article 5(1) Countries

In September 1996, the US, Canada and Australia sponsored a Defence Environmental Workshop for nations of the Asia-Pacific-Indian Ocean region to discuss the relationship between military activities and environmental impact, and actions militaries can take to conduct their activities in ways which mitigate environmental impact. Virtually all countries sent representatives of their military and environmental ministries. Another conference for nations of the Western Hemisphere is being held in June 1997. A global conference on military uses of ODSs is being organised in co-operation with TEAP, November 12-14, 1997, in conjunction with the annual Conference on Ozone Protection Technologies in Baltimore Maryland. Co-operatives networks such as these provide an excellent forum for increasing the awareness among military organisations about the Montreal Protocol.

In addition, the United States (U.S.) Navy and Defence Logistics Agency provided training on use of halon recycling equipment, halon banking strategies and halon alternatives in a number of Article 5(1) continues, including India and China. Extensive military participation in the halons technical options committee provided specific information in their reports for Article 5(1) countries. In addition, the U.S. Navy has provided assistance to Spain and other countries in converting shipboard refrigeration systems to CFC alternatives.

1.7.3 Unique Military Applications

1.7.3.1 Halons

With a military co-chair, the Halons Technical Options Committee expressed confidence in the technical and economic feasibility of halon alternatives, which provided the rational basis for moving halons from the least controlled of the ODS to the first to phase out. The phaseout was based on the fact that most halon uses are not emissive and a large supply of halons remain in existing equipment that can be used to service remaining important uses for which alternatives do not yet exist. The existence and proper management of this supply enables aircraft, ships and military tactical vehicles to continue to operate.

There remain important military uses for halons and CFCs which present unique challenges not experienced in the private sector. Examples include the use of halon as explosion suppressants in the crew compartments of tactical vehicles. These systems operate in fractions of a second and will save the lives of the crew in the event the vehicle is fired upon by enemy forces. Large research and development investments to date have failed to identify effective alternatives.

Military aircraft, like civil aircraft, continue to require halon for fire protection. Like the tactical vehicle, large investments in research and development over the past several years are only now beginning to reveal alternatives which could be applicable to new aircraft designs. Existing designs continue to require halons, and will likely to continue requiring halons through their economic lifetime. The U.S. recently announced their goal to produce the new military aircraft without the use of halons.

1.7.3.2 Refrigeration

Shipboard uses also present special challenges in a military context. Unlike commercial ships, military ships are highly integrated and lack surplus space to accommodate halon or refrigerant alternatives which would require larger physical plants or systems. Large investments in research and developments are being made to develop alternative fire protection, and refrigerant systems. Where physically possible, existing ships are being retrofitted to use alternatives. The U.S., Norway, Spain and other countries' navies have extensive and expensive programs underway to modify shipboard refrigeration systems. There has also been co-operation and assistance among militaries world-wide on the development and implementation of halon and CFC alternatives.

1.7.4 Military Halon and CFC Bank Management

A number of Non-Article 5(1) country militaries have instituted well conceived and managed "banking" systems to ensure the CFCs and halons necessary to support military operations will be available when and where they are needed. Based on the extent of the research and retrofit programs underway in Non-Article 5(1) country military organisations around the world. Forecasting future military ODS needs, particularly halons, is a very inexact science, especially since the total requirement over time is a strong function of the number of military conflicts. The military banking schemes currently in operation are professionally managed and secured. As a result, the TEAP recommends that Parties carefully consider the potential consequence to future essential use nominations of destroying existing supplies of halons and CFCs for which important military applications still remain.

1.8 SINGAPORE: A MARKET-BASED APPROACH FOR PHASING OUT CFCs

1.8.1 Introduction

Although Singapore never produced ozone depleting substances (ODS), significant quantities were used in economically important electronics manufacturing operations, for refrigeration and air conditioning applications and other common ODS applications. As a Non-Article 5.1 Party to the Montreal Protocol, Singapore successfully reduced the consumption of CFCs ahead of the 1996 phaseout deadline. The reduction in consumption of CFCs has enabled Singapore to be re-classified as an Article 5.1 Party as of March 1995. What was unique to Singapore's CFC transition experience was a strong reliance on innovative market-based and voluntary approaches rather than traditional command-and-control regulations, and without significant outside financing.

This essay highlights the use and effectiveness of non-regulatory strategies in implementing the Montreal Protocol. Adoption of these or other market-based and voluntary programs may be of benefit to other Parties to the Protocol or even to countries addressing other challenging environmental problems such as climate change.

1.8.2 Non-Regulatory Tools for CFC Allocation and Elimination

Various segments of the Singapore Government participated in a co-ordinated strategy to meet obligations under the Montreal Protocol to reduce and ultimately eliminate the use of CFCs. In addition to the Ministry of the Environment which had overall responsibility for the legal framework and policies to curb the use of ozone depleting substances, other segments of the Government including the Trade Development Board, the Productivity and Standards Board and the Economic Development Board implemented market-based and voluntary programs. The following outlines several of the non-regulatory programs adopted by the Singapore Government to control the supply and demand for CFCs and support a smooth transition:

1.8.3 CFC Tender and Quota Allocation System

In the late 1980s Singapore was faced with a situation of growing CFC demand and limited supply. To control use consistent with the Montreal Protocol consumption cap, a tender and quota allocation system was implemented. Through the tender system, market supply and demand forces dictated the price that the industries were willing to pay for CFCs. This system achieved two highly desirable outcomes: distribution of the limited quantity of available CFCs to those uses with highest replacement cost, and a strong market signal to induce ODS users to look into substitutes, conservation measures and recycling.

The allocation system set an amount of CFCs that would be available for public tender and an amount that would be distributed based on historical use. In order to participate in the tender exercise, CFC end users and ODS distributors were required to register and then submit bids for quantities needed and the price they were willing to pay. In the public tender, quotas were given to the highest bidders, but the actual prices were pegged at the lowest successful tender price. This strategy resulted in the maximum quantities being allocated to those companies willing to pay the most but at a price that avoided unnecessary economic burden.

To avoid unacceptable and unnecessary business disruptions, companies which were not successful in their tender bids were allotted a quantity based on a pro-rated share of their previous years' consumption or distribution of the controlled CFCs.

1.8.4 R & D and Technical Assistance

The tender and quota allocation system led to a significant rise in CFC pricing which in turn created strong incentives for recycling, conservation and transition to alternatives. In order to facilitate the growing demand for recycling and non-CFC alternatives, the Singapore Productivity and Standards Board (PSB) on a fee basis provided technical consultancy services to industries wanting to recycle controlled CFCs or switch to CFC substitutes. The PSB developed a CFC-113 recycling system which can regenerate CFC-113 to purity levels sufficiently high to meet even the stringent requirements of disk drive manufacturer's. The PSB also provided technical consultancy on CFC recycling to waste treatment companies as well as companies with in-house recycling facilities. To support the industry in adopting new cleaning alternatives, the PSB established a microcontamination diagnosis service to evaluate product cleanliness, materials compatibility and troubleshoot manufacturing process. The PSB also set up a database which contained technical information on CFCs including non-CFC technologies and sourcing for CFC alternatives.

1.8.5 ODS-Free Process Verification Scheme

Singaporean electronics and other high tech industries serve a large international market. As a result of the Montreal Protocol, many of Singapore's customers wanted assurance that manufacturing processes or products did not include materials or chemicals that contained ODS. In addition, regulatory requirements of other countries such as ODS-labelling requirements by the United States resulted in time consuming and costly verification processes. In order to facilitate the needs of these industries the Singapore Productivity and Standards Board (PSB) developed a verification scheme to provide third party proof that products and manufacturing processes do not use ozone depleting substances (ODS).

Instead of having to conduct verification with each existing or potential customer that processes are ODS free, companies now just show their PSB certificate. The PSB scheme puts companies and their manufacturing processes through a rigorous ODS screening process which eliminated the need for multiple audits of a company's operations by different customers, thus saving time and costs for both parties. The program also provides a competitive advantage for environment friendly companies and has been used in the marketing programs of many companies

The scheme operates through the following steps:

- Formal application: information submitted through a questionnaire, application form and other relevant documents;
- Preliminary assessment: PSB conducts a preliminary assessment of the plant and evaluates the chemicals/materials used in direct manufacturing;
- Audit: PSB formally audits the company's ODS-free quality system and the effectiveness of its implementation;
- Post-Award Routine Surveillance: PSB conducts post-award surveillance yearly to ensure that the ODS-free quality system is maintained; and
- Renewal of Certificate: PSB will renew the Certificate if the terms and conditions of the Scheme are met.

1.8.6 Financial Incentives

For small- and medium-sized enterprises (SMEs) which generally lacked in-house technical expertise on CFC reduction measures and alternatives and faced difficulties in financing investment in CFC alternative technology, the Singapore Economic Development Board (EDB) offered tax and financial incentives to help firms which needed to modify their equipment and production processes to conserve CFCs or adjust to substitutes. For example, a portion of the cost of equipment could be offset against taxable income. The scheme also allowed for hiring experts on CFC alternative technologies.

1.8.7 Response of Industry

Singaporean companies report no significant economic or performance losses resulting from the transition out of CFCs. They are satisfied with adopted alternatives which once implemented have been for the most part less expensive with lower overall environmental, health and safety impacts.

1.8.8 Conclusions

In Singapore, the Government adopted a number of highly innovative non-regulatory programs to control and ultimately eliminate the use of CFCs. By all standard measures Singapore's transition out of CFCs was fully successful: no businesses closed down; and there was a smooth transition without panic. The Singapore experience demonstrates market-based incentives and voluntary programs can be used to achieve a cost-effective reduction and elimination of ODS use.

Through its innovative programs to implement the Montreal Protocol, Singapore also gained confidence that non-regulatory programs can be very successful tools to achieve other environmental goals. For example, the tender and allocation program also serves as the model for the Singapore automobile purchase and allocation program to address pollution and traffic congestion problems.

Co-Authors were:UNEP TEAP, Mr. Phua Kia Chew (Singapore Trade Development Board), Ms. Tan Sai Ing (Singapore Productivity and Standards Board) and Ms. Doris Cheung, (Singapore Productivity and Standards Board).

1.9 CONTROL OF UNLISTED ODS

A variety of substances with uncertain ODP values are being, and will continue to be, developed either as substitutes to ODS or for other applications. The risk of their rapid extensive use exists due to aggressive marketing of the products. Chlorobromomethane (0.05 ODP)* and n-propyl bromide (0.03 ODP) developed as substitutes for ODS solvents are cases at hand.

There exists no mechanism at present for the control of consumption or production of such substances not listed by the Protocol which can therefore be commercialised without any restrictions. TEAP recommends that the Parties may wish to decide that any new chemical with an ODP value of more than 0.01 be listed as controlled and phased out at a date to be determined by the Parties.

TEAP also recommends that newly developed substances with uncertain ODP values also be listed in a separate annex and their status be reviewed periodically by TEAP.

**The ODP of chlorobromomethane is currently subject to debate. It should be noted that the Science Assessment Panel has not yet fixed an ODP.*

1.10 PRODUCTION EXEMPTION FOR ESSENTIAL USES

From 1 January 1997, Non-Article 5 Parties can produce CFCs only for supplying the basic domestic needs of Article 5 Parties or for essential uses permitted by a Meeting of the Parties.

TEAP wishes to point out that no Party has so far applied for exemption for production of CFCs for export to Non-Article 5 Parties for essential uses permitted by Meetings of Parties.

The TEAP understands that pharmaceutical producers in most Non-Article 5(1) Parties are obliged to buy their requirements of CFCs used in MDI products only from manufacturers registered with their regulatory agencies. The Parties may consider the advantage of granting transferable production exemptions that will allow Parties to acquire ODS from whichever Party is their supplier at the time. Producing Parties may be requested to report their exports for essential uses listing the destinations. This is suggested only to allow continued production of MDIs; it does not increase the overall quantities of CFCs produced.

2 POSSIBLE APPLICATIONS OF HYDROCHLOROFLUOROCARBONS (HCFCs)

2.1 Introduction

The Technology and Economic Assessment Panel was requested by the Parties to update its report on possible applications of HCFCs (Annex C, Group I). This list (as presented in Section 2.2) is intended to facilitate collection of data on HCFC consumption and does not apply that HCFCs are needed for the listed applications. The Technology and Economic Assessment Panel was, in the same Decision VIII/13, also requested to prepare the list of available alternatives for each of the HCFC applications.

For most applications of HCFCs there are technically and economically feasible alternatives; in several cases alternatives have matured with low or no Global Warming Potential (GWP), in other cases, alternatives are HFCs or PFCs with high GWPs. In Article 5(1) countries, CFCs and halons will, for a certain part, be substituted by HCFCs until the phaseout is completed, due to the lack of other economically feasible alternatives. The net result of lack of access to HCFCs would be a delay in the phaseout of CFCs in Article 5(1) countries. TEAP recommends that the Parties consult the Science Assessment for elaboration on the harmful environmental effects of increased usage of chemicals with high global warming potential.

2.2 Results of TEAP Investigations in 1996

TEAP identified the following general categories where HCFCs could possibly be used:

- As laboratory and analytical materials:
  Chemical research and development, reaction solvents or reaction feedstocks; reference chemicals; product testing (adhesive bonds, breathing filters); extraction; carriers, tracers; and sample preparation.

- As test agents:
  Discharge testing gas fire protection systems
  Leak testing sealed chambers and devices.

- As hydraulic and thermal fluids:
  Solar tracking devices, heat transfer fluids.

- As chemical separation media:
  Fluid and gaseous separation media in pharmaceutical and chemical manufacturing.

- As solvents:
  Electronics cleaning, metal cleaning, precision cleaning, dry cleaning, flushing solvents, as ingredients in coatings, adhesives, and dyes, etc.

- As refrigerants:
  Refrigeration, air-conditioning, heat pumps.

- As foam blowing agents:
  Rigid: packaging, insulating, safety foams
  Flexible: safety foams, speciality foams.

- As feedstocks and process agents:
  HFC and other fluorinated products, plastics, elastomers, etc.

- As diluents and inerting agents:
  With ethylene oxide sterilisation.

- As fire extinguishing agents:
  Total flooding applications, fixed systems, streaming agents, specialised applications.

- As aerosol propellants and solvent

2.3 Sector-specific details on possible applications of HCFCs and the availability of alternatives

2.3.1 Aerosols, Sterilants And Miscellaneous Uses

Miscellaneous uses including laboratory and analytical materials:

If HCFCs are used for standardisation and calibration of scientific equipment, there will be no alternative since it is implicit that the HCFC is being used for identification purposes.

HFCs can be used as test agents and hydraulic and thermal fluids.

Sterilant:

Non-flammable HFC, carbon dioxide, not-in-kind sterilisation systems. These alternatives may be limited in their applicability as HFCs have not been developed and approved, and other alternatives may not be applicable for all uses.

Aerosol propellant:

Use:	***Alternative:***
Hornet and Wasp Sprays	HFC-134a, N_2
Mould Release Agents	HFC-134a, HFC-152a, propane/butane
Tire Inflators	Propane/butane, HFC-134a with co-solvent
Electronic Cleaners	HFC-134a, HFC-152a
Streamers	HFC-134a

Aerosol solvent:

Electronic Cleaners	HFC 43-10mma, perfluoroethers, volatile siloxanes

Aerosol main product:

De-dusters	HFC-134a, HFC-152a
Boat Horns	HFC-134a, HFC-152a
Electronic Freeze Testers	HFC-134a

2.3.2 Foam Blowing

Rigid Insulation Foams including rigid polyurethane, extruded polystyrene, polyethylene and phenolic foams.

Available Alternatives

<u>Polyurethane</u>

- Appliances - Hydrocarbons, especially cyclopentane, can be used when the appliance design gives the required energy consumption with higher thermal conductivity foams. HFC-134a and CO2 have minor utility.
- Construction - Hydrocarbons, especially the iso and normal isomers of pentane, when the flammability standards can be met and conversion costs are not prohibitive (e.g. to an SME). HFC-134a and CO2 have minor utility.
- One-Component ("Do-it-Yourself" Canned Insulation Foam) - Flammable gases such as propane, butane and dimethyl ether (DME) are used either singly or in combination. HFC-134a is also now widely used and may take a dominant position. HFC-134a is also being combined with HFC-152a or DME and some hydrocarbons.

<u>Extruded Polystyrene</u>
Boards - CO2, HFC-134a or HFC-152a.

<u>Polyethylene Foam</u>
Boards and insulating pipe - CO2, hydrocarbons, HFC-134a or HFC-152a.

<u>Phenolic</u>
There are no technically suitable alternatives.

Polyurethane Integral Skin Transportation Foams In Safety Applications

Available Alternatives

This application is in the middle of a technological change with the expectation that CO2 (water)-based technology will eventually be widely used. However, the market does not uniformly have confidence that current formulations are suitable in all cases, especially with respect to skin quality. In addition, CO2 (water)-based technology is not yet commercially available in all markets. In the interim, HFC-134a and pentane are used in addition to CO2 (water).

2.3.3 Fire Extinguishing Agents

HCFC Alternatives

The Halon Technical Options Committee has been asked to provide information regarding fire fighting alternatives to HCFCs used for such purposes. The following table summarises the currently available alternative extinguishing agents and methods for total flooding, fixed system applications, and streaming agents for use in manually applied fire equipment.

The same limitations about applicability under certain circumstances apply as for these agents being used as halon alternatives (e.g. availability, official approval)

Total Flooding Agent Alternatives (fixed systems)

a) Gaseous

Halocarbons

HFC:	HFC-23; HFC-125; HFC-227ea; HFC-236fa
PFC:	FC-3-1-10; FC-2-1-8
FIC:	FIC-13I1

Inert Gases

Nitrogen:	IG-10
Argon:	IG-01
Nitrogen/Argon blend:	IG-55
Nitrogen/Argon/Carbon Dioxide blend:	IG-541
Carbon Dioxide	
Inert Gas Generators	

Water Based

Water Mist Technologies
Water Sprinkler Systems
Foam/Water Systems
High Expansion Foam Systems

Dry Powder

Conventional Dry Powder Systems
Fine Particulate Aerosol Systems

Streaming Agent Alternatives (portable extinguishers)

HFC: HFC-227ea; HFC-236fa
PFC: FC-5-1-14
FIC: FIC-13I1
Carbon Dioxide
Multipurpose Dry Powder (Chemical)
AFFF Foam
Water Stream
Water Fog

2.3.4 Refrigeration And Air Conditioning

The following sub-sectors of refrigeration, air conditioning and heat pumps use HCFCs in both the Non-Article 5(1) and Article 5(1) countries: commercial refrigeration, industrial refrigeration and cold storage, unitary air conditioning, chiller air conditioning, transport refrigeration and heat pumps for heating. Due to both the use of HCFCs in new equipment manufacturing and servicing, general conclusions are difficult to draw. A full picture will be presented in the 1998 Assessment report. Sector-specific availability of alternatives to HCFCs is as follows:

In commercial refrigeration ammonia is a mature alternative for certain applications. HFC blends are also being applied at present. Several demonstration plants using hydrocarbons have appeared on the market. In servicing, the HCFCs continue to be required; in certain cases a retrofit to HFC-blends will be possible.

In industrial refrigeration and cold storage ammonia is a mature alternative for many applications. Some HFC blends are also being applied, which is directly related to capacity and inventory. In certain countries where regulations forbid the use of ammonia, only HCFCs continue to be applied. In servicing, HCFCs are required, particularly in those cases where a retrofit of existing equipment is not feasible.

In unitary air conditioning a small amount of equipment could use HFC-134a; HFC blends have begun to be applied. The use of the flammable propane has been introduced in small portable units in Northern and Central Europe. The majority of the equipment uses HCFC-22, both in new production and servicing.

In chiller air conditioning ammonia is a mature alternative for a limited number of applications; there is a small use of absorption. HFC blends are not applied in this sector. HCFC-123 is being applied on a large scale in low pressure chillers and is required for servicing purposes; no alternative for HCFC-123, which is a highly efficient refrigerant, has so far matured. For reciprocating chillers HCFC-22 is still being applied for both manufacturing and servicing.

In transport refrigeration HFC-134a can be a replacement for HCFC-22 in a limited number of cases. Hydrocarbons, particularly propane, is being investigated in some countries. In a demonstration project, the air cycle is being applied. For many uses, HCFC-22 is still the main candidate in new manufacturing, and it will particularly remain important in servicing.

2.3.5 Solvents

All known uses of HCFC-141 (ODP equivalent to 1,1,1-trichloroethane) have technically and environmentally acceptable substitutes and alternatives. There are no known uses, that lack substitutes and alternatives, for other HCFCs listed in Annex C of the Protocol with the exception of HCFC-225.

There are important applications of HCFC-225 in specialised cleaning where the substitutes would be less technically satisfactory or where the environmental consequences of the substitutes may be more significant than the ozone depletion from the use of HCFC-225. For example, the most probable substitute for HCFC-225 in some precision applications may be the alcohol process using perfluorocompounds (PFCs) to inert explosions and to dry devices after cleaning. PFCs are greenhouse gases with exceptional atmospheric lifetimes and are controlled in some countries to protect against climate change. Other alternatives to HCFC-225 is the use of certain hydrocarbons with high flash points coupled with vacuum drying or air circulation oven drying at low temperatures.

An extensive list of all possible HCFCs used as solvents and their alternatives for different uses is being updated and shall be incorporated in the 1998 Report of the Solvents TOC.

3 EXECUTIVE SUMMARIES OF VOLUME II REPORTS

3.1 AEROSOLS, STERILANTS, MISCELLANEOUS USES AND CTC

Aerosol Products

For aerosol products, other than MDIs, there are no technical barriers to global transition. The major issue remaining for Parties to address is the use of CFCs in Article 5(1) countries and CEIT. The TOC believes that 1996 CFC consumption in the aerosol sector was less than 24,000 metric tonnes in Article 5(1) countries and CEIT excluding MDI use and some pharmaceutical products.

The phaseout of the remaining CFCs in the aerosol sector is dependent upon the availability of hydrocarbon propellants (HAPs). Risks associated with poorly planned or executed conversions to hydrocarbons makes it obligatory for governments to develop suitable monitoring procedures to ensure safe practices including proper design, management and use of prescribed filling equipment, hydrocarbon storage and handling facilities.

Negotiations between the World Bank/GEF and the Russian Government resulted in the approval of seven projects to phaseout CFC use in the aerosol sector. Since GEF funding of these projects has not become available, it is not expected that significant reductions of CFC consumption will occur before 1999. Acceleration of the implementation of these approved projects is particularly important to achieve reductions.

Use of HCFCs in aerosols is prohibited in many European countries and severely restricted in the USA. In Article 5(1) countries HCFCs will be limited in their use by cost considerations.

Metered Dose Inhalers

CFC-containing metered dose inhalers (MDIs) are inexpensive, reliable and effective therapy for respiratory diseases such as asthma and chronic obstructive pulmonary disease (COPD). Currently, some 500 million MDIs are used annually world-wide, using approximately 10,000 tonnes of CFC.

The TOC has reviewed the issue of the essentiality of MDIs for asthma and COPD, and concluded that they remain essential for patient health until an adequate range of technically and economically feasible alternatives are available.

The schedule for the safe introduction of new propellants and reformulated products suggested in the 1994 report and updated in the 1996 report of the Aerosols TOC remains on target. It remains possible that the major part of transition in most Non-Article 5(1) countries may have occurred by the year 2000 and minimal need for CFCs for MDIs is envisaged by the year 2005. However, at this point in time there are still many variables and an exact time scale is not possible to predict with certainty.

Dry Powder Inhalers (DPIs) are continuing to be introduced by a number of companies into many countries. There is good evidence that the previously noted trend of increased DPI usage continues but since overall inhaled therapy has increased further, they have not reduced the sales of MDIs.

In March 1995 the first approval for a CFC-free MDI was granted to 3M's Airomir™, a salbutamol product reformulated with HFA-134a propellant. By March 1997, over thirty five countries had approved Airomir™ (Proventil™-HFA in the USA) for use. Additional companies have submitted applications to market CFC-free inhalers in a number of countries. Approvals are anticipated in the coming year. It is anticipated that at least two salbutamol CFC-free MDIs will be available in a number of countries by the end of 1998. Since salbutamol MDIs are estimated to comprise half the total global use of MDIs the potential exists for a significant reduction in consumption of CFCs in 1999.

However two years after the introduction of Airomir™ in the United Kingdom it had only reached 1.5% market share. Factors influencing uptake of this non-CFC product include: lack of incremental benefit to patients, apathy of physicians to environmental benefits and higher cost than generic CFC salbutamol products although costs are similar to branded CFC MDIs. It is important to note that the lack of motivation to physician prescribing and economic considerations makes it unlikely that marketing and education programs alone will produce a significant switch away from CFC products in the absence of clearly defined and implemented national transition policies. However, to facilitate patient and physician utilisation of the reformulated products, education and training are required.

Most intellectual property protection concerning MDIs with CFCs has expired, and this technology has been widely copied without compensation. In contrast, there is very extensive world-wide intellectual property protection in place concerning the new HFC MDIs, and this may restrict the number of MDI manufacturers unless licensing agreements are reached.

For Article 5(1) countries where multinational companies are already operating, adoption of CFC-free technologies should take place as soon as possible. Parties may wish to add this commitment to the Code of Conduct approved at the Eighth Meeting of the Parties to encourage phaseout of CFCs.

Adequate supplies of CFCs to meet patient demand until non-CFC alternatives are available have to be provided. These are currently being met in Non-Article 5(1) countries through Essential Use allocations and existing stockpiles. However, as non-CFC alternatives become available and rationalisation across CFC suppliers and CFC MDI manufacturers occurs, there will be a need to carefully manage supplies. Parties may wish to monitor existing stockpiles to ensure a smooth transition.

At their Eighth Meeting, Parties granted a single request to transfer an essential use authorisation on a one-time basis. This Decision ensured an uninterrupted supply of CFCs to a Party where the CFC MDI manufacturer had chosen to rationalise production outside that Party. The TOC believes this one-time transfer could serve as a model for similar situations provided:

- both Parties agree to the transfer;
- total production volume does not increase; and
- the intended use does not change.

The Parties may wish to consider the advantages of a decision allowing for flexibility in transfer without previous approval by the Parties, but with subsequent approval at a Meeting of the Parties provided these conditions are met.

With the phaseout of other CFC uses, an imbalance between the capacity of the plants that still produce CFCs and the demand they have to meet could occur. To operate a CFC unit efficiently it is necessary to run it above a minimum capacity, therefore, the CFC producer will be forced to run it intermittently in what is called a “campaign”. Given the current schedule for final phaseout of CFC MDIs this campaign production probably will not be needed, except possibly at the end of the CFC MDI transition to provide for a final stockpile of pharmaceutical grade CFCs to meet special patient needs.

Prior to 1996 a number of drug manufacturers established strategic stockpiles of CFCs (estimated at 3-12 months of use in production) as contingency against uncertainties in the Essential Use process, and unforeseen disruption in Essential Use supplies (catastrophic plant failures, contamination of supplies, shifts in market share etc.). Reporting under the Accounting Framework will enable Parties to assess the size of existing stockpiles and determine whether these stockpiles represent a reasonable amount for contingencies. Whilst the Committee believes stockpiles of reasonable size are sensible and represent a safeguard of public health needs, excessive stockpiles could be utilised to prolong CFC MDI manufacture against the spirit of the Montreal Protocol, and act as an impediment to the transition to CFC-free alternatives.

The TOC believes that it is still too early to craft a global framework for CFC MDI phaseout because it is not currently possible to make accurate predictions on the introduction of non CFC alternatives. The TOC recognises that no single strategy will be applicable to all countries. The process of transition to non-CFC alternatives is best handled at the national level, involving dialogue between health authorities, environmental agencies and other interested groups.

The TOC congratulates the USA and Australia for the development of a proposed strategy for phaseout at the national level. The TOC recognises that other Parties may feel that different strategies better fit their needs. Preliminary examples of possible national strategies that Parties may wish to consider when they study their particular situation have been presented (these are examples and are in no way fully inclusive). Parties are encouraged to submit details of national policies for consideration by the TOC to facilitate policy sharing and to gain a better understanding of issues in different Parties involved with transition.

Under the Montreal Protocol, there is no restriction on movement of finished goods, i.e. manufactured MDIs. The Parties should note that if individual countries adopt export bans for CFC MDIs they could disrupt access to treatment options in importing countries. Conversely, once transition has taken place in a Party, there is potential for continued imports of CFC containing products from another Party. However, in a number of countries this will be controlled through existing regulations on the import of therapeutic goods and product license approvals.

The Aerosols, Sterilants, Miscellaneous Uses and CTC Technical Options Committee reviewed nominations for essential use production exemptions from 5 Parties and the European Community. For MDIs there was an almost universal reduction in CFC volumes requested for essential use exemption. The TOC approved only those nominations for asthma and COPD treatment.

An emergency request was made by the United States for 1997 under Decision VIII/9(10) for the transfer of 3 tonnes of CFCs approved for MDI use in a sterile aerosol talc. The United States also made an essential use nomination for CFC manufacture for sterile aerosol talc for 1998 and 1999. This product is used for the treatment of pleural effusion and it is not an inhalation product. The majority of TOC physicians favoured the limited availability of talc formulated as a CFC containing aerosol but a minority considered a dry powder insufflation method which has been in use for many years as a possible adequate alternative. The TOC found it difficult to make a firm recommendation on either the emergency request or the nomination. The request and nomination were inadequate as they do not provide sufficient information to allow a decision on essentiality. Therefore, the TOC were unable to recommend this nomination. However, the Secretariat may wish to grant the emergency request for 1997 and Parties may wish to consider a one year exemption for 1998. Further data is needed at the beginning of 1998 to justify essentiality for 1999.

Sterilisation

By the beginning of 1997, in Non-Article 5(1) countries CFC-12 use for "12/88" sterilant gas had virtually disappeared, as final inventories were depleted. There remain no technical barriers to the phase out of CFCs in sterilisation.

Global consumption of CFC-12 in this sector has decreased from 20,000 metric tonnes in 1991 to less than an expected 500 metric tonnes in 1997. It is anticipated that virtually all CFC-12 use in this sector will be discontinued by 1999.

HCFCs are important as transitional products in both Non-Article 5(1) and Article 5(1) countries for hospital sterilisation. The only barrier to the final conversion from CFCs to HCFCs remains cost. Where CFCs remain relatively inexpensive and there is no regulation to require conversion, there is no incentive for the final conversion from CFCs to HCFCs.

Global consumption of HCFCs in 1996 for sterilisation was 2,900 metric tonnes and estimated global consumption of HCFCs for 1997 is 3,100 metric tonnes. The projected global usage for HCFCs is expected to peak at no greater than 3,400 metric tonnes and then decline after the year 2000 as HFC replacements and new technologies replace HCFCs.

Miscellaneous Uses

Ozone-depleting substances have been used in a variety of miscellaneous uses including tobacco expansion, and laboratory and analytical uses amongst others. This report evaluates the current status of use of controlled substances and alternatives and reports progress on the availability of alternatives for laboratory and analytical uses. For other miscellaneous uses there have been no further developments as to alternatives. Further information will be provided in the 1998 report of the Aerosols, Sterilants, Miscellaneous Uses and CTC Technical Options Committee.

Parties may wish to consider the issue of the laboratory and analytical use exemption at their 9th Meeting in 1997. The global exemption expires at the end of 1997. Little progress has been made toward eliminating this use.

The TOC recommends that the Parties grant a further two year global exemption for the use of controlled substances for laboratory and analytical uses. Furthermore, it is recommended that Parties are encouraged to adopt within their National Ozone Programmes measures designed to reduce these uses.

The TOC also reiterates the importance of:

- organising National Consultative Committees to review and identify alternatives to laboratory and analytical uses and encouraging the sharing of information concerning alternatives and their wider use;

- encouraging national standards organisations to identify and review those standards which mandate the use of ODS in order to move to ODS-free alternatives;

- developing an international labelling scheme; and

- reporting data annually under a global essential use exemption framework which allows Parties to monitor the success of reduction strategies, and investigating and reporting published instructions, standards, specifications and regulations requiring the use of ODS.

Carbon Tetrachloride

CTC is an easily manufactured chemical which is widely available. To better understand the role of this chemical it is important to keep in mind that CTC can be:

- Used as a feedstock for other chemicals. The 1997 Report of the Process Agents Task Force (PATF) recommends that Parties consider feedstock to be defined as:

  "*A controlled substance that undergoes transformation in a process in which it is converted from its original composition except for insignificant trace emissions as allowed by Decision IV/12*."

- Used as a process agent. The 1997 Report of the PATF recommends that Parties consider process agent to be defined as:

  "*A controlled substance, that because of its unique chemical and/or physical properties, facilitates an intended chemical reaction and/or inhibits an unintended chemical reaction.*

  Controlled substances are typically used in chemical processes as process agents for at least two of the following unique chemical and/or physical properties:

  1.) Chemically inert during a chemical reaction

  2.) Physical properties, e.g.

  - boiling point

  - vapour pressure

- specific solvency

3.) To act as a chain transfer agent

4.) To control the desired physical properties of a process, e.g.,

- molecular weight

- viscosity

5.) To increase plant yield

6.) Non-flammable/non-explosive

7.) To minimise undesirable by-product formation

Note 1: *Refrigeration, solvent cleaning, sterilisation, aerosol propellants and fire-fighting are not process agents according to this definition.*

Note 2: *Parties need not consider use of ODS for foam blowing, tobacco puffing, caffeine extraction, or fumigation because these uses are already covered in other Decisions and/or by Technical Options Committee Reports."*

- Used as a solvent. This includes simple solvent extraction such as caffeine extraction and palm oil extraction, and cleaning applications such as metal degreasing and textile spotting. These uses should be discontinued to protect the ozone layer as well as to safeguard the health and safety of people using CTC where safer alternatives exist.

- Used in miscellaneous applications such as fire extinguishers, as grain insecticide fumigants, and as an antihelminthic agent (especially for the treatment of liver fluke in sheep).

- Used as a laboratory chemical.

- Produced inadvertently in some important industrial processes.

The distinction between these uses is not always clear cut and therefore makes it difficult to provide global data on both CTC production and consumption. Further information is required in some areas and where available will be presented in the next Report of the Aerosols, Sterilants, Miscellaneous Uses and Carbon Tetrachloride Technical Options Committee.

The main use of CTC is that of feedstock for the production of CFC-11 and CFC-12. Using 1995 data provided by the UNEP Ozone Secretariat, it is possible to extrapolate feedstock volumes of CTC from the figures that Parties reported for CFC production. Non-Article 5(1) countries declared that approximately 131,000 tonnes of CFC were produced in 1995 and Article 5(1) countries reported 107,000 tonnes of CFC production for the same year. From these figures, the TOC estimates a total CTC requirement as feedstock for CFC production of 285,000 tonnes in 1995. It can be estimated that 95 to 97% of CTC production is used in this manner. Given 1995 was the last year that Non-Article 5(1) countries were allowed normal manufacture of CFCs, the TOC believes that a substantial reduction could be expected for 1996 in Non-Article 5(1) countries.

The other major recognised use is as process agents. In its 1997 report, the Process Agent Task Force has estimated that production of carbon tetrachloride for process agent use is approximately 10,000 tonnes in Non-Article 5 and Article 5(1) countries for 1995.

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3.2 ASSESSMENT OF THE ECONOMIC VIABILITY OF METHYL BROMIDE ALTERNATIVES - SUMMARY

PREAMBLE - TEAP COMMENTS

TEAP undertook a variety of work in response to the several requests from Parties involving methyl bromide. The MBTOC responded particularly to requests concerning technical feasibility while the TEAP assigned individual TEAP members, teams of TEAP members, and the Economic Options Committee (EOC) to endeavour to collect and report findings on other topics. The EOC organised a Task Force to assist in its assignments. TEAP made its findings after reviewing the EOC Task Force report, reports of other economic evaluations, and the MBTOC report. While TEAP is indebted to its subsidiary bodies and advisers, TEAP accepts full responsibility for its findings.

The EOC is to be commended for quickly organising a Task Force of experts in agricultural economics who undertook an ambitious effort to more comprehensively report on economic feasibility of alternatives to methyl bromide. TEAP is grateful for the support of management expenses by the UK Ministry of Environment and for support of travel expenses for experts from Article 5(1) countries provided by the Ozone Secretariat.

TEAP had also asked the U.S. Strawberry Industry Association to provide economic analysis of specifically identified alternatives and substitutes to soil fumigation prior to strawberry cultivation but, unfortunately, this information was not forthcoming. Requests for economic analysis of comparative crop profitability on strawberry fields was also not forthcoming. Thus, the report of the EOC-organised Task Force is incomplete at this time. Nonetheless, the Task Force was able to report that the estimated costs of alternatives and substitutes for investigated applications either currently competitive to methyl bromide or are declining as commercialisation progresses.

As the Task Force was unable to draw conclusions for applications which were not considered, TEAP will continue to monitor the availability of economic analysis. A summary of the Task Force report is included in this report.

SUMMARY OF THE ASSESSMENT OF THE ECONOMIC VIABILITY OF METHYL BROMIDE ALTERNATIVES

3.2.1 INTRODUCTION

a. Decision VII/8 of the Parties requested the UNEP Technology and Economic Assessment Panel (TEAP) to prepare a report to the Ninth Meeting of the Parties to enable the Parties to consider further adjustment to the control measures of methyl bromide. In undertaking this task, TEAP was required to address the availability of alternatives to methyl bromide for specific applications. The TEAP instructed its Economic Options Committee to provide information on the economic viability of alternatives to methyl bromide (TEAP Report, June 1996, p. 116).

b. Information on the uses of methyl bromide was reviewed to identify those which were likely to be associated with the more significant economically positive or negative impacts of phasing out methyl bromide. The information also shows where alternatives are already in use which helps to put the issue of substitution into perspective with respect to different countries and products.

c. Although a number of promising alternatives and technologies are being tested, the Task Force focused on alternatives that are beyond the experimental stage and already in use. As soil fumigation is by far the largest and fastest growing use of methyl bromide, the Task Force gave most of its attention to this application. The quantities of methyl bromide used in post-harvest treatment and for treatment of structures are much smaller, but can have large economic value and therefore these uses were also addressed, but to a lesser degree, by the Task Force. Quarantine and pre-shipment uses are currently exempt from the control schedules of the Montreal Protocol and are, therefore, not addressed in this report.

d. External costs, which include environmental effects and human health effects, were addressed, at least qualitatively, in several of the studies reviewed by the Task Force. The Task Force itself was not able to directly deal with the issue of the external costs of methyl bromide alternatives. However, the Task Force recognised that these costs are important and that a close appreciation of their significance is needed to make informed decisions regarding the economics of methyl bromide and its alternatives.

e. The Task Force used the information resources available to it (particularly the 1997 MBTOC Progress Report to TEAP and the 1994 Assessment Report), drew on the expertise of MBTOC members and relied on the collective professional experience and judgement of its members. Microeconomic evaluations of the economics of specific alternatives were carried out and a sector model approach was used to assess the wider economic impacts of switching to methyl bromide alternatives.

3.2.2 CONCLUSIONS

3.2.2.1 General Conclusions

a. **Progress with alternatives.** Where alternatives have been adopted, users have become more efficient as they develop expertise. This learning process is typical when different technologies are introduced. In the case of crop production, yield outcomes almost always become more favourable over time. There are two general reasons for this improvement. First, the technologies themselves improve. That is, incremental improvements take place in aspects such as materials, equipment and application rates (in the case of chemicals). Secondly, the people using the alternatives become more knowledgeable and skilful with new alternative technologies over time. For example, they may better determine the optimal timing for certain tasks or become more adept at operating new equipment. Over time, these advances narrow the yield gaps between the alternatives and methyl bromide and there are examples where yield exceeds that with methyl bromide use.

b. **Technology transfer.** The Task Force also considered the potential for technology transfer between countries. Some technologies appear to be readily transferable, while others are constrained by factors such as climate (e.g., solarisation), regulation (e.g., pesticide registration requirements), and the knowledge and skills of agricultural workers (e.g., integrated pest management systems). Efforts to increase relevant human capital (e.g., by training agricultural workers) could speed up the transfer and adoption of alternatives. Alternatives are being developed in many places with technology transfer originating from both Non-Article 5(1) and Article 5(1) countries.

c. **Dangers of generalisation.** The costs of methyl bromide and alternatives will differ over time, by crop and by location. Therefore, one must be careful not to generalise about the economic superiority of specific chemical alternatives or methyl bromide itself, or between chemical and non-chemical technologies.

d. **Technical data.** On reviewing available information, the Task Force concluded that the technical and other information required for more comprehensive and rigorous comparative assessments of the relative economic performance were not yet available for specific situations for many methyl bromide alternatives, whilst recognising that ongoing work in many institutions is already making good progress in generating the necessary skills, technical data and other information required for further work.

e. **Production systems.** Whilst most of the work undertaken in this assessment addressed the relative economic performance of specific methyl bromide alternatives, the Task Force recognised the advantages of adopting an approach based on identifiable production systems possibly involving combinations of specific alternatives and techniques that might be used if further work on the economic viability of alternatives is requested.

3.2.2.2 Conclusions of the Microeconomic Evaluation: Soil Fumigation

a. **Dazomet.** The Task Force concluded, with input from MBTOC experts, that crop yields might initially decline by up to 10%. However, this yield loss can be overcome within 3 to 4 years as farmers become more familiar with the use of dazomet leading to improved application techniques. However, farmers may need assistance with the substitution process in the form of extension services, advice, and short term financial assistance.

b. **Dichloropropene (1,3 D or Telone) and chloropicrin**. The main findings are that (1) the product per unit costs are substantially more expensive than those for methyl bromide; (2) additional costs are incurred to modify equipment to enable implementation of these alternatives; and (3) on the basis of the data available to the EOC, yields are consistently lower with substantial variation in percentage decreases depending on the alternative used and the crop.

c. **Metam sodium.** The differences in production costs for metam sodium with respect to methyl bromide are quite varied. They range from +$1700/ha to +$800/ha in Colombia for cut flowers (TEAP, 1995); +$350/ha for strawberries in South Africa (FOE, 1996), and very small differences in Florida (Spreen et al. 1995). The switch to metam sodium involves costs on equipment, but no estimates are available; (2) a higher risk of crop failure is associated with metam sodium than with methyl bromide, but no estimates of the cost implications are available; and (3) the impact on yields vary.

d. **Integrated pest management (IPM).** The studies reviewed on IPM systems report consistently lower production costs than those for methyl bromide. The costs for IPM were estimated by TEAP to be lower by $1900/ha, or 28% lower (TEAP, 1995); and other estimates were lower by 67% (FOE, 1996). In a study on strawberry production, CSIRO (1995) estimated only slightly lower costs per square meter using IPM with only one annual crop and somewhat less than double the cost for one crop when IPM is used to get two crops. Yields using IPM are similar to those using methyl bromide for a single crop, whereas for double cropping, yields are about 75% higher for IPM. Profitability is also about 75% higher for IPM with double cropping. Apart from the CSIRO (1995) study, no quantitative impacts are cited for IPM yields although profitability is estimated to be higher in almost all cases.

e. **Soil-less substrates.** The main findings were (1) the costs of substitution will depend on whether the technique is only used for seedlings, or for the full growing of the crop. The estimates are as follows: $108/ha in Zimbabwe for tobacco seedlings; and $609/ha in Zimbabwe for paprika seed trays (FOE, 1996); (2) yield impacts are small or positive in switching to this alternative and risks are quoted as consistent with methyl bromide (MBTOC, 1997); and (3) the Danish study (Gyldenkaerne et.al. 1997) for greenhouse grown tomatoes estimates an increase in profitability of $2 to $3 per square metre and the pay back periods for investments in the technology are 1.4 to 4 years.

f. The use of soil-less substrate for seed trays appears to be an attractive alternative for tobacco and some other seedlings, and has been successfully applied in South Africa, the USA and Zimbabwe. This technology is used for several crops and in several countries. Its use for greenhouse tomatoes (Denmark) and for other high-value crops (e.g. strawberries in The Netherlands) is more difficult to transfer to other countries due to capital-intensity and the need to be able to sell in high price markets (e.g., winter tomatoes and strawberries).

g. **Solarisation.** The experience with solarisation technology reported from countries with abundant sunshine is encouraging, including several examples of lower production costs than with methyl bromide. The main factors affecting its adoption are that solarisation can only be technically effective where there is sufficient sunshine, soil conditions are favourable, technical assistance is available to local growers; and where the costs of an increased unproductive period can be accommodated.

h. **Steam.** The main findings are (1) where steam is a high cost alternative to methyl bromide the evidence suggests that it is suitable only in special circumstances where the higher cost is justified by the economic value of the reduced contamination risk e.g., in mother plant beds; and (2) the development of cost-efficient and mobile steam generating equipment is encouraging further uses of steam as an alternative to methyl bromide.

i. **Reduction of methyl bromide use through virtually impermeable film (VIF).** Improved tarping materials and techniques can reduce application rates by 30% to 50% leading to reduced emissions. Reported implications for production costs vary from cost savings of $1400/ha to a cost increase of $400/ha. Those facing cost increases would have an additional incentive to seek cost saving through the adoption of alternatives to methyl bromide.

3.2.2.3 Conclusions on Microeconomic Evaluation of Alternatives: Post-Harvest Treatment and Treatment of Structures

Use of heat, phosphine and carbon dioxide are prominent among the alternatives used for commodity and structural fumigation. The switch to an alternative may incur additional one-off costs and treatment costs may also be higher or lower. The cost estimates are subject to various site-specific factors that make it difficult to provide estimates of general applicability.

3.2.2.4 Conclusions on Economic Viability of Alternatives: A Sector Approach

a. **Sector analyses.** Sector analyses highlight the dynamic nature of agricultural production and trade. Sector models can provide insight into marketing and distributional effects of changes in production systems that cannot be obtained through case studies or budget analyses. Existing patterns of production and trade depend, in part, on production costs associated with the use of methyl bromide. Switches to alternatives having different production costs, together with market forces and trade policies, can lead to forces that could change the location of crop production, trade patterns, consumer prices, jobs and foreign exchange earnings.

b. **The North American market for specialty winter fresh vegetables (e.g., tomatoes, melons, strawberries).** This market includes producers in the USA (Florida, Texas, California) and Mexico. It accounts for more than 20% of global methyl bromide use for soil fumigation i.e., about 16% of total global methyl bromide use. Using a sector model based on information available in 1994 (Spreen et al., 1995), the authors concluded that a rapid phaseout of methyl bromide, given alternatives available at that time, would impose annual economic costs on Florida of $623 million in shipping point revenues and a total cost of $1.0 billion. These estimates were substantially reduced in a re-run of the model using information on alternatives as of February 1997; shipping point revenues were reduced to $300 million to lower supply costs and reduced migration of production to Mexico.

c. **The European and North African regional market for winter fresh fruits and vegetables.** As in the North American market, there has been substantial concern about the potential migration of European production of fresh fruits and vegetables to North Africa due to phasing out methyl bromide in the European Union. In principle, the same type of sector analysis as reported for the North America market is also applicable to this market. However, no model of this type is available for the European Union and North African market at present, although simpler quantitative models have been applied to Spain, France and Italy (Bonte, 1996). The results, based on alternatives available as of 1995, suggest economic losses for Spain, France and Italy and increased imports of selected fresh fruits and vegetables, probably from North Africa. Updated results are not available at this time. However, progress with alternatives and their application is likely to lower costs over time in ways that closely reflect the estimates reported for the North American market.

3.2.3 PRIORITIES FOR FURTHER WORK

3.2.3.1 Technical Data for Agricultural Production Systems

Assessments of the economics of alternatives depend on adequate technical data and other information that must be generated by the experimental work and field testing carried out by agricultural production scientists e.g., estimates of changes in crop yields, production costs, and the risks of crop failure for specific agricultural production systems in specific locations. Technical data on production systems and human capital inputs for IPM systems, whether chemical-free or not, would be of particular interest particularly for Article 5(1) countries.

3.2.3.2 External Costs

Assessments of alternatives to methyl bromide should include information on economic costs which are not internalised by market prices but are associated with agricultural production and marketing e.g., the effects of toxicity (of methyl bromide or alternatives) on human health. The Task Force could not address the issue of external costs in this report due to time and resource constraints. However, in further work on assessing the relative economics of methyl bromide and its alternatives, the external cost issue should be given high priority.

3.2.3.3 Quantitative Estimation of the Relative Economics of Alternatives

The application of quantitative methods to assessments of the relative economics of alternatives is both important and practicable. The North American model of the winter fresh vegetable market involving the USA, Mexico and Canada demonstrates the value of this approach and the potential for developing further applications to improve (1) assessments of the economics of alternatives and (2) estimates of the costs and benefits of phasing out methyl bromide in Article 5(1) countries.

3.3 SUMMARY OF THE PROCESS AGENTS TASK FORCE REPORT

PREAMBLE - TEAP COMMENTS

Use of Controlled Substances as Process Agents
The TEAP thanks the Process Agents Task Force (PATF) for their efforts in preparing a report that provides clear technical information and detailed data on use and emissions of controlled substances used as process agents.

Non-Article 5(1) Findings
Emissions in Non-Article 5(1) countries from the use of controlled substances as process agents are comparable to the insignificant and inadvertent emissions of ODSs from feedstock uses. Further significant reductions in use and emissions are projected for the coming five years. Additional controls in Non-Article 5(1) countries may shift production to Article 5(1) countries, where ODS emissions may be significantly higher. Such a shift of production could substantially increase the ultimate cost of the Article 5(1) phaseout. Therefore, TEAP unanimously recommends that Parties consider the advantages of henceforth treating chemical process agents in the same manner as feedstocks.

Article 5(1) Findings
Emissions in Article 5(1) countries from use of controlled substances as process agents are significant and, without assistance, will continue to grow. However, proven technologies are commercially available to convert some facilities to non-ODS processes and to minimise emissions from those processes where alternatives have not yet been proven. Therefore, TEAP unanimously recommends that Parties consider the advantages of technology co-operation and financing of emission reduction and process conversion projects in Article 5(1) countries.

SUMMARY AND CONCLUSIONS OF THE PATF REPORT

Products

Process agents are used to produce a wide variety of products that are considered to be useful to society. Some products can be produced without the use of ODS. For other products the ODS used as a process agent cannot be replaced for reasons of health, safety, environment, quality, yield, cost effectiveness, commercial viability, commercial availability, and technical feasibility.

Example uses identified in the report of the PATF are summarised in the following table:

Examples of Products Made Using Process Agents

Process	Product Uses
Chlorine	Necessary for production of 60% of the chemicals produced and 80% of the pharmaceuticals produced, also used to produce polymers, solvents and thousands of other products. Chlorine is also used as a water treatment chemical to maintain the safety of public water supplies.
Caustic Soda	Used to produce paper and as an intermediate in the production of other products.
Chlorinated Rubber	Used as a binder in corrosion resistant paint for ships, bridges and off-shore structures. Due to very high durability used as a major component of highway marking paints. Also used as a component of heavy duty adhesives - e.g. bonds rubber to steel in automobiles.
Endosulphan	A broad spectrum biodegradable insecticide-acaricide used in the control of pests in cotton and other crops.
Ibuprofen	A basic drug used in the manufacture of analgesic formulations for use as pain killers.
Dicofol	A broad spectrum non systemic acaricide with little insecticidal activity. Used on tea and many fruits, vegetables, ornamentals and field crops for the control of various species of mites.
Chlorosulphonated polyolefin (CSM)	It is used in automobiles for timing and fan belts. Also used as a sheathing for wire and cable, as a gasket in the doors of microwave ovens and as a roofing membrane. Many inflatable whitewater rafts and rescue boats are fabricated with this material.
PPTA polymer	Bullet proof vests, lightweight armoured vehicles, motorcycle and bicycle helmets and containers for the transportation of dangerous goods are examples of products made using the material.
Fluoropolymer resins	Used as a sheath for aircraft and computer electrical wiring. Also used as a non-stick coating for cookware.
Fine Synthetic Fibre Sheet Structure	Typical uses are for medical instrument packaging (allows sterilisation after packing), air infiltration barriers for buildings, protective clothing for workers handling toxic or dangerous chemicals and high strength, light weight packaging materials.

Definitions

In order to clarify uses of controlled substances as process agents the PATF recommends that Parties consider the following definitions:

Feedstock: A controlled substance that undergoes transformation in a process in which it is converted from its original composition except for insignificant trace emissions as allowed by Decision IV/12.

Process Agent: A controlled substance, that because of its unique chemical and/or physical properties, facilitates an intended chemical reaction and/or inhibits an unintended chemical reaction.

Controlled substances are typically used in chemical processes as process agents for at least two of the following unique chemical and/or physical properties:

1.) Chemically inert during a chemical reaction
2.) Physical properties, e.g.
    - boiling point
    - vapour pressure
    - specific solvency
3.) To act as a chain transfer agent
4.) To control the desired physical properties of a process, e.g.,
    - molecular weight
    - viscosity
5.) To increase plant yield
6.) Non-flammable/non-explosive
7.) To minimise undesirable by-product formation

Note 1: Refrigeration, solvent cleaning, sterilisation, aerosol propellants and fire fighting are not process agents according to this definition.

Note 2: Parties need not consider use of ODS for foam blowing, tobacco puffing, caffeine extraction, or fumigation because these uses are already covered in other Decisions and/or by Technical Options Committee Reports.

Where the term "Process Agent" is used in this report it refers to the use of a controlled substance used as a process agent.

The Montreal Protocol defines "consumption" as:

Consumption = production + imports - exports

Parties should be aware that if process agent applications are considered differently than feedstock applications the quantities of controlled substances required would then have to meet the definition of consumption. However, in the case of ODS used as process agents the supply of ODS used to replenish loss of process inventory may not equal emissions.

In the case of ODS used as process agents, the ODS consumption would be utilised to replenish process inventory losses resulting from transformation, destruction and emissions to the atmosphere from the process and/or trace quantities slowly emitted from the product.
However, the existing definition of consumption, when applied to process agent use of ODS, disregards transformation and destruction and could result in a disincentive to reduce emissions.

The Parties may wish to carefully consider the emission reductions achieved to date and expected in the foreseeable future and develop appropriate actions to recognise the transformation and destruction that may occur in process agent use of ODS.

For the purpose of this report the supply required for replenishment of lost inventory is referred to as “make-up” and defined as follows:

> **Make up quantity:** The quantity of controlled substance per year, needed to continue the manufacture of products in a plant, due to transformation, destruction and inadvertent losses (i.e. emissions and residual amounts in final product).

Identified Uses of ODS as Chemical Process Agents

Where possible case studies have been developed for identified process agent uses (see Appendix C of the complete PATF report). The studies elaborate on the use and consumption of controlled substances, availability and feasibility of alternatives, products produced and other relevant information.

Case Study	Application
1	Use of CTC in the elimination of NCl_3 in the production of chlorine and caustic soda
2	Use of CTC in the recovery of chlorine in tail gas from production of Chlorine
3	Use of CTC in the Chlorinated Rubber Process
4	Use of CTC in Endosulphan production
5	Usage of CTC in Ibuprofen production
6	Use of CTC in Dicofol production
7a	Use of CTC in Chlorosulphonated polyolefin (CSM) production in a Non-Article 5(1) country
7b	Use of CTC in Chlorosulphonated polyolefin (CSM) production in an Article 5(1) country
8	Production of Poly-Phenylene-Terephtal-Amide with the aid of CTC in an intermediate raw product
9	Use of CFC-113 in manufacturing a family of fluoropolymer resins
10	Use of CFC-11 in manufacture of a fine synthetic fibre sheet structure
No Case Study	Use of CTC in Styrene Butadiene Rubber (SBR) production
No Case Study	Use of CTC in Chlorinated Paraffin production

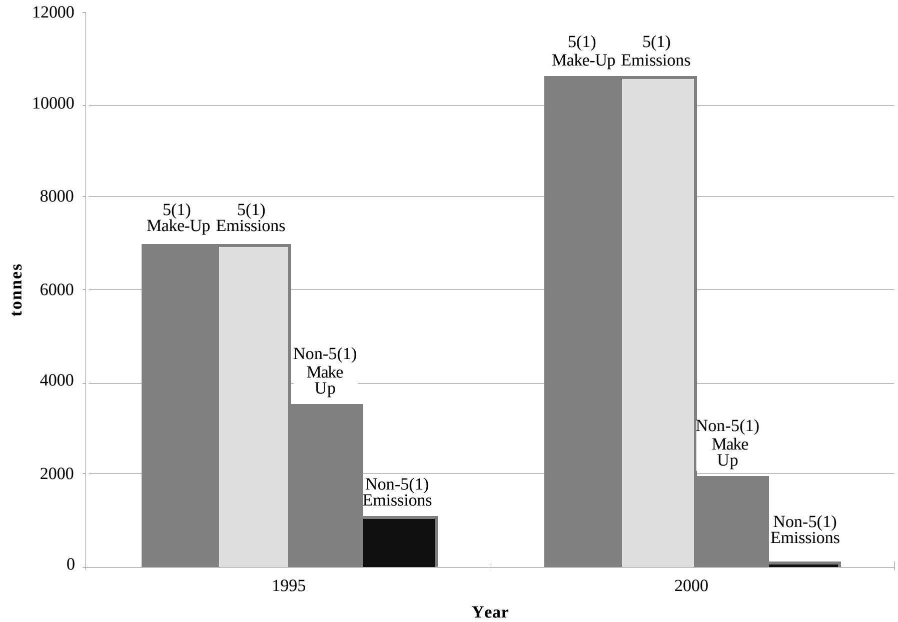
Feedstock Applications

Noting the definition of feedstock the PATF considers the following to be feedstock applications rather than process agent applications.

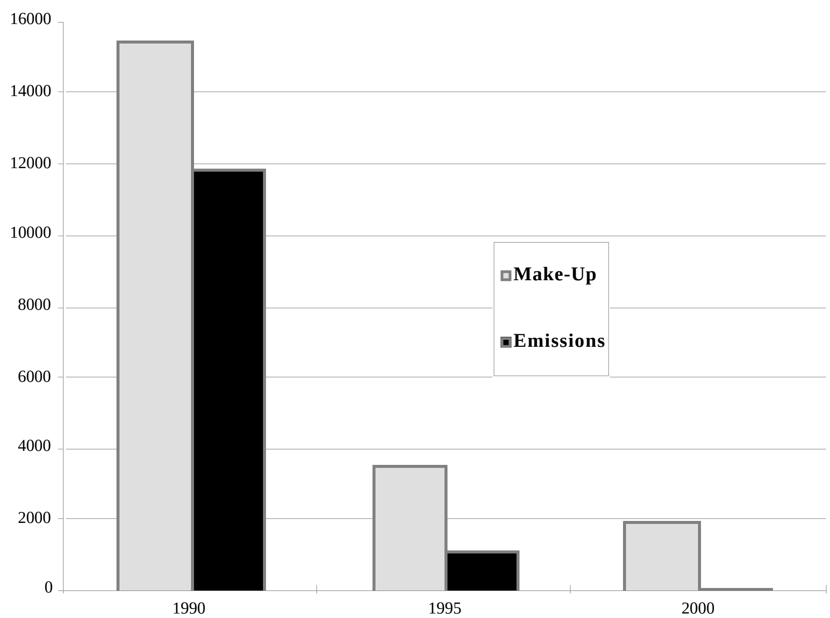
Case Study	Application
C-11	Use of Trichloroethane in the production of semiconductors
C-12	Use of CFC-12 in the purification of graphite

Estimates of Emissions of ODS Used as Process Agents

Global estimates of make-up and emissions for 1995 and 2000 (tonnes/year)



Make up and emissions of ODS used as process agent for Western Europe, North America and Japan - 1990, 1995 and 2000 (tonnes/year)



Emissions Associated with the Different Control Technologies and other Process Conditions under which Chemical Process Agents are Used

The preceding graphs clearly indicate the progress that has been made in Western Europe, Japan and North America in reducing use and more importantly emissions of ODS process agents up until now and for the foreseeable future. The new technologies that have made it possible to convert to the use of non-ODS process agents and the now proven technologies that have been employed to significantly reduce emissions are available for use elsewhere.

In general the various case studies have illustrated that emissions of controlled substances used as process agents can be minimised to "insignificant or trace levels" similar to that allowed for feedstock use where a process with adequate control technology and destruction capability are employed.

Minimisation of emissions can be achieved by use of practical control technologies to contain, destroy, or abate potential ODS emissions, i.e.

- carbon adsorption of gas streams
- steam stripping of aqueous wastes
- fugitive emission monitoring system
- leak detection monitoring
- destruction by means of technologies approved by the Parties to the Montreal Protocol.

However emissions of controlled substances used as process agents in simple batch processes are sometimes much more difficult to control. Simple batch type processes without advanced emission control technologies are typically used in Article 5(1) countries.

Alternative Process Agent Technologies or Products Available to Replace ODS in Such Uses.

Appendix C of this report provides case studies for most of the uses of controlled substances used in process agent applications identified by the PATF. Where alternative technologies or substitutes exist they have been identified in the case studies and summarised in Chapter 4. Some alternative products have been identified in the case studies, however, the information provided should not be considered as exhaustive.

All of the case studies illustrate clearly that the development and introduction of possible alternatives to ODS use in process agent applications depends on the following criteria:

- health and/or safety aspects
- environmental impacts other than ozone depletion
- quality and/or yield of the end product
- cost effectiveness and commercial viability
- commercial availability and restrictions due to proprietary technology
- technical feasibility

General Conclusions

Although the Non-Article 5(1) countries have significantly reduced and will continue to reduce their emissions, global emissions are expected to rise as the result of growth in Article 5(1) countries.

From an examination of the case studies of the identified processes the following conclusions are offered:

In most cases emissions from the use of ODS as process agents in Non-Article 5(1) countries are similar to the insignificant quantities emitted from feedstock uses.

For all of the identified processes, programs are underway to find and/or develop alternatives to the use of ODS as process agents.

Depending on the difficulties of the process under investigation there is a diversity of progress ranging as follows:

- phaseout achieved or achievable
- expected phaseout within the next few years subject to solution of final technical issues
- those processes with extreme difficulty to find an alternative.

Realising that these results been achieved in a period of 5 to 6 years, together with measures to significantly reduce emissions, there has been remarkable progress and further progress is expected in foreseeable future.

The expectation is that in the coming 10 years a substantial portion of the use of ODS as process agents will be virtually phased out in Non-Article 5(1) countries and that these new technologies can be applied in Article 5(1) countries. Adequate technical and financial assistance will facilitate the implementation of these technologies.

Conclusions Regarding Non-Article 5(1) Countries

The PATF has found that emissions from use of ODS as process agents in Non-Article 5(1) countries have been reduced significantly and could be considered as similar to the insignificant quantities emitted from feedstock uses. Use of ODS as process agents in the manufacture of pharmaceuticals and crop protection products was not fully investigated in the limited time period available to prepare this report.

Conclusions Regarding Article 5(1) Countries

The PATF found that emissions of ODS used as process agents are significantly higher in Article 5(1) countries including China, India and Brazil. In Article 5(1) countries those processes that utilise ODS as process agents are mostly of a simple batch type. In general, these batch type processes do not employ approved destruction technologies and may employ only rudimentary other types of emission control. As such the PATF found that the emissions from use of ODS as process agents resulted in much higher emission levels than use of ODS as feedstock. Significant opportunities exist to accomplish near phaseout of the use of ODS in Article 5(1) process agents by conversion of processes to the use of non-ODS process agents or processes.

For CSM and chlorinated rubber an alternative to conversion would be to employ emission reduction measures and reduce ODS emissions to insignificant levels. This may also be an appropriate strategy for use in some facilities that produce chlorine and for use in some cases of chlorine tail gas scrubbing.

The chemical process industries in Article 5(1) countries have the following options to reduce use and/or emissions:

- Modify production facilities to reduce their emissions to minimum possible levels;
- Changeover from CTC use to alternative non-ODS solvent use or alternative process/product;
- Shutdown and/or consolidate small scale plant/facilities.

The implementation of the above stated options by enterprises in Article 5(1) countries requires:

- availability of skilled manpower and their appropriate training;
- access to technology; and
- adequate financing.

Onetime changeover to an alternative non-ODS process/product has the distinct advantage of bringing about the near total phase out of the ODS and would be a sustainable solution.

Conclusions Regarding Countries with Economies in Transition (CEITs)

The PATF was unable to thoroughly investigate the use of ODS as process agents in countries with economies in transition. However, Poland has reported use of CTC for the recovery of tail gas from production of chlorine and use of CTC in the production of three pharmaceuticals; antical, disulfiram and ketofen.

3.4 SUMMARY OF THE REPORT BY THE TOC SUB-COMMITTEE ON FLAMMABLE REFRIGERANTS

This report presents a preliminary assessment of flammable refrigerant options such as hydrocarbons and their mixtures, as well as certain HFCs. It will be followed by a complete assessment in 1998 which will present a broader picture including all refrigerant options for all refrigeration, air-conditioning and heat pump sub-sectors.

The search for CFC and HCFC substitutes has, in parallel with the evaluation of non-flammable chemicals, resulted in the identification of flammable refrigerants as replacements. It has now led to a renewed evaluation of the possible use of these flammable refrigerants. They had previously not been widely considered because they could not meet the safety standards in force at that time for certain uses. This assessment presents a brief overview of the current national and international standards and compares the various approaches to safety. The report also shortly discusses risk assessment and other tools to make a given use safe and describes the present-day available status of purity requirements applicable to flammable refrigerants such as hydrocarbons.

Currently, the use of flammable refrigerants is primarily limited to the field of domestic refrigeration in Northern and Central European countries where it has captured about 35% of the market. This represents about 8% of the world refrigerator market. Although several flammable refrigerants could be used either as pure fluids or as blends, the most prominent flammable refrigerant option is isobutane (HC-600a), which is being applied in virtually all new domestic products that use a flammable refrigerant. Products, including compressors, have undergone life-testing with good results and a great deal of experience has been built up by appliance manufacturers in Europe. When applied in small refrigeration equipment such as domestic refrigerators, the energy efficiency of HC-600a is comparable to, or often better than, the energy efficiency of CFC-12 or HFC-134a.

The emphasis to date has been on newly designed units, but there has also been "retrofit activity". Changing to a flammable refrigerant when the refrigeration circuit needs to be repaired is an option in countries where repair is an attractive option because of the low cost of manpower and the relatively high cost of new appliances. This option is already used in some Article 5(1) countries. Training for safety measures should be emphasised for all technicians, in both the formal and informal sector, which would include instruction on product modifications. Questions still exist about technical maturity and reliability of several types of hydrocarbon mixtures since the results of proper life testing are not generally available.

Hydrocarbon refrigerants are also beginning to be used in other refrigeration sub-sectors, such as commercial refrigeration, and in some air-conditioning systems. This report also summarises the current status of the market for hydrocarbons in commercial refrigeration, chillers, heat pumps, as well as portable air-conditioning units.

For uses other than domestic refrigeration, the application of flammable refrigerants in new products has been rather limited to date since there has been no mass production The following trends may influence near-future market developments:

- manufacturers of commercial stand-alone equipment may benefit from the work which has been carried out on domestic appliances, particularly on compressors;
- a limited number of commercial refrigeration equipment has been installed in Germany, Sweden, the United Kingdom, in which options such as propane and propylene are being applied;
- compared to other European countries, the use of HCs in products other than domestic is most proliferated in the United Kingdom, where many pieces of stand-alone equipment are operated on hydrocarbons in the commercial sector;
- the market for heat pumps for heating only is restricted to Europe and the number of units using hydrocarbons is still rather limited (the number of outdoor units sold in Germany was about 800 in 1995);
- the air-conditioning market is dominated by American and Japanese companies which do not use hydrocarbons in this type of equipment. However, one Italian manufacturer of portable domestic AC systems uses propane for products sold on the German market (where the volume has been stated to be about 60,000 units in 1996).

With increasing experience in the Article 5(1) countries, flammable refrigerant technology is being and will increasingly be exported to the Article 5(1) countries, particularly in the field of domestic refrigeration. On the one hand, financial assistance from international mechanisms for conversions will certainly be contingent on studies of the differences between the operating costs for hydrocarbons and for other options. On the other hand, export of the technology will, for a larger part, be determined by the technology partnerships that exist or will be established between Non-Article 5(1) and Article 5(1) country manufacturers.

Information on the application of flammable refrigerants will continue to improve as more experience is gained from applications outside the domestic refrigeration sector. It particularly applies to cost comparisons and possibilities for and barriers to wider application. These aspects, amongst others, will be reflected in the 1998 Refrigeration, AC and Heat Pumps TOC Assessment Report.

MONTREAL PROTOCOL

ON SUBSTANCES THAT DEPLETE

THE OZONE LAYER

UNEP

Technology and Economic Assessment Panel

Part IV: Progress on the Restructuring of the Technology and Economic Assessment Panel
TEAP Membership Background Information
Contact Information for TEAP Members and TOCs

April 1997 Report

Montreal Protocol
On Substances that Deplete the Ozone Layer

UNEP Technology and Economic Assessment Panel

PART IV: PROGRESS ON THE RESTRUCTURING OF THE TECHNOLOGY AND ECONOMIC ASSESSMENT PANEL TEAP MEMBERSHIP BACKGROUND INFORMATION CONTACT INFORMATION FOR TEAP MEMBERS AND TOCS

April 1997 Report

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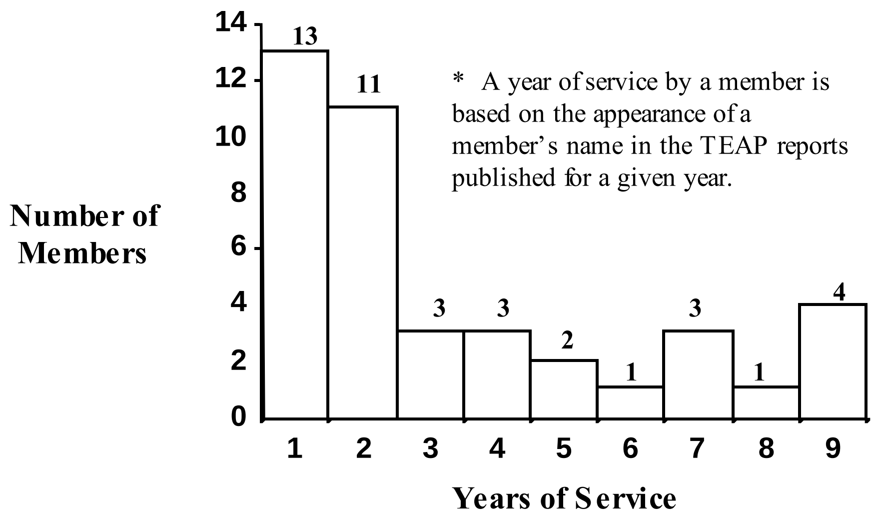
1 PROGRESS ON THE RESTRUCTURING OF TEAP IN CONFORMITY WITH THE TERMS OF REFERENCE

In 1998-99, the Scientific, Environmental Effects, and Technology and Economics Assessment Panels will undertake an integrated full Assessment for the Montreal Protocol. The TEAP Assessment will include separate full reports for each of its Technical Options Committees. In preparation for this Assessment, TEAP is continuing to restructure its membership in accordance with the Terms of Reference approved by the Parties in 1996.

Two concerns regarding TEAP operation are whether new expertise is coming in as required and whether adequate continuity of membership is maintained. In order to illustrate these factors, the attached figure presents the record of TEAP membership from 1988 through 1997. There has been substantial turn-over. Out of 41 members serving since 1988, only four members remain from the first Assessment. Thirteen TEAP members served for only one report, eleven served for two reports, three for three reports, three for four reports, two for five reports, one for six reports, three for seven reports and one for eight reports. Continuity has been maintained with at least one co-chair of each TOC continuing when other co-chairs departed.



TEAP currently has one opening for an Article 5(1) co-chair for the Economics Options Committee (the former co-chair, Bai Xianhong, China, has resigned) and an opening early in 1998 for a co-chair for the Methyl Bromide Technical Options Committee (Dr. Jonathan Banks will relinquish his co-chairmanship and continue as a member). TEAP anticipates an increasing pace of turnover during 1997-1999.

TEAP seeks nominations for an Article 5(1) co-chair of the Economics Options Committee. The candidate must be an economist and should have demonstrated committee management skills.

TEAP seeks nominations for co-chair of the MBTOC, preferably from the existing membership of the MBTOC, and with a strong reputation for independent, objective technical contributions and demonstrated committee management skills. Organisations sponsoring Non-Article 5(1) country co-chairs of TOCs have traditionally provided funding for the management, logistics, communication, and travel of the co-chair. The Methyl Bromide Technical Options Committee costs approximately US$75,000/annum plus the in-kind contribution of the co-chair and a part-time assistant . TEAP would welcome voluntary financing of MBTOC on a bilateral basis or from the Trust Fund. Generally, the availability of such funding might expand the choice of TOC co-chairs, including candidates from Article 5(1) countries.

Several TEAP members are shifting employment but are planning to continue on the TEAP. TEAP co-chair Dr. Stephen Andersen (USA) has a new joint EPA appointment where he will work on both stratospheric ozone protection and climate protection. TEAP co-chair, Dr. Suely Carvalho (Brazil), has a new position at the United Nations Development Programme (UNDP) office, where she will co-ordinate projects in the Latin-American Region. MBTOC co-chair, Dr. David Okioga (Kenya), is becoming a private consultant.

The principal TEAP goals of restructuring under the TOR are to increase Article 5(1) and CEIT participation and to improve its expertise balance so that it can provide a full inventory of alternatives and substitutes including descriptions of environmental acceptability, technical performance and economic feasibility. The TEAP will complete the implementation of the TOR approved by the Eighth Meeting by limiting the size of the TOCs to 20-35 members by eliminating the system of alternates prevalent in some committees and by avoidance of duplication of expertise. In addition, TEAP has asked the TOCs to consider retiring members-of-record who have not demonstrated technical competence, independence, objectivity, and successful completion of work. Alternates will no longer be designated and informal membership of “technical advisers” will be re-evaluated. As a result, the process of inducting more members from Article 5(1) countries, replacement of experts retiring/resigning, rationalising geographical balance is continuing in all TOCs.

All TOCs will make continued efforts to meet these goals. Significant changes will come to the Methyl Bromide TOC because its current membership is too large, Article 5(1) and CEIT experts are under-represented and there is unnecessary duplication of expertise.

In the 1994 Report of the TEAP for the 1995 Assessment, TEAP indicated that, despite the clear findings of the Science Assessment, persistent criticism of the science of ozone depletion was expressed by some MBTOC members who advocate less restricted methyl bromide use. This activity discourages investment in alternatives to methyl bromide.

TEAP has directed the MBTOC to reduce its membership of experts from Non-Article 5(1) countries, to increase the proportion of members from Article 5(1) countries and to simultaneously strengthen its expertise on alternatives and substitutes. TEAP has also instructed MBTOC co-chairs to use this opportunity to select experts who are able to objectively present the full range of views on technical and economic feasibility of the methyl bromide phaseout without instructions of their employers or governments.

Based on this direction, the MBTOC co-chairs presented a restructuring plan to the TEAP co-chairs.

TEAP co-chairs unanimously approved the restructuring plan requested from the co-chairs of MBTOC, mindful that many MBTOC members will not be re-appointed in order to reduce membership to the number specified in the TOR and to allow greater participation of Article 5(1) experts. As a result, a letter informing current MBTOC members of the restructuring will be mailed under signature of the MBTOC co-chairs prior to the 9th Meeting of the Parties.

2 TEAP MEMBERSHIP BACKGROUND INFORMATION

Since 1988 many Parties have made substantial in-kind and financial contributions to the operation of TEAP and its TOCs, Working Groups and Task Forces. The principal financial contributors include Australia, Canada, Germany, Japan, Netherlands, Sweden, Switzerland, United Kingdom, and the United States. In a typical year TEAP requires US$100,000-150,000 in administrative and management wages, communication, word processing, printing, and mailing costs. TOCs typically spend US$35,000-100,000 depending on whether the time of chairs is an in-kind contribution or a sponsored contribution.

Radhey S. Agarwal, Co-chair of the Refrigeration, Air-conditioning and Heat Pumps Technical Options Committee, is Professor of Mechanical Engineering at the Indian Institute of Technology (IIT Delhi), Delhi, India. IIT Delhi makes in-kind contribution for wages. Costs of travel, communication and other expenses are paid by the Ozone Secretariat.

Stephen O. Andersen, Co-Chair Technology and Economic Assessment Panel, is Deputy Director of the Stratospheric Protection Division of the U.S. Environmental Protection Agency, Washington, D.C., USA The U.S. EPA makes in-kind contributions of wage, travel, communication, and other expenses. With approval of its government ethics officer, EPA allows expenses to be paid by other government organisations and non-government-organisations (NGOs) such as the United Nations Environment Programme (UNEP).

Jonathan Banks, Co-Chair of the Methyl Bromide Technical Options Committee, is Head of the CSIRO Stored Grain Research Laboratory and program leader within CSIRO Division of Entomology, Canberra, Australia. CSIRO is an Australian government, non-profit research organisation. Funding for CSIRO is provided by industry, the government of Australia and by grants from other national and international government agencies.

Walter Brunner, Co-Chair of the Halon Technical Options Committee, is a partner in the consulting firm envico, Zurich, Switzerland. He is a consultant to the Swiss Government on halon regulations, and the Government of Switzerland makes in-kind contributions for his participation, travel, and other expenses.

Suely Carvalho, Co-Chair Technology and Economic Assessment Panel, is Director, Companhia de Tecnologia de Saneamento Ambiental (CETESB), of the Environmental Secretariat of the State of Sao Paulo, Brazil. CETESB makes in-kind contributions of wages and administrative support. Costs of travel are paid by the Ozone Secretariat. Since 1996, most costs of communication and other expenses are paid by the Ozone Secretariat.

Jorge Corona, Co-chair of the Solvents, Coatings and Adhesives Technical Options Committee, is in charge of foreign relations of the Environmental Commission of Camara Nacional de la Industia de Tranformacion (CANACINTRA), National Chamber of Industries, Mexico City. Communications, wages and miscellaneous expenses are covered personally. Travel expenses are paid by the Ozone Secretariat. From 1997, communications and other expenses are being covered by the Ozone Secretariat. During recent years, Jorge Corona has worked for UNEP and UNDP on a consultancy basis.

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3.2 1997 Technology and Economic Assessment Panel and Technical Options Committees

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