MONTREAL PROTOCOL

ON SUBSTANCES THAT DEPLETE

THE OZONE LAYER

UNEP

Report of the
Technology and Economic Assessment Panel
April 2000

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The TEAP thanks the Environment Protection Authority, Victoria, Australia, for hosting the meeting of the TEAP where this report was discussed, composed and finalised.

UNEP Report Of The
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Table of Contents **Page**

1 Introduction

Meetings of the Parties to the Montreal Protocol have taken a number of decisions, which request actions by the UNEP Technology and Economic Assessment Panel (TEAP). Responses of the TEAP to the 1999 requests and to requests made in earlier Meetings of the Parties are presented in this April 2000 report.

It concerns requests made in the following decisions:

Decision VII/34 *"Essential Use Nominations for Parties Not Operating under Article 5 for Controlled Substances"*

In accordance with Decision VII/34(5) the essential use nominations are dealt with in Chapter 2 of this report. It concerns the essential use applications for ODSs for the year 2001 and beyond. This part of the report is of a similar set-up as the Essential Use chapters in the April 1998 and April 1999 TEAP reports.

Decision X/19 *"Exemption for Laboratory and Analytical Uses"*

This decision requests the TEAP to report annually on the development and availability of laboratory and analytical procedures that can be performed without using the controlled substances in Annexes A and B of the Protocol. Chapter 2 (section 2.3) contains the second response of TEAP to this decision. It should be noted that, in Decision XI/15, a number of uses were removed from the global exemption.

Decision X/12 *"Emissions of ODSs from Feedstock Applications"*

This decision requests the TEAP to report on: (i) emissions of CTC from its use as feedstock, including options individual Parties may consider for the reduction of such emissions; (ii) emissions of other ODSs arising from the use of controlled substances as feedstock; and (iii) the impact of the CFC production phaseout on the future use of CTC as feedstock and emissions from such use". Chapter 3 of this report contains the information the TEAP has been able to collect.

Decision IX/24 *"Control of New Substances with Ozone Depleting Potential"*

In Decision VII/34 (c) the TEAP was requested to report on progress and developments in the control of substances each year. Decision IX/24 requests the TEAP to report to each ordinary Meeting of the Parties on any new substances with a certain Ozone Depleting Potential. As a follow-up to the Solvents TOC report given in 1999, this April 2000 report contains further information on the substance "n-propyl-bromide (nPB)", on halon-1202 and new ozone deleting substances according to Decision IX/24, paragraphs 3 and 4 (Chapter 4 of this report).

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. This request was renewed in Decision X/17 "…to keep the Parties to the Montreal Protocol informed of any important new developments on a year-to-year basis. Progress reports of the different TOCs (Aerosols, Economics, Foams, Halons, Methyl Bromide, Refrigeration and Solvents) can be found in Chapter 5 of this report.

Decision VII/34 *"Background and Contact Information for TEAP Members and TOCs"*

TEAP reported on progress towards improved geographical balance and other structural adjustments in past progress reports. Chapter 7 of this 2000 report presents further information on the operation of the TEAP and its TOCs, including some restructuring decisions taken. It also includes contact details of the TEAP members and membership lists of the different TOCs. It also gives background information of the TEAP members (Decision VII/34, paragraph (e)(iv)).

2. Essential Use Nominations

2.1 Review of essential use nominations for MDIs

Decision IV/25 of the 4th Meeting and subsequent Decisions V/18, VII/28, VIII/9 and VIII/10 set the criteria and the process for the assessment of essential use nominations for metered dose inhalers (MDIs).

2.1.1 Review of nominations

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

Concurrent with the evaluation undertaken by the ATOC, copies of all nominations were provided to the Technology and Economic Assessment Panel (TEAP). The TEAP was able to consult with other appropriate individuals or organisations in order to assist in the review and to prepare the TEAP recommendations to the Parties.

2.1.2 Committee evaluation and recommendations

Nominations were assessed against the guidelines for essential use contained in the *Handbook on Essential Use Nominations*. Further information was requested in case nominations were found to be incomplete.

The ATOC reviewed all of the nominations submitted for a production exemption. Production in this context includes import of ozone depleting substances for the purposes of manufacture.

In 2000 the following Parties nominated essential use production exemptions for MDIs (asthma and COPD).

Country	2000	2001	2002
Australia	(1)	✓	✓
European Community	*	*	✓
Poland	(2)	✓	✓
USA	*	*	✓

*Approved in 1998 and 1999.

For the year 2000 the following applies to Australia and Poland:

(1) Requested reduction in quantity for nomination previously approved by Parties in 1998.

(2) Parties approved a nomination for 400 tonnes in 1998. During 1999, Poland requested an emergency essential use nomination for an additional 4.5 tonnes, which was recommended for approval by the TEAP.

2.1.3 Observations

No essential use nominations for the Russian Federation have been received for production of CFCs for MDIs for 1999 and beyond, even though information available to ATOC indicates that production of CFC based MDIs in the Russian Federation is continuing.

The ATOC understands that domestic manufacture of CFC based MDIs is taking place by one company using an estimated 100 tonnes of CFCs. A second company has recently established a new manufacturing facility for the production of salbutamol CFC based MDIs.

Local CFC production is anticipated to cease in mid-2000. Since no essential use nominations have been received for the last 2 years, the source of CFCs needed for current and future MDI manufacture is unclear.

2.1.4 Future considerations

Based on the experience of assessments of essential use nominations over a number of years, ATOC makes the following observations and recommends changes to the *Handbook on Essential Use Nominations* accordingly.

Current nominations include extensive information about the diseases treated by metered dose inhalers and information about the prevalence of asthma and COPD. This information provides justification in support of MDIs as essential uses under Decision IV/25. However, much of this data is repeated unchanged annually. The detailed information currently provided adds little to the nominations unless there have been some significant unforeseen developments. It is therefore recommended that in future years, unless the situation changes, information under section II, A(1) of the *Handbook on Essential Use Nominations* is not required if the proposed use is for the treatment of asthma and COPD. Under section I A, a statement that the proposed use is for MDIs for the treatment of asthma and COPD would be sufficient.

Other information currently not provided in nominations would better respond to Decision IV/25 and assist in the assessment of nominations. ATOC recommends the following additional information be provided, and proposes changes to relevant sections of the *Handbook on Essential Use Nominations*:

1. Expand information provided under section II, B(1) to include which CFC-free MDIs are currently licensed, as well as information showing trends in the availability and usage of non-MDI treatments (for example, oral therapies, dry powder inhalers, and novel inhaler devices) and the likely impact of these trends on the need for CFCs for MDIs in the year of the nomination.

2. CFC use for newly approved production of CFC based MDIs may not meet the requirements of essential uses under Decision IV/25. ATOC therefore proposes that section II, C(2) be expanded and nominations include a statement as to whether any CFC is being requested for any MDI approved in the year prior to the year in which the nomination is made. Nominations should also include information about the type of product and justification as to whether it is essential or not.

3. Expand section II F to provide for a statement in nominations about the proportion of the nominated quantity intended for use in MDIs for export and to certify that these exports are not to markets where these product(s) have been declared non-essential.

2.1.5 Recommendations for Parties' Essential Use Nominations

Quantities are expressed in metric tonnes.

Australia

ODS/Year	**2001**	**2002**
Total	74.95	74.95

Specific Usage: MDIs for asthma and COPD

Recommendation: Recommend Exemption

Comments: The Australian nomination shows a commendable reduction in quantities of CFCs used, from 302 tonnes in 1993 to 136 tonnes in 1999. Australia notes a reduction in the expected quantities to be used in 2000 to 110 tonnes, compared with the previously approved quantity of 220 tonnes. ATOC notes a further reduction from the year 2000, to the nominated quantity of 74.95 tonnes for each of the years 2001 and 2002. The lack of continued reduction from 2001 to 2002 reflects a situation of declining domestic use, offset by increased exports to South East Asia, which is Australia's main export market.

European Community

ODS/Year	2002
Total	2785

Specific Usage: MDIs for asthma and COPD

Recommendation: Recommend Exemption with recommendation to reduce stockpile as production declines

Comments: The general trend for a reduction in anticipated use of the total amount of CFCs is commendable.

Based on the current accounting framework data, the volume of CFCs on hand, during 1999 (4272 tonnes), appears to be significantly more than the nominated amounts expected to be used in the years 2001 and 2002. The stockpile of CFCs reported by the European Union has increased and appears to be sufficient for around eighteen months of production by 2002. This seems to be excessive and warrants further comment and elaboration from the nominating Party.

Poland

ODS/Year	2001	2002
Total	320	300

Specific Usage: MDIs for asthma and COPD

Recommendation: Recommend Exemption

Comments: The ATOC notes that overall nominated quantities for Poland continue to decline yearly and are projected to continue to do so through to 2004. The nomination would benefit from being unified by the Polish authorities, rather than individual company requests.

It appears in retrospect that the previously approved nomination for 2000 (400 tonnes) was more than adequate and that Poland's emergency request in 1999 for 4.5 tonnes was unnecessary.

USA

ODS/Year	2002
Total	2900

Specific Usage: MDIs for asthma and COPD

Recommendation: Recommend Exemption

Comments: The volume of 2900 tonnes for the nomination for 2002 is approximately 6% less than the amount approved for 2001. It is also noted that there is a decrease of 22% in the US strategic reserve, as shown in the reporting accounting framework. The continued active management of this strategic reserve is commendable.

2.1.6 Review of previously authorised Essential Uses (Decision VII/28 (2a) and (2b))

Under Decision VII/28 (2a) and (2b), Parties decided that:

"(a) The Technology and Economic Assessment Panel will review, annually, the quantity of controlled substances authorised and submit a report to the Meeting of the Parties in that year;

(b) The Technology and Economic Assessment Panel will review, biennially, whether the applications for which exemption was granted still meets the essential-use criteria and submit a report, through the Secretariat, to the Meeting of the Parties in the year in which the review is made;"

The ATOC reviewed the essentiality of MDIs for asthma and COPD for 2001 and 2002 and concluded that they remain essential for patient health until an adequate range of technically and economically feasible alternatives are available.

New CFC-free product launches are likely to increase further over the next two years. As most nominations are received 2 years in advance, Parties may wish to continue to monitor and manage their own CFC acquisition and usage under authorised essential use quantities, and adjust their nominated quantities annually on an "as needed" basis. The ATOC will continue to monitor the changing market situation.

This year Australia requested in its essential use nomination a reduction in the nominated quantities to be used in 2000 to 110 tonnes compared with the previously approved quantity of 220 tonnes. The Parties may wish to consider noting this information in Decisions taken at their 12th Meeting.

2.2 Nomination by Poland for solvents used in the maintenance of oxygen systems of torpedoes

In 1997, Poland exercised its option under the Emergency Exemption (Decision VIII/9, paragraph 10). Import of 1,700 kilograms of CFC-113 for this use was authorised by the Secretariat after consultation with the TEAP and its STOC.

In 1998, Poland applied for 1700 kg of CFC-113 for use in each of the years 1999 through 2003.

In February 1998, the STOC requested additional information such as: substrate alloys for components and assemblies, types of coatings applied, types of non-metallic components used and type of grease to be removed and its liquefying temperature and approximate thickness of grease layer. Details of the grease-removing process and working conditions such as ventilation were also requested. Information was requested regarding problems that might arise from the use of recycled CFC-113, which alternative processes or substances have been evaluated and technical reasons for their rejection, types of tests carried out and criteria used for qualification.

TEAP considered this nomination and in its report of April 1998 documented that the STOC did not receive the information requested in February 1998 and, therefore, was unable to recommended this nomination for continued use. After considering the special circumstances, Parties approved the essential use.

In December 1998, TEAP Co-chairs asked the Head of the Ozone Protection Unit in Warsaw and the Head of the Polish Delegation, Ministry of Environmental Protection to organise a joint meeting with representatives of the Polish Navy, the manufacturers of the torpedoes and a team of STOC members. Kazakhstan was suggested as the venue. Subsequent direct communication between the Head of the Ozone Layer Protection Unit and a STOC Co-chair agreed on scheduling the meeting in Kazakhstan during 3 - 5 May 1999. There have been problems in receiving a proper response from the manufacturer of the torpedoes. STOC attempted to reschedule the meeting in September and in November 1999 but lack of information from the side of Kazakhstan prevented this.

TEAP therefore recommended that the nomination be forwarded to the 11th Meeting of the Parties to allow the opportunity to review supplemental information. Parties approved the essential use.

The Almaty (Kazakhstan) meetings (20-24 March 2000)

The purpose of the meeting was to discuss the possibility of phasing out CFC-113 from torpedo oxygen systems maintenance. The tasks to be accomplished were defined by the STOC as follows:

- Clarification and presentation of torpedo maintenance procedures;
- Explanation of ODS-free technical options;

- Discussion of technical and regulatory problems in changing to ODS-free approaches;
- Formulate conclusions that would specify further actions to be undertaken to accomplish the objective of the meeting.

Mashzavod, the manufacturer of the torpedoes in Kazakhstan, will provide six- month-status updates on the evaluation of alternatives to the Polish Navy. STOC will provide additional technical options for consideration and evaluation by the manufacturer.

Meeting held at Polish Navy Headquarters in Gdansk on 27 March 2000

The objectives of the meeting were:

- To discuss any outstanding issues which needed clarification following the Almaty meetings;
- To provide further information to the Navy to assist in their efforts to phaseout CFC-113 in torpedo maintenance.

The main outcome of the meeting was the manufacturer's commitment to evaluate further technical options and the Navy's commitment to perform and evaluate the unique flammability and compatibility tests on options suggested by the STOC.

The Navy also agreed to provide six-month-status updates on alternatives evaluation from the manufacturer and submit the STOC through the Polish Ozone Layer Protection Unit and the Polish Navy shall look into the possibility of utilising recycled CFC-113.

The STOC agreed to provide relevant information to the Navy on the practice of other naval and aircraft facilities on the qualification of alternatives for oxygen system maintenance.

Essential Use Nomination forwarded by Poland, February 2000

The recently received nomination from Poland for the torpedo oxygen system maintenance requests 0,85 metric tonnes of CFC-113 for each of the years 2001, 2002 and 2003.

Based upon the commitments of torpedo manufacturer and of the Polish Navy to take positive action to eliminate the use of CFC-113 and because of the relatively long time needed for qualification of an alternative.

TEAP and its STOC recommend the Essential Use exemption by Poland for 0.85 tonnes for CFC-113 for 2001 only.

2.3 Laboratory and analytical uses

2.3.1 Introduction

Typical laboratory and analytical uses include: equipment calibration; extraction solvents, diluents, or carriers for specific chemical analyses; inducing chemical-specific health effects for biochemical research; as a carrier for laboratory chemicals; and for other critical purposes in research and development where substitutes are not readily available or where standards set by national and international agencies require specific use of the controlled substances.

The Parties to the Montreal Protocol decided at their 6th Meeting (Decision VI/9(3)):

"That for 1996 and 1997, for Parties not operating under paragraph 1 of Article 5 of the Protocol, production or consumption necessary to satisfy essential uses of ozone depleting substances for laboratory and analytical uses are authorised as specified in Annex II to the Report of the 6th Meeting of the Parties."

The conditions for continuous use under the Global Exemption as specified in Decision VI/9(3), Annex II (See section 2.5 of the *Handbook for the International Treaties for the Protection of the Ozone Layer* (UNEP, 1996)), include requirements that:

"Parties shall annually report on each controlled substance produced: the purity, the quantity; the application, specific test standard, or procedure requiring its uses; and the status of efforts to eliminate its use in each application. Parties shall also submit copies of published instructions, standard specifications, and regulations requiring the use of the controlled substances."

The Parties, at their 10th Meeting, decided:

1. *To extend the global laboratory and analytical essential use exemption until 31 December 2005 under the conditions set out in annex II of the report of the 6th Meeting of the Parties;*

2. *To request the Technology and Economic Assessment Panel to report annually on the development and availability of laboratory and analytical procedures that can be performed without using the controlled substances in Annexes A and B of the Protocol;*

3. *That the Meeting of the Parties shall each year, on the basis of information reported by the Technology and Economic Assessment Panel in accordance with paragraph 2 above, decide on any uses of controlled substances which no longer be eligible under the exemption for laboratory and analytical uses and the date from which any such restriction should apply.*

Based upon information received from the Technology and Economic Assessment Panel, the Parties decided at their 11th Meeting:

> *"To eliminate the following uses from the global exemption for laboratory and analytical uses for controlled substances, approved in Decision X/19, from the year 2002:*
>
> *a) Testing of oil, grease and total petroleum hydrocarbons in water;*
>
> *b) Testing of tar in road-paving materials; and*
>
> *c) Forensic finger-printing."*

2.3.2 The use of controlled substances for laboratory and analytical uses

The *1998 ATOC Assessment Report* summarised reports from a number of Parties on the use of controlled substances for analytical uses. The European Union, Australia, the Czech Republic and the United States have adopted licensing systems in order to manage supplies into these applications. These systems license supplies to the distributors of controlled substances into the laboratory and analytical sector. Registration of the many thousands of small users in this sector is generally impracticable.

2.3.3 Available alternatives for laboratory and analytical uses

International and national organisations are working to eliminate the use of ozone depleting substances in many laboratory and analytical uses. Decision XI/19 taken in Beijing, which will eliminate three major uses from 1 January 2002, provides an example of such work. Further reports are now anticipated from the Parties on alternatives that have been identified and are now available or analytical methods that do not require the use of ozone depleting substances. The ATOC will report on these in future years.

2.4 Reporting Accounting Framework for Essential Uses

See next page.

Reporting Accounting Framework for Essential Use Exemptions 1997-1999

	A	B	C	D	E		F	G	H	I	J	K	L	M
Country	**Year of Essential use**	**Ozone Depleting substances**	**Amount Exempted for year of Essential use**	**Amount acquired by Production**	**Amount Acquired for Essential uses by import & Countries of Manufacture**		**Total Acquired for Essential use**	**Authorized but not Acquired**	**On Hand Start of the Year**	**Available for use in current year**	**Used for Essential use**	**Quanti contained in Exported Product**	**Destroyed**	**On Hand end of Year**
					Amount	**Country**								
Australia	**1999**	CFC-11	94	0	89.69	Netherlands	89.69	4.31	20.52	4110.21	43.28	24.24	0.137	66.79
		CFC-12	210	0	16.066	Spain	16.066	28.31	54.62	236.31	90.42	60.28	2.36	143.53
					165.62	Netherlands	165.62							
		CFC-113	5	0	2.83	Spain	2.83	2.17	0.55	3.38	1.88	1.44	0.415	1.09
		TOTAL	**309**	**0**	**274.206**		**274.206**	**34.79**	**75.69**	**4349.9**	**135.58**	**85.96**	**2.912**	**211.41**
	1998	CFC-11	64	0	60.46	Netherlands	60.46	3.54	43.1	103.56	82.96	27.696	0.084	20.52
		CFC-12	155	0	134.4	Netherlands	134.4	20.6	96.6	231	175.26	63.84	1.123	54.62
		CFC-113	4	0	0		0	4	2.4	2.4	1.65	0.836	0.198	0.55
		TOTAL	**223**	**0**	**194.86**		**194.86**	**28.14**	**142.1**	**336.96**	**259.87**	**92.372**	**1.405**	**75.69**
		(1) During 1998, the pre-1996 Australia stockpile was exhausted. The 75.67 metric tonnes on hand on December 1998 comprised of unused imports												
Canada	**1999**	CFC-11		0	0		0		26	26	3	2	0	23
		CFC-12		0	0		0		23	23	4	4	0	19
		CFC-114		0	0		0		7	7	5*	0	0	2
		TOTAL	**140**	**0**	**0**		**0**	**140**	**56**	**56**	**12**	**6**	**0**	**44**
	1998	CFC-11	128		31	USA	31	97	11	42	3	2	13	
		CFC-12	320		12	USA	12	308	19	31	8	4	0.2	
		CFC-114	65		0		0	65	7	7	0	0	0	
		TOTAL	**5113**		**43**		**43**	**470**	**37**	**80**	**11**	**6**	**13**	
European														
Community	**1999**	CFC-11	1773,5	1665,3	0		1665,3	108,3	1360,4	3025,7	N/A	N/A	N/A	N/A
		CFC-12	2391,3	2293,2	0		2293,2	98,1	2239,0	4532,3	N/A	N/A	N/A	N/A
	Note:	CFC-113	8	1,1	0		1,1	6,9	-0,2	0,9	N/A	N/A	N/A	N/A
	Estimate	CFC-114	256,2	178,6	29,9	USA	208,5	47,7	672,3	880,7	N/A	N/A	N/A	N/A
	only	**TOTAL**	**4429,0**	**4138,2**	**29,9**		**4168,1**	**260,9**	**4271,6**	**8439,6**	**0,0**	**0,0**	**0,0**	**0,0**
	1998	CFC-11	1779,7	1735,5	0,0		1735,5	44,2	1297,0	3032,6	1619,8	570,1	52,4	1360,4
		CFC-12	3297,7	2909,9	0,0		2909,9	387,8	2063,4	4973,3	2701,7	1027,5	32,6	2239,0
		CFC-113	7,6	1,4	0,0		1,4	6,2	2,4	3,8	3,7	0,2	0,3	-0,2
		CFC-114	377,5	236,6	20,4	USA	257,0	120,5	755,5	1012,5	335,2	119,8	5,0	672,3
		TOTAL	**5462,5**	**4883,4**	**20,4**		**4903,8**	**558,7**	**4118,4**	**9022,2**	**4660,4**	**1717,6**	**90,3**	**4271,6**

Reporting Accounting Framework for Essential Use Exemptions 1997-1999

	A	B	C	D	E		F	G	H	I	J	K	L	M
Country	**Year of Essential use**	**Ozone Depleting substances**	**Amount Exempted for year of Essential use**	**Amount acquired by Production**	**Amount Acquired for Essential uses by import & Countries of Manufacture**		**Total Acquired for Essential use**	**Authorized but not Acquired**	**On Hand Start of the Year**	**Available for use in current year**	**Used for Essential use**	**Quanti contained in Exported Product**	**Destroyed**	**On Hand end of Year**
					Amount	**Country**								
European														
Community	**1997**	CFC-11	1991	1867	0	-	1867	124	1369	3236	1910	841	246	1080
		CFC-12	3946	3373	0	-	3373	573	2115	5488	3290	1538	125	2073
		CFC-113	18.5	10	0	-	10	8.5	5	15	9	2	3	3
		CFC-114 +(	680.5	264	0	-	264	416.5	884	1148	383	196	18	747
		TOTAL	6636	5514	0	-	5514	1122	4373	9887	5592	2577	392	3903
Hungary	**1999**	CFC-11	3	-	0.6	Spain	0.6	2.4	0.504	1.104	0.431	0.26	-	0.673
		CFC-12	3	-	-	-	-	3	0.413	0.413	0.217	0.053	-	0.196
		CFC-113	0.23	-	-	-	-	0.23	0.705	0.705	0.067	-	-	0.638
		CFC-114	3	-	-	-	-	3	0.413	0.413	0.217	0.053	-	0.196
		TOTAL	**9.23**		**0.6**		**0.6**	**8.63**	**2.035**	**2.635**	**0.932**	**0.366**	**0**	**1.703**
	1998	CFC-11	6					6	0.968	0.968	0.464	0.15		0.504
		CFC-12	2.25		0.63	UK	0.63	1.62	1.053	1.683	1.27	1.001		0.413
		CFC-113	0.23					0.23	0.9	0.9	0.195			0.705
		CFC-114	1.7		0.63	UK	0.63	1.07	1.053	1.683	1.27	1.001		0.413
		TOTAL	**10.18**	**0**	**1.26**		**1.26**	**8.92**	**3.964**	**5.234**	**3.199**	**2.152**	**0**	**2.035**
	1997	CFC-11	5					5	2.215	2.215	1.163	0.083	0.084	0.968
		CFC-12	2		1.96	Spain*	1.96	0.04	1.074	3.034	1.958	1.316	0.023	1.053
		CFC-113	1					1	0.955	0.955	0.055			0.9
		CFC-114	2		1.96	Spain*	1.96	0.04	0.832	2.792	1.716	1.316	0.023	1.053
		TOTAL	**10**		**3.92**		**3.92**	**6.08**	**5.076**	**8.996**	**4.892**	**2.715**	**0.13**	**3.974**
Japan	**1999**	CFC-11	37	0	6.56	UK,Spain	6.56	30.44	84.33	90.89	27.62	0.17	2.61	60.66
		CFC-12	75	0	36.6	UK	36.6	38.4	171.81	208.41	63.95	0.17	0.21	144.25
		CFC-113	0.5	0	0		0	0.5	0.06	0.06	0.06	0	0	0
		CFC-113	24	0	0		0	24	66.47	66.47	11.47	0.01	0	55
		TOTAL	136.5	0	43.16		43.16	93.34	322.67	365.83	103.1	0.35	2.82	259.91

Reporting Accounting Framework for Essential Use Exemptions 1997-1999

	A	B	C	D	E		F	G	H	I	J	K	L	M
Country	Year of Essential use	Ozone Depleting substance	Amount Exempted for year of Essential	Amount acquired by Production	Amount Acquired Essential uses by & Countries of Manufacture		Total Acquired for Essential use	Authorized but not Acquired	On Hand Start of the Year	Available for use in current year	Used for Essential use	Quanti contained in Exported Product	Destroye	On Hand end of Year
					Amount	Country								
Japan	1998	CFC-11	53	0	50.03	UK,Spain	50.03	2.97	67.29	117.32	37.39	0.38	0.1	79.83
		CFC-12	105	0	103.07	UK,Spain	103.07	1.93	133.19	236.26	73.91	0.38	0.4	161.95
		CFC-113	0.5	0	0		0	0.5	0.09	0.09	0.03	0	0	0.06
		CFC-113	23	0	15	UK	15	8	57.92	72.92	11.08	0.03	0	61.84
		TOTAL	181.5	0	168.1		168.1	13.4	258.49	426.59	122.41	0.79	0.5	303.68
			*** These Substances were imported from Spain, but the Country of Manufacture is probably China**											
Poland	**1999**	CFC-11	120	-	59.85	Holland	59.85	60.15	38.98	98.83	63.04	23.43	-	35.79
		CFC-12	235	-	115.31	Holland	115.31	119.69	38.45	153.77	117.73	54.57	-	36.04
		CFC-114	25	-	4.07	Holland	4.07	20.93	6.61	10.68	6.667	0	-	3.98
		TOTAL	**380**	**0**	**179.23**		**179.23**	**200.77**	**84.04**	**263.28**	**187.437**	**78**	**0**	**75.81**
Poland	**1998**	CFC-11	130,00	-	89,13	Holland	89,13	40,87	30,36	119,49	80,51	22,19	-	38,98
		CFC-12	220,00	-	147,51	Holland	147,51	72,49	41,18	188,69	150,24	51,49	-	38,45
		CFC-114	30,00	-	16,23	Holland	16,23	13,77	5,35	21,58	14,97	1,02	-	6,61
		TOTAL	**380,00**	**0**	**252,87**	**0**	**252,87**	**127,13**	**76,89**	**329,76**	**245,72**	**74,7**	**0**	**84,04**
	1997	CFC-11	130	-	98	Holland	98	32	37.5	135.5	105.1	43.2	-	30.4
		CFC-12	220	-	193.7	Holland	193.7	26.3	42	235.7	134.5	88.8	-	41.2
		CFC-114	30	-	13.2	Holland	13.2	16.8	6.8	20	14.6	3.1	-	5.4
		TOTAL	**380**	**-**	**304.9**		**304.9**	**75.1**	**86.3**	**391.2**	**254.2**	**135.1**	**-**	**77**
Russian Federation	**1998**	Halon - 2402	255	79.67	-	-	79.67	175.33	3.08	82.75	82.75	-	-	-
		CFC-11	226	103	-	-	103	123	242.5	345.5	42.5	-	-	303
		CFC-12	226	174	-	-	74	52	266	440	243	-	-	197
		TOTAL	**707**	**356.67**	**0**	**0**	**256.67**	**350.33**	**511.58**	**868.25**	**368.25**	**0**	**0**	**500**
	1997	Halon-2402	300	161.5	-	-	161.5	179.5	161.5	-	158.42	-	-	3.08
		CFC-11	266	266	-	-	266	-	266	-	23.5	-	-	242.5
		CFC-12	266	266	-	-	266	-	266	-	-	-	-	266
		TOTAL	**832**	**693.5**	**-**	**-**	**693.5**	**179.5**	**693.5**	**-**	**181.92**	**-**	**-**	**511.58**

Reporting Accounting Framework for Essential Use Exemptions 1997-1999

	A	B	C	D	E		F	G	H	I	J	K	L	M
Country	**Year of Essential use**	**Ozone Depleting substances**	**Amount Exempted for year of Essential use**	**Amount acquired by Production**	**Amount Acquired for Essential uses by import & Countries of Manufacture**		**Total Acquired for Essential use**	**Authorized but not Acquired**	**On Hand Start of the Year**	**Available for use in current year**	**Used for Essential use**	**Quanti contained in Exported Product**	**Destroyed**	**On Hand end of Year**
					Amount	**Country**								
Switzerland	**1998**	F-11	2	0	0.28	Italy	0.28	1.72	0.2	0.48	0.12	0	0	0.36
		F-12	4	0	1.1	Italy	1.1	2.9	0.16	1.26	0.35	0	0	0.92
		F-114	2	0	0.21	Italy	0.21	1.79	0.01	0.22	0.05	0	0	0.17
		TOTAL	**8**	**0**	**1.59**		**1.59**	**6.41**	**0.37**	**1.96**	**0.52**	**0**	**0**	**1.45**
					Amount	**Country**								
USA	**1999**	CFC-11	1047.4	0	818.7	Netherlands	818.7	228.7	458.9	1277.6	760.2	44.8	229.9	242.7
		CFC-12	2434.4	0	1745.8	Netherlands	1745.8	688.6	1490.3	3236.1	1722.6	104.6	101.9	1307
		CFC-114	183.6	0	66	Netherlands	66	117.6	295	361	161.8	8.5	8.4	182.3
		TOTAL	**3665.4**	**0**	**2630.5**		**2630.5**	**1034.9**	**2244.2**	**4874.7**	**2644.6**	**157.9**	**340.2**	**1732**
	1998	CFC-11	1,204.3		735.4	EU	735.4	468.9	651.2	1,386.6	743.5	35	149.2	458.9
		CFC-12	2,809.7		1,465.2	EU	1,465.2	1,344.5	1,835.2	3,300.4	1,573.0	88	149.1	1,490.3
		CFC-114	349		35	EU	35	314	410	445	109	2	39	295
		TOTAL	**4,363.0**	**0**	**2,235.6**		**2,235.6**	**2,127.4**	**2,896.4**	**5,132.0**	**2,425.5**	**125**	**337.3**	**2,244.2**
	1997	CFC-11	1,138.6		526.4	EU	526.4	612.2	782.2	1,308.6	601.1	3.4	52.9	651.2
		CFC-12	3,023.8		1,410.2	EU	1,410.2	1,613.6	1,968.2	3,378.4	1,522.4	10.1	10.7	1,835.2
		CFC-114	493.6		95.7	EU	95.7	397.9	446.8	542.5	131.6	0.9	0	410
		TOTAL	**4,656.0**	**0**	**2,032.3**		**2,032.3**	**2,623.7**	**3,197.2**	**5,229.5**	**2,255.1**	**14.4**	**63.6**	**2,896.4**

3 Response to Decision X/12 on feedstock applications

3.1 Introduction

Carbon tetrachloride (CTC) is an easily manufactured chemical that is widely available. CTC has been extensively reviewed in the 1994 and 1998 Reports of the Aerosols, Sterilants, Miscellaneous Uses and Carbon Tetrachloride Technical Options Committee. Specific applications of CTC have been investigated in the *1995 Report of the Process Agents Working Group* and were further elaborated on in the *1997 Process Agents Task Force Report* (PATF); review can also be found in the *1995 Report of the Laboratory and Analytical Uses Working Group*. Inadvertent emissions and Process Losses were discussed in the *1994 Report of the Technology and Economic Assessment Panel (TEAP)*. Atmospheric emissions of CTC were estimated in the *1998 ATOC Assessment Report*.

In Decision X/12, Parties to the Montreal Protocol requested TEAP to investigate the use of CTC as feedstock and to report to the Parties at their Twelfth Meeting in respect of the following:

(a) *Emissions of CTC from its use as feedstock, including currently available and future possible options individual Parties may consider for the reduction of such emissions;*

(b) *Emissions of other ozone-depleting substances arising from the use of controlled substances as feedstock;*

(c) *The impact of CFC production phase-out on the future use of CTC as feedstock and emissions from such use.*

The *1997 Process Agents Task Force Report* defined feedstock 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."

3.2 CTC production and consumption

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

In the past, data on both CTC production and consumption have been difficult to obtain. This has been mainly due to the confusion existing regarding the reporting of feedstock uses, confusion between feedstock applications and process agent uses, and a lack of detailed knowledge on other, unspecified uses of CTC. A number of countries have mistakenly reported as consumption the amount of CTC used as feedstock for CFC production.

The new UNEP data reporting formats are enabling the collection of much clearer data and will enable a more detailed analysis of CTC uses. Calculated total CTC requirement for CFC production was calculated from CFC production reported to UNEP for 1998 as 203,017 ODP tonnes (section 3.6).

Using the same methodology to that used in the *1998 ATOC Assessment Report*, emissions of CTC used as feedstock to manufacture CFCs in 1998 are estimated to be 26,378 metric tonnes (-25 percent, +50 percent).

Potential measures to reduce emission of CTC as feedstock for CFC production have been described previously in the *1994 ATOC Assessment Report*, and remain relevant in 2000 (reproduced here in section 3.7).

3.3 Potential future emissions of CTC used as a feedstock

The *1998 ATOC Assessment Report* provided an estimate of emissions of CTC from feedstock use. Using the methodology described in Annex 2 of that Report, emissions of CTC as a feedstock for CFC manufacture can be estimated for the period of phase-out of CFC production and consumption, established under the Montreal Protocol and its adjustments and amendments (including those agreed at the 11th Meeting of the Parties in Beijing, 1999; section 3.8). This estimate can be considered as a 'worst case' as it makes the assumption that production of CFCs in both Article 5(1) and non-Article 5(1) countries will be at the level permitted under the provisions of the Montreal Protocol. In reality, it is anticipated that such levels will not be reached.

Table 3.1: *Total estimated emissions from the use of CTC as a feedstock to manufacture CFCs*

Year	CTC Emission (metric tonnes)
2000	26,087
2003	25,512
2005	9,727
2007	2,918
2010	0

Note: in line with the errors quoted in the *1998 ATOC Assessment Report* the accuracy in the estimates varies from -25% to +50%.

3.4 Emissions of other Ozone-Depleting Substances arising from the use of controlled substances as feedstock

TEAP and its TOCs have been unable to update available data on these other feedstock uses, but will be collecting this information for their 2001 reports. TEAP is investigating the establishment of a TEAP Task Force on Process Agents, which will be working during 2000 and 2001 and which will also be instrumental in this data collection.

3.5 Conclusions

CTC remains a widely available and used chemical. The primary source of atmospheric emissions of CTC is from its use as a feedstock to produce CFCs. This was estimated in 1996 by ATOC to be between 67 to 71 percent of total CTC atmospheric emissions. The majority of the emissions from feedstock use originates from CFC production in CEIT and Article 5(1) Parties.

CTC atmospheric concentrations have been reduced as a result of the phase-out of CFC production by non-Article 5(1) Parties and will fall significantly in the near future as CFC and CTC consumption in Article 5(1) countries will be phased out.

A number of measures have been previously suggested by the ATOC, which could lead to reductions in CTC emissions to the environment:

- Closure of CFC manufacturing facilities in CEIT and Article 5(1) Parties with accelerated introduction of alternatives;
- Use of improved emission control technology in CTC and CFC manufacturing facilities in all countries.

Due to the complexity of the industries using CTC, ATOC recommends that closure of facilities or improved emission control technology be considered on a case by case basis taking into account technical, economic and environmental considerations.

3.6 Calculation of 1998 production and emissions of CTC for feedstock use

3.6.1 Production of CFCs and CTC in 1998[1]

Table 3.2: *Article 5(1) Parties (1998) (ODP tonnes)*

	Reported CFC production	Calculated CTC requirement for CFC production
Argentina	2,962	4,147
Brazil	7,986	11,180
China	55,402	77,563
India	20,013	28,018
Korea, Dem. Rep	200 (est)	280 (est)
Korea, Rep	5,528	7,739
Mexico	5,252	7,353
Venezuela	3,652	5,113
TOTAL	100,995	141,393

Table 3.3: *Western Europe and others (1998) (ODP tonnes)*

	Reported CFC Production	Calculated CTC requirement for CFC production
European Union	32,278	41,961
Japan	0	0
USA	243	316
TOTAL	32,521	42,277

Table 3.4: *Eastern Europe (1998) (ODP tonnes)*

	Reported CFC Production	Calculated CTC requirement for CFC production
Czech Republic	6	8
Russian Federation	13,808	19,331
TOTAL	13,814	19,339

[1] Source: UNEP Production and Consumption of Ozone Depleting Substances 1986-1998, October 1999 plus update from UNEP Secretariat, April 2000.

Table 3.5: *Totals (1998) (ODP tonnes)*

	Reported CFC Production	**Calculated CTC requirement for CFC production**
Non-Article 5(1) producers	46,335	61,624
Article 5(1) producers	100,995	141,393
TOTAL	147,330	203,017

Notes to the Tables: CTC requirements have been calculated by multiplying the CFC production by a factor that converts CFC ODP tonnes to CTC ODP tonnes. This factor is 10 percent greater than the one that would be used to calculate the amount of CTC needed to produce a tonne of CFC. In the *1998 ATOC Assessment Report* the values of 1.14 and 1.3 were given for CFC-11 and CFC-12 respectively. Therefore, factors of 1.3 for the "Western Europe and Others" group (Table 3.3) and 1.4 for the Article 5(1) Parties and Eastern Europe (Tables 3.2 and 3.4) were used here. Reports of negative CFC production have been discounted.

3.6.2 Calculation of 1998 emissions of CTC from feedstock use

Using the 1998 UNEP data (Tables 3.2 - 3.5), CTC emissions from feedstock applications can be estimated by multiplying the calculated CTC requirements for the respective regions, with the emission percentages (the methodologies for calculating the emission percentages are given in the *1998 ATOC Assessment Report*). Data taken from Tables 3.2 - 3.4, are divided by 1.1, to convert from ODP tonnes to metric tonnes.

Western Europe and others	(42,277/1.1) x 0.04	= 1,537 tonnes
CEIT	(19,339/1.1) x 0.17	= 2,989 tonnes
Article 5(1) Parties	(141,393/1.1) x 0.17	= 21,852 tonnes
Total CTC emissions from feedstock uses		= 26,378 tonnes

3.7 Code of Good Housekeeping (Manufacture)[2]

3.7.1 Pre-delivery

This refers to measures that may be appropriate prior to any delivery of CTC to a facility.

- Facility operator to generate written guidelines on CTC packaging/containment criteria, together with labelling and transportation

[2] (reproduced from the *1994 ATOC Assessment Report*)

requirements. These guidelines to be provided to all suppliers/senders of CTC prior to agreement to accept such substances;

- Facility operator to seek to visit and inspect proposed senders stocks and arrangements prior to movement of the first consignment. This is to ensure awareness on the part of the sender of proper practices, and compliance with standards.

3.7.2 Arrival at facility

This refers to measures to be taken at the time CTC is received at the facility gate.

- Immediate check of documentation prior to admittance to facility site, coupled with preliminary inspection of the general condition of the consignment;
- Where necessary, special or "fast-track" processing/repacking facilities may be needed to mitigate risk of leakage/loss of CTC;
- Arrangements should exist to measure gross weight of consignment at the time of delivery.

3.7.3 Unloading from delivery vehicle

This refers to measures to be taken at the facility in connection with unloading CTC. It is generally assumed that CTC will normally be delivered in some form of container, drum, or other vessel that is removed from the delivery vehicle in total. Such containers may be returnable.

- All unloading activities should be carried out in properly designated areas, to which restricted personnel access applies;
- Areas should be free of extraneous activities likely to lead to, or increase the risk of, collision, accidental dropping, spillage, etc;
- Materials should be placed in designated quarantine areas for subsequent detailed checking and evaluation.

3.7.4 Testing and verification

This refers to the arrangements for detailed checking of the consignments of CTC prior to use.

- Detailed checking of delivery documentation should be done, along with a complete inventory, to establish that delivery is as advised and appears to comply with expectation;

- Detailed checks of containers should be made both in respect of accuracy of identification labels etc, and of physical condition and integrity. Arrangements must be in place to permit repackaging or "fast-track" processing of anything identified as defective;
- Where required, sampling and analysis of representative quantities of CTC consignments should be carried out to verify material type and characteristics. All sampling and analysis should be carried out using approved procedures and techniques.

3.7.5 Storage and stock control

This refers to matters concerning the storage and stock control of CTC.

- CTC should be stored in specially designated areas, subject to the regulations of the relevant local authorities;
- Locations of stock items should be identified through a system of control that should also provide a continuous update of quantities and locations as stock is used and new stock is delivered.

3.7.6 Measuring quantities used

- It is important to be aware of the quantities of CTC used. Where possible, flow meters or continuously recording weighing equipment for individual containers should be employed. As a minimum, containers should be weighed "full" and "empty" to establish quantities by difference;
- Residual quantities of CTC in containers that can be sealed, and are intended to be returned for further use, shall be allowed.

3.7.7 Facility design

This refers to basic features and requirements of plant, equipment and services deployed in the facility.

- In general, any facility should be properly designed and constructed in accordance with the best standards of engineering and technology, and with particular regard to the need to minimise, if not eliminate, fugitive losses;
- In many cases the quantities of CTC used by a process can be significantly reduced by using recovery and recycling technologies;
- CTC, where possible, should be pumped from containers, not poured;

- CTC Pumps: magnetic drive, seals, or double mechanical seal pumps should be installed to eliminate environmental releases resulting from seal leakage;
- Valves: valves with reduced leakage potential should be used. These include quarter-turn valves or valves with extended packaging glands;
- Tank Vents (including Loading Vents): filling and breathing discharges from tank/vessels should be recovered or vented to the destruction process;
- Piping Joints: screwed connections should not be used, and the number of flanged joints should be kept to a minimum that is consistent with safety and the ability to dismantle for maintenance and repair;
- Drainage Systems: areas of the facility where CTC are stored or handled should be provided with sloped concrete paving and a properly designed collection system. Water that is collected should, if contaminated, be treated prior to authorised discharge.

3.7.8 Maintenance

In general, all maintenance work should be performed according to properly planned programs, and should be executed within the framework of a permit system to ensure proper consideration of all aspects of the work.

CTC should be purged from all vessels, mechanical units, and pipework prior to the opening of these items to the atmosphere. The contaminated purge should be routed to a recovery or destruction process.

All flanges, seals, gaskets and other sources of minor losses should be checked routinely to identify developing problems before containment is lost. Leaks should be repaired as soon as possible.

Consumable or short-life items, such as flexible hoses and couplings must be monitored closely, and replaced at a frequency that renders the risk of rupture negligible.

3.7.9 Quality control and quality assurance

- All sampling and analytical work connected with the CTC, the process, and the monitoring of its overall performance should be subject to quality assessment and quality control measures in line with some recognised practices. This should include at least occasional independent verification and confirmation of data produced by the facility operators;
- Consideration should also be given to the adoption of quality management systems and environment quality practices covering the entire facility.

3.7.10 Training

- All personnel concerned with the operation of the facility (with "operation" being interpreted in its widest sense) should have training appropriate to their task;
- Of particular relevance is training in the consequences of unnecessary losses, and training in the use, handling, and maintenance of all equipment in the facility;
- All training should be carried out by suitably qualified and experienced personnel, and the details of such training should be maintained in written records. "Refresher" training should be conducted at appropriate intervals.

3.8 Levels of production of Annex A Group 1 substances (CFCs) permitted under the Montreal Protocol

Article 5(1) Parties:

Average of 1995-7 production = 107,293 ODP tonnes

Non-Article 5(1) Parties:

Average of 1995-7 production = 79,005 ODP tonnes

Table 3.6: *CFC production permitted by year and CTC feedstock required by year (ODP tonnes)*

Year	Potential CFC production in Article 5(1) Parties	CTC requirement	Potential CFC production in non-A5 Parties	CTC requirement†
2000	107,293	150,210	79,005	102,707
2003	107,293	150,210	63,204	82,165
2005	53,647	75,106	39,503	51,354
2007	16,094	22,532	11,851	15,406
2010	0	0	0	0

† Calculation level is 1.3 tonnes CTC per tonne of CFC produced, assuming that CFC production in the Russian Federation ceases in mid 2000.

Feedstock emissions of CTC can then be calculated from figures in Table 3.6, which are divided by 1.1 to convert from ODP tonnes to metric tonnes.

Table 3.7: *Potential feedstock emissions of CTC*

Year	A5(1) CTC requirement in ODP tonnes	A5(1) CTC requirement in metric tonnes	CTC emissions (emission rate = 17%) in metric tonnes	Non-A5(1) CTC requirement in ODP tonnes	Non-A5(1) CTC requirement in metric tonnes	CTC emissions (emission rate = 4%) in metric tonnes
2000	150,210	136,555	23,214	79005	71,823	2,873
2003	150,210	136,555	23,214	63,204	57,458	2,298
2005	53,647	48,770	8,291	39,503	35,911	1,436
2007	16,094	14,631	2,487	11,851	10,774	431
2010	0	0	0	0	0	0

4. Report on New Substances

4.1 1-Bromopropane (also called n-propyl bromide, nPB)

In compliance with Decision IX/24, the Solvents TOC evaluated the potential use of 1-Bromopropane (nPB) in the solvent sector. Other cleaning solvents or methods have been identified for all applications where nPB is used.

The 11th Meeting of the Parties requested that TEAP and the Science Panel give a combined assessment on the substance related to its ODP and impact on the ozone layer for consideration at the 12th Meeting of the Parties. N-propyl bromide has a highly uncertain ozone depleting potential. The only ODP reported so far is 0.026, which is similar to the one of HCFC-225.

The Science Assessment Panel indicates that the ODP will depend on the location (latitude) and season of emission. TEAP and its STOC will endeavour to estimate the latitude and season of possible emissions in the period 2000-2001.

4.1.1 Production of n-propyl bromide

At least six factories produce or are capable of producing n-propyl bromide -- three in the USA and one each in France, Israel and Japan, respectively.

4.1.2 Applications

N-propyl bromide is commercially marketed as a substitute for ozone-depleting solvents (CFC-113, 1,1,1-trichloroethane, carbon tetrachloride and HCFCs) and non-ozone depleting chlorinated solvents (trichloroethylene, perchloroethylene and methylene chloride). Its solvency is similar to that of 1,1,1-trichloroethane and it is considered as a “drop-in” replacement for use in open-top vapour degreasers and for cold cleaning and precision cleaning. It may also be used for some electronics defluxing and as a solvent in aerosols, adhesives, and coatings and inks.

4.1.3 Current consumption

The best estimate of 1998 consumption is about 1,000 tonnes in Europe, about 600 tonnes in Japan, and about 600-1000 tonnes in the USA. Consumption in Article 5(1) countries is relatively small but is increasing quite rapidly. Total global consumption is currently between 2,000 and 5,000 tonnes per annum and is increasing.

4.1.4 *Projected production and consumption*

In 1999, the STOC estimated a range of potential commercial production based on assumptions of probable applications and pricing relative to competing solvents. With this scenario, it is estimated that over 50% of the sales of nPB will be in non-Article 5(1) countries. Four scenarios were developed with projected production and consumption estimated at 60,000 to 100,000 tonnes within 5 years.

4.1.5 *Alternatives to nPB*

Trichloroethylene, methylene chloride and perchloroethylene are alternatives for low-cost vapour-phase cleaning. Other alternatives include aqueous and hydrocarbon solvents. Other non-ozone-depleting halogenated solvents for vapour-phase cleaning include HFCs and HFEs.

4.2 Halon 1202

Halon 1202 is used in the aircraft engine nacelle fire protection system for three military aircraft types and for the protection of aircraft auxiliary power units. The 1993 estimated amounts of halon 1202 in aircraft fire protection systems are shown in Table 4.1. Based on the available information, use of halon 1202 for fire-fighting applications is diminishing.

Halon 1202 also finds very limited use in balancing apparatus used to reduce vibrations in moving parts. It is estimated that total use for wheel balancing application is less than 3 tonnes.

Halon 1202 is also used as a feedstock for halon 1211 production.

Table 4.1: *Use of halon 1202 in aircraft fire protection systems*

Number of aircraft	Total installed quantity of halon 1202	Annual use of halon 1202 for servicing and use on fires
<1500	<110,000 kg	<2,000 kg

Increases in atmospheric concentrations of halon 1202, recently reported in scientific journals, cannot be explained by use as a fire extinguishant. Parties may wish to examine the possibility that inadvertent production and release of halon 1202 during halon 1211 production in Article 5(1) countries is the source of these atmospheric concentrations.

5. Progress and Development in the Control of Substances

5.1 Aerosols, Sterilants, Miscellaneous Uses and Carbon Tetrachloride Technical Options Committee (ATOC)

5.1.1 Aerosol products (other than MDIs)

5.1.1.1 Worldwide use of CFCs in aerosol products (other than MDIs)

There are no technical barriers for the transition to alternatives for aerosol products (other than MDIs). Most non-Article 5(1) countries ceased the use of CFCs in 1996, and in many cases use of these substances in aerosols had stopped before that date. However, CFCs are still consumed in some aerosol products in CEIT and Article 5(1) Parties. The main uses for CFCs in these countries have been identified as:

- Non-MDI medical aerosols such as local anaesthetics, throat sprays, nasal sprays, wound sprays, vaginal products and traditional Chinese medicine;
- Industrial/technical aerosols such as electronics cleaners, spinnerette sprays, anti-spatter sprays and tyre inflators;
- Small volume personal products (for these type of products, the amount of propellant per unit is so small that the cost is irrelevant, whereas odour from poorly processed LPG is unacceptable).

These products were also the last to use CFCs in the developed countries and required regulatory actions for their phase-out. This will probably be needed also for their conversion in Article 5(1) countries. Where capital outlays are also necessary for ODS phase-out, assistance is generally required from the MLF or GEF. The MLF assists aerosol fillers in Article 5(1) Parties, while the GEF assists Parties that are not eligible for MLF financing such as the Russian Federation and several other CEITs.

The ATOC estimates that 1999 CFC consumption in the non - MDI aerosol sector was slightly over 9,000 tonnes in CEIT and Article 5(1) Countries. The breakdown can be seen in Table 5.1.

Table 5.1: *1999 CFC consumption in non-MDI aerosols (metric tonnes)*

ASEAN countries	900
China	2,300
Indian subcontinent countries*	1,000
Latin America	500
Middle East, Africa	400
Russian Federation	3,500
Ukraine	500
Other CEIT, including CIS**	100
Total	**9,200**

* India, Pakistan, Sri Lanka, Bangladesh, Nepal and Bhutan

** CIS: Commonwealth of Independent States

The use of CFCs in most CEIT and Article 5(1) countries is slightly lower than reported for the previous year. In some cases better market conditions have resulted in higher numbers of aerosol fillings, including those by fillers that still use CFCs; these increases have partially offset reductions due to individual companies conversions that occurred mainly in the Russian Federation and in India.

Production of CFCs in the Russian Federation is anticipated to stop on 1 July 2000. Therefore, aerosol manufacturing plants that have not implemented GEF projects will have to cease production once they finish their inventories of CFCs.

The figures presented in the table above are estimates based on the market size of these countries/regions and local observations of the products containing CFCs available. Indeed, tracking the use of CFCs in aerosols is particularly difficult because in most cases purchases are not made directly from the CFC producer. This means that aerosol users are purchasing CFCs from distributors, and therefore their consumption is now much more difficult to identify.

An additional problem in some Article 5(1) countries is that many ozone officers reported that their countries had phased out CFC from aerosols, and are now reluctant to do projects in this sector, even when it becomes clear that CFCs are still being used. This has resulted in a lack of action in the aerosol sector world-wide, leaving a rather large remnant of CFC usage that is not being addressed, and will continue as long as CFCs are available.

To achieve further reductions, it is necessary to meet the conversion requirements of the three sub-sectors listed above, both from the technical and from the regulatory perspective. This will require specific actions from government environmental departments and their ozone offices to force aerosol producers to phase out ODS.

5.1.1.2 Alternatives for reducing or replacing CFCs

Currently available alternatives

There is a wide range of alternatives available for substituting CFCs in aerosol products. These include:

1. Alternative propellants (in order of use):

- hydrocarbons (HAPs) – including blends of hydrocarbons (propane, *n*-butane, *iso*-butane);
- dimethyl ether (DME);
- compressed gases (compressed air, CO_2, N_2, N_2O);
- HFCs (HFC-152a, HFC-134a, HFC-227ea, HFC-236fa);
- HCFCs (HCFC-22, HCFC-142b).

2. Alternative solvents, for example:

- Water;
- alcohols (ethanol, *iso*-propanol, *n*-propanol);
- chlorinated (methylene chloride, trichloroethylene, perchloroethylene);
- pentane, hexane, white spirits, acetone, methyl ethyl ketone, methyl *iso*-butyl ketone, glycols, methylal, etc.;
- HCFC-141b, HFC-43-10mee, HFC 245fa, hydrofluoro-ethers, etc.

3. Alternative delivery systems:

- finger pumps, trigger pumps, and air sprays;
- sticks (deodorants and antiperspirants, insect repellents);
- roller ball, brush, cloth, etc.;
- powder inhalers and nebuliser systems (pharmaceutical products);
- bag-in-can systems and piston-can systems.

The suitability of each alternative depends upon the product in which it is used. Each of the alternatives has its own physical, chemical and economic characteristics that make it an optimal choice for the product in question and is further discussed below.

Hydrocarbons

Hydrocarbons are the principal substitutes for CFCs used in aerosols. Mixtures of *n*-butane, *iso*-butane, and propane, with constant pressure, low odour and low olefin levels (unsaturates), are called “hydrocarbon aerosol propellants," or HAPs. Hydrocarbons are highly flammable and filling plant and storage facilities must be suitably sited to comply with local planning and legislative requirements.

Where HAPs were available at reasonable cost, transition out of CFCs has already taken place. Lack of HAPs is still a factor impeding the elimination of CFCs in India and in some ASEAN countries. In Jordan a small project funded by the MLF solved this problem. Similar projects could accomplish the same result for these countries.

Most large and medium size fillers have converted their factories to use hydrocarbon propellants. In several countries (India, Indonesia) there are small aerosol fillers who may be located in residential areas or in very congested industrial areas that cannot be converted to a flammable propellant because of their location. If there are local contract fillers available, the most economical solution is contract filling.

In many cases, the filling equipment of these small aerosol producers has proved inadequate for conversion. A test project was started last year in India to evaluate hand-powered production filling equipment, but its outcome is still uncertain. If this test proves positive, it will facilitate the conversion of small aerosol industries, by providing a moderately priced and safe alternative that uses HAPs. Final results of this test are expected in late 2000.

Dimethyl ether (DME)

Dimethyl ether (DME) is a flammable liquefied propellant with excellent solvency and water compatibility. It has found substantial use particularly in some European countries where it has been used as a combination propellant/solvent replacement. DME use has increased in the USA to reduce volatile organic compounds (VOCs) content in aerosol product formulations. DME is itself a VOC, but it can reduce total VOC content in a given product because of its high solubility with water, which can be incorporated in many formulations to replace VOC solvents.

DME can generally be used in filling facilities equipped to handle a flammable propellant. In the USA there are some additional safety requirements for the electrical equipment.

Hydrofluorocarbons (HFCs) and hydrochlorofluorocarbons (HCFCs)

HFCs that are being commercialised for use in aerosols now include HFC-152a, HFC-134a, HFC-227ea and HFC-43-10mee. The first three are propellants, while the latter is a vapour depressant and solvent. Two HFCs that have been mentioned recently as alternatives for aerosols are HFC-236fa and HFC-245fa. The price of HFCs increases with the number of fluorine atoms contained in the molecule, therefore HFCs such as -134a and -152a are the least expensive of the HFCs.

HFC emissions are controlled as greenhouse gases under the Kyoto Protocol and HFCs should be used responsibly. The HFC and PFC Task Force of the Technology and Economic Assessment Panel recommended in its 1999 Report that responsible use be guided by the following principles:

- Use HFCs only in applications where they provide technical, safety, energy, or environmental advantages that are not achieved by not in kind alternatives; and
- Select the HFC compound with the smallest GWP that still meets the application requirements.

HFC-152a is very slightly flammable, has a medium vapour pressure, no ODP and the lowest GWP of the HFCs. Since the HFCs do not contribute to tropospheric ozone formation, (they are no VOCs), HFC-152a is gaining favour as a propellant in the USA. ATOC estimates current HFC-152a usage in the USA at approximately 10,000 metric tons per year. This situation is unique for the United States, as HFC-152a is a very expensive propellant (approximately $3.80/kg) that would not be used were it not for VOC controls.

HFC-134a is replacing CFC-12 in MDIs. It is also the main non-flammable propellant in certain industrial products. HFC-134a usage in these segments is projected to be very modest. Total use in the USA is currently estimated at 5,000 metric tons per year for all aerosol applications (including MDIs).

Some convenience and novelty use aerosol products such as dust blowers, noisemakers, tire inflators and party streamers have been reported to use HFCs. Such use should be discouraged as it produces unnecessary emissions of HFCs, which are greenhouse gases.

HCFC-22 and -142b can be used as propellants, but they are restricted in the EU and in the USA. HCFC-141b, which is slightly flammable and has an ODP of 0.10, is a strong solvent, once viewed as a replacement for CFC-113. Its high solvency requires that it be mixed with milder solvents when used as an electronics cleaner.

Compressed gases

All of the previously mentioned propellants are in the liquid state inside the aerosol can (liquefied propellants). Compressed gases such as compressed air, N_2, CO_2 and N_2O can be used for some aerosol products. They normally produce coarser spray patterns unless special valves are used. Their main limitation for many products is the wet spray and pressure decrease as they expand while the can is emptied with the attendant lowering of the spray pattern quality.

Filling technology and quality control for compressed gases is much more demanding than for liquefied propellants. Compressed gases are used in about 5-9 percent of all aerosol products. Because of high quality control requirements and technical limitations, compressed gases will not be widely used in Article 5(1) countries.

Solvent reformulation

1,1,1-Trichloroethane (methyl chloroform, or MCF), CFC-113 and carbon tetrachloride (CTC, CCl_4) have all been used as solvents in aerosol formulations and they are still used in some CEIT and Article 5(1) Parties. The selection of a solvent for an aerosol formulation has to take into account several parameters such as solvency power, flammability, evaporation rate, density, viscosity and surface tension (wetting power), environmental acceptability, cost and local availability.

The controlled substances mentioned above are all non-flammable, have high evaporation rates, high density, low viscosity and surface tension, and are reasonably low cost and widely available. Their solvency power varies from very high in the case of CTC and MCF, to very low in the case of CFC-113. CFC-113 has generally been considered safe for most uses, MCF has much lower exposure levels and should be used only in well-ventilated places. CTC (CCl_4) is a well-known carcinogen that should not be used in aerosols for this reason alone.

It is possible to replace these solvents with non-ODS alternatives. However, in developed countries, particularly in certain states of the United States of America, VOC regulations made this substitution more difficult by limiting the amount of VOCs that could be used in each product category.

The multiplicity of aerosol products dictates that each formulation has to be carefully analysed in each case to determine which characteristics are more desirable. The aerosol product applications of 1,1,1-trichloroethane are dealt with in the *1998 STOC Assessment Report.*

Alternative non-aerosol methods

Finger pumps and trigger pumps are mechanical dispensing devices that have captured market share due to improved design. The disadvantages of pump sprays are that they produce larger droplets, and seldom work well with products that contain strong solvents.

Compact devices, which allow the user to compress air as needed, have also appeared in the market. They contain a liquid and an air intake pump and have been called “air sprays”. Their uses include hair sprays and cooking oils between others. These devices are more expensive than pump sprays.

Other non-spray dispensers include the solid stick, the roll on, or squeeze bottle for deodorants. Not-in-kind application by other means for other products has also been suggested, such as brushing or dipping.

5.1.1.3 Applications with potential problems

In most CEIT and Article 5(1) Parties, some residual uses of ODSs in aerosol products still remain. They relate to the following applications, for which most countries provided domestic CFC use exemptions:

Non-MDI medical aerosol products

These include nasal preparations, local anaesthetics, wound sprays, antibiotics, antiseptics, ancillary products and traditional Chinese medicine. These products do not require the narrow particle size range considered necessary for oral inhalers. Many topical sprays can use HAPs, DME, or nitrogen; while nasal and throat products can use HFC-134a. In some cases, not in kind alternatives such as pump sprays, powders, liquids and creams can also be considered.

Any new formulation requires time for tests and approval by regulatory agencies for therapeutic use. The time for such an approval may vary among countries. Phase-out of ODSs in this sector should be required through regulatory action.

Industrial and technical specialities

There are a number of industrial technical aerosol products that relied upon the non-flammable and inert characteristics of the CFCs and which, therefore, could not easily be reformulated. Products in this category include electronic cleaners, dusters, fault detectors, mould releases, aircraft disinfectants and insecticides, weld anti-spatter, polyurethane foam, and aerosol horns.

Where flammability is a concern, HFC-134a is close to being a direct substitute for CFC-12. It is a slightly poorer solvent, which must be taken into account. HFC-152a can also be used in some instances – it is slightly flammable, but difficult to ignite.

Electronic cleaners which use CFC-113 due to its good materials compatibility and non-flammability, have been the most difficult to reformulate. HCFC-141b mixed with CFC-113 could offer an interim solution in Article 5(1) countries, but the correct ratio of these two substances has to be determined carefully to assure that the new product will not damage sensitive plastic materials. Non ODS replacements of CFC-113 such as HFC-43-

10mee, volatile silicones (which are flammable), and hydrofluoro-ethers are currently four to five times more expensive than CFC-113, which is too expensive for the markets of Article 5(1) countries.

5.1.1.4 Article 5(1) Parties' perspective

CFC use in aerosols in Article 5(1) countries is declining slowly and a faster decline will not occur unless the specific problems of reformulation of non-MDI medical aerosols and industrial/technical aerosols are solved. Where lack of availability of HAPs is stopping conversion of non-MDI medical aerosols this problem needs to be solved. The final phase-out of CFCs will also require the conversion of small CFC users.

5.1.2 Metered dose inhalers

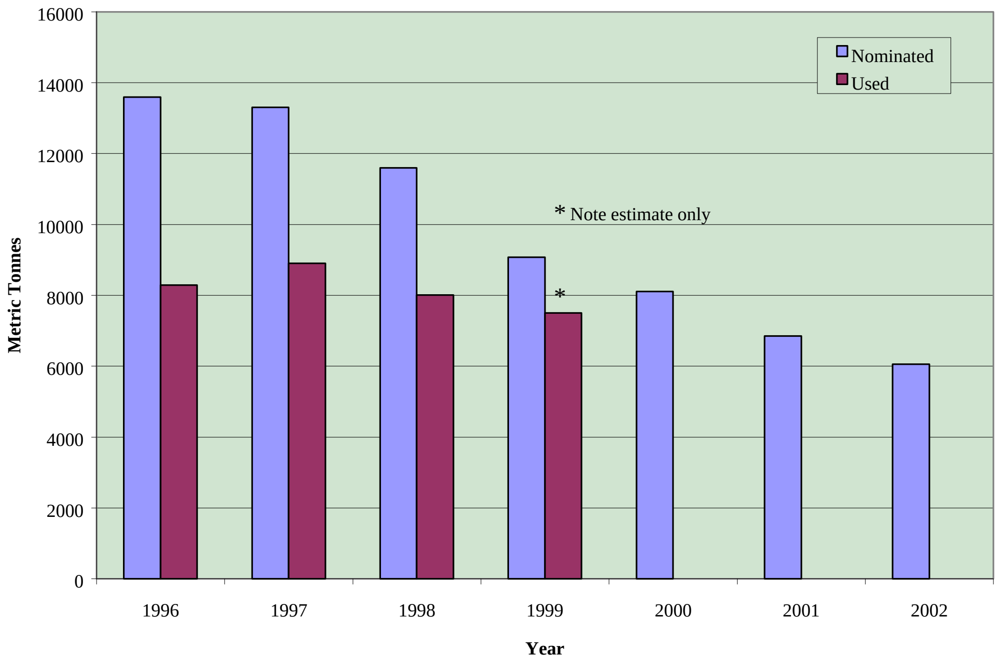
5.1.2.1 Trends in CFC consumption

The following trends are evident in Reporting Accounting Frameworks and from Essential Use Nominations for CFCs for MDIs.

- Recent CFC requirements in Essential Use Nominations appear to be much closer to actual use than earlier estimates in 1996 and 1997.
- Total CFC use for MDIs for essential uses has fallen by some 9.5% from 8290 tonnes in 1996 to an estimated 7501 tonnes in 1999.
- While the overall trend is for a reduction in CFC use, occasional local increased use by a Party usually reflects a change in regional circumstances; e.g., relocation of CFC-MDI manufacture from Canada to USA.
- From these data it would appear that the reduction in CFC use for MDIs is slower than anticipated. Of the estimated 450 million MDIs manufactured worldwide in 1999 approximately 380 million are CFC based MDIs and 70 million HFC MDIs.

Parties have reported that an estimated 7502 tonnes of CFCs were used for the manufacture of MDIs for asthma and COPD in 1999 in non-Article 5(1) Parties (using data provided in Reporting Accounting Frameworks and estimations for 1999). ATOC estimates that a total of 9,000 tonnes of CFCs was used world- wide for the manufacture of MDIs in 1999, including an estimated 1,500 tonnes used in Article 5(1) countries.

Figure 5.1: *Total amounts nominated, exempted and used for essential uses for MDIs 1996-2002*



* For 1999, the quantity of CFCs used for the manufacture of MDIs for asthma and COPD is estimated based on information provided in Reporting Accounting Frameworks and estimates made by Parties not able to submit complete Reporting Accounting Frameworks for 1999.

5.1.2.2 Availability of alternatives

HFC based MDIs

The International Pharmaceutical Aerosol Consortium (IPAC) group of companies submitted information to the ATOC that reported:

- At least one HFC based MDI has been approved in each of the twenty-two non-Article 5(1) countries surveyed;
- At least three HFC based MDIs have been approved in eighteen non-Article 5(1) countries;
- At least one beta-agonist has been approved in each of the twenty-two non-Article 5(1) countries surveyed, with at least one inhaled corticosteroid approved in seventeen of the non-Article 5(1) countries surveyed;
- At least five additional product filings for marketing approval are projected to be made by 2005 in each of the twenty-two non-Article 5(1) countries surveyed.

While it appears from these new data that the transition away from CFC based MDIs is progressing satisfactorily and is projected to continue in gaining pace, the actual timing of the transition to date represents a clear departure from previous best estimates (*TEAP April 1997 Progress Report*). Factors contributing to this delay include unanticipated difficulties in reformulation, and therefore filings, regulatory delay in reviewing filings, and an apparent lack of urgency on the part of some Parties' health authorities in addressing this issue.

It still appears that the bulk of the transition may be accomplished in many non-Article 5(1) countries by 2005, but it may be delayed beyond that in some countries (e.g. the USA).

One company, CIPLA in India, has already developed and introduced a salbutamol HFC based MDI. This may facilitate the transition process in some CEIT and Article 5(1) countries.

Other MDIs

In the past year one company has developed an MDI with an iso-butane propellant. Prototypes of this MDI have been developed for the clinical evaluation of salbutamol. The manufacturer anticipates product launch in Germany in 2001.

Dry powder inhalers

The introduction of new dry powder inhalers (DPIs) using existing technologies is continuing around the world. Data indicate that in established European markets the overall usage of DPIs continues to increase, although there are still large differences between countries in their acceptance of these devices. In other markets such as the USA and Japan, a smaller range of DPIs are available although there are indications that more DPI products are in the process of regulatory review.

The development of DPIs that rely on electrical or pneumatic power for deaggregation/aerosolisation of the dose is well advanced and some are in clinical trials. These devices are quite sophisticated. Some of these devices are designed for local delivery of pulmonary drugs, and therefore may be considered as alternatives to existing CFC products. However in other cases, they are mainly intended for the delivery of various systemically active drugs via the respiratory tract, for example insulin or growth hormone. These particular devices cannot be considered as replacements for CFC based MDIs.

5.1.2.3 Transition strategies

ATOC reiterates its prior recommendation that all Parties may wish to consider the development of national transition strategies that allow the implementation of an orderly transition to CFC-free alternatives.

Experience indicates that a co-ordinated approach between health and environmental authorities is needed to:

- Ensure the development of national strategies for transition to CFC-free alternatives; and
- Ensure that the transition process is perceived as both an environmental and a health priority, not an environmental priority alone.

In addition to encouraging the development of national strategies, Parties may wish to consider addressing some global factors that are of considerable importance in the overall transition away from CFC based MDIs worldwide. These factors include:

- The flow of CFC based MDIs from exporting countries to importing countries both to assure that importing countries have access to essential products and to prevent the unnecessary exportation of CFC based MDIs to countries where CFC alternatives are available;
- The likely need for MDI manufacturing companies to move their bulk CFC supplies in order to manage effectively the tail of the transition. Montreal Protocol controls and national regulations may not currently permit this;
- The importance of assuring the continued availability of pharmaceutical grade CFC for essential use production throughout the entire transition process which is occurring at a different pace in different geographical regions. Potential difficulties in maintaining supply of pharmaceutical grade CFC at the tail of the transition are anticipated. Consideration should be given to this issue.

Some countries have developed transition strategies that are now being implemented. The European Community reported that it intends during 2001 to ensure that no CFCs be made available to manufacture salbutamol-MDIs for the European Community market.

In addition, HFC based MDI products have now been introduced in Germany that fulfil the European Community category A (short-acting bronchodilators) requirements for non-essentiality. CFCs for the manufacture of MDIs will not be allocated for this category beyond the end of 2000. This is an early example of the phase-out of CFC use for an important category of asthma and COPD treatment in a significant market.

Experiences in transition

Reformulation of MDIs with non-CFC propellants has involved a complete redesign of inhalers with the result that the shape and feel of the new inhalers may be different from the old and the taste and the impact of the aerosol on the throat has altered. The need to prepare patients for these changes and the reinforcement of spoken messages with written information has been suggested in previous reports.

Experience with the transfer of millions of patients to the new inhalers is now available and the evidence suggests that transition is occurring seamlessly and without significant adverse effects. In the United Kingdom, where transition with bronchodilators is now well under way, fewer than 3 percent of calls to the National Asthma Campaign Telephone Helpline have involved questions regarding the new CFC-free MDIs. Manufacturers' advice regarding the weekly washing of the inhalers has needed to be reinforced to ensure optimal function of the inhaler. Care with prescriptions is necessary to ensure that those using an MDI with a spacer receive compatible devices.

A major study by the Drug Safety and Research Unit at the University of Southampton, UK, followed 12,081 regular users of a Ventolin™ MDI as they transferred from CFC to HFC based MDIs; it found no change in the reporting of adverse events for the new inhalers compared to the old ones. Less experience is available at present with transition to CFC-free corticosteroid inhalers but no apparent differences in adverse events have been observed so far.

It is likely that with adequate preparation by knowledgeable health care professionals, patients with asthma and COPD will be able to change to the new inhalers, as and when they become available, without fear of significant problems.

Continued CFC product approvals

ATOC has previously reported that further new CFC MDI approvals could impede phaseout. Nonetheless, CFC-based MDIs are still being introduced into the market in a number of countries. These introductions include markets where HFC based MDIs are already available. To facilitate the transition process, some Parties have adopted one of the following options as part of a national strategy to impede the continued introduction of new CFC based MDIs:

- Disallow further regulatory approval of CFC based MDIs where the law permits (e.g. Hungary and Japan)
- Withdraw health service reimbursement for CFC based MDIs where suitable HFC alternatives exist (e.g. Australia)
- Ensure no CFCs will be made available for manufacturing new MDIs for the market. For example, new salbutamol CFC based MDIs may no longer be considered “essential” in some countries (e.g. the European Community). This may apply to other active ingredients, depending on the rate of introduction of alternatives.

Strategic reserves

Strategic reserves are prudent to safeguard the health of patients with asthma/COPD during the transition to CFC-free alternatives. ATOC has previously reported that Parties may wish to consider monitoring and adjusting stockpiles according to local circumstances. The USA and the European Community have reported in their essential use nominations that they have received commitments that IPAC member companies will:

- Not increase strategic reserves beyond reasonable levels;
- Decrease those reserves in line with decreasing use;
- Destroy any strategic reserves once transition is complete.

CEIT and Article 5(1) Party considerations

ATOC notes that local production in CEIT and Article 5(1) countries of CFC-free alternatives will require the transfer of technology. Such transfer could avoid the establishment of new CFC MDI manufacturing facilities and facilitate transition to CFC-free alternatives. The technology for formulation and production of CFC-free alternatives are covered by a wide range of patents held by international pharmaceutical companies. In order to transfer technology for CFC-free alternatives, some of the following should be considered:

- Licensing arrangements to permit local manufacturers to acquire the technological expertise to set up or adapt production facilities to produce CFC-free alternatives;
- The availability of finance for the licensing arrangements;
- The availability of finance for new manufacturing facilities;
- The likelihood of a need for rationalisation of the number of MDI manufacturing facilities;

- The possibility of joint manufacturing facilities between local and multinational companies.

Where funding is necessary, assistance is generally required from the MLF or GEF. The former assists companies in Article 5(1) countries, while the latter may assist Parties that are not eligible for MLF financing such as the Russian Federation and other CEIT. Currently MDI transition is not considered eligible for MLF financing because this is still an essential use in non-Article 5(1) countries. However, ATOC believes that the following considerations may justify that projects in this area be approved soon for MLF financing:

- It is not foreseen that there will be an essential use process for CFC based MDIs in Article 5(1) countries. By 2010 there will be alternatives available;
- The conversion away from CFC based MDIs has already started in Article 5(1) countries such as India where CIPLA developed a salbutamol HFC based MDI;
- In cases where a manufacturer in an Article 5(1) country produces both CFC based MDIs and other medical aerosols, the conversion of CFC based MDIs may assist the conversion of non-MDI medical aerosols (that consume several thousand tonnes of CFC worldwide);
- It will take non-Article 5(1) countries more than ten years to complete the phaseout of CFC based MDIs. Article 5(1) countries will have less time to complete the same process.

Other Article 5(1) countries could look to the example set by Malaysia where the health and environment authorities, along with interested stakeholders from industry and patient support groups, have formed a working group to address the transition to CFC-free alternatives.

5.1.3 Sterilants

The situation in this sector remains the same as reported in 1999. Use of CFC-12/ethylene oxide (EO) mixtures (12/88) has disappeared in most non-Article 5(1) countries, as there are no technical barriers to the phase-out of CFCs in sterilisation.

Sterilisation can be conducted either in hospitals and laboratories, or in factories. The nature and size of items to be sterilised will vary with the user (e.g. small numbers of individual items, or large numbers of similar items). Some items are more robust than others are in relation to temperature and radiation. Therefore, a number of different processes can be used for sterilisation and each of them will offer specific advantages in a particular situation.

Use of CFC-12 in Article 5(1) and in some CEIT countries is estimated to be less than 1,500 tonnes. Estimated use of a substitute HCFC replacement is less than 100 ODP tonnes worldwide. Although HCFC replacements are virtual drop-in substitutes for CFC/EO, some users in Article 5(1) countries and in Eastern Europe view this option as significantly more expensive than the traditional mixtures of CFC/EO and EO/CO_2. Attempts to develop non-flammable mixtures of EO with HFCs have been reported, but these mixtures still require careful evaluation, as quality health care is dependent upon the assurance of sterility of medical devices. Commercial HCFC replacements were developed to assure constant composition for use in cylinders and their performance has been carefully validated for the sterilisation of a number of materials.

5.1.4 Carbon tetrachloride

Carbon tetrachloride (CTC) is an easily manufactured chemical that is widely available. CTC has been extensively reviewed in the 1994 and 1998 Assessment Reports of the Aerosols, Sterilants, Miscellaneous Uses and Carbon Tetrachloride Technical Options Committee. Specific applications of CTC have been investigated in the *1995 Report of the Process Agents Working Group* and were further elaborated on in the *1997 Process Agents Task Force Report* (PATF); review can also be found in the *1995 Report of the Laboratory and Analytical Uses Working Group*. Inadvertent emissions and Process Losses were discussed in the *1994 Assessment Report of the Technology and Economic Assessment Panel* (TEAP). Atmospheric emissions of CTC were estimated in the *1998 ATOC Assessment Report*.

An analysis of CTC production and consumption for its use as a feedstock is described elsewhere in this Report in response to Decision X/12. CTC remains a widely available and used chemical. The primary source of atmospheric emissions of CTC is those from its use as a feedstock to produce CFCs. Emissions of CTC used as a feedstock to manufacture CFCs in 1998 are estimated to be 26,378 metric tonnes (uncertainty varies from -25 percent to +50 percent). This type of CTC emission was estimated in 1996 by ATOC to be between 67 to 71 percent of total CTC atmospheric emissions, with the majority of the emissions from feedstock use originating from CFC production in CEIT and Article 5(1) Parties. Based on this previous methodology, the remaining emissions due to process agents, other CTC uses (solvents and laboratory and analytical uses) and inadvertent emissions can be estimated to be between about 10,800 and 13,000 metric tonnes.

5.2 Economic Options Committee (EOC)

The Economic Options Committee did not meet during 1999. However, the EOC Co-chairs served as members of the UNEP TEAP Task Force for the study on the 2000-2002 Replenishment of the Multilateral Fund as requested by the 10th Meeting of the Parties to the Montreal Protocol. The *1999 Replenishment Task Force Report,* as well as a *Supplement to the 1999 Replenishment Task Force Report,* were submitted to the 19th Open-Ended Working Group (OEWG) in Geneva (June 1999) and to the 11th Meeting of the Parties in Beijing, China (November 1999), respectively.

The EOC Co-chairs are making provisions to proceed with economic assessments in a different working modality. Since TEAP has approved this change (see chapter 7), assessments will, in future, be conducted by the present EOC Co-chairs as TEAP Senior (Economic) Expert Members. They will collaborate with a limited number of Consulting Members with acknowledged expertise in the application of economic analysis, in the assessment of specific economic issues of importance to the implementation of the Montreal Protocol. Experience suggests that constraints on funding and time can be expected to limit their participation in formal meetings, without diminishing their commitment to advise and support the Co-chairs.

In its future working modality, the EOC may assist (possibly in a Task Force set-up) the Methyl Bromide Technical Options Committee (MBTOC), which will address the issue of the economic viability of alternatives to methyl bromide in response to Decision XI/12.

5.3 Foams Technical Options Committee (FTOC)

5.3.1 General

Since the publication of the *1998 FTOC Assessment Report*, significant further steps have been taken towards the phase-out of ODSs, both in terms of technology and policy. This update highlights the major technological developments that have occurred and the impacts on phase-out, which has been observed as a result. It is not a full review of the status of technologies in all sectors.

5.3.2 Technology status

5.3.2.1 Polyurethane

Flexible foams

Slabstock foams: While methylene chloride (MC) remains the major ODS phase-out technology, CO_2 (LCD)[3] based technologies continue to grow in this sector, at the expense of methylene chloride and other ODS replacement technologies. Maintaining low densities for slabstock foam applications is still a challenge in certain areas. The introduction of Low Index Additive (LIA) technology is also providing a further alternative to existing methylene chloride technology, specifically in box foams where CO_2 (LCD) is not applied. Several new LIAs have entered the market providing improved foam properties at prices that approach those of traditional MC technologies. LIAs can also be used in combination with MC when MC alone does not provide final product requirements.

Moulded foams: The progress of direct CO_2 systems (CO_2 (LCD) and CO_2 (GCD)) is less spectacular than in slabstock foam and CO_2 (water) remains by far the most widely utilised ODS replacement technology. In developing countries, there is a greater tendency to use direct CO_2 because lower product densities can be achieved. Although some density improvements can also be obtained using CO_2 (water), this technology has been slower to penetrate.

Flexible integral skin foams: There has been renewed interest in the potential use of HFCs in this application in order to meet the process safety

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[3] Carbon dioxide or CO_2 as a blowing agent in foam can be chemically generated from the reaction between water and isocyanate but also added as an auxiliary blowing agent in liquid or gas form. The different options are hereafter referred to as CO_2 (water), CO_2 (LCD) and CO_2 (GCD).

requirements of the automotive sector amongst others. This is particularly the case for smaller producers where the cost of modification to hydrocarbon systems is excessive and the alternative CO_2 (water) systems do not have the required mechanical properties in certain applications. In some cases, in-mould coatings and air nucleation technologies can be used to offset the shortcomings of CO_2 (water) systems, which show themselves primarily in the quality of the skin. In developing countries, where densities tend to be lower, the incremental costs of using higher density CO_2 (water) technologies are often prohibitive, particularly when combined with surface improvement strategies.

Some work has also been carried out in reducing the loading of hydrocarbon to levels where the premixes are perceived as safe and users believe that no specific safety measures are needed. Currently, the FTOC does not have enough information on this subject to assess this approach.

Rigid foams

In the rigid foam sector, the main choices continue to be between HCFCs and HFCs on the one hand and hydrocarbons on the other. However, the boundaries are becoming blurred as blends of HFCs and hydrocarbons are under ever-wider consideration. The driving forces for such options are the maintenance of the key physical foam properties (e.g. thermal efficiency and flammability) at appropriate cost and minimal environmental impact. These balances are not simple to achieve and vary substantially depending on end applications, local legislative frameworks and standards.

Appliance foam: Several further studies have been completed looking at the relative energy efficiency of different insulation combinations. More recently, these have been related to cost-effectiveness criteria and new costing models have emerged in North America which support the use of higher cost blowing agents such as HFC-245fa where improved energy efficiency is justified. The preferred North American approach is not accepted in Europe and elsewhere where cyclo-pentane/iso-pentane blends are becoming ever more dominant. Pure cyclo-pentane also remains an option technically but is less cost-effective. The North American situation remains unique because of differences in product design and energy performance criteria, although it should be noted that some importation of appliances containing hydrocarbon blown foams is being considered from Mexico. Another differentiating aspect for the United States is that safety measures required for hydrocarbon plants are more demanding than in Europe.

In developing countries approximately 60% of projects are adopting hydrocarbons with the balance adopting HCFCs in appliance foam.

Current technology usage can be summarised regionally as seen in Table 5.2.

Table 5.2: *Regional breakdown of current blowing technology*

Blowing Agent	**North America**	**Europe**	**Japan**	**Latin America**	**India**	**China**
CFCs	No	No	No	30%	Yes	20%
HCFCs	Yes	<5 %	25%	50-60%	Yes	30%
C-pentane/iso-pentane (70/30)	No	35%	No	Yes	Yes	No
HFC-134a	Yes	Yes?	Yes?	No	No	No
C-pentane/iso-butane (80/20)	No	<15%	No	No	No	No
C-pentane	No	50%	75%	10-20%	Yes	50%

Flexible-faced laminate: In both North America and Europe manufacturers of flexible-faced laminate are increasingly adopting a dual technology strategy in order to provide themselves with the most versatile product ranges for increasingly demanding markets. Typically, this means that, within the auspices of one producer, some lines will convert to HFC use when available and others will convert to the use of hydrocarbons. Although this has been the case for European producers for some time, the use of hydrocarbons in North America is a clear development since the last *1998 FTOC Assessment Report*. Indeed, one North American producer has announced a pending transfer to hydrocarbon technology (cyclopentane/isopentane blends) alone.

In Europe, the initial enthusiasm for hydrocarbons is now being tempered by the emergence of the harmonised Euroclass fire classification system. This has introduced concern over the future fire classification of many polyurethane products and has led to the wider use of polyisocyanurate formulations based on aromatic polyester polyols. Blowing agent selection, however, continues to be an integral part of decision-making process and HFCs are being viewed more widely as potential options in this sector, leading to increasing use of the dual strategy mentioned previously.

The use of HFCs in themselves is also coming under discussion. ‘Liquid’ HFCs have long been identified as the major potential blowing agents for this sector, but blends between ‘liquid’ HFCs and HFC-134a are now being seen increasingly as the blowing agent of choice where flammability issues are paramount. It should be noted, however, that the non-azeotropic blend of HFC-365mfc with HFC-134a poses the possibility of becoming flammable if the HFC-134a evaporates prematurely. This can only occur if the blend mis-handled and will not be a problem if the suppliers’ instructions are followed. In any event, the flammability risks are lower than for hydrocarbons (e.g. in terms of minimum ignition energies).

Where flammability aspects are less important and the primary role of the HFC is to instil better thermal efficiency, blends with hydrocarbons such as pentane isomers are being increasingly evaluated. It appears that blends of up to 50/50 (HFC hydrocarbon) can be adopted, thereby providing a significant cost saving over pure 'liquid' HFC options.

Spray foam: Considerable work has been carried out by Exxon and IPI in North America to assess the possibility of using hydrocarbons in this application. Although the work is still in its preliminary stages, there is some evidence to suggest that the risk may be manageable in certain controlled uses. Accordingly, the US SNAP programme has approved a cyclo-pentane/iso-pentane technology as a viable option. However, strong concerns still exist as to how process safety controls will be ensured in an application, which, by its very nature, is non-routine.

There is some consideration of using CO_2 (water) technology in Europe, North America and Japan, although this approach suffers from poorer physical and thermal properties. Accordingly, the question of commercial viability remains unanswered.

A further major option in this application continues to be the potential use of HFCs, both in liquid and gaseous form. It is likely that non-flammable blends of liquid HFCs with HFC-134a will eventually be the preferred choice but further testing is required to verify this. As noted previously, care needs to be taken with the use of HFC-365mfc/ HFC-134a blends, since the blend is not an azeotrope and there is a risk that HFC-134a could evaporate prematurely leaving a potentially flammable mix. Handling of these blends may therefore need further investigation in spray applications. HFC-365mfc and its blends are also the subject of potential restrictions in North America because of licensing constraints under the original Bayer patent. Other tests in the USA have shown that pure HFC-245fa can also be used to produce technically sound products. However, the cost and availability of 'liquid' HFCs have been key issues in this assessment and these uncertainties are only now being resolved. Recent work has shown that the improved blowing efficiency of HFC-245fa may offset much of the incremental unit cost. Finally, it should be noted that the legislative framework for the use of HFCs in such applications is less well defined in many countries and is an on-going cause for concern.

5.3.2.2 Extruded polystyrene

Over the last 12-18 months research efforts and technology advances in the insulation boardstock area have been almost exclusively concentrated in Europe. This is covered in more detail in section 5.3.5 of this update. The prime driving forces for such change are the forthcoming HCFC controls.

In Europe CO_2 technology both with and without co-blowing agent continues to be refined. HFC-134a, both as a blend with HFC-152a or with an organic co-blowing agent, continues to be the main candidate for replacing HCFC-142b where excellent insulation performance is required by the market for a specific application. In products where HFC-134a content is maximised, the thermal performance can range from 15% to over 25% better than CO_2 – blown foam. There are clearly justified markets for both types of product.

In North America, density constraints are hitherto preventing the widespread consideration of the CO_2 technologies currently being adopted in parts of Europe.

5.3.3 Transitional status

Progress out of the use of ozone depleting substances is continuing in all regions of the world. As noted in the *1998 FTOC Assessment Report*, the need to eliminate uncertainties over the choice of alternative technologies increases as the phase-out of CFC use in Article 5(1) countries progresses. The fact that only one technology transition can be funded is an on-going complication to the decision-making process.

This update does not include a comprehensive quantitative analysis of the global progress out of ODSs. This will be included in the next full Assessment Report of the FTOC in 2002. However, the key issues affecting transition at this time are highlighted below.

5.3.3.1 Liquid HFC availability

The time-lines for the commercialisation of 'liquid' HFCs have not shifted substantially from the ones given in the *1998 FTOC Assessment Report*. AlliedSignal (now Honeywell) has announced the location of their production site in North America for HFC-245fa, while Solvay has recently opened their pilot plant for HFC-365mfc. Commercial availability is scheduled for mid-2002 in the case of HFC-245fa and by the end of 2002 for HFC-365mfc. However, Solvay will manufacture product on their pilot plant in growing quantities in the intervening period. AlliedSignal is also anticipating having semi-commercial quantities available for full-scale trials as well as some niche commercialisation activities. Nevertheless, there will still be substantial pressure on the foam industry to achieve an appropriate phase-out of HCFC use in the required timescale.

5.3.3.2 Issues affecting ODS phase-out in Artcle 5(1) countries

There is growing concern over the cost of non-HCFC technologies for small-scale operations. It has been shown that hydrocarbon projects replacing less than 50 tonnes of ODS may not be cost-effective. The incremental investment required for the comprehensive adoption of hydrocarbon solutions could reach 10% of the total foam sector expenditure. The threat of policy changes, which could further discourage the implementation of HCFC-based projects may slow down the rate of transition from the more damaging CFC-based technologies currently being used.

An additional concern has been the assessment of incremental operating costs associated with conversions. Work is currently in hand to resolve some of the uncertainties on raw material prices and foam density discrepancies that have emerged.

5.3.4 Regulatory activities

Because of uncertainties in regulatory frameworks, transition decisions have been delayed. Particular impacts have arisen from:

- The fact that a SNAP decision on allowing the replacement of HCFC-141b with other HCFCs has not yet been made in North America;
- Delays in the revised European Regulation and the unilateral strengthening of Member State legislation in its place;
- Future treatment of HFCs.

The latter has been particularly affected by inconsistencies on the weighting of energy efficiency arguments. These were dealt with at length in the *TEAP HFC/PFC Task Force Report* and Life Cycle Climate Performance (LCCP) and Total Equivalent Warming Impact (TEWI) remain key elements of assessment in the foam sector.

5.3.5 Extruded polystyrene technology update[4]

5.3.5.1 Boardstock

Low ODP technology

HCFC-142b and blends of HCFC-142b/HCFC-22 remain the primary blowing agents for extruded polystyrene boardstock insulation across most of the world, because of their important contribution as insulated gases in the product. The good insulation performance obtained helps to reduce and mitigate the amount of carbon dioxide produced from fossil fuel combustion in the home and commercial heating contributions of the global climate change challenge. Zero ODP alternatives are certainly commercially available in Europe. The acceptance of one option over another depends on the particular construction culture and local market acceptance.

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[4] This section is a full update of the Extruded Polystyrene Technology Options covered in the *1998 FTOC Technical Options Report*.

Zero ODP technology

Viable zero ODP alternative blowing agents for extruded polystyrene board-stock are the following:

- HFC-152a;
- Blends of HFC-152a and 134a;
- HFC 134a and an organic co-blowing agent;
- $C0_2$ and an organic co-blowing agent;
- 100 % CO_2.

Selection between these options is dependent on a variety of factors and there continue to be implementation constraints in some regions, in particular, with respect to the foam densities demanded to meet market requirements. Additionally, there are issues of blowing agent retention. For HFC-134a containing systems, investigation of aged foam samples shows that the cell gas is a mixture of HFC-134a and air or just air alone.

It is standard practice today and it also makes economical sense to maximise the use of CO_2 commensurate with process equipment constraints and product property requirements, in combination with other blowing agents.

It should be noted that it is technically impractical to make useful XPS foam with HFC-134a alone. A co-blowing agent (processing aid) is essential because of the very low solubility of HFC-134a in polystyrene.

HFC-152a, being fairly soluble in polystyrene, produces foam with reasonably low density but somewhat lower insulation value than HFC-134a. Its relatively low global warming potential (GWP=150) makes it a candidate for blending with HFC-134a to achieve a balanced set of functional properties. This alternative is not widely used as an ODS alternative and is generally more expensive than HFC-134a. HFC-152a is flammable, requiring capital expenditure for storage, processing and safety considerations.

The major disadvantage is the relatively high permeability of polystyrene to HFC-152a. The diffusion rate of HFC-152a out of XPS boards is similar to that of HCFC-22. Thus, after some 5 years, even in thicker board (80 mm) the insulation value is comparable to that of CO_2 - foam. Certainly standardised long-term (sliced) thermal resistance measurements show negligible difference, i.e. the cell gas is air.

HFC-152a blends with HFC-134a – here practically it is the HFC-134a which provides XPS with enhanced long-term thermal resistance and insulation performance equivalent to conventional HCFC-142b material.

The conversion away from HCFCs is most economically achieved by using blends of HFC-134a and HFC-152a. One company in Sweden has practised this technology since mid-1996. Depending on process equipment and product requirements the blends can range from 20% HFC-134a / 80% HFC-152a to 50/50%. It is to be noted that the higher the HFC-152a content the lower is the long-term insulation performance of the foam.

CO_2 / organic blowing agent technology is growing in significance. The organic element is typically ethanol and acts as a processing aid. This is proprietary technology and has been practised increasingly in Europe with steady improvements in technology, specifically Germany, over the last four years. The owners have declared that as of 2002 only this technology will be used in their five European plants. The owners claim that there is little or no density penalty (< 5%) i.e.: increase in density compared to HCFC-142b blown foam with otherwise identical physical properties across the whole range of their products. The owners claim further that improvements to the "radiation factor" contribution to overall thermal resistance of the product should result in commercially available material exhibiting a 10% increase in thermal resistance across all product range and thickness by 2002.

The use of ethanol and its rapid diffusion out of the foam demands longer curing time at the production site to avoid creation of flammable mixtures with air in the supply chain than does conventional HCFC 142b material. The long- term insulation properties of CO2 / ethanol blown foam are 15-20 % worse than for foam where the HFC 134a content is maximised.

100 % CO2 – while this option is the most environmentally preferred, it is the most difficult technically to perfect and commercialise. Significant capital investment is required to achieve 100% CO2 capability. Like that of the CO2 / ethanol material the thermal performance of 100 % CO2 is 15-20 % inferior to that of HCFC/ HFC-134a material since the cell gas is air. The thermal resistance differential increases with thickness of the boards. The density penalty increases with increasing thickness and at 160mm can exceed 20%. An increase in density for any given thickness equates to an economic penalty(!) Nevertheless, in certain market areas and in many applications where the thickness required is less than 80 mm, the "CO2" foams can and do compete economically with HFC foams.

However, HFC applications will certainly remain an important option for parts of the product mix where dimensional stability and thermal performance are key properties which must be met.

5.4 Halon Technical Options Committee (HTOC)

The Halons Technical Options Committee did so far not meet in 2000 (and will not meet in the remainder of 2000), because there are no important technical developments in the fire protection sector. In addition, there were no essential uses to be dealt with. The Russian Federation, in accordance with the statements provided in 1999, did not submit another essential use nomination for 2001. This indicates that the efforts to establish a halon 2402-management program in the Russian Federation have been making good progress. A halon recovery and recycling program is under development and GEF is considering supporting it. According to additional information provided by the Russian Federation, the halon 2402 production will be terminated in the summer of 2000.

Decision X/7, "Halon-management strategies", requests Parties to submit national or regional strategies for management of halons to the Ozone Secretariat by the end of July 2000. In the light of this timetable HTOC will not be able to report in time, via the TEAP, to the 12th Meeting of the Parties. Depending on availability of the strategies, HTOC will try to provide a preliminary assessment for the 12th Meeting and will undertake a full review of the strategies for the *2001 TEAP Progress Report*.

5.4.1 Progress in phasing-out halon production in China

The Executive Committee of the Multilateral Fund approved the Sector Plan for Halon Phaseout in China in 1997. Here the World Bank is selected as the implementing agency. The plan foresees a gradual reduction of production and consumption, to zero tonnes in 2006 for halon 1211 and in 2010 for halon 1301.

HTOC members participated at a World Bank workshop on halon management in Beijing for the fire protection authorities of the central government and of the provinces. On this occasion the HTOC received information on the important progress that has been made in halon phase-out in China.

The Halon Sector Phase-out Project is proceeding on schedule. The production in China diminished from 11,644 tonnes of halon 1211 in 1997 to 7,960 tonnes and 5,960 tonnes in 1998 and 1999, respectively. Consumption decreased from 10,849 tonnes to 7,160 and 5,370 tonnes for the respective years. China also produced 618 tonnes of halon 1301 at one plant, and consumed 300 tonnes. Production and consumption of halon 1301 remains stable. As the project has proceeded, the number of halon 1211 producers has been reduced to six, and halon 1211 production has been reduced through the establishment of annual targets under a quota regulation system, accompanied by technical assistance packages. Production and consumption of halon 1211 in 2000 will be 3,980 tonnes and 3,580 tonnes, respectively, with halon 1301 being maintained at the earlier level. Conversion of fire extinguisher manufacture has been to CO_2; foam and ABC dry chemical powder systems.

Since the start of the program, China has taken action to phase out production and consumption through development of supporting policies and regulations. Of the 14 halon producing plants at the start of the program, only six plants remain in operation, and the others have been closed and dismantled completely. Production and capacity has also been reduced at four other halon 1211 production plants. Closure of halons extinguisher manufacturing, and conversion of halon fire extinguishers and systems production to non ODS substitutes are underway at 73 companies which were manufacturing halon fire fighting equipment when the program started. A number of technical assistance activities have started, covering activities for strengthening the implementation capacity, the preparation of standards for substitute fire extinguisher agents and equipment, and the assurance of quality and reliability of halon substitute fire extinguishers and systems. This exercise has required close co-operation between the State Environmental Protection Administration (SEPA), the Ministry of Public Security (MPS), the China National Chemical Construction Corporation (CNCCC) and the fire fighting enterprises. Given the number of enterprises involved and their geographical distribution, the experience of implementation has confirmed the necessity for co-operation with provincial bureaux, intensive monitoring of targets, and strong policy enforcement to support the program.

The 1999 Annual Program targeted a reduction of halon 1211 production to a maximum of 5,970 tonnes, along with a reduction of consumption to 5,370 tonnes. This required a decrease in production of 1,942 tonnes from the previous year, as well as a decrease in consumption of 1,790 tonnes. Production and consumption of halon 1301 was targeted to be maintained at 300 tonnes in the year. The program was to deliver on these outcomes through a combination of closure of enterprises manufacturing halons or extinguishers, conversion of manufacturers of halon extinguishers to non-halon extinguishers, and technical assistance activities to help the phase-out work. The World Bank's review missions visited the halons and extinguisher manufacturing plants in the year, and improved reporting formats were agreed with SEPA to enable monitoring of halons production through the year. Four companies signed closure contracts. These closures accounted for quotas 'sold back' to Government for a total of 1,942 tonnes. The production levels achieved for 1999 will be reviewed by a performance audit of the halon program in 2000. An international audit of the entire halon project has also been proposed by the Bank, and is expected to take place in 2000.

As mentioned above, halon 1211 production will be reduced to a maximum of 3,980 tonnes and its consumption to a maximum of 3,580 tonnes in 2000. This will amount to reductions of 1,990 tonnes in production and 1,790 tonnes in consumption. The production quota for each enterprise in 2000 has already been established to meet this target. The halon 1301 production will be maintained at the agreed maximum level of 618 tonnes and consumption will be 300 tonnes. While this allowance has remained unchanged since the start of the program, actual production in 1999 fell well below the allowance, reflecting decreased national demand.

With the phase-out of halon production under way, the assured supply of alternative fire extinguishing agents and fire fighting equipment in sufficient quantity and of suitable quality is a concern. Special initiatives have been taken to strengthen the supply of substitutes such as ABC powder and foam. Contracts have been signed for setting up a new ABC dry powder plant based on US technology, and technical assistance has also been provided to support development of a new protein-based foam. Because China considers it necessary to develop lightweight cylinders for use in CO_2 technology, a feasibility study has been undertaken to assess the financial and technical parameters of setting up the production of lightweight CO_2 cylinders. A contract for a project to manufacture lightweight cylinders has been approved and is expected to be signed shortly.

Some issues that will require attention in the coming year are highlighted below.

- As halon production falls, China will also have to rely on halon banking in line with global trends. While there has been some progress with the halon banking management program, it is important that China make systematic projections about the future demand for halons in China. The use of innovative regulations to control the use of halons is encouraging and should be supported. A halon-banking workshop was conducted on 4 December 1999 in Beijing, involving UNEP HTOC experts; this workshop made with the UNEP HTOC experts and made recommendations on the management of halons;
- Adequate promotion of substitutes is a key concern in the program. While there has been progress in manufacture of ABC dry powder extinguishers to replace the reduced halon 1211 extinguisher production, there does not seem to be enough market willingness to adopt the substitutes. The servicing of new extinguishers is also an issue that needs to be addressed. It is necessary to promote public awareness of the benefits of not using halon-based extinguishers, as well as to promote demand for ABC extinguishers, which are more effective and less expensive.

In other policy initiatives, China has taken steps to establish a new office for the control of import and export of ODS, with oversight to be provided jointly by the concerned ministries for trade, customs and environment. The office will regulate applications for import or export of ODS.

5.4.2 A review of the use of halons by non-Article 5(1) countries in military applications and during peacekeeping and combat operations

Concern has been voiced by environmental organisations over the use of halons in peacekeeping operations and in other military applications. HTOC has been reviewing these applications and has provided the following assessment.

The military sector continues to rely upon halons in a number of critical use applications, despite the considerable effort devoted to finding, evaluating and implementing suitable alternative fire protection solutions. Also over the past decade, there has been an increase in the number of multinational peacekeeping operations around the world. There is concern that these operations may have resulted in significant additional quantities of halons being emitted to atmosphere.

The following paragraphs briefly describe the principal military uses of halon and the current progress that is being made in reducing these uses and, in this context, discusses the use of halons in peacekeeping and other combat operations. The current situation in CEIT and Article 5(1) countries is not specifically addressed though much will also be directly applicable to these nations.

Prior to the Montreal Protocol, halons found widespread use by military organisations throughout the world. In many countries, good progress continues in the conversion of halon systems in facilities within military establishments to HFC, inert gas or carbon dioxide extinguishants. In a significant number of cases, improved procedures, changing requirements and alternative fire protection strategies have allowed the removal of the halons without their replacement by an in-kind alternative.

However, there continue to be major difficulties in replacing halons in the large variety of applications found in front-line equipment. In confronting these difficulties, military organisations have been instrumental in the development of alternative extinguishants and fire protection methods and the assessment of their performance. These efforts have paid dividends. For new designs of most military equipment, halon systems are no longer considered to be necessary, though the long lead times in the development of equipment mean that a few systems are still being procured with halon on board.

In some countries, a number of existing front-line applications, normally protecting unoccupied spaces such as the engine compartments of vehicles have already been converted to suitable alternatives. Other, often lengthy conversion programmes are underway.

There will remain in service, however, for some considerable time, a significant number of military applications for which halons are currently the only feasible option. These critical uses are mainly in aviation applications and in the normally occupied spaces in naval vessels and armoured vehicles where personnel safety, operational capability, weight, space and fire extinguishing performance are all critical factors. Until more effective, safer, or more environmentally acceptable alternatives can be found and implemented, these applications are being supported by the responsible management of halon stocks normally obtained by the recycling of materials recovered from non-critical applications. Procedures have been widely adopted to maximise recovery and recycling and to minimise leakage, accidental discharges and use in training. Inevitably, any operational use of equipment, which relies on halons, such as in peacekeeping operations, may result in some additional or earlier release of the materials to the atmosphere. Ironically, the willingness of many nations to commit forces to an increasing number of peacekeeping operations means that conversion programmes are being delayed or becoming increasingly protracted because of the additional operational and financial commitments that are involved. Any such delay to conversion programmes is also likely to lead to an increase in overall emissions. However, with only one exception, emissions of halons to the atmosphere from military applications during recent peacekeeping and combat operations have not been found to be significantly higher than during peacetime.

The use of F-16 aircraft in recent peacekeeping and combat missions has, however, resulted in the release to atmosphere of appreciable extra quantities of halon 1301 that would not have otherwise occurred during peacetime. The F-16 aircraft, which is widely used by at least 18 non-Article 5(1) and Article 5(1) countries (Bahrain, Belgium, Denmark, Egypt, Greece, Indonesia, Israel, South Korea, Netherlands, Norway, Pakistan, Portugal, Singapore, Taiwan, Thailand, Turkey, United States and Venezuela) and often deployed, is fitted with a halon 1301 fuel tank pre-emptive inerting system to protect the aircraft from hostile action. When this system is activated, which is now only during combat missions, all the halon is discharged during each flight. This use of halon will only cease when the nations that operate the aircraft change operational procedures or implement a technical solution to avoid the use of the halon as a fuel tank inerting agent. The former option would expose aircrew to greater risk and is not considered to be an acceptable option by the air forces concerned. Significant resources have been devoted to finding a long-term technical solution to this problem but the most promising options have significant disadvantages and remain unproven.

5.5 Refrigeration Technical Options Committee (RTOC)

5.5.1 Introduction

Since the 1998 TOC Assessment Report, progress has occurred in several sub-sectors of the refrigeration and air conditioning sector. A summary of the technical progress in refrigeration, air conditioning and heat pumps is presented below; this report will also form the basis for first decisions on the technical assessment efforts to be made at the July 2000 Refrigeration TOC meeting. Since the RTOC did not meet in 1999, this July 2000 meeting will be the first RTOC meeting in the 2000-2002 assessment period.

Nevertheless, new developments on HFCs and other non-ODP alternatives were already reported by TOC experts who were members of the Montreal Protocol TEAP HFC Task Force in 1999 (see the *"1999 HFC/PFC Task Force Report"*). Several TOC members currently also participate in the drafting and reviewing of the IPCC Third Assessment Report, in particular the Appendix to Working Group III, Chapter 3, "Options to Reduce Global Warming Contributions from Substitutes for ODSs", either as Lead or as Contributing Authors (see chapter 6).

5.5.2 Refrigerant data

The refrigerant data section for the next RTOC Assessment Report needs to be updated to accommodate new refrigerant blends and data. There will be some expansion since, in 1999 and early 2000, more than a dozen new refrigerants were added to the (ARTI) Refrigerant Database on which the Annex in the *1998 RTOC Assessment Report* was based. Likewise, the information on refrigerants already included in the Database is continuously updated as additional and new information is obtained. Additional refrigerant introductions are anticipated as the HCFC-22 phase-out approaches in many non-Article 5(1) countries.

5.5.3 Domestic refrigeration

No significant new refrigerant has been identified and commercialised; alternative refrigerant selections remain centred on HFC-134a and HC-600a (isobutane). While HFC-134a still holds the vast majority of the market in the developed countries, the share of isobutane in domestic refrigeration is still increasing slightly. Transition from CFC-12 to non-ODS refrigerants in new equipment continues to proceed in the Article 5(1) countries in advance of the Montreal Protocol requirements. Although the majority of the industries in the Article 5(1) countries (particularly the multinational companies) have selected the HFC-134a option, a certain number of new applications are converting to isobutane. This may very well be a consequence of a greater proportion of cold-wall evaporator refrigerator construction in the countries where transitions are occurring (in comparison to e.g. Japan and the US); the option to convert to isobutane has a direct relation to costs, performance, export market opportunities, “green image” etc. It is being reported that, so far, no US or Japanese company currently plans to commercially implement isobutane based appliances for their domestic markets.

Disposal of refrigerators using a variety of refrigerants -and their recovery- has not been solved and is still under study. However, a large number of refrigerators using flammables is not expected to be disposed of until the period 2008-2010, due to the fact that large scale production only started in 1994; namely, one should take into account an average lifetime of at least 15 years. Early actions to recover historically used ODSs, particularly CFC-12, immediately prior to final product disposal would have significant environmental benefits. The technology to accomplish this recovery is readily available but there are logistic issues unique to national environments (see also below under “Refrigerant conservation and emission reductions”). Near term efforts to resolve these issues would be necessary to implement effective recovery programs and thereby avoid venting CFCs to the atmosphere.

Enhanced energy efficiency of domestic refrigerators is a topic of accelerating interest in many countries. Relative energy efficiency of optimised designs is approximately equivalent for either isobutane or HFC-134a. It is not the application of the refrigerant that results in a real efficiency increase, much more the overall (thermodynamic cycles, heat exchangers etc.) design of the equipment that determines the achievable energy efficiency. Where it concerns the circuit, this is related to component design and to cycle optimisation, the latter e.g. by the application of stepwise --frequency-- controlled compressors; this leads to a substantial decrease of energy consumption. Two significant developments in the thermal insulation part are the applications of optimised foam formulations using pentane blends and the announced intent for high volume HFC-245fa production (see section 5.3.2). Vacuum panel insulation technology development also continues to have high interest and activity. Several developed countries have enacted new energy efficiency regulations with required improvements ranging up to one-third of current-model power demand. Several other countries are considering similar required energy efficiency improvements.

In the developed countries, servicing is kept to a minimum. The highest fraction of residual CFC-12 demand for domestic refrigeration use continues to be for field repair of units originally designed for use of CFC-12. The European Union will ban service use of CFC-12 at short notice, which implies that equipment has to be disposed of if it cannot be retrofitted. Numerous refrigerant and refrigerant-blend alternative candidates continue to compete for the retrofit service market. No clear choice has emerged and original equipment manufacturers should continue to be consulted for recommended service procedures for their equipment.

Particularly in the Article 5(1) countries, servicing practices need to be further evaluated. For these countries, the option of servicing (i.e., retrofitting) appliances with a mixture of propane and isobutane so that mineral oil can be used, has been studied by UNEP (UNEP DTIE, Paris) in 1997. To date, some further studies on this issue have been carried out but several questions need still to be answered –according to RTOC experts– amongst which: (i) capacity and efficiency of the systems, (ii) reliability of systems, (iii) which type of training would be the best for technicians involved in a repair with hydrocarbons, and (iv) which component substitutions and other design modifications are required. The last point is unique and specific to the exact configuration of the particular product being serviced. Experts' advice is that the original equipment manufacturers should be consulted for their recommended, model-specific procedures.

5.5.4 Commercial refrigeration

Next to equipment on HFC-134a, stand-alone equipment is offered based on hydrocarbons (pure fluids or mixtures) in Northern Europe; world-wide, the vast majority of the commercial refrigeration sector has practically been taken over by R-404A. The uses of HFC blends such as R-407C and R-507A are much smaller. It should again be emphasised that it is not so much the choice of the refrigerant, but the design of the system that is of major influence on the energy consumption of the equipment.

Particularly in Northern Europe, a number of non-HFC, non-ODP alternatives are increasingly being applied together with secondary loops. It is difficult to get consensus values regarding the energy consumption of secondary loops. This because the increase in energy consumption depends on the evaporation temperature level, the temperature differences and the compensation of the pumping power by cooling capacity. The initial cost of secondary loop systems is assumed to be 10 to 15% higher, and it may further increase if comparable efficiency to direct systems has to be achieved by applying more expensive components.

While secondary loops are being more and more promoted, leakage of these secondary loops is difficult to detect. However, these systems need to be practically leak-free in order to guarantee proper and efficient functioning. The maintenance aspect of secondary loops and the time dependent costs involved are still being evaluated.

The HCFC issue seems to become a driver for changes in many developed countries, particularly in Western Europe (due to the preferred early regulatory phaseout of HCFC use in new and existing equipment). Experts state that this implies that recovery efforts will not be profitable and will not be undertaken, which would result in the venting of the HCFC bank of refrigerant.

5.5.5 Cold storage/ industrial refrigeration

In Northern Europe, including the UK, ammonia has further strengthened its position as the leading refrigerant within the cold storage and food processing sub-sector. This is particularly true in the case of larger systems that are not suitable for dry expansion. HCFC-22 is practically no longer used.

The conventional technology with pump circulation and large ammonia charges is still common, but the new technology using carbon dioxide (CO_2) as a secondary refrigerant has been taken into use, e.g. in several ice rinks. In this way, the ammonia charge is reduced by 90%, while the system efficiency is maintained. It is believed that this CO_2/ammonia combination will take over from the traditional ammonia systems for industrial purposes in densely populated areas.

HCFC-22 is no longer used in fishing vessels and factory ships in Northern Europe. Ammonia has taken over the leading position and is applied both in direct and indirect systems on board. Solutions based on CO_2 as a secondary refrigerant and as a primary refrigerant in the lower stage of low temperature cascade systems are under development, and the first vessels with CO_2/ammonia are expected within the short term.

Both R-404A and R-507A have acquired a foothold in the lower capacity region of industrial systems on shore, up to approximately 200-300 kW refrigerating capacity. This is partly a result of the introduction of electronic evaporator control, which has made it technically possible to extend utilisation of dry expansion evaporators towards larger capacities. HFC charges may be up to 500 kg per system or more. Pump circulation of HFCs is still very rare, if applied at all.

R-410A has been identified as clearly the most promising HFC for industrial purposes, especially for low temperature freezing. It will be practically as efficient as ammonia in freezing applications and has, at the same time, more than 50% greater capacity. However, the development in marketing components (compressors) for this high pressure HFC has been slow. A change is now apparent, and 40 bar compressors applicable for R-410A (and for CO_2 in the lower stage of low temperature cascade systems) are available (or will be within short) from several compressor manufacturers. In order to reduce the reliance on HFCs because of their global warming potential and their high cost, combinations of HFCs with CO_2 as a secondary (or primary) refrigerant are being evaluated.

Chillers with hydrocarbons (propane, hydrocarbon blends) for industrial process cooling (and other cooling purposes) have been available in Europe for some years, but have gained only a minor market share and then only in chillers with positive displacement compressors. HCFCs (HCFC-123 and HCFC-22) are still very common in process cooling (especially outside Europe), but the use of particularly HFC-134a is increasing. In many European countries, low charge ammonia chillers have increased their market position.

For this sub-sector in many developed countries, ammonia is one of the leading refrigerants, with an expected increasing market share in the near future. In several regions in the world, HCFC-22 is apparently still the refrigerant of choice (where ammonia is not an alternative). In some cases, new HCFC-22 systems are prepared for a possible changeover to ammonia in the future. In Article 5(1) countries, both ammonia and HCFC-22 are expected to remain very important alternatives; however, at a relatively low energy efficiency, due to specific system design.

5.5.6 Unitary air conditioning

The current state of the technical options has not changed dramatically since the completion of the *1998 RTOC Assessment Report*. The primary changes have been increased penetration of non-ODP technologies into the markets of the developed countries.

In Japan the air conditioning manufacturers have been moving forward with the transition to non-ODP technologies. Japanese manufacturers are almost exclusively using HFCs in their transition strategy. They are using both R-407C and R-410A to replace HCFC-22. Their choice of refrigerant is being determined by the product type. There has been a substantial shift to non-ODP technologies, with approximately 15 percent of their unitary products now using HFCs.

In the United States the shift to non-ODP technologies in unitary products has been occurring at a much slower pace. Several US manufacturers have introduced residential (5 to 20 kW refrigeration capacity) ducted products using R-410A. In 1999 less than 5% of the HCFC-22 usage was replaced by HFC refrigerants. The penetration of non-HCFC technologies is expected to increase significantly between now and 2006.

R-410A is being applied in smaller air conditioning units world-wide. However, compressors for large capacities at the occurring high pressure levels are so far not available.

In Europe the transition away from HCFC refrigerants is occurring at a much faster pace as a result of government regulations requiring an accelerated

HCFC phase-out in new equipment, and at a later stage, also for servicing. Here the HCFC replacement technologies have included both hydrocarbon and HFC refrigerants. An assessment of the pace and effectiveness of this transition should be made as soon as adequate data will be available. In the Article 5(1) countries, HCFC-22 will be available for many more years and the activity for the application of HFC blends is still relatively modest.

Propane and, to a smaller extent, ammonia are the most likely alternatives to HFC refrigerants in the mid-term. For larger systems this would imply the application of secondary loops, with the related energy efficiency impacts. Research and development has continued on the two options propane and ammonia, but also on other non-ODP technologies and refrigerants. At this time none of the other technologies and refrigerants have been introduced in commercial products.

5.5.7 Chillers

The primary non-ODP alternative in chillers is HFC-134a with some use of R-407C for smaller water chillers. The use of HCFC-123 for low pressure chillers is further proceeding, mainly in the United States where it is the most-widely used refrigerant in new centrifugal chillers; development is hampered in those countries that (intend to) introduce very stringent HCFC regulations. HCFC-123 chillers offer very good energy efficiency and a very low net (refrigerant release and energy related) global warming impact. This was outlined in several detailed studies, which also show that continued use of HCFC-123 use in chillers would have negligible and indiscernible impact on stratospheric ozone, and may help by accelerating CFC phase-outs. Nevertheless, it is an HCFC chemical that will be phased out at some point in the future for Montreal Protocol control schedule reasons. Development of HFC alternatives is further proceeding but no breakthrough is being reported; the next RTOC assessment will examine the impacts of the future use of HCFC-123.

Certain high pressure HFC (HFC-134a) equipment may also take over the low- pressure market in the future (or in those countries with very stringent short-term HCFC regulations). Continued improvement of emission reductions for both low- and high-pressure equipment is anticipated.

New water chillers using ammonia together with aluminium or stainless steel plate heat exchangers are being increasingly marketed in (Northern) Europe. The production of hydrocarbon chillers in Europe is very limited and has not gained more interest since the *1998 RTOC assessment*.

5.5.8 Transport refrigeration

In transport refrigeration the use of both R-134a and R-404A proliferates where R-134a is applied in smaller and R-404A in larger capacity units. Secondary loop systems are also being considered here; however, amongst the many organisations expressing a view, there seems to be no consensus on the application of flammable refrigerants. The definition of "acceptable risk" and the safety of the products which are marketed in practice are key areas of disagreement. The increase of energy consumption for secondary loops can be estimated to be 25% at maximum, dependent on the design of the system and the type of components used.

Although the use of ammonia on ships has a reasonable potential, its application has not proliferated significantly. R-410A is forecast to be one of the most important refrigerants for transport refrigeration, and its application is particularly expected on reefer ships.

The existing systems using CFC-12 on reefer containers, which still represent a significant proportion, will be retrofitted to an interim solution (a blend of refrigerants) or scrapped, since several countries (actually the EU countries) plan to forbid the use of certain equipment if it contains CFC-12 in the very near future.

With all the initiatives being undertaken such as the (i) limitation of the production of new HCFC equipment, (ii) the limitation of the emissions of HFCs to the extent possible, and (iii) a possible ban on certain HFC equipment in certain countries, it is difficult to plan a long term way forward. In the transport refrigeration sector local decisions are important, since the application is transported throughout the world, and is "sensitive to", or dependent on the most stringent regulatory regime.

In the Article 5(1) countries, the use of HCFC-22 is expected to continue for a number of years, but is expected to decline as the use of the alternative HFC-134a grows.

5.5.9 Mobile air conditioning

By the end of 1994, all automobile manufacturers in the developed countries had converted mobile air conditioning systems to HFC-134a. The existing fleet of vehicles operating with CFC-12 air conditioning is expected to phase out due to "old age" by the year 2008. The major issue remaining is to encourage all countries, particularly the Article 5(1) countries, to phase out the use of CFC-12 in motor vehicles as soon as possible while, in the meantime, preventing unnecessary emissions to the atmosphere. Accordingly, information needs to be provided on retrofit technology, recovery and recycling of refrigerant, service technician training, and current service and retrofit trends. *This information currently exists and is available from various out-reach programs, including the Montreal Protocol Multilateral Fund, the Society of Automotive Engineers, the U.S. EPA and the MACS (Mobile Air Conditioning Society).*

Where it concerns the use of HFC-134a, its inclusion into the Kyoto Protocol "basket of gases" obligates the mobile air conditioning industry to develop cost-effective emission mitigation strategies.

Options include improved designs by systems manufacturers, encouraging refrigerant recovery and recycling during system service and scrap, and providing equipment and training to the service industry to enable them to minimise emissions during service. The IPCC Program for National Greenhouse Gas Inventories is currently developing methodologies to estimate actual emissions from usage sectors, which promises to enable tracking of improvements made.

At the 1999 Joint IPCC-TEAP Expert Meeting on Options for the Limitation of Emissions of HFCs and PFCs in Petten, NL, the Mobile Air Conditioning Working Group made several recommendations. These included continuing efforts to (1) minimise HFC-134a emissions; (2) minimise refrigerant charge; (3) encourage (or mandate) HFC-134a recovery/recycling during service and scrap; (4) reduce overall industry emissions to a target level of $\leq$ 80 g per vehicle per year; and (5) continue the development of potential technologies to replace HFC-134a, i.e., the trans-critical carbon dioxide system and the secondary loop system enabling the use of hydrocarbons. New vehicles are expected to be equipped with HFC-134a until an alternative is developed and commercialised that offers comparable performance and reliability characteristics, and an economically attractive global warming advantage.

Where it concerns the issue (5) as mentioned above, alternative potential technologies, the following can be stated.

The general opinion is that air conditioning systems must be indirect if flammable refrigerants are used. In the case of the application of propane, the volumetric refrigeration capacity is estimated to be 15% higher. However, with slightly lower evaporation and higher condensation temperatures, the energy consumption of an indirect system is estimated to be up to 20% higher; further optimisation may lower this figure. In recent tests carried out by the SAE (Society of Automotive Engineering), certain (indirect system) designs for hydrocarbons systems proved to have comparable energy efficiency to HFC-134a systems. Though also being a flammable refrigerant, HFC-152a seems to offer substantially higher performance levels compared to HFC-134a, which could be of advantage when applied together with indirect systems. Further research and development is ongoing. Commercialisation is possible in 4-5 years.

Developments on trans-critical carbon dioxide (R-744) are also proceeding. Developments here are different from technology developments for flammable refrigerants where well known and proven procedures and components can be applied. Significant research and development work is proceeding in Europe in connection with the RACE (Refrigeration and Automotive Climate Systems under Environmental Aspects) project group and globally in the Society of Automotive Engineers -- U.S. EPA -- Mobile Air Conditioning Society world-wide “Mobile Air Conditioning Climate Protection Partnership”.

Trans-critical CO2 systems have been developed and used under road conditions, and joint evaluations are in progress. The carbon dioxide technology has not reached maturity for MAC application. The weight of the system is substantially larger than that of an HFC-134a system. Metallic hoses need to be further developed. Compressors for carbon dioxide need to be improved regarding their energy efficiency. Questions to long term reliability of carbon dioxide systems have so far been premature; they are complex, since it involves the application and containment of a fluid with a very high pressure. With successful development, the first commercial systems could appear in the next 4-7 years.

The development and commercialisation of a system operating with carbon dioxide will constitute a technical breakthrough. However, it should also be realised that development efforts for carbon dioxide systems could also lead to better components for systems using HFC-134a or other, flammable gases, where emissions could then be further reduced to a substantial degree.

A globally developed, periodically updated assessment of the current status and challenges (for reducing HFC emissions) facing the mobile air conditioning industry can be found on the Society of Automotive Engineers (SAE) web site at http://www.sae.org/calendar/pfa00/papers.htm.

5.5.10 Heat pumps (heating only and heat recovery)

HCFC-22 is still the most important HCFC refrigerant for the heat pump industry in terms of volume. Most European countries (EU) have regulations on HCFCs in order to phase them out more rapidly than has been agreed under the Montreal Protocol.

HFCs are currently the most important alternative refrigerants, both for new installations and for retrofits. Observations are that retrofits are still being carried out at a lower rate than expected. Small units are permitted to run their lifetime with the original refrigerant, and are replaced by new units not earlier than at breakdown. HFC-134a is still applied for retrofitting those larger, existing heat pumps that use CFC-12, and for charging new large and medium scale installations. HFC-134a heat pump technology is considered fully mature for new systems, but too expensive for use in smaller installations.

R-407C, R-410A and R-404A are the most promising HFC blend alternatives to replace HCFC-22 for heat pump applications. Units with R-404A and R-407C have been on the market for a few years. Though a few units with R-410A units are already available, several manufacturers now using R-407C have indicated a shift to R-410A within the next 3-5 years.

Ammonia still has a small, but slowly growing share in the heat pump market in Northern Europe. The main application areas for ammonia are industrial heat pumps and large heat pumps for space/tap water heating, often combined with space cooling, in large new commercial buildings and in district heating/cooling systems. The most interesting question is whether the trend observed during the last 5 years will be sustained, i.e., that ammonia is being used in smaller and more compact units.

Hydrocarbon blends, as well as pure hydrocarbons like propane and propylene are used in residential heat pumps, mainly in Europe. However, the market seems to be somewhat reluctant due to the fact that International and European Standards (EN 378/ IEC SC61D/ ISO TC86/ SC1) will come into force and will eventually replace national standards on the use of flammable refrigerants in most European countries. Hydrocarbon heat pump manufacturers and other interested parties have formed a joint interest group (Green Heat Pump Group), to assist and support information for the different working groups on Standards to ensure high quality solutions to deal with the safety aspects of hydrocarbons.

Carbon dioxide is a promising long-term environmentally friendly refrigerant in many heat pump application areas. The first heat pump water heaters are installed and are available from the manufacturer, while heat pumps for combined residential space/tap water heating and heat pump dryers are in the prototype stage. They are expected to reach the market within the next two years. Though components for CO_2 are not available in large quantities, components for almost all applications and sizes are on the market.

5.5.11 Refrigerant conservation and emission reductions

Refrigerant conservation is directly related to leak tightness of refrigeration systems and to recovery during maintenance and at the end of the product life.

Leak tightness of existing (CFC and HCFC) systems may be improved during maintenance but, owing to certain design features, a limited leakage cannot be avoided. The total amount of refrigerants vented to the atmosphere is, for a large part, also dependent on the recovery at the end of the product life. Although the techniques for recovery are mature, the overall recovery efficiency does not increase any longer, mainly because the recovery at the end of the product life is neglected. However, variations in recovery efficiency are often dependent on national regulations (e.g. mobile air conditioning systems in several countries).

Refrigerant containment in new systems is being steadily improved by manufacturers. Efforts are ongoing in different refrigeration sub-sectors to reach extremely high component leak tightness levels.

The need for limiting emissions of HFCs within the framework of the Kyoto Protocol gives rise to the consideration of measures such as (eco-) taxes on new refrigerants in several developed countries, amongst which there are several EU countries. However, a recent study carried out in France has shown that a general tax on new products does not lead to a real environmental benefit if these tax revenues are not used to buy recovered chemical product back.

In the European Union, the new regulation will ban sales and service of CFCs in equipment by the end of 2001, which implies that CFCs have to be destroyed in order to prohibit venting them to the atmosphere. Experts expect that large quantities of CFCs currently banked in systems will be vented if strict control measures are not implemented at shortest notice. The same would apply to HCFCs if the use of HCFCs in equipment is to be banned, which is currently being planned in the European Union for the year 2007.

5.5.12 The status of the refrigeration equipment sector in the Russian Federation

In accordance with the Resolution of the Government of the Russian Federation # 490, dated 5 May 1999, «On strengthening measures of the state control over production and consumption of ozone depleting substances in the Russian Federation», the ODS (CFC) production in Russia will be fully stopped as of 1 July 2000.

The Draft Government Resolution «On signing the Agreement between the Russian Federation and the International Bank for Reconstruction and Development on Grant for Financing the Project *«Special Initiative for ODS Production Closure in the Russian Federation»*» is currently awaiting its approval. It is anticipated that this Resolution will be signed soon and the Grant Agreement on the Special Initiative Project (SI Project) will then come into force in April 2000. Within the frame of the SI Project it is contemplated that Russia will be provided with a grant for ensuring the activities associated with the closure of ODS producing capacity in the order of 140,000 ODP tonnes (including halons). It is also contemplated that international control and monitoring of ODS production closure compliance will be provided on a on-going basis until 2005.

In accordance with the Resolution of the Government of the Russian Federation #1368, dated 9 December 1999, «On strengthening measures of the state control over exportation from and importation to the Russian Federation of ozone depleting substances (ODS) and ODS containing products», all export/import operations with ODS, enumerated in Annexes A and B to the Montreal Protocol, have been discontinued as of 1 March 2000. Acknowledging the fact that the Russian Federation is the sole source of ODS supplies to the countries of the Former Soviet Union (FSU), it is expected that the above measures will eventually lead to substantial reduction of ODS consumption in this region.

The Current Status of the Domestic Refrigeration Sector in Russia. In 1991 the domestic refrigeration sector encompassed the following enterprises located on the territory of the Former Soviet Union: 15 enterprises in Russia, 3 in Ukraine, one in Belorussia, one in Lithuania, one in Azerbaijan and one in Moldova.

At present only three big «world class» suppliers function on the territory of the former Soviet Union (the CIS states). Among them are Stinol in Lipetsk (Russia), Nord in Donetsk (Ukraine) and Atlant in Minsk (Belorussia). Each of them operates at a capacity of 650,000-1,000,000 units/year or more and produces modern design refrigerators of good quality comparable to Western European standards. In this regard these enterprises have developed export markets in Western Europe as a low cost producer for some models for that market (part of it is sold under major European brand names).

The enterprises have converted or are in the process (Nord and Atlant – under the GEF grants) of full conversion to non-ODS technology (HFC-134a in the circuit, cyclopentane in the foam). In fact, Nord and Atlant are also about to introduce low GWP hydrocarbon refrigerant models.

Within the frame of the third tranche of the GEF ODS Consumption Phase-out Project in the Russian Federation a sub-project has now been prepared for JSC «Iceberg» in Smolensk, which (while taking into account the location of the enterprise in the historical part of the city) plans to convert to HFC-134a and HCFC-141b as a foaming agent. Use of hydrocarbons in conversion was not allowed by the Smolensk fire protection service and the State Committee for environmental protection of the Smolensk Oblast. Other Russian producers of domestic refrigerators will convert their facilities to non-ODS refrigerant blends of Russian manufacture, as well as cyclopentane and HCFC-141b, to be used as foaming agents.

The Current Status of the Commercial Refrigeration Sector in Russia. Among the 12 producers of commercial refrigeration equipment and compressors in Russia, only 4 enterprises are so far viable. The largest producer of this sector, ANPO «Marikholodmash», located in Yoshkar-Ola, with a production capacity of 100,000 pieces/year, was included in the second tranche of the

GEF Project. The main foaming equipment has been delivered and the completion of this sub-project is anticipated in July 2000.

Within the third tranche of the GEF Project sub-projects are being prepared for the largest producer of compressors for commercial and domestic refrigeration equipment (600,000 pieces/year) – JSC «Kholodmash» in Jaroslavl and one manufacturer of commercial refrigeration equipment – JSC «Iskra» in Moscow (the average CFC-12 average consumption is 19.3 tonnes per year).

The Current Status of the Refrigeration Servicing Sector in Russia. Practically in each of 89 regions of Russia there is an organisation of up to 500 or more employees, involved in refrigeration servicing of commercial and domestic refrigeration equipment. The three most viable --from a financial point of view- have been included in the third tranche of the GEF Project: JSC «Kemerovotorgtekhnika», Kemerovo, JSC «Pyatigorsktorgtekhnika», Pyatigorsk, and JSC «Combine Torgtekhnika», Ekaterinburg. Part of the remaining servicing organisations is expected to be included for financing through a Small Grant Program under the third tranche of the GEF Project in Russia that is currently being prepared.

5.5.13 Technical progress in the developing countries and their concerns

The phase-out process in Article 5(1) countries is progressing well. In addition, ODS Production Sector Phaseout Projects have been approved by the Multilateral Fund for two major CFC production countries, i.e., China and India.   An accelerated phase-out schedule is on the agenda of some developing countries. Important guidance for the choice of new technologies is mainly given by TEAP reports and by the consultants of Implementing Agencies.

Domestic refrigeration

In this sub-sector, HFC-134a and HC-600a are the alternative options for new appliances in all Article 5(1) countries; this is not different from the situation in the developed countries. Most of the manufacturers in the Article 5(1) countries are gearing up to change over to one of the two technologies. It is expected that 75 to 80 percent of all production will move to HFC-134a and the remainder to HC-600a. Although developing countries have no commitment to reduce greenhouse gas emissions under the Kyoto Protocol, there is a keen interest to understand its implications and its impact when adopting HFC technologies. There has certainly been a sense of uncertainty in the industry in the developing countries with regard to the use of HFC technologies, which has been addressed in the *TEAP HFC/PFC Task Force Report*, published in 1999.

Servicing is one of the major issues in the Article 5(1) countries owing to the fact that the total requirement for servicing is substantial. There is a need to upgrade the servicing facilities so that the servicing technicians will be able to deal with the flammability of hydrocarbons and with the clogging of capillary tubes, caused by contamination and the hygroscopic nature of lubricants used in the case of HFC-134a.

Some of the Article 5(1) countries are also interested in retrofitting the existing CFC-based appliances to drop-in substitutes, such as a blend of HC-290/HC-600a; in this case CFCs can be phased out rapidly in the servicing sector (see also under "Domestic refrigeration" in this subchapter).

Commercial refrigeration

The leading technology option for stand-alone commercial refrigerator units is HFC-134a. Some of the Article 5(1) countries are also seriously considering a hydrocarbon blend of HC-290/HC-600a; this is because of the difficulties expected in the servicing of HFC-134a based appliances.

Unitary air-conditioning

Article 5(1) countries will continue to use HCFC-22 in unitary air-conditioning except in some cases where the original (new) equipment has been charged with R-407C or R-410A. It is likely that the servicing of HFC based unitary A/C systems will also be achieved by using HCFC-22. Amongst the many reasons for this are the cost of HFC refrigerant and the lubricant, as well as the non-availability of HFC-blend refrigerants.

Chillers

In Article 5(1) countries such as India HCFC-22 will continue to be used for small water chillers. It is very unlikely that there will be a changeover to HFC-134a or R-407C. The use of HCFC-123 is expanding in large, low-pressure centrifugal chillers. Chillers based on absorption systems are becoming more and more popular, in spite of the fact that they consume more energy.

Mobile air-conditioning

Article 5(1) countries are changing over to HFC-134a in the MAC sector. The recovery and recycling practices are also being adapted to reduce emissions. There is an incentive for the servicing technicians to implement these techniques because of the relatively large refrigerant charge in mobile air conditioning units (compared to domestic refrigerators and stand-alone commercial refrigeration appliances).

Table 5.3: *The advantages and potential disadvantages of major emission reduction options available to the refrigeration and air conditioning sector (copied from "The Implications to the Montreal Protocol of the Inclusion of HFCs and PFCs in the Kyoto Protocol", UNEP, Ozone Secretariat, October 1999)*

Option	**Advantages**	**Disadvantages**
Use of hydrocarbon Refrigerant	No HFC emission Commercially available Broad availability of proven technologies in most applications	Higher investment costs for secondary systems Flammability issues for primary systems Often increased energy consumption for secondary systems, if needed Potentially higher maintenance costs
Use of ammonia	No HFC emission Commercially available Especially high energy efficiency in freezing applications Broad availability of proven technologies in most applications	Higher investment costs for secondary systems Flammability and toxicity issues for primary systems Often increased energy consumption for secondary systems, if needed Potentially higher maintenance costs Objectionable aroma
Use of alternative Technology (i.e. absorption)	No HFC emissions No validation issues	Often higher energy consumption Most common working pairs, involving water, cannot operate at temperatures below freezing
Reduction of leakage Rates through improved design and quality of components	Potentially very cost effective	Depends on service training and motivation Enforcement critical for systems too small to be profitable and to avoid low-quality after-market parts
Reduction leakage rates through improved maintenance	Potentially very cost effective	Enforcement critical for systems too small to be profitable
Recovery during service and disposal	Highly profitable for large systems, very cost effective for systems >0.5 kg	Depends on service training and motivation Enforcement critical for systems too small to be profitable
Minimising charge of HFC refrigerant	No flammability issues No significant increase of costs for primary systems	Increased energy consumption for secondary systems Higher investment costs for secondary systems Increasing servicing requirement
Reduced demand for refrigeration and air conditioning	Energy savings	Often requires integrated solutions in e.g. architecture, logistics or agricultural policy

5.6 Solvents Technical Options Committee (STOC)

5.6.1 New developments in alternatives to ozone-depleting solvents

The following new developments can be mentioned:

- Parachlorobenzotrifluoride (PCBTF) is being used as a replacement for 1,1,1-trichloroethane (methyl chloroform) used for some speciality paints and coatings;

- The blasting of carbon dioxide pellets is showing good results in cleaning titanium surfaces;

- Carbon dioxide flakes have been adopted by some organisations for cleaning of sensitive optics.

5.6.2 Status of ozone depleting solvents used in the aerospace industry

The following four issues should be mentioned:

- Major aircraft manufacturers still rely on the use of stockpiled CFC-113 as a lubricant and coolant in certain drilling and riveting operations, particularly for wing assemblies. Complete elimination of CFC-113 for such applications is being sought;

- HFE-7100 is being used successfully to clean up hydraulic fluid from systems with complex configurations;

- Although CFC-113 is still prescribed in the specifications of some manufacturers for oxygen systems maintenance, HFE-7100 is being successfully used for all cleaning operations including elimination of fluorinated greases;

- 1,1,1-trichloroethane (methyl chloroform) or CFC-113 is still being used for critical bonded joints of aerospace assemblies.

5.7 Methyl Bromide Technical Options Committee (MBTOC)

5.7.1 Methyl bromide – Executive Summary

Methyl bromide (MB) is used mainly as a pre-plant treatment for soil, while moderate amounts are used for disinfestation of durable and perishable commodities and for disinfestation of buildings, ships and aircraft.

This update to the *1998 MBTOC Assessment Report* elaborates on the quantities of MB produced and consumed by CEIT, Article 5(1) and non-Article 5(1) Parties; recent changes to international regulations on MB use and policies that promote alternatives; recent techniques being tested as alternative treatments for soil, durable commodities, structures and perishable commodities; and methods for reducing MB emissions.

5.7.1.1 Production and consumption

Worldwide manufacture of MB (for all types of uses) was estimated to be about 71,400 tonnes in 1997, with industrialised countries accounting for the vast majority of production. In Article 5(1) Parties the production of MB for soil, storage and structural uses (excluding QPS and feedstock) was reported to be 321 tonnes in 1995, rising to 2,382 tonnes in 1998. Production in China accounted for much of this increase. In developed countries, production for these same uses fluctuated around 61,200 tonnes between 1996 and 1998. Companies in eight countries manufacture MB at present. The countries with production are Israel and the USA, followed by Japan, France and China, with minor amounts produced in India, Ukraine and Romania. Israel and the USA together produced about 80% of the global total in 1998.

MBTOC analysed the data on MB consumption reported to the Ozone Secretariat by the Parties. It indicated that Article 5(1) consumption of MB for soil, storage and structural uses (excluding QPS and feedstock) increased steeply from about 7,990 tonnes in 1991 to more than 15,980 tonnes in 1998. Consumption appears to have stabilised in Latin America, but continues to increase in parts of Africa and Asia. However, MB consumption increased in every Article 5(1) region between 1997 and 1998, possibly due to importing countries requiring exporting countries to use MB in specific cropping situations. There has been an increase in the consumption of MB in some Article 5(1) Parties, particularly in China (600 tonnes (25%) increase in 1999).

In non-Article 5(1) Parties, consumption of MB for soil/storage/structural uses decreased (with fluctuations) from about 55,380 tonnes in 1991 to approximately 41,680 tonnes in 1998. The greatest decrease has occurred in the EU where consumption was reduced by more than one-third in two years - from 18,178 tonnes in 1996 to 11,760 tonnes in 1998.

MBTOC (1998) estimated the global consumption of MB for QPS was about 16,000 tonnes. Only 17 Article 5(1) and non-Article 5(1) Parties provided detailed data on quarantine (Q) and pre-shipment (PS) uses. It is desirable for individual Parties to develop appropriate procedures for collecting data from MB users in order to meet the recent Beijing Amendment to Article 7(3) and Decision XI/13 that require governments to report data on QPS consumption.

5.7.1.2 Methyl bromide regulations and policies

Canada, the European Community, India, Kenya, The Netherlands, the United States and other Parties have harmonised national legislation with the controls under the Montreal Protocol for MB, or result in greater restrictions than those under the Protocol. Some countries have implemented policies and programmes intended to facilitate the adoption of alternatives. In the case of chemical alternatives, lack of registration, the inability of companies to capture profits from chemicals that lack patent protection, and limited market volume are all major constraints hindering the replacement of MB.

5.7.1.3 Alternatives for soil applications

The amount of MB available for soil disinfestation and non-QPS uses in non-Article 5(1) Parties was reduced by 25% in 1999. In most cases, appreciable savings in the amount of MB required for soil disinfestation have been achieved by the use of MB/chloropicrin mixtures with lower concentrations of MB, the use of lower doses of MB and/or the adoption of barrier films, and to a lesser extent by the adoption of alternatives. It is estimated that less than 5% of growers using MB previously have switched to alternative methods for soil disinfestation. In order for countries to satisfy future reduction schedules, alternatives will need to be adopted on a much wider scale.

Some chemicals, which directly replace MB, have gained wider acceptance. These include 1,3 dichloropropene/chloropicrin mixtures, chloropicrin and dazomet, used with or without additional pesticides. Continued research with methyl-iodide and propargyl-bromide demonstrate that they are effective as single chemical replacements for MB, although neither has been submitted for registration.

Greatest advances in adoption of non-chemical alternatives that directly replace or avoid the present uses for MB include: soilless culture, solarisation in areas where cropping practices and climates are suitable, and grafting and use of resistant plants for specific crop/pathogen complexes. The success of soilless culture, which has mainly been adopted in protected crops, will lead to expansion of its use in high value crops, where substrates are technically and economically feasible. Floatation systems, based on soilless substrates and hydroponics, are being used on more than 50% of tobacco seedling production in certain countries. The adoption of this technique has been a major success in Article 5(1) Parties and is currently expanding into cut-flower production.

The range of applicability for solarisation has been expanded by new techniques, although its adoption is still constrained by climatic conditions and heavy soils.

Grafting, new resistant rootstocks and varieties have been developed to control *Fusarium, Verticillium* and nematodes in tomatoes and cucurbits. These offer potential for greater adoption into areas where MB is now being used for these pests. Wider adoption of the technique in other crop/pest complexes where MB is used is constrained by the difficulty in developing plants resistant to a broad range of pathogens.

Other alternatives, such as biofumigation, organic amendments, and incorporation of green manure into the soil, have been subject to a considerable amount of research but, although promising, have not yet yielded consistent results as a replacement for MB. These alternatives are most useful as part of an Integrated Pest Management (IPM) programme.

Despite comprehensive research, MB is still required in some production systems: perennial tree and other replant, production of pest-free propagation material to meet legislative requirements, production of ginseng in China and controlling a specific virus of cucurbits in Japan. These uses were estimated by MBTOC to consume about 2000 tonnes of MB.

Demonstration projects such as those using dazomet, metam sodium, floatation trays, soil solarisation, steam and other techniques have been supported by the Multilateral Fund and bilateral aid but most have yet to be evaluated for their effectiveness.

5.7.1.4 Alternatives for durable commodities and structures

Since the 1998 Assessment, four additional fumigants have been identified as potential alternatives to MB: propylene oxide, methyl sulfonyl fluoride and some terpenoid and thiosulfinate natural products. None are registered as pesticides.

MBTOC was unable to identify existing alternatives for a very few specific non-QPS applications for durables and structures. These are estimated to consume less than 50 tonnes of MB globally per year. There were some particular QPS uses for which MBTOC did not identify approved alternatives. These include treatment of cotton against pinkboll worm and oak logs against oak wilt fungus, and these uses are expected to consume several hundred tonnes of MB per year.

MBTOC is not aware of any major durable commodity and structure applications where MB has been recently replaced by alternatives. It noted substantial increased use of MB in China for QPS treatment of wood and wooden packing materials.

Phosphine, usually generated *in situ*, is now available in various formulations as a compressed gas in cylinders mixed with either CO_2 or nitrogen, and has been registered in several countries. There are a number of phosphine generators under development, trial and use. Both these developments could further encourage acceptance of phosphine as a MB alternative. In-transit treatment of some bulk durable foodstuffs with phosphine in ships may potentially replace some pre-shipment uses of MB. It is estimated that this in-transit treatment could replace at least 500 tonnes per year of MB use (0.7% of current global consumption).

However, further expansion in the use of phosphine may be constrained by several factors. Increasing insect resistance has been reported particularly from the Indian sub-continent and from China, where it has resulted in an increase in the use of MB. Studies on the corrosive properties of phosphine have indicated that corrosion is greater at lower humidities than previously thought.

The use of sulfuryl fluoride in China and the USA to treat wood packaging materials in containers against quarantine pests has increased substantially since the last report. A significant change is the ongoing work to conduct laboratory efficacy trials to evaluate the potential of sulfuryl fluoride to control: stored product pests, log-infesting beetles and fungi, and quarantine pests of food commodities. The US manufacturer has estimated that sulfuryl fluoride could potentially replace about 4,000 tonnes of MB currently used in the USA and a total of 11,000 tonnes throughout the world.

Heat treatment is now increasingly used as an alternative to MB for timber and structures. It has been estimated that 15% of North American mills now disinfest with heat.

Demonstration projects for alternatives to MB for durable commodities and structures are in progress in 14 developing countries covering at least 17 commodities. They are expected to produce substantial information on the performance of alternatives to MB in Article 5(1) countries in a wide range of conditions. At least 32 workshops, conferences and seminars carried out in the past 2 years in 15 developed and developing countries have assisted with making stakeholders aware of alternatives for all uses of MB.

5.7.1.5 Alternatives for perishable commodities

Perishable commodities include fresh fruit and vegetables, cut flowers, ornamental plants, fresh root crops and bulbs. Almost all of the MB used for perishable commodities is for quarantine or pre-shipment (QPS) which is exempted from the control measures under the Montreal Protocol. The range of treatments was described in detail, both by technique and by crop, in the *1998 MBTOC Assessment Report*.

There are a number of quarantine research projects that have recently reported on techniques such as high voltage electricity, irradiation (gamma and electron beam), fumigants, chemical dips, water jets to wash pests off the surface of fruit, waxes and oils to suffocate mites and other pests, low oxygen combined with high carbon dioxide, heat treatments, cold treatments and inspection. Combinations of these technologies are often tested because of the synergistic effects compared to individual treatments. The research aimed at controlling pests is being conducted mainly in Australia, Israel, Japan, New Zealand and United States. In almost all cases, parallel experiments are being carried out to evaluate the effects of the treatment on commodity marketability.

MBTOC noted an increase in research on irradiation for quarantine treatments probably due to the release by USDA-APHIS of testing procedures for irradiation trials. In commercial practice increasing volumes of tropical fruit have been shipped from Hawaii and irradiated as a quarantine treatment on entry to mainland USA.

Researchers in Japan have begun to test the insecticidal effects of pure phosphine, a gas widely used for controlling pests on durable commodities, on pests typically found on fresh commodities. Some research indicated that pest control was possible without damage to the commodity.

Heat treatments to kill pests on tropical commodities continue to be developed based on the success of those approved recently in the United States. Of particular interest are a number of recent publications that propose standardising testing procedures for heat treatments leading to the development of an international thermo-tolerance database making it possible to expedite regulatory approval.

Commercialisation of alternative quarantine treatments will depend on a number of inter-related factors that include: proven treatment efficacy; commodity tolerance; equipment design and commercial availability; cost competitiveness; time limitations; regulatory approval; equipment capacity; availability and agreement on the scientific research required for regulatory approval; and technology adoption. Given all of these considerations, the time from conception to implementation of a disinfestation treatment for perishable commodities can vary from 2 to 15 years.

5.7.1.6 Quarantine and pre-shipment

The Beijing Amendment to Article 7(3) and Decision XI/13 will assist with developing a more comprehensive database on QPS use in the future. The Parties also agreed to a stricter definition of pre-shipment restricting treatment to within 21 days of shipment and clarifying those bodies able to authorise pre-shipment treatments.

The current exemption under the Protocol renders research on QPS alternatives lower priority than uses such as soil treatments where consumption under the Protocol is controlled. As a result, research laboratories involved in postharvest disinfestation of perishable commodities - and durable commodities that have QPS requirements - report continued difficulty in securing funds to continue research on the development of postharvest treatments that will substitute for MB.

Some Parties are putting in place control measures for QPS. For example, the European Community will adopt control measures in 2000 that include a freeze on QPS consumption from 1 January 2006, a requirement that each Member State must supply information on the quantity consumed and for what purpose, and the potential to reduce the quantity of MB for QPS depending on the technical and economic availability of QPS alternatives.

In response to Decision X/11, 25 Parties provided information on national regulations that mandate the use of MB for QPS. Thirteen Parties reported no specific regulations mandating the use of MB, including five that did not use MB at all for any purposes. Six Parties reported consumption of MB for QPS use in order to maintain compliance with importing Party regulations that specifically required the use of MB. Six Parties provided information on MB but did not address Decision X/11.

5.7.1.7 Reduction of methyl bromide emissions

Field and laboratory work aimed at reducing emissions of MB from soil fumigation has focused on research to better understand MB degradation in the soil, by promoting films with least permeability to MB, and by implementing better procedures when covering the soil with polyethylene films (PEF) during a MB soil fumigation.

Unfortunately, most PEF are permeable to MB and allow most of it to escape to the atmosphere - depending on PEF thickness, application depth, temperature, weather conditions, soil type and moisture, mineral content and micro flora-fauna. MB can also be released from film edges and directly from the soil after the film has been removed.

Although the use of virtually impermeable films (VIF) can reduce emissions significantly in some circumstances, in practice high emission reductions are difficult to achieve under normal circumstances on farms and in other agricultural situations. Ongoing research seeks to quantify the reductions, overcome constraints, supply issues, and economical disparities to determine the feasibility of wide-spread VIF.

There has also been some further research and development of previously identified technologies for capturing and recycling or destroying MB from commodity or structure fumigation. In addition to those sites described in the *1998 MBTOC Assessment Report*, a small recovery plant in the USA now captures MB for later destruction. These technologies have the potential to reduce MB emissions by 50 – 90% depending on the commodity. However, their cost and complexity and the absence of MB re-processing facilities currently limits consideration of this technology to locations where emission reduction is mandatory.

Dose reduction is possible for QPS treatments both through research that determines the minimal concentrations of MB required to control pests and by mixing MB at reduced dosage with other gases. However, some governments are requiring new QPS treatments for export of crops that will increase the amount of MB consumed.

Recycling has the potential to both reduce emissions from fumigation and to extend limitations on the quota of available MB where alternatives have not been implemented. However, issues concerning the purity and/or acceptability of the recovered MB to comply with specifications for established treatment schedules have not yet been fully addressed. Parties, regulatory agencies and the industry who wish to encourage the development and use of recovery and recycling technologies may need to consider the impact of the complexity of regulations surrounding re-labelling and reuse of recycled MB.

5.7.2 *Methyl bromide production and consumption*

This section provides an up-date on methyl bromide (MB) production and consumption trends, MB producers, and quarantine and pre-shipment (QPS) breakdown. It also provides information on baseline consumption of MB in Parties that have reported data. The baseline is used for calculating the freeze level and reductions for MB under the control schedules. Note that the baseline covers only the uses, which are controlled under the Protocol – soil, storage and structural uses – and it excludes uncontrolled uses of QPS and feedstock.

For more detailed information on MB consumption and production, refer to MBTOC (1998) and TEAP (1999).

5.7.2.1 Methyl bromide production

The worldwide manufacture of MB for all types of uses was estimated to be 71,425 tonnes in 1996 and approximately 71,400 tonnes in 1997, with industrialised countries accounting for the vast majority of production (MBTOC 1998). However, production of MB in Article 5(1) Parties has shown a significant increase in recent years, mainly because production in China grew from about 285 tonnes in 1995 to 2,330 tonnes in 1998. These national figures probably exclude the MB produced for QPS uses because the Protocol has not required countries to report on QPS, although the Beijing Amendment to Article 7(3) and Decision XI/13 will introduce compulsory reporting in the future.

The reported production of MB for soil, storage and structural uses, excluding QPS and feedstock, is shown in Table 5.4. Total production for soil/storage/structural uses was estimated to be about 61,436 tonnes in 1998, with 4% in Article 5(1) Parties and 96% in non-Article 5(1) Parties. The baseline production level for Article 5 regions is about 1324.5 tonnes, while the baseline for non-Article 5(1) regions (1991 level) is about 66,002 tonnes.

Table 5.4: *Reported production of MB for soil, storage and structural uses - excluding QPS and feedstock (metric tonnes)*

Countries	1991	1995	1996	1997	1998	Baseline
Article 5(1)	[a]124	321	1,118	1,477	2,382	1,324.5
Non-Article 5(1)	66,002	58,121	60,126	59,670	[b]59,054	66,002.0
Total non-QPS MB	[a]66,126	58,442	61,244	61,147	[b]61,436	

(a) Incomplete data.
(b) Estimated, because Israel has not reported production data for 1998.
Source of data: Reports by Parties to the Ozone Secretariat (as at March 2000).

5.7.2.2 *Methyl bromide producers*

There are now about 14 companies that manufacture MB, located in eight countries (Table 5.5). The major producers are Israel and the USA, followed by France, Japan and China, with minor quantities in India, Ukraine and Romania. Israel and the USA together produced approximately 80% of the global MB in 1998.

Table 5.5: *Current manufacturers of methyl bromide*

Country	Companies
China	Lianyungang Seawater Chemical First Plant, Jiangsu Province Changui Chemical Plant, Shandung
France	Elf Atochem SA
India	Tata Chemicals Ltd, Mithapore, Gujurat State
Israel	Dead Sea Bromine Ltd, Beer Sheva
Japan	Teijin Chemicals Ltd, Mihara, Hiroshima Prefecture Sanko Chemical Industry Ltd, Samukawa, Kanagawa Prefecture Nippon Chemicals Co Ltd, Isumi, Chiba Prefecture Dohkai Chemical Co Ltd, Kitakyushu, Fukuoka Prefecture Chemicrea Co Ltd, Chiba, Chiba Prefecture
Romania	SC Sintor-Oradea, Oradea
Ukraine	Saki Chemical Plant, Crimea
USA	Great Lake Chemical Corp, Arkansas Albermarle Corp, Arkansas

5.7.2.3 *Consumption of methyl bromide for soil/storage/structural uses*

Data on consumption of MB for soil/storage/structural uses, excluding QPS and feedstock and as reported by the Parties to the Ozone Secretariat, is shown in Table 5.6. Worldwide consumption of MB was about 63,370 tonnes in 1991 and fluctuated around 60,000 until 1997. Overall, the consumption of MB in industrialised countries has decreased, while consumption in developing countries has increased.

The data in Table 5.6 indicate the following trends in Article 5(1) countries for soil/storage/structural uses:

- Total consumption rose from 7,990 tonnes in 1991 to more than 15,970 tonnes in 1998;

- In every Article 5(1) region, MB consumption increased between 1997 and 1998;
- Consumption in the Middle East, Asia and Pacific region increased steeply from about 2,100 in 1991 to more than 4,800 tonnes in 1998, largely due to increases in China;
- In the Latin American and Caribbean regions, consumption rose steeply from about 2,630 tonnes in 1991 to 7,790 tonnes in 1994, and fluctuated around 5,800 from 1995 to 1998;
- In the African continent, consumption rose from about 3,000 tonnes in 1991 to about 3,700 tonnes in 1994 and increased recently to about 5,100 tonnes in 1998; and
- In the Article 5(1) CEIT countries, consumption decreased slightly from 250 tonnes in 1991 to 159 tonnes in 1994, increasing again to 255 tonnes in 1998.

For non-Article 5(1) countries, Table 5.6 shows the following trends for soil/storage/structural uses:

- Total consumption fell from 55,380 in 1991 to a reported figure of 38,903 in 1998 although the total for 1998 is more likely to be approximately 41,700 tonnes as consumption from Israel has yet to be reported;
- Consumption in Europe and non-Article 5(1) CEIT Parties was 19,660 tonnes in 1991 and 20,840 in 1995, falling substantially to 11,960 in 1998;
- In the USA, Israel, Japan and other non-Article 5(1) Parties, consumption decreased from 35,720 tonnes in 1991 to 27,430 tonnes in 1995 and an estimated 26,940 tonnes in 1998; and
- It is only in Europe, which includes the non-Article 5(1) CEIT countries, where a consistent downward trend in MB consumption was shown since 1995. In this region, consumption declined from 18,178 tonnes in 1996 to 11,760 tonnes in 1998, a 35% reduction in two years.

The baseline level of consumption for Article 5(1) countries (1995-98 average) is at least 14,475 tonnes, while the baseline for non-Article 5(1) countries (1991 figure) is about 55,380 tonnes.

Table 5.6: *Reported consumption of MB (tonnes) for soil/storage/structural uses - excluding quarantine and pre-shipment and feedstock*

Regions	**1991**	**1994**	**1995**	**1996**	**1997**	**1998**	**Baseline**
Article 5(1) Parties							
Africa	3,011	3,704	4,399	3,832	3,737	5,098	4,267
Middle East, Asia & Pacific	2,103	(a)	3,237	4,262	4,803	4,808	4,278
Latin America & Caribbean	2,627	7,792	5,874	5,590	5,733	5,815	5,753
Article 5(1) CEIT	250	159	145	118	193	255	178
Article 5(1) + CEIT total	7,991	12,790	13,655	13,802	14,467	15,977	14,475
Non-Article 5(1) Parties							
Europe & CEIT	19,660	(a)	20,840	18,178	16,918	11,760	19,660
USA, Israel, Japan and other non-Article 5(1)	35,720	(a)	27,430	26,555	30,055	26,943 (b)	35,720
Non-Article 5(1) total	55,380	(a)	48,270	44,465	46,973	(b) 38,903	55,380
Total non-QPS MB	63,371	(a)	61,925	58,267	61,440	(b) 54,880	

(a) Insufficient data reported by Parties
(b) Excluding consumption in Israel (data not yet reported)
Source: Compiled from Ozone Secretariat data (March 2000).

Baseline distribution

Consumption of MB varied considerably from country to country, even within the same climatic region. Table 5.7 shows the range of baselines among Article 5(1) and non-Article 5(1) Parties. The Article 5(1) Parties with the highest consumption (1,000 - 1,999 tonnes) are China, Brazil, Mexico, Morocco and South Africa, while the non-Article 5(1) Parties with the highest consumption (more than 2,000 tonnes) are the European Community, Israel, Japan and the USA.

Table 5.7: *Baseline consumption of methyl bromide in Article 5(1) and non-Article 5(1) Parties*

Baseline consumption (metric tonnes)	Number of Article 5(1) Parties	Number of non-Article 5(1) Parties
0 – 49 tonnes	66	15
50 – 99 tonnes	3	2
100 – 199 tonnes	5	1
200 – 499 tonnes	9	2
500 – 999 tonnes	4	1
1,000 – 1,999 tonnes	5	0
More than 2,000 tonnes	0	4

Source: Calculated from Ozone Secretariat data (at March 2000)

Quarantine and pre-shipment

MBTOC and TEAP have reported on QPS consumption previously (MBTOC 1998; TEAP 1999). MBTOC has recently conducted surveys to determine the use of MB for (a) quarantine and (b) pre-shipment purposes. Only 17 Parties provided MBTOC with data of this type (Table 5.8) and so MBTOC will carry out a further survey on QPS in 2001. It is desirable for individual Parties to develop appropriate mechanisms for collecting data from MB users in order to meet the recent Beijing Amendment to Article 7(3) and Decision XI/13 that require governments to report data on QPS.

Table 5.8: *Estimates of quarantine (Q) and pre-shipment (PS) consumption for countries responding to MBTOC surveys (tonnes).*

Country	1997			1998			1999		
	Q	PS	QPS	Q	PS	QPS	Q	PS	QPS
Article 5(1) Parties									
Chile	50	0	50	40	0	40			
Ethiopia	10	8	18	11	8	19			
Honduras				0	1.5	1.5			
Morocco	0	0.1	0.1	0	0.1	0.1			
Panama	0.3	0	0.3	0	0	0			
South Africa	[a]36		[a]36	[a]47		[a]47			
Thailand	0	584.2	584.2	0	500.9	500.9	0	718	718
Vietnam	296	70	366	320	75	395			
Non-Article 5(1) Parties									
Belgium	1	18	19						
Canada	2.2	10.1	12.3						[a]5.9
Greece	50	50	100	50	50	100			
Hungary	0	0	0	0	0.5	0.5			
Japan	2030	0	2030	1679	0	1679		0	
Netherlands	1	5	6	1	5	6	1	5	6
Norway	0.1	0.1	0.1						
UK	44.4	14.2	58.6	36.2	16.0	52.2	22.7	15.6	38.3
USA			[a]600			[a]550			[a]450

(a) Preliminary estimates. Source: MBTOC surveys 1999-2000

5.7.3 Methyl bromide regulations and policies

The 1998 MBTOC Assessment reported on legislative controls for MB in various countries (MBTOC 1998). This section discusses new legislation affecting MB consumption, and the expedited registration process for alternatives to MB implemented by Canada and the United States.

5.7.3.1 Legislative changes by country

Canada, the European Community, India, Kenya, The Netherlands, the United States and other Parties have implemented legislative changes that harmonise national legislation with the controls under the Montreal Protocol for MB, or result in greater restrictions than those under the Protocol.

Canada

Canada will be introducing amendments in 2000 to the Ozone Depleting Substances Regulations of the Canadian Environmental Protection Act (CEPA) to allow implementation of the controls for MB under the Protocol.

These changes will amend existing regulations under CEPA which included the 1995 freeze and a 25% cut in 1998. The new regulations will retain the permit system, which allocates import permits to over 120 users and allows them to either trade these permits with other users or relinquish them when no longer required.

In addition, in 1999 as part of the Industry Government Working Group, procedures were adopted that will be used to verify and support Canada's critical use nominations, if any, at the time of phaseout.

European Community

The European Community is in the process of replacing the current Council Regulation (EC No 3093/94) on substances that deplete the ozone layer with new legislation. On 23 February 1999, the Council of the European Community agreed a Common Position on a new Council Regulation on substances that deplete the ozone layer (Anon. 1999). The regulation is expected to be finalised by September 2000. The new regulation is expected to introduce, *inter alia*, a series of controls on MB consisting of:

- Phase out schedule for production and consumption: 60% cut 2001; 75% cut 2003; 100% 2005;
- Ban on use from 1 January 2006, with the exception for QPS, emergency uses and any critical uses;

- Freeze on consumption of MB for QPS based on average consumption in 1996-98, with provision for further reductions depending upon availability of alternatives; and
- Mandatory use of Virtually Impermeable Film or other comparable techniques for soil fumigation to minimise leakage.

India

Although India produces MB, the fumigant is banned for all purposes except for QPS uses. More recently, India introduced ODS regulations including measures to phase out MB by 2015 (Anon. 2000). These include steps such as immediate compulsory registration of exporters and importers and maintenance of records by users, importers, suppliers and stockists. The data will be collected and analysed by the Indian Ministry of Environment.

Kenya

In February 2000, Kenya passed the Environmental Management and Co-ordination Act that requires the import and export of ODS including MB, its storage, its use and disposal to be carried out under a license issued by the Minister for the Environment. This Act meets the requirement under Article 4(b) of the Protocol to put in place a licensing system by 2005 to control the import and export of ODS including MB.

The Netherlands

A regulation is being introduced in 2000 that will prohibit the use of MB after 1 January 2001, with an exemption for critical uses and QPS. The exemptions would cover use of MB for fumigation of containers for export to Australia and New Zealand, cocoa beans and similar commodities in units larger than 250 tonnes, and seeds and plant material.

Fumigation must be carried out in facilities equipped with activated carbon filters to minimise emissions. This regulation is expected to limit the use of MB in the Netherlands to current levels of 8 tonnes per year.

United States of America

In late 1998, the United States took legislative action to harmonise U.S. regulations on the phase out of MB with those of the Montreal Protocol. These included a final phase out date of 2005 (with graduated reductions in 1999 (25%), 2001 (50%) and 2003(70%)) as well as exemptions for quarantine and pre-shipment uses, critical agricultural uses, and emergencies. The U.S. Environmental Protection Agency (U.S. EPA) is currently in the process of developing regulations to implement the changes Congress made to the Clean Air Act in 1998.

5.7.3.2 Policy measures – registration

Lack of registration for pesticides in general is a major constraint in the development and adoption of alternatives to MB. Unlike the majority of alternatives to other ozone depleting substances, the use of MB alternatives with food requires them to be registered by the appropriate Government agencies before use. The major barriers inherent in the registration process are:

- Relatively high cost (US$10-15 million) in relation to potential profit and risk;
- Several years time delay to finalise registration;
- Small crop production and post-harvest volumes making profit recuperation difficult;
- Uncertain or insufficient profit expectations to justify registration expenditure; and
- Lack of patent protection for many prospective alternatives.

In order to overcome some of these difficulties, the Canadian Pest Management Regulatory Agency and the U.S. EPA have implemented expedited procedures for priority chemicals based on a joint review of reduced-risk pesticides. As MB is now categorised as a priority chemical, the total review and decision time related to regulatory approval for alternatives to MB in both Canada and the USA is expected to be reduced. Furthermore, since many other regulatory agencies support registration in their own countries based on US approval, this process is expected to expedite registration of chemical-based alternatives in many other parts of the world.

5.7.4 *Alternatives for soil treatments*

5.7.4.1 Introduction

Since the publication of the *1998 MBTOC Assessment Report*, clearer trends are developing on the effectiveness of alternatives to replace methyl bromide (MB) for preplant soil disinfestation of pathogens and weeds. Greatest advances in finding alternatives that directly replace the present uses for MB have been obtained with those methods which provide broad-spectrum control or those, which avoid the need for cropping in soil. These include:

- Soilless culture in areas where substrates are available;
- Cultural practices, such as floatation trays for tobacco seedling production, solarisation alone or in combination with other alternatives in areas where cropping practices and climates suit its use, and grafting for some specific crop/pathogen complexes e.g. tomatoes, melons;
- Resistant varieties for specific pathogens, particularly root knot nematodes;
- Fumigants applied alone or as mixtures e.g., 1,3-dichloropropene/chloropicrin (1,3D/PIC), metam sodium/PIC, PIC alone, and dazomet alone, with or without additional pesticides or other non-chemical alternatives; and
- Several new fumigants (e.g. methyl iodide and propargyl bromide) that are providing pathogen and weed control equivalent to MB but are yet to be registered anywhere in the world.

Improvements in control of a range of soil-borne pathogens and weeds have also been obtained by a combination of methods that form part of an integrated pest management (IPM) programme. Most IPM programmes have been developed for specific pests, climatic regions and soil types. They require considerable development in many countries before they can be expected to provide broad-spectrum control that is presently given by MB (Chellemi 1998; Besri 1999; Gabarra and Besri 1999; Porter *et al*. 1999).

This section discusses methods that have been used to reduce doses, non-chemical and chemical alternatives to MB, and uses of MB where alternatives have yet to be fully developed.

5.7.4.2 Methyl bromide dose reduction

Since 1998, MB dose reductions for preplant soil fumigation have been a major factor enabling countries to satisfy the commitments for MB reductions under the Montreal Protocol (Lopez-Aranda 1999ab; Porter *et al*. 1999).

In regions where MB has been traditionally applied by hot or cold gas injection at 100g/m^2, MB dose rate reductions have primarily occurred by the adoption of lower rates of 40 to 60g/m^2. Recently, further reductions of up to 50% i.e. 20-30g/m^2, have been possible by adoption of Virtually Impermeable Film (VIF) barrier films (Minuto *et al*. 1999a) or by combining solarisation with fumigation (Besri 1999; Tjamos 1999). In regions where fumigation is predominantly achieved by MB/PIC (98:2, 70:30, 67:33) mixtures injected into soil, dose rate reductions have mainly been achieved by using mixtures containing even lower concentrations of MB/PIC (50:50, 33:67). In these regions, barrier films such as VIF have been less effective because lower rates (30-40g) of MB/PIC mixtures have already been adopted (Lopez-Aranda *et al*. 1999b). Further information on VIF film, and minimum standards of film set in some countries, is provided in the section 5.7.8 "Reducing Methyl Bromide Emissions".

MB/PIC mixtures with lower rates of MB have the added benefit that they have provided excellent control of fungal pathogens and have produced significantly higher yields (14%) of crops than mixtures with higher ratios (98:2 and 70:30) (Porter *et al*. 1998). These low MB ratio mixtures, however, have the disadvantage that they are less effective for control of weeds, although this has been overcome in some areas by the incorporation of herbicides (Fennimore and Richard 1999; Gilreath *et al.* 1999b).

5.7.4.3 Chemical alternatives

Formaldehyde

A new formulation of formaldehyde has recently been shown to provide effective broad-spectrum control of soil-borne pathogens without the previously reported phytotoxicity (Kritzman *et al.* 1999). At the present time, regulations in many countries prevent the use of formaldehyde products because of health and safety concerns.

Fumigants applied alone or as mixtures

Recent studies have shown that several fumigant used alone or as mixtures provide control of pathogens and provide increases in yield, which are almost equivalent to that obtained with MB (Duniway *et al*. 1999; Freitas *et al*. 1999; Locascio *et al.* 1999; Porter *et al*. 1999). In these studies, however, the most promising alternatives have lacked the consistency obtained with MB, mainly because the efficacy of alternatives is influenced more by climate, soil type and condition, and method of application (Trout and Ajwa 1999a; Shaw and Larson 1999).

Some new chemicals, e.g. methyl iodide, other iodinated hydrocarbons, and propargyl bromide, have been reported to provide a similar efficacy to MB and have potential to be single chemical replacements for MB (Yates and Gan

1998; Hutchinson *et al.* 1999). The commercial viability of these new chemicals needs to be investigated as in most cases, research is identifying that combination treatments are required as MB alternatives.

Recent developments with 1,3D/PIC mixtures have not only broadened the range of pathogens effectively controlled, but also demonstrated control of germinated weeds (Gilreath *et al*. 1999b; Duniway *et al*. 1999; Locascio *et al*. 1999). It is the main fumigant combination presently replacing MB. However, the requirements for buffer zones in some countries that seek to address neighbour concern of offsite movement of fumigant, as well as concerns over lack of consistency, longer periods before crops can be replanted and enhanced biodegradation are all issues affecting expansion in use of this product as an alternative to MB (Ou 1998). In areas with high disease pressure or where depth of control is required (e.g. trees and vines) this mixture is not as effective as MB (Locascio *et al*. 1999). New emulsifiable formulations of 1,3-D/PIC, when applied through drip irrigation have shown promising results in research trials on strawberries and tomatoes. This methodology has the potential to reduce offsite movement of fumigants and may also be more cost-effective than existing application methods (Trout and Ajwa 1999b).

There is now wide acceptance that in areas where weed and nematode pressures are low, chloropicrin alone is as effective as MB for control of fungal pathogens (Locascio *et al*. 1999; Porter *et al*. 1999).

Methyl isothiocyanate (MITC) generators

Inconsistent control of pests has been the major factor affecting the adoption of the methyl isothiocyanate (MITC) generators as a replacement for MB (Locascio *et al.* 1999; Shaw and Larson 1999). Recent research has shown that more consistent results can be obtained by using application techniques, which provide a more uniform distribution of the fumigant in soil and tarping to reduce vapour loss (Haglund 1999).

Similarly, improvements in dazomet application are showing that it can also provide equivalent or better control than metam sodium (Locascio *et al.* 1999). Also, because dazomet is a granular formulation it is less hazardous to apply than other fumigants and therefore is particularly useful for application in confined spaces or for protected crops. Performance of both of these products has been shown to be equivalent to MB when combined with chloropicrin and when tarps are used (Porter *et al*. 1999; Minuto *et al.* 1999a).

A disadvantage of the MITC compounds is that they have long residue times in the soil and require longer periods before crops can be replanted than when MB is used, especially in cool conditions (Wiseman *et al*. 1998). A new, less toxic derivative of ITC, allylisothiocyanate, which has recently been developed in

Italy, shows similar results to MITC contained in metam sodium (Minuto *et al*. 1999b).

Recent reports about enhanced biodegradation of compounds containing MITC are placing doubts about the usefulness of these products as alternatives to MB as their effectiveness appears to be reduced after repeated applications (Wharton and Matthiessen 2000).

Methyl iodide and other iodinated compounds

Since the last report, methyl iodide has been tested on a wider range of crops and continues to demonstrate efficacy equivalent to MB (Hutchinson *et al.* 1999; Schneider *et al.* 1999; Zhang *et al.* 1998; Becker *et al.* 1998). Cost and registration issues are major factors affecting commercialisation. The potential for other iodinated hydrocarbons to replace MB for nematode control has recently been demonstrated (Rodriguez-Kabana 1999ab).

Ozone

Although ozone has been shown to increase tomato yields, the response is not attributed to disease control and therefore more research is required to determine if it is an alternative to MB (Pryor 1999).

Propargyl bromide

Trials in Florida have demonstrated excellent control of nematodes equivalent to that achieved with MB but regulatory concern and lack of registration still affect the potential for this product (Noling *et al*, 1999).

5.7.4.4 Non-chemical alternatives

Biofumigation

Biofumigation is the amendment of soil with organic matter that releases gases, which control pests. Since the last report (MBTOC 1998), much research has been undertaken to improve bio-fumigation techniques and to develop a greater understanding of the action of various by-products from organic amendments (Kirkegaard *et al.* 1999). Recent studies have shown the technique to be effective for control of certain pests in a broader range of crops. However, it does not disinfest soils as effectively as MB or other synthetic soil fumigants (Chavarria-Carvajal *et al.* 1999ab; Charron and Sams 1999; Bello *et al.* 1999; Elena *et al.* 1999).

Incorporation of the plant *Tagetes* species into soil has been found to reduce the nematode populations significantly. However, *Tagetes* has no effect on fungal diseases or weeds. This technique is now widely used in many countries on specific crops but, due to its lack of broad-spectrum activity, it is not considered a direct alternative to MB (Lung 1997).

Biological control

Biocontrol agents, although not providing the same broad spectrum control as MB, have demonstrated effective control of specific weeds, parasitic plants and soil-borne pathogens (Dinoor *et al.* 1999; Nof *et al.* 1999; Bedi *et al*. 1999; Gontmakher *et al.* 1999; Melo and Saito 1999; Soytong and Jonglaekha 1999; Matsumoto *et al*. 1999). Their major benefit as a replacement to MB is when they are part of an IPM programme.

Biorationals

In the past few years, a number of bio-rational compounds have been evaluated for controlling nematodes and weeds (Anon 1998; Noling *et al*. 1999). Most have provided inconsistent responses and none have provided control equivalent to that of MB. Crop yield is typically more than 20% less than that achieved in MB-treated plots. A combination of extracts of mustard meal and Neem, and mustard meal oil and an extract from chillies, have been shown to give broad-spectrum control of nematodes and weeds (Seal 1997; Anon 1998; Chavarria-Carvajal *et al*. 1999b). In comparison to untreated soils, however, several have provided yield responses in the absence of any pest control and thus highlight the potential advantages of some of these products as a component of an IPM programme (Noling *et al*. 1999).

Grafting

Grafting has been used successfully to control many soil-borne pathogens. Large-scale commercial production of grafted vegetable seedlings e.g. melons and tomatoes, is expanding in many countries and some new resistant rootstocks are now available (Mazollier 1999; Edelstein *et al.* 1999). Grafting is a replacement for MB only for certain specific crop-pest complexes and is sometimes used in combination with other practices/treatments.

Induced resistance

Attempts to utilise plant growth promoting rhizobacteria and the addition of mycorrhizal fungi have not proven completely successful for protecting crops against soil-borne diseases. Further development is required before they can be considered a replacement for MB (Elad 1999).

Naturally occurring compounds

Since the last report, more research has been conducted on the use of furfuraldehyde, a by-product of sugar cane processing, and benzaldehyde, found in essential oils of peach seeds (Chavarria-Carvajal 1999b). This research has demonstrated their effectiveness in managing nematodes and some pathogenic organisms.

Organic amendments

Use of organic amendments as a component of integrated cropping system is increasing because of their benefits as fertilisers and their ability to control soil-borne pathogens. Research continues to show that organic amendments, such as green manure and compost, can control various soil-borne pathogens although not to the same level of control as MB (McSorley *et al*. 1998; Anon. 1998; DeCeuster and Hoitink 1999; Tenuto and Lazarovits 1999; Tsror 1999). Amending composted plant refuse with a range of beneficial yeasts, actinomycetes, fungi and bacteria has prevented disease and enabled Colombian flower growers to avoid the use of soil fumigants (Pizano 1999).

Soilless culture

The use of soilless growing media has expanded in the last few years and, in many countries, now offers a competitive system which avoids the need for MB to produce high quality and high yielding crops (Papadopoulous 1999; Kipp *et al*. 1999; Benoit 1992). Soilless production has predominantly gained acceptance for plant production in protected cropping situations e.g., polyhouses and glasshouses, or plant nurseries. Presently, the techniques are considered to have less potential to replace MB for large-scale open field operations because of limited availability of suitable local substrate materials. A new form of 'hydroponic' soilless culture, however, where beds 15cm deep are carved directly out of the ground, lined with black polyethylene and filled with burnt rice hulls, is being increasingly adopted for production of carnations in Colombia (Pizano 1999).

The development of a various substrates materials now means there are many different options available for a given crop. Standards and guidelines exist for a wide range of flower and vegetable crops in protected cultivation and for tree nurseries (Kipp *et al*. 1999).

Successful implementation of substrates has led to the development of the floatation tray method to produce tobacco seedlings in many countries such as Australia, Argentina, Brazil and Zimbabwe and for cut-flower production in Kenya (Thomas 1999). This technique is now applicable for both large and small farm operations, has been extremely effective in many regions and has been adopted in most instances as an alternative to MB. It has been particularly successful at reducing production costs in areas such as Argentina where substrate materials are locally available (Miguel Costilla, Estacion Experimental Agro-Industrial Obispo Colombres, pers. comm.). Indications are that most tobacco seedlings worldwide could be grown by this method.

The incorporation of fungi and bacteria into substrates has increased the potential of several substrates as a soilless growing media because of either; i) increased resistance of plants to disease by induction of a host defence response (Yedidia *et al*. 1999; Kubota & Abiko 1999) or, ii) improvement in biological control of pests (DeCeuster and Hoitink 1999). Incorporation of *Trichoderma* into substrate mixes of forest seedlings has provided protection against a range of soil pathogens and improved their establishment once transplanted into soil (Gromovykh *et al*. 1999).

Soil solarisation

Since the last report, there have been numerous studies conducted on the use of soil solarisation for broad-spectrum control of pathogens and weeds, particularly in combination with fumigants, biocontrol agents and organic amendments as replacements for MB. Even in hot climates, solarisation must be combined with other methods to achieve control of pathogens to levels approaching those obtained with MB (Yucel *et al.* 1999; Gamliel *et al.* 1999ab; Chase *et al.* 1998a). New plastic formulations that increase soil temperature have extended solarisation's usefulness into cool regions (Chase *et al.* 1998bc). The technique of solarisation can be improved in a cultivation system where vertical root growth is restricted to within the solarised layer by polyester cloth (Mihira *et al.* 1999).

Steam

Although there have been no major technological advances, steam continues to be a direct replacement for MB in high value protected crops. For example, steam has been proposed as a demonstration project for cut flowers and strawberries in Argentina (Anon. 2000), as well as in demonstration projects in a number of other Article 5(1) countries.

5.7.4.5 Article 5(1) perspective – alternatives for soils

Since 1995, the Multilateral Fund and bilateral assistance have allowed many alternatives to be demonstrated in developing countries (Stubbs 1999; Pizano 1999, 2000; Patino 1999; Castello-Lorenzo 1999; Cao 1999). In general, the results have yet to be accepted and adopted by farmers and therefore adoption of alternatives to MB continues to be a priority area for Article 5(1) Parties.

Non-chemical alternatives have been adopted in order to meet market demands of non-Article 5(1) Parties, such as specific Codes of Conduct on Flower Production and Trade, which are aimed at discouraging the use of banned or controlled pesticides. The Article 5(1) countries have recently been made aware of the benefits of growing their crops for export markets under internationally acceptable environmental standards (e.g., The Netherlands MPS programme and German BGI Flower label programme). Countries like Colombia, Ecuador, Kenya, Malawi, Uganda and Zimbabwe have made (or are now in the process of making) arrangements to implement similar schemes that meet environmental standards for crops grown without MB, other banned or controlled pesticides. Such schemes as these, and other eco-labelling initiatives, will accelerate the reduction in use or phase-out of MB.

Solarisation is one alternative, which is cost-effective in Article 5(1) countries and normally suitable for regions with high solar radiation and minimum cloud cover. Demonstration projects are being implemented in Argentina, Brazil, Cameroon, Chile, Costa Rica, Croatia, Dominican Republic, Ecuador, Guatemala, Kenya, Lebanon, Macedonia, Morocco, Philippines, Sri Lanka, Turkey and Uruguay. The projects are likely to yield results that will lead to adoption of this technology.

Steam pasteurisation is expensive for many farmers and only limited demonstration projects have been conducted in Brazil, Guatemala, Jordan, Kenya, Morocco, Sri Lanka and Zimbabwe.

A recently completed demonstration project in China demonstrated that alternatives that were environmentally acceptable and cost effective were available for all crops presently using MB except ginseng (Anon. 1999). The use of dazomet, local substrates and biofumigation were amongst the most promising alternatives to MB. The antibiotic avermectin was also effective for nematode control, but concerns over its impact on other organisms warrant further investigation. Floatation trays, substrates and soilless cultivation techniques were considered the best alternatives to replace MB in certain crops, particularly for tobacco and strawberries.

Demonstration projects involving the use of dazomet and metam sodium, 1,3D, in combination and alone, have recently been approved for several Article 5 (1) countries.

Investment projects in many African, South and Central American Article 5(1) Parties are now being formulated for approval and funding by the Multilateral Fund and reductions in MB are anticipated.

5.7.4.6 Areas yet to find alternatives for soil treatments

Despite some new developments in the area of controls for perennial tree and other replant problems e.g. the use of soil-applied streptomycin and activated charcoals, the manipulation of *Rhizosphere* bacteria and the application of 1,3-D/chloropicrin by micro-irrigation, little progress has been made replacing MB (McKenry 1999; Brown 1999; Mazzola 1999; Trout and Ajwa 1999b; Schneider *et al.* 1999; Luzzati and Katan 1999).

To date, an alternative has not been found to replace MB treatment for replant of medicinal herbs e.g., ginseng in China (Anon. 1999). In several places worldwide, there is still a mandatory and increasing requirement for the treatment of soils with MB to satisfy certification requirements such as turf in the United States.

5.7.5 Alternatives for durable commodities and structures

5.7.5.1 Introduction

Durables are commodities with low moisture content that, in the absence of pest attack, can be stored for long periods without deterioration. They include foods such as grains, seeds, dried fruits and beverage crops; and non-foods such as timber, wood products and tobacco. Wood products include museum artefacts and other items of historical significance, timber products and bamboo-ware, and packaging materials and other items that can be of quarantine significance.

Structures include entire buildings (or portions thereof) being treated to control wood-destroying organisms and other pests. Treatment of structures may also include food production and storage facilities for control of stored product insects and other pests. Transport vehicles, including ships, aircraft, freight containers and others, may require treatment to control stored product insects, rodents and other pests.

Currently, MB as a fumigant of durables and structures, is primarily used to disinfest grain stacked in bags, food processing facilities such as mills, durable foodstuffs such as cocoa, grain, certain dried fruits and nuts. MB is also used for a wide variety of quarantine applications, notably treatment of logs and wooden packaging materials.

The *MBTOC 1998 Assessment Report* reported that 15% of MB used worldwide was used on durables and structures. This percentage is unlikely to have changed significantly since that time. MBTOC was not aware of any recent major areas of substitution of MB use with alternatives. However, it noted particularly substantial increased use of MB in China for QPS treatment of wood and wooden packing materials as a result of quarantine requirements of USA and Canada. This increase amounted to about 900 tonnes per year. Use is likely to increase further with increased trade if China becomes a member of the World Trade Organisation and if an alternative to MB is not in place.

MB is favoured worldwide where there is a tradition of successful use e.g., bag stack disinfestation in parts of Africa or treatment of flourmills in North America. MB is used particularly where logistical constraints require very short treatment times, such as in some export situations or where approved alternatives are unavailable, such as in many quarantine situations or where structures are insufficiently gastight to allow extended fumigations with phosphine.

Target pests for MB treatment include stored product pests (mites, beetles, moths), cockroaches, silverfish, psocids, flies, spiders; wood-destroying insects (termites, beetles); and rodents.

This section builds upon previous information from the *1998 MBTOC Assessment Report* and should be read in conjunction with that report (MBTOC 1998). It discusses non-MB techniques and methods for disinfestation of durables, some constraints to implementation and adoption, situations where a non-MB treatment has yet to be developed, and provides a developing country perspective.

5.7.5.2 New techniques and methods

MBTOC has only become aware of four potential techniques that may have application as a MB alternative that were not included in the *MBTOC 1998 Assessment Report*. These are fumigation with some terpenoid and thiosulfinate natural products, methyl sulfinyl fluoride, and propylene oxide. None are registered as pesticides.

The remainder of this section updates research on techniques previously assessed by MBTOC.

Sulphonyl fluoride

Sulphonyl fluoride (SOF_2) has been tested (Reichmuth C., in press) under laboratory conditions as a potential new fumigant. It is highly active against stored product insect pests, but will require extensive further study as well as commercial sponsorship in order to achieve registration for use.

Natural products

Terpenoids derived from an *Artemesia* species and thiosulfinates derived from an *Allium* species have been proposed as MB replacements (Dunkel and Sears, 1998; Auger *et al.*1999). Both mixtures have high toxicity to several stored product insect pests.

Propylene oxide

Propylene oxide (PPO) has been suggested as a possible replacement for MB for fumigation of some food products, particularly those fumigated under vacuum (Griffith 1999). PPO must be applied under vacuum for safety and efficacy reasons. The material has registration and residue tolerances for use as a sterilant for nutmeats, cocoa powder, and spices in the USA. PPO is listed by the U.S. EPA as a 'likely carcinogen' (Griffith 1999).

Carbon disulphide

Carbon disulphide is in routine commercial use as a grain fumigant in parts of Australia and as a disinfestant for non-oily cereals and products such as 85% extraction flour (Desmarchelier *et al.* 1998), and polished rice in China. Carbon disulphide has traditionally been used in stores that are not well sealed. These studies have shown improved efficacy when carbon disulphide is used in sealed stores, and provide further data on airing of residual fumigant from grain and effect of processing on residues in finished products (Ren and Allen 1998). Australian studies aimed at modernising application technology and improving the data to support registration are continuing.

Carbonyl sulphide

Further small-scale field trials on this patented MB replacement have been conducted (Desmarchelier *et al.* 1998). In trials in 50 tonne lots of grain, residues have been found to decay rapidly to naturally occurring levels upon airing. The penetration of carbonyl sulphide has been shown to be superior to MB through both soft and hard wood timbers, but neither penetrated effectively across the grain of the wood (Ren *et al.* 1997).

Controlled atmospheres

Controlled atmospheres derived from an exothermic generator have been tested for disinfestation of dried figs (Demarli *et al.* 1998). Complete mortality of the moth pest, *Ephestia cautella*, was achieved in 10 tonne lots treated with <1% O_2, 10-15% CO_2, balance N_2 at 25°C for 30 h. Commodity quality was unchanged.

Debarking of timber

Removing bark from timber is practised to a very limited extent as a control measure against pests, particularly bark beetles. Debarking appears to have the potential to reduce the need for MB fumigation where bark-borne pests are the objects of the treatment. Debarking can be easily done for certain species of timber, but not all species.

Heat treatment

Heat treatment of flour mills, processing facilities, timber and commodities can result in complete pest mortality. It is one of the very few processes with the potential to meet rapid treatment requirements. Heat treatment is now increasingly used as an alternative for MB.

One major North American milling company currently heat treats 30% of their mills. It has been estimated that 15% of North American mills currently disinfest with heat (J. Heaps, Pillsbury Ltd, pers. comm.). Effectiveness of this process requires quality control programs to monitor pest infestation, disinfestation of packing materials and storage containers.

Heat treatment of timber against certain pests is becoming increasingly common. To some extent, the observed increase in the use of this technology is being driven by pests not normally controlled by MB e.g., pine wilt nematode in timber and timber packing in trade from USA to China or control of certain fungal pest for timber imports into USA. Heat treatments will differ depending on the pests being controlled. This will lead to different treatments for different situations e.g. Malaysia and the USA have different heat regimes for control of pests in timber.

Very high dosages of MB are required for control some fungal pathogens associated with timber in trade. Heat is effective as an alternative against many fungi. As heat can eliminate both quarantine and non-quarantine pests continued expansion in use is likely. For further information, contact http://www.ars.usda.gov/is/np/mba/jan97/steam.htm.

Kidd (1999) has provided an updated review of the use of heat in combination with controlled humidities as well as controlled atmospheres to replace MB fumigation for the treatment of valuable artefacts.

Inert dusts

There continues to be substantial interest in the use of inert dusts for control of insects of stored products (Golob 1997; Korunic 1998).

Irradiation

Expanded commercial availability of electron beam and X-ray irradiation equipment may increase the number of machines available for the irradiation disinfestation of durable commodities. In the United States, several electron beam and X-ray irradiation facilities have recently been constructed. Additionally, the approval of a new food standard for Australia and New Zealand may facilitate future approvals of new uses of irradiation by providing a standard for irradiation applications (Australia & New Zealand Food Authority Standard A-17 1999).

Phosphine

Typically, phosphine is applied as aluminium phosphide or less commonly as magnesium phosphide preparations. These decompose by the action of ambient humidity liberating the fumigant gas. Problems of slow and uncontrolled release of gas, inadequate dosage profiles and residues from formulations have driven interest in developing an external supply system for phosphine.

An external supply system for phosphine consists of cylinders of this gas compressed and mixed with either CO_2 or nitrogen. Various formulations are registered in several countries including Australia, Cyprus, Germany and USA (Cytec 2000). There are also a number of phosphine generators under development, trial and use. These are based on hydrolysis of aluminium or magnesium phosphide in some form of reactor. In many designs, a stream of CO_2 is used to entrain the liberated gas to reduce its flammability (Horn 1998). Forms of these devices are in use in China for disinfestation of bulk grain and have been successfully trialled for treatment of mills in USA, empty shipholds in Canada (Fields and Jones 1999) and grain in silo bins in Australia. Where the corrosion problems associated with phosphine and its slow action can be tolerated, generators may provide an efficient alternative to MB fumigation. Target concentrations are achieved more rapidly. They avoid formulation residues and can give more controllable and consistent dosage profiles.

Phosphine in-transit fumigation

In-transit treatment of some bulk durable foodstuffs with phosphine in ships may potentially replace some pre-shipment uses of MB. It is estimated that this in-transit treatment could replace at least 500 tonnes per annum of MB use, equivalent to 0.7% of current global consumption (C. Watson, Director Igrox Ltd UK, pers. comm.). For example, in-transit phosphine could replace MB when the latter is used as a rapid disinfestant at point of export to meet official phytosanitary requirements of some importing countries. Much of this use could be in Article 5(1) countries, particularly in Thailand and Vietnam. Typical examples include shipments of rice, cassava chips and other durable foodstuffs in bulk and bags. These treatments may be conducted at the dockside, in lighters or barges prior to loading a ship, or in the ship after loading and before sailing. Phosphine could also be used to replace MB as an in-ship quarantine treatment for bulk cargo at the discharge port.

For safety and efficacy reasons, in-transit treatment with phosphine is restricted to specially-designed bulk carriers, tanker-type vessels and other ships where the holds are gastight or can be made so (Semple and Kirenga 1994). In addition, equipment must be installed to circulate the phosphine through the cargo mass (Watson *et al.* 1999). The circulation equipment ensures that the gas penetrates throughout the load and can be aired from the load prior to unloading. In-transit treatment of quarantine pests with phosphine requires treatment acceptance by regulatory authorities, in addition to requiring appropriate vessels and equipment (Watson *et al.* 1999; IMO 1996; Semple and Kirenga 1997).

The 1996 revision of the International Maritime Organisation (IMO 1996) specifically recommends that cargoes should not be fumigated in ships with MB prior to sailing due to the risks resulting from the difficulty in ventilating the cargo effectively. Despite the recommendations of the IMO, the practice of MB fumigation in ships prior to sailing remains widespread.

Phosphine treatment in ships in port

A summertime demonstration was carried out comparing MB and two formulations of phosphine (supplied by generator or from gas cylinders) for disinfestation of empty shipholds (Fields and Jones 1999; Mathews and Shaheen 1999; Cavasin *et al.* 1999). It showed phosphine was effective in controlling several different stored product insects. The phosphine treatments required 72-hour exposures to kill lesser grain borer compared to less than 32 hours for MB, but were more rapid than MB against red flour beetle.

Phosphine treatment of export hay

Phosphine has been demonstrated to control Hessian fly *Mayetiola destructor* to quarantine level of security in compressed hay using 60g/28.3m^3 phosphine for 7 days at 15.4 – 19.6°C (Yokoyama *et al.* 1999). Wrapping bales in low-density polyethylene bales did not affect the efficacy of the treatment.

Sulfuryl fluoride

Sulfuryl fluoride has been used primarily to fumigate structures and furniture to control dry-wood termites and other wood-destroying pests in the United States. Secondary uses include fumigation of wood products and transport vehicles. During these treatments all food products must be removed or excluded prior to treatment since no food tolerances exist. Sulfuryl fluoride is also used in China and the USA to treat sea containers that contain wood packaging materials potentially infested with the Asian longhorned beetle. This quarantine use has increased substantially in the past two years.

A significant change is the ongoing work with commodity associations, government research agencies, and university researchers to conduct laboratory efficacy trials to evaluate the potential of sulfuryl fluoride to control: stored product pests, log infesting beetles and fungi, and quarantine pests of food commodities. In addition, trials are ongoing to determine effects of sulfuryl fluoride on taste, quality of dried fruits and tree nuts and on residue levels, and its phytotoxicity to perishable commodities. Field trials are being conducted in a variety of food processing mills to improve fumigation efficiency and stewardship for this potential new use pattern.

Discussions with the U.S. EPA are ongoing to define registration submission requirements for food use. It has been reported by the US manufacturer of sulfuryl fluoride that their timetable for completion of registration in the USA is 2005 for several important commodities. Registrations in other countries are under consideration as well. Assuming future registration on food and other uses in a number of countries, the US manufacturer estimates that sulfuryl fluoride could potentially replace about 4,000 tonnes of MB currently used in the USA and a total of 11,000 tonnes throughout the world, equivalent to 15% of global MB use.

5.7.5.3 Constraints to adoption

Principal constraints to the adoption of phosphine have been detailed in the *MBTOC 1998 Assessment Report*. There continue to be concerns with registration, resistance and corrosiveness that collectively are reducing the ability of this fumigant to substitute for MB.

Phosphine registration

The use of phosphine in the USA is being reviewed prior to re-registration. Some worker safety and off-site incidences have led to U.S. EPA proposing additional safety measures. Included in these proposed risk mitigation measures are buffer zones, various notifications and lower worker exposure allowances. These EPA measures may lead to future label changes and additional restrictions and consequently may reduce or eliminate the feasibility of phosphine as an alternative to MB in some circumstances in both USA and elsewhere.

Phosphine registrants in USA have suggested a fumigation management plan *in lieu* of the buffer zone, to conduct monitoring studies of various fumigation sites and to provide worker safety data.

Phosphine resistance

Phosphine treatment is often a convenient, approved and effective alternative to MB where a longer time for treatment is acceptable. Phosphine requires exposure times exceeding 7 days for full effectiveness against several important stored grain pests e.g., grain weevils and khapra beetle. In many countries it has largely or completely replaced MB treatment of cereal grains and other durable commodities. This replacement is now threatened in some countries by the development of resistance to phosphine by target pests. For example, use of MB in China has recently increased because of the development of phosphine-resistant strains of stored grain pests.

Increased phosphine resistance has been reported from many places in Africa, the Indian subcontinent, China and from Hawaii (e.g., Rajendran 1999, Reichmuth 1999). Some strains of stored grain pests have become virtually immune to short-exposure phosphine treatments. The rise of phosphine resistance has been attributed to the use of short exposure times, (e.g., 48 hours), poor sealing of the treatment enclosures and inadequate dosages.

Phosphine corrosiveness

Phosphine has been extensively reported as causing corrosion of certain equipment and electronics, giving concern about its potential as a MB alternative. Two research projects were conducted to assess corrosive activities of phosphine on copper and copper alloys. Unexpectedly, corrosion was found to be greater at lower relative humidities e.g., 35-40% RH. In addition, in tests to force failure of common electrical components, the components were found to be more resistant to failure than expected although persistent exposures eventually resulted in failure (Brigham1997; Brigham 1999). This study also assists with developing practical measures to avoid phosphine corrosion.

A phosphine corrosion model has been constructed to assist industry to determine the expected corrosion under existing environmental conditions in a particular application, and therefore to determine whether to use phosphine and at which concentration (Woods and Fields 2000).

5.7.5.4 Uses of methyl bromide without an approved alternative

MBTOC (1998) identified a list of commodities without approved treatments for non-QPS uses that included 1) fresh chestnuts; 2) fresh walnuts for immediate sale; 3) elimination of seed-borne nematodes from alfalfa and some other seeds for planting; and 4) control of organophosphate-resistant mites in traditional cheese stores. Additionally, it may be necessary to resort to the occasional use of MB in the treatment of mills and food processing facilities where IPM systems have failed; and for disinfestation of aircraft of non-quarantine pests where hydrogen cyanide is not available and there are no proven alternatives to MB. The total of these non-QPS MB uses i.e. controlled under the Protocol is unlikely to exceed 50 tonnes per annum.

MBTOC also did not identify approved alternatives for a number of QPS uses of MB. These include: military equipment contaminated with soil; oak logs with oak wilt fungus; cotton against pink boll worm; empty ships where other methods have failed; and disinfestation of aircraft where hydrogen cyanide is not available. Fumigation of oak logs and cotton consumed 180 and 150 tonnes MB respectively in USA in 1998 (Schneider and Vick 1999).

5.7.5.5 Developing country perspective – durable commodities

A number of potent treatments for durable commodities have been identified and demonstrated to be viable alternatives to MB in a number of Article 5(1) countries including phosphine, carbon disulphide, diatomaceous earths (DE), contact pesticides, inert dusts, hermetic storage and IPM procedures.

A range of MLF-funded demonstration projects is underway in 14 countries covering at least 17 commodities. All of the projects above have approved completion dates before 2001. They are expected to produce substantial information on the performance of MB alternatives under a wide range of Article 5(1) country conditions. These projects are summarised in Table 5.9 and show potential for MB to be replaced by:

- Phosphine (alone or in combination with CO_2) for pest control for grain in storage or in transit, in many Article 5 (1) countries e.g., Kenya, Egypt, Indonesia, Malawi, Thailand, Vietnam and Zimbabwe;
- Phosphine for timber pests in Malaysia and for control of pests in stored peanuts in Senegal. Raising the awareness of alternatives and education in their use remain significant challenges in many of these countries;
- Inert gases (CO_2 and nitrogen) for pest control in grain under gas-proof hermetic storage. This method is affordable for small-scale farms typical of Article 5(1) countries, but many farmers are not yet aware of its applicability;
- Deltamethrin for pest control in grain in China when used in conjunction with IPM systems;
- DE for pest control in China and Zimbabwe. A DE project for Kenya has been approved. It is likely that DE as part of an IPM programme will directly replace MB for fumigation of grain in storage and transit.

At least 32 Workshops, Conferences and Meetings have also been held in developed and developing countries which have assisted in technology transfer (Table 5.10) of some of these projects. Most of them have been attended by MBTOC members.

Table 5.9: *Multilateral Fund and bilateral assistance projects for demonstration of methyl bromide alternatives for durable commodities.*

Country	Commodity	Technique to be Demonstrated
Argentina	Cotton, post-harvest	Phosphine and carbon disulphide fumigation
China	Grain	Diatomaceous Earth (DE), deltamethrin
Egypt	Wheat	Phosphine/carbon dioxide in cylinders, hermetic storage, carbon dioxide
Indonesia	Rice, coffee, maize	IPM plus phosphine, cylinderised phosphine, phosphine generators, DE
Iran	Dried fruit and vegetables, nuts, grains, seeds	Phosphine
Jamaica	Tobacco in store	Phosphine, carbon dioxide, methoprene
Kenya	Grain	DE

Country	Commodity	Technique to be Demonstrated
Malaysia	Timber	Sulfuryl fluoride, phosphine in IPM approaches
Mexico	Structures, storages	Phosphine, DE, deltamethrin, heat, cold, IPM approaches
Senegal	Peanuts for seed	Phosphine
Syria	Wheat	Cylinderised phosphine, modified atmospheres
Thailand	Rice, cassava chips	Phosphine, cylinderised phosphine with carbon dioxide, carbon dioxide with Integrated Commodity Management (ICM)
Tunisia	Dried dates	Phosphine, ICM, high pressure carbon dioxide
Vietnam	Rice	Phosphine, cylinderised phosphine, DE
Zimbabwe	Grains, particularly maize	Phosphine, hermetic storage, DE, nitrogen

Data abstracted from inventory of approved projects as of November 1999 (Multilateral Fund Secretariat, 1999)

Table 5.10: *Examples of workshops, conferences and meetings on alternatives to methyl bromide (MB) from 1 May 1998 until 15 April 2000*

Date (and location)	Title of Conference, Workshop or Meeting	MBTOC attendees
26-29 May 1998 (Rome)	Second International Workshop on Alternatives to MB (European Commission and UNEP TIE jointly organised). Proceedings available.	Lodovica Giullino, Rodrigo Rodriguez Kabana, Antonio Bello, Maria Nolan, Melanie Miller, Bob Taylor
October 1998 (Nashville, TN, USA)	National Pest Control Meetings, Session on MB	Bill Thomas, Ken Vick
October 1998 (Beijing)	MB Alternatives Workshop, part of the 7th International Working Conference on Stored Product Protection	Jonathan Banks, Linda Dunn, Chris Watson, Chris Bell, Wang Yuejin
7-9 December 1998 (Orlando, USA)	1998 Annual International Research Conference on MB Alternatives and Emission Reductions. Proceedings available	Lodovica Giullino, Mohamed Besri, Maria Nolan, Melanie Miller, John Sansone, Bob Taylor, Stappies Staphorst, Ken Vick
10-11 December 1998 (Orlando, USA)	USDA/Grower MB Meeting on Soil Treatment Issues	Ken Vick
20-21 April 1999 (Monterey CA, USA)	USDA/Grower Meeting on Soil and Post-harvest issues	Ken Vick, Bill Thomas, Frank Westerlund
May 1999	British Pest Control Association PestEx Conference - Seminar on MB	Chris Bell, Maria Nolan, Bob Taylor and Chris Watson
May 1999	Canadian Industry/Government Working Group on MB	Linda Dunn, Michelle Marcotte
25-30 July 1999 (Jerusalem)	XIV International Plant Protection Congress. Some papers were on alternatives to MB	Mohamed Besri, Yaakov Katan
6 –10 September 1999 (Malawi)	Workshop on Alternatives to MB for Eastern and Southern African Countries	Marta Pizano, Grace Ohayo-Mitoko and David Okioga

Date (and location)	Title of Conference, Workshop or Meeting	MBTOC attendees
8-9 September 1999 (Stellenbosch, South Africa) Proceedings available	Tenth Annual Interdisciplinary Meeting/Seminar of the Soilborne Plant Diseases - Awareness of the phase-out of MB and the need for research for alternatives	Stappies Staphorst, Mohamed Besri
27-29 September 1999 (Washington DC, USA)	Earth Technologies Conference: Session on MB	Tom Batchelor, Bill Thomas
12-14 October 1999 (Manhattan, Kansas, USA)	USDA/MB user Meeting on Post-harvest Durable Uses	Ken Vick
1-4 November 1999 (San Diego, USA)	1999 Annual International Research Conference on MB Alternatives and Emissions Reductions. Proceedings available on www.epa.gov	Rodrigo Rodriguez-Kabana, Tom Batchelor, Michelle Marcotte, John Sansone, Bob Taylor, Melanie Miller, Ian Porter, Ken Vick, Stappies Staphorst, Bill Thomas, Ian Porter
4-8 November 1999 (San Diego, USA)	USDA/grower Meeting on Nursery and Floriculture Issues	Ken Vick, Bill Thomas
May and November 1999	Canada-US Working Group Meetings	Michelle Marcotte, Ken Vick
November 1999 Pine Mountain, Georgia	Alternatives to MB for Turf Grass Production	Bill Thomas, Ken Vick
29 November - 3 December 1999 (Colombia)	UNIDO study tour of Colombian flower farms for four participants from Kenya	Marta Pizano
8-10 December 1999 (Heraklion, Crete)	Third International Workshop on Alternatives to MB (European Commission and Greece jointly organised). Proceedings available.	Tom Batchelor, Mohamed Besri, Patrick Ducom and Melanie Miller
13 – 16 December, 1999 (Dominican Republic)	UNIDO workshop on alternatives to MB	Marta Pizano
27-29 July 1999 (Beijing, China)	Consultative Workshop for the Development of a Policy Framework for Control of MB Growth in China	Cecilia Mercado, Jonathan Banks, Melanie Miller, Ian Porter, Wang Yuejin, Patrick Ducom
25-27 October 1999 (Guatemala)	International Workshop on Alternatives to the Use of MB in Guatemala	Rodrigo-Rodriguez Kabana, Bill Thomas
8-10 November 1999 (Beijing China)	Workshop on Alternatives to MB for Soil Fumigation in China	Cecilia Mercado, Ian Porter, Wang Yuejin
14-16 December 1999 (Dakar, Senegal)	Regional Policy Development Workshop to Phase out MB for Africa	David Okioga
31 August, 1999 (Tokyo)	MAFF Meeting of Soilborne Viruses Control. The meeting discussed strategies for controlling soilborne viruses, as there is a heavy reliance on MB in this area.	
September 1, 1999 (Tokyo)	MAFF Meeting on Soilborne Pest Control. Attended by agents from most of the 47 prefectures in Japan. Regional trials for MB alternatives were presented. The alternatives included chemicals, solarisation, trap crops, biological control and combinations.	

Date (and location)	Title of Conference, Workshop or Meeting	MBTOC attendees
6 December 1999 (Kochi, Japan)	Kochi Symposium of MB Alternatives. The use of MB for soil in Kochi is the most intensive in Japan. Participants were growers, local administrators, companies, and researchers.	
23-26 January 2000 (Honolulu, Hawaii)	USDA/Grower and MB User Meeting on Exotic pests and QPS	Ken Vick
26 January, 2000 (Tokyo)	MAFF Meeting of MB Alternatives: Cut flowers. Present status & tasks for converting control systems to those that need no MB.	
27 January, 28 January 2000 (Tokyo)	MAFF Meeting of MB Alternatives: Cucurbits. Present status and tasks to convert systems to those that need no MB.	Seizo Horiuchi
3 and 4 February 2000 (Tokyo)	MAFF Meeting of MB Alternatives: Tomatoes and Strawberries. Present status & tasks to convert systems to those that need no MB.	
11-12 April 2000 (Santa Catarina, Brazil)	Workshop on the alternatives to the use of MB in the tobacco sector	Miguel Costilla

5.7.6 Alternatives for perishable commodities

Perishable commodities are those commodities whose marketability reduces quickly unless stored under conditions that preserve their quality. They include fresh fruit and vegetables, cut flowers, ornamental plants, fresh root crops and bulbs.

MBTOC's 1994 and 1998 Assessments identified both existing and potential alternatives for controlling a range of pests, particularly pests of quarantine concern. These treatments are based on various chemical (fumigation, dips), physical (e.g. cold, heat, electricity, high-pressure water, irradiation, waxes and oil coatings), and combinations of these treatments. Some of these techniques were not previously reported by MBTOC as research has only commenced recently. Other research has focused on the development of new research tools that aim to expedite the development of quarantine treatments.

To date, few alternatives have actually replaced MB primarily because the alternative may be effective at controlling the pest but cause unacceptable damage to the commodity, or once proven effective against the pest without commodity damage, there are often delays pending regulatory approval.

This section reports on research using a range of technologies to indicate the activity underway to develop suitable alternatives for MB as a quarantine treatment. Some of these treatments have been implemented in developing countries, but in general, for both Parties further development is required. The final part of this section discusses the interception of new quarantine pests at the border of a country and the use of MB in these cases to allow product entry.

5.7.6.1 Technology development

Chemical dips

Two recent areas of research not previously reported by MBTOC include research using tebufenozide, a new-generation, narrow-spectrum pesticide that has not been used previously as a postharvest treatment; and research on ethanol to control mite pests that are difficult to control with non-chemical techniques:

- *Epiphyas postivittana* larvae were very susceptible to less than 5 ppm tebufenozide pesticide for up to 7 days when incorporated into synthetic diet, and some stages even more susceptible to this chemical when combined with a high-temperature controlled atmosphere treatment (2% O_2, 5% CO_2, 40^{o}C) (Whiting *et al.* 1999a). Very dilute concentrations of tebufenozide look promising for controlling this quarantine pest on apple exports to Japan, the United States and other countries.

- The mortality of non-diapausing and diapausing two-spotted spider mite (*Tetranychus urticae*) on apples when immersed in dilute ethanol solutions at various temperatures (Dentener *et al.* 1998). Mites are pests on apples exported from New Zealand to Japan and are subject to quarantine restrictions.

Controlled atmosphere

MBTOC previously reported on the use of controlled atmospheres (CA) on grapes. This research is now nearing conclusion and offers potential as a quarantine treatment for export of Thompson Seedless grapes to Australia and other countries from California.

More recent research has found that the CA treatment most likely to achieve quarantine security of Pacific spider mite *Tetranychus pacificus*, *Platynota stultana* (Lepidoptera: Tortricidae) and western flower thrips *Frankliniella occidentalis* is 12 days under 45% CO_2 + 11.5% O_2 at 0^oC (Mitcham *et al.* 1997). Concentrations of CO_2 less than 45% did not affect the quality of the grapes. This treatment is commercially feasible as high CO_2 treatments are easier to achieve than low O_2 conditions, and 0^oC is the optimum transportation temperature for grapes.

Subsequent research by Zhou and Mitcham (1998) suggested that the disinfestation period under 45% CO_2 could be reduced using ‘shock’ treatments (where ‘shock’ is defined as short term treatments in extreme atmospheres) consisting of 65, 80 or 95% CO_2 for 1, 2 or 3 days at 0^oC followed by an 18 day treatment at 0^oC in air, 8% CO_2 in air or 20% CO_2 in 5% O_2.

Coolstorage

Coolstorage is the most widely used disinfestation treatment, applied mainly to control tropical and subtropical insect pests potentially infesting a range of commodities. Recent work shows potential for reducing coolstorage time for blueberries, and for controlling pests on New Zealand apples.

Twelve days at 1.0^oC would be sufficient to control *Bactrocera tryoni* (Queensland fruit fly) potentially infesting blueberries (Jessup *et al.* 1998). To minimise coolstorage costs and delays in marketing this perishable fruit to the USA and other markets from Australia, the researchers suggested the United States Department of Agriculture consider adding this shorter treatment to the current Animal and Plant Health Inspection Service (USDA) – Plant Protection and Quarantine (APHIS-PPQ) treatment schedule that requires 18 days at 1.1^oC or below.

Increased pesticide resistance of mealybug on New Zealand apples has resulted in increased incidence of this quarantine pest on harvested apples which, in turn, has raised the concern of Regulatory Authorities in the United States and some South Pacific countries. Large-scale trials using mealybug artificially infested on apples showed this pest could be effectively controlled by 42 days at 0^oC (Hoy and Whiting 1997) rather than using MB fumigation.

Electricity

The use of electricity for controlling pests in perishable commodities has not been previously reported by MBTOC and therefore this is a new development with potential to replace MB.

Micro-second pulses of up to 9,000 Volts, each lasting less than 1/20,000th of a second, were effective in killing fruit fly infesting citrus (Hardin 1999). Less than 3% of the eggs hatched, and of those that did, none formed adults. The treatment may not affect fruit quality since very little heat was generated. An industrial partner is currently being sought to further explore the potential of using electricity as a quarantine treatment.

Essential oils

Some essential oils extracted from plants were recently found to have fumigant activity at concentrations sufficient to rapidly kill pests found on cut flowers. Shaaya *et al.* (1997) reported that a 2h exposure at 10 gm^{-3} was sufficient to obtain 100% mortality of whitefly, and 4h at 20 gm^{-3} sufficient to obtain 100% mortality of thrips. Further research is required to determine the commercial potential of these extracts as quarantine disinfestation treatments.

Fumigation

Phosphine generated from magnesium phosphide or aluminium phosphide pellets generates phosphine by-products that are toxic to perishable commodities. Recent research with pure phosphine reduced and in some cases eliminated commodity phytotoxicity. Further work is also investigating low doses of phosphine by combining this fumigant with low doses of MB, and the use of new fumigants such as carbonyl sulphide and methyl iodide:

- No injury was observed on Nijisseiki pears fumigated with phosphine at 1-3 gm^{-3} for 24 hours at 15^oC (Soma *et al.* 1999). These concentrations killed *T. urticae* but not the peach fruit moth (*Carposiana niponensis*); and
- Individual applications of carbonyl sulphide and methyl iodide were not phytotoxic to fresh lemons and therefore both fumigants appeared promising (Obenland *et al.* 1998).

New analyses of previous data on MB treatments suggest that researchers should be cautious when submitting research that argues for several varieties of fruit to be accepted by regulatory authorities based on a common set of pest-mortality responses. Robertson and Yokoyama (1998) reported that failure of the confidence limits to overlap (in statistical tests of treatment efficacy in MB treatments) might be due to natural variation in codling moth rather than differences in responses of the different fruit varieties being tested. The results of their detailed analyses of MB efficacy data obtained from disinfestation research on apples and stonefruit suggested that insect stages should be tested in randomly selected cohorts within a population for several generations so that toxicity ratios and their corresponding 95% confidence limits could separate natural variation from other phenomena. These analyses should be considered in further MB research that seeks to gain approval of quarantine treatments by Regulatory Authorities.

Heat

Heat treatment facilities have been installed in commercial packinghouses on Hawaii, Kauai, Molokai and Oahu islands in Hawaii. Other facilities have been constructed in Fiji, Tonga, the Cook Islands and are under construction in New Caledonia (Armstrong *et al.* 1998; Waddell *et al.* 1997; Waddell *et al.* 1997).

Despite these examples of commercial heat treatments, few heat treatment schedules have been approved in the US probably because approval depends on *in-situ* pest-fruit trials, precisely controlled temperatures to avoid commodity damage, and compliance with regulatory treatment criteria and equipment certification. Development of these schedules is therefore largely empirical, costly and time-consuming resulting in the commercialisation of relatively few heat-based quarantine treatments.

To expedite the development of cost-effective treatment schedules, an international thermotolerance database, based on standardised testing procedures and analysis methods, has been proposed (Jang *et al.* 1999; Mangan and Shellie 1999; Thomas and Shellie 1998; Hansen and Sharp 1997; Whiting and Hoy 1998; Shellie 1998; Lay-Yee *et al.* 1998). Once such a database has been developed, it would enable the use of a thermotolerance hierarchy that could provide assurances to regulators that an existing treatment schedule would control a new pest species and avoid unnecessary duplication of costly research. Furthermore, acceptance of temperature profiles and other techniques by regulators would expedite the commercial implementation of non-MB quarantine treatments.

Recent research on heat treatment includes:

- Immersion of guavas (*Psidium guajava*) for 35 minutes in water at 46.1± 0.2°C slowed softening, sweetening and colour development of fruit and delayed ripening by 2 days (Whiting *et al.* 1999a). Delaying the waxing of heat-treated guavas or reconditioning them for 24 hours at 20°C before cold storage promoted normal ripening and helped to maintain the quality of heat-treated fruit;
- Complete mortality of codling moth larvae and western cherry fruit fly maggots in several cherry varieties when exposed for up to 60 minutes at 40°-50°C (Simmons and Hansen 1998). Complete mortality of codling moth was obtained in treatments that lasted for 45 minutes at 45°C and 15 minutes at 50°C; and for western cherry fruit fly maggot in treatments that lasted for 30 minutes at 45°C. The effect of these pesticidal treatments on fruit quality was not reported;
- Slower heating rates to attain the target temperature delayed the onset of mortality *E. postvittana* larvae heated in air but not water (where no mortality delay was observed) (Alderson *et al.* 1998);
- Preliminary trials indicated that limes potentially infested with pink mealybug *Pseudococcus odermatti* imported from the Caribbean to the USA could be disinfested by 20 minutes immersion in water at 49°C (Gould and McGuire 1998). Soap, vegetable and petroleum oil coatings appeared to cause the mealybug to leave the fruit. More extensive entomological work with heat and waxes is required to develop a treatment undamaging to limes;
- Currently, approved treatments for grapefruit, orange and tangerine against Mexican fruit fly *Anastrepha ludens* include MB fumigation and vapour heat; and for grapefruit, cold treatment and multi-stage HTFA. Some of these treatments cause unacceptable damage to the fruit, are not economical or allow survival because of variation in fruit size. Mangan *et al.* (1998) demonstrated the acceptability of 210 minutes at 45°C for tangerines, 250 minutes at 46°C for oranges and 300 minutes at 46°C for grapefruit. Shellie and Skaria (1998) showed that such treatments may also inhibit green mould *Penicillium digitatum* growth; and
- Jones and Waddell (1996) reported on research using hot water at 46-50°C for less than 11 minutes to control tydeid mite *Orthotydeus californicus* as a potential quarantine treatment for exports of apricots from New Zealand to Australia.

High-pressure water

Whiting *et al.* (1998ab) reported that high-pressure water treatments, some with a warm water pre-treatment, were effective at removing mealybug

(*Pseudococcus viburni*) and *E. postvittana* quarantine pests, and a range of insect contaminants, from New Zealand apples and kiwifruit. The process and machinery for the apple treatment has been patented. There was no increase in fruit damage compared with standard packhouse procedures (Whiting and Jamieson 1999). These results indicate commercial implementation of high-pressure water jet technology could be successful in reducing the incidence of quarantine pests detected before shipment of export fruit and avoiding the potential for MB fumigation on arrival.

Irradiation

The interest in using gamma irradiation as a quarantine treatment continues to grow in some countries, particularly with the release of treatment acceptance criteria by the UDSA-APHIS (previously reported by MBTOC). Commercial exports from Hawaii for irradiation on the US mainland have continued to increase in the past two years with over one million pounds shipped to date. Recently, an X-ray facility for horticultural produce was approved for construction in Hilo (Hawaii) (Michelle Marcotte, Marcotte Consulting, pers. comm.).

The FAO/IAEA also has a co-ordinated research programme, initiated in January 1999, promoting the use of irradiation. This programme focuses on the development of minimum irradiation doses to inactivate insects other than fruit flies (Loaharanu 1998). This programme followed similar ones that developed recommended minimum doses for mites (150-320 Gy), diptera (100 Gy), most insects (< 300 Gy) and nematodes (less than 4,000 Gy). IAEA reports that many types of fruit and vegetables and some cut flowers tolerate all these doses, except those applied for nematode control, and suggests irradiation would be suitable as a quarantine treatment in many circumstances.

Recent initiatives on irradiation determined that a dose of:

- 250 Gy may be sufficient as a quarantine treatment for *Cryptophlebia* moth species that attack longan and prevent potential exports from Hawaii (Follet *et al.* 1998);
- 600 Gy or less may be a potential quarantine treatment for ‘Bing’ and ‘Rainier’ sweet cherries (Drake and Neven 1997; Drake and Neven 1998). Irradiation caused some loss in firmness but no loss of green stem colour which was observed in MB-treated cherries;
- 300 Gy or less, or 15 days at 1.1^{o}C, have potential as quarantine treatments for lychee shipped from Florida to California to control Caribbean fruit fly *A. suspensa* (McGuire 1997b);
- 300 Gy on longan fruit has potential as a quarantine treatment as cold treatment caused damage (McGuire 1998);

- 400 Gy electron beam irradiation sterilised seven pest species on imports of cut flowers (Dohino *et al.* 1998). However, this dose damaged some cut flower species (particularly chrysanthemum) and did not prevent aphids transmitting viruses. Damage to cut flowers was ameliorated to some extent by storing the flowers in preservative or sugar solutions after irradiation;
- 90 kGy or less was considered acceptable as a quarantine treatment for apples as changes in quality grade, firmness, acid content and external-internal colour were not sufficiently evident to reduce marketability (Drake *et al.* 1998); and
- 92 Gy was considered suitable as a quarantine treatment for plum curculio *Conotrachelus nenuphar* potentially shipped in blueberries (Hallman 1998). Doses of irradiation at about this level are not likely to damage blueberries when irradiated commercially.

Other research includes:

- Testing of the 'GrayStar' portable, pallet irradiator for uniformity of treatment, insect and bacterial control and product phytotoxicity by the USDA, in co-operation with the manufacturer GrayStar Inc (Melnick 1997). The portable irradiator is reported to irradiate up to 4,160 kg of produce per hour which would be suitable for many packhouse operations;
- Proposing 'prevention of pupation' as a criterion of irradiation treatment efficacy rather than 'non-emergence of adults' as, for those tephritid fruit flies with a diapause (over-wintering stage) (Hallman and Thomas 1999). This criterion would allow research results to be known in a less than a week rather than several months. Based on irradiation trials using this criterion, apple maggot *Rhagoletis pomonella* and blueberry maggot *R. mendax* were prevented from pupation when treated with 58 and 24 Gy respectively when irradiated as third instars in fruit;
- Starting irradiation research on US-based irradiation of papaya from Belize has commenced in the event that fly free certification is lost. Papaya from Belize, Hawaii, Mexico and Chile potentially infested with fruit fly and exported to the US must 1) originate from an area certified free of fruit fly; 2) have undergone an approved heat treatment (vapour, single or multi-stage HTFA); or 3) have been irradiated (Hawaii only) (Miller and McDonald 1998); and
- Recommending that fruit potentially infested with Mexican and West Indian fruit fly species be irradiated within 2-3 days of being packed in order to avoid the presence of later developmental stages that are 40% more tolerant to irradiation than third instars (Hallman and Worley 1999).

Species identification

Accurate and rapid identification of intercepted species as non-quarantine - often of only one insect specimen - can avoid fumigation with MB, or avoid destruction costs if no alternative is available.

Armstrong *et al.* (1997) reported on the ongoing development of a molecular technique for distinguishing thirteen out of nineteen species of fruit flies within the genus *Bactrocera* that potentially infest tropical commodity imports. Similarly, Beuning *et al.* (1999) report on a molecular technique for distinguishing a quarantine species of mealybug from closely related non-quarantine species potentially intercepted on apple exports to the USA.

Systems approach

In a study that examined the feasibility of the Systems Approach for fresh prune exports from California, Yokoyama and Miller (1999) reported one infested fruit per 8,500 harvested. Their finding was based on prune culls taken at random in the packhouse and opened and inspected for immature insects. These results indicated that the risk of infestation of fresh prunes exports was minimal and therefore the Systems Approach offers potential replacement of MB for quarantine purposes.

Mangan *et al.* (1997) reported survival of Mexican fruit fly in citrus and mango, even after a quarantine treatment (previously shown to be at least 99.9968% effective) had been applied, when no pest pre-harvest management procedures were in place. Standard pest management procedures reduced predicted survival rate to less than 1 reproductive pair per shipment, which is an acceptable level of quarantine security. This work highlighted the need to maintain pre-harvest pest control measures with postharvest quarantine treatments in order to maintain an acceptable level of quarantine security.

Wax coating

Gonzalez (1997) reported that Chilean-grown cherimoya (*Annona cherimoya*) were damaged by MB fumigation. However, coating the fruit with wax killed *Brevipalpus chilensis* mites (probably by preventing respiration) to Probit-9 security level without fruit damage. The treatment has been approved by the USDA-APHIS.

Importantly, wax coating is now being considered for controlling *Brevipalpus phoenisis* on citrus. It also may be possible to apply a wax formulation to grapes to kill *B. chilensis*, an important quarantine pest that results in most Chilean grapes being fumigated with MB on arrival in the United States.

Combined treatments

The combination of two or more treatments, when the elements of each treatment are less 'harsh' than when used individually, often offers the advantage of controlling pests without damage to the commodity. It is therefore a natural step that once a single treatment is known to control the pest but at levels damaging to the commodity that a combination treatment is evaluated. As many single treatments cause damage, not unexpectedly, there is great interest in combination treatments – either carried out simultaneously, or one after the other.

The most recent research results on combination treatments are:

- Texas researchers showed in experimental and commercial trials that coolstorage at $14^{o}C$ combined with ultra-low oxygen for up to 21 days could provide quarantine security against 3^{rd} instar larvae of the Mexican fruit fly (*Anastreph ludens*) infesting 'Rio Star' grapefruit (Shellie and Mangan 1998; Shellie 1999). Well-controlled, ultra-low oxygen conditions may provide an alternative to MB for controlling Mexican fruit fly in citrus providing the incidence of some physiological disorders can be minimised;
- Lay-Yee *et al.* (1997ac, 1998) reported on various heat treatments (water and air) up to $46^{o}C$ combined with at $0.5^{o}C$ for up to 10 weeks to control quarantine pests on two New Zealand apple varieties. Pre-harvest and pre-treatment conditions as well as fruit maturity influenced the fruit susceptibility to damage. The research is not at a stage were conditions for a commercial disinfestation treatment could be recommended;
- Fifth instar *Epiphyas postivittana* larvae that were exposed to 4 hours CA (1.2% O_2, 5% CO_2, $40^{o}C$) had a significantly reduced survival rate to pupation, a changed sex ratio, increased pupal deformity, lower female pupal weight and reduced oviposition in those females that emerged as adults (Markwick *et al.* 1998). Sublethal effects as a result of CA treatments reduced the ability of a pest to become a quarantine risk and offer potential as a replacement for MB;
- Grape mealybug *Pseudococcus maritimus*, a pest on potential exports of grapes from California to Australia, experienced high levels of mortality when exposed to CO_2 followed by 30 minutes of sulphur dioxide (less than 0.5%) (Mitcham and Zhou 1998). Further research is determining the range of CO_2 required to achieve significant mortality;
- Neven and Drake (1998) reported that a combination of warm air and CA generated in specialised, purpose-built equipment provided control of both codling moth and western cherry fruit fly while preserving fruit quality. The treatment on sweet cherry showed potential to replace MB fumigation;

- McDonald *et al.* (1998) reported grapefruit damage was reduced when they were exposed for 2 hours to 20, 38 or 42^oC prior to irradiation at 1000 Gy. Similarly, conditioning of lemons for 3 days at 15^oC before methyl iodide fumigation lessened lemon peel injury (Obenland *et al.* 1998);
- Heat (35 and 40^oC) and CA (0.4 – 21% O_2) were effective in controlling *Pseudococcus affinis* scale in less than 15 hours making this a possible disinfestation treatment for New Zealand apples exported to markets that have concerns for this and other species of scale insects (Whiting and Hoy 1997; Whiting *et al.* 1999b). Some varieties of New Zealand apples are tolerant of many of the combinations of CA and heat and therefore one or more combinations have potential as quarantine treatments (Lay-Yee *et al.* 1997a);
- Leafroller and mite pests are major impediment to exports of fresh fruit from New Zealand, particularly apples and kiwifruit. Whiting *et al.* (1995; 1996) reported on a range of air or CAs (2% O_2; 5% CO_2) combined with heat (up to 40^oC, Hoy and Whiting 1998) that have potential to control leafroller pests on export apples and kiwifruit. Kiwifruit where not damaged when exposed to temperatures up to 40^oC in air for as long as 10 hours followed by cooling in ambient water or air and stored for 8 weeks (Lay-Yee and Whiting 1996). Kiwifruit tolerated shorter treatments at elevated temperature under the CA;
- Dentener *et al.* (1997) considered 5 hours in 47^oC water followed by 40 days at 0^oC an effective quarantine treatment to control *Epiphyas postvitanna* leafroller and *Pseudococcus longispinus* mealybug on persimmons. Persimmons were undamaged by 20 minutes at 54^oC (Lay-Yee *et al.* 1997b), and moreover, the heat reduced chilling injury (Woolf *et al.* 1997); and
- Yokoyama *et al.* (1999) reported complete mortality of omnivorous leafroller (*Platynota stultana*) in table grapes exposed to 3-weeks low temperature storage + sulfur dioxide. This combination treatment could be carried out in existing packinghouse facilities and therefore has potential to be used as an alternative to MB to control pests of regulatory concern in exported table grapes.

5.7.6.2 Areas of special concern

New species interceptions

With the ever-increasing volumes of perishable commodities being exported and imported around the world, the risk of accidentally importing quarantine pests increases. To date, MB is the predominant method of controlling accidental import of unwanted pests in perishable commodities, some pests being intercepted and identified for the first time. Examples of these pests and their control treatments are:

- A new species of mealybug *Pseudococcus odermatti* that is a quarantine pest has been officially described in order to distinguish it from closely related species. This species has restricted the movement of citrus from the US to Japan and from the Bahamas to the USA. It also has the potential to restrict the movement of species of ornamentals with the genus *Aglaonema* that are widely grown in subtropical areas and greenhouses (Miller and Williams 1997).
- The white peach scale *Pseudaulacaspis pentagona* was collected for the first time on the eastern seaboard of the island of Hawaii in September 1997. Its distribution is expected to expand rapidly, affecting the vigour of papaya trees and downgrading fruit quality as well as causing concern as a quarantine pest. A vapour heat treatment of papaya over a four hour period that achieved a core temperature of 47.2^{o}C was considered sufficient to control the white peach scale on export shipments of Hawaiian-grown papaya (Follet and Gabbard 1999).

Commodities without an approved alternative

There is a general concern that alternatives are not available to substitute for MB for all of its pre- and post-harvest uses in apple and certain other horticultural exports (Kidd 1999). Moreover, leaders of these export industries from developed countries comment that it appears unfair that developing countries have a 10-year grace period that allows prolonged use of MB and therefore a competitive advantage. Agricultural industries also acknowledge that some alternatives are available for postharvest uses such as heat and/or cold treatments, irradiation and the Systems Approach. They are concerned that these treatments are more complex than MB and might have higher costs. These are factors that will also impede their adoption in developing countries.

MBTOC notes the necessity to promote technology transfer between developed and the developing countries to facilitate access the same alternatives to MB. This will help to reduce the disparity in production costs for exports from both developed and developing countries.

Commercialisation of alternative quarantine treatments depends on a number of inter-related factors that include: proven treatment efficacy; commodity tolerance; equipment design and commercial availability; cost competitiveness; time limitations; regulatory approval; equipment capacity; availability and agreement on the scientific research required for regulatory approval; and technology adoption. Given all of these considerations, the time from conception to implementation of a disinfestation treatment for perishable commodities varies from 2 to 15 years.

5.7.7 *Quarantine and pre-shipment*

The majority of perishable and durable products enter markets without any requirement for methyl bromide (MB) fumigation. However, occasionally pests are detected - either before export or more often on arrival - and a disinfestation or quarantine and pre-shipment (QPS) treatment is required before the product can be released onto the market. MB has been the predominant QPS treatment because it can be applied relatively easily, it is fast acting and its efficacy in controlling a wide range of pests is well documented.

MB used for QPS is currently exempt from controls under the Montreal Protocol. QPS treatments are always applied after harvest - quarantine treatments for quarantine purposes and pre-shipment treatments typically for non-quarantine pests.

This section:

- Reports on the steps taken at the Eleventh Meeting of the Parties in Beijing to restrict the use of MB for QPS;
- Discusses the impact on current research on QPS alternatives of no control measures under the Protocol; and
- Reports on the number of countries that mandate the use of MB for QPS treatments.

5.7.7.1 Agreement on QPS at the Beijing Meeting of the Parties

TEAP reported in April 1999 that MB used for QPS was estimated to be 22% of the global MB consumption, and that for some Parties, QPS consumption was increasing. A number of Parties in Beijing expressed concern that MB consumed for QPS is now much greater than when the exemption was originally agreed in 1992.

In the light of concerns about increasing consumption, Parties agreed to mandatory rather than voluntary reporting of QPS consumption to the Ozone Secretariat. Mandatory reporting of QPS will ensure that the statistics on the consumption of MB for QPS are more comprehensive in the future.

The Parties also agreed to a stricter definition of pre-shipment as a way of addressing concerns over potential inconsistencies in the interpretation of pre-shipment. The additional wording has helped to clarify the definition of pre-shipment:

- Only those treatments authorised by official authorities (rather than commercial-contractual agents) can be considered exempt under the Protocol;
- MB use under the exemption is to be restricted to one-application 21 days prior to shipment. Previously, the date for application of MB was not specified, leading to multiple applications prior to shipment;
- MB used more than 21 days before shipment is not exempt and should be counted under the controlled quota of MB in a country; and
- "Stored Product Authorities" was added to the list of authorities that officially authorise the use of MB for pre-shipment.

Under Decision XI/12, the Parties requested TEAP to report in 2003 on the technical and economic feasibility of alternative treatments for QPS and to provide an estimate of the volume of MB that would be replaced by the implementation of alternative, non-MB QPS treatments. Under this same Decision, Parties were also:

- Urged to review their national plant, animal, environmental, health and stored product regulations with a view to remove the requirement for the use of MB for QPS where technically and economically feasible alternatives exist. This action is particularly relevant for pre-shipment treatments where MBTOC (1998) reported a range of alternatives;
- Urged to implement national procedures to monitor the use of MB by commodity and quantity in order to target efficiently the use of research resources for developing alternatives for QPS; and
- Encouraged to implement recovery and recycling technology for QPS when technically and economically feasible in order to reduce emissions until such time that alternatives to QPS are available.

5.7.7.2 The implications of exemptions on QPS research priorities

The current exemption renders research on QPS alternatives lower priority than uses such as soil treatments where consumption under the Protocol is controlled. For soil treatments, the need to ensure that alternatives are in place in developed countries by 2005 is widely recognised as urgent.

As a result, research laboratories involved in postharvest disinfestation of perishable commodities - and durable commodities that have QPS requirements - report continued difficulty in securing funds to continue research on the development of postharvest treatments that will substitute for MB.

5.7.7.3 Regulations that mandate the use of methyl bromide for QPS

Decision X/11 of the Tenth Meeting of the Parties requested:

> *"Parties submit by 31 December 1999 a list of regulations that mandate the use of methyl bromide for quarantine and pre-shipment treatments".*

In response to this Decision X/11, 25 Parties provided information to UNEP (Michael Graber, UNEP Ozone Secretariat, personal communication). Six Parties provided information on MB but did not address Decision X/11. Thirteen Parties reported no specific regulations mandating the use of MB, including five that did not use MB at all for any purposes.

These Parties noted that, while there were no specific regulations requiring the use of MB, there were general Statutory Instruments or Standards that permitted its use, and officers of the Regulatory Authority selected MB in many cases as the only viable choice while others chose MB as this was considered to be the only option. Six Parties reported consumption of MB for QPS use in order to maintain compliance with importing Party regulations that specifically mandated the use of MB.

5.7.7.4 Regional efforts to reduce the amount of methyl bromide for QPS

MBTOC notes that some Parties are in the process of adopting control measures for QPS. For example, a new European Community Common Position (Document No 5748/3/99 REV. 3) introduces *inter alia* new requirements for QPS treatments that must be reported annually to the European Commission by each of the 15 Member States (MS):

- The quantities of MB authorised by each MS for QPS;
- The QPS purpose(s) for which the MB was used; and
- Progress made by the MS in evaluating and using QPS alternatives.

The European Commission will also take steps to reduce the amount of MB for QPS in the light of technical and economic availability of alternative substances or technologies. In addition, the Common Position mandates a freeze on QPS consumption from 1 January 2006 based on average consumption in 1996-98, with provision for further reductions depending upon availability of alternatives.

5.7.8 Reduction of methyl bromide emissions

The *1998 MBTOC Assessment Report* elaborated on reducing MB emissions from soil fumigation using agricultural films (MBTOC 1998). Soil fumigation accounts for about 70% of the global use of MB. This section builds on this previous report by providing an update on technological developments for:

- Reducing MB emissions from soil treatments;
- Reducing emissions from quarantine treatments;
- Recovery and recycling.

This section also reports on a method that has been developed to rapidly and accurately measure film permeability. Based on the research results using film for soil fumigation and a concern with the release of MB from such operations, some Parties have released minimum standards for the use of films for soil fumigation.

5.7.8.1 Emission reduction from soil fumigation

Agricultural films (also referred to as plastic sheets or tarps) are used to cover the soil to retain as much MB in the soil as possible for maximum fumigation efficacy. Since publication of the *1998 MBTOC Assessment Report*, a significant amount of field and laboratory work has been undertaken to quantify and reduce emissions of MB from soil fumigation through a better understanding of the permeability of various kinds of agricultural films, and determination of the quantity of MB that degrades in the soil under natural and artificial situations.

There are two types of films. The first are called Polyethylene Film (PEF) films (high density (HDPE) and low density (LDPE)) that are relatively permeable to MB. And the second is Virtually Impermeable Film (VIF) which is considered to be quite impermeable to MB under controlled conditions.

Recent research indicates that the amount of MB emitted to the atmosphere is dependent on a number of complex and inter-related factors including: film thickness and type; method of film placement on the field; wind-speed over the field; soil conditions that contribute to degradation of MB such as organic matter, moisture, mineral content / concentration; soil flora; injection depth; and temperature (Miller *et al.* 1999; Thomas 1998; Ou 1998; Wang *et al*. 1998a; Wang *et al*. 1998b; Yates *et al*. 1998).

Polyethylene films

PEF continues to be globally the predominant agricultural film covering for soil fumigation. While HDPE film tends to provide a somewhat greater barrier to MB than LDPE film, a significant portion (up to 90%) of MB can nevertheless pass through these plastic sheets (Gamliel *et al*. 1998; Thomas 1998; Wang *et al*. 1999; Yates *et al*. 1998).

PEF also is susceptible to the same leakage problems and issues associated with their use as those described for VIF in the next section.

Virtually Impermeable Film

VIF film consists of either 1) multi-layer laminates with outer layers of low-density polyethylene and a barrier layer of polyamide or ethylene vinyl alcohol, or 2) a mixture of these materials, often call an "alloy".

Field research has shown that the use of VIF agricultural films can reduce emissions to less than 4% of applied MB, versus emissions of 68% of applied MB when using PEF/HDPE under similar conditions (Yates *et al*. 1998).

However, MB degradation issues, film logistical constraints, supply issues, and economical disparities need to be resolved before VIF agricultural films can be utilised to significantly reduce MB emissions on a wide-spread basis in commercial agriculture (Gamliel *et al*. 1998; Thomas 1998; Wang *et al*. 1998a). These include: consistent degradation of MB under VIF in variable soil conditions, film flexibility, availability of VIF, cost, field handling difficulties, and length of time the film needs to be on the field (Thomas 1998; Wang *et al*. 1998b).

In general, VIF can reduce MB emissions from soil fumigation by keeping the MB in the soil to allow for degradation (Yates *et al*. 1998) when:

- The entire field is covered with VIF film;
- All film strip over-laps are well glued and sealed;
- The VIF film edges are sealed (buried under soil);
- The MB is injected deeply in the soil;
- The film is kept on the field, completely sealed, for 10 to 20 days; and
- The soil temperature, moisture and organic matter content are optimal - medium temperatures, moist soil, existence of organic matter.

In general, VIF is inefficient (if not entirely ineffectual) at reducing MB emissions from soil fumigation (Rice *et al*. 1996; Thomas 1998; Wang *et al*. 1999) when:

- Only part of the field is covered with VIF;
- Any of the film strip over-laps become unglued or are otherwise unsealed;
- Any of the film edges anywhere around the field become unsealed;
- The film seal is broken before 10 to 20 days have passed; and
- Soil temperature, moisture, organic matter are in any way sub-optimal - hot, soil dry or very wet with little organic matter.

VIF film leakage at the edges and overlaps, cracks from photo-deterioration of VIF, holes from animals crossing the field before the MB is degraded will result in MB emissions, especially if the leakage is near the beginning of the fumigation and not immediately sealed. The longer the VIF film is on the soil, the more likely both the film and seal points could deteriorate due to wind or other weather conditions. Because of the greater MB retention by VIF compared to PE film, there is greater risk of farm worker and residential exposure unless conditions under the film promote MB degradation (Thomas 1998).

Since the publication of the *1998 MBTOC Assessment Report*, little progress has been reported on environmentally sound ways to dispose of agricultural films after use in a soil fumigation, especially with regard to air quality, environmental and health issues should the films be burned. While recycling and biodegradable plastics would likely ameliorate the disposal process, no breakthroughs have been reported since the last MBTOC report regarding the difficult issue of recycling the combination of plastics used in VIF.

Because logistical realities may make it difficult to keep the VIF tarp on the soil for sufficient time to allow for degradation, several researchers are investigating ways to reduce the time necessary for degradation. Research has been conducted on: 1) the response of fumigant emissions to the addition of nitrogen fertilisers and organic amendments (Gan *et al*. 1998); 2) augmenting specific MB degrading soil bacteria to increase the degradation rate (Miller *et al.* 1999; Ou 1998); and 3) the addition of materials such as titanium dioxide to the agricultural film itself (Kobara *et al*. 1999). While these methods and products have succeeded in enhancing degradation of MB in the laboratory and small-scale tests, full-scale field tests will be necessary in the near future to test commercial viability.

In addition, further research will be needed to determine the suitability of this technology for commercial agriculture when used with MB and its alternatives such as metam sodium, telone and chloropicrin. These alternatives are also permeable to PE films. Work is on going to address the problems associated with the use of VIF film to reduce MB emissions. Some researchers are optimistic that the current obstacles can be overcome (Watanabe *et al.* 1999; Rimini 1999; Yates *et al*. 1998).

VIF permeability standards

Both the British Pest Control Association and French Ministry of Agriculture have released film permeability standards to ensure continuity and consistency of research into VIF. Policy makers could consider adopting these or similar standards in order to minimise emissions of MB from soil fumigations using VIF.

The British Pest Control Association has stated that film integrity, especially in regard to sealing sheets that are joined in the field, is a critical part of emission control. The adhesive that is to be used with VIF film must ensure the seal does not fail in windy conditions and be practical to use for the film and fumigant applicator. This organisation submitted the following standard definition to the European Community in September of 1999 for consideration in controls on MB use:

> *The virtually impermeable film (VIF) is a plastic film material with the normal physical and life-expectancy properties and which can be sealed effectively to drastically reduce methyl bromide emission to the atmosphere. The VIF must have a permeability standard which does not permit more than 1.0 gram of methyl bromide to pass through a square metre of film per hour from a contained concentration of 100% at 20 degrees C. The permeability standard units are in* $g\ m^{-2}\ h^{-1}$.

The French Ministry of Agriculture has a standard VIF definition with regard to soil fumigation similar to that proposed by the British Pest Control Association, but differs in that it allows no more than 0.2 $g\ m^{-2}\ h^{-1}$ permeability. This “Standard for VIF” was put forth by the French Association for standardisation in September 1997 under the reference NF T54-195.

A rapid and accurate method has been developed to measure the permeability of agricultural films to MB and other soil fumigants. This method uses a static flow-through chamber to measure the permeability of films independent of the concentration gradient, allowing comparisons to be made rapidly under different application conditions (Papiermik *et al.* 1999).

Practices to reduce emissions from soil

MBTOC wishes to re-enforce the concepts that were described in the 1998 report regarding practices that can reduce MB emissions from soil treatments:

- Limiting the frequency of MB fumigation by requiring intervals of 12 – 60 months between treatments, and using alternative treatments in the intervening periods;
- Increasing the monitoring and recording of pests and using pest control tools only when pest populations exceed a set economic threshold;
- Reducing doses by combining MB with other treatments such as solarisation, biological controls and VIF films where appropriate;
- Reducing doses of MB without compromising efficacy;
- Regulating, licensing and training MB users; and
- Injecting MB deep into the soil.

Examples of MB reduction using VIF film alone or in combination with lower concentrations of MB are provided in the section 5.7.4 "Alternatives for Soil Treatments".

5.7.8.2 Emission reduction by recovery from fixed-wall facilities

Currently, most fumigation chambers or enclosures release MB into the atmosphere during venting at the end of the fumigation period. There are very few fumigation sites worldwide where any attempt is made to capture the used MB in order to reduce emissions. Where they do exist, the impetus has been to meet local clean air requirements and therefore retain operating permits. Those facilities and the technologies being used were described in the *1998 MBTOC Assessment Report*, as were other technologies still under development. The information given in the following section describes ongoing research on two of the technologies and presents information on recent demonstration projects.

Recovery of MB for recycling

A new recycling process has been developed and is being demonstrated to the industry by a Canadian company. The process uses zeolites to recover available MB for subsequent reuse. Zeolites are special type of silica-containing materials that have a porous structure which make them valuable as adsorbents and catalysts. The process supersedes an earlier zeolite-based process that was trialled unsuccessfully at the Port of San Diego, USA and in Santiago, Chile (MBTOC 1998). The new process has been altered and improved so that direct recycling is no longer necessary. Instead, the captured MB is recovered from the zeolite bed, refined in an off-line step and is potentially available for other fumigation operations (Willis 1998). This change significantly reduces the complexity of operation of the recovery plant because it is no longer necessary to have complex or expensive analytical equipment to measure MB concentrations as there is no direct recovery and re-injection into the fumigation operation.

The process of MB capture has been demonstrated on diverse operations such as fumigation of an empty ship hold, shipping containers and a lumber warehouse (Weightman 1999). Data from the ship hold trials indicate that the process is capable of capturing up to 90% of the applied MB (Fields and Jones 1999). No information has been published on the success of the recycling component of the technology. It is intended that zeolite reprocessing to capture MB for recycling will take place in Nevada, USA and the technology is now being promoted in North America. It would be difficult for the technology to be adopted in other parts of the world unless other reprocessing sites were established.

An issue with this process, and any other aimed at recycling MB, is whether the recovered MB is sufficiently pure to be able to be reused as "pure MB" to comply with the specifications for established quarantine schedules and whether it can meet the labelling requirements of individual countries to be sold as MB for any permitted use. Recycling processes have the potential to provide a means of reducing emissions from a range of fumigation operations, and making MB available for uses where MB alternatives are more difficult to implement.

Recovery and destruction

The *1998 MBTOC Assessment Report* described a process under development in the USA using activated carbon to capture MB. The intention of developers was to provide a supply and disposal service by transporting the MB-laden carbon to a central processing site where it would be reprocessed or destroyed (MBTOC 1998). The further development of the process has been reported (Knapp *et al*. 1998, Leesch *et al*. 2000) and a small commercial unit is now in operation at Dallas/Fort Worth airport capturing MB from quarantine operations (McAllister and Knapp 1999). The plant reduces the MB concentration in the chamber down to a level of 500 ppm before venting the remainder. Once the plant has processed sufficient MB to fully load the activated carbon bed, it will be shipped to Pennsylvania to be incinerated. Preliminary data suggested that in excess of 95% of the MB being vented could be removed. After allowing for MB lost by adsorption into the commodities being fumigated, this represented a recovery of 50 – 75% of the original dose applied.

Previous indications were that the cost of a complete MB supply and removal service would be about 7 times that of the current MB price, but on a per unit basis for commodity treated, the price may be affordable (Leesch 1998). One of the critical features of this process is the environmental impact (truck fuel, energy use) of transporting equipment containing the activated carbon beds saturated with MB over some distance to the reprocessing or destruction plant. While it may be feasible to consider this technology in the continental USA and other areas where quarantine treatments are concentrated, it is unlikely to be cost effective in other parts of the world.

Modification of treatment schedules

MBTOC has suggested previously that Parties encourage their Regulatory Authorities to review their current treatment schedule requirements and confirm that the minimum amount of MB required to control quarantine pests are in practice. Recent research has shown that MB dose reduction is possible while still controlling quarantine pests. For example, cut flowers from Israel consist of many different species, each with different tolerances to MB and each with a range of pests of quarantine concern to overseas markets. The MB dose could be reduced to avoid phytotoxicity by 2-2.5 times compared to previous schedules while at the same time controlling three of the main quarantine pests (Kostyukovsky *et al.* 1999).

Mixing MB with other gases such as pure phosphine may also allow a significant reduction in MB concentration. For example, satsuma mandarins (*Citrus reticulate*) fumigated with MB, phosphine and a mixture of MB and phosphine. No injury was observed on fruit at 48 gm^{-3} of MB for 2 hours at 15, 20 and 25^{o}C and mixtures of 14 gm^{-3} of MB and 3 gm^{-3} of phosphine for 3 hours at 20^{o}C (Akagawa *et al.* 1997). However, waxed fruit were damaged when fumigated with the mixture. This research demonstrates that half the dose of MB could be feasible compared to the use of MB alone.

However, efforts at dose-reduction may be negated by other research that continues to increase the dependency on MB. For example, research is still being commissioned in Australia, the USA and other countries to develop MB-based treatments for export crops to Japan that will continue to add to the amount of MB consumed for quarantine and pre-shipment treatments. For example, Californian ‘D’Agen’ plums could be exported to Japan in the future following the results of research that showed treatment with MB at 48 gm^{-3} for 2h at > 19^{o}C to control codling moth (Leesch *et al.* 1999). In order to compensate for absorption of the gas by the packaging, the MB dose was approximately *twice* that required to control the most resistant stage of codling moth. This treatment is similar to MB treatments on cherries, apples, walnuts and nectarines exported to Japan from a number of countries including the USA, Australia, New Zealand and France.

5.7.8.3 Constraints implementing recovery and recycling operations

The relatively small amount of research undertaken to develop recovery and recycling or destruction technologies is a reflection of the uncertainty surrounding the future use of MB and of the perceived additional costs and operational complexity to the fumigation industry of implementing potential technologies. Uncertainties include the possibility that the Parties could curtail the current exemption for QPS uses in the future. Parties, regulatory agencies and the industry who wish to encourage the development and use of recovery and recycling/destruction technologies may need to consider the following the impact of the following issues:

- The complexity of regulations surrounding the re-labelling and reuse of recycled MB;
- The need to verify the purity of the recycled substance;
- The regulations relating to the safety of the transport of the captured MB to the reprocessing or destruction facilities; and
- The impact of local environmental emission control regulations.

5.7.9 *References – Methyl Bromide*

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6 TEAP Co-ordination with the Framework Convention on Climate Change

In November 1998, the Fourth Conference of the Parties to the UN Framework Convention on Climate Change (Decision 13/CP.4, FCCC/CP/16/Add. 1) invited organisations, including the relevant bodies of the Montreal Protocol, to provide information on available and potential ways and means of limiting emissions of hydrofluorocarbons and perfluorocarbons, including their use as replacements for ozone depleting substances. It also encouraged "the convening of a workshop by the IPCC and the Technology and Economic Assessment Panel under the Montreal Protocol in 1999 which will assist SBSTA to establish information on potential ways and means of limiting emissions of hydrofluorocarbons and perfluorocarbons…..". In November 1998, at their 10th Meeting, the Parties to the Montreal Protocol adopted Decision X/16 in which they requested the TEAP to provide information to the UNFCCC and to assess the implications to the Montreal Protocol of the inclusion of HFCs and PFCs in the Kyoto Protocol. In addition, the Parties to the Montreal Protocol also encouraged the IPCC and TEAP to jointly convene a workshop on "available and potential ways and means" of limiting emissions of HFCs and PFCs.

6.1 Response to Parties by TEAP

The Joint IPCC/TEAP Expert Meeting was held at ECN Petten, The Netherlands, 26-28 May 1999. It was attended by approximately 100 participants from 24 countries; ten participants were from CEIT and Article 5(1) countries. The meeting was chaired by the co-chairs of IPCC, WGIII, and the TEAP (Dr. Ogunlade Davidson and Dr. Lambert Kuijpers). The meeting report was reviewed by a Technical Advisory Committee, which included the meeting co-chairs, and the three TEAP co-chairs. It was also reviewed by all meeting participants. After that all the comments were dealt with, the revised report was submitted to the UNFCCC secretariat. A second volume of the meeting report contains all the papers presented at the meeting. The meeting report was presented to the SBSTA, at its 11th session, in Bonn in October 1999 (FCCC/SBSTA/1999/INF.7).

The TEAP created the Task Force on HFCs and PFCs (HFC/PFC Task Force) to undertake the assessment requested by the Montreal Protocol Parties. The Task Force consisted of 31 members (chair of the Task Force: Dr. Stephen Andersen, co-chair TEAP), who met on a large number of occasions in the period February 1999- October 1999. Members of the Task Force also participated in a large number of workshops and conferences around the world during the above-mentioned period.

The Task Force published its findings in a report (the *"1999 HFC/PFC Task Force Report"*) in October 1999 and reported these findings to the Eleventh Meeting of Parties in Beijing, November 1999.

6.2 Collaboration with the Intergovernmental Panel on Climate Change (IPCC)

In Decision XI/17, Parties encouraged ongoing collaboration with international organisations including the Subsidiary Body on Science and Technology (SBSTA) under the United Nations Framework Convention on Climate Change and the Intergovernmental Panel on Climate Change (IPCC).

One aspect of this ongoing collaboration is that several TEAP and TOC members are Lead Authors of the Appendix to Chapter 3 of the IPCC Third Assessment Report, Working Group III, entitled: "Options to Reduce Global Warming Contributions from Substitutes for Ozone Depleting Substances."

Lead Authors from the TEAP include Dr. Stephen O. Andersen (USA), Dr. Suely Carvalho (Brazil), Mr. Yuichi Fujimoto (Japan), and Dr. Lambert Kuijpers (Netherlands), and Dr. Barbara Kucnerowicz-Polak (Poland). Dr. Sukumar Devotta (India) is a Lead Author from the Refrigeration, Air Conditioning and Heat Pumps Technical Options Committee. Dr. Mack McFarland (USA) is also a Lead Author and is a member of the Montreal Protocol Science Assessment Panel (SAP); he also served on the TEAP Task Force on HFC and PFCs.

In addition, Contributing Authors include TEAP members Mr. Paul Ashford and Mr. E. Thomas Morehouse and TOC members Dr. Paul J. Atkins, Mr. James A. Baker, Dr. Denis Clodic, Mr. Abid Merchant and Mr. Robert Russell.

7 Technology and Economics Assessment Panel (TEAP)

7.1 TEAP Operation

As the availability of technical options increases, the technical issues related to the implementation of alternatives and substitutes have gathered more importance for the purpose of assessment.

This shift in paradigm warrants that TEAP should move its focus from an assessment of technical options to a technical assessment that includes both the technical and economic feasibility of options and the implementation of technologies and their specific aspects, particularly for the Article 5(1) countries.

Consequently, TEAP proposes to rename the present Technical Options Committees (TOC) as Technical Assessment Committees (TAC), with a slight modification in the structure. Each TAC will have 20-35 “Reporting” Members and a lesser number of “Consulting” Members. Reporting Members would be expected to attend all TAC meetings to provide technical expertise and to complete reports according to the Terms of Reference and assignments by the Meeting of the Parties. Consulting Members would contribute technical information, but would not necessarily attend meetings.

TEAP continues to restructure its membership in accordance with the Terms of Reference (TOR) approved by Parties in 1996. The principal goal of TEAP in this venture is to increase Article 5(1) and CEIT participation and to improve its balance of expertise so that it can provide a full inventory of alternatives and substitutes including descriptions of environmental acceptability, technical performance and economic feasibility, as well as a complete assessment of the implementation of technologies and their specific aspects.

The following changes need to be mentioned:

- TEAP is transforming the Economic Options Committee (EOC). EOC Co-chairs will become TEAP Senior (Economic) Expert Members, who will utilise Consulting Members and Task Forces to respond to assignments from Parties.

- Jorge Corona is moving from Co-chair of the Solvents Technical Options Committee to become a Senior Expert Member.

- Effective December 2000, Dr. Thomas Batchelor and Dr. Rodrigo Rodriguez-Kabana will retire as Co-chairs of the Methyl Bromide Technical Options Committee and as TEAP members.

TEAP is working with the Ozone Secretariat to identify candidates for the Co-chair positions of the Solvents and Methyl Bromide Technical Options Committee, who will be presented to the July 2000 OEWG for approval at the 12th Meeting of the Parties in December 2000.

Tables 7.1 and 7.2 present an overview of the composition of TEAP and its TOCs as of April 2000.

Table 7.1: *Country representation in TEAP as of April 2000*

Total Membership	Article 5(1) and CEIT	Non-Article 5(1)	% Article-5(1) and CEIT
23	10	13	45

Table 7.2: *Country representation in TOCs as of April 2000 (including Co-chairs who serve as TEAP members)*

Body	Total Membership	Article 5(1) and CEIT	Non Article 5(1)	% Article 5(1) and CEIT
ATOC	32	10	22	31
EOC	14	6	8	43
FTOC	20	5	15	25
HTOC	18	6	12	33
MBTOC	35	12	23	34
RTOC	42	11	31	26
STOC	29	10	19	34
Total	**191**	**60**	**131**	**31**

7.2 Networking with Ozone Agencies

In preparing its annual progress reports, TEAP has become aware of certain gaps in information available to its TOCs regarding the introduction of alternative technologies in CEIT and Article 5(1) countries. The information currently available to TEAP members could be complemented by the sector information available to the Fund Secretariat, the Global Environment Facility (GEF) Secretariat, and the implementing agencies (UNEP, UNDP, UNIDO, and the World Bank). The TEAP invites these organisations to share relevant information and to attend TEAP meetings as necessary to ensure that the assessments by TEAP are as complete as possible. TEAP requests the Meeting of the Parties to invite, permit and encourage these organisations to contribute sector and country information to the TEAP and to participate in the assessment process.

7.3 Technology and Economic Assessment Panel Co-chairs, Senior Expert Members and Members 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. In 1999, the principal financial contributors included Australia, Canada, Finland, Germany, Japan, Norway, Switzerland, the United Kingdom, and the United States. In a typical year TEAP requires US$100,000-150,000 in administrative and management charges, 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. Currently, 10 of the 23 TEAP members are from CEIT or Article 5(1) countries.

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Gary Taylor	Taylor/Wagner	Canada
Helen Tope	Environment Protection Authority, Victoria	Australia
Robert van Slooten	Consultant	UK
Ashley Woodcock	University Hospital of South Manchester	UK
Shiqiu Zhang	Peking University	China

TEAP Aerosols, Sterilants, Miscellaneous Uses and Carbon Tetrachloride Technical Options Committee

Co-chairs	**Affiliation**	**Country**
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Helen Tope	Environment Protection Authority, Victoria	Australia
Ashley Woodcock	University Hospital of South Manchester	UK

Members	**Affiliation**	**Country**
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Paul Atkins	Glaxo Wellcome	USA
Olga Blinova	Russian Scientific Centre "Applied Chemistry"	Russia
Nick Campbell	Elf-Atochem SA	France
Hisbello Campos	Ministry of Health	Brazil
Christer Carling	Astra Zeneca	Sweden
Francis M. Cuss	Schering Plough Research Institute	USA
Chandra Effendy	p.t. Candi Swadaya Sentosa	Indonesia

Charles Hancock	Charles O. Hancock Associates	USA
Eamonn Hoxey	Johnson & Johnson	UK
Javaid Khan	The Aga Khan University	Pakistan
P. Kumarasamy	Aerosol Manufacturing Sdn Bhd	Malaysia
Robert Layet	Ensign Laboratories	Australia
Robert Meyer	Food and Drug Administration	USA
Hideo Mori	Otsuka Pharmaceutical Company	Japan
Robert F. Morrissey	Johnson & Johnson	USA
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Dick Nusbaum	Penna Engineering	USA
Tunde Otulana	Aradigm Corporation	USA
Martyn Partridge	Whipps Cross Hospital	UK
Fernando Peregrin	AMSCO/FINN-AQUA	Spain
Jacek Rozmiarek	Glaxo Wellcome SA	Poland
Abe Rubinfeld	Royal Melbourne Hospital	Australia
Albert L. Sheffer	Brigham and Women`s Hospital	USA
Greg Simpson	CSIRO, Molecular Science	Australia
Robert Suber	RJR-Nabisco	USA
Ian Tansey	Expert	UK
Adam Wanner	University of Miami	USA
You Yizhong	Journal of Aerosol Communication	China

TEAP Economic Options Committee

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Suely Carvalho	Montreal Protocol Unit - UNDP	Brazil
Stephen DeCanio	University of California	USA
Shreekant Gupta	University of Delhi	India
H.B.L. Lunogelo	Agrisysterms	Tanzania
Anil Markandya	University of Bath	UK
Melanie Miller	Consultant	Australia
David O'Connor	Senior Consultant, OECD	USA
Sergio Oxman	KIEN Consultants	Chile
James Schaub	Dept of Agriculture	USA
John VanSickle	University of Florida	USA
Diego Velasco	Department of Environment	Colombia

TEAP Flexible and Rigid Foams Technical Options Committee

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Lalitha Singh	Independent Expert	India

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Daniel Bien	Exxon Chemical	Netherlands
Mike Cartmell	Huntsman Polyurethanes	USA
John Clinton	Intech Consulting	USA
Kiyoshi Hara	JICOP	Japan
Jeffrey Haworth	Maytag Grp.	USA
Seishi Ishii	Bridgestone	Japan

Mike Jeffs	Huntsman Polyurethanes	Belgium
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Kee-Bong Lee	LG Electronics	Korea
Candido Lomba	ABRIPUR	Brazil
Yehia Lotfi	Technocom	Egypt
Risto Ojala	Consultant	Finland
Robert Russell	Dow Plastics	USA
M. Sarangapani	Polyurethane Association of India	India
Bert Veenendaal	RAPPA	USA
Dave Williams	Allied Signal	USA
Jin Huang Wu	Elf Atochem	USA
Alberto Zarantonello	Cannon	Italy
Lothar Zipfel	Solvay	Germany

TEAP Halons Technical Options Committee

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Barbara Kucnerowicz-Polak	State Fire Service Headquarters	Poland
Gary Taylor	Taylor/Wagner	Canada

Members	Affiliation	Country
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David V. Catchpole	Consultant	USA
Michelle M. Collins	National Aeronautics and Space Administration	USA
Phil J. DiNenno	Hughes Associates	USA
Matsuo Ishiama	Halon Recycling & Banking Support Committee	Japan
H. S. Kaprwan	Defence Institute of Fire Research	India
Nicolai P. Kopylov	All-Russian Research Institute for Fire Protection.	Russia
David Liddy	Ministry of Defence	UK
Guillermo Lozano	GL & Associados	Venezuela
John J. O'Sullivan	British Airways	UK
Erik Pedersen	World Bank	Denmark
Reva Rubenstein	US Environmental Protection Agency	USA
Michael Wilson	Michael Wilson & Associates	Australia
Roy Young	Consultant	UK
Hailin Zhu	Tianjin Fire Research Institute	China

Consulting Experts	Affiliation	Country
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Thomas A Cortina	Halon Alternatives Research Corporate	USA
Steve McCormick	US Army SARD-ZCS-E	USA
Joseph A. Senecal	Kidde Fenwal	USA
Ronald Sheinson	Navy Research Laboratory	USA
Ronald W. Sibley	DoD Ozone Depleting Substances Reserve	USA
Malcolm Stamp	Great Lakes Chemical (Europe) Limited	UK
Daniel Verdonik	Hughes Associates	USA
Brian Ward	Kidde Fire Protection	UK
Robert T. Wickham	Wickham Associates	USA

TEAP Methyl Bromide Technical Options Committee

Co-chairs	Affiliation	Country
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David Okioga	Ministry of Environment and Natural Resources	Kenya
Rod Rodríguez-Kábana	Auburn University	USA

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Chris Bell	Central Science Laboratory	UK
Antonio Bello	Centro de Ciencias Medioambientales	Spain
Mohamed Besri	Institut Agronomique et Vétérinaire Hassan II	Morocco
Chamlong Chettanachitara	Department of Agriculture	Thailand
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Sheila Daar	Bio-Integral Resource Center	USA
Ricardo Deang	Consultant	Philippines
Patrick Ducom	Ministère de l'Agriculture	France
Linda Dunn	Industry Canada	Canada
Joop van Haasteren	Ministry of Housing, Spatial Planning and the Environment	Netherlands
Seizo Horiuchi	National Research Institute of Vegetables, MAFF	Japan
Mokhrarud-Din Bin Husain	Department of Agriculture	Malaysia
Jaacov Katan	Hebrew University	Israel
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Michelle Marcotte	Marcotte Consulting Inc	Canada
Cecilia Mercado	UNEP Industry and Environment	Philippines
Melanie Miller	Consultant	Australia
SK Mukerjee	Ozone Cell, Ministry of Environment and Forests	India
Maria Nolan	Department of Environment, Transport and Regions	UK
Marta Pizano	HortiTecnia - Consultant	Colombia
Ian Porter	Institute for Horticultural Development	Australia
John Sansone	SCC Products, Anaheim Institute	USA
Don Smith	Industrial Research	New Zealand
Stappies Staphorst	Plant Protection Research Institute	South Africa
Bob Taylor	Natural Resources Institute	UK
Bill Thomas	Environmental Protection Agency	USA
Ken Vick	Department of Agriculture	USA
Chris Watson	Igrox Ltd, Worlingworth	UK
Jim Wells	Jellinek Schwartz & Connolly	USA
Frank Westerlund	California Strawberry Commission	USA
Wang Yuejin	Ministry of Agriculture	China

TEAP Refrigeration, Air Conditioning and Heat Pumps Technical Options Committee

Co-chair	Affiliation	Country
Radhey S. Agarwal	Indian Institute of Technology, Delhi	India
Lambert Kuijpers	Technical University Eindhoven	Netherlands

Members	Affiliation	Country
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James A. Baker	Delphi Harrison	USA
Marc Barreau	Elf Atochem	France
Lorenzo Battisti	University of Trento	Italy
Steve Bernhardt	EI Du Pont de Nemours	USA
S.C. Bhaduri	Tecumseh, India	India
Francois Billiard	International Institute of Refrigeration	France
Jos Bouma	IEA Heat Pump Centre	Netherlands
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Denis Clodic	Ecole des Mines	France
Daniel Colbourne	Calor Gas	UK
Jim Crawford	Trane /American Standard	USA
Sukumar Devotta	National Chemical Lab.	India
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Martien Janssen	Re/genT b.v.	Netherlands
Makoto Kaibara	Matsushita Electric Industrial Corporation	Japan
Ftouh Kallel	Batam	Tunisia
Michael Kauffeld	DTI Aarhus	Denmark
Fred Keller	Carrier Corporation	USA
Holger König	Bitzer GmbH	Germany
Horst Kruse	FKW Hannover	Germany
Anders Lindborg	Ammonia Partnership	Sweden
Edward J. McInerney	General Electric	USA
Mark Menzer	Air Conditioning and Refrigeration Institute	USA
Haruo Ohnishi	Daikin Industries	Japan
Hezekiah B. Okeyo	Ministry of Commerce and Industry	Kenya
Roberto de A. Peixoto	Maua Institute of Technology	Brazil
Günther Reiner	Sulzer Friotherm	Switzerland
Frederique Sauer	Dehon Service	France
Erik Schau	Unitor Ships Service	Norway
Adam M. Sebbit	Makerere University	Uganda
Stephan Sicars	Sitec Consultancy	Germany
Arnon Simakulthorn	Thai Compressor Manufacturing	Thailand
Ganesan Sundaresan	Copeland Corporation	USA
Pham Van Tho	Ministry of Fisheries	Vietnam
Trude Tokle	SINTEF Energy	Norway
Vassily Tselikov	ICP "Ozone"	Russia
Paulo Vodianitskaia	Multibras	Brazil
Lau Vors	L&E Teknik og Management	Denmark
Kiyoshige Yokoi	Matsushita Refrigeration.	Japan

TEAP Solvents, Coatings and Adhesives Technical Options Committee

Co-chairs	**Affiliation**	**Country**
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Mohinder Malik	Lufthansa German Airlines	Germany

Members	**Affiliation**	**Country**
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Pakasit Chanvinij	Thai Airways International	Thailand
Mike Clark	Mike Clark Associates	UK
Bruno Costes	Aerospatiale	France
Ahmad H. Gaber		Egypt
Brian Ellis	Protonique	Switzerland
Joe Felty	Raytheon TI Systems	USA
Yuichi Fujimoto	Japan Industrial Conference for Ozone Layer Protection	Japan
Jianxin Hu	Center of Environmental Sciences, Peking University	China
Peter Johnson	European Chlorinated Solvents Association	Belgium
William Kenyon	Global Centre for Process Change	USA
A.A. Khan	Indian Institute of Chemical Technology	India
Stephen Lai	Singapore Inst. of Standards and Industrial Research	Singapore
Colin Lea	National Physical Laboratory	UK
Seok Woo Lee	National Institute of Technology and Quality	Korea
Abid Merchant	DuPont Fluoroproducts Fluorochemicals Laboratory	USA
James Mertens	Dow Chemical	USA
Fritz Powolny	Pfizer	Brazil
Patrice Rollet	Promosol	France
Hussein Shafa'amri	Ministry of Planning	Jordan
John Shirtz	Coastal Safety & Health Services	USA
Darrel Staley	Boeing Defense and Space Group	USA
John Stemniski	Consultant	USA
Katsuyuki Takei	Japan Association for Hygiene of Chlorinated Solvents	Japan
John Wilkinson	Vulcan Materials	USA
Shuniti Samejima	Asahi Glass	Japan
X`Avier HK Yoong	National Semiconductor	Malaysia

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N.B. How the reports are referenced in this 2000 TEAP Progress Report is given in parentheses, italics and in quotes after the details on the reference, e.g. *("Supplement to the 1999 Replenishment Task Force Report"),* etc.

Appendix 1: TEAP /TOCs and Task Force Meetings period January 1999- July 2000

Title of Meeting	Date	City, Country
Technology and Economics Assessment Panel	April, 1999	Maastricht, Netherlands
Technology and Economics Assessment Panel	April, 2000	Melbourne, Australia
Aerosol Technical Options Committee	March 1999	Singapore
Aerosol Technical Options Committee	March 2000	Rio de Janeiro, Brasil
Foams Technical Options Committee	March 1999	Singapore
Foams Technical Options Committee	April 1999	Maastricht
Foams Technical Options Committee	March 2000	Den Haag, Netherlands
Halon Technical Options Committee	March,1999	Winterthur, Switzerland
Methyl Bromide Technical Options Committee	January 1999	San Francisco, USA
Methyl Bromide Technical Options Committee	February 2000	Beijing, China
Refrigeration Technical Options Committee	July 2000	Purdue University, USA
Solvents Technical Options Committee	April 1999	Larnaca, Cyprus
Solvents Technical Options Committee	October 1999	Seattle, USA
Solvents Technical Options Committee	May 2000	Toulouse, USA
Task Force on Replenishment of the MLF	February 1999	Paris, France
Task Force on Replenishment of the MLF	April 1999	Maastricht, Netherlands
Task Force on Replenishment of the MLF	September 1999	Washington D.C., USA
HFC/PFC Task Force	January 1999	Washington D.C., USA
HFC/PFC Task Force	September 1999	Washington D.C., USA

Appendix 2: Conferences and Workshops with Official TEAP/TOC Participation 1999*

Date, City, Country	Conference/Workshop Title	Participating Countries
17 February, Arlington, USA	"The Alliance for Responsible CFC Policy/ The International Climate Change Partnership HFC Workshop"	USA
1–3 March, Bangkok, Thailand	"Lessons Learned in Technology Transfer under the Multilateral Fund"	Australia, Bangladesh, China, India, Indonesia, Italy, Japan, Republic of Korea, Laos, Malaysia, Philippines, Thailand
15 March, Tokyo, Japan	"Japan Electrical Manufacturers Association/Japan Industrial Conference on Ozone Layer Protection Workshop"	Japan, USA
4–5 May, Mexico City, Mexico	"Workshop for Latin America on Technology Assessment in Refrigerants and Air Conditioning"	Argentina, Bolivia, Brazil, Chile, Colombia, Costa Rica, Cuba, Ecuador, El Salvador, Honduras, Mexico, Nicaragua, Panama, Paraguay, Peru, Uruguay, Venezuela,
5-7 May, Budapest, Hungary	"NATO Workshop on Approaches to Implementing Pollution Prevention Technologies at Military Bases"	Azerbaijan, Belgium, Canada, Czech Republic, Estonia, Georgia, Germany, Hungary, Kazakhstan, Latvia, Lithuania, Moldova, the Netherlands, Norway, Poland, Sweden, UK, USA
5–7 May, Bali, Indonesia	"Seminar on ODS Phaseout: Solutions for Refrigeration"	Bangladesh, China, Laos, Malaysia, Myanmar, Nepal, India, Pakistan, Papua New Guinea, Philippines, Sri Lanka, Thailand, Vietnam
10–12 May, Amman, Jordan	5th Meeting of the Regional Network of ODS Officers for West Asia	Bahrain, Jordan, Kuwait, Lebanon, Oman, Palestine, Qatar, Saudi Arabia, United Arab Emirates, USA, Yemen
26 –28 May, Petten, Netherlands	"The Joint IPCC/TEAP Expert Meeting on Options for the Limitation of Emissions of HFCs and PFCs"	Australia, Austria, Belgium, Brazil, Canada, People's Republic of China, Denmark, Finland, France, Germany, India, Japan, Kenya, Mexico, The Netherlands, Poland, Sri Lanka, Sweden, Switzerland, Thailand, UK, USA, Vietnam
31 May- 2 June, Berlin, Germany	"Heat Pumps – A Benefit for the Environment"	Austria, Belgium, Belorussia, Canada, Denmark, Finland, Germany, Ireland, Italy, India, Hong Kong, Japan, Korea, Luxembourg, the Netherlands, Norway, Poland, Spain, Sweden, Switzerland, UK, USA

* MBTOC participation in conferences and workshops is listed under the 5.7 of this report

Date, City, Country	Conference/Workshop Title	Participating Countries
13 June, Geneva, Switzerland	"Workshop on HCFC Alternatives"	Algeria, Austria, Belgium, Benin, Botswana, Brazil, Canada, China, Colombia, Comores, Congo, Denmark, Dominican Republic, El Salvador, Fiji, Finland, France, Gambia, Germany, Ghana, Hungary, Iceland, India, Indonesia, Italy, Japan, Kenya, Latvia, Lebanon, Malaysia, Mauritius, Mexico, Netherlands, Nigeria, Panama, Papua New Guinea, Philippines, Portugal, Republic of Korea, Seychelles, Singapore, South Africa, Sweden, Switzerland, Tajikistan, Tanzania, Turkmenistan, UK, USA, Western Samoa, Republic of Yemen, Zimbabwe
3–6 August, Sao Paulo, Brazil	"VI Conbrava Brazilian Refrigeration, Ventilation and Air Conditioning Conference"	Brazil, Germany
6-10 September, Lilongwe, Malawi	"Workshop on Alternatives to MB for Eastern and Southern African Countries"	NOU Representatives from Eastern and Southern African Countries, The Netherlands, Colombia, France, Sierra Leone, USA
8–10 September, Noordwijkerhout, Netherlands	"Second International Symposium on Non-CO_2 Greenhouse Gases"	UK, The Netherlands
12–14 September, Taipei, Taiwan	"1999 Taipei International Conference on Atmosphere Protection"	Japan, Netherlands, New Zealand, Taiwan, USA, Vietnam
15 September, Phoenix, USA	"10th Annual Solvent Substitution Workshop"	USA
17 September, Seoul, Korea	"1999 Industry Workshop on Ozone and Climate Protection"	Korea, USA
19- 24 September, Sydney, Australia	"XXth International Congress of Refrigeration"	Over 50 countries represented
19–21 September, Hanoi, Vietnam	"International Exhibition and Conference on Environment in Vietnam"	Australia, Malaysia, Singapore, USA, Vietnam
27-29 September, Washington D.C., USA	"Earth Technologies Conference"	List not available
11-15 October, Sydney, Australia	"1999 Main Meeting of the SEAP Network of ODS Officers"	Australia, Brunei Darussalam, Fiji, Lao people's Democratic Republic, Indonesia, Malaysia, Mauritius, Myanmar, Philippines, Singapore, Sweden, Thailand, Vietnam
25-27 October, Guatemala	"International Workshop on Alternatives to use of MB in Guatemala"	List not available
1-4 November, San Diego, USA	"1999 Annual International Research Conference on MB alternatives and Emission Reductions"	List not available

Date, City, Country	Conference/Workshop Title	Participating Countries
4 December, Beijing, China	“World Bank Workshop on Halon Management in China	China, Canada, Poland, Switzerland, USA
6-7 December, Tokyo, Japan	“Report on Responsible Use of HFCs”	Australia, India, Japan, UK, USA
8-10 December, Heraklion, Crete, Greece	“Third International Workshop on Alternatives to MB (EU and Greece)”	List not available
14-16 December, Dakar, Senegal	“Regional Policy Development Workshop-Phase out MB for Africa”	List not available