Abt Associates of Canada
Social Research Consultants

Project Report

CANADIAN USE PATTERNS AND CONTROL OPTIONS FOR METHYL BROMIDE

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I INTRODUCTION

Methyl bromide is a wide spectrum pesticide with a variety of agricultural and related food storage and food processing applications in Canada. Recent scientific assessment has indicated that emissions of methyl bromide contribute to the destruction of the stratospheric ozone layer. This study assesses Canadian consumption and use patterns for methyl bromide and provides an assessment of the technical options for reducing the use of methyl bromide. The report also provides some preliminary estimates of the costs of various control scenarios. These scenarios include reductions and possible phase-outs of the use of this pesticide.

This study has been sponsored jointly by Agriculture Canada and Environment Canada. The assistance of a number of individuals including industry sources and members of the Steering Committee is gratefully acknowledged. In the report, a number of products and firms are referred to for identification purposes only. In some cases, there are competing products or processes and reference does not reflect any endorsement of a particular approach.

The 4th meeting of the Contracting Parties to the Montreal Protocol will be held in November, 1992 and the parties will consider amending the Protocol to include methyl bromide. This follows a series of scientific and technology assessments including most recently the UNEP *Synthesis Report of the Methyl Bromide Interim Scientific Assessment* and the related report, *Methyl Bromide Interim Technology and Economic Assessment* (1992). This study provides background information that will constitute an input to the Canadian position at these meetings.

Due to its relatively recent identification as an ozone-depleter, the background information on many aspects of methyl bromide use, alternatives to its use and even its precise contribution to the destruction of stratospheric ozone is not definitive. Continuing scientific, technical and economic assessments are in progress. For this reason, the conclusions and estimates in this study are subject to a considerable degree of possible error.

The existing scientific studies estimate that the ozone depletion potential (ODP) of methyl bromide is 0.7. Its short atmospheric lifetime means that its contribution to ozone depletion will be relatively greater in the short term when ozone losses are expected to be greatest. As the Montreal Protocol reduces the use of CFCs and halons, the relative share of methyl bromide as an ozone-depleter will increase if it is not regulated. This explains concerns over the substantial quantities of current use. The uncertainties in this area also should be noted. There is incomplete scientific information about the relative contribution of anthropogenic or man-made sources relative to naturally-occurring sources as well as uncertainty about emission rates in soil applications.

Applications of methyl bromide in Canada include uses as a soil fumigant, commodity fumigation, space fumigation by food producers and very limited uses as a structural fumigant. Alternatives exist in each of these application categories but there are some specific applications in which the UNEP Technology and Economics Panel has concluded that known alternatives are much less effective and other applications in which there are no known alternatives.

The structure of this report is as follows:

- Chapter II provides the highlights of the report.
- Chapter III describes the sources and uses of methyl bromide in Canada.
- Chapter IV reviews control options or alternatives by application.
- Chapter V establishes an economic framework within which to assess costs and provides preliminary estimates of reduction costs. It also considers different reduction scenarios that might be feasible for Canada.
- Chapter VI assesses the potential for the use of economic instruments to achieve whatever regulatory targets are selected.

II HIGHLIGHTS

A. OVERVIEW

This report assesses Canadian consumption and use patterns for methyl bromide and provides an assessment of the technical options for reducing its use. Methyl bromide is a wide spectrum pesticide that, according to recent scientific evidence, contributes to the destruction of stratospheric ozone The report also provides some estimates of the potential costs associated with reduced methyl bromide availability.

Methyl bromide is used in Canada as a soil fumigant, in space fumigation associated with the manufacture and transport of food products and in quarantine applications related to imports and exports of food and related agricultural commodities. This study assesses alternatives to methyl bromide use and the costs of these alternatives in these different applications. The report is intended to provide background information that will constitute an input to the Canadian position at the upcoming 4th meeting of the Contracting Parties to the Montreal Protocol.

B. USE PATTERNS

An estimated 200 tonnes of methyl bromide will be consumed in Canada in 1992. All of this quantity is imported from the United States from firms whose methyl bromide labels are registered with Agriculture Canada under the *Pest Control Products Act*.

Methyl bromide is a broad spectrum pesticide for which soil fumigation and space fumigation account for approximately 95% of total consumption. Soil uses are roughly equally divided between greenhouse and field applications. Space fumigation consists of fumigation activities primarily in food production and food processing facilities and in the context of transporting grain and grain products. Approximately 90% of Canadian consumption is accounted for by users in Ontario and Quebec.

Quarantine applications in support of national regulatory programs to prevent the spread of exotic pests are a major global use category for methyl bromide. However, very little methyl bromide is used in Canada for this purpose. Some export products are fumigated with methyl bromide as are some imports if infestation is observed. Most imports for which treatment is required arrive in Canada with a phytosanitary certificate indicating fumigation at the point of origin or in transit.

Grain as a commodity is fumigated using aluminum phosphide when treatment is required. However, empty ships, trucks and railroad cars must be fumigated with methyl bromide if found infested. Grain mills if exporting are inspected and most mills fumigate with methyl bromide. As routinely defined, these would all be space fumigation applications. However, it is clear that they are related to commodity quarantine and have similar economic importance.

It is important to reiterate that Canada uses almost no methyl bromide to fumigate export commodities and fumigates almost no imports in Canada. Imports to Canada arrive with phytosanitary certificates which certify that the commodity was fumigated at the point of origin when this is required. Fumigations are carried out only if infestation is discovered by Agriculture Canada. **This means that a narrowly defined exemption for quarantine applications would not include many of the activities that are most valuable for Canada.**

C. METHYL BROMIDE CONTROL OPTIONS

Control options for methyl bromide are the policies to reduce or eliminate its uses. These options are most limited for quarantine applications in which commodities are fumigated although recycling systems may allow continued use of methyl bromide without emissions. In the other use categories of soil fumigation, space fumigation and structural fumigation, different options do exist but there are concerns about their cost-effectiveness. The main body of this report reviews individual control options for each of the four major use categories of soil, space, structural and commodity fumigation.

D. COSTS OF METHYL BROMIDE CONTROLS

International decisions are likely to be taken soon to incorporate methyl bromide in the Montreal Protocol and to initiate controls on consumption. This report considers the potential costs of these controls in a number of categories reflecting the different applications of methyl bromide.

International controls on methyl bromide use through the provisions of the Montreal Protocol will generate economic costs in Canada through restrictions on

Canadian consumption. In addition, if reduced availability elsewhere increases the prices of agricultural products purchased as imports in Canada, there will be additional costs to Canada. Our report considers both sets of costs.

The extent of costs that will be incurred depends on the extent to which methyl bromide consumption is restricted and on how soon the controls are implemented. Our assessment is that an immediate and complete elimination of methyl bromide would have very substantial costs for Canada.

The Canadian proposal is for a freeze in methyl bromide consumption in 1995 at 1991 levels followed by a reduction to 75% of the 1991 benchmark by 1998. This proposal would also include an exemption for quarantine applications of methyl bromide and exemptions for related uses supporting the export of Canadian grain and grain products. We estimate that the costs of implementing the Canadian proposal will be a small fraction of the costs of total elimination. Specifically, we estimate the cost of the freeze in 1995 as less than $650,000 per year and the cost of the 25% consumption reduction would be an additional $862,500 annually beginning in 1998. The present discounted value of both of these costs at a discount rate of $7\frac{1}{2}$% over a ten year time interval for each is less than $10 million measured in 1995 dollars.

Costs to Canadians from reduced use of methyl bromide elsewhere would be in addition to this amount. In the case of the Canadian reduction proposals, our assessment is that these costs would be moderate.

E. IMPLEMENTING CONTROL POLICIES

The most likely control system for methyl bromide would be modelled on the controls already in place for other ozone-depleting substances. These are essentially quota-based systems in which quota amounts are measured relative to the 1986 benchmark consumption data.

In implementing parallel controls for methyl bromide, our analysis indicates that control costs will be held down by encouraging transferability of quotas and of methyl bromide. This promotes the direction of limited quantities to users for whom adjustment costs are greatest.

The other important factor to consider in developing controls is that all methyl bromide consumed in Canada is imported. This means that allocating quotas to users based on their benchmark consumption would promote competition to supply the Canadian market. This implies lower adjustment costs for Canada than a control regime in which a single firm is granted the right to most of the quantities to be imported.

III SOURCES AND USES OF METHYL BROMIDE IN CANADA

A. SOURCES OF CANADIAN SUPPLY

1. Sources and Quantities

The 1992 Draft Report of the EPA on methyl bromide identifies 16 producers of methyl bromide in the world with production facilities in ten countries. None of these facilities are located in Canada. Most of Canada's consumption of methyl bromide consists of imports, primarily from the United States and primarily from a single producer, Great Lakes Chemicals with headquarters in West Lafayette, Indiana. In some years, small quantities (usually less than 10,000 kg) from Ameribrom have also been reported. TRI-CAL of Hollister, California, through its subsidiary Trident Agricultural Products, imports and applies roughly 9,500 kg of methyl bromide annually as a soil fumigant in British Columbia.

Some quantities may be entering Canada that are not being captured in the data now available to Environment Canada and Agriculture Canada. Firms specializing in propagation of strawberry plants in Ontario report purchases from Reddick Fumigants in North Carolina but these quantities are recent and may be captured in subsequent Environment Canada data.

Canada imports and uses a very small fraction of the world total, a fraction that has declined in recent years to approximately 0.2%. The reasons for the declining Canadian share and the declining absolute quantities are not entirely clear but some observers have suggested that it is the result of increased regulatory stringency in Canada. Recent growth has been in the area of soil fumigation. Based on these data, we estimate that Canadian consumption in 1992 may be as high as 200 tonnes.

Unofficial estimates indicate that the U.S. accounts for approximately 60% of world consumption or roughly 40,000 tonnes in 1990. The world-wide growth of methyl bromide consumption at an annual rate of approximately 5% is attributed to the effectiveness of methyl bromide as a fumigant and to the removal of ethylene dibromide from the market in 1984 due to health concerns.

It should be noted that most of the published data does not distinguish among quantities of methyl bromide products based on their methyl bromide concentration. Pure methyl bromide gas constitutes the largest single import category but mixtures with 2% chloropicrin and 33% chloropicrin are also imported. The ratios fluctuate annually but a rough average would be 55% pure gas, 5% of the 2% chloropicrin mixture and approximately 40% of the 33% chloropicrin mixture.

The mixtures with chloropicrin are used in soil fumigation applications. Chloropicrin is used because of its biocidal action against diseases present in soil. In addition, chloropicrin is used as a warning agent since methyl bromide is odourless.

2. Mode of Entry

Methyl bromide enters Canada predominantly from a single producer and as far as we have been able to determine, entirely by truck. Sizes of containers can vary substantially. The largest unit is a 13,000 pound tank that can be shipped three per truck and the smallest is a one pound can designed for single application space fumigation. Cylinders are also shipped with popular sizes being 50, 100 and 200 pounds. All of these sizes have been shipped in recent years.

Large users buy directly from U.S. producers, but Canadian wholesalers of chemical products also purchase methyl bromide for resale to smaller users. The largest wholesalers reported to us are Van Waters and Rogers and Chorney Chemical Company. Larger cylinders are used to fill smaller cylinders in Canada so that there is a potential to reduce filling losses. Our understanding is that due to its hazardous properties, methyl bromide can be sold for use only to certified applicators. Certification is regulated provincially.

B. USES OF METHYL BROMIDE IN CANADA

1. Overview

This section reviews the uses of methyl bromide in Canada. Registration and related regulations limit the use of methyl bromide to certain approved applications which must be described on the label. Methyl bromide is registered for use in Canada under the Pest Control Products Act and is regulated by Agriculture Canada and in certain applications by provincial governments. For example, the Ontario Ministry of the Environment must approve permits for space and soil fumigation in Ontario. The requirement for registration and the reporting procedures maintained by Agriculture Canada and Environment Canada mean that substantial data exist on broadly-defined use patterns. Exhibit III-1 provides an overview of these uses of methyl bromide in Canada.

Worldwide and particularly in the United States, the use of methyl bromide is heavily concentrated in the area of soil fumigation. In Florida and California, a year-round growing season means that methyl bromide is used extensively for crops such as strawberries and tomatoes. Estimates of the proportion of all U.S. soil fumigation consumption of methyl bromide accounted for by these two states alone are in the order of 80%.

Methyl bromide use in the north-eastern United States and the central states, areas with climates more like that of Canada, is in much smaller quantities and the relative use pattern is also different. As subsequent sections of this report indicate, this means that the impacts and relative costs of restrictions on the use of methyl bromide will be different in Canada than in the United States because the use patterns differ. In particular, soil fumigation with methyl bromide constitutes a smaller proportion of the Canadian use pattern than in the United States.

2. Use Categories

Methyl bromide is effective against a wide variety of pests and consequently is used in a variety of different applications. There is not a standard and uniformly accepted set of definitions of the major use categories for methyl bromide. In this report, methyl bromide is discussed in the following use categories:

- Soil fumigation.
- Space fumigation.
- Commodity fumigation.
- Structural fumigation.

Soil fumigation is confined primarily to Ontario, British Columbia and Quebec, where a number of agricultural and horticultural applications are observed. Much of the literature also refers to these as "pre-plant" applications.

EXHIBIT III-1 What is Fumigated in Canada?

Type	Major Applications
Soil Fumigation (45%)	Greenhouse crops. Nursery stock (strawberries, sodfarms, trees for reforestation).
Space Fumigation (50%)	Flour mills, pasta plants, bakeries, confectioneries and other food processing. Breweries, ships, trucks and rail cars that transport grain.
Commodity Fumigation (5%)	Required for: Exports; small quantities of fruit, nursery stock. Imports; see Appendix A. Also used for other crops on "as required" basis following inspection on arrival in Canada.

Note: Proportion of total Canadian methyl bromide use is shown in brackets for each type.

Space fumigation refers to fumigating activities in food processing and distributing plants, in breweries, in holds of ships that may carry grain and in rail cars, trucks and other areas that may be subject to infestation. The distinction between this category and the following category in which commodities may be present in some of these facilities is not always clear.

Commodity fumigation has as its clearest example fumigation related to quarantine requirements as supervised by Agriculture Canada. Other examples would include grain fumigation in storage areas and other applications in which the existing product is the central concern as opposed to the facility in which it is currently located.

Commodity fumigation frequently involves international quarantine requirements. However, the distinction as to what constitutes a quarantine use is not always clear. Agriculture Canada inspects flour mills and related facilities and certifies products for export purposes through regular inspections. If pests are present that may become part of a Canadian shipment, this certification is withheld until the problem is resolved. This is, in other words, essentially a quarantine activity in which the production facilities are certified. Most such facilities are fumigated with methyl bromide but we have classified this as space fumigation. Much space fumigation can, for this reason, be viewed as being related to quarantine use of methyl bromide.

Structural fumigation is used in this report to refer to fumigation to exterminate structurally damaging pests such as termites. Some sources use structural fumigation to describe any fumigation within a structure. However, in this report, activities of that kind would be described as space fumigation unless the application is directed specifically at pests that may affect the structural integrity of the facility. Climactic conditions in Canada mean that methyl bromide is used very infrequently for structural fumigation.

The availability of data limits the extent to which data can be organized according to theses four categories. In fact, in the sections that follow, the data, are generally presented in terms of soil fumigation and other types of fumigation, a category that combines commodity and space fumigation. However, when control options are assessed, the four categories are useful for considering the available alternatives.

3. Use Patterns

The data on the use pattern for methyl bromide in Canada fluctuate from year to year in terms of the importance of different applications. In part, this appears to be the result of how the data are collected. The data refer to shipments rather than applications and it appears that the commodity is stored from year to year. Shipments of a form of methyl bromide intended for soil fumigation may carry over from one planting year to another making interpretation of the data more difficult. For this reason, we use a two year average of data for 1990 and 1991 to estimate the proportion applied to soil fumigation.

For the 1990-1991 time period, we estimate that 44.6% of the methyl bromide shipped to Canada was destined for soil fumigation. The remainder is divided between commodity and space fumigation. This ratio of soil fumigation to total uses of methyl bromide appears low by world standards. This is confirmed in Exhibit III-2 which shows the relative importance of soil fumigation for Canada relative to world, North American and Australian usage.

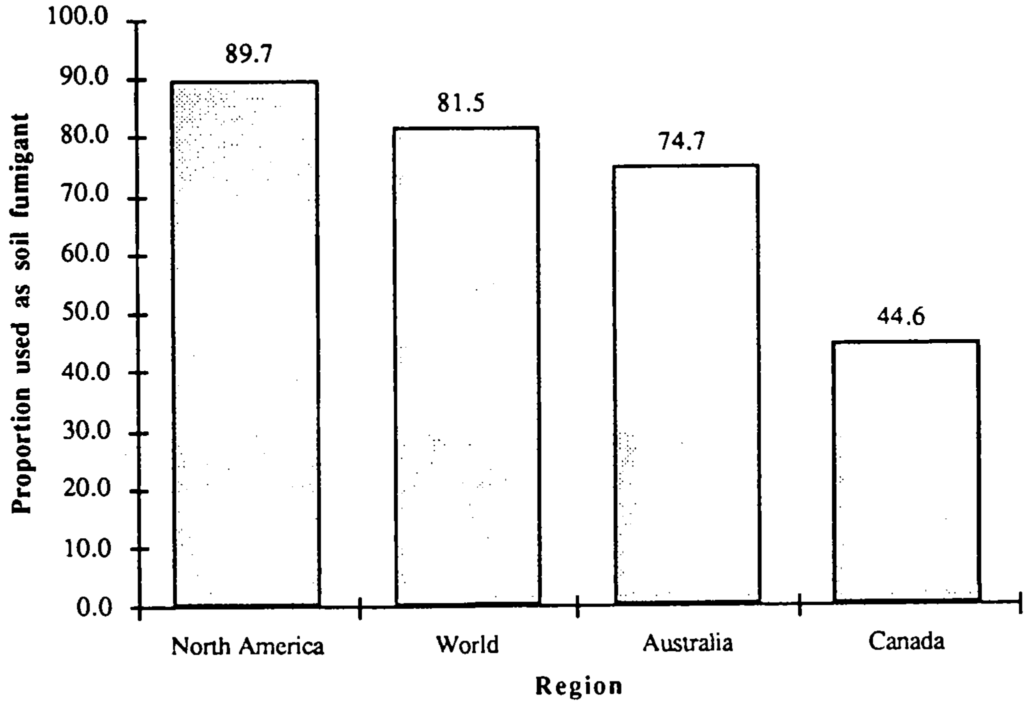
For 1992, the soil fumigation proportion may be somewhat higher than indicated in Exhibit III-2. Two users in strawberry plant propagation in Ontario consume approximately 45,000 kg in pre-plant applications. Previously, they used VAPAM which is cheaper but the effectiveness of methyl bromide is reported to be much greater. The 45,000 kg of methyl bromide support roughly $3.2 million of export sales of nursery stock to the U.S. and Europe.

Some caution should be exercised in interpreting the data on the proportion of methyl bromide used in soil fumigation. The base quantities are relatively small so that the total can be affected significantly by the decisions of a few individuals to switch to methyl bromide. The new strawberry plant propagation application described above now uses 45,000 kg in Ontario on approximately 300 acres of land. The apparent advantages of methyl bromide over most other alternatives mean that new uses like this could develop substantially.

Based on the interviews conducted in preparing this report, the economic value of methyl bromide use in Canada can be ranked from most valuable to least valuable as follows:

- Commodity, especially quarantine.
- Space, particularly food processing.

EXHIBIT III-2 The Relative Importance of Soil Fumigation



Source: World and North America data are for 1990 as published in EPA (1992), Tables 2-6 and 2-8, excluding chemical intermediates. Canadian data are an average for 1990 and 1991 as estimated by Abt Associates.

- Soil.
- Structural.

The data in Exhibit III-2 indicate that Canada has a series of applications that fall in the higher value categories relative to those other parts of the world shown in the exhibit. This is relevant for a Montreal Protocol reduction schedule approach since most other countries would have relatively more low value uses to eliminate. With a 70% cut, for example, Canada would have to cut more valuable applications when other countries could concentrate most or all of their reductions in soil fumigation.

Overall, the distribution of methyl bromide consumption among the four use categories can be summarized as follows:

- Space fumigation; 50%.
- Soil fumigation; 45%.
- Commodity fumigation; 5%.
- Structural fumigation; 0.

Within the category of space fumigation, most of the applications are in food processing. For shipping, holds of grain vessels may account for 10,000 to 15,000 kg per year of methyl bromide in fumigating approximately 50 ships. This estimate is based on data for Vancouver indicating that approximately 25 ships are fumigated per year with an average methyl bromide quantity of 200 kg per ship.

4. Value of Commodities Treated

The terms of reference for this study call for an estimate of the value of commodities treated with methyl bromide. Technically, this refers only to the small proportion of methyl bromide used for commodity fumigation although we provide some data related to space fumigation as well.

For soil fumigation, the analogous amount is the value of crops grown on soil treated with methyl bromide. We estimate that approximately 45% of 1990 consumption of 131,000 kg or nearly 60,000 kg were used for this purpose in Canada. Of this total, our estimates indicate that approximately 45,000 kg were used to support greenhouse agriculture in Ontario with an estimated crop value of $50 million. More recently, nursery stock applications in producing strawberry plants have developed using approximately 45,000 kg of methyl bromide for crops with an export value of $3.2 million.

In the case of space fumigation, large volumes of product flow through mills and related facilities that are fumigated. However, there is no direct relationship between these total flows and the amount of methyl bromide used. Without methyl bromide, greater costs would be incurred in these facilities some due to product losses but these losses would be a small fraction of total output. Data from Statistics Canada show that, for 1988, manufacturers in the food sector using methyl bromide shipped products with a value of $6.2 billion.[1]

C. QUARANTINE APPLICATIONS

The Plant Protection Division of Agriculture Canada has the responsibility for administering the *Plant Protection Act* and its Regulations. The intent of this legislation is to prevent the spread of pests not native to Canada and to increase the value of Canadian exports by maintaining high quality standards in terms of pest control.

In terms of commodity fumigation, very few Canadian export products are treated with methyl bromide, but large quantities of imports have been fumigated with it in the country of origin. Some Canadian fruit products destined to Japan are fumigated with methyl bromide as is some nursery stock destined for the EEC. There is also a significant demand to treat wood with methyl bromide.

Grain as a commodity is fumigated using aluminum phosphide when treatment is required. However, empty ships, trucks and railroad cars must be fumigated with methyl bromide if found infested. Grain mills if exporting are inspected and most mills fumigate with methyl bromide. As routinely defined, these would all be space fumigation applications. However, it is clear that they are related to commodity quarantine and have similar economic importance.

[1]The estimate here is based on data from Statistics Canada, *Products Shipped by Canadian Manufacturers*, cat. no. 31-211. The major industry groups included in the total are Flour and Wheat Milling, Cocoa and Preparations, Food Preparations of Flour, Cereal Foods, Pasta and Products, Soups, Broths and Preparations and Breweries. Data for 1988 are from the Census of Manufacturers and are the most recent available.

It is important to reiterate that Canada uses almost no methyl bromide to fumigate export commodities and fumigates almost no imports in Canada. Imports to Canada arrive with phytosanitary certificates which certify that the commodity was fumigated at the point of origin when this is required. Fumigations are carried out only if infestation is discovered by Agriculture Canada. **This means that a narrowly defined exemption for quarantine applications would not include many of the activities that are most valuable for Canada.**

IV CONTROL OPTIONS FOR METHYL BROMIDE

A. OVERVIEW

For methyl bromide, control options are the policies or alternatives that might be pursued as part of a strategy of reducing and phasing out this substance. The alternatives being pursued and the timing of the various transitions are clearly important in this regard.

The most important point to make with regard to control options for methyl bromide is that a single replacement with the same broad spectrum properties is very unlikely. Control options will vary depending on the specific application and in some areas, combinations of approaches may be required to replace methyl bromide. As well, there are applications in which no substitutes have been identified.

The search for control options for methyl bromide appears to be more constrained than has been the case for the CFCs. This reflects the nature of the product since any effective fumigant will, in varying degrees be harmful to human health at some dose level. Fumigants are regulated in their use and a variety of alternatives to methyl bromide such as ethylene dibromide have been removed from the market due to health concerns. VORLEX continues to be used and available in Canada but it is being withdrawn from the U.S. market by its manufacturer. A common reaction in the interviews conducted for this report was that "there aren't any fumigants left". Other sources indicated that the development and registration of pesticides is more difficult than the development of new industrial chemicals.

Many individuals pointed out the substantial utility of fumigants. As gases, they permeate crevices and other areas that are difficult or impossible to access using other approaches. The prospects for developing new fumigants are limited. Only certain types of small molecule chemical compounds can be used as fumigants and experts indicate that virtually all likely alternatives have been examined already (Bond, 1984).

B. STRUCTURAL FUMIGATION

As noted previously, climate conditions mean that virtually no structural fumigation activities are carried out in Canada. Sulfuryl fluoride manufactured by DowElanco as VIKANE has been identified as an acceptable option for this application.

C. SOIL FUMIGATION

1. Overview

Methyl bromide is used as a soil fumigant to eliminate a wide range of pests such as nematodes as well as diseases and weeds. It is used in Canada primarily in intensive agricultural applications such as greenhouses in the Leamington area where vegetables including tomatoes, cucumbers, lettuce and peppers are grown throughout the year. These uses in this specific area appear to account for approximately 30% of total Canadian consumption in 1990. Soil fumigation outside greenhouses also occurs, primarily in Ontario and Quebec.

Methyl bromide replaced steam sterilization in this kind of intensive agriculture because steam was more expensive and increased in relative terms as energy prices increased. As well, methyl bromide fumigation in a greenhouse can be carried out in less than an hour in contrast to approximately 16 hours for steam. Steam is also less effective particularly with regard to nematodes and weed seeds.

In greenhouse applications, the most promising approaches have been developed in The Netherlands. In the early 1980's, Dutch consumption for greenhouse use was in the order of 3,000 tonnes annually. As a benchmark, current Canadian consumption for all uses is approximately 150-200 tonnes. The initial Dutch reduction approaches focused on gas-tight films to reduce use and emissions. More recent approaches have been in the area of alternative cultural practices. Use declined annually after 1982 and further use for soil fumigation in the Netherlands was banned as of January, 1992.(Mus and Huygen, 1992).

The Dutch approach as reported in the 1992 UNEP *Interim Technology and Economic Assessment* is based on artificial plant growth substrates and alternative pest control approaches including the use of steam sterilization. The key appears to be the investments in the substrate technologies that the UNEP report indicates have been cost-effective. The UNEP report (p. 7) notes, however, that further evaluation is required to determine the applicability of the approach to other agricultural systems and regions. We have not been able to determine the cost and related constraints that might exist in transferring this approach to the greenhouse growing environment faced in Canada.

2. Major Soil Fumigation Options

For soil fumigation, the major control options are:

- TELONE-II and TELONE C-17 which are respectively 1,3-dichloropropene (1,3-D) and a blend of 1,3-D and chloropicrin.
- Metam-sodium-VAPAM. Active ingredient is methyl isothiocyanate.
- Dazomet-BASAMID. Active ingredient is methyl isothiocyanate (MIT).
- Chloropicrin.
- VORLEX-80% 1,3-D and 20% MIT.
- Soil solarization.
- Plant growth-promoting rhizobacteria (PGPR).
- Furfuraldehyde.
- Steam.
- Integrated pest management systems.
- Gas tight tarpaulins.

All of the control options listed above have applications in which they are effective but all have associated limitations as well. An overview of these options with comments about likely efficacy and applicability is provided in Exhibit IV-1.

EXHIBIT IV-1 Major Control Options for Methyl Bromide in Soil Fumigation in Canada

Control Option	Assessment
TELONE-II	Nematocide only. Waiting period of 4 to 6 weeks. Slow dissipation in cooler climates.
TELONE-C-17	Nematocide, fungicide but no herbicide action. Limitations as for TELONE-II.
VAPAM	More difficult application, longer waiting period. Less effective for weeds and disease. Effective nematocide.
BASAMID	Discovered in 1952. Never registered for food products in Canada. Requires 3 week waiting period prior to planting.
Chloropicrin	Effective fungicide but not effective for weeds, nematodes.
VORLEX	Widely used substitute for methyl bromide particularly in tobacco products. Product being withdrawn by manufacturer in United States due to 1,3-D concerns. Causes tumours in rats.
Soil Solarization	Solar heating of covered field. Limited applicability in cooler climates.
PGPR	Not broad spectrum. More research required.
Furfuraldehyde	Selective nematocide. Still at developmental research level.
Steam	Less effective and much more costly.
Integrated Pest Management	Crop rotation increases costs in greenhouse applications.
Gas Tight Tarpaulins	Reduces consumption and emission rate

Note: In this exhibit and in the text, registered trade names are indicated by the use of capitals.

The control options for methyl bromide consist of other fumigants already registered with Agriculture Canada, fumigants that are not registered at this time, as well as other chemical and non-chemical alternatives that do not require registration. In the case of non-registered alternatives, the required time to gain registration status may be substantial and some of the existing alternatives such as TELONE and VORLEX may become unavailable due to concerns about 1,3-D. As a number of reports have indicated, the use of methyl bromide is increasing partly due to the disappearance of alternatives resulting from regulatory concerns. The existing situation with regard to each of the fumigants listed above is that Canadian regulatory authorities are reviewing their registration status.

A major concern with regard to methyl bromide controls and regulations of substances using 1,3-D is nematodes. Braxton (1991) reports poorer and less consistent performance for contact nematocides including TEMIK, NEMACUR, FURADAN, VYDATE and MOCAP. This is particularly the case when these non-fumigant agricultural chemicals are used where nematode pressure is greatest.

One control option for methyl bromide consumption is to use less per application through the more widespread use of the 67/33 mixture with chloropicrin. This formulation is more effective due to the combined action of the two fumigants but is more expensive. However, the evidence that we have assembled indicates that 67/33 is already the fumigant of choice in virtually all soil applications. Some quantities of 98/2 are used for soil fumigation in Canada but these quantities are already small.

Steam sterilization has been used in greenhouse applications but its use has declined relative to fumigants. A report by Culice Inc. (1985) indicates that the costs of steam are approximately three times the cost of fumigation. This differential is compounded by the greater efficacy of fumigation.

The use of gas-tight tarpaulins has the potential to reduce the quantity of methyl bromide required in a specific fumigation and to reduce the emission rate. Presently, firms in Canada carrying out soil fumigation use coverings that are intended to hold the gas in the soil to reduce exposure and increase efficiency. New and less permeable tarpaulin systems are being developed that would be more effective than existing tarpaulins.

In the Canadian context, and in the United States where much of the research work on alternatives is being carried out, the most relevant fumigant alternatives in terms of fumigating properties are VORLEX, VAPAM and BASAMID. A number of sources indicate that VORLEX is the most reliable option and that VAPAM is associated with more pest damage and may not support economic production of a number of crops.

The prospects of BASAMID are not clear at this time. It is currently used with nursery stock and in other non-food horticultural applications. This fumigant is based on the release of methyl isothiocyanate (MIT) and some sources indicate that the release characteristics of MIT may restrict its use to ornamentals and other non-food applications. Deissler (1992), a representative of the manufacturer, has argued that in many respects, BASAMID is an extremely promising replacement for methyl bromide. It shares the general broad spectrum properties of methyl bromide and the economics of its use are comparable. The major limitations are a required three week waiting period after its application before replanting and its regulatory fate with regard to use on food products. It is currently registered in Germany for food product uses. Production capacity is currently limited so that Deissler estimates that BASAMID could replace methyl bromide as a soil fumigant according to the following schedule:

- 1993: 5%.
- 1994: 10%.
- 1995: 25%.
- 2000: 100%.

This schedule could clearly not be followed on an international basis since regulatory requirements would proceed more slowly than assumed in the initial years shown above.

There are obviously highly divergent views about the potential for replacing methyl bromide with BASAMID in a wide range of soil applications. This illustrates a general problem of specifying control options and likely outcomes with any degree of accuracy. The extent of consensus among industry knowledgeables is limited in many areas. These issues will be resolved over time but they limit the types of conclusions in this report about the specific control options that might be adopted in soil fumigation. This is also reflected in the available literature. The UNEP *Interim Technology and Economic Assessment Report*, for example, notes that current opinion is that 30% to 90% of methyl bromide in soil fumigation could be replaced by 1997 with a best estimate of 50%. This is clearly a wide range.

For Canada, greenhouses operators presumably have the technical capacity to eliminate methyl bromide since this has been done already in the Netherlands. The issue then becomes one of cost and we have not discovered any cost data on the Dutch approach.

In other soil applications, alternatives do exist. One plant propagator reported having switched recently to methyl bromide from VAPAM because of the substantially better results with methyl bromide. Cost issues are discussed in more detail in the following chapter of this report. For most of the soil fumigation alternatives reviewed in this section, there are potential environmental or health and safety costs of greater use. Groundwater contamination is an issue that is under review with regard to the use of TELONE II, TELONE C-17, VAPAM, VORLEX and BASAMID.

D. SPACE FUMIGATION

1. Overview

In Canada, space fumigation with methyl bromide consists of a variety of applications with food processing plants, breweries and food storage and food transportation facilities being the most important. Other specialized applications include the fumigation of aircraft. The most prominent control option for methyl bromide in these applications is aluminum phosphide.

In addition to aluminum phosphide, the primary control options for reducing methyl bromide consumption include the following:

- Pesticides such as malathion.
- Volume displacement methods.
- Carbon dioxide or nitrogen blends.
- Heat treatment.
- Freezing.
- Spot fumigation.

The likely efficacy of these alternatives differ from application to application. The following subsections provide a review of the potential uses of each of these options. A brief summary for each option is shown in Exhibit IV-2.

2. Aluminum Phosphide

The major fumigant control option for methyl bromide in space fumigation is aluminum phosphide. However, aluminum phosphide already competes with methyl bromide in this market and methyl bromide tends to be used primarily for applications in which aluminum phosphide poses important problems.

In space fumigation, aluminum phosphide is used extensively in silos for grain fumigation where it is the commodity rather than the space that is to be treated. Methyl bromide does not penetrate into grain and would not be used for this purpose. Pellets of aluminum phosphide are mixed throughout the grain to ensure penetration.

In a food processing plant such as a bakery or a flour mill, methyl bromide has two distinct advantages over aluminum phosphide (ALP). In the case of ALP, the facility must be sealed for 72 hours in contrast to 24 hours for methyl bromide. This is in addition to 24 hours before and after to carry out sealing and then to remove it. This translates into a downtime of 5 days for ALP in contrast to 3 days for methyl bromide.

The other limitation on the use of ALP is that it is corrodes precious metals at the heat and humidity levels often encountered in the summer when fumigation is normally required. This raises the likelihood of damage to electronics or telecommunications equipment in the facility. If AP were to be used, such equipment would have to be removed or sealed. In the absence of these metals and if there is not a time constraint, aluminum phosphide is already used extensively.

Most grain mills and food processors using flour fumigate annually with methyl bromide. In addition, all grain carriers — ships, trucks and railroad cars — are inspected regularly by Agriculture Canada and must be fumigated with methyl bromide if any infestation is detected. This fumigation is done when the carrier is empty. Aluminum phosphide is an alternative in these applications but the additional time costs may be more of a constraint, especially for ships carrying grain. These costs have been estimated at $20,000 per day.

EXHIBIT IV-2 Major Control Options for Methyl Bromide in Space Fumigation in Canada

Control Option	Assessment
Aluminum phosphide (phostoxin)	Major control option. Facility must be sealed for at least two additional days. Assumes corrosivity issue can be resolved. More difficult for shipholds in cold weather.
Pesticides (e.g. malathion)	Reduces methyl bromide requirements. Approach used extensively already.
Volume displacement	Innovative process. Significant reduction potential at moderate cost.
Carbon dioxide or nitrogen blends	Not an approved use. Reductions could be as large as 50%.
Heat treatment	Used in some U.S. mills. More Canadian research required.
Freezing	Theoretical alternative. Damage to structures likely too great for this to be feasible.
Spot fumigation	Effective in segmented plants. Procedure is already used.

3. Pesticides

Pesticides such as malathion used in spray form can keep down pest populations especially when combined with effective sanitation practices. The EPA (1992) indicates that this can eliminate the need for fumigation but most other sources seem to suggest that this alternative can reduce the frequency of fumigation but not eliminate it. Our information indicates that most food plants and related users of methyl bromide already carry out spot insecticide treatments to control problems between fumigations.

4. Volume Displacement

The technique of volume displacement is a patented process for reducing the use of methyl bromide or any fumigant in space fumigation.(Chaudoin, 1992). Silos, ships and facilities like food processing plants contain large volumes of air that must be brought up to the required fumigant concentration even though the pests are concentrated in crevices and related areas. The volume displacement process involves filling the structure with large impermeable polyethylene bladders during the fumigation and thereby reducing the air volumes that must be mixed with methyl bromide. The methyl bromide reduction depends on the volumes displaced but could be substantial in food processing plants and in holds of ships.

5. Methyl Bromide Mixtures

The use of a mixture of methyl bromide with either nitrogen or carbon dioxide could reduce required quantities of methyl bromide in space fumigation. In the most optimistic scenario in which a 50:50 mixture of methyl bromide and CO_2 or nitrogen is used, methyl bromide reductions could be in the order of 50%. Less methyl bromide is required in these mixtures to kill pests because the mixture accelerates the respiration rate of the pests and leads them to ingest the required quantities more readily.

Methyl bromide mixtures are anticipated to be more costly due to the requirement of introducing another gas. As well, both CO_2 and nitrogen dissipate more quickly than the existing mixture so that more costs would have to be incurred to seal facilities more tightly. Methyl bromide is not currently approved for use in a mixture of this kind so that there would be potential regulatory delays in introducing this control option.

6. Heat Treatment

The successful use of heat treatment as an alternative for fumigation to control insects in some North American food processing plants has been documented by Thompson (1992). Quaker Oats and General Mills are two firms that have used this process in their plants in the United States. The technique involves the distribution and use of heaters to raise the temperature of the plant to as much as 130 degrees Fahrenheit (54 Celsius) for 24 to 30 hours. This is used as part of a broader system of control that includes the use of insecticides and good housekeeping.

The technique is reported effective for most food plant insect pests with the exception of cockroaches. Treatments are required four to six times per year scheduled to upset insect lifecycles. Cited advantages include reduced use of toxics and less reporting and regulatory pressure particularly in the U.S. including "Community Right to Know" reporting.

The potential negative aspects of heat treatment as a control option include the following:

- The method is not effective if substantial amounts of commodities are in the plant since the heat does not penetrate stored grain very quickly.
- Some buildings, particularly those with pre-cast concrete roofs will not tolerate this much heat.
- Some electronics may be too heat-sensitive for this treatment.
- Older fire control sprinkler heads will have to be replaced with higher rated units.
- Set-up costs for heaters are high. Each room of 43,000 cubic feet requires heaters costing between five and twenty thousand dollars.
- Hollow walls and wooden equipment transmit heat slowly requiring longer treatments.

7. Freezing

Many of the comments above with regard to heat apply to the use of low temperatures for pest control. This method requires longer times to be effective and may have more constraints associated with damage to buildings and production facilities. It is regarded as a very unattractive option.

8. Spot Fumigation

Typical procedures for fumigating a food processing plant involve sealing the entire facility and introducing methyl bromide. Depending on the nature of the facility, pest problems may be concentrated in particular areas of the plant. If these areas can be sealed off and spray pesticides can be used in the less critical areas, substantially less methyl bromide would be required.

An approach of this kind would also require more detailed programs of maintaining a clean facility. A number of firms report that they are already moving in this direction to minimize the extent of fumigation activity.

E. COMMODITY FUMIGATION

Commodity fumigation is used to deal with pest control in stored products and for international quarantine treatments. As noted above, this is a relatively small use of methyl bromide in Canada but one with a high value and for which control options are limited. Quarantine requirements are determined by Agriculture Canada for imported commodities and by other governments for Canadian exports. Wood products cannot now be fumigated in Canada using methyl bromide but this is an area where Agriculture Canada is reviewing the possibility of adding this application to existing labels.

There are a number of theoretical control options that are not explicitly considered in this section. These include options such as ethylene dibromide, a fumigant no longer used due to concerns about its carcinogenic and other dangerous properties. There seems no prospect of altering past regulatory initiatives to reinstate products of this kind. Exhibit IV-3 summarizes the most relevant options.

Commodity and quarantine fumigation is a potentially difficult area in which to replace methyl bromide. The UNEP Technology and Economic Assessment report notes the following:

> Development of acceptable alternatives to methyl bromide for certain commodities is complex and-----unlikely to be available by the end of the century. UNEP(1992), p. 8.

EXHIBIT IV-3 Major Control Options for Methyl Bromide in Commodity Fumigation in Canada

Control Option	Assessment
Aluminum phosphide (phostoxin)	Effective for grain but already used in that application. Phytotoxic and more time-consuming. Not a significant option.
Irradiation	Effective approach. Positive comments from more technical sources. Consumer and regulatory reticence.
Heat, cold	Effective for very few products. Damages produce.
Modified atmospheres	CO2 and others. Limited applicability except for stored products.
Emission controls	Potential option for quarantine applications. Canadian blue bottle technology may be effective.

The source of this concern about the importance of methyl bromide for commodity fumigation reflects the fact that most alternatives have higher application costs, are less effective, and take more time. Vail (1992) has argued that it will not be possible to replace methyl bromide with a single alternative. "Methyl bromide quarantine treatments would take years to replace with alternatives which would be country, commodity and organism specific". He also notes that: "historically, quarantine treatments have been technically tedious to develop, and may also have political or economical overtones."

The other fumigant used in these applications is aluminum phosphide but this is usually restricted to use on grains. Aluminum phosphide is phytotoxic and requires much longer times to be effective. Methyl bromide can be effective in as little as two hours in contrast to seven days for aluminum phosphide in some applications. Aluminum phosphide is already used for some fumigations where time is not a constraint in stored product applications.

Other control options for methyl bromide in stored product and quarantine applications in Canada include the following:

- Irradiation.
- Heat, cold.
- Controlled/modified atmospheres.
- Emissions controls and recycling.

The growth of irradiation as an alternative to fumigation with methyl bromide has the potential to be an important future option using a technology that has been extensively developed and tested in Canada. A detailed outline of the potential of irradiation is provided by Marcotte (1992). The major constraints relate to regulatory approval and consumer acceptance. Plant protection officials view this as a technically viable option but not one that will realistically be used in the short term.

Marulli (1992) suggests that 5% of methyl bromide commodity use could be replaced immediately by low dose irradiation but that this fraction would grow only slowly until substantial new resources were devoted to more irradiation facilities.

Heat and cold treatments have the advantage of having virtually no negative environmental impacts. However, the range of products for which they are effective is very limited because of damage to the product being treated.

For stored products, controlled/modified atmospheres are presently used. Oxygen levels are reduced as levels of nitrogen or carbon dioxide are increased. Some products such as apples are stored in these conditions for extended periods of time. Low risk gases are used and the process is well known. It is not likely to be effective in many quarantine applications.

Reducing emissions by recapturing methyl bromide for subsequent use appears to be a very attractive control option in quarantine applications. Some of this fumigation activity is carried out in fumigation chambers where the logistics of recapture are more manageable than in space applications where much larger volumes of air would have to be handled and in which emissions cannot be as effectively controlled. In principle, it should be possible to reduce fumigation chamber emissions almost entirely although there are as yet no commercially available systems of this kind.

The Canadian blue bottle or molecular sieve approach is potentially applicable for fumigation chambers and even for some of the space fumigation applications discussed in the previous sub-section. Halozone Recycling of Toronto currently markets related devices for CFCs and a company official has indicated that, in principle, the technology should work for methyl bromide as well. The toxicity and explosiveness at a critical concentration of methyl bromide in air mean that extensive testing would be required. However, that testing should take a year or less and all indications are that the process is feasible.

If almost complete recycling is feasible in critical applications such as quarantine, some consideration might be given to exemptions for methyl bromide fumigation controls where recycling facilities are in place. Such an approach is not consistent with the existing Montreal Protocol controls in which complete consumption phase-outs are mandated regardless of the emission rate. An approach that focuses on emissions may be more relevant for at least some methyl bromide applications because of the greater difficulty of finding acceptable alternatives compared to the existing substances controlled under the Protocol.

V COSTS OF REDUCED METHYL BROMIDE AVAILABILITY

A. OVERVIEW

Methyl bromide is recognized as an ozone-depleter and international decisions will be taken shortly to consider its status within the Montreal Protocol. One proposal from the U.S. Environmental Protection Agency is to freeze methyl bromide consumption in 1995 at 1991 levels and reduce annually thereafter in a transition to a complete phase-out in 2000. Other proposals including the Canadian position are less restrictive than this but reductions in availability appear likely. This section considers the potential costs for Canada of reduced availability of methyl bromide.

The estimation of such costs is not straightforward and the existing data are not well-developed for such an assessment because concern about methyl bromide use in Canada has been so recent. In this report, we present data that are relevant to the consideration of cost but we are not generally able to provide the cost data that we ideally wish to have. Where possible, direct estimates of costs that will be incurred are presented, but it is usually not possible to do this.

B. ISSUES IN MEASURING COST

The costs of not being able to use methyl bromide in the future must be calculated on a disaggregated basis. That is, the cost impacts will differ not only in magnitude but in terms of impacts depending on the application involved. Some space fumigation, for example, might switch to aluminum phosphide and here the costs would involve extra time that the facility is closed. In a quarantine application on the other hand, the cost of not being able to use methyl bromide might be the loss of a shipment of fruit with longer term costs associated with less trade in such commodities because of the greater costs of products that are destroyed and refusals by many countries to accept imports.

In terms of the previous sections of this report, the costs of doing without methyl bromide, either partly or entirely, consist of the costs of introducing the control options discussed in Chapter IV. This highlights the difficulties in estimating costs since there is still substantial uncertainty about, for example, the efficacy or the continuing regulatory status of some control options.

The economic approach to considering the costs or reduced availability is shown in Exhibit V-1. This exhibit shows the Canadian market for methyl bromide in terms of demand and supply. No methyl bromide is produced in Canada so that Canadian demanders face a perfectly elastic (horizontal) supply curve at the world price. Canadian demand, as shown in the downward sloping demand curve, is a reflection of the existing use patterns and reflects the available alternatives to using methyl bromide.

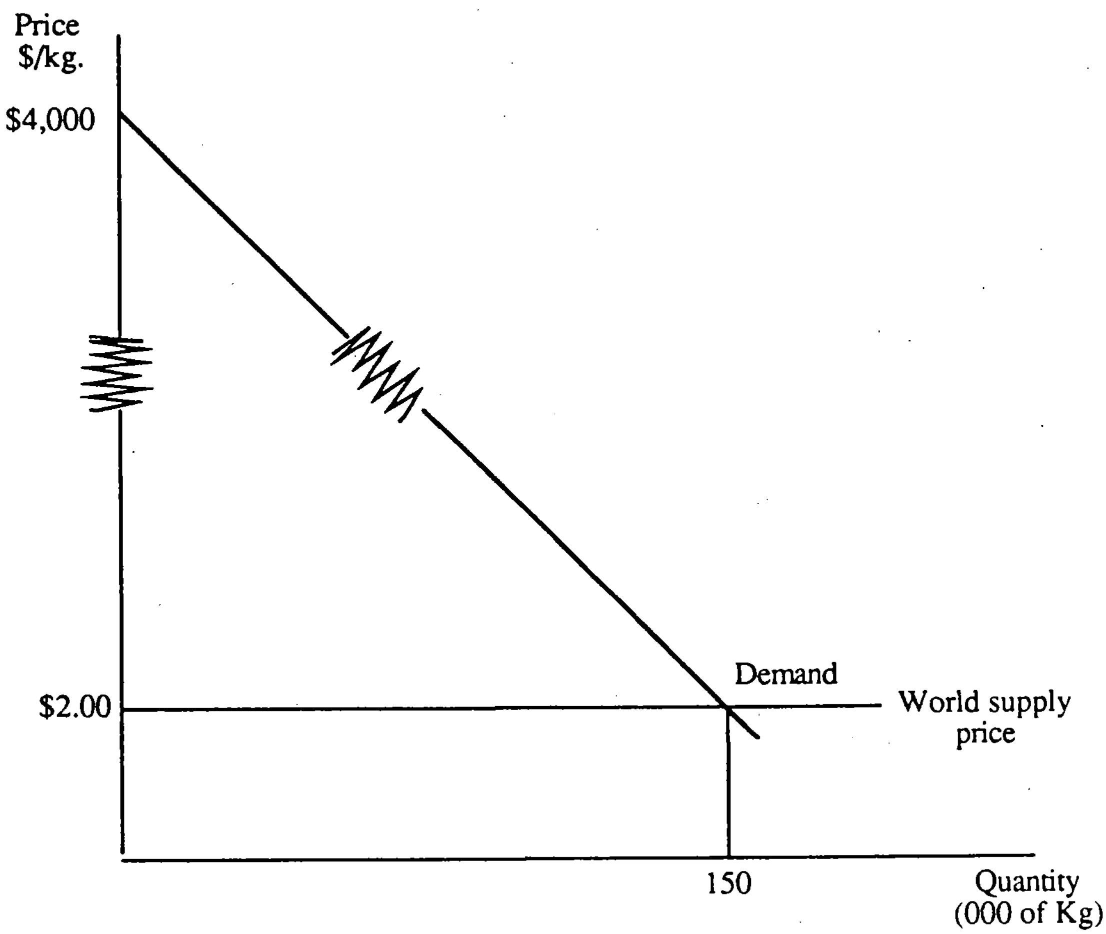
If methyl bromide were not available at all, the cost to Canada would be the lost consumers' surplus in Exhibit V-1. This is the area below the demand curve and above the horizontal price line. In assessing the costs of reduced availability of CFCs, the EPA built a model of this kind based on lost surplus. The approach has also been used in Canada in connection with reductions in the availability of methyl chloroform and carbon tetrachloride.

Why does the demand curve tell us something about the cost of reduced methyl bromide availability? The demand curve shows us what users are willing to pay for methyl bromide. In the exhibit, we show demand for 150,000 kg of methyl bromide at a price of $2.00. This approximates our estimate of the 1991 market.

This demand curve aggregates all users of methyl bromide and assumes that they all pay exactly the same price for it. This will not be literally true in that larger users likely pay less but the extent of this variation is likely small. What does differ substantially is the value of the methyl bromide to the user. Some users who are "at the margin" would stop using methyl bromide if its price were to increase by even a small amount. Others would continue to use it even at substantially higher prices although they would obviously prefer a lower price. Users who can purchase methyl bromide at $2.00 when they would willingly pay more rather than do without receive a benefit called consumer surplus.

As an example, consider greenhouse agriculture applications of methyl bromide. Steam sterilization is both less effective and more costly than methyl bromide. When would a grower ever voluntarily switch from methyl bromide back to steam? The answer is that this switch would take place when the price of methyl bromide rises sufficiently to offset its advantage over steam. The cost of converting to

EXHIBIT V-1 The Canadian Market for Methyl Bromide



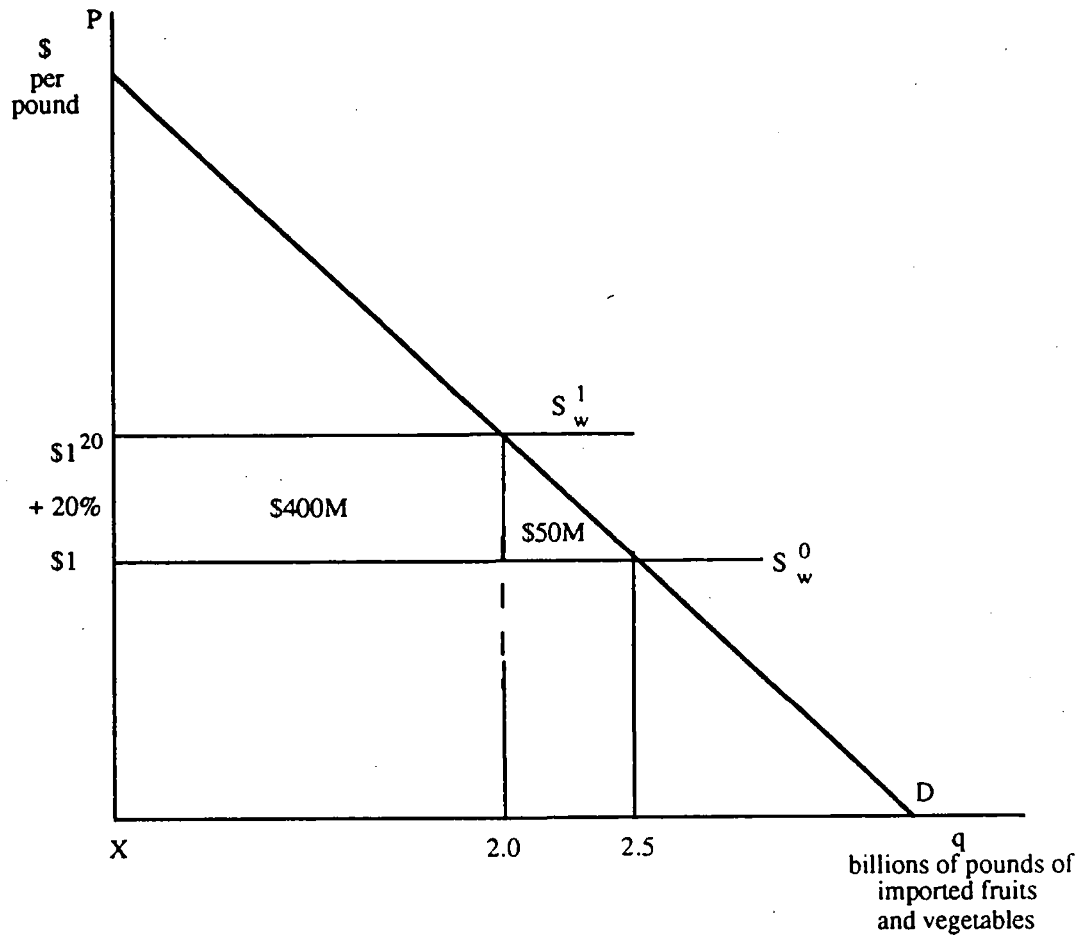
steam can in other words be measured in terms of the willingness to pay for methyl bromide. If methyl bromide were only marginally better than steam, then the cost of losing methyl bromide would be small. Correspondingly, the willingness to pay for methyl bromide would not be much greater than the current price.

This means that if we knew empirically the shape of the complete demand curve for methyl bromide, we could calculate the cost of no longer having it available. If we are willing to assume that the demand curve is a straight line, we can estimate the costs if we know the intercept on the vertical axis. This is the price of methyl bromide that is high enough to eliminate all uses. This price would be the one that we observe in the commodity fumigation sector. How much would the owner of a shipment of fruit be willing to pay for methyl bromide if the alternative is the destruction of the complete fruit shipment? The answer is that the owner would be willing to pay an amount for enough methyl bromide to do the fumigation that is nearly equal to the value of the shipment. Many people that we interviewed pointed out that the cost of fumigation with methyl bromide is very small in relation to the value of commodities fumigated.

To carry out a rough calculation, assume that we have a load of fruit with a market value to the owner of $200,000. Assume also that 50 kg of methyl bromide would be required to fumigate it. This means that the owner would be willing to pay nearly $4,000 per kg at least in this specific case. If we use this as the intercept in Exhibit V-1, then the annual cost of complete elimination of methyl bromide would be $300 million, the area of the triangle above the $2.00 price line. The present discounted value of this amount at a 7.5% discount rate over ten years is approximately $2.2 billion. This is clearly a very large multiple of the value of methyl bromide used in Canada. These are assumed values for purposes of this example since we do not have enough demand information to do a more precise calculation.

A related perspective is provided in Exhibit V-2. This exhibit focuses on fruit and vegetable imports to Canada. A complete analysis would focus on each product separately and develop a model for analyzing separate impacts. This diagram aggregates all imported Canadian fruit and vegetables into a composite commodity with a single average price. The purpose is to provide a rough assessment of the potential impacts on Canada of the removal of methyl bromide for import quarantine applications. Note that this loss is based on methyl bromide use in countries that now export to Canada.

EXHIBIT V-2 The Costs of Higher Import Prices



Note: This example is illustrative. The quantity is accurate but the composite price per pound may not be. Note as well that methyl bromide fumigation is not required for all imported fruit and vegetables. These Canadian impacts would result primarily from reduced availability of methyl bromide in countries exporting these commodities to Canada. The impacts are related to both soil fumigation and quarantine uses of methyl bromide..

The assumption in Exhibit V-2 is that the loss of methyl bromide causes imported fruit and vegetable prices in Canada to increase by 20%. We assume that prior to the increase, 2.5 billion pounds were sold at an average price of $1 per pound. This total sales figure of $2.5 billion is approximately the correct value for Canada according to data published by Statistics Canada. The annual loss to Canadian consumers is the lost consumers surplus in the exhibit and this totals $450 million per year. Over a 10 year period at a discount rate of 7.5%, this has a present value of $3.3 billion. This loss to Canadian consumers from methyl bromide restrictions elsewhere likely exceeds the costs from reduced usage within Canada. An economic approach of the type described above was used in the National Agricultural Pesticide Impact Assessment Program study at the USDA (Padula, 1992).

C. POTENTIAL COSTS BY APPLICATION

The preceding discussion of the costs of losing the services of methyl bromide as a fumigant is illustrative of the potential economic costs involved. However, it will also be useful to present the available data on costs for each of the applications of methyl bromide in Canada.

1. Soil Fumigation

In Canada, most soil fumigation is in greenhouses, either for new plants or for intensive greenhouse cultivation of vegetables. Steam sterilization would be much more expensive and is much less effective so that this option is unlikely to be pursued except as part of the integrated Dutch approach. If BASAMID were approved for food products, this might be an option that would replace methyl bromide at a moderate cost. Since the waiting period is three weeks, as much as 6% of annual production might be lost. For Ontario, where most of the methyl bromide is used for this purpose, this would be in the order of $3 million plus the additional costs of BASAMID use. It is not clear, however, that this use for BASAMID will be approved.

The Netherlands has developed an approach to intensive greenhouse cultivation that has been widely publicized. Its existence is well known but its costs are not. The UNEP Technical Options report states that further work is necessary to determine its cost and applicability to other regions. Canadian sources did not have cost data for this approach. Existing growers doubt that it is economic in Canada.

2. Space Fumigation

The costs of reducing the use of methyl bromide in space fumigation options should be moderate. Volume displacement, for example, is a very low cost method of reducing consumption.

The central issue in the complete elimination of methyl bromide in space applications appears to be the extent to which aluminum phosphide can take its place. We have encountered a variety of positions on this question. There is widespread agreement that aluminum phosphide takes two or more days of down time and is corrosive. Some sources indicated that the corrosion problem could be handled by removing and covering sensitive equipment. This will obviously be more costly. The down time issue is a cost but if plants have some excess capacity, lost output could be produced at other times. This may be the case for grain mills, but bakeries and other food processors may not be in the same situation. Overtime premium costs would be involved. This cost would be approximately once per year per plant.

Data for Ontario in 1991 show 62 fumigations with methyl bromide in mills and related food production and storage applications. Incremental costs of aluminum phosphide when combined with other control options might be as low as $10,000 per plant for a total of $620,000 annually. If Ontario accounts for a third of the national total, this implies a total of less than $2 million annually. This includes most but not all space fumigation applications with methyl bromide. If the corrosivity problem cannot be resolved then these costs would be higher.

For trucks and rail cars that carry grain, fumigation costs with ALP instead of methyl bromide should be moderate. However, the costs of holding empty grain-carrying ships in port for an extra two days would be very high. Agriculture Canada is in the process of gathering data on the number of such fumigations but the data are not maintained in a form that will allow speedy retrieval. The cost would be the number of annual ship fumigations times the costs of an extra delay of two days. If the daily cost is $20,000, then the annual cost could exceed $1 million.

3. Commodity Fumigation

Very little commodity fumigation using methyl bromide is carried out in Canada. The use of methyl bromide on wood products could increase this use in the future but heat should be a viable alternative. If the Halozone approach is feasible, the costs would be the recycling systems plus new fumigation chambers. These costs would be moderate.

D. COSTS OF CANADA'S PROPOSED REDUCTION SCHEDULE

1. Overview

The previous subsections of this chapter provided on overview of measurement issues with regard to the costs of eliminating the use of methyl bromide. To simplify this exposition, the scenario examined was the one of immediate and complete elimination of methyl bromide in all of its applications. This section is more specific in that it looks at the costs that might result from the specific reduction scenario that is being proposed by Canada.

2. The Canadian Proposal

The Canadian proposals to be presented at the 1992 Copenhagen meeting of the parties to the Montreal Protocol consist of the following elements:

- Addition of methyl bromide to the Protocol list of ozone-depleting substances.
- Freeze 1995 consumption of methyl bromide at 1991 consumption levels.
- Reduce consumption of methyl bromide to 75% of 1991 benchmark by 1998.
- Provide an exemption for quarantine applications of methyl bromide and exemptions for related uses supporting the export of Canadian grain and grain products.
- Review the proposed reduction schedule at the 1994 meeting of the parties in the light of new information on the benefits and costs of controls.

3. Assessment of Costs

As noted above, complete and immediate elimination of methyl bromide would entail substantial economic costs for Canada. However, the Canadian proposal is for an initial freeze followed by a 25% reduction that would not take place until 1998 and incorporates quarantine-related exemptions. The costs of implementing this proposal will be a small fraction of the costs of total elimination.

There are two major uncertainties in assessing the costs of the Canadian proposal. Both relate to the extent of growth in methyl bromide consumption between now and 1995. These uncertainties relate to:

- The continuing availability of VORLEX in Canada. This product has been withdrawn in the U.S. It remains available in Canada and we assume that this will continue. Without VORLEX, methyl bromide demand would be much larger.

- The regulatory status of methyl bromide for use on wood and wood products. The status of methyl bromide is being reviewed and a clarification of existing labels might increase methyl bromide use. Although this would increase Canadian consumption, the environmental impact would be minimal since Canadian fumigation would almost entirely replace fumigation with methyl bromide elsewhere.

Estimates elsewhere in this report indicate that 1992 consumption of methyl bromide in Canada is likely to be approximately 200 metric tonnes. In the absence of regulation, this could grow to 220 to 250 tonnes by the end of 1994. If the 1991 baseline of 150 tonnes is used, this implies a reduction in 1995 of 30-40%. We estimate that most of the increase in consumption from 1991 to the end of 1994 will be soil-related for both greenhouse and field applications.

Chapter IV of this report reviews control options and indicates that in many applications, substitutes for methyl bromide are limited. However, in most applications, reductions in use are possible at moderate cost for small reductions. It is for this reason that we characterize the overall costs of the consumption freeze in 1995 and the 25% reduction by 1998 as moderate.

More specific estimates can be made if we are willing to make assumptions about the elasticity of the demand curve for methyl bromide shown in Exhibit V-1. As supply is limited (for example, reduced in 1995 to 1991 levels), the price of methyl bromide goes up. This will lead users with options cheaper than the now higher-priced methyl bromide to switch to these options. The price at which users switch to these options is referred to as the "trigger price."

A complete cost study would develop information on the range of trigger prices for different users. Trigger prices differ across users depending on the costs of the alternatives they face. The demand curve for methyl bromide reflects these trigger prices.

In fumigation applications, the cost of methyl bromide is a very small fraction of the total cost of the fumigation. In space fumigation, the plant must be sealed and remain inactive so that the actual gas costs are a relatively small component of the total. Similarly for soil fumigation, equipment and labour to deliver the methyl bromide and cover the area with tarpaulins far outweighs the gas costs.

The low fraction of methyl bromide cost to total fumigation cost implies that the demand for methyl bromide should be quite inelastic. To provide an order of magnitude cost estimate, we assume that in this range, the demand curve has an elasticity of 0.2.[1] This means that the current $2.00 per kg price of methyl bromide would have to increase to $20 to reduce demand from 220 tonnes to 150 tonnes. The cost of this adjustment in the case of the 1995 freeze is measured as lost consumers' surplus on the input demand curve. This amount would be $630,000 per year or $4.6 million over ten years at a discount rate of $7\frac{1}{2}$%. The method of calculating this cost is shown in Exhibit V-3.

The cost of the 1998 cut of 25% from 150 tonnes to 113 tonnes is estimated by assuming that the demand curve used above is linear. Our estimate is that costs will be $862,500 annually beginning in 1998. This cost and all others in this section are measured in 1995 dollars. The discounted present value of this amount over ten years and discounted back to 1995 is approximately $5.1 million. This gives a total cost in discounted present value terms of $9.7 million in 1995 dollars for the freeze and the 25% reduction together. The basis for these calculations is also shown in Exhibit V-3.

The critical parameter in these calculations is the price elasticity for which no hard data exist. Our assessment is that the true elasticity is not smaller than the number used here and is probably larger. If it is larger, the true costs would be less than those estimated above.

In these cost estimates, no specific account has been taken of the quarantine exemption. That is because it is not clear how the exemption would relate to the 1995 freeze. Presumably it would reduce the size of the consumption cut in 1995, thereby reducing costs. However, the extent of use of methyl bromide inside Canada for quarantine purposes is so small that no reasonable adjustment would make a significant impact on the result.

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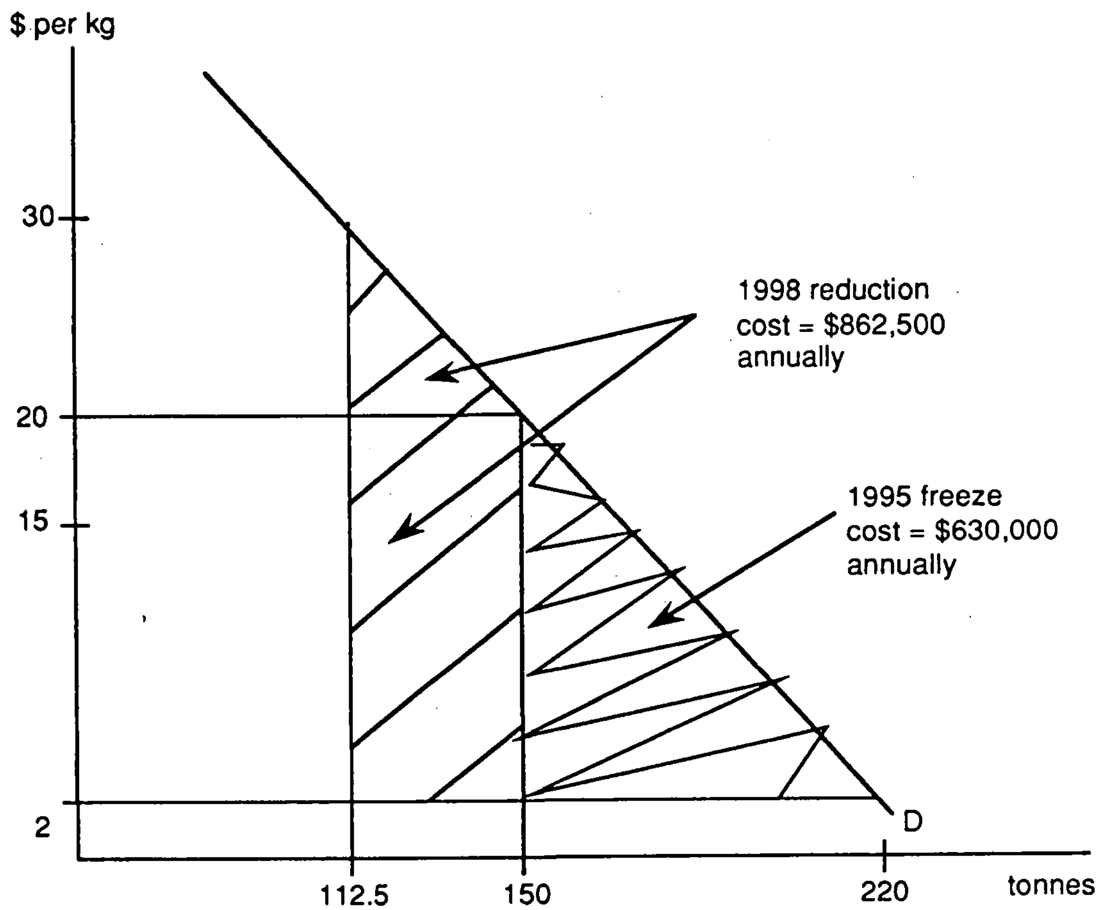
[1]The precise value in the calculations is 0.23.

EXHIBIT V-3 Costs of Canadian Methyl Bromide Proposals



The final point to make about these costs estimates is that they refer only to the costs of Canadian restrictions on methyl bromide use. As noted above, however, the costs to Canadians of reduced methyl bromide use in other countries are likely to be substantial. Estimates of these costs require assumptions about control policies elsewhere and are beyond the scope of this report.

E. POSSIBLE REDUCTION SCHEDULES

At this point, there appears to be insufficient information to develop a realistic reduction schedule for methyl bromide use in Canada. A variety of control options exist and many will likely be implemented but it is difficult to predict the schedule for adopting them. The regulatory framework will clearly have an important impact on the rate of adoption of many of the control options.

A possible or feasible reduction schedule cannot be separated from issues of cost. Reducing and phasing out sooner has higher costs than a slower schedule. In order to consider feasibility and cost together, we consider each application and provide an estimate of a feasible reduction pattern.

- Structural fumigation. Few uses. Immediate phase-out possible at little cost.

- Soil fumigation. Existing greenhouse operators are not well informed about Dutch approaches. A reduction program aimed at a phase-out by 2000 may raise costs enough to make this business uneconomic. Other fumigants also raise costs.

  Faster schedules should be feasible in field applications if no other fumigants are removed but alternatives are more costly.

- Space fumigation. Reductions could begin whenever required with a feasible target of elimination by 2000. This assumes that problems associated with aluminum phosphide use can be resolved. The exception to this may be ships carrying grain.

- Commodity fumigation. Large reductions in use do not appear feasible. Some reductions are possible with more conservation particularly with more effective sealing of materials to be fumigated. Commercial systems to do this are now widely available. If recycling is successful, emissions could be reduced to nearly zero at the cost of recycling systems and constructing fumigation chambers. There would be a significant industrial benefit to Canada if the Halozone system is used for this purpose.

VI MANAGEMENT OPTIONS FOR ENVIRONMENT CANADA

A. OVERVIEW

This chapter sets out the policy implications for Environment Canada of the control options review and the assessment of control costs. In it, we provide an outline of how economic instruments can contribute most effectively to consumption reductions for methyl bromide.

Any reduction schedule, whether rapid or gradual, should be implemented with a view to minimizing the economic disruption costs of the transition. The same reduction objective can be achieved at a lower economic cost if the most efficient institutional mechanism is used to implement it. This chapter provides an overview of some of the important policy issues in designing a plan to achieve Canada's consumption targets.

B. EVALUATION CRITERIA

In developing management options, some assumptions are required as to the criteria to be used in assessing those options. The scope of the project was not intended to include a complete socio-economic evaluation but cost and other considerations would have to be taken into account in a complete analysis.

In developing the management options in this chapter, the factors incorporated in the analysis are:

- The procedures to be followed should be clear in order to facilitate long-run planning to reduce methyl bromide use.

- The reduction strategy should provide the maximum possible economic incentive to reduce methyl bromide use and to develop substitutes quickly.

- The strategy should seek to minimize economic disruption in the form of adjustment costs implied by the option.

- The strategy should be administratively efficient in terms of the costs of implementing and operating it.

- ➤ The reduction strategy should encourage users of methyl bromide to reduce consumption in a manner that minimizes the social costs for Canada of meeting its consumption reduction target.

C. IMPLEMENTING CONTROLS FOR METHYL BROMIDE

In this chapter, we assume that the controls required will be related to the existing framework of the Montreal Protocol. That is, quantity reductions will be mandated relative to an initial baseline that might be the 1991 quantity of methyl bromide consumed as a benchmark.

The terms of reference for this project specifically refer to the potential use of market-based instruments as a method of implementing controls for methyl bromide.

- ➤ A market-based approach will be generally preferred for any level of reduction that is required because costs are lower.

- ➤ The Montreal Protocol approach is not generally consistent with environmental charges or taxes due to the quantity uncertainty problem relative to the international obligations that are acquired with the Protocol. Quotas are directly related to the Protocol requirements and have been the basis for existing Protocol initiatives in Canada and the U.S.

Given that methyl bromide is likely to be added to the Montreal Protocol, the obvious assumption is that controls would be implemented as they have been in the case of existing substances that are regulated under the terms of the Protocol.

The Protocol originally applied to CFCs and to halons with methyl chloroform and carbon tetrachloride being added to the Protocol in June of 1990 at the meeting of the parties in London. The original policy framework was established for CFCs and for halons and the reasons for establishing somewhat different control regimes are instructive with regard to the best system for methyl bromide.

For the CFCs, Canada produced substantial quantities and there were many individual users. Controls were established in terms of limited quantities for producers and importers. The system was essentially quota-based with baseline quantities established for 1986. For CFCs, quantities were established for producers and importers whereas for halons quantities were established for users.

Economists refer to the allowable baseline quantities as rights. That is, the implementation procedure established a right to produce or import specified quantities for CFCs and a right to consume certain baseline quantities for halons. In terms of meeting the overall requirements of the Protocol, there are no differences between the two approaches. Both mandate a required target and reporting procedures must be put into place to monitor compliance.

The difference has to do with economic impacts. If all quantities are imported, then the result of quotas will be higher prices charged by importers. Particularly if there are few importers, the quantity restrictions are likely to translate into higher prices and profits for existing importers. Granting the right to import in this case entirely to existing importers raises issues of competition policy and the distribution of the gains from higher prices.

If rights to consume are allocated to existing users who purchase from importers, then there is more actual and potential competition among importers. Since methyl bromide is imported almost entirely from a single importer, Canadian purchasers and the Canadian economy will be served better by an allocation system in which existing consumers are granted rights to consume specified quantities. They may continue to use the same importers but if others are willing to offer lower prices that option will be present which would not be the case if rights are granted to importers.

D. IMPORT CONTROLS

Canada does not produce any of the methyl bromide that it uses. As a result, quantities consumed in Canada can be controlled through restrictions on annual import quantities. The extent of reduction is determined by the reduction schedule chosen. This section deals with how a consumption reduction decision might be implemented after it is made.

In carrying out this consumption reduction, Canada would set maximum import quantities on an annual basis and specify how these import quantities are to be distributed. The import restriction would be denominated in units of ODP reflecting the widespread use of a 67:33 mixture with chloropicrin.

The system described above is essentially one of import quotas. Each unit of quota can be regarded as a right to import and consume a specified ODP quantity.

What are the options for determining to whom the methyl bromide quota should be allocated in the first instance?

The major options with regard to disposition of the quota amount determined by regulation are:

- Allocate import rights to importers.
- Allocate import rights to users.
- Auction rights to highest bidders in an auction in which both producers and users would be eligible to participate.
- Develop a hybrid system containing elements of the above.

In the case of an auction, no information is required on the identity of users of controlled substances prior to the auction. If, on the other hand, rights are allocated to importers or users, baseline quantities would have to be established to divide the total quota amount of ODP among members of these groups in proportion to their baseline consumption.

E. COSTS ASSOCIATED WITH POLICY OPTIONS

In principle, the auction concept is an attractive one. Rights to import would go to the highest bidders. High bids are a signal that for these bidders, the costs of not being able to use these substances is high. Economic efficiency is achieved when limited quantities are allocated to those for whom reduction costs are greatest and this would be the theoretical result of the auction.

In spite of this theoretical advantage, the auction method has not been used widely as an instrument of environmental policy. In the related case of CFCs, most reservations about the auction system focus on potential uncertainties about the price and availability of import rights and CFCs immediately following the auction. As well, Environment Canada may not have the statutory authority to use an auction.

Relative to an auction, there is a greater degree of certainty associated with a system of allocating import rights either to importers or users. In both Canada and the United States, import and production rights for CFCs have been allocated to producers and importers based on their baseline 1986 quantities.

A major advantage of allocating import rights to importers instead of end users is that the costs of developing and monitoring this system would be smaller. A relatively small number of importing firms account for total import quantities. The number of end users on the other hand is larger. If all import rights are allocated to end users, the baseline consumption of each user must be established and each year, their total must be revised again for a large number of users.

An allocation system that provided importers with annual quotas would retain many of the efficiency aspects of the auction system described above. Importers with quota amounts would sell methyl bromide to those customers who are willing to pay the most. This corresponds, in general, to a situation in which limited quantities are being allocated to uses which are most valuable from the perspective of the Canadian economy. In economic terms, this system would have a high degree of transferability of the right to consume methyl bromide, a condition generally associated with economic efficiency.

The concept of transferability of quota rights is an important component of developing an efficient system for reducing methyl bromide consumption. The costs of achieving consumption reductions will differ across users and an efficient control policy will target reductions to areas where costs are lowest. Transferability of import quotas should allow this efficient pattern of use to emerge.

What is involved in making methyl bromide quotas transferable? In essence, the approach limits the direct government role to establishing annual quota quantities and then allocating them according to one of the methods described above. In establishing the system, it should be made clear to users and importers that both methyl bromide and quotas can be bought and sold freely. If this approach is followed, those users that are squeezed out of the market for methyl bromide should be those for whom control costs are less than the costs of paying more. Allocation formulas under which quota quantities are allocated rigidly to users without the possibility of transfer will increase the costs of meeting Canada's reduction targets.

In addition to transferability, the allocation of the right to import is important because all quantities of methyl bromide are imported. Transfers to producers outside Canada are real resource costs for the Canadian economy. The actual system implemented should focus on generating competition among importers to sell to the Canadian market.

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APPENDICES

APPENDIX A

COMMODITIES REQUIRING METHYL BROMIDE FUMIGATION AS A CONDITION OF ENTRY

COMMODITIES REQUIRING METHYL BROMIDE FUMIGATION AS A CONDITION OF ENTRY[1]

COMMODITY	ORIGIN	DESTINATION IN CANADA	METHYL BROMIDE TREATMENT
ALMOND (Prunus amygdalus, P. communis) a) Plants, cuttings, scions, buds, rootstocks, grafted finished trees and seedlings.	USA - Approved sources in certain states	B.C.	Treatment - Dec. C6
APPLE (Malus) a) Plants, cuttings, scions, buds, rootstocks, and finished grafted trees not including seed and true seedlings	USA - Approved sources in certain states Approved sources in France, Germany	B.C. B.C.	Treatment - Dec. C6 Treatment - Dec. C6
b) True seedlings	USA - Approved sources in WA state Approved sources in France, Germany	B.C. B.C.	Treatment - Dec. C6 Treatment - Dec. C6
e) Fresh fruit and used containers	Australia	Canada	Treatment - Dec. C4
APRICOT (Prunus armeniaca) a) Plants, cuttings, scions, buds, rootstocks, grafted finished trees and seedlings	USA - Approved sources in certain states	B.C.	Treatment - Dec. C6
b) Seed	USA - Approved sources in certain states	B.C.	Treatment - Dec. C6

[1]Plant Protection Manual, Import Inspection, Chapter 3.00, pages 13-108.

COMMODITY	ORIGIN	DESTINATION IN CANADA	METHYL BROMIDE TREATMENT
d) Fresh fruit and used containers	Argentina, Brazil, Chile, France, Germany, Greece, Hungary, Italy, Mexico, Morocco, Switzerland, Turkey, Uruguay, USA, Yugoslavia	B.C.	Treatment - Dec. C6
	Australia	B.C.	Treatment - Dec. C6
		Other Areas	Treatment - Dec. C4
	New Zealand	B.C.	Treatment - Dec. C6
BLUEBERRY (<u>Vaccinium</u> spp.) d) Used containers	USA - Certain states	Other Areas than PEI, NS and NB	Treatment - Dec. C10
CHERRY (<u>Prunus</u>) a) Plants, scions, buds, cuttings, rootstock, tissue cultured plants, finished grafted trees and seedlings (excludes seed)	USA - Approved sources in certain states	B.C.	Treatment - Dec. C6
	Approved sources in France, Germany	B.C.	Treatment - Dec. C6
d) Fresh fruit and containers	Australia	Canada	Treatment - Dec. C4
CHESTNUT (<u>Castanea</u>) c) Nuts for consumption or processing	US state of HI and other countries	Canada	Treatment - Dec. C3
CHRISTMAS TREES a) Cut <u>pinus</u> (pines)	USA - non-infested counties of ME, NH, NY, VT	B.C.	Treatment - Dec. C7
	USA - CA, CT, DE, MD, DC, MA, MI, NJ, OH, PA, RJ, VA, WV, WA	B.C.	Treatment - Dec. C7
	Other US states	B.C.	Treatment - Dec. C7

COMMODITY	ORIGIN	DESTINATION IN CANADA	METHYL BROMIDE TREATMENT
CURRANTS (Ribes) a) Fresh fruit	Australia	Canada	Treatment - Dec. C4
GRAPES (Vitis) a) Plants, cuttings, scions, vines, budwood and any parts for propagation (not including seed)	USA - certain states and approved sources in France, Germany	B.C.	Treatment - Dec. C8
c) Fresh fruit	Australia	Canada	Treatment - Dec. C4
PEACH (Prunus domestica) a) Plants, cuttings, scions, buds, rootstock, grafted finished trees and seedlings	USA - Approved sources in certain states	B.C.	Treatment - Dec. C6
b) Seed	USA - Approved sources in certain states	B.C.	Treatment - Dec. C6
d) Fresh fruit and used containers	Argentina, Brazil, Chile, France, Germany, Greece, Hungary, Italy, Mexico, Morocco, Switzerland, Turkey, Uruguay, USA, Yugoslavia	B.C.	Treatment - Dec. C6
	Australia	B.C.	Treatment - Dec. C6
		Other areas	Treatment - Dec. C4
	New Zealand	B.C.	Treatment - Dec. C6

COMMODITY	ORIGIN	DESTINATION IN CANADA	METHYL BROMIDE TREATMENT
PEARS (<u>Pyrus communis</u>) a) Plants, cuttings, scions, buds and any part for propagation (except seed and true seedlings)	USA - Approved sources in Contracosta County of California	B.C.	Treatment - Dec. C6
	USA - Approved sources in certain states	B.C.	Treatment - Dec. C6
	Approved sources in France, Germany	B.C.	Treatment - Dec. C6
b) True seedlings	USA - Approved sources in Contracosta County of California	B.C.	Treatment - Dec. C6
	USA - Approved sources in certain states	B.C.	Treatment - Dec. C6
	Approved sources in France, Germany	B.C.	Treatment - Dec. C6
PINE (<u>Pinus</u>) a) Plants and plant parts for propagation (excluding seed)	USA: Non-infested counties of ME, NH, NY, VT	B.C.	Treatment - Dec. C7
	Other US states	B.C.	Treatment - Dec. C7
	Approved growers in the Netherlands	B.C.	Treatment - Dec. C7
b) Cut trees and forestry products i) with bark	USA: Non-infested counties of ME, NH, NY, VT	B.C.	Treatment - Dec. C7
	CA, CT, DE, MD, DC, MA, MI, NI, OH, PA, RI, VA, WV, WA states in US	B.C.	Treatment - Dec. C7
	Other US states	B.C.	Treatment - Dec. C7

COMMODITY	ORIGIN	DESTINATION IN CANADA	METHYL BROMIDE TREATMENT
PLUMS (<u>Prunus</u>) a) Plants, cuttings, scions, buds, rootstock, grafted finished trees and seedlings	USA - Approved sources in certain states	B.C.	Treatment - Dec. C6
b) Seed	USA - Approved sources in certains states	B.C.	Treatment - Dec. C6
d) Fresh fruit	USA - CA	B.C.	Treatment - Dec. C6
	Other US states	B.C.	Treatment - Dec. C6
	Australia	Canada	Treatment - Dec. C4
	New Zealand	B.C.	Treatment - Dec. C6
	Argentina, Brazil, Chile, France, Germany, Greece, Hungary, Italy, Mexico, Morocco, Switzerland, Turkey, Uruguay, Yugoslavia	B.C.	Treatment - Dec. C6
QUINCE (<u>Cydonia</u> and <u>Chaenomeles</u>) a) Plants, cuttings, scions, buds, and any part for propagation except seeds and true seedlings	USA - Approved sources in certain states	B.C.	Treatment - Dec. C6
	Approved sources in France, Germany	B.C.	Treatment - Dec. C6
b) True seedlings	USA - Approved sources in certain states	B.C.	Treatment - Dec. C6
	Approved sources in France, Germany	B.C.	Treatment - Dec. C6
c) Seeds	All countries	B.C.	Treatment - Dec. C6

COMMODITY	ORIGIN	DESTINATION IN CANADA	METHYL BROMIDE TREATMENT
e) Fresh fruit and used containers	Australia	B.C.	Treatment - Dec. C6
		Other areas	Treatment - Dec. C4
	New Zealand	B.C.	Treatment - Dec. C6
	Argentina, Brazil, Chile, France, Germany, Greece, Hungary, Italy, Mexico, Morocco, Switzerland, Turkey, Uruguay, USA, Yugoslavia	B.C.	Treatment - Dec. C6
RASBERRIES (Rubus) c) Fresh fruit and used containers	Australia	Canada	Treatment - Dec. C4
STRAWBERRIES (Fragaria) b) Fresh fruit and used containers	Australia	Canada	Treatment - Dec. C4

MCF:mg (c:mcf\0730.trt)

APPENDIX B

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