# Integrated Pest Management in Food Processing:

# Working Without Methyl Bromide

*This document was produced by:*

*Methyl Bromide Industry Government Working Group:*
*Subcommittee on Alternatives for the Food Processing Sector:*


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## Foreword

*The Methyl Bromide Industry Government Working Group was set up as a consultative forum to provide direction on effective implementation of Canada's program for the control and phase out of methyl bromide under the Montreal Protocol on Substances that Deplete the Ozone Layer. A Subcommittee on Alternatives for the Food Processing Sector was established to address alternatives to methyl bromide fumigation for pest management in the food processing sector.*

*There is unlikely to be a single product to replace methyl bromide for all facilities. An integrated pest management approach that combines all available prevention and treatment strategies is therefore the preferred approach. This document outlines the steps required to adopt integrated pest management for food processing facilities.*

*The Pest Management Regulatory Agency is committed to promoting sustainable pest management, and is pleased to have acted as Chair and Secretariat for the Subcommittee and to publish this document on their behalf.*

## Executive Summary

*Methyl bromide is identified under the Montreal Protocol on Substances that Deplete the Ozone Layer as an ozone-depleting substance. Schedules have been established for its reduction and phase out. A large portion of Canada's methyl bromide use has been in large space fumigation, for example, in flour and oat mills, and in food processing operations.*

*The Canadian Methyl Bromide Industry Government Working Group established a subcommittee to examine alternatives to methyl bromide fumigation for the food processing sector. A number of pest management products and techniques exist or are under development for use in food processing facilities. It is clear, however, that there will not be a single treatment or practice that will suffice to replace methyl bromide.*

*A combination of preventative and treatment practices will be necessary, therefore, for effective pest management. The Subcommittee has developed a guideline of practices to facilitate use of an integrated pest management (IPM) approach in food processing facilities. The steps involved in an IPM strategy are as follows:*

- *assessment;*
- *development of pest management plan;*
- *plan implementation;*
- *evaluation of plan; and*
- *adjustments.*

*The pest management plan should encompass the following elements:*

- *building and materials design and retrofitting;*
- *exclusion practices;*
- *good sanitation practices;*
- *building maintenance;*
- *inspections and monitoring;*
- *pest identification; and*
- *physical and chemical controls.*

*Key points to implementation of an IPM approach for food processing are:*

- *an operational IPM strategy and pest management plan will need to be developed and tailored for specific locations and needs;*

- *the key to success is a commitment by senior company management to proactively develop and implement an IPM strategy in a facility, and allocate expertise to lead, manage and fine tune an effective IPM program; and*

- *consistent and effective sanitation is the most important component of an IPM plan.*

# I. INTRODUCTION

Methyl bromide has been an effective and important tool for controlling pests in food processing facilities. However, methyl bromide has been identified as an ozone-depleting substance under the Montreal Protocol, and targets have been set for reduction and phase out of most uses of methyl bromide. Phase out dates and interim reduction targets are outlined in Appendix 1.

The Methyl Bromide Industry Government Working Group is a consultative forum to provide direction on effective implementation of Canada's program for the control of methyl bromide. Progress has been made through the efforts of industry and government using demonstration projects, research trials, and joint initiatives with other countries. In early 1997, a subcommittee was established to pursue alternatives to methyl bromide fumigation for the food processing sector, using a broad integrated pest management (IPM) perspective. The work would not focus solely on identifying replacement treatment products, but would look at such products within an inclusive management strategy.

This document provides a guideline of practices to facilitate use of IPM in food processing facilities. The steps involved in an IPM strategy are as follows:

- assessment;
- development of pest management plan;
- plan implementation;
- evaluation of plan; and
- adjustments.

An operational IPM strategy and pest management plan will need to be developed and tailored for specific locations and needs, using this document as a template. A list of references that may be useful in preparing specific plans is provided in Appendix 2. In addition, development, documentation and implementation of a sanitation and pest control program is one of the prerequisite programs under the Food Safety and Enhancement Program (FSEP) of the Canadian Food Inspection Agency. FSEP is a program to encourage the development, implementation and maintenance of Hazard Analysis Critical Control Points-based programs in federally registered food processing establishments.

At present, there are areas where alternative treatments to methyl bromide are not available. Procedures and criteria are being developed in Canada and under the Montreal Protocol for emergency and critical use exemptions. One of the criteria for such exemptions is a demonstration that there are no technically and economically feasible alternatives and that there is a concerted effort to develop and gain approval for alternatives and substitutes. Development and adoption of this integrated management strategy may be a key part in meeting these criteria. In cases where a critical use of methyl bromide may be allowed, it should continue to be one part of the overall integrated management approach.

The aims and anticipated benefits of this document are as follows:

- promote the use of IPM and guide development or improvement of IPM strategies in the food processing sector;
- provide a common basis of understanding among those dealing with food processors,

including ingredient suppliers, pest control product manufacturers and suppliers, and government agencies;

- provide a basis for determining needs for new tools, both treatment alternatives and broader management tools, and facilitate the research needed to identify products and to develop data bases for regulatory approvals; and
- reduce the number of circumstances under which methyl bromide use may be considered necessary and, where necessary, provide a basis for seeking emergency and critical use exemptions.

Adoption of an IPM program may not necessarily eliminate the need for methyl bromide in any particular facility. It is clear that there will not be a single treatment or practice that will suffice to replace methyl bromide. Regardless of the preventative or treatment options available, therefore, a combination of the practices described in this document will be necessary. A commitment to IPM by management of food processing facilities will be especially important, building on the key leadership role that Canadian industry has played and continues to play in adapting to the phase out of methyl bromide.

## II. INTEGRATED PEST MANAGEMENT FOR FOOD PROCESSING

Integrated pest management (IPM) is a dynamic combination of varied control practices designed and implemented to meet the need of maintaining controls of pests using a variety of techniques. There are numerous definitions of IPM, following a similar theme. The Expert Committee on IPM (of the Canadian Agri-Food Research Council) describes IPM as “a decision-making process that uses all necessary techniques to suppress pests effectively, economically and in an environmentally sound manner”. By using a variety of methods, pests can be managed without total reliance upon pesticides.

IPM provides a systems approach to the replacement of methyl bromide. It is generally acknowledged that there will not be a single pest control product that will serve to replace methyl bromide in all its uses in the food processing sector. Therefore, a variety of management methods, adapted to local situations, will be needed. At least some of the elements of IPM are already used in many food processing facilities.

The steps outlined in this section are necessary for implementing an ongoing IPM strategy in a food processing facility. The same basic steps can equally be used to address an unanticipated specific pest problem that arises, such as the introduction of a new pest in a shipment. When designing and building a new facility or renovating an existing facility, it is essential that the IPM strategy be incorporated at the earliest stages.

### 1. Assessment

The first step of the IPM strategy is an assessment of the actual or potential pest problem. In developing a new facility, identification of potential pest problems can be based on past experience, knowledge of similar facilities, and knowledge of particular pests in the region in which the plant is located. Some useful references are listed in Appendix 2.

For existing plants, a similar assessment can be performed. In addition, there should be a specific assessment of the pest situation in the plant.

- **Inspections** are used to identify the type and variety of pests that are or may be present. Detailed inspection is required of both the interior and exterior of a facility on a continual basis. Incoming commodities may vary at different times of the year, and pests associated with those commodities may also vary. In addition, different pests will seek harbourage during different times of the year, and therefore inspections need to be undertaken at frequent intervals.

- **Monitoring**, by trapping, for example, is used to determine the intensity of a pest problem and to determine the distribution of pests in and around a facility. The monitoring program should include schedules for placing and checking traps or other techniques.

- **Observations** in and around the facility can be used to confirm the results of inspection and monitoring.

## 2. Development of Pest Management Plan

The next stage is to develop a pest management plan for implementation, based on the assessment findings.

- **Information gathering** is required after an assessment is made of the actual or potential pest problems in a plant. Information is needed on the biology of the pest organisms and their management. References and sources of information include:

  - pest control companies;
  - pest management publications: trade magazines, journals;
  - reference texts; and
  - Internet sites.

  Some useful references are listed in Appendix 2.

- **Elements** that should be included in the pest management plan[1] for effective IPM include:

  - building and materials design and retrofitting;
  - exclusion practices;
  - good sanitation practices;
  - building maintenance;
  - inspections and monitoring;
  - pest identification; and
  - physical and chemical controls.

[1]The elements of the pest management plan are described in more detail in Section III.

## 3. Plan Implementation

Implementation of the pest management plan starts with a facility's management and decision makers. They must have an awareness of what needs to be accomplished and a commitment to making successful pest management an ongoing activity. The leadership shown by the management of a facility and a company, indeed by the industry as a whole, may be the most important step in adoption of IPM.

- **Education:** Employees must be trained with an awareness of the IPM program and its elements, particularly sanitation. They should learn to recognize pests, pest habitats, and pest conditions, and ways to deal with them.

  In some cases, facilities have made sanitation and other aspects of pest management a responsibility of all working units, not solely the sanitation department. However, the specific responsibilities will depend on the division of responsibilities within specific plants.

  Employees can be involved in training, in design of programs, facilities and equipment, in validation, and in treatments, subject to the licensing requirements for application of pesticides. Contract companies are often hired for pest control, but they can also provide knowledge and training to a facility's staff. Food and pest control industry associations, consultants and training organizations are also valuable sources of knowledge and training.

- **Communication**: Written procedures should be available for all aspects of an IPM program, including cleaning, monitoring, identifying and correcting of problems, and treatments. A written procedure will set out a proper and standardized way of conducting an operation, and incorporate a process of verification that the operation was conducted. Attention to detail is required both in setting out and following the written procedure.

There are numerous sources of information that can help determine what written procedures are needed, guide the development of a written procedure, or provide a specific written procedure; a few are listed in Appendix 2.

- **Monitoring Activities** must be aimed both at the target pest populations and at the implementation of the pest management plan itself. Pest monitoring is one of the elements of the plan, and monitoring the implementation of the plan requires accurate record keeping.

- **Record Keeping:** The report system that is incorporated in the pest management plan must be user friendly to facilitate the procedures being used. The written procedures should be followed as a day to day, ongoing activity, not a periodic exercise.

### 4. Evaluation of Plan

The overall effectiveness of the pest management plan must be reviewed based on monitoring of pests and inspection reports. The evaluation should answer the following questions:

- Was the anticipated or required level of control achieved?
- If not, why not?

### 5. Adjustments

Changes to the pest management plan are designed and implemented based on the analysis of the plan's effectiveness. Changes can be made to achieve the desired level of control; to adjust to new situations, such as new equipment, new products, and new pests; or to incorporate new pest management techniques. The adjustments begin a renewed round of assessment, planning, implementation and evaluation.

# III. ELEMENTS OF THE PEST MANAGEMENT PLAN

Effective integrated pest management (IPM) should include the following elements:

## Building and Materials Design and Retrofitting

The food processing facility and its equipment should be designed and purchased with consideration of the IPM program. The facility and its equipment should not promote pest populations, and should be amenable to control and treatment methods. Detailed information on plant and equipment design can be found in *Engineering for Food Safety and Sanitation: A Guide to the Sanitary Design of Food Plants and Food Plant Equipment*, by Thomas J. Imholte (1984). Highlights and examples of design consideration are given in Box 1.

The design considerations for a new facility apply equally to retrofitting an existing facility. Review of an existing facility against these design considerations can also be useful in determining where retrofitting may be beneficial, or where increased efforts in other areas of the pest management plan may be needed, for example, concerning a change in use of a building or area from its original function.

## Exclusion Practices

Reducing or eliminating infestations in incoming food and ingredients is a key component of an IPM strategy.

Control of materials entering the plant begins with careful supplier selection and strict purchase specifications. Supplier contracts should specify delivery of material that is free from pests to an acceptable level, with strict specifications. Audits of suppliers, even if they are parts of the same company, can be used to ensure that practices are being followed that will lead to delivery of acceptable material. Such specifications and audits are especially important if treatment of incoming materials is not practical.

Raw material should be received in a building that is separate from the main processing facility, or in an isolated area of the facility. In that way, a contaminated shipment can be identified and managed without contaminating the main facility. The incoming material should be inspected before unloading. If necessary, materials should be treated before entering the main process flow. Another approach is to refuse shipments that are contaminated; this can be specified in supplier contracts.

A variety of techniques are in use or under development for treatment of stored grain and other products. These would have importance in reducing the number of pests coming into a food processing facility. The techniques include use of phosphine gas, irradiation, malathion, diatomaceous earth, carbon dioxide and high energy non-ionizing microwave and millimetre-wave radiation.

Phosphine is the most frequently used alternative to methyl bromide for durable commodities. It is widely used to kill pests in cereals, legumes, dried fruits, nuts and other commodities. Its effectiveness against pests is well understood and accepted. Phosphine requires a long exposure period (5 to 15 days) and usually temperatures of over 15°C for effective action, but it can be used in transit in some situations. The temperature requirements for release of phosphine from its usual tablet form can make its use unacceptable in colder climates.

Irradiation is a technically effective alternative to fumigation for many stored products, and could be used to disinfect packaged or bulk products entering into or produced in the plant. In several countries, irradiation is already used

**1** Considerations for plant and equipment design (based on Imholte, 1984)

Materials, construction and layout of the building and equipment should avoid creating surfaces and cavities where dust, food material, insects and rodents can collect. Flat surfaces that can collect dust should be avoided, especially in locations that are hard to reach. Cracks, crevices and cavities in floors, walls, ceilings and equipment should be avoided. Open ends of conduits should be sealed. Seams on duct work should be sealed, especially in areas with grain-based products. Insulation must be sealed off to prevent insects from colonizing there. Cavities should either be completely sealed or made completely accessible.

Many of the steps to avoid accumulation of dust are also important in ensuring that all parts of the plant and equipment are accessible for easy cleaning. Tight spaces not only collect dust and provide harbourage for insects, but they are also difficult to clean. There must be adequate space around, under and over equipment, supports and beams for cleaning. Service lines should be laid out so as not to block access to equipment or create difficult cleaning problems. Equipment and duct work must have access ports to remote areas for cleaning and inspection, particularly on long horizontal sections. Equipment must also be elevated from the floor for effective cleaning. Dust collection systems should be easy to clean.

Floors, walls, ceilings and equipment surfaces must be made from a material that is appropriate to the use of the area and is easy to clean. The equipment should be compatible with treatment methods such as gas or heat, and the plant should be structurally sound to accommodate and retain controlled atmospheres, gases and heat. Any equipment that is not compatible with treatments should be mobile or easily isolated.

Design considerations also apply to the exterior of the plant to avoid attracting and supporting insects and rodents, and to control entry to the facility. The building and surrounding grounds should be free of harbourage sites for rodents. Trees and shrubs should not be grown next to the building and those known to attract insects should be avoided. Exterior lighting with sodium vapour lights can reduce the number of insects attracted, and lights can be shielded above to avoid attracting high flying insects.

Doors and windows need to be closed or screened with proper seals to keep out pests and night lights should not be directly over doors. Entry ways for trucks and railcars need special attention. Ventilation intakes should be designed to keep out birds and insects. Particular attention is needed to seasonal insect problems. Where there may be release or spill of material from exhaust vents, the surrounding area must be amenable to clean up.

for this purpose. Regulatory approval for the use of irradiation to control pests or bacterial contamination of food products sold in Canada has been obtained for only a few foods, such as wheat and wheat flour, spices, herbs and vegetable seasonings. Work is ongoing to broaden the potential use of this technology as a disinfestation technique for other foods. Determining labelling requirements and addressing consumer perception and acceptance of the technology would be important prerequisites to including irradiation as part of an IPM program.

High-speed centrifugal impact machines (Entoleters) are useful to destroy any insects that may be in flour. This procedure is less useful for semolina, however, as it tends to break up the larger particles.

In addition to incoming food and ingredients, personnel can be a route for introducing pests. A separate area should be provided for personal items such as coats, shoes and lunches that are brought into the plant.

Exclusion of pests also depends on proper design of doors, windows, ventilation, intakes and other entry ways, as well as exterior areas.

### Good Sanitation Practices

The facility should be operated to minimize the opportunity for pests to become established. Cleaning and sanitation, therefore, requires utmost priority. Cleaning must be conducted thoroughly, regularly and frequently, with written procedures identifying cleaning methods. The length or frequency of the cleaning cycle should be adapted to specific buildings and equipment, however, it should be appropriate to maintain a high level of control. Known trouble spots should be inspected and cleaned more frequently, and the cleaning cycle shortened if necessary.

Cleaning tools must be effective, designed for the task, and must themselves be kept clean. Air hoses should generally not be used for cleaning, unless areas are not accessible for vacuum cleaners.

In addition to cleaning, the generation and accumulation of dust should be prevented. Leaks in pipes should be avoided, and when they occur quickly identified and repaired. Dust collectors and seals on equipment should be cleaned and maintained in good working order. In particular, it is important to keep dust, flour, insects or other material from reaching areas that are inaccessible for cleaning, treating and inspecting.

Opportunities for pests to become established should be minimized by removing food sources and pest harbourages. Product should be kept away from walls and in pest-proof packaging. Maintaining reduced inventory and faster rotation of stock can also reduce establishment of pests. Sanitation is also needed outside the plant to reduce food sources.

The importance of cleaning and sanitation must be emphasized to all staff. In particular, cooperation among cleaning crews, quality control officials, and a pest control service will be beneficial.

### Building Maintenance

Regular and preventative maintenance is important. Holes and cracks in floors, walls, ceilings, roofs, doors and windows allow access for vermin and allow dust to collect, and therefore must be fixed. Roof drains must be in good shape and debris removal is often required on top of buildings to prevent vegetation growth, accumulation of water that can attract birds, and collection of decaying organic matter. Interior attractors, such as food and harbourage sites, must be eliminated using techniques such as storing idle equipment on racks off the floor and covering food and waste containers.

## Inspections and Monitoring

A monitoring program for pest infestation is necessary to guide treatment schedules and to monitor the effectiveness of the overall management strategy.

The monitoring program should include establishment of targets and action levels, and schedules for placing and checking traps or other techniques. Methods of trapping can include pheromone traps, glue boards and light traps for flying insects. In addition, a monitoring program can include product sampling and physical inspection of the plant and process equipment. Zone mapping can be used to establish different inspections, pest thresholds and control procedures for different parts of the facility, related to the level of risk for the product.

Effective traps are available for many of the insects that infest food processing facilities. Pheromones, volatile chemicals that attract specific insects, are available for the Indian meal moth, red flour beetle, confused flour beetle, cigarette beetle, and cockroaches, and can be used with traps to increase the number of insects captured. Traps can be arranged in a grid pattern throughout the facility following manufacturers' guidelines for placement and spacing. Generally, moth traps attract insects from a wider area and fewer may be needed than for beetle traps that do not attract insects from as large an area. When the traps are in place, they should be checked on a regular basis and the numbers and species of insects carefully recorded. Traps should also be replaced on a regular interval.

The number of insects caught is determined by several factors; trap placement, temperature, duration of sampling and condition of pheromone lure, that can be unrelated to the number of insects in the building. The interpretation of trap data is difficult because it is a relative, not an absolute measure of insect populations. The best approach is to look for trends in trap catches. Low or no trap catch followed by a sudden increase in numbers is an indication of a developing infestation. If this happens, traps can be concentrated in the areas where traps catch the most insects. As the search area is reduced, it is often possible to pinpoint infestations and to deal with them without treating the entire facility.

Light traps must be strategically located, so they do not attract flying insects from outside. The light traps need to be cleaned regularly to prevent secondary infestation from occurring.

Mechanical traps or adhesive boards in covered stations should be used along the interior walls for rodent control. The traps should be checked weekly and the data logged in a siting manual for future reference. Portable black light or ultraviolet light can be used to detect evidence of rodent activity.

The use of monitors or traps will help minimize the amount of pesticides applied by focusing treatments in specific harbourages with active signs of infestation.

### Pest Identification

Accurate identification of pests is necessary to select the most appropriate control methods. Some reference sources of pest identification are listed in Appendix 2, and identification is also available through pest control companies.

### Physical and Chemical Controls

A variety of control actions can be targeted at pests. These include physical and mechanical treatments, controlled atmospheres, and pesticide applications.

**Methyl bromide** is currently available and used for fumigations. Procedures for its use are well established. However, its use is scheduled to be phased out under the Montreal Protocol on Substances that Deplete the Ozone Layer. Use of methyl bromide, in the period preceding phase out or after phase out under defined exemption criteria, should be conducted within an overall IPM strategy.

A number of other techniques or products are in use or under development; various combinations of these techniques may be the most promising approach. There is not likely to be a single treatment that will replace methyl bromide for food processing plants. A combination of methods, used together or at different times, might be required, along with the other components of an IPM strategy.

Any pesticide treatment should be used as one component of an overall integrated management strategy. The choice of treatment will be situation specific to deal with specific problems, and can range from spot treatments to full site treatments as necessary. Pest control professionals should be consulted to determine the range of available products. Prior to any application, it is imperative to read the label to ensure that the product can be applied in a food processing facility and determine whether there are any restrictions, conditions or safety equipment required for its use. All pesticides must be stored, handled, and used according to label instructions.

**Baiting and Trapping:** Two types of baits may play a part in an IPM program. Insect baits are available for cockroaches and ants. This should be the principal type of material to be used inside a structure when pesticide use is justified.

Pheromone traps have also been used in a few places to reduce insect populations of cigarette beetles, Indian meal moth and Mediterranean flour moth in warehouses and flour mills. Use of pheromone traps for control has involved traps at densities 10 times greater than those used for monitoring, modified trap design to prevent overloading the trap with insects, or use of cards covered with a fast acting insecticide, cypermethrin, combined with pheromones. One limitation of this approach is that it would not control the red flour beetle or the confused flour beetle, common pests of warehouses and food processing facilities. Also, initial populations must be low, and months can pass before population reduction occurs.

Rodent baits should only be used outdoors and placed in tamper proof bait stations. These should be secured to the exterior of the building and their position indicated on a location map. It should be noted that sanitation is critical when employing baits for rodents and insects.

**Natural and synthetic pyrethrins and organophosphates** are the main groups of insecticides for structural use. Formulations are available in various concentrations for a variety of applications. A frequent and particularly useful method is to apply the insecticide as small particles in an air suspension, a method referred to as Ultra Low Volume (ULV) or Ultra Low Dosage (ULD).

ULV/ULD equipment breaks an insecticide into small particles with mechanical action and high speed air. The optimum size for effective insect control is one to 30 microns. Above 30 microns, the particles of insecticide fall rapidly and do not penetrate cracks and crevices above floor level. In addition, larger volumes of insecticide are used. Particles below one micron produce a typical thermal fog. Thermal fogs suspend well but do not impinge on the insects as well as particles above one micron. Specific training is required for ULV applications.

ULVs have a role in an IPM Program. They are very effective for a rapid knockdown of flying insects, such as Indian meal moths, tobacco moths, and flies. ULVs will not solve a problem, however. The source of infestation must be discovered and corrected.

**Crack and Crevice Treatment** usually refers to the use of a liquid or aerosol formulation of insecticide. The material is applied in small amounts to likely harbourage areas or areas where infestation has been noted. The insecticides applied may have either a residual or non-residual activity.

**Exterior Treatments** involve applications of residual insecticides to thresholds, the foundations and soil adjacent to the foundation. This method is useful in controlling some outdoor insects, which can occasionally become a nuisance or invade if the population builds up. Products used could be synthetic pyrethroids, chlorpyrifos in liquid or granular form, or diazinon in liquid or granular form.

**Heat** has been successfully used in a number of locations to treat a facility. A treatment generally requires achieving a temperature of

51 to 57EC for a period of 24 hours. Heat treatments are most feasible where existing in-plant heat sources can be used, but portable heating units have been used to treat truck trailers and buildings. Uniform air circulation to distribute heat through the facility is critical.

The frequency of heat treatments will depend on the facility. Estimated costs of four to six heat treatments per year are similar to two fumigations with methyl bromide beyond initial equipment expenditures.

During a heat treatment, equipment or products susceptible to heat damage must be removed, stored in air conditioned rooms, or insulated. Contact insecticides are used on thresholds to stop escaping insects.

**Low temperatures** can be used to reduce the development rate, feeding, and fecundity of insects, and to reduce their survival. This technique is used primarily for bulk storage, either through refrigeration or exposure to ambient air in colder climates. The technique has also been used to control insects in food processing facilities, for example in the use of winter freeze outs in flour mills.

To conduct a freeze out, a building is thoroughly cleaned and stock removed as much as possible. Water lines are emptied, filled with antifreeze, or protected from the cold, and sensitive equipment removed or insulated. Fans are used to bring in the cold air and to rapidly bring down building temperatures. In general, temperatures needed to control insects are approximately -20°C for one minute, -10°C for one to seven days, or 0°C for one week to one month, depending on the type of pest and the rate of cold penetration of all areas of the facility. Use of cold or freeze outs would be restricted to winter months and may be possible in only a few facilities. Nevertheless, as emphasized earlier, integrated management of insects without methyl bromide will require the use of a variety of techniques that need to be adapted to local needs. Use of cold may therefore be valuable in certain cases.

Cold may also be used for more specific treatments. Small cold air tubes can be installed inside equipment, for example, to lower the air temperature to a level that slows or eliminates insect reproduction. This is especially useful for equipment that presents particular infestation or cleaning problems.

**Phosphine gas** is generated by the reaction of metallic phosphide with atmospheric moisture. Aluminum phosphide granules and tablets are registered for use in Canada. Magnesium phosphide technical is registered, and magnesium phosphide end use products are expected to be available in the near future. A variety of additional delivery mechanisms have been developed or proposed, including the use of compressed gas cylinders mixed with carbon dioxide, or by reacting phosphide granules with water and carbon dioxide (Horn Generator). Used on its own, relatively high concentrations and long exposure times are required, for example, initial dosages of 900 to 1200 ppm and final concentrations of 200 to 400 ppm for 36 to 48 hours.

## **2** Studies on Phosphine Corrosion

In 1997, the Canada-U.S. Methyl Bromide Industry Government Working Group initiated a study on the effect of the phosphine, carbon dioxide and heat combination treatment on possible corrosion of electronic equipment.

The study generated data on corrosion of copper, brass, silver and solder under carefully controlled steady-state exposure conditions covering a range of temperatures, relative humidities, carbon dioxide concentrations and phosphine concentrations. Two distinctly different processes were found to occur. First, surface films were formed consisting of oxides of phosphorus, producing a weight gain, and second, a dissolution or corrosion occurred of the underlying metal. Although it is not clear which process is associated with failure of electronic components, the one failed component examined in this study ceased to function due to the build up of surface deposits.

The effects of some parameters measured in the study reflected experience in the field that lower temperatures and lower phosphine concentrations reduce the risk of corrosion effects. Carbon dioxide concentration had no effect. High humidity, however, resulted in less weight gain on copper than low humidity. How can this result be rationalized with anecdotal evidence that suggested that high humidity should be avoided?

When generating phosphine from metallic phosphides under conditions of high temperature and high humidity, there would tend to be a rapid decomposition of the phosphides, resulting in much higher than targeted initial phosphine concentrations. Higher initial concentrations may explain why high relative humidities have been found to be damaging. If so, careful control of phosphine concentration throughout the application may be the key to managing corrosion.

Studies of the optimum relative humidity and phosphine concentrations for minimizing corrosion are scheduled as a second phase of the study. Phase Two will also be examining the effects of repeated exposures.

While known examples of corrosion damage on electronic components is cause for concern, phosphine has also been used routinely for some fumigations with no significant effects. Further studies that will quantify the kinetics of the processes and determine the morphology of the corrosion products with sophisticated analytical tools should provide results that will enable fumigators to select the best operating parameters to reduce the risk of corrosion.

The study was conducted by Dr. Bob Brigham of Natural Resources Canada, and a report of the study has been published by Agriculture and Agri-Food Canada *(Corrosive Effects of Phosphine, Carbon Dioxide, Heat, and Humidity on Electronic Equipment).*

One concern that has been raised is the potential for corrosion of certain metals during phosphine treatments. Anecdotal evidence has suggested that this can be quite serious for computer controls and telephone systems, and some information suggests that copper and copper-containing compounds are most susceptible. In addition, there is concern that repeated fumigations can increase the risk of corrosion. Recent studies initiated by the Canada-U.S. Methyl Bromide Industry Government Working Group are providing insights into parameters that may affect corrosion. These and subsequent studies should provide results that will enable fumigators to select the best operating parameters to reduce the risk of corrosion (Box 2).

One technique that can be used is to seal off sensitive areas such as electric panel rooms and flood them with carbon dioxide at positive pressure. In addition, use of phosphine in combination with other treatments may reduce the corrosion risk.

Resistance of pests to phosphine has been known to develop, particularly under conditions of frequent use with poor sealing of structures before treatments. It is important to carefully follow the most recent label instructions for dosages and conditions of use in order to ensure continued efficacy of the product. Anyone involved in phosphine treatments should consult the Canadian applicator's manual, that is distributed with the product. This manual was recently developed under a label improvement initiative involving registrants, the industry and regulatory bodies. When using phosphine, the adoption of an overall IPM program can contribute to more targeted use of the product and therefore a reduction in potential for development of resistance.

**Diatomaceous earth** (DE) is mined from a geological deposit formed from the fossilized skeletons of diatoms. The fossilized diatoms are amorphous silicon dioxide. DE works as an insecticide by adsorbing to the wax coatings on insect bodies, leading to death by drying. DE is registered for a number of consumer and commercial insecticidal applications, including use on grain, in grain storage and transport containers, and in food processing plants and flour mills. It is primarily used in specific areas as a spot treatment or surface treatment of containers. It can also be applied inside electrical and control panels and in dead spaces behind walls before they are closed up. Application methods include hand or power dusters or in a slurry. One issue in the use of DE is that its effectiveness is reduced at high relative humidity. Recent studies have examined the use of DE in conjunction with heat for facility treatments.

A combination of **heat and DE** has been used in experiments in the laboratory and on a pilot scale in a commercial plant. The use of DE provided effective treatment at a lower temperature than normally used for heat treatment of the facility. While the test results may not be representative of a full plant treatment, the synergistic effect of heat and DE may reduce the time and heat needed to conduct an effective plant treatment.

There is also experience with use of a combination of **heat and phosphine and carbon dioxide**. Both heat and carbon dioxide increase respiration in insects, allowing reduced concentration of phosphine to effect control. Lower levels of phosphine reduce the potential for corrosion. A typical combination treatment would involve heating the facility to 30 to 38EC, adding carbon dioxide to a concentration of three to seven percent, and phosphine gas to an initial dosage of 150 to 500 ppm. Control can be achieved in 24 to 36 hours. These values compare to temperatures over 50EC for a heat treatment alone, or an initial dosage of phosphine of 900 ppm or more when used on its own. This combination treatment requires careful monitoring and control of heat and gases. In addition, large amounts of carbon dioxide are necessary. However, successful fumigations of this type have been performed in the U.S. and on a trial basis in Canada.

## IV. SUCCESS STORIES

The development and use of integrated pest management (IPM) strategies and other alternatives is already in place in the food processing industry. The following examples illustrate the kinds of activities that are under way:

### Griffith Laboratories

Griffith Laboratories in Scarborough, Ontario manufactures a wide variety of food ingredients for most sectors of the food industry. Over the past two decades, Griffith Laboratories has moved from total structural fumigation on a semi-annual basis to complete phase out of methyl bromide. An IPM approach has been put in place with an emphasis on sanitation, monitoring and trapping, and careful supplier selection.

Their strict sanitation program is designed according to Food Safety and Enhancement Program and Hazard Analysis Critical Control Points guidelines and International Standards Organization format. The program incorporates written procedures and work instructions for all aspects impacting on food safety, including equipment and utensils, overhead structures, floors, walls, ceilings, drains, lighting devices, and refrigeration units. A key adjustment has been to shorten the cleaning cycle from 90 days, when methyl bromide was used, to 30 days. Dust controls have been increased and each department is responsible along with the sanitation department for managing spills and dust residues. Careful selection criteria are applied to suppliers, outside warehouses, and transport vehicles to help ensure pests are not introduced into incoming product. Raw materials are received in separate buildings. Trucks are inspected before unloading and untreated spices are treated with ethylene oxide. Heat treatments will be used instead of methyl bromide for vault treatment of oats and flour containing insects. The pest control program is carried out in cooperation with a pest control contractor, and uses frequent monitoring and spot treatments when necessary.

IPM is viewed as an ongoing process requiring continuous improvement. The plant is constantly being monitored and inspected for areas that need to be repaired or upgraded to control damaging pests.

For more Information:
Diane Lohnes (416) 288-3343, or
Terry Ramalho (416) 288-3354,
Griffith Laboratories

### Quaker Oats

The Quaker Oats Company of Canada operates a cereal milling and processing facility in Peterborough, Ontario. Parts of the facility are almost 100 years old, and are made with timber posts, wooden floors and stone walls. The IPM system at Quaker is anchored firmly on its sanitation program, and heat treatments of the facility.

Important components of Quaker's IPM system are knowledge, training, cleaning, standards, monitoring, plant design and retrofitting, and equipment purchase. Sanitation has been made the responsibility of each manufacturing unit, and employees have been trained to have a high level of awareness and concern for sanitation. Suppliers must be approved and meet strict sanitation standards for incoming products; infested shipments are rejected. Significant investments have been made to minimize chemical interventions and make the plant compatible with heat treatments. The use of methyl bromide has been significantly minimized by the IPM system, and it is used only on occasion in response to a known need, and where heat treatments cannot be made.

In addition, Quaker Oats has been actively involved in research trials of new treatments, specifically combinations of heat and diatomaceous earth (DE), and heat, phosphine and carbon dioxide.

For more information: Jim Rosborough, Quaker Oats Company of Canada Ltd., (705) 743-6330

## Rogers Foods

Rogers Foods Ltd. is a flour mill in Armstrong in the Okanagan Valley of British Columbia. It mills 200 tonnes of wheat a day, and its most important products are bakery flour, grocery flour and granola.

Careful and thorough sanitation is a key component of pest management at Rogers Foods, along with careful control of incoming grain.

The policy at Rogers Foods has always been to turn away trucks that have live grain insects in the wheat. The use of DE in incoming wheat and in empty wheat bins has been encouraged, and local farmers have been following these practices for 15 years. DE has also been used by suppliers to treat infested shipments that might subsequently be accepted. In addition, DE is dusted lightly into dead spaces in the mill before they are sealed to provide lasting control in unreachable locations.

When treatments are necessary, phosphine has been used with good results. The Okanagan Valley is a virtual desert during the summer, and the low humidity has resulted in little problem with electrical damage from corrosion. Trials have also been done and are continuing with heat treatments and combination treatments including heat/phosphine/carbon dioxide, and heat/diatomaceous earth.

For more information: Rudy Bergen,
Rogers Foods, (250) 546-8744, extension 241

## V. FUTURE CHALLENGES

As noted above, the key to implementing an integrated pest management approach (IPM) in a food processing facility will be a sustained commitment from company management. Collecting information to develop a pest management plan will be challenging, however, information sources and pest management expertise are available.

A variety of tools are available for use in IPM. Further work on optimum use of these tools, or development of additional tools could enhance adoption of IPM. Some of the identified needs are as follows:

- greater variety of approved monitoring and trapping devices, including effective pheromone traps for certain varieties of insects;
- viable registered fumigants, especially for use as a preventative and in emergency situations;
- greater variety of residual insecticides;
- information on managing the phosphine corrosion problem, particularly in high relative humidities such as for pasta dryers. A study is currently under way under the Canada/U.S. Methyl Bromide Working Group to study corrosion associated with phosphine use;
- facilitation of heat treatment, requiring adequate sources of heat, capital outlay to adapt facilities, and ability to remove or protect sensitive equipment and material;
- for combination treatment, procedures for close monitoring and control of temperature, and concentration of phosphine and carbon dioxide during combination treatment; and
- commercial scale trials of effectiveness of heat and diatomaceous earth on resident insect population.

## Appendix 1 - Phase-out Dates and Interim Reduction Targets for Methyl Bromide

The Montreal Protocol is an international agreement aimed at reversing the damage done to the stratospheric ozone layer, the earth's natural protective shield from the sun's rays. When the Montreal Protocol was amended in Copenhagen in 1992, methyl bromide was added to the list of ozone-depleting substances subject to control and a freeze in consumption and production was established for 1995.

After signing the Montreal Protocol in 1987, Canada developed a control program to meet its international requirements. At a minimum, the program has to achieve the controls and timetable provided for in the Montreal Protocol. Canada's Ozone Layer Protection Program was revised in 1995, and the following measures were adopted for methyl bromide (Table 1):

Table 1: Canadian Reduction Schedule for Methyl Bromide

| | |
|---|---|
| 1995 | Freeze production and consumption* |
| 1998 | 25% reduction* |
| 2001 | 100% elimination** |

* Excluding quantities used for quarantine and pre-shipment applications.

** Excluding quantities used for quarantine and pre-shipment applications and quantities used for emergency and critical uses.

For further information contact:

Josée Portugais
Environment Canada
Commercial Chemicals Evaluation Branch
14th Floor, Place Vincent Massey
Hull, Québec
K1A 0H3
Telephone: (819) 997-7935
Facsimile: (819) 953-4936
E-mail: josee.portugais@ec.gc.ca

## Appendix 2 - Selected References

The following references provide useful information for various aspects of integrated pest management (IPM), including identification and biology of pests, sanitation, and treatment and control. A few of these books are out of print, but should be available through libraries. A selection of Internet sites is also given.

The list is not intended to be complete or authoritative and many other useful publications and information sources exist. Pest control operators and associations, food industry associations, food safety consultants and specific training organizations are valuable sources of information. Many of these groups can be found on the World Wide Web.


**A Flour Mill Sanitation Manual**, by Robert Mills and John Pederson. (1990). Eagan Press.

- equipment inspection and cleaning, IPM, regulatory considerations, factors responsible for product contamination, heat sterilization, insecticides
- available from Eagan Press, 3340 Pilot Knob Road, St. Paul, Minnesota 55121-2097 U.S.A. (612) 454-7250

**AIB Consolidated Standards for Food Safety**. Third edition, rev. (1990). American Institute of Baking.

- inspection and sanitation rating system for food processing facilities
- available from American Institute of Baking, 1213 Bakers Way, P.O. Box 3999 Manhattan, Kansas 66505-3999 U.S.A. (913) 537-4750

**Basic Food Plant Sanitation Manual**. Third edition, rev. (1979). American Institute of Baking.

- sanitation and pest issues for food facilities
- available from American Institute of Baking, 1213 Bakers Way, P.O. Box 3999 Manhattan, Kansas 66505-3999 U.S.A. (913) 537-4750

**Ecology and Management of Food Industry Pests**. Food and Drug Administration technical bulletin No. 4, by J. Richard Gorham (editor). (1991). Association of Official Analytical Chemists.

- ecology prevention, inspections and regulations within food facilities
- available from AOAC International, Signet Bank Lockbox, PO Box 75198 Baltimore, MD 21275-5198 U.S.A. (301) 924-7077

**Engineering for Food Safety & Sanitation**, by Thomas J. Imholte. (1984). Technical Institute of Food Safety.

- sanitation and IPM through design
- currently out of print

**Food Safety Enhancement Program Implementation Manual [kit]**. Ottawa: Agriculture Canada, 1993. Four volumes and one videocassette.

- The Food Safety Enhancement Program Manual has been prepared as an aid to implementation and inspection teams of the Canadian Food Inspection Agency, and to industry's management and employees. Its use is intended during the implementation phases of Hazard Analysis Critical Control Points (HACCP). Under HACCP, critical stages in production of a food product are identified and monitored. HACCP plans are unique for each establishment and specific food product.

**Guidelines for Food Processing Plants.** ASI Food Safety Consultants.
- inspection, audit and sanitation; rating system for food processing facilities
- available from ASI Food Safety Consultants, 7625 Page Boulevard, St. Louis, Missouri 63133 U.S.A. (314) 725-2555

**Handbook of Pest Control: The Behavior, Life History, and Control of Household Pests**. Eighth edition, by Arnold Mallis, edited by Dan Moreland. (1997). Franzak & Foster.
- pest control manual
- available from Franzak & Foster, 4012 Bridge Avenue, Cleveland, Ohio 44113 U.S.A. (800) 456-0707

**Insect Management for Food Storage and Processing**, by Fred J. Baur (editor). (1984). The American Association of Cereal Chemists.
- insect identification, inspection techniques, control measures for food facilities
- out of print

**Insect Pests of Flour Mills, Grain Elevator and Feed Mills and their Control**. Research Branch, Agriculture Canada Publication 1776E, by R.N. Sinha and F.L. Watters. (1985). Canadian Government Publication Centre.
- pest identification and control within the grain industry
- out of print

**NPCA Field Guide to Structural Pests**, by Eric H. Smith and Richard C. Whitman. (1992). National Pest Control Association.
- pest identification and control measures
- available from the National Pest Control Association, 8100 Oak Street, Dunn Loring, Virginia 22027 U.S.A. (703) 573-8330

**Pest Control**. (periodical).
- available from Advanstar Communications, 7500 Old Oak Boulevard, Cleveland, Ohio 44130 U.S.A. (440) 243-8100

**Pest Control Becomes a Team Effort**, by Dean Stanbridge. (1998). Pest Control, May 1998:50-52.

- an account of the successful integration of pest management into a food plant's good manufacturing practices, resulting in eliminating methyl bromide treatments, nearly eliminating the use of contact and residual insecticides, and saving the company money

**Pest of Stored Products and Their Control**, by D.S. Hall. (1990). Belhaven Press.

- insects, rodents, and bird pests described as well as their chemical physical and biological control, and IPM
- available from Belhaven Press, 25 Floral Street, London, England, WC2E 9DS

**Stored Product Protection... A Period of Transition**, by David K. Mueller. (1998). Insects Limited Inc.

- alternatives, options and strategies for pest management in stored food products
- available from Fumigation Service & Supply, 10540 Jessup Boulevard, Indianapolis, Indiana 46280-1451 U.S.A.

**Truman's Scientific Guide to Pest Control Operations**. Fifth edition, by Gary W. Bennett, John M. Owens, Robert M. Corrigan. (1997). Purdue University.

- pest identification and control measures
- available from Advanstar Communication, 7500 Old Oak Boulevard, Cleveland, Ohio 44130 U.S.A. (440) 243-8100

**UNEP 1994 Report of the Methyl Bromide Technical Options Committee**. (1994).

- addresses the technical availability of chemical and non-chemical alternatives for methyl bromide
- includes alternatives still under research or development
- assessment is being updated during 1998
- available from SMI (Distribution Services) Ltd., P.O. Box 119, Stevenage, Hertfordshire, England, SGI 4TP

**Urban Entomology**, by Walter Ebeling. (1975). University of California, Division of Agricultural Sciences.

- pest control and pest identification reference
- out of print, but posted on the World Wide Web with the proviso that "many chemical control procedures recommended are NOT current and/or currently recommended. Regulatory changes have made the application of some of the control procedures no longer legal or advisable. However, species information is still of great value."
  Location: http://entmuseum9.ucr.edu/ENT133/ebeling/ebeling.html

# Internet Resources

## Government and University Links: Research and General Information

Agriculture and Agri-Food Canada:

Cereal Research Station has information on good storage practices, and stored product insects

A http://res.agr.ca/winn/home.html

Report on the use of heat and diatomaceous earth as a replacement for methyl bromide

A http://res.agr.ca/winn/Heat-DE.htm

Canadian Food Inspection Agency:

Reference Listing of Accepted Materials, Packaging Materials and Non-Food, Chemical Products

A http://www.cfia-acia.agr.ca/reference/conteng.html

Food Safety Enhancement Program

A http://www.cfia-acia.agr.ca/english/food/haccp/haccp.html

CISRO, Australian Stored Grain Research Laboratory

A http://www.ento.csiro.au/research/storprod/storprod.html

EXTOXNET is a collaborative effort between several U.S. universities to offer information on pesticides written for the lay person

A http://ace.ace.orst.edu/info/extoxnet/

Health Canada's Pest Management Regulatory Agency offers an overview of the agency, recent reports and a telephone directory

A http://www.hc-sc.gc.ca/pmra

Purdue University, projects ongoing within the university and extensive links to other World Wide Web sites

A http://pasture.ecn.purdue.edu/~grainlab

USDA-ARS, Grain Marketing and Production Research, the main U.S. Department of Agriculture working on storage of cereals

A http://bru.usgmrl.ksu.edu/index.html

## Government and University Links: Methyl Bromide

Environment Canada’s page on methyl bromide
A http://www.ec.gc.ca/ozone/mbrfact.htm

U.S. Department of Agriculture, Agriculture Research Service methyl bromide page
A http://www.ars.usda.gov/is/mb/mebrweb.htm

U.S. Environmental Protection Agency’s site on the phase-out of methyl bromide
A http://www.epa.gov/docs/ozone/mbr/mbrqa.html

United Nations Environment Program:
Methyl Bromide Technical Options Committee
A http://www.teap.org/html/methyl_bromide.html
Ozone Secretariat, including publications
A http://www.unep.org/unep/secretar/ozone/home.htm

## Industry Links

There are numerous sites on the World Wide Web with information from the pest control and food processing industries, including national organizations and local suppliers. Searches will yield numerous resources. Suggested key words include:

- food plant pest control
- food safety and hygiene
- food processing sanitation
- pest control + food processing
- pest control industry