Irradiation as an Alternative to Methyl Bromide Fumigation of Food and Agricultural Commodities

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FAO/IAEA Consultants' Meeting on the Role of Irradiation as an Alternative to Methyl Bromide Fumigation of Food and Agricultural Commodities

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I. Introduction

The Meeting was convened by FAO and IAEA through their Joint FAO/IAEA Division of Nuclear Techniques for Food and Agriculture, at IAEA, Vienna, to evaluate the role of irradiation as an alternative phytosanitary treatment to methyl bromide fumigation of food and agricultural commodities. The participants of the Meeting are listed in Annex 1.

Dr. James D. Dargie, Director of the Joint FAO/IAEA Division welcomed the participants on behalf of FAO and IAEA. He stressed the role of the Division in taking a proactive stand on the issue of global phase-out of methyl bromide as developing Member States need guidance with regard to suitable alternative phytosanitary treatments. Trade in food and agricultural commodities has become increasingly global following the establishment of the World Trade Organization. The proposed global phase-out/ban of methyl bromide could have serious repercussions on international trade in these commodities, especially for developing countries where more sophisticated technologies may be difficult to implement. He emphasized that the world should not be caught by surprise as it did when ethylene dibromide was banned in mid-1980's. During the past decade, the Joint FAO/IAEA Division has been instrumental in developing research data on irradiation as a quarantine treatment for pests of fresh fruits and vegetables and some stored products/durable commodities. These data are beginning to play a role in facilitating the use of irradiation for quarantine pests, especially on its use as in the USA.

Dr. Dargie also informed the participants of the recent establishment of the FAO/IAEA Training and Reference Centre for Food and Pesticide Control at the IAEA Laboratories in Seibersdorf. The Centre will perform the role of strengthening the analytical capacity of

Member States, especially those from developing countries, for various food contaminants in trade.

Dr. Patrick Vail, Laboratory Director, USDA/ARS Horticultural Crops Research Laboratory, Fresno, California and Dr. R.W.D. Taylor of Natural Resources Institute, Chatham, UK, were invited to serve as Chairman and Rapporteur of the Meeting, respectively. The Meeting Agenda is attached as Annex 2.

II. Background

Methyl bromide (MB), the most widely used fumigant to control insects in food and agricultural commodities is being phased out globally under the Montreal Protocol, an international treaty for the regulation of ozone depleting substances worldwide and under the auspices of the United Nation Environmental Programme. Currently, MB's use as a pre-shipment and quarantine treatment is proposed to be exempted under the Montreal Protocol.

The US Environmental Protection Agency issued a Final Rule to prohibit the production and consumption of MB under its Clean Air Act by 31 December 2000, with no exemption. Thus, MB can neither be produced nor imported into the USA starting 1 January 2001. It is still unclear whether the US authorities would allow products treated with MB from other countries to enter the US when the ban is effective.

The impact of the ban/phase out of MB as a fumigant for food and agricultural commodities will have strong trade and economic repercussions worldwide. Among several potential alternatives being considered to replace certain uses of MB for these commodities, irradiation offers promise as a broad spectrum treatment for stored products and fresh horticultural comodities. It is being used on a limited scale both for stored products disinfestation and for fresh horticultural products to overcome quarantine barriers.

III. Objectives of the Meeting

The Meeting was convened to assess the global trade impact on the ban/phase-out of methyl bromide as a fumigant for perishable and durable food and agricultural commodities and the role of irradiation as an alternative insect disinfestation method.

IV. Methyl Bromide : Status and Phase-Out Schedule

In 1991 methyl bromide was identified as an ozone depleting substance. Environmental concerns regarding thinning of the ozone layer and an increase of more than 50% in the world production and sales of MB between 1984 and 1992, as indicated in the Table below, resulted in its addition to the list of ozone-depleting substances in 1992, under the terms of the Montreal Protocol Agreement. There was also agreement that, from January 1995, production and consumption of methyl bromide in developed countries should be no greater than in 1991.

Global sales of methyl bromide by use sector (x 1000 t); (China, India and former USSR not included).

Year	Soil	Commodity/ Quarantine	Structural treatments*	Chemical intermediates **	Total
1984	30.4	9.0	2.2	4.0	45.6
1985	34.0	7.5	2.3	4.5	48.3
1986	36.1	8.3	2.0	4.0	50.4
1987	41.3	8.7	2.9	2.7	55.6
1988	45.1	8.0	3.6	3.8	60.5
1989	47.5	8.9	3.6	2.5	62.5
1990	51.3	8.4	3.2	3.7	66.6
1991	55.1	10.3	1.8	4.0	71.2
1992	57.4	9.5	1.9	2.6	71.5

Data Source: Methyl Bromide Global Coalition (1994)
* Includes residential, commercial and industrial buildings
** Not released into the atmosphere. (After Anon., 1994).

Concerted efforts were made by the Methyl Bromide Technical Options Committee (MBTOC) of United Nations Environment Programme to compile data on the global uses of methyl bromide and on the status of alternative methods of insect control. The production of an MBTOC Report (Anon., 1994) permitted the Protocol Parties at their seventh meeting, in 1995, to agree to a further programme of controls on methyl bromide.

There was early recognition that there was no immediate or in-kind replacements for MB where applications need to be completed quickly. This resulted in agreement by the Parties in 1995 to exemptions from controls on the fumigant when used for quarantine and pre-shipment (phytosanitary) purposes. It was also recognised that, after phase-out of MB, there might continue to be certain uses for which no alternatives had been found. These 'essential uses' would, however, be defined nearer to the phase-out date. However, granting "essential uses" will be strictly controlled. Some individual states and regions, including the Nordic countries, and the European Union, decided to review their own position on methyl bromide independently of the Montreal Protocol. This may result in phase-out programmes being introduced more quickly than called for under the Protocol as indicated in the next Table. However it must be noted that the demand for MB in cold climates may be considerably less than that of subtropical and tropical areas. This is particularly the situation in the USA where a total phase out of methyl bromide is proposed by 1 January 2001 under the provisions of the Clean Air Act of 1990, legislation that includes regulating the production and distribution of substances with ozone-depleting potential.

National legislation/policies for reducing or phasing out domestic uses of MB more rapidly than under the Montreal Protocol

Country	**Measure and year adopted**	**Agreed phase-out or reductions**
USA	Regulation 1994	Phase-out by 2001, exemptions possible
Canada	Regulation 1994	25% cut in 1998
	Policy	Phase-out by 2001
Austria	Regulation 1994	Phase-out storage facility use by 1998
	Policy	Phase-out by 2000
Denmark, Sweden	Regulation 1994	Phase-out by 1998
Norway, Finland,	Nordic Environ.	
	Strat. Agreement	
Indonesia	Decree 1994	Phase out by 1998
European Union	Regulation 1994	25% cut in 1998

Source: Prospect Consulting (1997)

The expectation that new information would come from research programmes on methyl bromide and on alternatives provided a basis for reviewing the phase-out programme periodically, with subsequent amendments to the Montreal Protocol Agreement as appropriate. In order to permit the Protocol Parties to consider possible further amendments at their 1997 meeting, the Methyl Bromide Technical Options Committee was requested to provide another report in early 1997. This would include information on the technical and economic status of potential alternatives, and on the degree to which these had been field tested in both developed and developing countries.

UNEP Committee Reports

The 1997 Methyl Bromide Technical Options Committee (MBTOC) Assessment Report addresses the extent to which alternatives to the chemical listed in the 1994 Assessment Report have been tested in the laboratory, and under field conditions, and particularly in developing countries. It also provides an update on any further developments on alternatives to methyl bromide.

The Report contains little in the way of major advances in the development of alternatives to methyl bromide for commodity treatment. A new compound, methyl phosphine, that acts selectively against phosphine-resistant insects is under investigation in the UK. There has been further development of the use of inert dusts, particularly activated silicas, as grain protectants and these may have a role in reducing the need for fumigation in some circumstances. The greater part of the chapter on durable commodities describes further extension of the use of existing and well known alternatives such as phosphine, with continued interest in, and development of, on-site generation of the gas, and the use of controlled atmosphere treatments.

On perishable commodities the Report notes that almost all treatments with methyl bromide are for quarantine and pre-shipment purposes, and are therefore exempt from controls under the present Protocol Agreement, although it is noted there will be countries scheduled to ban all uses of the fumigant, including these exemptions. For these countries alternative disinfestation techniques are more urgently required. The Report states that the difficulty of developing alternative treatments for quarantine and pre-shipment use should not be underestimated as most are generally complex, and require substantial time to refine to a stage where they kill pests without affecting the marketability of the product. However, approximately 100 approved alternative pre-shipment treatments to methyl bromide have been identified for use on specific perishable commodities. None has been approved for treatment of imported commodities found to be infested with pests of quarantine importance on arrival.

Approval of quarantine treatments by importing countries usually takes years to develop data to show efficacy of the treatment. In at least one case, more than 15 years was required.

On issues relating to the developing countries, the Report indicates that there has been an increased use of alternatives in some countries in the last three years with a corresponding overall decrease in methyl bromide use. In many countries use of the chemical has remained little changed. However, in other countries use has even increased because of delayed development and adoption of alternatives or because of pest resistance to phosphine.

Conclusions from the Reports of MBTOC, from other Technical Options Committees and from the Economic Options Committee have been combined into a single report produced by the Technical and Economic Assessment Panel (Anon., 1997). This panel (TEAP) is the senior committee operating under the United Nations Environment Programme. Regarding methyl bromide, the report of TEAP concludes that: *'it is technically feasible to phase out approximately 75% of non Quarantine and Pre-shipment methyl bromide use by 2001, provided that current emergency and routine essential use provisions are modified and made applicable to methyl bromide. TEAP finds no compelling technical or economic reasons why Non Article 5(1) (developed) and Article 5(1) (developing) countries could not pursue similar phase-out schedules'. It should be noted that these conclusions were made independently by the TEAP, and are not taken directly from the 1997 MBTOC Assessment.*

The 1997 Montreal Protocol Meeting

To celebrate the tenth anniversary of the establishment of the Protocol, the ninth meeting of the Parties was again held in Montreal. A further programme of controls on methyl bromide was agreed and is summarised in the table following:

New controls on the use of methyl bromide agreed at the 1997 Montreal Protocol meeting.

	Date of implementation (date of any previous agreement in parenthesis)	Percent reduction in consumption or other decision
Developed countries	1999 (2001)	25
	2001 (2005)	50
	2003	70
	2005 (2010)	100 (phase-out)
Developing countries	2002	Freeze based on 1995-98 use
	2003	Review of interim reductions
	2005	20
	2015	100 (phase-out)

(It should be noted that the reductions for developed countries relate to the quantities used in 1991 which formed the baseline on which a freeze was introduced on 1 January 1995).

Source: Taylor 1997.

The most significant changes for developed countries are the introduction of a 70% reduction in methyl bromide usage by 2003, and a shortening of the period before phase-out by five years. For developing countries, the agreement for a phase-out date (2015) and an interim reduction in 2005 are particularly important steps forward.

For all countries, it continues to be recognised internationally that there is no acceptable alternative to methyl bromide for commodity fumigations conducted for quarantine and pre-shipment purposes, and where a short treatment period is considered to be essential. Use of methyl bromide under these circumstances will not, therefore, count against the quota sytems for the fumigant operating in developed countries. In principle, the parties to the Protocol also agreed that during the post phase-out period an exemption system for critical uses of methyl bromide is likely to be necessary. The method by which an exemption system would operate has not yet been defined but the criteria agreed for a critical use exemption are as follows:

1. the specific use is critical because the lack of availability of methyl bromide for that use would result in significant market disruption;

2. no technical or economically feasible alternatives or substitutes (for methyl bromide) are available to the user that are acceptable from the standpoint of environment and health and are suitable for the crops and the circumstances of the nomination.

Consideration of Irradiation as a Proposed Commodity Treatment as Related to the Economic Impact of the Methyl Bromide Ban

Concerns over the transport of exotic pests across national borders has led to a complex web of phytosanitary rules, often country specific, governing trade in agricultural commodities. While it is clear that phytosanitary treatments help to ensure safe trade, it must be recognized that treatments also have limitations and cause some level of loss for the commercial sector. At issue also are difficulties for the government agencies that are responsible for ensuring that regulatory requirements are met. Efforts to harmonize sanitary and phytosanitary rules across national borders began following the Uraguay round of the General Agreement on Tariffs and Trade, and are continuing under the World Trade Organization (WTO). While the WTO has as its objective harmonization, it also recognizes the sovereign right of governments to establish their own standards for the protection of plant, animal, and human health. Harmonization ensures that such standards are justified based on scientific evidence, with attention given to principles such as transparency, consistency, and notification.

Phytosanitary rules are sometimes considered trade barriers, particularly when they are unnecessarily restrictive, and when their implementation results in shipment delays, decreased product value, or other undesirable outcomes affecting the overall profitability of traded commodities. However, exclusion of agricultural pests is often a valid concern, and in such cases it is important that commodity handlers have access to a fast, effective, and economically feasible alternative. A large selection of treatment options increases opportunities for finding such an alternative and ensures the safe trade of commodities that might otherwise be limited or excluded by phytosanitary concerns. For many commodities, MB fumigation has historically provided an exceptionally high level of protection. This is partly due to its relatively low cost, ease of use, and short exposure times, but also to the conservative regulatory philosophies of quarantine authorities that result in standards that are perhaps more strict than they need be.

A high proportion of commodity fumigations conducted world wide with MB are in connection with import and export, principally because this allows treatment to be completed quickly, but also because some trading contracts require use of the chemical. The Participants agreed that a ban on MB use will inevitably affect many aspects of trade, particularly in countries where commodity export systems have evolved using MB, unless alternative systems can be developed and introduced quickly. For example, Thailand, which annually exports four million tonnes of rice, almost all of which is fumigated before shipment, operates a system based exclusively on MB. Much of the rice is treated in barges during the 24-hour period between loading at the wharf and delivery to ships at the deepwater port. This system operates satisfactorily because of the short fumigation period achievable with MB. It is difficult to see how the present transport/fumigation system could be adapted to use phosphine because the fumigation period would be much longer. A ban on the use of MB would inevitably require the design of a new system of disinfestation and/or changes in handling procedures. Other countries, such as Vietnam, also rely heavily on MB in connection with export programmes for rice.

Egypt probably uses the greatest quantity of MB for commodity fumigation in Africa (Anon. 1997), much of it for treating large quantities of foodgrains that have to be imported. The short time period within which MB fumigation can be completed allows commodities to be moved promptly away from port areas preventing them from becoming congested. The MB ban would have a very significant effect on transport logistics in Egypt. MB is also extensively used for treating both imported and exported commodities in the USA. It is a requirement of USA law that certain commodities imported from specified countries be fumigated prior to entry in order to prevent the spread of particular pests into the country. Many of the commodities are fruit and vegetables imported during the winter months when they are not available domestically. A ban on the use of MB in the USA, scheduled for 2001, which permits no exclusions for quarantine purposes, is expected to have a serious effect on trade (Ross, in press). This ban may also affect exporting countries, many of these being developing countries in Latin America and the Caribbean. Provided that developing countries are permitted to continue to use MB after 2001 there may be options in the short term for commodities destined for the USA to be fumigated in the exporting country immediately prior to shipment. However, this issue has not been resolved.

The phase out of MB under the Montreal Protocol has forced a rethinking of how post-harvest treatment should be carried out. For countries operating under the Montreal Protocol the present programme for phasing out MB provides exemptions for commodities that are fumigated for pre-shipment and quarantine purposes. The Participants agreed, however, that these exemptions will not continue indefinitely, thus making it imperative that alternative treatment methods that are technically and economically acceptable world-wide, are identified as soon as possible.

Existing efforts to assess the economic impact of losing MB for postharvest treatments suggest substantial losses if effective and economically attractive alternatives are not developed. For example, in 1993 the United States Department of Agriculture's National Agricultural Pesticide Impact Assessment Program conducted a study on critical uses of MB for postharvest application in the United States. Twenty high value commodities were identified for the study, many of which are exported and dependant on MB fumigation as an export requirement. The annual loss for quarantine uses of MB was estimated at $444-450 million per year for imports, while the annual losses in export markets for cherries, peaches, nectarines, walnuts, cotton, and oak logs was estimated at $206 million annually. A University of California study also identified over US$10 million in losses to the California walnut industry from switching from the current MB fumigation technology to a phosphine-base treatment. These losses were due entirely to the slower action of phosphine, resultant increases in handling times, and thus the inability of a portion of California's walnut crop to reach the European market in time for the winter holidays.

The Participants agreed that use of irradiation may mitigate these impacts in some circumstances, or even expand and enhance existing trade opportunities in others, especially those which are treated for quarantine reasons. There has been limited research, however, on the effectiveness of irradiation in controlling non fruit fly pests, so that there is some unexplored potential for expanded use of irradiation in quarantine treatments. Cost considerations, primarily logistical, associated with treatment of unpackaged materials could limit the use of irradiation with most grains and durables, although it may be possible that some applications to high value products or specialty grains might be developed. Instead, it is more likely that irradiation will find use in the treatment of fresh fruits and vegetables that are often subject to quarantine restrictions, and for which MB is currently used.

Little quantitative evidence exists on the potential for irradiation to substitute for MB. Forsythe and Evangelou (1993) analyzed the cost of irradiation disinfestation for selected fruits and vegetables using grapes, nectarines/peaches, okra, and plums as test products. Several scenarios were tested varying MB costs and irradiation effects. Their results indicated that irradiation can generate net gains from trade of US$650-US$1100 million over a five year period. These gains did not include phytosanitary benefits or the reduction of harm to the ozone layer. Another US study evaluated (Aegerter and Folwell, 1996) the economic impact of the loss of MB as a post-harvest fumigant for apple exports. This study showed that MB treatment of apples costs $32,10/tonne as compared to irradiation cost of $115.64/tonne if treated at a privately owned facility and $60.47/tonnes if treated at a port-owned facility. Although each of these studies indicate potential for irradiation to substitute for existing MB uses, there are still significant potential applications that need further research. Such research is essential for the continued expansion of existing international trade flows in agricultural commodities.

V. Potential Alternatives

MB is one of the few fumigants left for insect disinfestation. Its use for commodity treatments represents approximately 10% of total use in agricultural situations (Anon., 1992). No other registered chemicals are available that provide the same physical and chemical characteristics as MB that would make them useful as broad scale alternative commodity treatments, including phytosanitary treatments: that is, fast action times of 2-24 hours depending on the commodity, ease and flexibility of application, and gaseous/efficacious at a broad range of temperatures. In short there are no "in kind" replacements for MB. The potential implications of the loss of MB worldwide without suitable and economical alternatives are severe for both developed and developing countries. Such losses would impede international commerce both from the standpoint of commodity protection treatments and also because of the more rigid requirements demanded of quarantine treatments. Phytosanitary treatments are designed to exclude specific pests from countries not having them and are required by the importing country. The Participants agreed that the likelihood of finding another fumigant with the characteristics of MB is not great. Although short term predictions have been made (Anon., 1993; Ross and Vail, 1993), the long term impact of loss of MB on export markets is country specific and is unlikely to have been determined. The diversity of uses of MB makes the development of alternatives difficult. The Meeting evaluated the following alternatives to MB for stored products and fresh horticultural produce:

* **MB fumigation with trapping and recycling (no loss to the atmosphere)**

The technology for this type of operational system is available but can be expected to have high capital costs which could alter the cost effectiveness relationship of fumigation with MB. Additionally, if reduced production of MB results in increased cost of the gas there will be an additional cost increase from this source.

* Heat treatments

<u>Stored products:</u> Grain can be disinfested by heating to a temperature lethal to the pests. For bulk grains this can be done during drying (except rice). There is a dedicated heat treatment design using fluidized bed technology proven to the pilot unit stage in Australia. Costs are likely to be higher than fumigation and gamma irradiation because of the energy inputs needed.

<u>Fresh horticultural produce:</u> Heating can be done with circulated hot air, or hot water or vapor applications. Other heating systems such as microwaves or infra-red are currently not available commercially for reasons which include uneven temperature distribution. Circulated hot air systems are variously termed Vapour Heat Treatment (VHT) and High Temperature Forced Air (HTFA). with systems using air of saturated humidity the most efficient if product injury can be avoided. Hot air systems are probably best suited to high value commodities handled in relatively low volumes. Hot water is the more efficient way of heating fruit but for disinfestation against fruit flies it frequently results in commodity injury. Temperature control needs to be very precise as there is a small tolerance before damage occurs regardless of the system. Heat disinfestation is widely used for mangoes and citrus imported into USA from Central and South American Countries and Hawaii and for mangoes exported from Australia and the Philippines to Japan. Capital and operating costs are typically high.

*Cold treatments

<u>Stored products:</u> Reduction of temperature can be used to inhibit pest multiplication or to actively disinfest stored products. For commodities handled in bulk such as grain cooling is done by forced aeration , selecting the coolest ambient temperature available or by circulating refrigerated air through bulks. Use of ambient air is very economical and very effective if adequately low temperature air is available but has little applicability in warm climates. Cooling by refrigerated aeration requires substantial capital investment and

operating energy costs. For commodities handled in packaged form refrigerated storage is a practicable option for disinfestation but confers no residual protection. In general cold disinfestation is slow and logistically complex. Refrigerated aeration systems are used on a limited scale in Australia and Israel.

Fresh horticultural produce: For commodities which will tolerate temperatures near freezing a suitable period of cold storage will result in mortality at efficacy levels appropriate for quarantine security against some pests. Few tropical fruits will tolerate sufficiently low temperatures without unacceptable injury and the method is mostly used for temperate fruits such as pome fruits and citrus. Cold disinfestation to quarantine standards is slow because of the time needed to achieve the required efficacy. Although most commercially produced fruit and vegetables are cooled immediately after harvest it is not logistically practicable to use routine cooling procedures for disinfestation. Citrus for export to the USA and Japan from Australia is routinely disinfested by cold storage.

* **Irradiation**

Stored products: Irradiation has the advantage that it can be a continuous process whereas fumigation is a batch process. It will disinfest grains and other stored products at relatively low treatment dosages. However, as with MB, irradiated product is subject to immediate reinfestation. In addition, unlike MB which can be "taken" to the commodity, a treatment by irradiation demands that the commodity be "taken" to the irradiation source. Re-treatment is typically required where storage times exceed one pest life cycle, upwards of 6 weeks depending on ambient temperature and humidity. Where the product has an incipient infestation or is infested by migrants, radiation treatment will suppress any infestation at an efficacy level comparable to MB. At present there are no commercial installations which can treat grain flows of up to 4000 tonnes/h currently used to load ships in international trade. A perceived problem, that of slow death following low dose irradiation, is not necessarily disadvantageous because 1) the infestation will not multiply further, 2) feeding of the pest will be reduced or eliminated, and 3) mortality will be significant if not complete after 6 weeks, the typical delivery time for delivery by sea. High powered electron beam irradiation appears to be the most appropriate technology for stored products handled in bulk. Apart from a commercial unit at Odessa in the Ukraine, currently unused, there are no known grain irradiator installations. However, packaged stored products such as spices are routinely irradiated, in a number of countries.

Fresh horticultural produce: Irradiation has been shown to be as efficacious as MB for tropical and temperate fruit flies and codling moth, the two most important pests of fresh horticultural produce in international trade (ICGFI, 1991) It is also highly efficacious against a range of other pests in this category including thrips, scale insects and mites. Again there is perceived problem of slow death following irradiation or survival at doses designed to ensure quarantine security through sterility of the irradiated pests. This can be overcome for fruit flies by adoption of an enzyme spot test (Nation *et. al.*,1995; Mansour and Franz, 1996). or similar method to confirm that insects found alive after treatment have been irradiated. High standards of pest management during production could result in little, if any, infestation and should have the added benefit of a higher quality product. At some point dosimeters to verify irradiation dose may be accepted by regulatory agencies. Approvals are in place in the USA for quarantine irradiation against fruit fly, infesting papaya, litchi and carambola for export from Hawaii to mainland USA and commercial usage is expected to commence when facilities are commissioned.

* **Chemicals**

Stored products: Fumigants are the most commonly used chemicals for control of stored product pests. MB is preferred where there are time constraints but phosphine is widely used because of its relative convenience of application in tablet or pellet form despite application constraints of extended times for fumigation, minimum temperature for insecticidal activity and equilibrium humidity of grain. For all fumigants and particularly phosphine, sealing is of paramount importance if optimum efficacy is to be achieved. It is a characteristic of fumigants that there is no residual protection after the treated grain is areated. An additional usage of chemicals for stored products protection is admixture of an insecticide with grain which can confer both disinfestation and residual protection for 6-12 months. A requirement of all chemical usage is that the maximum residue level (MRL), based on good agricultural practices as well as health and safety considerations, not be exceeded. Consumer preferences, world wide are for food free of pesticide residues regardless of their level of health/safety risk.

Fresh horticultural produce: Postharvest disinfestation of fruit and vegetables is undertaken mainly for quarantine purposes. Fumigation is the method of choice. MB is not widely used for fresh produce because of the risk of phytotoxicity. Phosphine is even more phytotoxic than MB at the doses necessary for disinfestation of important quarantine pests. Ethylene Dibromide which was very effective for fruits and vegetables and generally caused little phytotoxicity has been discontinued in most countries because of health/safety considerations. As with stored products, insecticides can be applied postharvest to disinfest fruit and vegetables but MRL's must not be exceeded.

* **Microbial control**

Non synthetic insecticides such as insect pathogens or their products can be used to provide long term protection against pests of stored products. They are generally not as efficacious as the synthetic pesticides and are unlikely to come into widespread usage. Their specificity may be of concern when a commodity is infested by a complex of pests.

* **Biocontrol**

Predators and parasitoids have been demonstrated to suppress insect populations in storage. They are most likely to be used to reduce sources of infestations in the environs of the stored commodities. These organisms are likely to be incorporated into systems approaches as a mortality factor for stored product and quarantine pests that would reduce the need for more severe treatments. They are not likely to be used as stand alone treatments.

* **Detection systems**

Detection of infested units of commodities other than by visual inspection is not developed to the commercial stage. It needs to be linked to rejection or treatment systems to be an effective control system. There are a number of chemical and physical parameters that could be used to develop detection systems.

* **Combination treatments**

Stored products: Combinations of treatments can confer cost benefits or sometimes synergism. For stored grains it usually involves a disinfestation treatment without residual protection with storage conditions unfavourable to pest multiplication.

Fresh horticultural produce: Combination treatments are favoured when either component alone would cause unacceptable injury or not sufficient quarantine security. Quarantine treatments are often severe; combination treatments may reduce efficacy levels required of a single treatment.

* **Systems approaches**

Many routine operational procedures during production and postharvest handling of commodities contribute to end point freedom from pests. When these are quantified it is sometimes possible to show that quarantine security can be achieved without further treatment or with less severe treatment than would be required to achieve quarantine security with a single postharvest treatment. The concept is equally applicable to non-perishable stored products and to perishable fresh horticultural produce. In practice, complex, difficult and extensive research is required over a number of seasons to obtain the supporting data required. Consequently, the costs of development would often be very high. Systems approaches may involve field surveys, sampling at harvest, etc., and may also demand a specific, but possibly less severe post-harvest treatment. Systems approaches might also incorporate any of several of the above technologies.

* **Controlled atmospheres**

Stored products: For stored grains controlled atmosphere disinfestation is analogous to fumigation but does not leave chemical residues. It usually involves modification of the storage atmosphere by adding nitrogen or carbon dioxide or by oxygen depletion by cycling the storage atmosphere through a gas burner or differential membrane systems. Sealing of storages to contain the atmosphere is more critical than for fumigants, which makes the storages costly to maintain and creates access problems. Since controlled atmospheres will not support life and are not easily detectable there is considerable ongoing danger to operators.

<u>Fresh horticultural produce</u>: Controlled atmospheres involving reductions of oxygen levels are widely used in combination with low temperatures to extend the storage life of some fruits (i.e., apples) for up to one year. These storage conditions can in some instances be used as a component of quarantine treatments (i.e., controlled atmospheres) plus a methyl bromide fumigation. However the commodities for which this technology is applicable are limited and the storage times involved normally make it impracticable for use specifically for the purposes of disinfestation.

V. Criteria for MB Alternatives

As compared to the attributes of MB (Annex 3), it is likely that most potential alternatives will be significantly more costly, more sophisticated, involve considerable training, have higher energy requirements and not provide the flexibility of application required for quarantine treatments. Some will require large capital investments, while public acceptance of some treatments may be an issue. Depending on the type of treatment, many methods must be developed that are specific to given commodities. Often their influence on specific cultivars of perishables also will have to be determined. Many potential alternatives, by necessity, will require changes in handling, packing, and storage systems and will be more costly than MB. The more severe quarantine treatments may result in high levels of damage. The large volume of many U.S. commodities (55 million boxes of stone fruits from the San Joaquin Valley of California in 1992, for example) coupled with short storage life may exclude some alternative treatments. Many potential alternatives will have impacts on postharvest handling procedures.

When the MB issue surfaced, a number of potential alternatives were identified, including other fumigants (i.e., methyl iodide and carbonyl sulfide), trapping/recycling of MB, irradiation, heat treatment, cold treatment, certification, combination (multiple) treatments, controlled atmospheres, microbial control agents, biological control agents, systems approaches, integrated pest management, insect hormones and analogs, and detection systems, etc. The feasibility of these potential alternatives for use as quarantine or commodity protection treatments was assessed (Annex 4). Various essential factors that needed consideration for the adoption of a potential alternative were identified (Annex 5). Several of these factors warrant further explanation:

1. **Application:** For what specific commodities will the potential alternative be used? Is the efficacy of the treatment such that it could be used for commodity protection, quarantine application, or both? How often would commodities be treated with the alternative proposed? Would the treatment "stand alone"?

2. **Ease of use:** Is the potential alternative as easy to use as MB or does it require higher technological input, sophisticated machinery, training, etc.?

3. **Efficacy requirements:** Are the efficacy levels provided by the potential alternative high enough to be considered useful as a commodity protection treatment, quarantine treatment, or both?

4. **Treatment time:** Is the time of treatment equivalent to that of MB treatment? If not, why? Is there an impact of increased treatment time on handling procedures?

5. **Compatibility of time, temperature, etc.:** Does treatment have an adverse effect on commodity quality, storage life, etc.? Does use of the treatment influence other steps in the handling of the product? If so, what changes are necessary?

6. **Economics:** Are the direct costs of the technology similar to those of MB? Does the use of the alternative or combination with other alternatives cause indirect

problems such as increased handling, process changes, more highly trained labor, demand for more storage space? Will treatment times, volumes, handling, etc., increase, decrease or stay the same? What are the maximum and optimum throughputs of the technology?

7. **Logistics:** Does the treatment cause changes in the way the product is handled, stored, packaged or shipped? Are volumes treated per unit of time significantly altered?

8. **Engineering:** Some technologies may or may not be amenable to increases or decreases in size, patterns, or volumes of commodities to be treated. Does the new technology involve high engineering input or unusual maintenance requirements? What are the economies of scale? Will the new technology alter current methods of handling commodities? What volumes of commodity can be treated/unit time?

9. **Presence of live insects after treatment:** Irradiated insects may stay alive for some time after treatment. Post treatment survival is inversely related to absorbed dose. Even though the insect may survive for sometime after treatment, they are sterile and are unable to feed/cause damage. Regulatory agencies need to be aware that although some survival may occur further damage is minimal.

10. **Presence of live treated quarantine insects in commodity:** There is no simple and rapid test to determine if a live insect has been irradiated, although a test has been developed for detecting irradiated fruit flies.

VI. Current Status of Irradiation

a. Regulations

The Codex Alimentarius Commision of the FAO/WHO Food Standards Programme which has as its primary objectives to protect consumer health and ensure fair practice in food trade, adopted a Codex General Standard for Irradiated Foods in 1983. Such a standard recognizes the safety and effectiveness of irradiation as a food processing/preservation method of any food commodity treated up to an overall average dose of 10 kGy.

Currently, 40 countries have used the Codex Standard to frame their national regulations or issued specific approval for the use of irradiation for treating various food commodities for sale and public consumption. Initially, most countries have approved specific foodstuffs by specific food commodities (e.g. rice, wheat, maize, sorghum, etc.). Recently, however, an increasing number of countries have followed the recommendation of the International consultative Group on Food Irradiation (ICGFI), established under the aegis of FAO, IAEA and WHO since 1984, by approving irradiated food by food classes (e.g. fruits, vegetables, cereal grains and pulses, poultry, meat, seafood, spices, etc.).

The specific approvals of irradiation of food for insect disinfestation and quarantine treatment are attached in Annex 6. All approvals are for insect disinfestation in general. In addition, the USA has approved irradiation of fresh papaya, lychees and carambola from Hawaii against fruit flies in 1997. The USDA issued a policy to allow irradiation as a phytosanitary measure against major fruit fly species regardless of commodities in May 1996. There is a regional standard on irradiation as a phytosanitary measure issued by the North American Plant Protection Organization in 1996.

b. Applications

Commercial application of food irradiation depends on the need and the economics of the process. Currently, 30 countries have applied this technology for processing a number of food products, especially spices and dried vegetable seasonings (Annex 7).
The quantities of food processed by irradiation in different countries vary significantly from less than 100 metric tonnes/annum in countries such as Croatia, Cuba and Finland to over 20,000 tonnes/annum in China, France, the Netherlands and USA. Most of these applications are for ensuring hygienic quality of spices and food of animal origin, sprout inhibition of roots, tubers and bulbs, and shelf-life extension of some fruits and vegetables.

With regard to commercial application of irradiation for insect disinfestation purposes, the Ukraine processed between 200,000 and 400,000 tonnes of imported grain per annum at its Odessa Port during the 1980's, using two electron beam machines each having a capacity of treating 200 tonnes of grain/hour at a dose between 200 and 400 Gy. The facilities are no longer in operation, however, as the Ukraine is in the process of introducing a new food law following its separation from the former Soviet Union. Small commercial quantities of rice, beans and other pulses have been irradiated in China, Indonesia and Thailand for market trials in recent years with positive consumer acceptance.

Since 1995, small commercial quantities of fresh papaya, lychees, rambutan, and carambola have been irradiated by a commercial irradiator in the Chicago area to satisfy US quarantine regulations. These commodities were put on sale in several mid-western States of the USA with success. Some 100 grocery stores have been involved in such a trial which provided not only the regulatory authorities with the needed information with regard to commercial irradiation and control of these commodities but also the food retailers with marketing experience in selling irradiated fruits to the consumers. Following the success in such a market trial, the Hawaiian authorities have decided to build a semi-commercial irradiation facility in Hilo, Hawaii to treat commercial quantities of fresh fruits for the US mainland market. A ground breaking for this facility is expected before the end of 1997.

c. *Types of irradiation facilities*

c.1 Electron beam (EB) accelerators

Major advantages of E-beam machines are:

- They can be switched on and off.
- They are capable of very high processing rates
- Their unit costs are very low at high throughputs.

Major disadvantages are:

- Their penetration is low compared to X-rays.
- The initial investment is high.
- They require professional operating staff.
- Breakdowns are not infrequent and can be costly.

E-beam machines are ideal for treating high throughputs of thin products.

C.2 X-Ray machine

When accelerated electrons are made to strike a metal target, X-rays are produced. They have a much greater penetration than electrons but at the maximum permitted electron energy of 5 MeV, the conversion efficiency is only 5-8%. Serious consideration of such a facility must wait until the maximum energy is lifted to 7.5 MeV and a full scale prototype demonstrated.

C.3 Gamma irradiators

The majority of agricultural products which require irradiation will be packed into boxes, bags or drum - either loose or palletised. There are several types of gamma irradiators but only the pallet irradiators are really suitable for multi-purpose irradiators of agricultural produce. There are those employing a batch system and those employing a continuous system.

1) Batch Pallet Irradiators

In this system, product on trolleys is wheeled into the chamber which is shielded by 2-meter thick concrete walls, with a Cobalt-60 radioactive source shielded at the bottom of an 8-meter pool of water. The product handlers vacate the irradiator, the shielding door is closed and the source is raised to the centre of the chamber where irradiation of the product commences. After each one-quarter cycle, the product is rotated 90° for another side exposure. At the end of the 4 cycles, the source drops to the bottom of the pool, the door opens, the handlers remove the batch and refills with the next one.

The advantages of this type of irradiator are:

- least expensive facility type.
- simple to run and does not require highly trained operators.
- very reliable and will operate 24 hours per day, 350 days per year.
- highly versatile and products with different densities and/or different dose requirements can be exchanged within minutes.

The disadvantages are:

- Time is lost during the batch-changing operation.
- Energy utilisation efficiency is lower than in a continuous operation.
- Maximum capacity is limited to 900 kCi for a dose of 250 Gy.

2) Continuous Pallet Operation

In this system, pallets are moved automatically on rollers/carriers past a plaque source a total of four times - each time being irradiated from each side.

The advantages of this type of irradiator are:

- There is no time lost as a result of product changing.
- Energy utilisation efficiency is higher than batch operation.
- Products requiring different doses but similar densities can circulate simultaneously.

The disadvantages are:

- The facility is relatively expensive.

- Operators require a higher degree of training (system is computer controlled).
- Products of different densities have to be treated sequentially.

3) Cesium-137 Self Contained Irradiator

This novel irradiator suitable for the irradiation of smaller quantities of food is a self shielded irradiator using Cesium 137. It is self-contained and the irradiator is its own transport container.

There is no operational unit of this type yet but a prototype will be installed in the USA soon.

d. Consumer Acceptance

Sufficient data are available to apply irradiation commercially for the control of a number of quarantine and stored product pests. Besides the more obvious statutes and regulatory constraints often applied by various countries there are several real or perceived constraints that need to be addressed. Consumer acceptance has often been raised as a factor influencing the adoption of this technology. However, more recently there have been indications that consumer acceptance may be less of an issue than previously thought. Commercial quantities of several types of irradiated food including small volumes of some perishable and durable commodities have been irradiated and consumers appear in several countries to be less concerned about irradiated food than purchasing a quality product. Often these marketing studies have been conducted at low volume, speciality type retail outlets. More studies need to be conducted in larger markets with more general retailers and consumers to obtain more reliable evidence of consumer preferences.

COST COMPARISONS
(Units Capable of Processing 100,000 tonnes per annum)

US$(x 103)	E-beam	X-ray	Co-60 batch	Co-60 continuous	Cs-137	MeBr.
Equipment cost	5,150	5,440	1,300	2,100	1,500	-
Isotope costs	-	-	770 (550 kCi)	260 (180 kCi)	?	-
Operating costs (US$/hr.)	330	340	90	123	?	-
Unit costs (UScent/kg)	6.7	6.8	0.7	1.1	1.6	0.9

Source: Basson (1997)

VII. Action Plan

The Participants agreed that irradiation has a potential broad application for use as a quarantine treatment of fresh horticultural produce and selected durable commodities. With exception of data on irradiation as a quarantine treatment against tephritid fruit flies and codling moth, little data are available on the use of this technology against other arthropod pests of quarantine importance. In view of the global phasing out of methyl bromide, there is an urgent need to investigate the role of irradiation as a broad spectrum quarantine treatment against these pests, with a view to maintain the same level of trade in these commodities. The Participants therefore recommended that a Co-ordinated Research Programme on this subject be implemented at the earliest opportunity:

Title: Coordinated Research Programme on Irradiation as a Phytosanitary Measure of Food and Agricultural Commodities

Background: Global trade in food and agricultural commodities has become liberalized following the GATT Uruguay Round, especially in relation to the Agreement on the Application of Sanitary and Phytosanitary Measure of the World Trade Organization. The trade in such commodities could be seriously hampered when methyl bromide is phased out globally under the Montreal Protocol (an international treaty to protect the environment which has been ratified by most advanced and developing countries) because of its ozone depletion properties. Although the specific schedules for the phase-out have not yet been finalized for developing countries, most advanced countries have agreed to phase out this chemical not later than the year 2010. The USA under its Clean Air Act has issued a regulation to prohibit the production and consumption of this chemical by 1 January 2001.

As methyl bromide is widely used as an insect disinfestation fumigant, there is an urgent need to identify suitable alternatives to maintain food security and facilitate glabal trade in food and agricultural commodities. Irradiation offers considerable potential as an alternative insect disinfestation method to methyl bromide for both durable and perishable commodities. Although data on radiation sensitivity of most stored product insects are available, the efficacy of irradiation treatment of various food and agricultural commodities at the pilot or semi-commercial scale has not been demonstrated. In addition, data on the effectiveness of irradiation as a quarantine treatment are limited largely to tephritid fruit flies. There is a need to develop research data on the effectiveness of irradiation on other arthropod pests of quarantine importance based on criteria acceptable to regulatory authorities.

Overall Objectives: Investigate the use of irradiation as a phytosanitary treatment for food and agricultural commodities in trade, particularly as an alternative to methyl bromide.

Specific Research Objectives:

* Identify commodity/pest systems amenable to efficient use of irradiation technology
* Identify efficacy requirements and data needs acceptable to regulatory agencies.
* Develop efficacy data for pests/commodities systems.
* Determine if systems/combinations are amenable to irradiation technology.

Specific Outputs:

* Select appropriate pest/commodity systems, based on broad geographical usage.
* Standardized protocols for irradiation.
* Dose responses for important arthropods/host systems, *in situ*
* Phytotoxicity/quality data for appropriate treatments
* Data for efficacy and quality as required by regulatory agencies.

Logical framework for the FAO/IAEA Co-ordinated Research Project on "Irradiation as a Phytosanitary Measure of Food and Agricultural Commodities"

Narrative Summary	**Objectively Verifiable Indicators**	**Means of Verification**	**Important Assumptions**
Overall Objective To investigate the use of irradiation as a phytosanitary treatment of food and agricultural commodities in trade, particularly as an alternative to methyl bromide.			

Narrative Summary	**Objectively Verifiable Indicators**	**Means of Verification**	**Important Assumptions**
Specific Objective * Identify commodity/pest systems amenable to efficient use of irradiation technology * Identify efficacy requirements and data needs acceptable to regulatory agencies * Select pest/commodity systems * Develop efficacy data for pests/host systems * Determine if systems/combinations are amenable to irradiation technology.	Number of laboratories/institutes conduct research on irradiation as a phytosanitary treatment.	Number of plant protection and quarantine reports submitted for approval by governments	1. National support is provided to participants. 2. Constant co-ordination between research agreement and contract holders 3. Existing regulation on food irradiation.

Narrative Summary	**Objectively Verifiable Indicators**	**Means of Verification**	**Important Assumptions**
Outputs			
1. Data collected according to standardized protocols for irradiation.	1. Protocols written	1. Protocols distributed to all participants.	1. Standardized protocols are appropriate and workable in all laboratories.
2. Dose responses for important arthropods/host systems.	2. Data developed	2. Progress reports	2. Sufficient expertise and resources available in participating institutes.
3. Phytotoxicity/quality data for appropriate treatments.	3. Data validated	3. Progress reports.	3. Established national criteria for determining phytosanitary and quality of food and agricultural commodities.
4. Data for phytosanitary or quality control requirements of regulatory agencies.	4. Data established.	4. Data acceptable to regulatory agencies.	

Narrative Summary	**Objectively Verifiable Indicators**	**Means of Verification**	**Important Assumptions**
Activities			
1. Form network of national plant protection and quarantine laboratories.	1. Ten contract and 5 agreement holders identified.	1. Approval of contract and agreements.	1. Suitable proposals submitted.
2. Organize 1st RCM to agree on research protocol and other procedures.	2. RCM held (1998)	2. Participants' and CRP Progress Report.	2. Research Protocols are available and workable.
3. Organize 2nd RCM to analyse and validate data.	3. RCM held (2000)	3. Participants' and CRP Progress Report.	3. Research results can be analysed successfully.
4. Organize 3rd RCM to evaluate the efficacy of irradiation treatment.	4. RCM held (2002)	4. Participants' and CRP Final Report.	4. Results are useful in plant protection and quarantine.
5. Early contacts made with relevant regulatory agencies	5. Contacts made	5. Governments approve the proceses	Governments accept radiation treatment
6. Collate all reports and synthesize results.	6. TECDOC and/or scientific papers published.	6. Evaluation of Final Reports by Project Officer.	6. Final reports are submitted by participants to the Agency.

VIII. Recommendations:

The Participants made the following recommendations to FAO and IAEA through their Joint FAO/IAEA Division with regard to the implementation of action plans on irradiation as a phytosanitary treatment of food and agricultural commodities, particularly as an alternative to methyl bromide fumigation:

1. The CRP on Irradiation as a Phytosanitary Treatment of Food and Agricultural Commodities should be implemented as soon as possible to develop data urgently required to expand the use of irradiation as an alternative to methyl bromide fumigation.

2. Priorities should be given to research on selected pests/commodities combinations (e.g. insect pests asociated with cotton bales, thrips on cut flowers, moths and other insects in dried dates, mites and moths in fresh and stored products), which would represent major trade problems and have a realistic opportunity to implement the use of this technology in the near term. Ideally, one major commodity from each geographical region would be selected. Radiation biology of these pests should already be determined.

3. The Joint FAO/IAEA Division should provide guidelines for the development of standardized research procedures for pests/commodities systems to insure that research data would be suitable for regulatory agencies to take action on phytosanitary issues without undue loss of time and research effort.

4. Research emphasis should be on determining the optimum condition for irradiation of various commodities to minimize the phytotoxicity of perishable products.

5. There is an urgent need to develop/prepare standardized training materials/manual(s) on irradiation as a phytosanitary treatment for scientists/researchers and for regulatory officials. The International Consultative Group on Food Irradiation should be asked to assist in preparing such standardized training manuals/materials for these two target groups.

6. There is a need to organize training courses with a broad perspective to cover all phytosanitary aspects for countries in other regions, especially in Africa, in the immediate future. It was noted that training courses on irradiation as a quarantine treatment of fresh fruits and vegetables have been organized by the Joint FAO/IAEA Division for scientists/officials from countries in Asia and Latin America in the past. FAO/TCP should be requested to provide proper funding for such training courses.

7. Noting that the North American Plant Protection Organization (NAPPO) has issued a standard on irradiation as a phytosanitary treatment and that the Asia and the Pacific Plant Protection Commission is in the process of developing such a standard, the Secretariat of the International Plant Protection Convention (IPPC) should be asked to implement an international standard on this subject at the earliest opportunity.

8. Governments which are interested in developing demonstration projects on irradiation as a phytosanitary treatment should consider applying for financial assistance from Multilateral Funds of the Montreal Protocol, to assist developing countries to phase out MB, which is administrated by UNIDO.

9. To expedite commercial application of irradiation technology for insect disinfestation, particularly as an alternative to MB, realistic economic feasibility/investment studies should be conducted by the radiation industry in consultation with the producers/processors of respective commodities.

10. As irradiation technology could play an important role for insect disinfestation of food and agricultural commodities and as a substitution for MB, information about the potential role of irradiation should be widely disseminated on the Internet, USDA Methyl Bromide Newsletter, UNEP Ozone Newsletter, annual conferences of methyl bromide alternatives, etc. to increase awareness of potential users of this technology.

IX. References

Aegerter, A.F. and Folwell, R.J. (1996). Economic alternatives to the use of methyl bromide in the postharvest treatment of selected fruits. Proceedings of Annual International Conference on Methyl Bromide Alternatievs and Emissions Reduction. pp II. Clarion Plaza Hotel, Orlando, Florida.

Anon. (1992). Methyl Bromide Science Workshop proceedings, Washington, D.C. (June 1992).

Anon. (1993). Methyl Bromide Atmospheric Emissions Reduction/Postharvest Commodity Treatments: Assessment of Research and Extension Needs and Priorities. In "Proceedings of Crop Protection Coalition Conference", Burlingame, California, 14-15 October 1993.

Anon. (1994). Report of the Methyl Bromide Technical Options Committee for the 1995 Assessment of the UNEP Montreal Protocol on Substances that Deplete the Ozone Layer. Ozone Secretariat, Nairobi, Kenya. 304 pp.

Anon. (1997). April 1997 Report of the Technology and Assessment Panel, Volume 1. The MBTOC Report to TEAP and Miscellaneous Methyl Bromide Issues. UNEP, Ozone Secretariat, Nairobi Kenya. 35-124 pp.

Forsythe, K.W. and Evangelou, P. (1993). Costs and benefits of irradiation and other selected quarantine treatments for fruit and vegetable imports to the United States of America. In "Cost-Benefit Aspects of Food Irradiation Processing", IAEA, Vienna, 271-290 pp.

ICGFI (1991). Irradiation as a Quarantine Treatment of Fresh Fruits and Vegetables. Report of a Tack Force Convened by the International Consultative Group on Food Irradiation (ICGFI) held in Bathesda, Maryland, January 1991. ICGFI Document No. 13. IAEA, Vienna.

Karliner, J., Morales, A., and O'Rourke, D. (1997) The Ecologist, Vol. 27, No. 3 May/June. 90-98 pp.

Mediterranean fruit fly (Diptera: Tephritidae) larvae. J. Econ. Entomol. 89, pp 695-699.

Nation, J.L., Smittle, B.J., and Milne, K. (1995). Radiation induced changes in melanization and phenoloxidase in Caribbean fruit fly larvae (Diptera: Tephritidae) as the basis for a simple test of irradiation. Ann. Entomol. Soc. Am. 88, pp. 201-205.

Prospecting Consulting (1997) Second Interim Report on Methyl Bromide. Prepared for the Commission of the European communities, DG XI. 207 pp.

Ross, R.T. Impact of domestic and international regulatory controls on the competitiveness of American agriculture. In "Proceedings of International Conference on Controlled Atmosphere and Fumigation", Nicosia, Cyprus, 21-26 April, 1996 (In Press).

Ross, R.T. and Vail, P.V. (1993). Recent actions taken on methyl bromide under the Montreal Protocol: Their potential economic implications on international trade, pp. 139-154. In "Cost-Benefit Aspects of Food Irradiation Processing". IAEA, Vienna.

Taylor, R.W.D. (1994). The potential for reducing methyl bromide emissions associated with the fumigation of durable commodities in developing countries. Proceedings of the Annual International Research Conference on Methyl Bromide Alternatives and Emissions Reductions, Orlando, Florida, USA, 13-16 November 1994. 92-1 to 92-4 pp.

Taylor, R.W.D. (1996). Commodity fumigation beyond the year 2000. Pesticide Outlook, (7) 4, 31-34 pp.

UNEP (1997). UNEP/OzL Pro/WG.1/15/CRP.9 Report of the 15th meeting of the Open-ended Working Group of the Montreal Protocol, Nairobi, Kenya, June 1997.

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CONSULTANTS' MEETING on The Impact of the Phase-out/Ban of Methyl Bromide and the Possible Role of Irradiation in Trade Food and Agricultural Commodities.

VIENNA, 11 - 15 August, 1997

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Table 1. Ideal attributes of methyl bromide as a commodity treatment for perishable and durable commodities.

- Quick mortality (2-24 hr) for most organisms
- Broad spectrun of activity
- No known resistance among pests
- Cost effective
- Good penetration of commodities
- Effective at relatively how temperature
- Easy to use
- Non-flammable and non-explosive
- Recognized world-wide as an effective treatment
- Does not damage the product
- Public, regulatory, and legal acceptance
- Safe to use
- Environmental impacts minimal or none
- Readily available
- Adaptable to many scales of use

Annex 4. Potential Alternatives for Methyl Bromide (MB) as Commodity/Quarantine Treatments[1]

Factors to be considered for use	MB trapping/ recycling	Radiation	Heat treatment	Cold treatment	Combination treatments	Systems approaches	Controlled atmospheres	Chemicals	Microbial control	Biocontrol	Detection System
Ease of use	0	+	+	+	+	+	+	+/0	+/0	+	?
Time for treatment	0	?	+/0	+	+/0	+/0	+	+/0	0/-	0	0/-
Compatibility as regards market life and quality	0	0	+/0	+/0	+/0	+/0	+	+/0	0	-	?
Economics	0	+	+	+	+	+	+	+/0	+/0	+	?
Logistics	0	+	+	+	+	+	+	+/0	+	+	?
Engineering	+	+	+	+	+/0	?	+	+/0	+/0	0	+
Public acceptance	0	?	-	-	0/-	-	-	+/0	0/-	-	-
Safety	-	-	-	-	-	?	-	+/0	-	-	-
Environmental implications	-	-	-	-	-	?	-	+/0	-	-	-
Availability (ex. CO_2)	0	?	-	+/0	+/0	?	+	+/-	-	+	?
Residues	?	-	+	-	-	?	-	+/?	-	-	-
Potential for expanded use[2]		G									
Protection	U	G	L	L	G	G	L	P	L	L	U
Quarantine	U	G	L	L	G	G	L	L	N	N	U
Comments	Should not alter present MB uses.	Commodity and source dependent. Large scale use may deplete isotope availability. Must be able to differentiate irradiated insects.	Three application methods; phytotoxicity could be a problem.	Will depend on commodity.	Compounded by more than one treatment. Not preferred as quarantine treatment; regulation more difficult.	Multiple components may complicate quarantine use.	Facilities must be well sealed to hold atmospheres. Very temperature dependent.	No new fumigants available. Phosphine causes severe damage to fruits and vegetables. Registration issues.	Used as protectants; economics would depend upon number of fumigations prevented. Specificity may be a problem.	May sustain itself; good for sanitation and space treatments; insect fragments may become an issue.	Would alleviate use of MB but may have high tech requirements.

[1]Legend: + = More of a problem than present MB use; 0 = Similar to MB use; - = Less of a problem than MB use; ? = Not known.
[2]Legend: G = Good; L = Limited; P = Poor; N = Nil; U = Unknown.

Table 2. Possible technologies for alleviation of environmental methyl bromide levels and their technical feasibility as commodity or quarantine treatments.

	Technical Feasibility for	
	Commodity Protection	Quarantine Treatments
Chemicals — methyl iodide — carbonyl sulfide	+/-	+/-
MB Trapping and/or Recycling[1]	+	+
Radiation	+	+
Heat Treatment	+	+
Cold Treatment	+	+
Certification	+	+
Combination Treatment	+	+
Controlled Atmospheres	+	+/−
Microbial Control Agents	+	−
Biological Control Agents	+	−
System Approaches	+	+
Integrated Pest Management	+	±
Hormones, analogs, etc.	+	−
Detection systems	+	+

[1]Assumes emissions control would be an "acceptable" usage of methyl bromide under the U.S. Clean Air Act.

Material compiled by USDA-ARS HCRL, Fresno, California.

APPROVED DISINFESTATION, INCLUDING COMMODITY/QUARANTINE TREATMENT

COUNTRY	PRODUCTS
ARGENTINA	DRIED FRUITS, DRIED VEGETABLES.
BANGLADESH	PULSES, RICE, WHEAT AND WHEAT PRODUCTS, MANGOES, PAPAYAS AND DRIED FISH.
BRAZIL	AVOCADO, BANANA, BEANS, DRIED FISH, MAIZE, GUAVA, LEMON, MELON, ORANGE, PAPAYA, PERSIMMON, PINEAPPLE, RICE, TOMATO, WHEAT AND WHEAT FLOUR.
CANADA	WHEAT AND WHEAT FLOUR.
CHILE	COCOA BEANS, DATES, DRIED FISH, MANGO, PAPAYA, RICE, WHEAT AND WHEAT PRODUCTS.
CHINA	CEREAL GRAINS, DRIED FRUITS, LITCHI, MANDARIN, PEANUT.
COSTA RICA	COCOA BEANS, CONDIMENTS, DRIED FISH, LEGUMES, MANGO, PAPAYA, RICE, WHEAT AND WHEAT PRODUCTS.
CROATIA	CEREAL GRAINS, CEREAL MUESLI, DRIED FRUIT, DRIED VEGETABLES.
CUBA	COCOA BEANS, DRIED FISH, MANGO.
FRANCE	DRIED FRUIT (CEREAL FLAKES, CEREAL GRAINS, CEREAL GERM, CEREAL MUESLI AT 10 kGy AND DATES- 6 kGy, DRIED FIGS - 6 kGy, RAISINS-6, RICE FLOUR AND RICE MEAL-5 kGy) AND DRIED VEGETABLES.
HUNGARY	PEAR.
INDONESIA	CEREAL GRAINS, PULSES, GREEN CHILI.
ISRAEL	CEREAL GRAINS, COCOA BEANS, COFFEE BEANS, EDIBLE SEEDS, FRUITS, NUTS, PULSES, VEGETABLES.

KOREA REP. OF	**DRIED MUSHROOMS.**
MEXICO	**CEREAL GRAINS AND PRODUCTS, MAIZE AND PRODUCTS, FRUITS AND DRIED FRUITS, HERBS, MANGO, PAPAYA, RICE AND PRODUCTS, SOY BEAN AND PRODUCTS, VEGETABLE, WHEAT AND WHEAT PRODUCTS.**
NETHERLANDS	**CEREAL FLAKES, DRIED FRUITS, LEGUMES.**
PAKISTAN	**CEREAL GRAINS AND PRODUCTS, DRIED FISH, FRUITS, DRIED FRUITS, HERBS, NUTS, DRIED POULTRY, DRIED MEAT, PULSES, SPICES, VEGETABLES, DRIED VEGETABLES.**
RUSSIAN FED.	**BUCKWHEAT MUSH, DRIED FOOD CONCENTRATE, DRIED FRUIT, GRAINS, DRIED GRUEL, DRIED PUDDING, RICE.**
SOUTH AFRICA	**HERBS, SORGHUM MALT BEER.**
SYRIA	**DATES, DRIED FISH, MANGO, PAPAYA, PULSES, RICE, WHEAT AND WHEAT PRODUCTS.**
THAILAND	**BEANS, COCOA BEANS, DRIED FISH, INDIAN JUJUBES, MANGO, PAPAYA, RICE, SPICES, WHEAT AND WHEAT PRODUCTS.**
UNITED KINGDOM	**CEREAL GRAINS, VEGETABLES, FRUIT.**
USA	**FRUIT, FRESH VEGETABLES.**
VIETNAM	**DRIED FISH, GREEN BEANS, PAPRIKA POWDER.**
YUGOSLAVIA	**CEREAL GRAINS, LEGUMES, DRIED FRUIT, DRIED MUSHROOM, DRIED VEGETABLE- ALL UP TO 10 kGy.**

Note: All approvals mentioned above are for insect disinfestation in general. Only the USA has specific quarantine approvals of papaya, litchis and carambolas. The USDA has issued a policy to approve irradiation as a quarantine treatment of fruit flies at specific minimum doses regardless of commodities.

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COMMERCIAL ACTIVITIES ON FOOD IRRADIATION
(As of July 1997)

Facilities with locations underlined are under construction or planned;
Countries underlined are irradiating food for commercial use

(All facilities use Co-60 as radiation source except those indicated by *
which are electron beam facilities)

Country	*Location (starting date for food irradiation)*	*Products*
Algeria	Mascara	Potatoes
Argentina	Buenos Aires (1986)	Spices, spinach, cocoa powder
Bangladesh	Chittagong (1993)	Potatoes, onions, dried fish
Belgium	Fleurus (1981)	Spices, dehydrated vegetables, deep frozen foods
Brazil	Sào Paulo (1985)	Spices, dehydrated vegetables
	Piracicaba	Fruits, vegetables, grain
	Manaus	
Canada	Laval (1989)	Spices
Chile	Santiago (1983)	Spices, dehydrated vegetables, onions, potatoes, poultry meat
China	Chengdu (1978)	Spices and vegetable seasonings, Chinese sausage, garlic.
	Shanghai (1986)	Apple, potatoes, onions, garlic, dehydrated vegetables
	Zhengzhou (1986)	Garlic, seasonings, sauces
	Nanjing (1987)	Tomatoes
	Jinan (1987)	Not specified
	Lanzhou (1988)	Not specified
	Beijing (1988)	Not specified
	Tienjin (1988)	Not specified
	Daqing (1988)	Not specified
	Jianou (1991)	Not specified
	Beijing (1995)	Rice, garlic, spices
Croatia	Zagreb (1985)	Spices, food ingredients, dried beef noodles
Czech Rep.	Prague (1993)	Spices, dry food ingredients
Cuba	Havana (1987)	Potatoes, onions, beans

Country	*Location (starting date for food irradiation)*	*Products*
Denmark	Riso* (1986)	Spices
Finland	Ilomantsi (1986)	Spices
France	Lyon (1982) Paris (1986) Nice (1986) Vannes* (1987) Marseille (1989)	Spices Spices, vegetable seasonings Spices/herbs Poultry (frozen deboned chicken) Spices, vegetable seasonings, dried fruit, frozen frog legs, shrimp, poultry (frozen deboned chicken).
Germany	Munich (1997)	Spices
Hungary	Budapest (1982)	Spices, onions, wine cork, enzyme
India	Bombay Nashik Vashi, New Bombay	Spices Onions, potatoes Spices
Indonesia	Pasar Jumat (1988) Cibitung (1992)	Spices, rice
Iran	Tehran (1991) Yazd*(1997)	spices Dried fruits, nuts
Israel	Yavne (1986)	Spices, condiments, dry ingredients
Italy	Bergamo* (1996) Padoa*	Spices Spices
Japan	Shihoro (1973)	Potatoes
Korea, Rep.	Seoul (1986)	Garlic powder, spices and condiments
Mexico	Mexico City (1988) Mexico City (1997)	Spices and dry food ingredients Spices and dry food ingredients
Netherlands	Ede (1981)	Spices, frozen products, poultry, dehydrated vegetables, egg powder, packaging material
Norway	Kjeller (1982)	Spices
Poland	Warsaw (1984) Wlochy* (1991) Lodz (1984)	
Peru	Lima (1996)	Spices, food additives, animal feed

Country	*Location (starting date for food irradiation)*	*Products*
South Africa	Durban (1989) Pretoria (1968) Kempton Park (1982) Cape Town (1986)	Spices Shelf-stable food Spices Fruits, spices
Thailand	Patumthani (1989) Leam Chabang (1998)	Onions, Fermented pork sausages, enzymes, spices Service irradiator for food and non-food products
United Kingdom	Swindon (1991)	Spices
USA	Rockaway, NJ (1984) Whippany, NJ (1984) Tustin, CA (1984) Ames, IA* (1993) Mulberry, FL (1992) Schaumberg, IL Columbus, OH Morton Grove, IL Haw River, NC Salem, NJ Hilo, HI (1998)	Spices Spices Spices Spices, poultry Fruits, vegetables, poultry, spices Spices Spices Spices, fruits Spices Spices Tropical fruits
Yugoslavia	Belgrade (1986)	Spices

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