ALTERNATIVES TO METHYL BROMIDE FOR DURABLES AND TIMBER

H.J. BANKS
Cochair, Methyl Bromide Technical Options Committee, Canberra, Australia
apples3@bigpond.com

ABSTRACT

Methyl bromide (MB) has a number of desirable features as a fumigant for durable commodities and timber including a rapid speed of treatment, low infrastructure requirements, recognition by quarantine authorities, broad registration for use, good penetrant ability, and rapid airing after exposure. There is, however, a range of existing and potential alternatives to MB which, alone or in combination, could be adopted to replace the few remaining non-QPS uses of MB. The strengths and weaknesses of each alternative are discussed in the paper.

Change inevitably brings some costs and difficulties as new techniques are learned and adapted to fit the prevailing commercial and regulatory environments. The change may be minor if the alternative rapid-acting fumigants (e.g. sulfuryl fluoride) become registered on foodstuffs and available soon. If non-chemical techniques, such as heating are adopted, there may be substantial investment and changes in procedure needed. However there is also an opportunity as MB is not an ideal fumigant. Adoption of alternative pest management systems may end up providing better and cheaper processes for disinfestation and protection of durables and timber.

Keywords: Methyl bromide, alternatives, heat, phosphine, intergrated pest management, quarantine, pre-shipment, durables, timber

INTRODUCTION

In 1998, the Methyl Bromide Technical Options Committee (MBTOC) estimated 12% of global methyl bromide (MB) production was used as a fumigant on durable commodities, including timber and wooden products. Durables are commodities with a low moisture content that, in the absence of pests, typically can be stored for long periods at normal temperatures without deterioration. Durables include a number of foodstuffs, such as grains, oilseeds, dried fruit and nuts, and cereal-based milled products. Dry non-food commodities such as timber, wooden packaging and cotton as also classed as durables.

Many durables in trade and storage can be attacked by pests, including insects, mites and fungi, causing loss of quality and value. They may also carry pests and diseases that may be a threat to agriculture, health or the environment. There are a wide variety of measures that can be taken to manage these pests so that the damage they cause or risk that they pose is acceptable. Fumigation with methyl bromide is one such measure.

Most current uses of MB on durables, worldwide, are highly specialised. In a few instances, in a few industries and countries, MB use has been in routine use for decades as a well-developed system with a good record of successful use. In such cases, prior to MB phaseout because of its ozone-depleting properties, there was little reason to adopt alternative practices. An example of a widespread specialised use is the fumigation of durables and export timber for quarantine purposes. Fumigation of bagged grain in store in parts of Africa or stored dried vine fruit (sultanas) in Australia are examples of well established, ‘traditional’ use.

Alternatives to MB need to be assessed against the properties of MB as a fumigant and its place in the general management of the quality of durables and timber. MB has a number of desirable features as a fumigant including a rapid speed of treatment, low infrastructure requirements, recognition by quarantine authorities, broad registration for use, good penetrant ability, and rapid airing after exposure. When considering alternatives, these properties need to be viewed against a background of MB as a highly toxic, odourless gas with a substantial ozone-depleting potential and adverse effects on a number of durables, particularly loss of viability, quality changes, taint and residues.

Most remaining uses of MB on durables are as a control agent against insects, mites and vertebrate pests. However MB also has activity against nematodes, snails and fungi, although at much higher dosages (*ct*-products) for these organisms than against insects (typically *ct*-products exceeding 5000

g h m^{-3}, compared with about 200 g h m^{-3} for insects). At very high dosages, MB also can devitalise seeds. Alternatives to these other uses are more restricted than for those for control of insect, mite and vertebrate pests.

MB has a particular application in quarantine and preshipment (QPS) treatments. It has a long and successful history as a quarantine fumigant for durables and timber in trade. In many situations it is the only treatment approved by national quarantine authorities. There is a large body of data on responses of pests to MB to support its use, it is relatively noncorrosive, and it can be applied easily to shipping containers or to bagged, palleted or bulk commodities 'under sheets'. The treatments may be applied before shipment as a precaution against particular quarantine pests or on receival, where there is a detection of a quarantine pest or risk that one such pest is present. These treatments come under a number of international and national agreements and regulations, including particularly the IPPC and various national quarantine regulations.

MB fumigation can also be the treatment of choice in pre-shipment situations where infrastructure limitations and need for a rapid treatment make phosphine fumigation, the main current alternative, a less convenient option.

The challenge now is to develop, register and deploy alternatives to non-QPS uses of MB before the 2005 phaseout date in developed countries, and to meet agreed freeze in consumption and partial phaseout in developing (Article 5(1)) countries. There is also a need to work out ways of avoiding MB for QPS to avoid disruption to trade in the event of restrictions being placed on this emissive MB use. The EC has already curtailed MB use in QPS under regulation EC2037/00 in order to restrict QPS use of MB and assist in protecting the ozone layer. Many see restriction of QPS MB as inevitable, though the timeframe for this is not clear.

ALTERNATIVES

MBTOC has produced two Assessment Reports (MBTOC 1995, 1998) that detail alternatives to MB for durable and timber uses. There are also updates to these reports (TEAP 1999, 2000, 2001) and a new full assessment is in preparation (scheduled for publication in late 2002). Despite the unique properties of MB, these documents show that there are a wide range of potential alternatives to MB use for durables, with a more restricted choice for timber and timber packaging.

A particular difficulty encountered when discussing and assessing MB alternatives is the lack of definition of what existing MB treatments actually achieve in practice, and what they are expected to achieve in terms of level of pest control or kill. The level of tolerance of infestation varies widely with each commercial situation, pest(s) present or possibly present, and even different national standards. Some quarantine treatments aim for Probit 9 level of kill of all pest stages present, while, at the other extreme, treatments may be carried out to kill off easily visible infestation or even just reduce the infestation level somewhat. There is a wide variation in the practise of MB fumigation worldwide, with some treatments being of questionable utility and effectiveness. Treatments are often applied as routine prophylactic measures or commercial requirements without determining whether a treatment is actually necessary. For the purposes of this presentation, a process is considered to be an alternative if it achieves the same (undefined) success as MB, as typically applied.

Generally, there are technically feasible alternatives for almost all non-QPS uses of MB on durables. When considering alternatives to MB, it is clear that the alternatives are situation specific. Development of a single, direct replacement for MB is most unlikely. Selection of the best alternative will have to be made on a case-by-case basis.

For non-QPS MB applications, MBTOC (1998) found only very few instances for durables where there was no technically effective alternative. These were:

- Disinfestation of fresh chestnuts;
- Disinfestation of fresh walnuts for immediate sale;
- Elimination of seed-borne nematodes in some seeds for planting; and
- Control of organophosphate-resistant cheese mites in traditional stores.

World use of MB for these applications was considered by MBTOC unlikely to exceed 50 tonnes per annum and there good progress was reported in developing alternatives.

Some alternatives given below may be more expensive in material cost, or overall, than MB while achieving the same result. Some require capital investment (e.g. heat treatments), but may be competitive with MB at current prices in terms of running cost. There may also be one-off costs associated with the transition from MB. However, many alternatives also avoid the onerous and extensive restrictions associated with fumigations using toxic gases such as MB, and thus turn out to be more appropriate than MB in the long term.

Alternatives for durables and timber are discussed below by technology, not by commodity or situation. Many alternatives are generic, with applicability to many different durables with only minor changes in technique to cope with different pest complexes and situation. Where reference is sought to alternative treatments for a particular commodity, readers are referred to the postharvest section of the TEAP/MBTOC index of alternatives to MB (www.teap.org). This index provides page references to discussion of particular alternative/commodity combinations. The index is to be updated periodically to incorporate progress in development of alternatives.

Alternatives are grouped below under the following categories: Alternative fumigants (in-kind alternatives); and Non-fumigant alternatives (not in-kind alternatives). The latter is a large category – essentially it is all of the non-fumigant technology of stored product protection – and only general approaches as alternatives to MB are given. Alternatives discussed in this paper are those that are available in at least some developed countries now, or look likely to gain registration in some developed countries by the date of MB phaseout (1 January 2005).

Tables 1, 2 and 3 list in-kind alternatives for durables, not in-kind alternatives for durables and alternatives for timber and wooden products respectively. A brief summary of the strengths and weaknesses of particular alternatives is also given. For more detailed discussion the MBTOC Assessment Reports (1995, 1998) should be consulted.

Tables 1, 2 and 3 list single MB alternatives. Many of these options are best applied in combination or sequentially as part of a rational system of protection of durables and timber. For instance, a phosphine fumigation may be followed by cooling to protect stored grain from reinfestation and subsequent need for further treatment. Such a combination may avoid the need for a MB fumigation later in the life of the stored grain prior to export or end use.

Table 1: In-kind alternatives to MB for durables – principal strengths and weaknesses.

Fumigant	Weaknesses	Strengths
Methyl bromide	Ozone depletor, residues, taint	Range of registration/acceptance, reputation
Carbon bisulphide	Flammability, registration, residues	
Carbon dioxide (high pressure)	Infrastructure needs, small scale	Rapid, low toxicity gas
Carbonyl sulphide	Registration	Naturally occurring
Controlled atmospheres (atmospheric pressure)	Slow acting	May not need registration, less regulation
Controlled atmospheres (vacuum)	Slow acting	Low technology, may not need registration
Dichlorvos	Poor penetration, residues, resistance	Useable in unsealed enclosures
Ethyl formate	Highly sorbed, registration	Rapid
Ethylene oxide	Carcinogenic, flammable, infrastructure needs, residues	Sterilant
Hydrogen cyanide	Reputation, unstable in storage, highly sorbed	Very rapid
Phosphine (cylinder gas)	Flammability, corrosiveness, poor action at low temperatures, slow, resistance	Excellent penetration
Phosphine (phosphide	Flammability, corrosiveness, poor	Excellent penetration, low

Fumigant	Weaknesses	Strengths
formulations)	action at low temperatures, slow, resistance, tablet residues	technology, cheap, broad range of registration
Propylene oxide	Infrastructure needs, flammable, registration, highly sorbed	Sterilant
Sulfuryl fluoride	Registration, low effectiveness against egg stage	Good penetration, little sorption

Table 2: Not in-kind alternatives to MB for durables – principal strengths and weaknesses

Process	Weaknesses	Strengths
Integrated Pest Management/Integrated Commodity Management	Can be complex to operate	Avoids unnecessary treatments
Biologicals	Registration, often too specific, live material remains present	
Cold treatment (down to 4°C)	Not rapidly insecticidal	Long term protection, no registration required, no toxic chemicals
Cold treatments (below –15°C)	Not feasible on large scale	Rapidly insecticidal
Heat treatment	Infrastructure requirements for large scale use	Rapid, residue free
Inert dusts	Not active at high humidity, acceptance and product quality, slow acting	Long term protection, low technology process
Irradiation	Public acceptance, infrastructure required, product quality, live, but sterile pests can remain	Active against all pests
Pest exclusion/physical removal/sanitation		Simple process
Pesticides of low volatility (e.g. organophosphates, pyrethroids)	Market and regulatory acceptance, slow, resistance, residues	Low technology process, long term protection

Table 3: Alternatives to MB for timber and timber products

Process	Weaknesses	Strengths
Methyl bromide	Ozone depletor, not very effective against some fungi, does not penetrate wet timber	Low infrastructure needs
Debarking	Not effective on pests in wood, not all timber easily debarked	
Drying	Infrastructure needed, not applicable to whole logs, does not control all pests	
Heat	Infrastructure needed	Can be used on wet timber, can control fungi
Immersion	Requires extensive holding areas, applicable to logs only	
Phosphine	Slow, not active at low temperatures, little fungal control	
Sulfuryl fluoride	Not very effective against egg stages	

CONSTRAINTS TO ADOPTION OF ALTERNATIVES

Registration constraints are a particularly difficult issue in the context of MB alternatives. MB is used on a diverse range of durable foodstuffs. Any new chemical process, including fumigants, faces an expensive, complex and protracted assessment if it is to be registered for use. The total non-QPS MB market on durables is small and fragmented, restricting commercial development of new products. Nevertheless there are several fumigants that are in the process of registration, either to extend their current registrations (e.g. sulfuryl fluoride) or to gain new registration (e.g. carbonyl sulphide).

Development of non-MB quarantine treatments is particularly problematic. Not only do most specific usages consume little tonnage of MB, giving a very small market base, but also new quarantine treatments require extensive bilateral trials and negotiation for acceptance. MB treatment of export timber is one of the few quarantine applications of MB that consume large quantities of MB (worldwide, several thousand tonnes).

One of the main features of MB as a fumigant that make it desirable commercially is its speed of action compared with its principal competitor, phosphine, for protection/disinfestation of durables. MB exposure periods are typically 24h or less for a high level of kill of insect pests, with some pests requiring a 48h exposure. In contrast, phosphine requires several days even at 25°C to achieve the same level of control.

In-transit fumigation of durables with phosphine in ships, or phosphine or carbon dioxide in containers, appears to overcome the lack of speed-of-action of alternatives in the export trade, provided the ships or containers are well sealed and with appropriate safety precautions (see TEAP 2000).

CONCLUSIONS

There is a range of existing and potential alternatives to MB for durables and timber. The challenge now is which of these, alone or in combination, should be adopted to replace the few remaining non-QPS uses of MB. Already MB uses that a few years ago that were held to be irreplaceable have now been substituted with alternatives. For instance the disinfestation of Californian walnuts in storage, formerly a significant MB use, is now largely carried out using cylinderised phosphine.

Change inevitably brings some costs and difficulties as new techniques are learned and adapted to fit the prevailing commercial and regulatory environments. The change may be minor if the alternative rapid-acting fumigants (e.g. sulfuryl fluoride) become registered on foodstuffs and available soon. If non-chemical techniques, such as heating are adopted, there may be substantial investment and changes in procedure needed. However there is also an opportunity. MB is not an ideal fumigant. Adoption of alternative pest management systems may end up providing better and cheaper processes for disinfestation and protection of durables and timber.

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ALTERNATIVES TO METHYL BROMIDE FOR DISINFESTATION OF STRUCTURES AND FOOD FACILITIES

D.K. MUELLER
President, Fumigation Service & Supply, Westfield, IN 46074, United States of America
insectsltd@aol.com

ABSTRACT

Fumigation of milling facilities with phosphine has been difficult in the past due to its corrosive effect on copper, brass and other precious metals contained in electrical, computer and other valuable equipment. A recently registered formulation of phosphine called Eco_2Fume^{TM}, when combined with specific fumigation practices, now makes fumigation with phosphine possible. A large milling facility was fumigated in the United States using low concentrations of phosphine as Eco_2Fume^{TM} combined 3-5% CO_2 and elevated temperatures. The fumigation time was 24 hours. 100% of all life stages of the confused flour beetle were killed by the treatment and no beetles were caught in traps in the following two weeks after fumigation. The cost of the fumigation was comparable to MB. Other companies have adopted this disinfestation method when disinfestation is required. Eco_2Fume^{TM} fumigation is becoming more widely used as a replacement for the ozone depleting fumigant methyl bromide.

Keywords: New phosphine formulation, carbon dioxide, heat combined with fumigant

INTRODUCTION

With methyl bromide (MB) due to be phased out by 2005, the milling industry is under intense pressure to find a safe, viable, legal, and cost-effective substitute for structural fumigation. The Pillsbury Co. has been leading efforts to find such a substitute. In December 1997, the company's board of directors decided to stop the further use of MB in company facilities. Instead, the company has implemented an integrated pest management (IPM) program combining proper sanitary design of equipment and buildings, detailed sanitation procedures, good manufacturing practices, targeted use of labeled pesticides, detailed inspections, and heat treatments. None of these are cure-alls in themselves.

One alternative, phosphine, is well known as an effective treatment against stored product insects. However, traditionally, it has not been used for structural fumigation because of concerns over phosphine's potential to corrode milling equipment. Metals such as copper or brass, precious metals such as gold or silver, small electric motors, smoke detectors, brass sprinkler heads, batteries and battery chargers, fork lifts, temperature monitoring equipment, switching gears, communication devices, computers, calculators, and other electrical equipment may be damaged by exposure to high levels of phosphine. The fumigant also will react to certain metallic salts, which are contained in sensitive items such as photographic film and some inorganic pigments.

FUMIGANT

A new phosphine/ CO_2-based product called Eco_2Fume^{TM} phosphine fumigant has been able to replace traditional phosphine fumigation with tablets. Eco_2Fume^{TM} features a relatively low concentration of phosphine that is monitored strictly to help manage corrosion concerns. Pillsbury set out to test this product in an actual fumigation at its flour mill/warehouse complex in Hillsdale, MI, USA in May 2001 (there was also a fumigation in October 2000).

ECO_2Fume^{TM}, which was granted a label in August 2000 by the Environmental Protection Agency for structural fumigation in food plants, is a blend of 98% carbon dioxide (CO_2) and 2% phosphine, shipped in 205-lb. high-pressure cylinders. Developed in the early 1990s in Australia where more than 12 million metric tons of wheat are fumigated annually, Eco_2Fume^{TM} is manufactured and marketed worldwide by Cytec Industries Inc., West Paterson, NJ (1-973-357-3100/ www.cytec. com).

The Pillsbury facility was the first flour mill in the United States to be fumigated using a patented method combining Eco_2Fume^{TM} with heat and additional CO_2. This patent is held by Fumigation Service & Supply (FSS), which performed the actual fumigation with guidance from Pillsbury

personnel. In order to use Eco_2Fume^{TM}, the user must not only be a certified applicator but also must attend and pass Cytec's product stewardship programme.

METHOD

The fumigation method used in May combined three elements:

1. A modified atmosphere containing 2% to 5% CO_2 by volume. Pest insects breathe through abdominal openings called "spiracles." High levels of CO_2 in the atmosphere cause these spiracles to remain in an open position in order to obtain more oxygen, thus allowing more phosphine to enter the insect.
2. Temperatures inside the building of 30.6°C to 35°C, which cause the insects to breathe faster, also increasing their intake of phosphine. (Note: this is a much lower temperature range than used in unsupplemented heat treatments. A straight heat treatment normally requires a temperature of about 54°C).
3. A low level of phosphine released from the Eco_2Fume^{TM} cylinders.

FSS supplied the Eco_2Fume^{TM} and technical help for the fumigation and served as the fumigator of record. In addition, 15 tons of CO_2 were obtained from Airgas Inc., Radnor, PA (1 610-687-5253/www.airgas. com). The work was done over a weekend, when the plant was shut down.

Two days prior to fumigation, employees were instructed to keep windows and doors closed as much as possible to aid in heating the building. Outdoor temperatures were about 26°C during the day and about 15 °C at night.One day before the fumigation, crews began to pre-seal the building, with special attention to windows, unused doors, window and exhaust fans, roof fans, and other exterior openings that could be sealed without affecting day-to-day operations. Steam heaters were used to raise indoor temperatures. By the day of the fumigation, indoor temperatures hovered around about 32°C.

Before the fumigation began, local emergency personnel were notified, including fire, police, the hospital emergency room, and county emergency 911 central dispatch personnel. All of these were provided with material safety data sheets for CO_2 and Eco_2Fume^{TM}, the Eco_2Fume^{TM} label, and emergency first aid information.

On fumigation day, early morning temperatures outside were about 4°C, with daytime highs about 21°C. That night, the temperature dropped to around 10°C, with calm winds. Nevertheless, interior temperatures remained about 32°C.

Note: Before fumigation, it's important to locate heat sinks inside a milling facility. These areas may be difficult to seal properly for heating. These locations should be cleaned thoroughly and fogged with an appropriately labeled pesticide such as DDVP (Vapona) or esfenvalerate (Conquer). These materials must *always* be used according to label instructions. To check the efficacy of the fumigation, test insect samples were placed both inside the fumigated area and outside the area.

For this test, FSS supplied samples of confused flour beetle, including 25 adult cages, 10 larvae cages, and 10 egg cages. One case of each was selected at random and kept outside the fumigated area as controls. Care was taken to place at least some cages in areas considered "difficult" for the gas to reach.

Before the fumigation proceeded, a final walk-through was conducted to make sure that all non-fumigation personnel were gone, sealing was complete, insect cages were placed, fumigation materials were on hand, equipment and raw materials were removed or protected as needed, and warning placards were in place.

After the walk-through, the Airgas tanker arrived. CO_2 was introduced into the building at 09:00 hours Saturday. After the required levels of 3% to 5% CO_2 levels were reached, Eco_2Fume^{TM} was introduced at 12:30 hours Saturday. The fumigation was completed at 12:30 hours Sunday. To detect any phosphine leakage from the plant, Plant Sanitarian Ernest Ellenwood took exterior air readings at 15:30 hours and 20:00 hours Saturday and 07:00 hours Sunday.

RESULTS

After the fumigation was completed, FSS personnel, wearing appropriate personnel protective equipment, entered the building and began aerating it. Sealing materials were removed, air and ventilation systems turned on, and insect cages retrieved. By startup time Monday, the Eco_2Fume^{TM} phosphine fumigant levels in the atmosphere were non-detectable.

The insect cages were held for 30 days after the fumigation, to simulate the life cycle of confused flour beetle. All of the adult and larval insects exposed to the fumigant were killed. There was no mortality in the adult control cage. The control larvae died; it is thought that improper handling of the cage was the cause. The control eggs hatched into normal larvae over the 30 days following the fumigation. None of the eggs exposed to the fumigation hatched. Thus, 100% of the insects in all stages of life that were exposed to the Eco_2Fume^{TM} combination method were killed.

In addition, pheromone traps for warehouse beetles were placed around the plant before and after the fumigation. No beetles were caught for two weeks following the fumigation.

Finally, FSS calculated the cost of the Eco_2Fume^{TM} treatment and compared it to a comparable methyl bromide treatment. The company calculated a final cost of US$18.53 per 1,000 cu. ft. for MB vs. US$18.06 per 1,000 cu. ft. for Eco_2Fume^{TM}.

Fumigation Services & Supply performed an experimental fumigation at a Pillsbury flour mill and warehouse complex in Hillsdale, MI, in May. At most, 15 tons of CO_2 is introduced into atmosphere.

ACKNOWLEDGEMENTS

This article is based on a paper under preparation by Jerry Heaps, BCE/RS, supplier quality manager; and Ernest Ellenwood, plant sanitarian at Hillsdale, MI, for The Pillsbury Co., Minneapolis, MN (1 612-330-2370/www.pillsbury.com) and David Mueller, insectsltd@aol.com.

ALTERNATIVES TO METHYL BROMIDE FOR THE TREATMENT OF WOOD, TIMBER AND ARTEFACTS IN THE EUROPEAN COMMUNITY

CH. REICHMUTH
Federal Biological Research Centre for Agriculture and Forestry, Berlin, Germany
c.reichmuth@bba.de

ABSTRACT

Methyl bromide (MB) is used to control insects and fungi in timber, wood, wood products and artefacts, partially for quarantine and pre-shipment purposes. Research on alternatives to replace MB has identified some physical measures such as heat, irradiation and kiln drying; and some chemical substances such as sulfuryl fluoride, phosphine and hydrogen cyanide. Insects in artefacts of organic origin can be effectively controlled over a relatively long period using humidified nitrogen containing less than 1 vol.-%. oxygen. A non-MB, rapid-acting quarantine treatment has yet to be developed to control fungi such as *Ceratocystis fagacearum* and insects in logs, timber and wood.

Keywords: wood, timber, artefacts, pest control, alternatives, methyl bromide, heat, irradiation, sulfuryl fluoride

INTRODUCTION

Treatment of export logs or at point of import, is one major use of methyl bromide (MB) fumigation (Anon 1998). The procedures are typically carried out against quarantine pests and are required by plant quarantine authorities as a condition of importation. Two major classes of pests require control: insects and fungi. In some instances control of mites, snails and slugs, and/or nematodes, may be needed.

Approximately 5% of the global MB production is consumed controlling insect pests and some fungi of wood products, timber and artefacts in the following applications:

a) Treatment of internationally traded logs also in quarantine: Timber, which is infested by the oak wilt fungus *Ceratocystis fagacearum*, a quarantine pest for Europe, is usually fumigated with MB under gas-proof sheets or in chambers at the high rate of 240 g/m³, prior to export from the USA (Schuerch 1968, Schmidt *et al.* 1982, Rütze & Liese 1983, Kappenberg 1998).

b) Treatment of dwellings and other buildings: Pest control in structures is used to prevent or control pests in either an entire structure, or a portion of a structure. Many conditions exist which require structural pest control; only some of these are treated primarily by MB fumigation (Unger *et al.* 1992). The main application is the control of direct structural damage by wood-boring insects to domestic, commercial and historic buildings. Two major classes of pests require control: insects and fungi.

c) Treatment of wood products also in quarantine: Generally, wood products which require treatment with MB can be classified into two categories: those items separate from buildings and structures, and those forming an integral part of a structure. Wood products include raw material such as logs, sawn timber and products made of wood such as pallets, bamboo ware, packaging materials and other items of quarantine significance. For pests that infest wood products, alternatives for control can be classified into two types of treatments: those that are applied directly to the product, and those that utilise an enclosure for treatment in a confined space. The nematode *Bursaphelenchus xylophilus* is a European quarantine pest that can be found in imported timber, wood and wood products.

d) Disinfestation of museum objects: The preservation and protection of artefacts represents a broad area of interest including commercial aspects and artefacts of substantial value or of irreplaceable cultural and national significance. Many of the objects held in museums, libraries and similar repositories are subject to attack by rodent and insect pests and, under highly humid conditions, by fungi. Infested materials include those made of wood, paper, leather, and skins, feathers, wool and other natural fibres. Artefacts and similar objects made of organic materials are

also objects of international trade and may carry pests of quarantine significance. Many museums, libraries and similar repositories have installed a quarantine system to ensure that only insect-free artefacts enter the location. Freezing or treatment with nitrogen gas can be the option for quarantine (Pinniger 1991). Emphasis is thereafter focused on minimising the risk of introducing damaging pests.

Quarantine treatments in international trade require high speed and thoroughness of the disinfestations, which is provided by the use of MB. In museums, longer exposure periods for pest control are not a constraint.

ALTERNATIVES TO METHYL BROMIDE

Chemical Substances

Sulfuryl fluoride

For a), b), c), and d) above: Sulfuryl (sulphuryl) fluoride (SF) was developed in the late 1950s as a structural fumigant, mainly for termite control (Stewart 1957, Gray 1960). It is applied to buildings, which are covered with gas-proof sheets or otherwise sealed. The gas provides good penetration, requires a short fumigation period of approximately 24h against adult insects. The egg stage of many insects appears to be up to 10 times more tolerant than adult insects.

SF is considered a practical alternative to MB for many uses, particularly for quarantine fumigation applications (Woodward & Schmidt 1995) and for use in empty food processing facilities (Reichmuth *et al.* 1997). It is toxic to post-embryonic stages of insects (Kenaga 1957) but the eggs of many species are very tolerant especially at low temperatures, requiring concentrations of over 50 g/m³ and exposures of up to three days for complete kill (Williams and Sprenkel 1990). Eggs of *Ephestia kuehniella* at 25°C required a ct-product of about 1000 gh/m³ to prevent hatch and 800 gh/m³ to prevent emergence (Bell & Savvidou 1999).

SF is currently registered for use under the trade name Vikane®. It is used in some European countries to control a wide range of pests including: wood-destroying beetles, furniture and carpet beetles and clothes moths. Research is ongoing to evaluate the potential of this chemical for timber treatment for plant quarantine purposes (Anon 1998). Efforts are underway to develop treatment schedules to fumigate timber being imported into the USA, Europe and Japan to control wood-destroying beetles or fungal pathogens (Chambers & Millard 1995; Kappenberg 1998).

Phosphine

a) Fumigation of logs using phosphine is effective in controlling bark beetles, wood-wasps, longhorn beetles and platypodids, at a dose of 1.2 g/m³ for 72 h exposure at 15°C or more. The length of time required to complete treatments restricts its commercial acceptability. New developments include phosphine to treat bamboo in transit to avoid MB quarantine treatments in Japan.

b) and d) Phosphine is used to fumigate wooden objects, paper and other materials of vegetable origin. With some materials, e.g. furs and paper, phosphine may be preferred to MB because of the reduced risk of taint. Phosphine may adversely affect metals like copper, silver and gold and pigments in paintings and is therefore rarely used for treating objects of this type. Compared to MB at the same temperature, fumigation with phosphine requires a longer exposure period for complete control of insects.

Hydrogen cyanide

b) The first use of hydrogen cyanide (HCN) for control of *Anobium* spp. dates back to 1921 when the king's castle in Kalmar/Sweden was fumigated (Unger 1988). The formation of chemical complexes with various metals and its high water solubility restrict the application of HCN, but it has potential.

d) HCN is also used for pest control in artefacts, with a recommended dosage of 20 g/m³ for 72 h exposure. The use of HCN is very limited because of its low fungicidal effect and slow desorption, as well as possible reaction with the treated material.

Bifluorides

a) and c) the timber is immersed in a 10% solution of the chemical for five to ten minutes. No monitoring equipment is required. Temperatures must be above freezing. This relatively inexpensive treatment is accepted in many European countries.

Contact insecticides

b) and d) Contact insecticides are used as part of pest management strategies in museums. A variety of specific insecticides based on pyrethroids like permethrin, cypermethrin, deltamethrin, and cyhalothrin or based on organosphates like dichlorvos and chlorpyrifos are the most common. In Japan, artefacts such as museum specimens, collections, books antiques and art crafts are treated with cyphenothrin, applied as a 1% solution in liquid carbon dioxide, to control the cigarette beetle, the powder-post beetle, the black carpet beetle, the book borer, the oriental silverfish and others.

Contact insecticides/preservatives

a) Contact insecticides, including dichlorvos, may be applied as part of a pest management strategy. There is an approved quarantine treatment involving immersion of logs in water and treating the upper surface of the logs above the water level with an insecticide mixture. In the USA and Japan, a dip-diffusion treatment in a solution of borate is registered for sawn timber. Australia allows pressure impregnation of insecticidal mixtures as an alternative to MB for treatment of wooden pallets for control of *Sirex noctilio* and other wood pests.

b) Products such as boric acid, pyrethroids, silica gel, diatomaceous earth and sodium octaborate tetrahydrate, are applied as spot treatments or into cavities created by insects in the wood. Application of dusts can be labour-intensive and requires boring into the wood in the structure.

Physical methods as alternatives to MB

Controlled Atmospheres

a) The efficacy of controlled atmospheres (CAs) with low residual oxygen content at elevated temperatures for treatment of logs for export is being studied in New Zealand (Anon 1998).

b) Carbon dioxide instead of MB has been effectively used for insect control in furniture and artefacts in a large church in Germany. Insufficient sealing resulted in excessive use of carbon dioxide.

c) CAs have the potential for use in wood products but long exposure times are required for treatment at ambient temperatures (Adler *et al.* 2000).

d) CAs are being increasingly used for insect control in artefacts and replace MB in this field. The treatment may take 2 to 8 weeks in gas-tight chambers (Gilberg 1991; Reichmuth *et al.* 1992; Newton 1993; Adler *et al.* 2000). CAs with humidified nitrogen in a carefully constructed gas-tight enclosure, can control all stages of museum insect pests after purging to reduce oxygen contents well below 1 vol.-% and holding the artefacts for up to 30 days in these conditions. Atmospheres with more than 60 vol.-% carbon dioxide in air are proving to be also effective replacements for MB in museums (Newton 1993).

Heat and cold treatments

a) Steam heat or hot water dips are generally most suitable, but kiln drying or dry heat is suitable for sawn timber. Heat treatment by steam has been shown to eradicate all tested fungi when 66°C is held at the centre of wood for 1.25 h (Miric & Willeitner 1990, Newbill & Morrell 1991). Using microwave energy as a heat source is also a possibility.

d) Heat and cold treatments can be used to disinfest artefacts, provided condensation and cracking of wood and other sensitive materials can be avoided by appropriate control of moisture. Exposure to –18°C can disinfest woollen artefacts of clothes moths in a few days (Brokerhof *et al.* 1993). A commercial technique employing heat and humidity to disinfest museum artefacts has been field-tested. Strang (1992) reviewed heat and cold treatments for artefacts.

Irradiation

a) A dose of 6 – 8 kGy kills the nematode *Bursaphelenchus xylophilus*, an economic and quarantine pest of timber (Anon 1998). Collaborative research in Russia and the USA aims to introduce gamma irradiation as quarantine treatment for logs.

c) Some wood products are commercially irradiated on arrival in Australia as a quarantine treatment.

d) Irradiation has been effectively used to control insect and fungal problems in historical artefacts, art objects, and books and paper archives. The minimum recommended dose for pest control ranged between 0.5 kGy to 1.6 kGy for insect control (Fan *et al.* 1988).

MISCELLANEOUS

Under water dipping

a) Dipping logs under water is necessary to improve plywood quality. Immersion of logs in water for more than 30 days suffocates pests and is an approved treatment. The upper surface of the logs above the water level is sprayed with an insecticide mixture. In Japan, approximately 14% of the logs imported in 1992 avoided MB due to the use of this technique.

Removal of bark

a) At present, removing bark from logs prior to export is practised to a very limited extent as a control measure against pests, particularly bark beetles.

c) Debarking, together with conversion to sawn timber in the country of origin, appears to have the potential to reduce a need for MB where bark-borne pests are the objects of the treatment, including quarantine treatments.

CONCLUSIONS

Replacement of MB as a pest control agent is progressing. Sulfuryl fluoride is a good candidate that can be used in many situations. Nitrogen and carbon dioxide with low residual content of oxygen are already considered replacements for MB in museums for pest control of artefacts. Irradiation, kiln drying and other applications of heat seem to be promising new solutions for disinfestation and disinfection of timber and wood.

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PREVENTATIVE CLEANING AND INSPECTION AS AN ALTERNATIVE TO METHYL BROMIDE FOR TREATMENT OF FOOD FACILITIES IN THE EUROPEAN COMMUNITY

M. RAYNAUD
Agro Technology Manager, Frito Lay International, Thurmaston, United Kingdom
magali.raynaud@intl.fritolay.com

ABSTRACT

Insects and other pests in food facilities constitute an unacceptable health risk and must be eradicated to maintain food safety. Fumigation is reactive, very costly and can cause other problems such as residues, ozone depletion and facility shutdown. A more effective and proactive way of eradicating insects is by sanitation and inspection. A well-integrated cleaning and inspection programme within a food facility prevents insect development and provides a safe environment by reducing the risks of foreign object contamination. This paper describes the cleaning programme, schedules, procedures, record keeping, inspection periods, inspection personnel and training, and expected results. Early detection and eradication of insect activity eliminates the need for pesticide treatment, saves time and reduces costs.

INTRODUCTION

Insects and other pests are a common feature in food facilities. However, in the interest of food safety, they are not acceptable and must be eradicated. Very often, at the first indication of insect activity, fumigation is used on materials and on facilities. However, fumigation is a reactive method, it is very costly and can engender other issues including fumigant residues, ozone depletion and facility shutdown. A more effective and proactive way of eradicating insect activity is through sanitation and inspection. Indeed, the best prevention method against insects and pests in a food facility is thorough cleaning and inspection. If insects are denied food and a time interval in which to breed, they will go elsewhere. A comprehensive, integrated cleaning and inspection programme within a food facility will not only prevent the development of insect activity but also provide a safe environment, improve food safety by reducing the risks of foreign object contamination and provide support for a sound “due-diligence” programme.

CLEANING PROGRAMME

Cleaning is an essential and integral part of any successful food or food related business. Cleaning will prevent risks of contamination from micro-organisms, foreign objects and insects.

A robust cleaning programme must start with the commitment and involvement from people at all levels in the development of the programme. Cleaning standards must be set, clearly defined and communicated and everyone must be personally committed to ensuring that satisfactory standards are constantly achieved. All personnel should be instructed and motivated through training and communication. The system should be easy to use and practical. In addition adequate resource of staff, materials and equipment should be available. The more time spent on cleaning, the less time and expense will be required to use chemicals to eradicate insect problems.

A planned approach to cleaning is essential to prevent infestation and contamination. Cleaning can be divided into three categories: housekeeping, periodic cleaning and deep cleaning.

Housekeeping covers clean-as-you-go tasks such as floor sweeping, spillage removal and regular surface cleaning. Removal of spillage and debris inside as well as outside the facility will make the area unattractive to rodents, birds, insects and other pests. Housekeeping should cover areas such as grain receiving pits, grain spillages, removal of sweeping bags and waste dump areas.

Periodic cleaning refers to equipment and areas that need to be cleaned on a frequent basis, according to a pre-planned schedule and following documented cleaning procedures. Periodic cleaning must be recorded and the use of a Master Sanitation Schedule (MSS) is useful in the planning, monitoring and communication process. Examples of items to include on an MSS would be grain receiving pit, drag conveyors, the base of elevators, housings, dead-ends such as the drives to conveyors, under silos, tunnels and harvesting equipment.

Deep cleaning refers to equipment or areas which cannot be cleaned periodically because of their location, convenience, the need for special cleaning equipment, and may require the hire of an external company. For instance, interiors of silos can only be cleaned when the silos are empty and special equipment for silo entry such as harnesses can be required. Walls, ceilings, overhead beams, roofs, silos and stores will need to be deep-cleaned at least once a year, depending on the location, weather, temperature and likelihood of insect ingress.

CLEANING SCHEDULES / MASTER SANITATION SCHEDULE

A cleaning schedule is a list of all areas and items that require cleaning. It must also include the frequency of cleaning and the person(s) responsible for carrying out the cleaning. When this is compiled, it should provide a visual overview of the cleaning requirements in the whole facility and is referred to as a Master Sanitation Schedule. An MSS is a plan of the work to be completed during the year ahead. It is usual for each area/department to have its own MSS. Figure 1 shows an example of MSS. This schedule allows you to see at a glance what needs to be done on a weekly basis.

Figure 1: Example of a Master Sanitation Schedule in a grain receiving area

Task	Frequency	Respons-ibility	WEEK 1	WEEK 2	WEEK 3	WEEK 4	WEEK 5	WEEK 6	WEEK 7	WEEK 8
Receiving Pit	Weekly	X								
Elevator	Two weekly	Y								
Conveyor A	Two weekly	Y								
Conveyor B	Two weekly	X								
Tunnel	Three weeks	X								
Ceiling	Monthly	Y								
O/h beams	Monthly	X								
Silo	Two months	Y								

Frequency of cleaning will depend on the type of area, external factors such as temperature and on the life-cycle of the targeted insects. Equipment and areas prone to insect infestation should be cleaned on a minimum of a weekly basis and no less than once a month.

The MSS should include tasks to be completed on and appropriate basis such as weekly, monthly or quarterly, and should be accompanied by a cleaning procedure. The schedule can be modified according to the level of dust accumulation. Harvest equipment and other equipment only used seasonally can be put on a modified schedule.

CLEANING PROCEDURES

Equally important to the MSS are the cleaning procedures that will explain what needs to be cleaned, how, when, why, by whom, with what and so on. For all weekly and periodic cleaning tasks, a fully detailed procedure is required. The procedure should indicate:

- Task, location, frequency, cleaning responsibility and inspection responsibility;
- Supplies and materials, i.e. equipment and chemicals required to carry out the task such as vacuum cleaner, hoses, tools, eye protection, gloves, brushes, cleaning chemical preparation;
- Safety measures and critical points which must be undertaken to safeguard the people and the products, e.g. the system must be emptied at the end of the production run, electrics must be covered, area must be isolated. For many specialist areas such as silos, a full Health and Safety risk assessment should be undertaken to minimise the possiblity of accidents;
- Step by step method of cleaning, e.g. remove all lids from the conveyor. Keep bolts and nuts in a safe place. Vacuum out all dust and debris in the conveyor, in the dead ends, in the motion sensor, in the slide gates. Replace the lids and all nuts and bolts; and

- Standard of cleaning to be achieved, e.g. all dust, old product and debris must be removed; clean from top to bottom; inspect and clean ledges inside equipment/silos.

If external contractors are to be used, they should be given, or they should develop cleaning procedures and schedules, in line with company standards.

CLEANING RECORDS

The provision of cleaning records is an essential part of a "due-diligence" defence. Any cleaning undertaken should be recorded on the MSS. This enables you to check progress-to-date and what tasks remain outstanding. Tasks should be signed off on completion by the person who carried out the cleaning and also by a responsible person, such as the Hygiene or Area Manager, upon inspection of the cleaning standards.

INSPECTION PROGRAMME

Although a good cleaning programme will certainly reduce insect activity, it will be even more effective if it is integrated with a good inspection programme. Inspections will not only allow for early detection of insect presence, but also identify poor cleaning practices and potential risks of contamination. To that end, an internal inspection programme should be in place at the food facility.

INSPECTION FREQUENCY

Inspection frequency should be tailored to the type of insects and their life-cycle, to the location of the facility (warm/cold country), to the time of the year (winter/summer), but the recommended frequency is a minimum of once a month.

PHYSICAL INSPECTION

The internal audit must consist of a physical inspection and an audit of procedures and records. The physical inspection must be very thorough and detailed. Adequate equipment must be used, such as a torch to look into dark corners and places, a scraper to look for insect activity, a flexible mirror to look under or behind equipment, a screw-driver to open electrical panels, drives or lids, and of all these whilst compliant with the Health and Safety legislation.

Insect activity will start outside the facility, therefore all areas of the facility, including roof and external grounds must be inspected in order to evaluate and prevent attraction of insects. Such attraction could be pools of water, product debris, old equipment and other items.

Physical inspection does not mean strolling around the facility, but inspecting every corner, every room, every ledge, every gap, underneath, over, on the sides, inside equipment. It would be wise to wear appropriate clothing.

INSPECTION SCHEDULE

The food facility should be divided into sections, and only one section should be inspected at a time, on a rota basis. The inspections need to be very thorough, and inspecting the whole facility at once could lead to tiredness and lack of attention and issues could be missed. For instance, the facility could be divided into four sections, and a different section could be inspected every week.

INSPECTION TEAM

The inspectors should receive adequate audit training. The inspection should be carried out by a cross-functional multi-disciplinary team. For example, inspections will be much more effective if a new pair of eyes are brought in every now and then. Although the inspection programme should be the responsibility of the Food Safety Manager, personnel from different functions within operations, such as raw materials, finished goods or manufacturing; and front line operators as well as managers should take part in the audit process.

RECORD KEEPING

At the end of an inspection, the auditor should give verbal feedback on the audit outcomes to the plant management team. Key points and comments should be raised and any corrective actions required should be time-bound, discussed and agreed. A written audit report, including issues, corrective actions and time limits, should be left on site.

Where a non-conformance or insect activity has been identified, there is a need not only to correct the immediate situation but also to identify, where possible, the underlying cause of the problem. Once this has been identified, actions should be taken to prevent recurrence.

OUTPUT

A comprehensive and preventative cleaning and inspection programme will render the facility unattractive to insects and therefore remove the need for chemical treatment.

Such a programme must not only be in place in the food facility, but must be applied to the whole crop to consumer chain, this chain only being as strong as its weakest link. Cleaning and inspection of equipment should take place at every stage of the production process, from site selection, to site preparation, to plantation, to crop management, to harvest, to transport. Early detection and eradication of insect activity, through inspections and effective cleaning, eliminates the need for pesticide treatment, hence saving the facility time and money.

ALTERNATIVES TO METHYL BROMIDE FOR TIMBER TREATMENTS

A. LÓPEZ DE ROMA
Centro de Investigación Forestal (CIFOR), Madrid, Spain
iroma@inia.es

ABSTRACT

This paper describes some of the consequences of the Biocidal Products Directive 98/8/EC on the authorisation of wood preservatives and approval of active substances in the European Community. Consideration of the environment, human safety and treatment cost is required when searching for alternatives to methyl bromide for wood treatments. Further research is required to find biological agents or natural products that have low environmental impact, physical treatments and to determine risk evaluation based on the location of where the wood presevation is carried out.

Keywords: Biocides products directive, methyl bromide, risk assessment, wood preservation, wood preservatives.

INTRODUCTION

The Biocidal Products Directive 98/8/EC covers the placing of biocidal products on the European Community market and establishes which active substances, including substances or microorganisms that work with general or specific action against hazardous organisms, are approved for use within the European Community. The biocidal products containing these active substances must be approved for use in any Member State in which it could be registered for commercial use. The authorisation obtained in a Member State in which the product is first registered should be recognized by the other Member States.

The aim of the BDP is to ensure a harmonised, high level of protection for human, animal and the environment for the use of biocidal products. BDP also creates a European market without internal constraints. This Directive, from the legislation point of view, its very complex as it requires core data common to all active substances and biocidal products. In addition, specific data requirements are defined for each of the 23 biocidal products by type. The BPD covers all products as well as their variations in risk.

Technical Guidance Notes (TGNs) provide full details on the toxicologocial, ecotoxicological and efficacy tests required for the different biocidal products and their active's substances. TGNs are now finalised (December 1999) and are to be used as reference for all chemical active substances but not for the biological biocides.

Type 8 products within the BPD list are defined as "products used for the preservation of wood, from and including the raw-mill stage, or wood product by the control of wood destroying or wood-disfiguring organisms". These products may have preventive and curative character. Methyl bromide (MB) may have a curative character that destroys organisms that infect wood it cannot protect against reinfection.

Active substances used in wood preservation that were on the market before 14 May 2000 must be revised before 27March 2004 according to Commission Regulation 1896/00. Products containing one or more active substance that were on the market before 14 May 2000 must be authorised following the specific details and technical process for product assessment contained in the BDP Directive and its TGNs.

Due to this Directive, some current wood preservative formulations may be, in a short period of time, out of the market because the costs of generating the data and the preparation of the dossier makes the product uneconomic. It is extremely unlikely that any new active substance will be developed only for use as a wood preservative as it would not be economic. The wood preservation industry is concerned there will be discontinuity of future preservative supplies due to a lack of warranty for active substances.

Other problems outlined by the BPD relate to the difficulty of meeting the informational requirements for their final authorisation of wood preservatives due to the lack of information allowing a correct risk assessment. Several situations should be considered:

- Applications method (brushing, dipping and vacuum-pressure impregnation);
- Domestic or industrial applications;
- Personnel qualified or not; and
- Wood treated by different type of exposure: indoor, outdoor, ground contact or without, continued or discontinued submersion in water.

To compensate for this lack of information in the past years, many initiatives had been formulated. The most important actions have been:

- COST E2 Wood Durability;
- European Wood Manufacturers Group;
- OECD workshop on "Assessing Environmental Exposures to Wood Preservatives";
- Working Groups of TEC 38/CEN (WG 21, Natural Durability and Risk Types and WG 27 Exposure Aspects); and
- COST E22 Wood ´s Environmental Optimisation.

Many of these working groups and meetings achieved improvements for the final version of the TGNs, but still many points are not resolved. For example, environmental risk assessment depends on the place and conditions where the wood treatment is taking place (industrial or domestic application). Also there is no consideration of the risks produced during the wood treatment itself or during the final drying process, as well as the problems caused by elimination of treated woods.

The situation of wood preservation is complicated by the fact that treated wood is the main product for construction and must fulfil the essential requirements of the Construction Products Directive (89/106/ EEC), especially the characteristic of durability.

In order to reduce the toxicological and ecotoxicological risks required by BPD without reducing the efficiency of wood treatments it is necessary to carry out fundamental research in wood protection in the following areas:

- Protection with biological agents or natural products. This could be of interest due to the low impact on the environmental but they are generally are not economically competitive;
- New chemical wood preservatives with high level of efficiency with less toxicological risks and known to be harmless to the environment;
- Physical treatments; and
- Environment risk evaluation according to where the wood is preserved.

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