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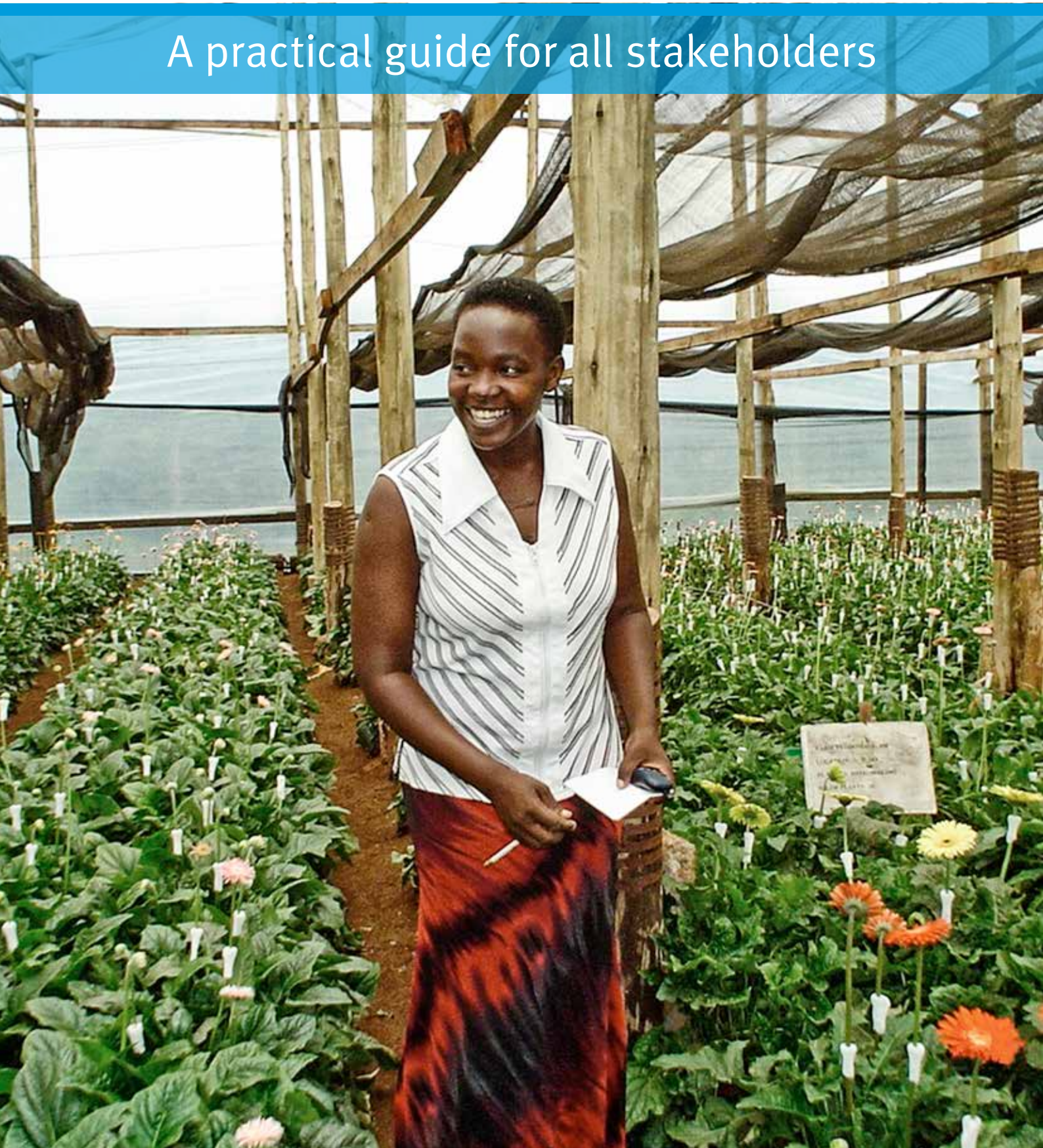
UNIDO toolkit for sustainable compliance with the methyl bromide phase-out

A practical guide for all stakeholders



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FOREWORD

For decades, methyl bromide has been used as the fumigant of choice in intensive agriculture around the world as well as in the storage treatment of perishable goods and commodities. However, due to its high ozone-depleting potential, in 1992, methyl bromide was included among the Ozone Depleting Substances under the Montreal Protocol. Since then, phase-out schedules for this chemical were agreed upon, for all Parties to the Protocol, and financial support was granted to assist developing countries with their phase-out activities.

Since 1996, the United Nations Industrial Development Organization (UNIDO) has implemented a total of 175 projects in 55 developing countries for the elimination of more than 8,000 metric tonnes of methyl bromide, representing 70 per cent of the total phase-out of this chemical in developing countries.

This has been a great challenge for UNIDO and, at the same time, has created opportunities to promote a variety of non-chemical alternatives and to contribute to the overall development of countries and local communities. All projects have provided market headway to various agricultural sectors by making them more competitive on the international markets, which are increasingly requiring produce compliant with environmental standards.

The results achieved by UNIDO would not have been possible without the assistance provided by the Multilateral Fund for the Implementation of the Montreal Protocol and bilateral donors such as Canada, Italy, Japan, France and Spain, as well as by numerous governments, universities, experts, colleagues, friends and partners with whom we have worked over the past decades. Our deepest thanks and gratitude go to all of them.

This publication stems from the contribution of UNIDO to the phase-out of methyl bromide and is aimed at supporting key stakeholders (i.e. National Ozone Units, phytosanitary authorities, growers, fumigators, technical assistants, trainers, researchers, customs officials, chemical importers and pesticide dealers), as well as other parties involved in this thematic area. Furthermore, each section of this publication contains its own supporting information, allowing flexibility in using the chapters individually according to the needs of the various stakeholders. We hope all stakeholders will find this toolkit useful and keep on working for the phase-out of methyl bromide with the enthusiasm and spirit of cooperation they have shown over the past 20 years.

Stephan Sicars

Director, Environment Branch, UNIDO

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Part I – PHASING OUT METHYL BROMIDE FOR CONTROLLED USES

The Montreal Protocol and methyl bromide

The Montreal Protocol on Substances that Deplete the Ozone Layer was signed in 1987 by a group of countries mindful of their obligation *"to take appropriate measures to protect human health and the environment against adverse effects resulting or likely to result from human activities, which modify or are likely to modify the ozone layer…"*.

The Parties to the Montreal Protocol established the Multilateral Fund (MLF) to provide financial assistance to Article 5 countries to phase out ozone-depleting substances (ODSs), and designated four Implementing Agencies to undertake projects and other actions on the ground: the United Nations Environment Programme (UNEP), the United Nations Industrial Development Organization (UNIDO), the United Nations Development Programme (UNDP) and the World Bank.

In 1992, methyl bromide was listed as an ODS and specific control measures were agreed on for its phase-out. When emitted to the atmosphere, the methyl bromide molecules will break and release bromine, which is far more destructive than chlorine (present in many other ODSs). The methyl bromide phase-out directly impacted agriculture and food safety and security, giving rise to very specific challenges, since this fumigant was in commercial use for over 60 years to control soil-borne pests, diseases and weeds and for disinfesting food-processing buildings and stored durable commodities among others.

In addition, methyl bromide is a well-established treatment for quarantine and pre-shipment (QPS) control of a diverse range of pests and diseases on many commodities in trade. The Montreal Protocol exempted methyl bromide for QPS purposes from the phase-out controls, because in 1992 it was considered that there were no feasible alternatives for such treatments and that the unavailability of methyl bromide would put international trade and many agricultural businesses at risk.

A clear differentiation between controlled and exempted uses is thus essential to ensure the sustainability of the phase-down achieved for controlled uses and, most importantly, avoid methyl bromide intended for QPS from being used for controlled used (now banned).

The UNIDO toolkit aims at providing key stakeholders impacted by the regulations of phasing out methyl bromide with essential tools to maintain the methyl bromide phase-out achieved in a sustainable manner.

Controlled uses

All uses of methyl bromide not intended to provide treatments for QPS control are considered to be "controlled uses" and are meant to be phased out. Controlled uses of methyl bromide are now fully phased out except for some "critical uses", which Parties can obtain under very specific circumstances. But such exemptions, when approved by the Parties, are granted for a period of one year.

When requesting critical uses, a large number of reporting requirements must be met, including a detailed application, a comprehensive list of alternatives which are available in the country that is submitting the nomination, a national phase-out strategy and an annual accounting framework with reports of methyl bro-

mide use and the quantity acquired and used, as well as stocks of methyl bromide that are available at the beginning and the end of each year.

Exempted uses (QPS)

In 1992, the use of methyl bromide for QPS treatments accounted for about 10% of the global consumption. In the absence of site-specific alternatives, methyl bromide thus continues to be available after the 2015 phase-out deadline due to the QPS exemption and could thus be used for any controlled application.

Parties have nevertheless been urged to adopt alternatives for QPS treatments and to reduce the use and emissions of methyl bromide whenever possible. At present, the Protocol's Methyl Bromide Technical Options Committee (MBTOC) estimates that about 40% of methyl bromide used for QPS treatments could be replaced with immediately available alternatives.

The Montreal Protocol requires Parties to report annual data on production, consumption, feedstock uses and destruction of ODSs, including methyl bromide consumed for QPS applications. UNIDO has been assisting Parties with QPS reporting. A logbook format in this regard has been developed, which licensed fumigators should fill in whenever applying a QPS treatment (http://www.unido.org/en/what-we-do/environment/safeguarding-the-environment/emerging-compliance-regimes/phase-out-of-methyl-bromide/unido-toolkit.html).

Global consumption of methyl bromide for controlled uses

Phasing out methyl bromide for controlled uses has been a very successful effort worldwide. The global baseline consumption went down from nearly 80,000 metric tonnes in 1992 to less than 500 metric tonnes in 2014 (wholly comprising critical uses). Article 5 Parties made great strides by phasing out more than 85% of controlled uses ahead of the 2015 deadline.

Reasons for using methyl bromide, sectors and stakeholders involved

Methyl bromide was mainly used as a soil fumigant for controlling soil borne pests, diseases and weeds affecting the production of some high value crops. A smaller proportion (10%) was used in some countries for post-harvest fumigation of durable commodities (e.g. grain, dried fruit and other foodstuffs) and structural fumigation (e.g. warehouses, mills).

Users in Article 5 Parties were diverse, ranging ranged from small farmers to very large enterprises. The advantage perceived by users when using methyl bromide to treat soil or commodities was that this fumigant eradicated virtually all living organisms present in the soil or infesting commodities or structures.

Aside from direct users, a variety of stakeholders were impacted by the phase-out. These included government authorities, researchers and technical assistants and importers.

Actions undertaken by UNIDO to assist the phase-out of methyl bromide

UNIDO positioned itself as a proactive agency ready to provide tailor-made solutions to each country requesting its assistance. Since 1996, UNIDO has acted as an implementing agency in 55 out of the 77 Article 5 countries where the MLF has funded projects aimed at phasing out methyl bromide, working on its own, or sometimes in cooperation with other agencies and/or specific donor countries, and always in coordination with governments requesting its assistance.

Alternatives implemented

Alternatives were carefully selected taking into consideration the specific circumstances of each country and sector. Furthermore, acceptance and agreement from key stakeholders, availability of and economic feasibility of the selected options and training and technical assistance were also considered. A wealth of information on methyl bromide alternatives is now available for virtually all climates, growing systems and circumstances under which methyl bromide was previously used.

The main technologies selected for replacing methyl bromide for each key sector in countries where UNIDO implemented projects are summarized in this toolkit. In addition, case studies from countries where alternatives proved to be particularly successful are also featured.

Ensuring a sustainable methyl bromide phase-out

Experience has proven that the best option when replacing methyl bromide is to adopt a multi-disciplinary approach giving way to sustainable production practices, which often increases the competitiveness of the sectors involved. UNIDO thus used an integrated approach to manage pests and diseases on the crops. This provides an efficient means to respond to consumers' demands of high quality products, which at the same time require observance of environmental, health and socio-economic standards, as well as food safety and security. This has opened and widened markets, particularly for horticultural products exported from Article 5 Parties. A sustainable phase-out should further comprise economic, regulatory and political aspects.

Impact of the methyl bromide phase-out

The phase-out process generated much information particularly on intensive agricultural production systems where methyl bromide was primarily used. A large number of growers and other key stakeholders were trained. As a result, growers all over the world learned how to comply with strict sustainability standards and have become more competitive. They also have opportunity to access new markets for their products. A more rational use of chemical products also benefitted the environment and human health. The phase-out of methyl bromide also provided women in some sectors with ample opportunities to improve their general welfare; for example, sectors adopted grafting technologies employed a large number of women.

Part II -ASSURANCE OF COMPLIANCE WITH THE METHYL BROMIDE PHASE-OUT

Part II of the toolkit provides the various categories of stakeholders with different tools in order to assist them in sustaining the phase-out achieved. Each section describes the role of the stakeholder category and contains relevant definitions and decisions derived from the Montreal Protocol. Specific tips to ensure correct operation are also included.

Compliance tools for National Ozone Officers (NOUs)

National Ozone Officers play a key role in maintaining governments' commitments acquired under the Montreal Protocol. They authorize and monitor methyl bromide consumption; monitor compliance with legislation relating to methyl bromide and update regulatory efforts; report on the consumption (for both controlled and QPS uses) and other issues to the Ozone Secretariat and the MLF; participate in negotiations and propose

topics for discussions and modifications to the Decisions of the Montreal Protocol; and translate these into Decision text when necessary.

Compliance tools for customs and phytosanitary authorities

Customs officers are instrumental for the enforcement of pesticide regulations, particularly restrictions on imports. It is essential that they are well informed on the current legislation and that they are able to correctly identify products coming in, their destinations and their proposed uses.

Phytosanitary authorities need to work in close collaboration with customs officers as their work is highly inter-related. This is the only way that bans and restrictions placed on chemicals, quarantine dispositions and authorized treatments can be adequately enforced. A clear understanding of the concepts of “Quarantine” and “Pre-shipment” is critical for both customs and phytosanitary authorities.

Compliance tools for importers

As suppliers of methyl bromide (whether for critical uses or QPS treatments), importers play a critical role in supporting the phase-out of methyl bromide. A special permit or quota authorization may be required to source the methyl bromide. If they also provide fumigation services, they most likely need to request supervision or license from official authorities.

In addition, importers are often also suppliers of alternatives, and as such play a key role in supporting the sustainability of the phase-out.

Compliance tools for technical assistants and extension staff

Technical staff and individuals involved in academic activities play a crucial role in supporting information dissemination efforts and the successful adoption of alternatives. Research findings and results of experiments often provide the basis on which the efficiency of alternatives is assessed and ways to optimize their implementation.

Compliance tools for direct users

Direct users are ultimately the stakeholders most affected by the phase-out of methyl bromide. Replacement of methyl bromide often requires direct users to introduce changes in their production systems, including varying the investment components, getting extensive training and addressing problems differently. The approach taken by UNIDO allowed users to conduct experiments with respect to new technologies, which helped them gain confidence with their use.

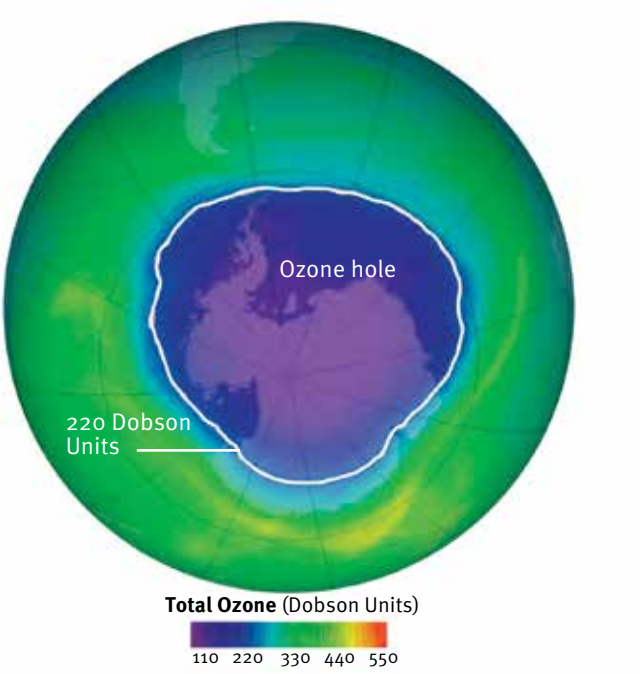
UNIDO has always emphasized the need to integrate different options and develop a comprehensive approach towards pest and disease control. The Organization always kept in consideration the long-term sustainability of alternative fumigants – even when they do not damage the ozone layer, – and worked towards achieving sustainable production systems. Assessing the technical and economic feasibility of potential alternatives is also very important. In many cases, implementing alternatives required changes in, for instance, production or storage systems while maintaining access to specific markets and complying with quality and other commercial requirements.

Part I – The methyl bromide phase out

- A historical perspective
- Lessons learned
- Compliance requirements

1. Introduction – The Montreal Protocol and methyl bromide

The United Nations Environment Programme (UNEP) Montreal Protocol was signed in 1987 by a group of countries, which were already signatories to the Vienna Convention for the Protection of the Ozone Layer, *"to take appropriate measures to protect human health and the environment against adverse effects resulting or likely to result from human activities which modify or are likely to modify the ozone layer"*. A large number of compounds were classified as "ODSs" (Ozone Depleting Substances), mostly in industrial sectors, and were deemed responsible for the significant thinning of the ozone layer over Antarctica, a thinning which appears during the southern hemisphere spring and is know as the "ozone hole". The ozone layer prevents harmful UV rays from reaching the Earth's surface. Without the Protocol, UV radiation levels would have increased to extremely dangerous levels, with disastrous effects to our planet.



The ozone hole as illustrated by NASA

The Parties to the Montreal Protocol established the Multilateral Fund (MLF) to provide financial assistance to Article 5 Parties for phasing out ODSs and designated four implementing agencies to undertake projects and other actions aimed at replacing these substances: the United Nations Industrial Development Organization (UNIDO), UNEP, the United Nations Development Programme (UNDP) and the World Bank.

In 1992, Methyl Bromide was listed under the Montreal Protocol as an ODS and specific control measures were agreed for its phase-out. This fumigant has a high ozone-depleting potential (ODP). When emitted to the atmosphere the methyl bromide molecules break, releasing bromine, which is far more destructive than chlorine (present in many other ODSs).

Methyl bromide is a unique ODS as its phase-out directly impacted agriculture and food safety and security, giving rise to very specific challenges. Work on methyl bromide-related issues started as early as 1994, with the identification of priority sectors using methyl bromide and the assessment of its possible alternatives. Over the years, UNIDO has positioned itself as the implementing agency with the most experience on methyl bromide, undertaking over 70% of the projects related to this substance.

METHYL BROMIDE PHASE-OUT DIRECTLY IMPACTED AGRICULTURE AND FOOD SAFETY AND SECURITY, GIVING RISE TO VERY SPECIFIC CHALLENGES.

Methyl bromide is a fumigant that was in commercial use for more than 60 years to control pests including various soil borne fungi, bacteria, insects, mites, nematodes and rodents as well as many weeds and seeds. It was also used extensively to disinfest food-processing buildings (e.g. mills, warehouses, ship-holds and containers) and stored durable commodities such as grain (including rice, wheat, maize and others), dried fruit and other dried foodstuffs and beans (e.g. coffee, cocoa). It had many more miscellaneous uses including disinfesting museum artefacts that could be subject to damage from pests.

In addition, methyl bromide is also a well-established treatment for quarantine and pre-shipment (QPS) control of a diverse range of pests and diseases on many commodities in trade; including timber, wooden packaging and various perishables such as fruits, vegetables and cut flowers. The Protocol exempted QPS of methyl bromide from phase-out controls because in 1992 it was considered that there were no feasible alternatives for such treatments and that, in consequence, the unavailability of methyl bromide would put international trade and the livelihood of many agricultural sectors at risk.

The sustainability of the methyl bromide phase-out is sensitive to the Montreal Protocol, for two main reasons. First, the methyl bromide production capacity, although reduced, will ensure the availability of the chemical in the market for exempted uses (QPS). Secondly, the end users of methyl bromide were not subject to significant technology conversion; therefore it might be possible for them to go back to their previous practices that involved application of methyl bromide. In contrast, other ODSs (e.g. refrigerants) generally require production plants to undertake significant technological conversions, thus going back to the previous practices would rarely be justifiable.

THE UNIDO TOOLKIT AIMS AT PROVIDING KEY STAKEHOLDERS IMPACTED BY THE METHYL BROMIDE PHASE-OUT WITH ESSENTIAL TOOLS TO MAINTAIN THE METHYL BROMIDE PHASE-OUT ACHIEVED IN A SUSTAINABLE MANNER.

This dual use of methyl bromide – controlled and exempted – poses various challenges and requires a clear understanding of the implications.. As of 1 January 2015, however, using methyl bromide for controlled uses would bring a country under non-compliance with the Montreal Protocol, unless it was for approved critical uses.

The UNIDO toolkit aims at providing key stakeholders impacted by the methyl bromide phase-out with essential tools to maintain the methyl bromide phase-out achieved in a sustainable manner. It includes a historical perspective of methyl bromide use around the world in the past and its remaining uses, actions taken by countries to achieve the phase-out in different sectors, and information on alternatives to methyl bromide as well as how best to implement them.

2. Methyl bromide uses and controls under the Montreal Protocol

Considering the different nature and aim of treatments traditionally conducted with methyl bromide, as explained in the previous section, these treatments were classified under the Protocol as controlled and exempted (QPS) uses.

2.1. Controlled uses

All uses of methyl bromide not intended to provide treatments falling within the definition of QPS (see section 2.2) are considered to be "controlled uses" and are meant to be phased-out. These include for example pre-plant soil fumigation in the production of many crops such as strawberries, vegetables, tobacco seedlings and cut flowers; treatment of stored grain; and disinfestation of flour mills. For a more detailed list of controlled uses of methyl bromide and the main sectors and regions where these occurred, see Chapter 3.

ALL USES OF METHYL BROMIDE NOT INTENDED TO PROVIDE TREATMENTS FALLING WITHIN THE DEFINITION OF QPS ARE CONSIDERED TO BE "CONTROLLED USES" AND ARE MEANT TO BE PHASED-OUT.

Control schedules leading to the phase-out of controlled uses of methyl bromide were agreed under the Montreal Protocol in 1995 and 1997 as shown in Table 1 below:

TABLE 1. **PHASE-OUT SCHEDULES FOR CONTROLLED USES OF METHYL BROMIDE UNDER THE MONTREAL PROTOCOL**

Developed (non-A5) Parties*	Developing (A5) Parties*
› 25% cut on production and consumption by 1 January 1999 according to 1991 baseline › 50% cut on 1 January 2001 › 70% cut on 1 January 2003 › Total phase-out by 1 January 2005 with provision for Critical Use Exemptions (CUE)	› Freeze on production and use on basis of average levels for 1995 – 1998 (baseline consumption) in 2002 › 20% cut on production and use according to 1995-98 baseline, as of 1 January 2005 › Phase-out by January 2015 with provision for CUE

** Parties to the Montreal Protocol are classified as Article 5 (A5) or Non-Article 5 (Non-A5) in relation to their consumption of ODS. In general, A5 Parties are developing countries whilst non-A5s are developed countries*

2.1.1. Critical Uses

As shown in Table 1, controlled uses of methyl bromide are now fully phased-out except for remaining "Critical Uses", which Parties can obtain under special permission.

Critical uses of methyl bromide refer to very specific cases where the applicant (a Party) shows, by submitting very detailed information, that no economically or feasible alternatives exist for a particular methyl bromide use under specific circumstances.

The Critical Use Nomination (CUN) process is very complex and in principle needs to follow Decision IX/6 of the Protocol, whereby the applicant needs to provide proof that alternatives do not work and/or lead to significant market disruption. Nominations are assessed by the Protocol's Methyl Bromide Technical Options Committee (MBTOC), which may recommend the nomination in full or only partially, or may altogether not recommend it. The Parties will then decide whether or not to grant the Critical Use Exemption (CUE). Exemptions are granted only for one year.

As per Decision Ex I/4, Parties that have been granted Critical Uses must submit information to the Ozone Secretariat on stocks available in 2015 and yearly thereafter. They must also present a National Management Strategy indicating how they plan to phase the authorized Critical Uses out.

2.1.2. Reporting requirements for Critical Use Exemptions

Decisions from the Montreal Protocol established a large number of reporting requirements when Critical Uses are authorized, for example:

- Annual reports on the implementation of Decision IX/6 (the main Decision defining CUE)
- Databases of alternatives for soil fumigation and postharvest uses which are available in each country submitting CUNs
- Detailed nominations (a special Handbook exists guiding the applicant on this process, it includes a specific timetable which should be observed.
  See http://ozone.unep.org/en/node/5737 and
  http://ozone.unep.org/en/data-reporting/data-reporting-and-tools
- A National Phase-Out strategy describing how the applicant Party intends to replace methyl bromide, which needs to be updated.
- An annual accounting framework reporting methyl bromide use, quantity acquired and used and methyl bromide stocks at the start and end of each year.
  See http://ozone.unep.org/en/data-reporting/data-reporting-and-tools

2.2. Exempted uses (QPS)

As mentioned earlier, since methyl bromide was classified as an ODS in 1992, quarantine and pre-shipment (QPS) uses were specifically excluded from control measures because at the time it was considered that no feasible and equally efficient alternatives to methyl bromide were available for a diverse range of treatments carried out for QPS.

Although in 1992 QPS was about 10% of global methyl bromide consumption at the time, this was nevertheless significant in trade of commodities treated with methyl bromide *in the absence of site-specific alternatives*. Such trade could be between countries (international) but also within a country (national), when a quarantine pest or disease was limited to a certain region.

UP TO 40% OF QPS USES OF METHYL BROMIDE COULD BE REPLACED WITH FEASIBLE AND IMMEDIATELY AVAILABLE ALTERNATIVES.

Ever since the exemption came into force, however, Parties have been urged to adopt alternatives to methyl bromide for QPS and reduce emissions and use of this fumigant whenever possible. At present, the Protocol's MBTOC estimates that up to 40% of QPS uses of methyl bromide could be replaced with feasible and immediately available alternatives.

Because phase-out of controlled uses is now almost complete, over 90% of methyl bromide world consumption is now destined for QPS.

2.2.1. Definitions

To clearly differentiate between controlled and exempted uses, it is essential to understand the following definitions.

Specifically, the Seventh Meeting of the Parties decided in Decision VII/5 that:

a) *"Quarantine applications"*, with respect to methyl bromide, are treatments to prevent the introduction, establishment and/or spread of quarantine pests (including diseases), or to ensure their official control, where:

i. Official control is that performed by, or authorized by, a national plant, animal or environmental protection or health authority;

ii. Quarantine pests are pests of potential importance to the areas endangered thereby and not yet present there, or present but not widely distributed and being officially controlled;

b) *"Pre-shipment applications"* are those treatments applied directly preceding and in relation to export, to meet the phytosanitary or sanitary requirements of the importing country or existing phytosanitary or sanitary requirements of the exporting country.

The definition of 'pre-shipment' is unique to the Montreal Protocol and refers to *"those non-quarantine applications applied within 21 days prior to export to meet the official requirements of the importing country or existing official requirements of the exporting country"*. Official requirements are those "*performed by, or authorized by a national plant, animal, environmental, health or stored product authority*". Pre-shipment treatments target non-quarantine pests that may be present in both the exporting and importing country. These pests usually affect storage or end-use quality of the exported commodities, and are outside the scope of the International Plant Protection Convention (IPPC).

The definition of a quarantine pest under the Montreal Protocol differs from that under the IPPC in that it refers to *"pests of potential importance"* while the Convention definition refers to "*pests of potential* ***economic*** *importance"* and this is in reference to the effect of changes (e.g. in biodiversity, ecosystems, managed resources or natural resources) on human welfare.

The IPPC deals with pests of plants – specifically pests of propagation material and seeds for planting – that do not include pests that affect quality in storage or livestock. Under the Montreal Protocol, QPS treatments may also refer to 'sanitary' treatments, e.g., against human or animal pathogens and vectors (e.g. mosquitoes), covered by international agreements such as those monitored by the World Health Organization (WHO).

2.2.2. Reporting requirements

Article 7 of the Montreal Protocol requires Parties to report annual data on production, consumption, feedstock uses and destruction of ODS.

Decision IX/28 (1997) approved official forms for ODS reporting, including data on Methyl bromide production and consumption for QPS applications. The Beijing Amendment (Article 7(3)) further requires annual data on amounts used for QPS.

QPS data remained confidential until 2008 when the Parties made it public information through Decision XX/6. This Decision further encouraged Parties to submit a National Management Strategy for QPS.

The EU submitted such a strategy, which can be found at: **http://ozone.unep.org/Exemption_Information/Quarantinne_and_preshipment/Dec_xx-6_Strategy_to_reduce_emmission_of_mbr_for_QPS-European_Commission-07072010.pdf**

In 2012, Decision XXIV/15 emphasized the importance of methyl bromide data reporting for QPS, and asked Parties who had not yet established procedures for data collection on methyl bromide use for QPS or wishing to improve existing procedures, to consider elements identified as essential in the Technical and Economic Assessment Panel (TEAP) 2012 Progress Report (section 10.4.4).

2.2.3. UNIDO Logbook for QPS reporting

UNIDO has had the opportunity to assist some Parties with QPS reporting. A logbook format has been developed, which licensed fumigators should fill whenever applying a QPS treatment. This should then be sent to the NOU every 3-4 months, for reviewing and consolidating data. The logbook form is intended to collect information on methyl bromide consumption for QPS purposes and should be electronically completed by each fumigator involved in QPS applications with methyl bromide in each country. It should then be submitted to pertinent authorities on a periodical, but specific basis (day, month and year).

In summary, the following information required for the logbook includes:

1. General information and company contact details, including fiscal information (i.e. VAT No.)
2. Data directly related to the treatment conducted, comprising seventeen questions of which seven are considered essential (in bold):
   - i. Date of treatment
   - ii. Category treated
   - **iii. Commodity treated**
   - iv. Location of fumigation (Port, airport, other)
   - v. Type of fumigation enclosure (ship, aircraft, chamber etc.)
   - vi. Volume of space treated
   - **vii. Total of methyl bromide (in kg) used for this commodity/treatment**
   - viii. Methyl bromide formulation (pure or in mixture with other chemical)
   - ix. Total kg of methyl bromide recaptured (if any)
   - x. If recaptured, techniques available
   - **xi. Placed on the local market (after fumigation)**
   - **xii. Country/ies of destination (if exported)**
   - **xiii. If the commodity is exported, tentative date of export**
   - **xiv. Name of National Authority authorizing treatment**
   - xv. Location of Authority
   - **xvi. Name of Authority/company in importing country**
   - xvii. Commodity treated

Although at present the Montreal Protocol only requires reporting of total quantities of methyl bromide consumed or produced for QPS purposes, keeping track of actual categories of use will evidently help in tracking methyl bromide use and enforcing the ban on controlled uses. In addition, it will help Parties comply with new requirements which may eventually be put in place by the Parties to monitor QPS uses.

UNIDO draft Logbook, is available for download at:

http://www.unido.org/en/what-we-do/environment/safeguarding-the-environment/emerging-compliance-regimes/phase-out-of-methyl-bromide/unido-toolkit.html

Countries are welcome to use it and adopt it to their needs.

2.3. Supporting framework: National Ozone Officers (NOUs) and projects

Through the MLF also, the Montreal Protocol established *National Ozone Units* within the governments of each Article-5 Parties1. These units are in charge of the ozone programmes in each country and serve as a channel of communication with the implementing agencies. NOUs have played an instrumental role in achieving the required phased-out of ODS, including methyl bromide, by providing and disseminating relevant information, bringing key stakeholders together and coordinating project activities.

NOUS HAVE PLAYED AN INSTRUMENTAL ROLE BY PROVIDING AND DISSEMINATING RELEVANT INFORMATION, BRINGING KEY STAKE-HOLDERS TOGETHER AND COORDINATING PROJECT ACTIVITIES.

Three main types of projects were put in place to assist with the phase-out (Table 2).

TABLE 2. **TYPES OF METHYL BROMIDE PROJECTS DEVELOPED WITH ASSISTANCE FROM THE MLF, GOALS AND ACHIEVEMENTS**

Project Type	Goals and achievements
Technical Assistance and Training	Key for improving data collection on methyl bromide consumption, integrating the NOUs to phase-out activities and developing or strengthening policy packages aimed at sustaining the phase-out achieved. Also important in providing training and demonstrations on the implementation of alternatives. Normally not aimed at replacing specific quantities of methyl bromide.
Demonstration	Instrumental in raising awareness on methyl bromide phase-out, identifying key sectors impacted by phase-out and evaluating alternatives. Generally not aimed at phasing a particular amount of methyl bromide out. Served to identify problems hindering adoption of alternatives and provided essential lessons for investment projects implemented later.
Investment	Generally implemented once successful alternatives were identified during the demonstration stage. Carried agreement from the country to phase methyl bromide consumption out for controlled uses by an agreed deadline, and to support sustainability of the phase-out achieved with a policy package aimed at banning future methyl bromide use for controlled uses.

In general, investment projects included an agreement from the country involved to phase methyl bromide for controlled uses out entirely, and to support the phase-out with a policy package banning methyl bromide imports for controlled uses.

The capacity to track actual use of methyl bromide imported into the country, and specifically to ensure that methyl bromide intended for QPS use does not deviate into controlled applications is extremely important.

Supporting the registration of alternatives to ensure their availability for users is also crucial.

1 *Parties to the Montreal Protocol are classified as Article 5 (A5) or Non-Article 5 (Non-A5) in relation to their consumption of ODSs. In general, A5 Parties are developing countries whilst non-A5s are developed countries*

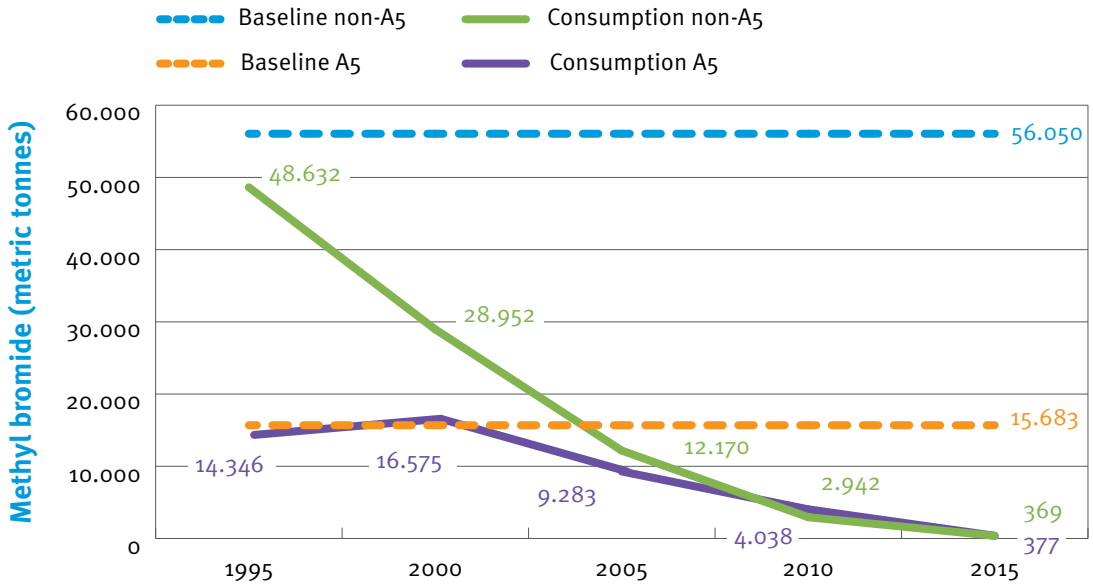
3. Controlled uses of methyl bromide: historical perspective

3.1. Global consumption

ARTICLE 5 PARTIES ON THEIR PART MADE GREAT STRIDES BY PHASING MORE THAN 85% OF CONTROLLED USES OUT AHEAD OF THE 2015 DEADLINE.

Phasing out methyl bromide for controlled uses has been a very successful global effort. From a baseline consumption of nearly 60,000 metric tonnes in 1992 among non-Article 5 Parties, consumption went down to less than 500 metric tonnes in 2014 (wholly corresponding to critical uses). Article 5 Parties on their part made great strides by phasing more than 85% of controlled uses out ahead of the 2015 deadline.

FIG 1. **GLOBAL CONSUMPTION OF METHYL BROMIDE (CONTROLLED USES) 1992-2015**



Source: Ozone Secretariat database, 2015. MBTOC CUN final reports 2014, 2015. Decisions of the Parties

3.2. Main countries using methyl bromide: past and present

In 2001, fifteen countries accounted for about 86% of total Article 5 consumption of methyl bromide, and had a baseline at or larger than 500 metric tonnes. Peaks of consumption were evident in the baseline years (1995-1998) and sometimes also right before the required 2005 reduction step, representing 20% of the baseline level.

Under the Protocol, "Consumption" means production plus imports minus exports of controlled substances (Montreal Protocol, Article 1).

By 2013 and often ahead of the phase-out deadline for developing countries, many of these countries had phased-out methyl bromide completely (e.g. Brazil, Lebanon, Morocco, Turkey and Zimbabwe) and by 2014 most of them reported zero consumption.

3.3. Reasons for using methyl bromide, sectors and stakeholders involved

As stated previously, methyl bromide is a highly efficacious broad-spectrum fumigant, which became an increasingly preferred method for pest and disease control among farmers around the world after its introduction in the 1970s. It was mainly used as a soil fumigant for controlling soil borne pests, diseases and weeds in the production of some high value crops. However, there are many examples of agro-industries that developed with high success and never depended on methyl bromide.

Similarly, methyl bromide was also widely used in some countries for post-harvest fumigation of durable commodities (grain, dried fruit and other foodstuffs) and structural fumigation (warehouses, mills). However, some large grain producers never adopted methyl bromide for treating such commodities.

Commercial strategies and good results undoubtedly account for the widespread use of methyl bromide in some countries.

3.3.1. Variety of methyl bromide users

Methyl bromide users in Article 5 Parties were diverse, ranging from small farmers (0.5 hectares (ha) and less) to very large enterprises (sometimes even hundreds of hectares). There was also much variation with respect to the level of technical expertise, as this was not necessarily correlated to the size of the operation, but possibly more to the destination of the crop – local market or export, the latter generally imposing stringent quality requirements and in consequence being more technically demanding. Other key factors coming into play were the availability and price of alternatives, general experience in their use and the relative ease or difficulty to implement them.

An important issue is that methyl bromide consumption was not restricted to technically advanced enterprises. Simple, low technology methods of methyl bromide fumigation – particularly disposable methyl bromide canisters – were used in many Article 5 Parties and stimulated methyl bromide use because large and expensive injection rigs and professional applicators for soil treatments were not required. Early banning of methyl bromide canisters in some Article 5 Parties was a key factor in achieving the phase-out more quickly and efficiently.

3.3.2. Categories of use

As a versatile product, methyl bromide was used for many and varied purposes. These are summarized in Table 3.

TABLE 3. **HISTORIC CONTROLLED USES OF METHYL BROMIDE WORLDWIDE**

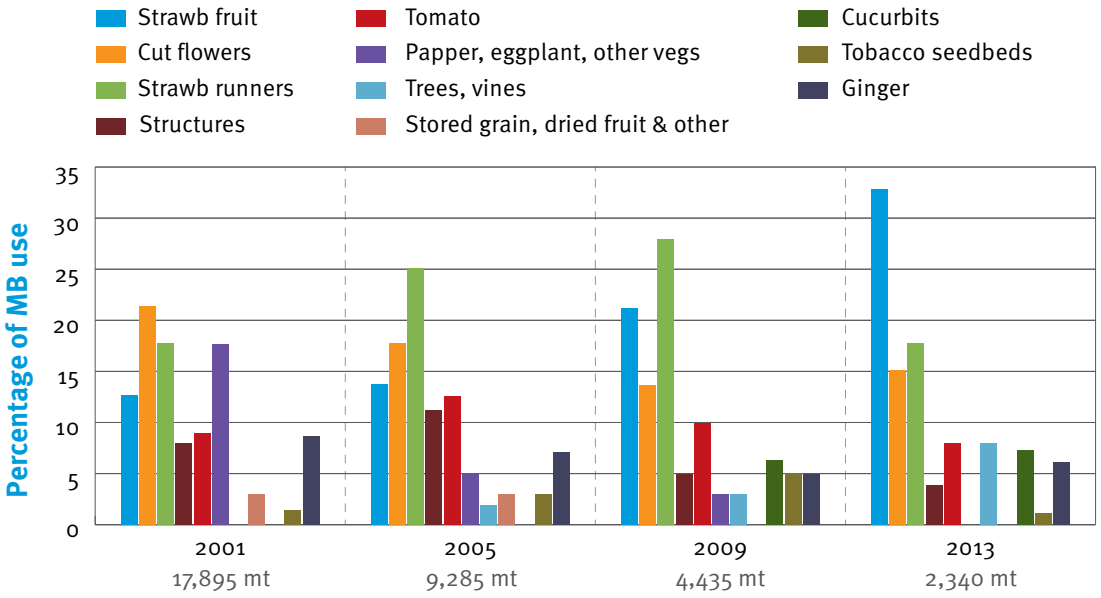
Controlled uses of methyl bromide		How initial difficulties in replacing methyl bromide were solved
IN SOIL	Pre-plant treatment to control soil borne pests (nematodes, fungi and insects) and weeds of high-value crops such as cut flowers, tomatoes, strawberry fruit, cucurbits (melon, cucumber, squash), peppers and eggplant;	Changing production schemes to adopt an Integrated Pest Management (IPM) approach (such schemes may include fumigants).
	To control 'replant disease' in some vines, deciduous fruit trees or nut trees;	
	Treatment of seed beds principally against fungi for production of a wide range of seedlings, notably tobacco and some vegetables;	Adapting substrates/ floating trays systems, training.
	To control soil borne pests in the production of pest-free propagation stock, e.g. strawberry runners, nursery propagation materials, which in some cases need to meet certification requirements;	High health requirement ("disease-free" plant material) required hygienic measures, IPM.
IN DURABLES	To control damage caused by cosmopolitan insect pests in stored products such as cereal grains, dried fruit, nuts, cocoa beans, coffee beans, dried herbs, spices, also cultural artefacts and museum items;	Longer treatment times necessary with phosphine required changes in logistics, combining options. This and other alternatives required adopting an IPM approach.
IN STRUCTURES AND TRANSPORT	To control insects and rodents in flour mills, pasta mills, food processing facilities and other buildings;	
	To control insect pest and rodents in ships and freight containers, including aircraft, empty or containing durable cargo.	

Source: Extracted from the MBTOC 2006 Assessment Report

3.3.3 Key sectors

Although methyl bromide was used for controlling a wide variety of pests, diseases and weeds, such uses were somewhat concentrated on a relatively low number of sectors. Traditionally, about 90% of controlled uses were applied for soil fumigation in various intensive agriculture sectors and the remaining 10% in postharvest and structure treatments. Although these proportions remained relatively stable throughout the phase-out period, the actual sectors changed as alternatives were found more easily for some sectors than for others as shown in Fig. 2 below.

FIG.2. **MAIN SECTORS USING METHYL BROMIDE 2001 -2013 IN ARTICLE 5 PARTIES (CONTROLLED USES)***



** Tonnages correspond to total methyl bromide usage, in metric tonnes, for all Article 5 Parties in the given year*

Source: MBTOC Assessment Reports 2002, 2006, 2010 and 2014.

In 2015 only critical uses of methyl bromide remained: a total of 369 metric tonnes of methyl bromide were approved by the Parties for fumigation of strawberries, strawberry and raspberry runners, ginger, tomato and structures in Article 5 Parties.

3.3.4. Targeted pests and diseases

Overall, the number and type of pests, diseases and weeds that were controlled with methyl bromide in the past was not very large. The advantage perceived by users when treating soil or commodities with this fumigant was its wide spectrum of action, whereby a single fumigant eradicated virtually all living organisms present in the soil or infesting commodities or structures. Often, it was unnecessary to identify the pest present and there were cases where fumigation was performed as a preventative treatment which, as it turned out, was not really required.

THE ADVANTAGE PERCEIVED BY USERS WHEN TREATING SOIL OR COMMODITIES WITH THIS FUMIGANT WAS ITS WIDE SPECTRUM OF ACTION, WHEREBY A SINGLE FUMIGANT ERADICATED VIRTUALLY ALL LIVING ORGANISMS PRESENT IN THE SOIL OR INFESTING COMMODITIES OR STRUCTURES.

Table 4 lists pests, diseases and weeds typically controlled or prevented in key consuming sectors of the past with methyl bromide. The list is only meant to illustrate the variety of organisms controlled by methyl bromide and is not comprehensive. Pests and diseases and the severity of their attacks vary with the crop, cultivar grown, location, environmental conditions and other factors.

TABLE 4. **KEY PESTS AND DISEASES TRADITIONALLY CONTROLLED WITH METHYL BROMIDE IN KEY CONSUMING SECTORS**

SOIL FUMIGATION	
Crop	**Pathogens or pests**
Tomato	**Viruses:** Tomato mosaic, Double streak, Spotted wilt, Ringspot **Fungi:** Root and collar rots *(Pythium, Rhizoctonia solani, Sclerotium rolfsii)* Wilts *(Fusarium oxysporum f.sp. lycopersici, Verticillium spp)* **Oomycetes:** Late blight *(Phytopthora infestans)* **Nematodes:** Root-knot *(Meloidogyne spp)*, Stubby root *(Rotylenchus spp)* False root-knot *(Naccobus spp)*
Strawberry *(fruit and runners)*	**Fungi:** Wilt *(Fusarium oxysporum f.sp. fragariae)* Root rot *(Rhizoctonia solani, Pythium, Macrophomina phaseolina)*
Cucumber, melon, watermelon	**Bacteria:** Soft rot *(Erwinia carotovora)* **Fungi:** Root rots *(Phomopsis, Pythium)* Wilts *(Fusarium, Verticillium)* Vine decline *(Monosporascus cannonballus)* **Virus:** Green mottle, Cucumber mosaic, Melon necrotic spot
Pepper	**Fungi:** Root rots *(Pythium spp, Scerotinis sclerotiorum, Rhizoctonia solani)* **Oomycetes:** Blight *(Phythopthora spp)*; Late blight *(Phytopthora infestans)*
Lettuce and medicinal plant	**Nematodes:** Root-knot *(Meloidogyne spp)* **Fungi:** Rots *(Rhizoctonia solani, Pythium spp, Bremia spp Fusarium spp)*
Cut flower	**Fungi:** Wilts (*Fusarium oxysporum, Verticillium spp)* Root rots *(Rhizoctonia, Pythium, Sclerotium)* **Nematodes:** Root-knot *(Meloidogyne spp)* Cyst *(Heterodera spp)* **Bacteria:** Crown gall (*Agrobacterium tumefaciens)*
Eggplant	**Fungi:** Wilts *(Fusarium oxysporum, Verticillium spp)* Root rots *(Rhizoctonia, Pythium, Sclerotium)* Nematodes (*Meloidogyne spp)*
Ginger	**Bacteria:** Wilt *(Ralstonia solanacearum)* Rot *(Pythium spp)*
Tobacco	Damping off *(Pythium sp, Rhizoctonia sp, Fusarium sp, Alternaria sp)*
All	**Weeds:** Nutsedge(*Cyperus spp)*, Portulacca spp, Witchweed S*(triga spp,)*
COMMODITIES (AND STRUCTURES)	
Wheat, maize, rice, others	Red and confused flour beetles *(Tribolium spp)* Flat headed flour beetle (*Cryptolestes spp)* Warehouse moth *(Ephestia (Anagasta) cautella)* Grain weevil (*Sitophilus granarius)* Maize weevil (*Sitophilus zeamais)* Grain moth *(Sitotroga cerealella)* Lesser grain borer *(Rhyzopertha dominica)* Sawtoothed beetle *(Oryzaephilus surinamensis)* Khapra beetle *(Trogoderma graniarum)**
Dates	Date moth or Karob moth *(Ectomyelois ceratoniae)* Sawtoothed beetle *(Oryzaephilus surinamensis)*

** For many countries, this is a serious quarantine pest*

3.3.5. Key stakeholders

Identifying and involving key stakeholders impacted by the methyl bromide phase-out proved essential to the success of projects. Aside from direct users, a variety of stakeholders are impacted in one way or another by the methyl bromide phase-out (Table 5).

TABLE 5. **MAIN STAKEHOLDERS INVOLVED IN THE METHYL BROMIDE PHASE-OUT**

Stakeholders	Issue of interest
Government authorities	Pesticide registration, environmental issues, customs officers, quarantine and phytosanitary inspection
Research/ academia	Research centres, universities, training centres
Suppliers/ importers	Companies that import, produce or otherwise source alternatives or materials needed to implement alternative technologies. Authorized methyl bromide importers (for QPS or Critical Uses)
Direct users	Growers, contract fumigators, including licensed methyl bromide fumigators for QPS
Technical assistants/ extension staff	Consultants or technicians assisting growers or producers on production practices, postharvest handling and storage and others
Others	Trade associations, cooperatives, local or regional organizations

4. Actions undertaken by UNIDO to assist the phase-out

From 1994 onwards, the Multilateral Fund initiated activities aimed at assisting Article 5 Parties with the methyl bromide phase-out. Since that time, nearly 400 projects have been implemented, to provide technical assistance and training, disseminate information, demonstrate and trial alternatives under varying circumstances and environments, and directly replace methyl bromide in commercial sectors.

Approximately USD 140 million have been invested in these efforts, with very good results overall. Table 6 shows the general distribution and expenditures for such projects from 1994 until 2014 and the phase-out progress made.

TABLE 6. **NUMBER OF PROJECTS SUPPORTED BY THE MLF, IMPACT AND EXPENDITURES**

Project type	No. Projects	Impact (tonnes)		Phased out (tonnes)		USD approved by Dec 2014
		ODP	Metric	ODP	Metric	
Investment	129	8,054	13,423	6,865	11,422	110,159,000
Demonstration	44	23	39	23	39	14,119,000
Technical assistance	74	292	486	414	691	7,785,000
Training	21	6	11	6	11	1,739,000
Project preparation	130	–	–	–	–	3,411,000
Total	**398**	**8,375**	**13,958**	**7,309**	**12,182**	**137,214,000**

Source: Multilateral Fund Secretariat, 2015. Numbers have been rounded

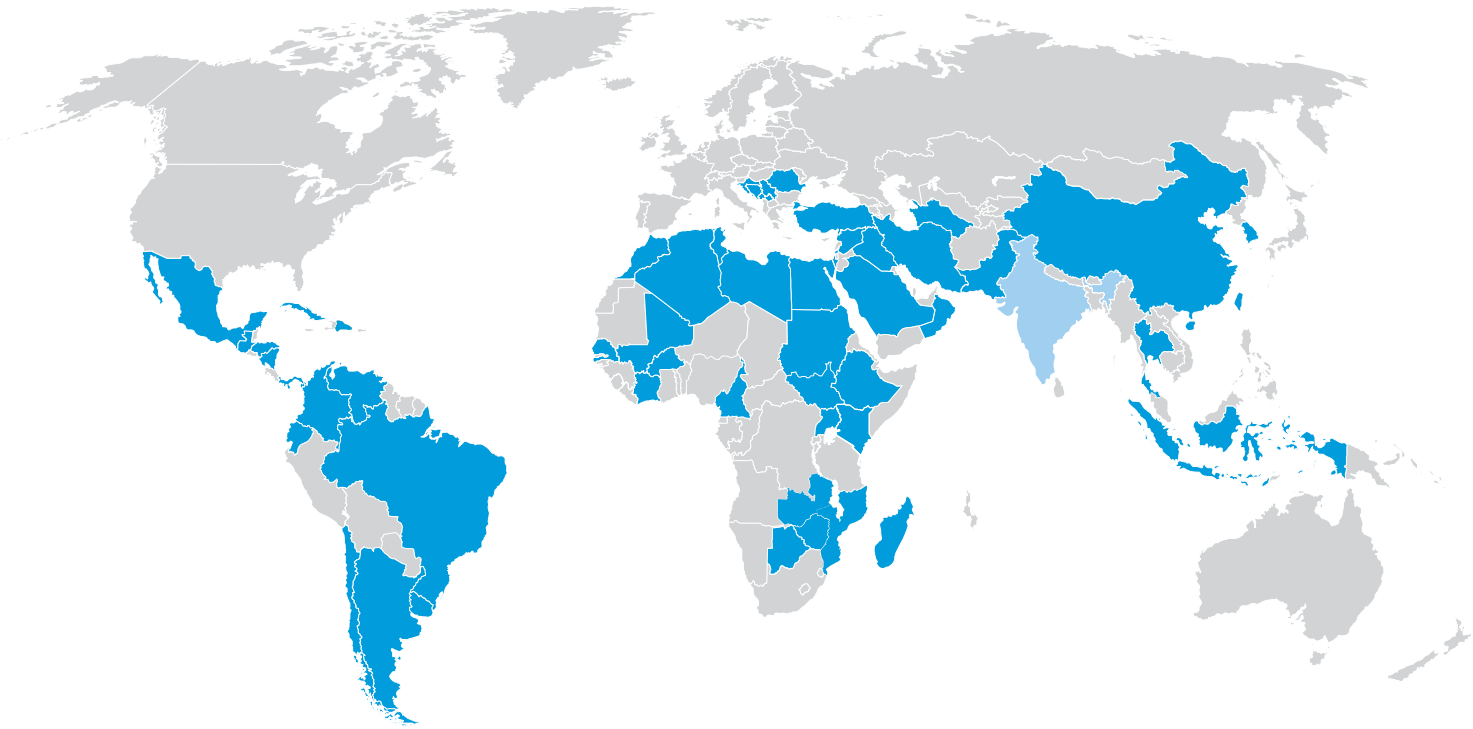
4.1. UNIDO's role

UNIDO HAS ACTED AS AN IMPLEMENTING AGENCY IN 55 OUT OF THE 77 (OR OVER 70%) ARTICLE 5 PARTIES WHERE THE MLF HAS FUNDED PROJECTS AIMED AT PHASING METHYL BROMIDE OUT, FROM 1996 TO DATE

From the very start of the process aimed at substituting methyl bromide in Article 5 Parties, UNIDO positioned itself prominently as a proactive agency ready to provide tailor-made solutions to each country requesting its assistance. Working on its own or sometimes in cooperation with other agencies and/or bilateral agreements with specific donor countries, and always in coordination with Governments requesting its assistance, UNIDO has acted as an implementing agency in 55 out of the 77 (or over 70%) Article 5 Parties where the MLF has funded projects aimed at phasing methyl bromide out, from 1996 to date (see Fig.3).

Work conducted by UNIDO includes project preparation, technical assistance, demonstration and investment projects, mostly in individual projects but also at the regional level. The agency has worked on all key sectors using methyl bromide for controlled uses in the past and in the process generated a wealth of information.

FIG 3. **UNIDO'S PRESENCE (COUNTRIES COLOURED IN BLUE) IN METHYL BROMIDE PHASE-OUT RELATED ACTIVITIES IN DEVELOPING COUNTRIES (ALL PROJECT TYPES) 1994 - 2015**



Source: MLF. Two countries in light blue (India, Jamaica) depict cancelled projects

4.2. Overview of alternatives implemented

The alternatives and replacement technologies to be implemented were selected carefully taking into consideration the particular circumstances of each country and sector. These included, in the first instance, acceptance and agreement from key stakeholders, particularly direct users; availability of products and supplies required to implement the selected alternatives; training and technical assistance; and economic analyses to further ensure the feasibility of the selected options.

A strong integrated pest management (IPM) approach where replacement of methyl bromide is conceived as a production system combining different options was always the rule. See more information on IPM in section 4.3.

A STRONG INTEGRATED PEST MANAGEMENT (IPM) APPROACH WHERE REPLACEMENT OF METHYL BROMIDE IS CONCEIVED AS A PRODUCTION SYSTEM COMBINING DIFFERENT OPTIONS WAS ALWAYS THE RULE.

In addition, many study tours were organized, where methyl bromide users and other stakeholders were able to observe and discuss alternatives already put successfully in place at the commercial level in similar sectors and conditions. This encouraged information exchange and served to build trust in the selected alternative options.

The following table summarizes the main technologies selected from each key sector previously using methyl bromide, in countries where UNIDO implemented investment projects aimed at fully replacing methyl bromide, or other kinds of projects that supported the full phase-out. The majority of these projects are now finished.

TABLE 7. **TECHNOLOGIES ADOPTED IN METHYL BROMIDE PHASE-OUT PROJECTS IMPLEMENTED BY UNIDO, BY REGION**

Region	Country	Sectors	Technologies selected
CENTRAL AMERICA/ CARIBBEAN	**Cuba**	Tobacco seedlings	Floating trays., biocontrols
		Structures (mills), stored grain	Phosphine + CO_2 and heating, sulfuryl fluoride
	Dominican Rep.	Melons, cut flowers, tobacco	Floating trays, solarisation, metham sodium (MS), steam, substrates
	Guatemala	Melon, watermelon, cut flowers	Chemicals, grafting, biocontrols, steam
	Honduras	Melons, watermelons	Chemicals, floating trays, grafting, biocontrols
	Mexico	Melons, peppers, tomatoes, strawberries cut flowers,	Grafting, chemicals, IPM, steam, solarisation
		Stored grain, flour mills	Phosphine + CO_2
SOUTH AMERICA	**Argentina**	Tomatoes, strawberries, cut flowers	Chemicals (1,3-D/Pic, MS, Dimethyl disulphide (DMDS), steam, floating trays, grafting
	Brazil	Tobacco seedlings Cut flowers	Floating trays, substrates, metham sodium (MS), steam, solarisation (solar collectors)
	Colombia	Bananas	Dazomet. Eradication of affected areas with glyphosate + quarantine and monitoring of diseased areas
	Chile	Strawberries, tomatoes, peppers	1,3-D/pic, steam, steam + Trichoderma, MS (rotary-spading injection)
	Ecuador	Cut flowers	Substrates, chemicals, biofumigation
	Uruguay	Tomato, peppers, cut flowers	Solarisation + chemicals (1,3-D/Pic, MS, DMDS), biofumigation, steam
NORTHERN AFRICA	**Egypt**	Tomato, pepper, strawberries, cut flowers,	Substrates, steam, biofumigation, grafting
		Stored grain, dates	Phosphine, PH_3 + CO_2
	Morocco	Tomatoes, cucumbers, peppers, strawberries, bananas, cut flowers, green beans	1,3-D/pic, MS, grafting, solarisation + chemicals, steam, substrates, compost
	Libya	Tomatoes, cucumbers, peppers	Solarization + fumigants, grafting, biofumigation
	Senegal	Stored grain (peanut seed)	Phosphine, (tablets of metallic phosphide) IPM
	Tunisia	Dates	Phosphine + CO_2 (carbon dioxide)

Region	Country	Sectors	Technologies selected
SUB-SAHARAN AFRICA	**Cote D'Ivoire**	Stored grain	PH_3 (phosphine) + CO_2
	Kenya	Cut flowers , horticulture	MS (rotary-spading injection), substrates, steam, grafting, IPM
		Stored grain (maize)	Phosphine, PH_3 + CO_2, chilling
	Sudan	Dates, stored grain	Phosphine, IPM
	Uganda	Cut flowers	MS (rotary-spading injection), steam, substrates, 1,3-D/Pic
	Zambia	Vegetables, tobacco seedlings, cut flowers, stored grain	Dazomet, floating trays, biofumigation + solarisation, MS
		Post-harvest	Phosphine
	Zimbabwe	Cut flowers, tobacco,	Steam, IPM, floating trays
		Stored grain	Phosphine
SOUTH AND SOUTH-EAST ASIA	**China**	Strawberries tomatoes, peppers, ginger,	MS, grafting, chloropicrin, 1,3-D, limited biocontrol
		Stored grain	Phosphine
	Iran	Olive and fruit tree nurseries,	Steam, solarisation, with IPM
		Dried fruit, nuts, grain	Phosphine, IPM
	Lebanon	Strawberries, vegetables	1,3-D, 1,3-D/ Pic, MS, solarisation, solarisation + reduced doses of chemicals, grafting, crop rotation, biofumigation, floating trays
	Syria	Grain storage,	Phosphine + CO_2 , IPM
		Tomatoes and other vegetables, cut flowers	Solarisation, solarisation + reduced doses of chemicals, grafting, crop rotation, biofumigation
	Turkey	Tomatoes, peppers, eggplant, cucumbers, cut flowers, dried fruit	Grafting, MS, 1,3-D, 1,3-D/Pic, solarisation, substrates, grafting, resistant varieties, steam
		Dried fruit, dates	CO_2 and phosphine
	Indonesia	Stored grain	Phosphine, IPM
EUROPE / CEIT	**Bosnia & Herzegovina**	Tobacco seedlings, vegetables, flowers	Floating trays, solarisation, biofumigation
	Croatia	Tobacco seedlings	Floating trays
	Macedonia	Tobacco seedlings, vegetables (tomatoes, cucumbers)	Floating trays, solarisation + biofumigation
	Romania	Tomatoes, cucumbers, peppers	Grafting, solarisation + 1,3-D/ Pic, MS

Source: MLF, 2014, UNIDO 2015.

4.3. Ensuring a sustainable methyl bromide phase-out

Methyl bromide continues to be available after the phase-out deadline due to the QPS exemption and could thus be used for any controlled application. In contrast, implementing alternatives to other ODSs (e.g. aerosols, refrigerants) generally require factories to undertake significant technological conversions, which rule out returning to the old substances (ODSs).

Since experience has proven that the best option when replacing methyl bromide is to adopt a multi-disciplinary approach that combines different possibilities, that gives way to sustainable production practices and that often increases the competitiveness of the sectors involved, UNIDO adopted an integrated management approach to pest and disease control.

The basic principle that substituting or avoiding methyl bromide requires a grower to consider agricultural production and pest control implies that there is no single replacement for this product. Instead, a whole programme incorporating different measures which together lead to disease reduction is the answer.

THE ADOPTION OF IPM SYSTEMS PROVIDED AN EFFICIENT MEANS OF RESPONDING TO CONSUMER DEMANDS OF HIGH QUALITY PRODUCTS WHILST AT THE SAME TIME ADDRESSING ENVIRONMENTAL, FOOD SAFETY AND SECURITY, HEALTH AND SOCIO-ECONOMIC ISSUES.

The adoption of IPM systems provided an efficient means of responding to consumer demands of high quality products whilst at the same time addressing environmental, food safety and security, health and socio-economic issues. IPM is a broad, rational, ecological approach to pest and disease management that combines, either concurrently or sequentially, biological, physical and chemical tools ensuring protection of the environment whilst maintaining profitability and fulfillment of consumer demand for decreased or no pesticide use.

Together with IPM, the concept of Good Agricultural Practices (GAP) was included, which addresses sustainable production from an environmental and social point of view. Production within GAP parameters has opened and widened markets for many products, particularly horticultural products exported from Article 5 to non-Article 5 Parties, which increasingly require products that are certified for sustainable production through specific standards.

IPM is a proven and effective technology for growers in many parts of the world and offers an excellent basis for the replacement of methyl bromide, as well as other soil fumigants. Products such as 1,3-D, chloropicrin, dazomet, metham sodium and others may not damage the ozone layer but still pose hazards to human health and their use is increasingly restricted around the world. The IPM system provides a rational and needs-based approach towards pest and disease control with minimized use of chemical interventions such as fumigation.

In IPM, it is essential to detect pests and diseases at the earliest possible stage, treating foci as soon as they appear and using non-chemical options whenever feasible. In summary, IPM requires a grower to learn to recognize symptoms caused on plants by pests or diseases, understand the life cycle of a pest or pathogen, its epidemiology and dissemination, surviving forms, alternate hosts and others. With information like this at hand, a programme can be developed through which pest populations are reduced using different tools in rational combination and timing. In essence, IPM involves making use of all possible resources – not just chemical control – to reduce and prevent the incidence and effects of a given disease or pest. All of these contribute in some way to pest reduction and lead to far less usage of chemical pesticides, even though on their own they rarely provide a complete cure.

In its practical application IPM leads to excellent results not only by improving the efficiency of the business but because, over time, it represents significant savings both in natural and economic resources.

Together with the issues above, a sustainable phase-out should comprise economic, regulatory and political aspects as shown in Table 8.

A SUSTAINABLE PHASE-OUT SHOULD COMPRISE ECONOMIC, REGULATORY AND POLITICAL ASPECTS

TABLE 8. **FACTORS IMPACTING THE SUSTAINABILITY OF THE METHYL BROMIDE PHASE-OUT**

Factor	Definition
Technical	Refers to the level of control obtained with the alternatives selected and implemented. In general, if alternatives perform similarly or not significantly different to methyl bromide, technical feasibility is achieved. However, even more important is that the selected production technology is suited to the particular circumstances of the productive sector and stakeholders involved – not necessarily in direct comparison with methyl bromide.
Economic	Whether alternatives are affordable, at least to the same degree as methyl bromide. Once again, the most important issue is that an acceptable profit is achieved, not how such costs directly compare to methyl bromide. For example, an alternative may be more expensive than methyl bromide but lead to higher yields and quality and better market penetration, thus compensating the additional investment.
Regulatory	If alternatives are locally registered and readily available to users, and/or whether there are any restrictions to the use of chemical alternatives (e.g. buffer zones) or regulations that may restrict implementation of technologies.
Political	Whether methyl bromide phase-out is legally supported, for example by entirely banning methyl bromide imports for controlled uses or restricting them strictly to authorized critical uses if these are authorized. If imports destined for QPS uses can be easily tracked and monitored to avoid diversion of use (i.e. that methyl bromide imported for QPS ends up being illegally used for controlled uses).
Commercial	Types of users (e.g. small farmers selling at the local market or exporters competing at the international level). The degree of technical development, access to supplies, services (e.g. maintenance) and technology updates. Whether services and supplies related to alternatives are locally available or need to be imported, whether a certain production technology allows for competitive access to a given market.

4.4. Impact of the methyl bromide phase-out

The methyl bromide phase-out process generated a wealth of information on agricultural production systems, including pest and disease control, fertilization, watering and cultural practices. This is particularly relevant to intensive agriculture systems where methyl bromide was primarily used.

Integrated Pest Management (IPM) and Integrated Crop Management (ICM) programmes, non-chemical alternatives (grafting, soil-less culture, biofumigation), crop rotation and others were evaluated from technical and economical standpoints and successfully implemented commercially. Large numbers of growers and other key stakeholders were trained.

As a result, growers all over the world have gained increased competitiveness, opened new markets for their products and learned how to produce within higher sustainability standards.

GROWERS ALL OVER THE WORLD HAVE GAINED INCREASED COMPETITIVENESS, OPENED NEW MARKETS FOR THEIR PRODUCTS AND LEARNED HOW TO PRODUCE WITHIN HIGHER SUSTAINABILITY STANDARDS.

In general, a more rational use of chemical products has been put in place (including fumigants, pesticides, and chemical fertilizers) with associated benefits to the environment and to human health.

4.5. Illustrative case studies of projects implemented by UNIDO

Case studies focus on specific circumstances of a sector and sometimes not on the entire sectors covered by the project (e.g. case study in Mexico).

4.5.1. **Ecuador:** Cut flowers

Since Ecuador banned the registration of methyl bromide as a measure to enforce the phase-out of this highly toxic pesticide the cut flower sector needed technical assistance to find alternatives. Through this project, UNIDO assisted flower growers in adopting a non-chemical solution to replace methyl bromide. The new method called biosolarization, which combines soil biofumigation and soil solarization, would help to maintain soil health. In some specific cases, alternative fumigant (1,3-D/Pic) was also used. A robust and integrated approach of pest management was taken in all cases.

ECUADOR	
Sectors	Cut flowers (mainly field grown “summer flowers”)
Technologies selected	Biosolarization (biofumigation or biodesinfestation coupled with solarization), alternative fumigants (1,3-D/Pic)
Phase-out	68 metric tonnes
Donors	MLF
Budget	USD 317,000
Partners	Technical Ozone Unit (UTO) of the Ministry of the Industry and Productivity of Ecuador (MIPRO); the Ecuadorian Association of Flower Growers and Exporters (EXPOFLORES); UNIDO

Significance of the sector

Ecuador is the world’s third largest exporter of cut flowers (after The Netherlands and Colombia), exporting primarily to markets in the USA, Canada, Russia and Europe. Greenhouse roses make up about 75% of exports (on a value basis) with the rest largely conformed by a group of cut flowers known as “summer

flowers", which grow in the open field, including *Gypsophyla*, *Hypericum*, *Delphinium, Lisianthus*. In 2014, the floriculture sector employed over 100,000 people and generated USD 800 million of business revenue. The regions of Azuay, Cotopaxi and Pichincha located near Quito, the Ecuadorian city, are ideal for flower production; Pichincha in particular is a major rose production site.

Challenges

Summer flower production relied heavily on soil fumigation for controlling soilborne fungi, nematodes and weeds, which can cause severe losses in yield and quality. Baseline consumption of methyl bromide was 110 metric tonnes. The country came into non-compliance with the 20% reduction in methyl bromide consumption for controlled uses required under the Montreal Protocol for Article 5 Parties in 2005 but was able to come back into compliance. In order to support with the complete phase-out of 2015 the Government set forth a strong policy package banning methyl bromide for all uses in 2013. Alternatives were urgently needed for exporters faced with steep international competition, and stringent quality requirements, as well as the market's demand for flowers produced by sustainable and environmentally friendly practices.

Strategy

Under the monitoring and coordination of the Technical Ozone Unit (UTO) of the Ministry of the Industry and Productivity of Ecuador (MIPRO), UNIDO worked closely with flower growers and EXPOFLORES, the Ecuadorian Association of Flower Growers and Exporters. Stakeholders involved in the project also included AGROCALIDAD, a division of the Ecuadorian Ministry of Agriculture and Livestock in charge of pesticide registration and imports.

Technologies selected

After a thorough discussion with the growers involved, UNIDO's technical assistance was focused on trialing and demonstrating biosolarization (biofumigation or biodesinfestation coupled with solarization). Biofumigation is the emission of volatile compounds resulting from the decomposition of organic matter incorporated into the soil, which contributes to pathogen control. Solarization is achieved by trapping heat from solar radiation under clear plastic to elevate the temperature of moist soil and kill pests and diseases. Alternative fumigants, particularly 1,3-Dichloropropene + chloropicrin (1,3-D/Pic, commercial name Agrocelhone®) were also implemented in particular cases.

Biosolarization was found to provide very good results for field-grown summer flowers such as *Gypsophyla* spp and *Hypericum*. This technique combines biofumigation and solarization, which together produce a

synergistic effect, since the time required for effective solarization to take place is reduced. This mainly occurs because the organic matter content of the soil is improved and populations of beneficial microorganisms are increased. Depleted organic matter, often coupled with deficient fertilization and irrigation practices, were found to be a common cause of sub-optimal plant development and yield decline over time (a condition often referred to as "soil fatigue"), and not a high incidence of soilborne diseases. Biosolarization offered a way to correct this situation to the extent that in some cases the need for soil fumigation was questioned.

Under particular circumstances of confirmed high pest pressure, some growers preferred to use 1,3-D/Pic at least initially, in order to rid the soil of harmful pests and pathogens.

Technology Transfer

UNIDO used its past technical expertise and tools to provide the flower growers with technical assistance and capacity building, and helped the Government of Ecuador to comply with Montreal Protocol requirements in a sustainable manner.

Field trials were undertaken to test the selected alternatives on several flower farms in Ecuador. In particular, growers were able to determine the correct amounts of organic matter and amendments needed for optimizing biosolarization results at different locations and for the different types of flower involved. On-site training, field days where growers were able to observe results and workshops were conducted. Assistance from international experts was provided. All these activities encouraged information exchange amongst growers and helped increase their confidence in the alternative systems.

Additional information

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4.5.2. **Kenya:** post-harvest storage of white maize in silos

Phosphine fumigation and grain chilling were chosen as alternative methods for disinfestation and quality maintenance of white maize stored in concrete silo bins in Kenya, phasing-out the remaining authorized use of controlled methyl bromide (11 metric tonnes) in the country. The selected technologies fitted well with the existing fumigation infrastructure and the technical expertise of the pest-control personnel. Awareness raising and training provided along with an introduction of these technologies offered an opportunity to build confidence in the selected options, as well as to assist and monitor the adaptation activities, ensuring a successful transition.

KENYA	
Sectors	Post-harvest: storage of white maize, horticulture
Technologies selected	Phosphine gas integrated with grain cooling
Phase-out	11 metric tonnes
Donors	MLF
Budget	USD 310,000
Partners	NOU, Ministry of Environment and Mineral Resources, Kenya, National Cereals and Produce Board (NCPB), UNIDO

Significance of the sector

White maize is the main cereal crop grown in Kenya. About 60% of the grain produced in the country is stored at a farm level, while the storage of the remaining 40% is regulated and controlled by the National Cereal and Produce Board (NCPB). The NCPB provides storage capacity for 1.8 million tonnes, 0.17 million tonnes which were fumigated with methyl bromide for protection against pests. The NCPB holds much of its total maize stock in stacked bags in warehouses. A proportion of that stock is held for several years, as a strategic reserve against famine.

Challenges

Since 2011, the NCPB was the only authorized user of controlled methyl bromide in the country subject to phase-out under the Montreal Protocol. It used methyl bromide to control pests in concrete silo bins containing stored white maize at four warehouses: Bungoma, Kisumu, Moi's Bidge and Nakuru. The storage of domestically produced white maize requires treatments that result in a grain with very low or zero insect numbers at outturn from the silo bins ('insect-free'), while meeting domestic standards for breakage and grain quality. Only a limited set of alternatives fulfill these criteria.

Strategy

UNIDO, in partnership with the NCPB, took into account the existing infrastructure, technical and economic feasibility and availability of selected alternatives, their acceptance, institutional capacity to sustain the achieved phase-out by means of technical assistance and training, while the Government of Kenya offered full cooperation through their agricultural and industrial organizations. Further, Kenya introduced regulatory measures to control the imports and the use of methyl bromide, to monitor consumption, and to ensure compliance with the requirements of the Montreal Protocol.

Technology selected

The alternatives chosen for implementation and sustainable use included phosphine fumigation (at Bungoma, Kisumu, Nakuru) as well as an integrated combination of phosphine fumigation and grain chilling (at Moi's Bridge), representing already registered pest control measures in the country. Both techniques were applied using modified, existing infrastructure. Furthermore, a strategy for managing pest resistance to phosphine was put in place.

The phosphine system provides effective disinfestations and fits well with the fumigation infrastructure in silos that were using methyl bromide and also with the technical expertise of the NCPB's pest-control personnel, which was already familiar with handling and safety requirements for phosphine gas and its formulations.

Although phosphine fumigation takes longer to achieve disinfestation than methyl bromide, the equivalent treatment rate was achieved by treating multiple grain bins simultaneously. Technology utilizing phosphine integrated with grain cooling provided a means to (a) avoid the need to repeat fumigations, (b) manage pest resistance development risk while ensuring appropriate quality maintenance and sustainable use of the alternative fumigant and (c) provide better storage conditions.

Technology Transfer

Awareness raising and the provision of equipment and tools (such as a phosphine generator, phosphine gas metres, safety equipment, a chiller, a power generator), a training programme assisted by an international expert and technology providers (for managers, technicians and workers of silos), technical assistance and international expert visits, enabled proper demonstration, dissemination and transfer of alternative methods to the NCPB personnel.

4.5.3. **Mexico**[2]: tomato, pepper, cucurbit and strawberry

Grafting was the major technology selected by farmers in the production of cucurbits (melons and watermelons) and tomatoes in Mexico. The technology helped eliminate the use of methyl bromide in these sectors, and provided an opportunity for farmers to expand market access, increase yields and grow high quality products. Grafting techniques allowed for replacing 406 metric tonnes of methyl bromide in Mexico, or 27% of the country's overall phase-out goal for this fumigant. As part of the project, hundreds of women were also trained on the grafting technology. This helped generate employment opportunities for Mexican women, thereby improving their general welfare.

MEXICO	
Sectors	Tomato, pepper, cucurbit (melon, watermelon), strawberry, cut flower, post-harvest (commodities and structures)
Technologies selected	Grafting, soilless culture (substrates), vaporization, steam and Integrated Pest Management, soil solarisation and soil-less substrates were used for the wide range of crops comprised. In the particular case of cucurbits, tomatoes and peppers grafted was the most successful option.
Phase-out	1,491 metric tonnes total. Grafting techniques replaced about 27% of this amount
Donors	MLF, The Government of Italy, The Government of Spain, The Government of Canada
Budget	USD 9,222,379 total
Partners	The Government of Mexico, Unit for the Protection of the Ozone Layer (Unidad Técnica del Ozono, UTO) of the Secretariat of Environment and Natural Resources (SEMARNAT), Italy, Spain, Canada, UNIDO

Significance of the sector

Mexico is the world's second largest exporter of fresh tomatoes accounting for 21% of the global market share in 2012. Cucurbit exports are also on the rise, with very positive prospects.

Challenges

Over the last 25 years, methyl bromide consumption in these two sectors increased in conjunction with the expansion of these crops. Soil fumigation was used to control soilborne pathogens, nematodes and weeds at the pre-plant stage. Between 1995 and 1998, (the baseline years for Article 5 countries) Mexico was the largest user of methyl bromide in the developing world, with an average consumption of 1885 metric tonnes per year. In 2007, methyl bromide consumption was concentrated in six main sectors, namely tomato, cucurbits, peppers, strawberries, flowers and structural fumigation (e.g. flour mills).

Strategy

In 2008, with funding from the MLF and other donors, an investment project aimed at full phase-out of methyl bromide was approved. The Government of Mexico

2 *This case study focuses on specific sectors and not on the all sectors covered by the project (as listed in the table).*

worked with UNIDO, the National Ozone Unit and SEMARNAT to implement alternatives suited for each sector, including the grafting technology for the crops addressed in this case study. Different teams worked separately in each of the six sectors included in the project and held periodic meetings to exchange information and evaluate the implementation progress.

Technology selected

Grafting was the major selected technology in the production of tomato, pepper, melon, and watermelon. Grafting units were set up at commercial locations with the support of the project and trials were conducted to identify the best-suited rootstocks and cultivars for these products. Compared to non-grafted plants grown on soil treated by methyl bromide, grafted melons grown on non-fumigated soil produced significantly greater yields and enhanced fruit size and firmness. Planting densities were reduced by up to 50% with respect to non-grafted plants and, since grafted plants are more costly, this clearly contributed to the economic sustainability of grafting. For example, in the case of tomato production, both the fruit weight and total yield were significantly improved, whereas the planting density was reduced by 60%, which contributed to optimizing the production cost. Strawberry growers mostly preferred alternative fumigants, particularly 1,3-D/Pic and metham sodium. Application of metham sodium with a "spading machine" significantly improved results obtained with this chemical.

Technology Transfer

Awareness-raising activities, training and demonstration sessions allowed for a smooth transition to these alternatives. Grafting facilities were established at various commercial sites and rootstocks that were best suited for the preferred varieties in Mexico were selected. An active training and dissemination program involving hundreds of growers and other stakeholders further supported the commercial uptake of this technology.

A methyl bromide consumption database was developed including information on consumer's location, type of companies and sectors, consumption volumes and alternatives used for each particular application.

Additional information

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http://www.unido.org/news/press/el-injerto-ayuda-a-l.html (in Spanish)

Video (English): https://drive.google.com/file/d/0B4l9z8yY6Ij8b19vbTdRaXBpejQ/view?usp=sharing

Video (Spanish): https://drive.google.com/file/d/0B4l9z8yY6Ij8UoRpMEtQTG9fbEE/view?usp=sharing

SEMARNAT website: **http://sissao.semarnat.gob.mx**

Camacho, F., Ricárdez, M. and Huitrón, M.V. 2011. Watermelon and melon grafting in Colima, Mexico as an alternative to soil disinfection with methyl bromide. Acta Hort. (ISHS) 898:265-269

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4.5.4. **Morocco:** green bean, cucurbit and tomato

The activities promoted by Morocco, UNIDO and *Association des Producteurs et Producteurs Exportateurs des Fruits et Légumes* (APEFEL) gave farmers the opportunity to become more competitive in international markets as well as to yield higher quality products. In particular, grafting and compost had a significant impact on improving crop production. This environmental intervention has not held back the country's industrial development. An introduction to alternatives in Morocco took place hand in hand with training and research. All new technologies are used in combination with Integrated Pest Management to ensure the effective suppression of pest damage with the least possible hazard to people, property and the environment. Today, grafting is used for tomatoes, cucurbits and a large proportion of the melon and watermelon sectors; while compost is mainly used as a soil fertilizer for various agricultural products. In the strawberry sector, however, a chemical alternative (metham sodium) is applied.

MOROCCO	
Sectors	Tomato, green bean, cucurbit (melon and watermelon)
Soil technologies selected	Organic matter (compost), solarization, grafting, soilless production (substrates), Integrated Pest Management (IPM)
Phase-out	866 metric tonnes total (including all sectors comprised by the project)
Donors	MLF, The Government of Italy, The Government of Spain
Budget	USD 5,040,000
Partners	NOU, Ministère du Commerce, de l'Industrie et de l'Arti Morocco; Direction de la Protection des Végétaux, des Contrôles Techniques et de la Répression des Fraudes (DPVCTRF); Association des Producteurs et Producteurs Exportateurs des Fruits et Légumes (APEFEL)

Significance of the sector

Agro-industry plays a crucial role in the Moroccan economy. Fruit and vegetable production not only covers the country's market demand but provides significant exports in particular to European countries. For many years the crops grown on methyl bromide treated soil included tomato, strawberry, banana, melon and watermelon, green bean, cucurbit and cut flowers. The methyl bromide baseline for compliance for Morocco was 1162 metric tonnes.

Challenges

Once methyl bromide was subject to controls and phase-out under the Montreal Protocol, production within the high quality standards favoured by end consumers became a challenge. Firstly, fewer chemicals were available to growers mainly due to the fact that other pesticides and fumigants besides methyl bromide were subjected to regulatory measures, and secondly, importing markets were demanding produce grown with fewer chemicals.

Strategy

In the best interest of growers, the *Direction de la Protection des Végétaux, des Contrôles Techniques et de la Répression des Fraudes (DPVCTRF)*, in conjunction with UNIDO, has directly involved key stakeholders throughout the methyl bromide phase-out process. These include private sector institutions, in particular APEFEL as the main responsible entities for the methyl bromide phase-out activities. APEFEL, with support provided by UNIDO, took this as an opportunity not only to replace the use of methyl bromide with non-chemical alternatives, but, at the same time, to sustain the future of agro-industry by promoting sustainable agriculture focusing on soil health, optimization of resources and waste reduction.

Soil technologies selected

With the aim of developing reliable, non-chemical soil pest management options in Morocco, UNIDO has set up a composting pilot unit including a laboratory in Agadir in cooperation with APEFEL and international partners. This option has further provided an excellent solution to the large amounts of organic waste typically generated by horticulture, turning waste into a natural fertilizer that is rich in antagonists. In particular, the integration of compost with solarization and grafting has been shown to effectively control soil-borne pathogens. In the process, some sectors have adopted alternative chemical fumigants, e.g. 1,3-Dichloropropene + chloropicrin (1,3-D/Pic) and metham sodium (MS). Morocco has also become a leader in non-chemical options, notoriously in grafting, which is now very widely adopted in tomatoes, peppers, cucurbits and other vegetables showing

excellent results, particularly when used as part of an Integrated Pest Management (IPM) scheme. In 2006, 95 % of the total tomato protected area comprised grafted plants and this is presently still the case. Many rootstocks are available on the market and their number is increasing yearly. Soilless production is also in place for some greenhouse crops and circumstances where this option works well.

Technology Transfer and Training

In conjunction with APEFEL, a Centre for Technology Transfer (CTT) was developed in Agadir. The centre, which promotes new non-chemical control options, has hosted many training events. It has also prepared technical and promotional materials including manuals and toolkits to assist growers in their phase-out activities, and research and extension services of high technical level are readily available. Between 2011 and 2013 about 1,000 people visited the CTT.

Additional Information

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UNIDO, UNIDO and the Ozone Day Celebration in Morocco **https://www.youtube.com/watch?v=9O4ByZrSW6s (in French)**

UNIDO, Tomato Farming in Morocco, **https://www.youtube.com/watch?v=fDmJpOGeAhA**

4.5.5. **The Former Yugoslav Republic of Macedonia**: tobacco and horticulture

Floating tray system (FTS), and biofumigation with solarization techniques were chosen as alternative methods in the tobacco and horticulture production sectors respectively, in order to phase out the remaining use of controlled methyl bromide (45.3 metric tonnes) in the Former Yugoslav Republic of Macedonia (FYRM). For example, in the production of tobacco seedlings, excellent results were achieved in controlling fungi, nematodes and weeds by applying the floating tray system. Moreover, the quality of the plants are better compared to the ones obtained using the method of methyl bromide, while maintaining the same amount of yields. This project resulted in an annual elimination of 45.3 metric tonnes of methyl bromide use in the two sectors. By employing the strategy, train the trainers', the project was able to provide about 12,500 tobacco farmers and 1,200 vegetable growers with training related to the selected alternative methods. Furthermore, it enhanced the local production of materials such as floating trays, thereby contributing to the overall development of local economy.

FORMER YUGOSLAV REPUBLIC OF MACEDONIA	
Sectors	Tobacco seedling, horticultural seedlings
Technologies selected	Soilless cultivation (floating tray system), biofumigation + solarization
Phase-out	45.3 metric tonnes
Donors	MLF
Budget	USD 1,075,000
Partners	NOU, Ministry of the Environment, Faculty of Agronomy (National University) and Institute of Agriculture, UNIDO

Significance of the sector

Tobacco is the major crop produced in the FYRM, with a cultivated surface area of about 22,000 ha, and the total yearly production of tobacco leaves is more than 34,700 tonnes, of which over 50% is being exported. Annual sale is around USD 80 million, providing high revenue for farmers (around USD 2,000 per ha). Furthermore, tobacco sector employs about 10% of Macedonia's population.

Challenges

Tobacco production in Macedonia is an important sector that brings high revenues to farmers, but the usage of methyl bromide in this sector amounted to over 40 metric tonnes every year, which is ten times more than that used in vegetable seedlings and other crop production. Therefore, given the large scale of the tobacco production sector and its huge importance to the national economy, as well as the highly toxic nature of methyl bromide, it is a particularly pressing issue to phase out methyl bromide in this sector.

Strategy

The project pursued a close cooperation with a wide representation of stakeholders including both the public and private sector, including the Faculty of Agricultural Sciences who was in charge of the training program, the Institute for Tobacco, the Institute of Agriculture, the extended network of the Agency for Agricultural Development, farmers and companies, and the United Nations Industrial Development Organization.

Technology selected

The floating tray system (FTS) was selected as the best alternative method for tobacco growers. This technique was developed in the late 1990s and thousands of growers around the world, after receiving training on the implementation, adopted this method in replacement of methyl bromide. In general terms, the FTS requires the construction of shallow pools (brick or wooden walls, about 12 cm high) which are lined with thick black polyethylene and filled with a nutrient solution also containing al algaecide (algae growth on the trays can detract from production). Tobacco seeds are sown in trays typically containing 288 cells (sometimes less, depending on particular circumstances) and filled with substrate. The trays are placed inside the pools on the "waterbed" where they float.

Based on the results of the initial demonstration project, tobacco farmers changed their way of producing tobacco seedlings by adopting the new method that uses expanded polystyrene floating tray systems installed in micro-tunnels.

At the time when the project was implemented, the horticulture sector of Macedonia comprised about 300 ha of glasshouses and 7,000 ha of plastic houses dedicated to tomato and cucumber production. Methyl bromide use in this sector was however very small compared to the tobacco sector and other pest control measures were already in place. Where alternatives were needed, biofumigation combined with solarization was introduced, resulting in yield and quality increases as compared to treatment with methyl bromide only.

Technology Transfer

The selected alternative methods were widely accepted and adopted by farmers and key stakeholders who were involved in the phase-out of methyl bromide in these sectors. This can be attributed to the intensive awareness-raising and demonstration activities, technical assistance and training that enabled the proper transfer of alternative methods. The strategy 'train the trainers' provided about 12,500 tobacco growers in different regions of the country with training in the related areas. As a result, the floating tray system was successfully adopted in the FYRM.

Part II – Assurance of compliance with the methyl bromide phase-out

Specific tools for key stakeholders

The following sections provide the different categories of stakeholders with tools to assist them in maintaining the phase-out achieved. They are intended for use as independent “fact sheets”.

5. Compliance tools for National Ozone Officers (NOUs)

5.1. Role of the NOU in the methyl bromide phase-out

National Ozone Officers play a key role in maintaining Government authorities abreast of commitments acquired under the Montreal Protocol. They are usually part of the delegations attending meetings of the Protocol (e.g. Open Ended Working Group and Meeting of the Parties, regional meetings). They need to act on four main areas:

NATIONAL OZONE OFFICERS PLAY A KEY ROLE IN MAINTAINING GOVERNMENT AUTHORITIES ABREAST OF COMMITMENTS ACQUIRED UNDER THE MONTREAL PROTOCOL.

a. Authorize and monitor methyl bromide consumption

b. Monitor compliance with legislation relating to methyl bromide and update regulatory efforts

c. Report on consumption (for both controlled and QPS uses) and other related issues to the Ozone Secretariat and the MLF

d. Participate in negotiations, propose topics for discussions and modifications to the Decisions of the Montreal Protocol and translate it into Decision text.

5.2. Relevant definitions and Decisions from the Montreal Protocol

The following is a compilation of essential pieces of information to be referenced to all NOUs' in their activities.

Issue	Definition	What the Protocol says or requires	Sources of information
Controlled uses	All uses not classified as QPS. Alternatives have been found and are in use for virtually all controlled uses	Phase-out for controlled uses was 1 January 2015. There is a provision for Critical uses	For a more detailed definition of controlled uses see Chapter 2
Critical uses	Specific uses allowed by parties for particular instances or uses where no technically or economically feasible alternatives are available	Should be requested following specific timetable. Deadline for submitting nominations is 24 January of each year	See more info - Chapter 2 See Handbook of Critical Use Nominations. See http://ozone.unep.org/en/node/5737 and http://ozone.unep.org/en/data-reporting/data-reporting-and-tools
QPS uses (Quarantine and Pre-shipment)	Treatments to prevent the introduction, establishment or spread of quarantine pests or to ensure their official control. *Pre-shipment applications* are applied directly before export, to meet the requirements of the importing country or existing requirements of the exporting country.	Exempted indefinitely at present	For clear differences between controlled and exempted uses see Flow chart (Fig.4). For QPS reporting guidelines see http://ozone.unep.org/en/node/5740 and http://ozone.unep.org/en/data-reporting/data-reporting-and-tools
Monitoring and reporting	Ozone officers need to report promptly to the Ozone Secretariat, by 30 September of each year, on the consumption and production (if any) of methyl bromide for controlled and exempted uses. This includes critical uses if any.	Under Article 7 both controlled and exempted consumption and production need to be reported to the Ozone Secretariat. If Critical Uses have been granted, stocks of methyl bromide and a National Management Plan must be submitted	For Article 7 reporting requirements see http://ozone.unep.org/en/data-reporting/data-reporting-and-tools For definitions refer to Chapter 1 For stocks and National Management Plans refer to Decision Ex I/4 and see http://ozone.unep.org/en/node/5740

5.3. Tips for smart operation

The following table is a checklist to help Ozone Officers ensure that they are addressing all factors leading to sustainable compliance with the methyl bromide phase-out. It may need to be adjusted to specific circumstances of sectors or even countries, but should give good guidance to achieve the intended goal.

Area	Topic	Date due	Action list for compliance
REGULATORY ISSUES	Official regulations in place with respect to methyl bromide. Specific authority (or authorities) are normally in charge of authorizing methyl bromide imports	Generally upon finishing a project, to support phase-out. No later than 1 January 2015	Check with Ministry of Agriculture Check within Ministry of Environment Check with Customs Office Check with Foreign relations (multilateral agreement obligations)
	Formulations of methyl bromide that are legally registered, and specific uses permitted	Should go in hand with point above. As of 1 January 2015 only QPS uses or use under the critical use exemption allowed	Check formulations: 100% generally for QPS, 98:2, 67:33 etc. for other uses (including ISPM-15)
	Cap or quota system on methyl bromide imports Importers should be specially licensed for methyl bromide	If in place, should be enforced/ checked at least twice yearly.	Check with Pesticide Registration Check with customs officers Keep importers informed
	Tracking system in place to ensure final use of methyl bromide (ensuring methyl bromide imported into the country is not diverted to illegal uses)	System should operate continuously	Check with Pesticide Registration Check with customs officers Check with NOU from exporting country (particularly if participating in iPIC)
	Requirements for performing a QPS fumigation	Every time a fumigation is performed	Check that fumigation is done under official supervision and in response to official requirement. Must respond to the presence of a quarantine pest (or ISPM-15) Go to UNIDO logbook http://www.unido.org/en/what-we-do/environment/safeguarding-the-environment/emerging-compliance-regimes/phase-out-of-methyl-bromide/unido-toolkit.html

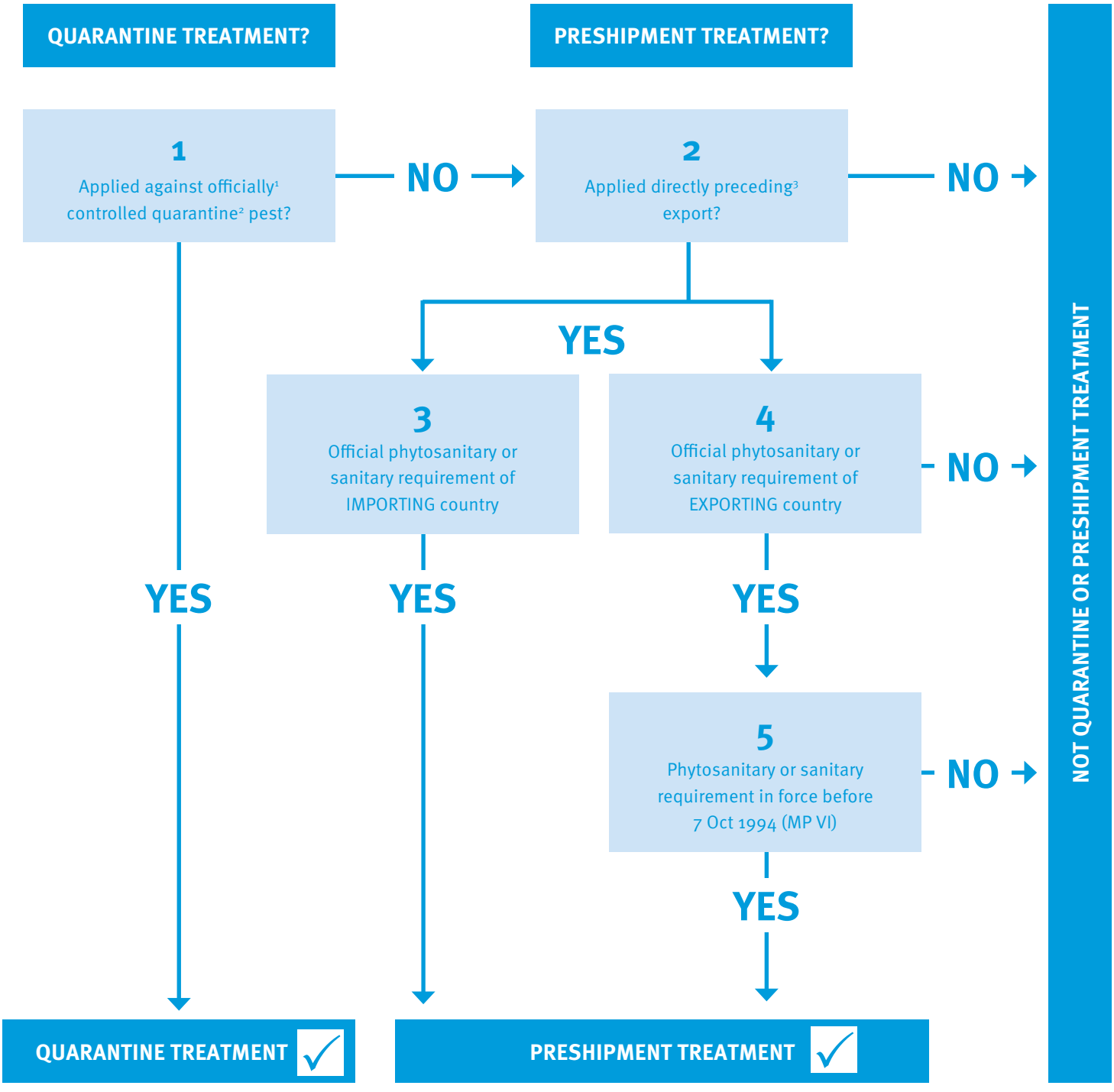
Area	Topic	Date due	Action list for compliance
REPORTING OBLIGATIONS	Article 7 data – controlled production and consumption	Due by Sept 30 each year (to Ozone Secretariat)	Go to Ozone Secretariat website http://ozone.unep.org/en/data-reporting/data-reporting-and-tools
	Article 7 data – exempted production and consumption (QPS)	Due by Sept 30 each year (to Ozone Secretariat)	Go to Ozone Secretariat website http://ozone.unep.org/en/data-reporting/data-reporting-and-tools
	Recording information on QPS applications	Record each application; consolidate information at least twice a year. If willing, report to Ozone Secretariat (Decision XXIV/15)	Go to UNIDO logbook http://www.unido.org/en/what-we-do/environment/safeguarding-the-environment/emerging-compliance-regimes/phase-out-of-methyl-bromide/unido-toolkit.html Go to Ozone Secretariat website http://ozone.unep.org/en/data-reporting/data-reporting-and-tools
	Critical Use Exemptions	If requested, should be submitted to the Ozone Secretariat by January 24th of each year	Go to CUN Handbook http://ozone.unep.org/en/Assessment_Panels/TEAP/Reports/MBTOC/MBTOC_Handbook_ver_6_Dec_07_final.pdf
	National Management Strategy	If requesting CUEs from 2016 onwards should be submitted each year.	Go to Ozone Secretariat website http://ozone.unep.org/en/data-reporting/data-reporting-and-tools
	Accounting framework (stocks available)	If requesting CUEs from 2016 onwards should be submitted each year.	Go to Ozone Secretariat website http://ozone.unep.org/en/data-reporting/data-reporting-and-tools

Area	Topic	Date due	Action list for compliance
STAKEHOLDERS IMPACTED BY METHYL BROMIDE CONTROL MEASURES	Key consuming sectors: Direct methyl bromide users in the past Sectors requesting CUNs (if any) Sectors using methyl bromide for QPS purposes	Update continuously, yearly at minimum	See list of UNIDO projects (Table 7) Check with producers or associations (if CUNs requested) Check with phytosanitary authorities (NPPO), customs officers, trade authorities (for QPS uses)
	Phytosanitary authorities in charge of QPS applications - National Plant Protection Organizations (NPPO)	Frequent information exchange (at least every 3 months)	Go to UNIDO logbook http://www.unido.org/en/what-we-do/environment/safeguarding-the-environment/emerging-compliance-regimes/phase-out-of-methyl-bromide/unido-toolkit.html Go to Ozone Secretariat website www.ozone.unep.org Go to IPPC website www.ippc.int
	Pesticide registration authorities	Frequent information exchange (at least every 3 months).	Check with phytosanitary authorities (NPPO), customs officers, trade authorities Consider issuing a joint license (imports need to be authorized by NOU and pesticide authorities)
	Licensed Methyl bromide importers	Have full information available, update at least twice yearly	
	Technical assistants, trainers, researchers, consultants	Keep a list in case potential users need assistance. Update at least yearly	
	Regional networks of Ozone Officers	Periodic meetings (once or twice a year)	OzoneAction www.unep.org/ozonaction/RegionalNetworks/tabid/6203/Default.aspx
	Implementing agencies	Contact periodically Make use of Montreal Protocol meetings (agencies are always present)	UNIDO www.unido.org and http://www.unido.org/en/what-we-do/environment/safeguarding-the-environment/emerging-compliance-regimes/phase-out-of-methyl-bromide/unido-toolkit.html UNEP OzonAction Programme www.unep.org/ozonaction Ozone Secretariat www.ozone.unep.org
	Information on alternatives	MBTOC reports, implementing agencies, project reports	Contact UNIDO For MBTOC reports go to Ozone Secretariat website http://ozone.unep.org/en/assessment-panels/technology-and-economic-assessment-panel For UNEP publications go to OzonAction website www.unep.org/ozonaction

5.4. Links to further information

Topic	Role or why it is important	Information sources (and links)
Alternatives to methyl bromide	Ozone Officers should be able to provide different stakeholders with thorough information on alternatives. A summary of alternatives is provided in Chapter 8. Further information may be found from sources listed in the column at right.	MBTOC reports http://ozone.unep.org/en/assessment-panels/technology-and-economic-assessment-panel Critical uses and National Management Strategies http://ozone.unep.org/en/node/5737 UNIDO publications https://www.unido.org/montreal-protocol.html Meetings, symposia, workshops
Regional Ozone officers	Maintaining communication with ozone officers in the region (and other regions) is essential for information exchange, problem sharing, analysis and identifying solutions or ways forward	CAP www.unep.fr/ozonaction Ozone Secretariat www.ozone.unep.org Lists of participants from Protocol meetings Network meetings
Methyl bromide consumption and production reports	Global, regional and individual Party consumption information is available at the Ozone Secretariat website for both controlled and exempted uses of methyl bromide.	Ozone Secretariat Data Access Centre http://ozone.unep.org/en/data-reporting/data-centre

FIG. 4 **FLOW CHART – DIFFERENTIATING CONTROLLED FROM EXEMPTED USES OF METHYL**



1 Official control is that performed by, or authorized by, a national plant, animal or environmental protection or health authority

2 Pests of potential importance to an area endangered thereby and not yet present there, or present but not widely distributed and being officially controlled

3 Treatment to be within 21 days of export

Source: UNEP/ IPPC, (2008). Methyl Bromide: Quarantine and Preshipment uses. United Nations Environment Programme, Nairobi, Kenya, 16 pp

6. Compliance tools for customs officers / phytosanitary authorities

6.1. Role of customs and regulatory (phytosanitary) authorities

Customs departments and customs officers are instrumental for the enforcement of pesticide regulations, particularly restrictions placed on imports. For this reason, it is essential that they are well informed on the current legislation and that they are able to correctly identify products coming in and are versed about their destination and proposed use. Phytosanitary and sanitary authorities on their part need to work in close collaboration with customs officers, as their work is highly inter-related. Bans and restrictions on chemicals, quarantine dispositions and authorized treatments and uses are only a few examples of this. The tools below are aimed at assisting customs and phytosanitary officers in ensuring that compliance with the methyl bromide phase-out guidelines is enforced.

6.2. Relevant definitions and Decisions from the Montreal Protocol

Clear understanding of the concepts of "Quarantine" and "Pre-shipment" is critical for customs officers. The main definitions are presented in the box below. Please also refer to the ensuing tables and the flow chart explaining the differences between exempted and controlled uses presented in Fig.4 of this toolkit.

QUARANTINE

The target pest species to be controlled with methyl bromide fumigation must be identified

a. Exports: The pest must be **officially controlled** in the destination country
b. Imports: The pest must be **officially controlled** in the importing country

If the pest is not under official control by Government authorities then this is not a quarantine treatment but *a controlled use.*

Pre-shipment

The treatment with methyl bromide must be applied *21 days or less* prior to export

a. Exports: The methyl bromide treatment must be officially required by Government authorities in the destination country
a. Imports: The methyl bromide treatment must be officially required by importing country authorities

The requirement for treatment must have been in place before 7 December 1995.

Please note that treatments required by companies, banks (letter of credit) or other commercial entities are not considered QPS *and count as controlled methyl bromide consumption*

Important note: All treatments that do not fall within the above definitions are considered "controlled uses".

Issue	Definition or explanatory remarks	What the Protocol says or requires	Sources of information
Controlled uses	All uses not classified as QPS Alternatives have been found and are in use for virtually all controlled uses	Phase-out for controlled uses was 1 January 2015. There is a provision for Critical uses	For a more detailed definition of controlled uses see Chapter 2
Critical uses	Specific uses allowed by parties for particular instances or uses where no technically or economically feasible alternatives are available	Should be requested following specific timetable. Deadline for submitting nominations is 24 January of each year	See more information Chapter 2 See Handbook of Critical Use Nominations. See http://ozone.unep.org/en/node/5737 and http://ozone.unep.org/en/data-reporting/data-reporting-and-tools
QPS uses (Quarantine and Pre-shipment)	Treatments to prevent the introduction, establishment or spread of quarantine pests or to ensure their official control. *Pre-shipment applications* are applied directly before export, to meet the requirements of the importing country or existing requirements of the exporting country	Exempted indefinitely at present	For clear differences between controlled and exempted uses see Flow chart (Fig.4) For QPS reporting guidelines see http://ozone.unep.org/en/node/5740
Monitoring and reporting production and consumption	Under Article 7 of the Protocol Ozone officers need to report promptly to the Ozone Secretariat, by 30 September of each year, on the consumption and production (if any) of methyl bromide for controlled and exempted uses. This includes critical uses if any	Collaboration between customs officers and the NOU is essential to achieve prompt and correct information reporting	For reporting requirements see http://ozone.unep.org/en/data-reporting/data-reporting-and-tools For definitions refer to Chapter 1

6.3. Tips for smart operation

Area	Topic	Date due	Compliance action points
GENERAL REGULATORY ISSUES	Official regulations in place with respect to methyl bromide. Specific authority (or authorities) are normally in charge of authorizing methyl bromide imports	Generally upon finishing a project, to support phase-out. No later than 1 January 2015	Check with National Ozone Unit Check within Ministry of Agriculture (e.g. quarantine service, pesticide registration) Check within Customs Office Check with Foreign relations authority (multilateral agreement obligations)
	Formulations of methyl bromide that are legally registered, and specific uses permitted	Should go in hand with point above. As of 1 January 2015 only QPS uses or use under the critical use exemption allowed	Check formulations: 100% generally for QPS, 98:2, 67:33 etc. for other uses (including ISPM-15) Check agreement and sufficient information exchange between customs, pesticide registration and quarantine
	Cap or quota system on methyl bromide imports Importers should be specially licensed for methyl bromide	If in place, should be enforced/ checked at least twice yearly.	Check with Pesticide Registration Check with customs officers Keep NOU informed Keep importers informed
	Tracking system in place to ensure final use of methyl bromide (ensuring methyl bromide imported into the country is not diverted to illegal uses)	System should operate continuously	Check agreement and sufficient information exchange between customs, pesticide registration and quarantine Contact NOU

Area	Topic	Date due	Compliance action points
QPS APPLICATIONS	Requirements for performing a QPS fumigation	Every time a fumigation is performed	Phytosanitary (quarantine) authorities should supervise fumigations Fumigations need to be performed in response to official requirement (from importing country or officially by country of origin). Fumigations must respond to the presence of a quarantine pest, ISPM-15 or an official pre-shipment requirement (in which case must take place 21 days or less before export) Go to UNIDO logbook http://www.unido.org/en/what-we-do/environment/safeguarding-the-environment/emerging-compliance-regimes/phase-out-of-methyl-bromide/unido-toolkit.html
	Reason for conducting a QPS application (should fit definitions from the Montreal Protocol)	Continuously update. Maintain frequent contact with NOU	Check your country's official list of quarantine pests Check ISPM-15 (consider treating with heat instead of MB) Check agreement and sufficient information exchange between customs and quarantine Maintain NOU informed Check with trade authorities (possible bi-lateral agreements to use alternatives)
	Recording information on QPS applications	Record (supervise) each fumigation Check and process information every six months	Go to UNIDO logbook http://www.unido.org/en/what-we-do/environment/safeguarding-the-environment/emerging-compliance-regimes/phase-out-of-methyl-bromide/unido-toolkit.html Go to Ozone Secretariat website http://ozone.unep.org/sites/ozone/files/dec24-15%284%29-example_data_reporting_forms.pdf

Area	Topic	Date due	Compliance action points
STAKEHOLDERS INVOLVED WITH METHYL BROMIDE CONTROL MEASURES	Key consuming sectors: Sectors requesting CUNs (if any) Sectors using methyl bromide for QPS	Update continuously, through NOU	Check with NOU Check with licensed importers/ fumigators
	National Ozone Unit	At least every 3 months	Check full list of focal points at www.unep.org/ozonaction
	Ministry of the Environment Ministry of Agriculture		Check agreement and sufficient information exchange between customs, pesticide registration and quarantine authorities Keep frequent contact with NOU Consider joint approval of methyl bromide import licenses
	Methyl bromide importers	Establish period of renewal for licenses	Issue special license to importers Check quantities imported, check compliance with quota system (if in place)
	Fumigators		Issue special permit/ registration to fumigators Request information as suggested in UNIDO logbook http://www.unido.org/en/what-we-do/environment/safeguarding-the-environment/emerging-compliance-regimes/phase-out-of-methyl-bromide/unido-toolkit.html
SOURCES OF INFORMATION AND SUPPORT OF PHASE-OUT MEASURES	Training for customs officers, pesticide registration authorities.	At least once a year	Make sure training activities (e.g. as promoted by UNEP) include methyl bromide issues. HS codes are listed under the Harmonized Commodity Description and Coding System managed by the World Customs Organization www.wcoomd.org In particular, customs codes and chemical names under which methyl bromide – or mixtures containing methyl bromide – may be traded.
	Alternatives for QPS		For TEAP/ MBTOC reports go to http://ozone.unep.org/en/assessment-panels/technology-and-economic-assessment-panel Contact UNIDO www.unido.org Quarantine treatments or schemes approved by IPPC www.ippc.int
	Regional networks, organizations	Continuous	OzoneAction, CAP www.unep.org/ozonaction Ozone Secretariat www.ozone.unep.org

6.4. Links to further information

Topic	Role	Further information
iPIC	Do you participate in iPIC (informal prior informed consent)?	iPIC is a voluntary mechanism of information exchange on intended trade between designated authorities in importing and exporting countries which are responsible for issuing trade licenses for ODS http://www.unep.org/ozonaction/ecanetwork/Default.aspx?tabid=29768
Relevant international organizations and agreements	Global or regional organizations provide useful linkages and information, in relation to methyl bromide phase-out and its alternatives but also to international trade, quarantine pests and phytosanitary issues including treatments. The sanitary and phytosanitary measures agreement under the World Trade Organization contains important information	› IPPC (International Plant Protection Organization) www.ippc.int and linkages to other organizations https://www.ippc.int/en/liason/organizations/ › IAPC (Inter-African Phytosanitary Council) http://www.au-iapsc.org **Asian** The Association for South East Asian Nations (ASEAN) has specific phytosanitary agreements www.asean.org The OIRSA (Sanitary and Phytosanitary Regional International Organization) of Central America www.oirsa.org FAO www.fao.org WTO (World Trade Organization) www.wto.org The SPS Agreement https://www.wto.org/english/tratop_e/sps_e/spsagr_e.htm

7. Compliance tools for importers

7.1. Role of importers

As suppliers of methyl bromide (in the past for controlled uses, or currently for Critical Uses of QPS treatments), importers play a critical role in supporting the methyl bromide phase-out and as such should be well aware of the Montreal Protocol guidelines. For example, they may require a special permit or quota authorization in order to be able to source the methyl bromide. If they also provide fumigation services, they most likely need to request supervision from official authorities or be licensed by these to perform such fumigations.

In addition, methyl bromide importers are often also suppliers of alternatives and/or materials associated with the implementation of alternatives. This could include materials as diverse as alternative fumigants, machinery, floating trays or resistant rootstocks, as well as maintenance services for required equipment. As such, importers play a key role in supporting the sustainability of the phase-out by making methyl bromide technically and economically feasible replacements to this fumigant available.

7.2. Relevant definitions and Decisions from the Montreal Protocol

Issue	Definition	What the Protocol says or requires	Sources of information
Controlled uses	All uses not classified as QPS Alternatives have been found and are in use for virtually all controlled uses	Phase-out for controlled uses was 1 January 2015. There is a provision for Critical uses	For a more detailed definition of controlled uses see Chapter 2
Critical uses	Specific uses allowed by parties for particular instances or uses where no technically or economically feasible alternatives are available	Should be requested following specific timetable	See more info Chapter 2 See Handbook of Critical Use Nominations. See http://ozone.unep.org/en/node/5737
QPS uses (Quarantine and Pre-shipment)	Treatments to prevent the introduction, establishment or spread of quarantine pests or ensure their official control. *Pre-shipment applications* are applied directly before export, to meet the requirements of the importing or exporting country	Exempted indefinitely at present	For clear differences between controlled and exempted uses see Flow chart (Fig.4)

7.3. Tips for smart operation

Area	Topic	Date due	Compliance action points
GENERAL REGULATORY ISSUES	Official regulations in place with respect to methyl bromide. Specific authority (or authorities) are normally in charge of authorizing methyl bromide imports	Generally upon finishing a project, to support phase-out. No later than 1 January 2015	Check with National Ozone Unit Check within Ministry of Agriculture (e.g. quarantine service, pesticide registration) Check within Customs Office Check with Foreign relations authority (multilateral agreement obligations)
	Specific authority (or authorities) in charge of authorizing methyl bromide imports		Check with NOU Check with pesticide registration unit Check with customs office License or permit may be issued jointly
	Formulations of methyl bromide that are legally registered, and specific uses permitted	Should go in hand with point above. As of 1 January 2015 only QPS uses or use under the critical use exemption allowed	Check formulations: 100% generally for QPS, 98:2, 67:33 etc. for other uses (including ISPM-15) Check agreement and sufficient information exchange between customs, pesticide registration and quarantine
	Specific uses registered (crop, commodity) and destination	As of 1 January 2015 only QPS uses or use under the critical use exemption allowed	Check with Ministry of Agriculture (phytosanitary and pesticide registration authorities) Check with NOU
	Cap or quota system on methyl bromide imports (jointly agreed between importers and authorities, in observance with Montreal Protocol guidelines)	Agreed/ revised yearly	Check with NOU Check with pesticide registration unit Check with customs office
	Penalties (fines) in place to deter potential smugglers from attempting illegal imports or distribution		Check with NOU Check with pesticide registration unit Check with customs office
STAKEHOLDERS IMPACTED BY THE METHYL BROMIDE PHASE-OUT	Key consuming sectors: Sectors requesting CUNs (if any) Sectors using methyl bromide for QPS		Check with NOU Check with licensed fumigators (QPS uses)
	National Ozone Unit		See full list of focal points at www.unep.org/ozonaction
	Officials involved with CUEs and QPS applications	Often authorize imports jointly.	Check with NOU Check with Ministry of Agriculture (pesticide registration, phytosanitary authorities) Check with licensed fumigators

Area	Topic	Date due	Compliance action points
ALTERNATIVES	Alternatives to methyl bromide (for controlled uses) best suited for each sector including their technical/ economic feasibility. Additional supplies (materials, equipment) plus maintenance services. Alternatives need to be registered/ available		For TEAP/ MBTOC reports go to http://ozone.unep.org/en/assessment-panels/technology-and-economic-assessment-panel Contact UNIDO www.unido.org
	Alternatives for QPS uses	TEAP/ MBTOC reports www.ozone.unep.org Ozone Secretariat http://ozone.unep.org/en/node/5740 See section on sources of information	For TEAP/ MBTOC reports go to http://ozone.unep.org/en/assessment-panels/technology-and-economic-assessment-panel Contact UNIDO www.unido.org Quarantine treatments or schemes approved by IPPC www.ippc.int

7.4. Links to further information

Topic	Role	Further information
methyl bromide uses and their alternatives	It is essential to become familiar with previous methyl bromide uses and alternatives, which are suitable for specific circumstances of a sector and region.	See Chapters 1,2 MBTOC Assessment Reports MBTOC reports http://ozone.unep.org/en/assessment-panels/technology-and-economic-assessment-panel Ozone Secretariat www.ozone,unep.org

8. Tools for technical assistants, trainers, researchers

8.1.Role of technical assistants and extension staff

Technical staff and individuals involved in academic activities (research, teaching, training, demonstration trials) play a crucial role in supporting information dissemination efforts and accompanying the process of successful adoption of alternatives. Research findings and results of trials often provide the basis on which the efficiency of alternatives is assessed and, most importantly, provide ways to optimize their implementation.

8.2. Relevant definitions and Decisions from the Montreal Protocol

Issue	What the Protocol says or requires	Sources of information
Controlled uses	Phase-out for controlled uses was 1 January 2015. There is a provision for Critical uses	For a definition of controlled uses see Chapter 2
Critical uses	Should be requested following specific timetable. Deadline for submitting nominations is 24 January of each year	See more info in Chapter 2 See Handbook of Critical Use Nominations. See http://ozone.unep.org/en/node/5737
QPS uses	Exempted indefinitely at present, however alternatives are available for some categories of use	For clear differences between controlled and exempted uses see flow chart (Fig.4)

8.3. Tips for smart operation

Area	Topic	Date due	Compliance action points
GENERAL REGULATORY ISSUES	Official regulations in place with respect to methyl bromide. Specific authority (or authorities) are normally in charge of authorizing methyl bromide imports	Generally upon finishing a project, to support phase-out. No later than 1 January 2015	Check with National Ozone Unit Check within Ministry of Agriculture (e.g. quarantine service, pesticide registration) Check within Customs Office Check with Foreign relations authority (multilateral agreement obligations)
	Formulations of methyl bromide that are legally registered, and specific uses permitted	Should go in hand with point above. As of 1 January 2015 only QPS uses or use under the critical use exemption allowed	Check formulations: 100% generally for QPS, 98:2, 67:33 etc. for other uses (including ISPM-15) Check agreement and sufficient information exchange between customs, pesticide registration and quarantine
	Specific uses registered (crop, commodity) and destination	As of 1 January 2015 only QPS uses or use under the critical use exemption allowed	Check with NOU Go to Ozone Secretariat website www.ozone.unep.org
STAKEHOLDERS IMPACTED BY THE METHYL BROMIDE PHASE-OUT	Key consuming sectors: Direct methyl bromide users in the past Sectors requesting CUNs (if any) Sectors using methyl bromide for QPS purposes	Update continuously, yearly at minimum	See list of UNIDO projects (Table 7) Check with producers or associations (if CUNs requested) Check with phytosanitary authorities (NPPO), customs officers, trade authorities (for QPS uses)
	National Ozone Unit		See full list of focal points at www.unep.org/ozonaction
	Importers (of alternatives and methyl bromide).	Frequently update suppliers of products and services (including maintenance)	List of licensed importers (for both methyl bromide if used and for alternatives)
	Authorities involved with the methyl bromide phase-out, CUEs and exempted uses (QPS)	Be aware of specific regulations, quotas , permits	Check with NOU Ministry of the Environment, Ministry of Agriculture (pesticide registration, customs, environment, agriculture)
SOURCES OF INFORMATION AND OTHER ISSUES	Alternatives. Specific options for each sector and appropriate for local specific circumstances, often with necessary adaptations	Check efficiency (crop yield and quality) together with technical and economic feasibility after every crop cycle	Check with NOU For TEAP/ MBTOC reports go to http://ozone.unep.org/en/assessment-panels/technology-and-economic-assessment-panel Contact UNIDO www.unido.org For UNEP publications go to the OzoneAction website www.unep.org/ozonaction
	Projects conducted and alternatives implemented		Check with NOU For TEAP/ MBTOC reports go to http://ozone.unep.org/en/assessment-panels/technology-and-economic-assessment-panel Contact UNIDO www.unido.org

8.4. Links to further information

Topic	Role	Further information
Suppliers	Access to suppliers of alternatives and associated materials (machinery, equipment and other inputs including for example trays, grafted plants or rootstocks) and implementation services is essential.	Importers and other suppliers Research/ training centres
Literature/ publications/ meetings	Being familiar with research results and recent publications is important. Participating in training sessions, scientific/ technical meetings is also very useful	See Chapter 11 for sources of information. Annual meetings, literature reviews, contact with research teams and research centres. International Society for Plant Pathology (ISPP) http://www.isppweb.org/

9. Tools for direct users (growers, fumigators)

9.1. Role of direct users

Direct users were ultimately the stakeholders most affected by the methyl bromide phase-out and those in urgent need of a replacement. The gradual process by which in most cases such replacement occurred allowed for trials to be conducted and confidence to be gained with respect to new products and technologies.

Replacement of methyl bromide often required growers and fumigators to introduce changes in their production systems, sometimes varying the investment components, focusing on extensive training and addressing problems differently.

9.2. Relevant definitions and Decisions from the Montreal Protocol

Issue	What the Protocol says or requires	Sources of information
Controlled uses	Phase-out for controlled uses was 1 January 2015. There is a provision for Critical uses	For a definition of controlled uses see Chapter 2
Critical uses	Should be requested following specific timetable. Deadline for submitting nominations is 24 January of each year	See more info in Chapter 2 See Handbook of Critical Use Nominations. See http://ozone.unep.org/en/node/5737
QPS uses	Exempted indefinitely at present. The definition of pre-shipment is particularly important for persons involved in grain storage	For clear differences between controlled and exempted uses see flow chart (Fig.4). For QPS reporting guidelines see http://ozone.unep.org/en/node/5740

9.3. Tips for smart operation

Since the beginning, UNIDO emphasized the concept of integrating different options and developing a comprehensive approach towards pest and disease control, rather than seeking a one-to-one replacement for methyl bromide. The long-term sustainability of alternative fumigants – even when they do not cause damage to the ozone layer – was always questioned, so working towards sustainable production systems was always a clear goal.

In replacing methyl bromide it is essential to be well aware of the target pests and diseases for which control is sought, and have complete information on their life cycles, host ranges and the environmental conditions conducive to their development.

Assessing the technical and economical feasibility of potential alternatives is also very important. In many cases, implementing alternatives requires changes in production or storage systems, cropping practices and others in order for alternatives to work efficiently, as well as maintaining access to specific market windows and complying with quality and other commercial requirements.

In the following section, Tables 1 and 2 summarize the most successful alternatives adopted in the various sectors and countries where UNIDO has worked. They are meant to provide general information and overall guidelines on their implementation.

Alternatives have been divided into “in-kind”, or direct replacements and “not in-kind” or options that work best as part of an integrated approach. In all cases, observance of the IPM concept is strongly recommended.

9.4. Links to further information

A wealth of information on methyl bromide alternatives is available for virtually all climates, growing systems and circumstances under which methyl bromide was previously used. Information sources are listed below and in previous chapters. Please also see Chapter 10.

Topic	Role	Further information
Alternatives	It is essential to be aware of alternatives that are in use/ available in your region and under your circumstances. Learning about research efforts and results is also important. Countries that have requested CUE have submitted National Management Strategies. Plant Protection societies (e.g. ISPP) provide good information on pests and diseases of many crops and their control. Various meetings on methyl bromide alternatives have taken place or still take place, for example the Methyl Bromide Alternatives Outreach (MBAO) conference Composting Associations provide useful information on elaborating compost and solving problems that may arise	MBTOC/ TEAP Assessment Reports http://ozone.unep.org/en/assessment-panels/technology-and-economic-assessment-panel National Management Strategies http://ozone.unep.org/en/node/5737 UNIDO publications https://www.unido.org/montreal-protocol.html International Society for Plant Pathology (ISPP) http://www.isppweb.org/ Methyl Bromide Alternatives Outreach (MBAO) conference www.mbao.org The United States Composting Council http://compostingcouncil.org The European Compost Network http://www.compostnetwork.info
Relevant activities undertaken	What projects were implemented in your country? Local, regional, international workshops/meetings?	For a full list of projects by country and region see Table 7. Final project reports are available from UNIDO https://www.unido.org/montreal-protocol.html
Regulations	Regulations to ban methyl bromide for controlled uses (with a provision for Critical Uses if necessary) and restrict uses to QPS only need to be issued by all countries. Knowledge about regulations in place and which alternatives are registered is essential	Ministry of Agriculture, Pesticide registration, phytosanitary issues (including quarantine) Customs authorities Ministry of the Environment
Suppliers, technical assistance	Access to suppliers of alternatives, materials needed to implement alternatives (machinery, equipment and other inputs including for example trays, grafted plants or rootstocks) is essential. Similarly, access to technical assistance and keeping abreast of research results is very important.	Importers and other suppliers Research/training centres Technical assistance and extension staff
Other users	Information exchange with other growers/storage companies/fumigators is extremely useful.	Trade associations Cooperatives Growers Storage companies

I. ALTERNATIVES FOR PRE-PLANT SOIL FUMIGATION

Not in-kind alternatives	Description	Sector where best applicable	Recommendations
Substrates	Refers to plant production in artificial or soil-less substrates (away from soil). Sometimes called "hydroponic production" Substrates include various materials such as rock wool, tuff, clay granules, polyurethane, glass wool, peat, coconut husk (cocopeat), volcanic gravel, pine bark, grape industry waste, and others	Tomatoes, peppers, strawberries, cucurbits flowers, vegetable seedlings, nurseries	Mostly used in covered or protected agriculture, but can be adapted to field cropping (i.e. in Egypt). Initial investment is often high, but higher planting densities are possible. Yield and quality are improved. Locally available substrates generally more economical. Plant/ water relations and pest management need close monitoring. There is potential ground water pollution from systems that do not recycle the nutrient solutions.
Floating trays	Seedlings are planted in polystyrene trays, which contain cells filled with substrate and are placed inside a shallow pool filled with a nutrient solution. Seedlings grow faster, and are uniform and high quality. The system is very space-efficient.	Tobacco and vegetable seedlings	Developed in late 1990´s, were adopted by thousands of tobacco growers around the world previously using methyl bromide. Adopted through methyl bromide projects in Brazil, Croatia, Macedonia, Romania, Argentina, Zimbabwe and others. Economic feasibility may be challenging if necessary inputs (substrates, trays, pelleted seeds) are not locally available.
Steam	Process whereby hot water vapour is injected into the soil to kill pests, diseases and weeds, using a boiler and pipes or other means of injection. When properly applied, is an excellent alternative to methyl bromide in protected agriculture. Many variables influence its success and cost, i.e. the type of boiler and fuel used, soil type and structure, soil preparation, depth of treatment	Cut flowers Seedling (nursery) production	Is more effective and less expensive when a limited amount of substrate is treated. Requires relatively large amounts of water. Treated substrate can easily become re-contaminated if hygienic measures not observed. Over-heating of soil can lead to mineral toxicity (particularly manganese), and excessive kill of beneficial organisms. Works best if combined with biocontrols and organic amendments within an IPM programme.
Grafting	A graft is the union of two portions of plant tissue that grow together as a single plant. It is possible to graft plants with desirable commercial characteristics, which are susceptible to soil borne diseases, onto roots that are resistant to those pathogens. The rootstock may be from a different cultivar, species or genus within the plant family of the scion. Grafting provides excellent protection against soil borne pathogens of vegetables and fruit crops, especially root-knot nematodes (e.g. *Meloidogyne* spp) and fungi (e.g. *Fusarium* spp., *Verticillium dahliae* spp.,) or oomycetes (*Phytophthora* spp).	Tomatoes Peppers Eggplants Cucurbits Fruit trees	Generally costly due to requiring intensive labour and various supplies, but these are usually compensated by higher yields and improved quality. Grafted plants are often more vigorous and fewer plants are required per unit area. When used within an IPM approach including alternative chemicals (fumigants, pesticides, herbicides) and/or solarization provides an excellent alternative to methyl bromide. Rootstock resistance may break down under high pathogen population pressure, when new races of the pathogen evolve, and under some environmental conditions such as high temperature or salinity. Increasing number of rootstocks now commercially available for most crops. Wild local species are also successfully used.

Not in-kind alternatives	Description	Sector where best applicable	Recommendations
Solarization/ Biofumigation	Solarization is achieved by trapping heat from solar radiation under clear plastic to elevate the temperature of moist soil and kill pests and diseases. Originally used in arid and semi-arid regions with high radiation and minimal rainfall, but now adapted to many regions. Biofumigation is the emission of volatile compounds during the decomposition of organic matter incorporated into the soil, which contributes to pathogen control.	All	The combination of these two techniques leads to very good soil borne pest and disease control comparable to methyl bromide. Further combination with other options such as metham sodium or dazomet, biofumigation, and bio controls provides excellent results. The process normally takes about four weeks, which may require appropriate planning of cropping schedules
Compost, organic amendments	Organic amendments such as composts, animal and green manures and various by-products from agriculture, forest and food industries incorporated into the soil help manage pathogenic fungi and nematodes. Populations of beneficial soil microorganisms are enhanced and soil health and properties improved, leading to long-term decline of soil pathogen populations. Compost preparation needs to be done in observance of environmental conditions (temperature, pH, oxygen aeration, humidity).	All	Long-term approach that can help reduce need for soil fumigation and is a relevant component of IPM. Possible inconsistency of results due to variable processing techniques. Large amounts of materials are needed for treatment to be effective. Can be enriched with beneficial organisms such as *Trichoderma,* yeasts and beneficial bacteria for more successful results. Excellent results for example in Morocco. Depending on the plant types used, process can take between four and five months.
Biocontrol agents	Various kinds of beneficial organisms but in particular fungi of the genus *Trichoderma* are successfully used as part of IPM systems to reduce populations of soil borne pathogens.	All	Very successful for example in the melon sector in Honduras and Guatemala. Preparations of beneficial organisms are now available in Egypt and used with excellent results. Massive applications need to be made, and viability of the beneficial organisms constantly monitored

In kind alternatives	Description	Sector where best applicable	Comments
1,3-D, 1,3-D/Pic	1,3- dichloropropene (1,3-D) is a soil fumigant principally effective against soil insects and nematodes, particularly cyst nematodes like *Meloidogyne* sp. Often combined with chloropicrin (Pic) to broaden its range of action to fungi and some weeds. Usually injected 15 to 20 cm into the soil before planting, and then compacted and covered tightly with canvas, polyethylene or VIF	Strawberries Tomatoes, peppers, cut flowers, cucurbits	Commercial names include Telone, Telopic and Agrocelhone. Waiting periods before re-planting vary according to the crop and results are influenced by soil type and moisture. Heavy, wet, cold soils difficult to treat. 1,3-D is a potential contaminant of underground water and this causes restrictions to its use in some regions
Pic alone	Chloropicrin alone is used as a fumigant mainly against fungi, with good results for example in strawberries.	Strawberries (runners and fruit)	Commercial names include Piclor Not as widely registered around the world.
Metham sodium	Liquid, wide-spectrum soil fumigant belonging to the group of chemicals known as "MITC generators". Effective for controlling soil fungi (*Verticillium, Fusarium, Pythium, Rhizoctonia, Phythophthora, Sclerotinia*), nematodes and weeds. Not a good bactericide.	All	Miscible in water, suitable for application with irrigation systems. Efficacy strongly influenced by its diffusion in soil, constrained in heavy and/or cold soils. Application through overhead sprinklers ineffective and banned in many countries. Rotating-spading fumigation equipment very effective as it ensures homogeneous distribution in soil. Biodegradation of MITC compounds can occur after repeated applications in sandy soils. Avoiding excessive application rates, rotating with other treatments or adding beneficial microorganisms such as *Trichoderma* following fumigation are thus recommended
Dazomet	Also an MITC generator, Dazomet is a granular soil fumigant effective against germinating weeds, nematodes (but not *Meloidogyne* cyst nematodes), soil fungi and insects (stages that occur underground).	All	Generally sold under commercial name Basamid. Application in cold soils may bring phytotoxicity problems, so long waiting period before replanting may be required. Biodegradation of MITC compounds can occur after repeated applications in sandy soils. Avoiding excessive application rates, rotating with other treatments or adding beneficial microorganisms such as *Trichoderma* following fumigation are thus recommended.
DMDS	Dimethyl- disulphide is a more recently developed product proving very efficient against nematodes attacking many crops. It is a good herbicide, controls yellow nutsedge, *Cyperus* spp	Many crops including vegetables and tobacco	Commercial name Paladdin. Application may be constrained by its strong, pungent odor in some areas. Can be combined with other fumigants (Pic, metham sodium for enhanced control

2. ALTERNATIVES FOR POST-HARVEST AND STRUCTURES

Not in-kind alternatives	Description	Sector	Comments
Controlled or modified atmospheres	Modified atmospheres (high CO_2, low O_2) are created through hermetic sealing or vacuum. Low oxygen environments stop development of stored product pests.	Grain and beans (cocoa, coffee), tobacco, dried fruit, nuts	Generally inexpensive and easy-to-use technology. Its use is increasing around the world.
Heat treatment	A minimum temperature of about 55°C is needed, but often should not exceed 60°C to prevent treated items from damage. Humidity control may be necessary. Simple and inexpensive solarization methods have been developed to treat artifacts. Heat works best as part of an IPM system	Flour-mills and other structures, museum artifacts, grain	There are two general types of heat treatments: structural (full-site) and spot treatments (performed when a pest outbreak is detected). Although most pests die in less than 1 hour at 56°C, treated structures must be maintained at this temperature for 24-36 hours to ensure uniform heat distribution in the structure. Walls and floors in concrete constructions may even be impossible to heat to the required level. Insulated floor mats, diatomaceous earth and/or insecticide sprays may be needed to complement treatment on such surfaces.

In kind alternatives	Description	Sector	Comments
Phosphine, **Phosphine + CO2**	Phosphine (PH_3) is registered and used worldwide. It is highly toxic, therefore used in low concentrations. Penetrates well into commodities and can be rapidly removed by aeration after treatment. Can be combined with CO_2 to avoid flammability and corrosion risks associated to pure phosphine. The mixture is also faster acting and less likely to induce pest resistance.	Stored grain and dried foodstuffs, spices, tobacco Structures, wooden items	Generally acts slower than methyl bromide so longer exposure times are required, particularly under low temperatures. Overall ineffective below 15°C. Reacts with metals such as copper causing corrosion so use is restricted when electrical equipment or copper fixtures are present. Many pests can develop resistance to phosphine, particularly in tropical areas, so measures must be taken to avoid this. Chambers or recipients where treatment takes place should have optimum gas-tightness; correct exposure times and appropriate application technology must be observed.
Sulfuryl fluoride (SF)	Sulfuryl fluoride (SO_2F_2) is a non-flammable, odourless and colourless gas that disperses quickly. Developed in the late 1950's in the USA as a structural fumigant, mainly for termite control. Has been used for controlling wood and structure pests and since 2003 to control pests affecting the food industry in some developed countries.	Buildings, furnishings, construction materials, and transport vehicles to control a wide range of pests	Registration of this product is not yet widespread in developing countries Usually non-corrosive, so can be used where sensitive equipment and electronic devices are present.

10. Additional information

A large amount of information on alternatives to methyl bromide and their implementation has been made available throughout the more than 25 years after this fumigant was labeled an ODS.

As presented in this toolkit, UNIDO has undertaken extensive work on methyl bromide. Important examples of such work can be found on the UNIDO website
https://www.unido.org/montreal-protocol.html

The Protocol's Methyl Bromide Technical Options Committee (MBTOC) conducts very thorough work on methyl bromide use and its alternatives, for both controlled and exempted uses. Quadrennial Assessment Reports, yearly Progress Reports and other relevant publications can be accessed and downloaded from the Ozone Secretariat website:
http://ozone.unep.org/en/assessment-panels/technology-and-economic-assessment-panels

UNEP's OzonAction Programme also offers various reports and other kinds of information on methyl bromide, which can be accessed at
http://www.unep.org/ozonaction/Topics/MethylBromide/tabid/6221/Default.aspx

Assistance to A5 Parties of the Montreal Protocol is provided through Methyl Bromide Officers in UNEP's Compliance Assistance Programme (CAP). Regional offices and contacts may be found at
http://www.unep.org/ozonaction/AboutTheBranch/StaffContacts/tabid/6190/Default.aspx

The Multilateral Fund for the Montreal Protocol offers reports on monitoring and evaluation activities conducted on ODS including methyl bromide. These can be consulted at
http://www.multilateralfund.org/Evaluation/evaluationlibrary/default.aspx

UNIDO Logbook for QPS reporting, available at
http://www.unido.org/en/what-we-do/environment/safeguarding-the-environment/emerging-compliance-regimes/phase-out-of-methyl-bromide/unido-toolkit.html

LIST OF ACRONYMS

1,3-D/Pic	1,3- Dicloropropene + Chloropicrin
ASEAN	Association of Southeast Asian Nations
CEIT	Countries with Economies in Transition
CUE	Critical Use Exemption
CUN	Critical Use Nomination
DMDS	Dimethyl-disulfide
EU	European Union
FTS	Floating Tray System
GAP	Good Agricultural Practices
ha	Hectares
IAPC	Inter African Phytosanitary Council
ICM	Integrated Crop Management
IPM	Integrated Pest Management
IPPC	International Plant Protection Convention
ISSP	International Society of Plant Pathology
MBTOC	Methyl Bromide Technical Options Committee
MLF	Multilateral Fund for the Implementation of the Montreal Protocol
MS	Metham Sodium
NOU	National Ozone Unit
NPPO	National Plant Protection Organization
ODP	Ozone Depleting Potential
ODS	Ozone Delpleting Substance
PH_3	Phosphine
QPS	Quarantine and Pre-shipment
SF	Sulfuryl Flouride
SPS	Sanitary and Phytosanitary Standards
TEAP	Technical and Economic Assessment Panel
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
UNIDO	United Nations Industrial Development Organization
UV	Ultraviolet
VAT	Value Added Tax
WHO	World Health Organization
WTO	World Trade Organization

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