Miljønyt Nr. 54 2000

Alternatives to Methyl Bromide; Integrated Pest Management in Danish flour mills

Generalised Guideline

Poul Asthon
Asthon Skadedyrcenter ApS

Henrik L. Lange
Tanaco Danmark A/S

Miljøstyrelsen
Miljø- og Energiministeriet

IPM Integrated Pest Management is described as an alternative to the routine use of Methyl bromide for controlling insect pests in Danish flour mills, after the phasing out of Methyl bromide at the beginning of 1998. Emphasis is placed on preventive measures. Good hygiene and housekeeping practises together with the systematic monitoring of the situation are discussed along with the need for good communications and training of personnel.

Contents

Preface

Methyl bromide has been extensively used as a fumigant for insects in flour mills.

Following the Danish Ministry of the Environments notice NR. 478 3 June 1994, prohibiting the use of Methyl bromide after 1998, there was a need to find alternative treatments and methods of controlling pests in flour mills. This need forms the basis for this project.

Initial project

The aim of the project is to examine information collected from the flour mills together with the experience gathered through many years of pest control, thereafter to provide guidelines for establishing a system of pest control without the use of methyl bromide which is least harmful to the environment.

This project also aims to determine whether it is feasible to commence a major project concerning the implementation of an alternative method of pest control to methyl bromide, in the flour mills.

The primary target group is the Danish milling industry, but the results could help promote the use of alternative pest control in other European countries and within other sectors of the food industry.

Possible methods

The project focuses primarily on preventive pest control methods through the development of integrated pest management strategies. There are also brief descriptions of alternative methods and treatments to methyl bromide, which could be used in the case of sudden acute infestation.

Expertise

The project group have drawn upon the knowledge of foreign experts and have exchanged information regarding trials and experiences in foreign mills. Amongst these have been Dr. Christoph Reichmuth "Institut für Vorratsschutz", Berlin and David Müller "Insects Limited Inc". USA.

Financial support

The project was supported by "Rådet for Genanvendelse og Mindre Forurenende Teknologi", who paid 50% of the costs.
The project was carried out by members of "Forening af Danske Handelsmøller" and "A/S Skadedyrcentralen" who provided the remainder of the costs. Chairman for the control group was Michael Høst Rasmussen, Miljøstyrelsen.

Project group

Members of the project group and the secretariat were:
Henrik L. Lange, A/S Skadedyrcentralen Danmark.
Paul Ashton, A/S Skadedyrcentralen Danmark

Control group

Jens Erik Kristensen, SID.
Vagn H. Madsen, Direktoratet for Arbejdstilsynet.
Thorkil Hallas, Dansk Teknologisk Institut.
Bente Stærk, Forening af Danske Handelsmøller.
Lise Stengård Hansen, Statens Skadedyrlaboratorium

Summary

Methyl bromide has been used as a fumigant throughout the Danish milling industry for many years, for insect pest control when insect infestations reached unacceptable levels.

Its approval in Denmark, as a fumigant, will be withdrawn from 1998, in accordance with notice from The Ministry of the Environment, order number 478, 3 July 1994, concerning the use of ozone depleting substances.

Integrated Pest Management system

Integrated Pest Management as a system of pest control is looked at and the parameters of its implementation are discussed.
This project looks at methods of insect control in Danish mills, concentrating on preventive pest control to maintain pest free conditions on site without the use of methyl bromide. Alternative fumigants that might be used in emergency situations are also looked at.
The project investigates the importance of establishing and delegating clear lines of responsibility together with the pursuance of good cleaning and house keeping routines.

Included is a brief description of stored product insects.
Attention is given to the necessity of sound construction and maintenance practices together with good cleaning routines if an IPM system is to succeed.

The following points ought to be considered when implementing an Integrated Pest Management system .

- A comprehensive knowledge of the site.
- An assessment of the potential risks.
- Preventive proofing and control.
- Modification of plant and construction to remove regions of harbourage.
- Access to all areas, and detailed full site plans.
- Knowledge of the material flow through the site.
- Working practices and cleaning routines.
- Future plans regarding new products, machinery or building alterations.
- Clear lines of communication and responsibility.
- Any agreements/contracts between the mill and an outside pest control contractor.

- The number and limits of any hygiene inspections.
- Communication at all levels of the hierarchy within the mill and with outside contractors.
- Training of personnel in pests and stored product insects.
- Documentation, the content and filing of all reports concerning Integrated Pest Management.
- Quality control.
- Testing new methods and assessing existing ones.
- Contingency plans in case of an acute infestation.

There is no single alternative to methyl bromide in all its uses, though alternatives or a combination of alternatives exist in many cases. Preventive control is the aim and can be accomplished effectively and efficiently through an Integrated Pest Management system tailored to the needs of an individual mill.

1 Introduction

1.1 **Background**

Methyl bromide has been identified as an ozone depleting substance under the Montreal Protocol, and pursuant to the protocol is subject to a freeze in production and consumption from 1995.
In 1993 agreement was reached within the European community to a reduction of 25% from 1998.

A complete ban has been decided upon in Denmark from 1.1.1998 .

Th. E. Hallas from The Danish Institute of Technology together with researchers from the Danish Plant Health Authorities have produced a report for the Nordic Council of Ministers regarding the use of methyl bromide in the Nordic countries and alternatives to its use (13).
Briefly the conclusion is that in all areas, alternatives which are less harmful to the environment are available, albeit there are certain areas, amongst others the milling industry, which will require special initiatives, to help with the implementation of these alternatives.

Usage of Methyl bromide

About 3.9 tons of Methyl bromide has been used annually by the milling industry in Denmark (Dec. 1993) out of a total consumption of about 33 tons.
The consumption by the milling industry has been much greater in Norway, and Finland, and greatest in Sweden at about 13.7 tons per year.
The Nordic report concludes that this can be replaced by IPM, combining alternatives and options which are available today.

The results of this project are expected mainly to benefit the other Nordic countries, as the situation in the milling industry and the situation in general, is similar to Denmark.

1.2 **Methyl bromide**

Methyl bromide has in the past been an effective and important pest control tool in the milling industry.
It has a number of advantages over other fumigants. It is relatively cheap and easy to produce. It presents no fire hazard. It is effective, leaves no harmful residues and probably the greatest advantage is, that it is quick-acting. The main disadvantage is its acute toxicity.

However due to its ozone depleting properties it has been phased out and is forbidden from 1.1.1998, in Denmark.

Alternatives or alternative methods therefore need to be found.
In certain situations alternatives already exist, for example phosphine or hydrocyanic acid.
This paper looks at Integrated Pest Control, IPM, which is a collection of methods and techniques to suppress pests, tailored to suit the specific needs of any food processing plant. Alternative full-site

treatments are also looked at. These provide backup in cases where IPM processes break down and infestation levels become unacceptable.

1.3 **Danish flour mills today**

Starting point

The starting point must be the condition and situation of Danish mills today. Many are situated in older premises which have been built, altered and re-furbished over many years, without any special attention to pests or pest related problems.

Previously, fumigation with methyl bromide was carried out once or twice a year, whenever production and temperature allowed, either on a routine basis or when the infestation levels reached unacceptable levels. In the intervening periods, few resources were available for pest control or preventive measures, apart from ordinary cleaning. In many cases design of the mill did not lend itself to thorough cleaning and disinfestation
In more recent years efforts have been made to reduce the amount of methyl bromide used for preventive pest control.

We believe that with the implementation of a tailored IPM system together with the full support of the responsible management, that full site fumigation can be replaced by other methods or spot treatments.

There will always be some risk of pests being introduced to a factory or of undetected harbourages. However, with regular inspections by competent personnel, coupled with the necessary commitment from all members of staff, these risks can be reduced to a minimum, and fumigations or other full-site treatments only used as a last resort in the case of acute sudden infestation.

1.4 **Stored products pests**

The pests encountered can be divided into two groups:

1. Stored product pests

Stored product pests

2. Casual intruders

1. Stored product pests can be found in and can complete their life cycle within the product and therefore contaminate the product

The most common stored product pests to be found in the Danish mills are (12):

Mediterranean flour moth	*Ephestia kuhniella*
Tobacco moth	*Ephestia elutella*
Indian meal moth	*Plodia interpunctella*
Confused flour beetle	*Tribolium confusum*
Granary weevil	*Sitophilus granarius*
Yellow meal worm	*Tenebrio molitor*
Book lice	*Psocoptera*

	Flour/grain mites	*Acarus siro* *Lepidoglyphus destructor*

Casual intruders

2. Casual intruders are insects to be found in and around buildings, not necessarily related to stored products, such as spiders, some flies, predatory beetles, wood boring insects and so on .

Stored product pests of the first group present the greatest risk. Mills often provide an environment in which they thrive, an abundant food supply, the right temperature and undisturbed harbourage.

It is important to be able to quickly identify any insects found, to assess the risks and, if necessary, to carry out some form of treatment or corrective action. The presence of particular pests is often a good indicator of where an infestation problem may be found. The presence of slow breeding pests (such as *Tenebrio molitor*) are indicators of a long standing problem of poor hygiene and pest control in a mill.

Knowledge of the habits of the insects increases the chance of locating them, and of choosing the best measures to limit the spread of the infestation. The wrong choice can result in spreading the problem.

There are many good books available on insects and their identification (see 4 and 5). Professional help can also be obtained from The Danish Pest Infestation Laboratory or from a competent pest control company.

2 Integrated Pest Management

2.1 **Integrated Pest Management (IPM)**

Pests

Throughout the food chain, the identification, control and extermination of pests in the food industry requires many resources, from producer to manufacturer, carrier to distributor together with surveillance and control by the authorities responsible.
Pests are all around us and can turn up in raw materials and finished goods at any time.

IPM

Mites, insects and rodents can all be introduced in many ways and forms to the food chain, they can enter through their own efforts into buildings, arrive with raw materials, packaging and machinery or in damaged or returned goods.

How we prevent their access and how we control the environment in which food is produced, stored and sold, demands detailed planing and a well organised program of preventive measures. This approach is known as IPM - Integrated Pest Management.

Decision making

IPM is not a treatment or a patented solution, nor is it any special formula to keep away pests. It is a process, an attitude, a system which continually aims at keeping pests at acceptable levels.

IPM is a decision making process where all options are gathered together and assessed. The aim of the IPM system is to be able, at any time, to propose effective, economical and environmentally sound solutions to pest control problems within the tolerance limits set by the mill or factory.

In certain situations the main guidelines may be at odds, for example, the most effective solution is not always the most environmentally sound.

The aim is best achieved by denying pests access or by reducing their chances of survival through thorough preventive measures. The measures include good cleaning and housekeeping practices,
regular inspections by qualified personnel, combined with chemical treatments where necessary. Permanent “designing out” of pests through modification of machinery and buildings can much reduce pest pressure.

IPM is difficult to define and therefore implement as the terms “preventive” and “treatments” cover such a wide range of possibilities, making it hard to maintain an overall general view, without sifting through numerous details.

Choice of method

Characteristic for IPM is the openness of the system, it is not at all rigid. Each mill must tailor its IPM system in keeping with its own aims, legislation and chosen parameters, such as health, safety and customer requirements.

Chemical treatments, where necessary as part of IPM, ought to be

limited as far as possible and the pesticides chosen from an environmentally sound perspective. Residues from treatments must be acceptable to the end markets and comply with accepted Maximum Residue Limits.

The choice of a particular pesticide or particular treatment can affect and alter the needs of the system and visa - versa . The situation will be different from site to site, depending upon raw materials, temperature, building construction, condition, age and size, production rhythm, customer demands, attitude of management, workers and so on.

Generally speaking, the larger the company and factory site, the more complicated it is, with the potential risk of pest infestation being inherently greater.

IPM must therefore be tailored to the specific location and must change in step with changes in the situation. For example, when IPM has been implemented for some time, more emphasis may be put on preventive, pro-active measures than on treatments or re-active measures.
To function well, IPM requires a high level of commitment from all concerned.

Pest requirements

When IPM is introduced to a facility, one must bear in mind that all insects as pests have certain things in common.

1. Their need for nourishment, the right temperature, safe harbourage, and time to complete their life cycle.
   The removal of any one of these factors will significantly reduce their chances of survival.

2. Their ability to invade or penetrate a site, either flying, crawling, or captive in raw materials, packaging or other goods.

An IPM system must continually monitor all areas and aspects of the facility for actual pests and potential risks, including checks on incoming materials, goods and vehicles, whilst at the same time providing preventive control through the use of bait stations, traps, pheromones, good cleaning practices and proofing.

If a satisfactory result is to be reached, it can only be done by removing or reducing the root causes and conditions favourable to pests. In this way a more permanent solution can be reached without a dependency on chemicals. Creating fewer environmental or health problems and less risk of developing resistance.

2.2 **A brief history of IPM**

Start of IPM

The principles of IPM were first set out about 35 years ago in California, when it was discovered that insects harmful to crops were becoming resistant to insecticides. Also, formerly innocuous insects were becoming serious pests, because some of their natural enemies were being eliminated.

Interest heightened in 1972 when The Council for Environmental Quality published a report entitled IPM, focusing on the fact that

chemicals had become the main method of controlling pests, and this was having negative effects on the environment including untargeted insect species. A systematic approach was needed, one which was effective, economic and less harmful to the environment.
The report was based on agriculture but the principles are the same wherever there are pest control problems.

IPM now

Modern IPM programs aim at controlling pests, keeping their numbers and activities below the level where they present economic, environmental or health risks, and are tailored continually to meet each new situation. They use a rational combination of measures to achieve the desired level of pest control. This contrasts with the use of a single measure, e.g. methyl bromide fumigation, which attempts to eliminate pests from an area.

Prevention

IPM focuses primarily on prevention, first and foremost by physically denying pests access, at the same time having the knowledge and experience at hand to remove conditions favourable to pests, should they somehow enter the plant.
All personnel ought to undergo some basic training on the subject.

Pheromone lures, traps, temperature alteration, cleaning, treatments, inspection are all factors which play a part in IPM.

It should be noted that, although IPM aims to reduce the use of chemical insecticides, it does not exclude their use.

In the food industry, consideration of environmental issues together with a growing awareness and concern over the use of chemicals, has led many food producers and chain stores to introduce their own hygiene standards, requiring sub-contractors to document their pest control efforts, preventive measures and insecticide usage.
At the same time, this has forced many pest control contractors to re-assess their role in quality control.

2.3 **Quality policies and risk assessment**

Risks

Most companies assess the risks inherent in their particular industry. Mills must evaluate many factors that directly or indirectly influence their production, reputation and profit such as legislation, labour markets, the environment, working conditions etc. Pest control is also one of the factors.

Producing safe, uncontaminated food in accordance with legislation must be the primary aim. Thereafter comes the demands of customers and quality control, which are often more stringent than the formal legislative requirements.
With these things in mind, each individual mill must tailor the IPM system to reduce any risks involved and to meet the requirements in their particular set of circumstances.

Zero tolerance

Zero tolerance with regards to any form of pest contamination in food stuffs (be it adults, eggs, larvae, pupae or cast off or broken parts) would be desirable. However the introduction of such criteria in the food chain would be extremely expensive and at the same time extremely difficult to

implement.
All raw materials that are originally grown as plants, can contain the remains of mites, insects and other pests.

If one looks at the pests in question the picture becomes more complex, as some pests are agents of disease or degrade the quality of the product. Apart from this small group, there are many others which on closer inspection have no or very little measurable effect on the products or product production.

The opinion of the project group is that careful consideration should be given before deciding upon levels of tolerance. The benefits of zero tolerance would be negligible, and the attainment of such levels would be almost impossible and therefore unrealistic.

Important elements of IPM

In order that the various elements of IPM can function as a coherent whole, it is vital that:

Management assessment

Management determine where the likely risks of pest infestation can occur, in consultation with experts in the field where necessary. This will help shape and define company policy and have a direct influence on the standards, aims and tolerances to be set.

Policy

The policy must be clearly formulated and visible to all employees, to help ensure full commitment and involvement at all levels.

Policy maintenance

The success of the system rests upon allocating responsibility and maintaining the policy in the future.
The commitment of senior management must be visible and they must be available to avoid conflicts of responsibility or misunderstandings, internally or with outside contractors.
The involvement of mill staff gives first hand experience and allows problem areas to be identified and resolved quickly. IPM is part of production of a quality product.

Resources

If there is a contract between the company and an outside pest control contractor, its important that a detailed agreement with clear lines of responsibility is established from the start.

Preventive pest control is the aim. However contingency plans should be in place if an acute problem arises. Management must have a realistic perception of preventive measures or active treatments and have access to the resources necessary.

Clearly the overnight implementation of a comprehensive IPM system in the mills would be a very expensive exercise. The risks need to be evaluated against the costs involved. The implementation can be carried out in stages, but the main principles of IPM will need to be in place from the start.

Companies must precisely define their goals, determine which risks they can afford to run and those they can not accept, and realistically tailor the IPM system to the situation, bearing in mind that methyl bromide is no longer an option.

2.4 **Building design and cleaning**

Two factors, which have a decisive influence upon a long lasting solution to the problem of pests, are building design and cleaning.

Buildings should be structurally sound and designed in such a way that pests are not encouraged and are easily monitored. See 2.5

Internally things should be arranged so that all areas are accessible and easily cleaned.

New constructions

When new facilities or structural modifications are contemplated the exclusion of pests must be given a high priority, cracks, crevices and potential pest harbourages must be known and "built out". Professional advice may be necessary.

Areas of high risk

Dividing the facility into areas of risk, according to the sensitivity of the area, or products therein, can help maintain a heightened awareness and greater respect for the measures taken.

Cleaning routines

At the start of an IPM program, the mill and machinery should be audited to determine where there is harbourage for infestation and where infestations are most likely to affect the product chain. Engineering modification of the high risk areas, at least, should be considered to build out pests or allow fully effective cleaning.

Good sanitation is the first line of defence. Detailed cleaning routines should be drawn up and employees trained and encouraged to follow the highest standards of hygiene.
Responsibility for cleaning should be delegated to individuals and their working areas. An example of such a cleaning routine can be seen in appendix 3. Many more points would of course be included in an actual situation.

2.5 **Inspections**

2.5.1 **Factory inspection**

Effective inspections, on a regular basis, through thorough competent surveillance of the whole facility both inside and outside, are necessary if the system is to function properly.

Site plan

A site plan must be used, clearly defining individual areas of the whole site. Areas should be numbered or named in such a way that misunderstandings do not occur.

All baits, traps and pheromone traps should be charted on the plan with a number and symbol as to their type.

Check lists must be drawn up for each type of trap giving a complete view of the situation and enabling pest populations to be monitored and compared with previous findings.

Scope of inspection

If an outside pest control contractor is employed, clear lines of communication should be agreed upon so that all findings or comments

by employees concerning pests, in the periods between routine inspections can be discussed and acted upon.

Inspections should cover all aspects of the site and include inspection for all types of flying and crawling insects, rodents, birds, condition of building, potential harbourage, housekeeping, storage, incoming goods and raw materials plus any other factors which could encourage pests.

2.5.2 **Inspection check lists**

The following section includes advice and guidelines on check lists and inspection reports which must be as comprehensive as possible whilst at the same time being clear and easily read. Examples are given below

Outside inspections

Perimeter fences
Potential harbourage
Waste disposal areas
Flower beds, plants and weeds
Rubbish
Neighbours

Buildings

Building condition and maintenance
Drainage- and down pipes
Proofing
Roofs and ventilation
Lofts, cellars and outbuildings
Lights and other installations
Elevators

Indoors

Raw materials, returned goods
Packaging
Wooden pallets
Cleaning
Housekeeping
Personnel hygiene
Stores, silos. Workshops, canteens, laboratories, offices
Vehicles

The inspector should be aware of potential hiding places outside, examine the exterior closely for cracks, crevices and defects which would allow pests access. The outside area must be kept tidy. Pallets, containers, building materials, used machinery and so on should, if necessary, be stored away from walls and off the ground.

Lawns, flower beds and bushes should be kept tidy and away from walls. Eaves of roofs examined and, if necessary, bird proofed.

Silos

Flour and grain is often stored in silos. As the commodity may remain in the silo for longer periods, infestation can occur. Silos must be inspected frequently and, if necessary, cleaned. Likewise the commodity, silo top and bottom should be inspected frequently (at least once a month).

Design

Flow path. Finished product should not be stored close to raw materials. This is to avoid cross infestation.

Refuse and container area
The flow of factory waste should be checked from start to end. All areas with refuse are possible hiding places for pests. The refuse and container area should be laid with concrete and supplied with a drainage gully and hose pipe so that it may be cleaned frequently.

Refuse container
The refuse containers should have tightly closing lids, and be large enough to prevent overloading. They should arrive clean, and if held on site for longer periods, they should be cleaned often . Small waste containers should be sited away from walls and proofed against rodents and flies.

Refuse
Refuse that does not contain food should also be stored as above to avoid providing hiding places for pests.
Guidelines for emptying refuse should be prepared.

Flagged areas and drainage systems
Flagged areas should be well drained, as water often attracts pests.
Holes, cracks and crevices should be properly sealed, especially around refuse areas.

Weeds
Heavy weed growth gives good hiding places for rodents. Weeds, flower beds etc. should be removed from around buildings. Generally there should be no vegetation within 1 meter from the building that pests can hide in.

Preventive rodent control
Beside external tidiness, the siting of permanent rodent bait stations is an excellent method of preventive rodent treatment.

The bait stations should be sited outside, along the outer walls at intervals of 15 meters surrounding the building.
It is especially important to site bait stations at the entrances to buildings, containers and refuse areas. Bait stations should also be sited along the perimeter fence. Note, rodent baits can be a source of infestation for insect pests. Baits should be checked regularly for infestation or treated with a residual insecticide. It is essential that effective procedures are in place to prevent any contamination of product by traces of rodent bait.

Preventive insect control
Insects, usually flies, can indicate poor hygiene. Once again cleaning is necessary together with a broad vegetation free belt around the building, and fitting windows with insect netting. Cracks and crevices should be sealed to prevent insect access.

Ad.: Building structure

Preventive rodent control
Inspect the building inside and outside for holes and gaps where rodents can enter. Doors, sliding doors, windows and ventilation pipes must be kept closed when not used. They must fit the framing so that no cracks or

holes are larger than the diameter of a pencil. A metal plate on the lower part of wooden doors and gates prevents rodents from gnawing through. Rooftop ventilation pipes should be secured with galvanised metal netting.

Preventive insect control
Check that all windows have intact insect netting, with a 1/10 gauge mesh. If there are plastic curtains these should be checked for possible defects. Automatic doors are recommended.

Preventive bird control
Birds can contaminate food and be instrumental in the spread of disease and insect infestations develop in nesting material. Birds must be prevented from nesting on roofs and under eaves. Doors should be equipped with plastic strip-curtain preventing birds form entering.
Modify buildings to eliminate roosts and nesting sites.
Check windows, as a defect skylight often is the cause for internal problems with birds.

Roofs
Food particles e.g. dust escaping through the roof ventilation gaps, often causes pest problems (mice, rats, birds etc.).
The roof should therefore be kept clean and the ventilation gaps be provided with dust filters and galvanised netting at the mouth. The filters should be cleaned frequently and if necessary replaced.
Skylights should be provided with a lock and be tight fitting. Inspection of the roof is essential.

Light
Insects, which are attracted by fluorescent lights at night, can become a problem. If so, the problem may be reduced by replacing the fluorescent tubes with tubes without GROLUX.

Other areas
All other areas such as compressor rooms, pump rooms etc. should also be inspected.

Indoors
Many pest problems arise because goods are stored close to or up against a wall impeding cleaning, and creating harbourage.
Goods should not be stored closer than 50 cm to walls and preferably well above the level of the floor.

Stores
Electrician and Millwright stores often have items that are not moved for long periods and may provide habitat for pests. They need periodic inspection and cleaning.

Raw materials
Inspection of raw materials include 2 kinds of inspection. One is the inspection/spot test of the goods and packaging. The other is inspection of the raw material supplier.
Suppliers of raw materials, often from distant countries, do not always show due consideration to pest control. Pests are often brought into a plant in this way.
To avoid this, the buyer ought to pay his suppliers a quality control visit

at least once a year. As this not always practical, the supplier should document that the goods are pest free and the goods be checked at the first possible opportunity.

Raw materials or finished products for ongoing distribution should be inspected on arrival and before entering the plant (se app. 6, page 48).

The packaging/pallets must be inspected for rodent activity or droppings as well as evidence of insects. Samples should be taken of all goods arriving by ship or tanker and kept for a sufficient length of time for eggs to hatch.
Pheremone trapping in the incoming goods storage area may indicate if infested goods are being received. Suppliers of infested commodities should be advised and corrective action taken.

Finished products
The finished product store is the last stop before delivery to the customer. Therefore this store must be easy to inspect, and clean and organised in such a way that any product can be traced back to its production time, line and source of raw material. The plant should be organised so finished products are not stored close to raw materials to prevent the risk of cross infestation.

Returned goods
Goods are often returned because of damaged packaging, elapsed sell-by date etc. Returned goods are often stored randomly, together with other goods, and therefore present a risk of infestation, as pests have easy access when the packaging is damaged. It is essential that returned goods are stored in
quarantine storage and that the goods are examined for evidence of pests or other contamination.

Packaging
The buyer should impose conditions on the packaging supplier. It has often been proved that pests are brought into factories with the packaging. This must therefore be inspected along the same lines as incoming raw materials or other incoming goods.
Corrugated cardboard packaging is particularly favoured by pest moths as a pupation site. Rigorous hygiene and stock control should be carried out in the packaging store.

Walls
Walls should be of an easily cleaned material with mouldings at the floor to avoid dust accumulations and ease of cleaning. Look for cracks and crevices around pipes and ventilation openings in walls. These cracks and crevices must be sealed to prevent providing insect breeding and hiding places.

Floors
The floors should be impervious. All cracks or crevices must be sealed. The sealant must have sufficient flexibility to accommodate normal thermal and other movements of the building. Be aware of places with "false floors" e.g. concrete with a suspended wooden floor. The cavities between are likely to create pest problems. Rodents will hide there and insects may find food/dust residues and live and breed there.

Suspended ceilings
Suspended ceilings often cause pest problems and should therefore be constructed in a way that enables access to the cavities. All crevices should be sealed, in order to avoid dust accumulations and eliminate insect hiding places. Cracks around ventilation shafts should be sealed. Light fittings should be supported at least 2 cm clear of ceilings and walls.

Lift shafts
Lift shafts should be clean and pest free. They should be inspected frequently for possible damp problems, causing pest infestation e.g. mould beetles, as well as food residues which could attract pests.

Siting of goods, machinery etc.
All machinery, goods etc. should be sited away from walls and off floors to enable cleaning under and behind them.

Floor drain
Floor drains often attract pests. Rats can gain entry as well as cockroaches, fruit flies, mould beetles etc. The drain should be kept clean and be covered with a screwed steel grating that can be removed for cleaning purposes.

Sanitary installations
Condensation, obstructed, broken or damaged pipes can all cause pest problems (se above concerning floor drain) as such conditions are often favourable to pests.

Ventilation systems
Production odours can attract pests. Therefore, all windows should be fitted with insect netting. Louvers must be cleaned and the integrity of the seals checked when closed.

Poor ventilation can cause many problems in mills e.g. condensation, mould and smells. A poorly constructed ventilation system with defective, missing or saturated filters can accumulate enough dust and food residues to attract insects and other pests. Ventilation shafts and pipes should be cleaned frequently. Modification may be needed to allow easy access for thorough cleaning.

2.5.3 **Traps and indicators**

Pheromone traps

At present some of the most effective tools in an IPM-system are pheromone traps. A pheromone is a chemical or a mixture of chemicals secreted by an individual which in a gaseous state causes a reaction from another individual of the same species.

Progress within chemical analysis and synthesis methods has made it possible to identify and reproduce the chemical compositions that form the pheromones some insects use.
The pheromones are specific for each species and are only used in very small amounts. Currently there are synthetic pheromones for the most common pests in mills.
Pheromone traps are used to attract insects.

Indicators

The traps are used as indicators. They indicate the presence of a certain species of pests.

Based on the number of adults found, the size of the infestation can be estimated and the risk of spreading assessed, giving a general view of the situation.
For a more detailed view, smaller traps - locators with a limited range of only a few meters can be used. They enable swift location of a smaller pest infestation. A grid of traps can be used to detect regions of a mill e.g. a particular machine, which is infested and in need of particular attention.
When using pheromone traps as indicators at low temperatures, the activity level of pests will also be low. Only a small number of pests are likely to be caught, although there may be many in the area.
High levels of pheromone traps can "trap out" a low population of some moth pests, particularly when combined with hygiene measures.
Pheromone traps are used to monitor the efficiency of cleaning, fumigation or other treatments.
The traps can also be used without pheromones, i.e. no attracting effect, to catch casual intruders.

Electric insect killers

In less dusty areas i.e. store rooms etc. electric fly killers may be used, attracting flying insects with UV-light. The insects are trapped and killed in a high voltage grate behind the fluorescent tubes. The insects are collected in a tray at the bottom of the device and should be identified and counted.

Electric insect killing traps should not be sited in areas with high concentrations of flour/sugar dust because of the risk of a dust explosion.

Poorly sited traps can attract insects from outdoors and so cause a problem. It is important that electric fly killers are only used in an IPM-system, where insect netting is in place at windows and doors and other preventive measures are installed.

Servicing of traps

All traps and bait stations must be inspected regularly, contents or evidence noted on the department check lists, and the bait or pheromone replenished, if necessary.

2.6 **Storage**

As previously mentioned, it is important to inspect goods for pests prior to items being stored.

It is also important that storage is carried out on well organised shelves, raised off the floor to allow immediate, easy removal of spillage and to facilitate and encourage visual inspection.

"First in - first out"

To prevent pests reproducing on site, it is essential that the storage principle "first in – first out", for raw materials, packaging, products etc. is adhered to, allowing goods to be stored for the shortest possible time.

2.7 **Training of personnel**

Personnel

IPM in the mills should involve all personnel . Each individual should be conscious of his/her responsibility to report evidence of pests or conditions that may cause pest infestation.

Training

All personnel should receive some training concerning the life cycle of pests, cleaning, housekeeping, lines of responsibility among personnel and management, company policy and aims.

Seminars

The training should provide each individual with enough information to be able to carry out their duties in a professional manner.

2.8 **Alternatives – not fumigants**

Options

A brief look at some of the available options that may be used in an IPM-system follows. Some are more relevant than others, as new ways, means and methods are developed all the time.
It is therefore important for the IPM-system user to keep abreast of developments and choose the most appropriate methods in each situation.
Appendix 4 shows the undermentioned methods in schematic form. Several have the same or similar characteristics.

2.8.1 **Pesticides**

Cold foggers

Space/fog treatments are carried out normally with synergised natural pyrethrum. It is sprayed as a fine fog/mist into the air space, the mist remains suspended in the air for some time and kills the insects it comes in contact with. Fogging is of limited effect as it cannot penetrate the places where the insects hide and develop: goods in sacks, machinery, cracks etc. It has no residual effect and may kill beneficial insects, particularly wasp parasitoids of pest moths.

Surface treatments with chlorpyrifos or deltamethrin play a large part in

Surface treatment

preventive treatments in Denmark. These insecticides are sprayed into cracks and crevices where insects may hide or as a continuous belt in places where insects contact the insecticide when they wander.

Knowledge of the insects' habits and a careful application of the insecticide is required, in order not to contaminate surfaces where foods is handled. The advantage of these insecticides is that they are residual – even for months. In a mill they may quickly become inefficient if they become covered with flour dust.

2.8.2 **Diatomaceous earth.**

Diatomaceous earth, a very fine inert dust, consisting of the fossilised remains of single-celled plants called diatoms is obtained from mineral deposits.

Slow residual

Diatomaceous earth formulations are slow acting they are thought to cause death by desiccation as a result of disrupting the waxy outer layer of the insect cuticle.
They are visible, easily removed from surfaces and best suited for cavities and undisturbed areas. The insecticide may be an excellent IPM-tool for less accessible, dry areas where a long residual effect is wanted. They are not effective at over 75% rh, but in dry conditions can maintain effectiveness for some years.

2.8.3 **Biological control**

All insects are pests

Many insects or mites live off other insects, either as predators or as parasites on the eggs or larvae. This fact can be utilised for biological control where predators or parasitoids are released in a controlled manner in areas with pest problems. Additional insects are undesirable in food factories and more study is needed.

Food factories and predatory insects

"The Danish Pest Infestation Laboratory" is at present doing research on the control of the Mediterranean flour moth in mills using these techniques.

2.8.4 **Freezing**

Small valuable Consignments

It is possible to freeze goods in order to eliminate all stages of insects. At present the method is only relevant for small amounts of valuable product.
Not all goods are suitable for freezing. Tolerance to cold is different for different species.

Speed is important and limits the amount of goods that can be frozen together without extending the freezing time.

2.8.5 **HTST**

Heat treatment over a short period

High **T**emperature **S**hort **T**ime is a method using high temperatures to treat cereals e.g. to sterilise grain for mink feed. In Denmark tests have been made with HTST for killing insects with air temperatures up to 700°C for 10 seconds without damaging e.g. the germination or baking qualities.
Note that temperatures greater than 500°C are lethal to stored product pests typically in less than a day. At temperatures above 600°C disinfestation takes only a few minutes.

2.8.6 **Entoleters**

Cleaning of grain

Entoleters are impact machines, material is fed into a rotor revolving at

high speed and flung outward onto studs on the walls of the machine, the speed can be adjusted to avoid damage to sound kernels, however damaged kernels and insects are broken on impact and separated from the bulk. Entoleters are best used to disinfest milled products.

2.8.7 **Cold storage**

Cold storage

Insect pests typically require temperatures above 14°C in order to be able to multiply. Below this temperature many pests slowly die off, with eggs, larvae and pupae often susceptible to moderately low temperatures. Some adult pests and those able to enter a resting stage known as diapause may persist for months or even years.

Storage at below 14°C and under dry conditions is a useful management tool for raw materials which are at risk of carrying a low level of infestation. Subsequent processing may eliminate the pests while the cold prevents their spread or multiplication in store.

3 Direct alternatives to Methyl Bromide

IPM - no patent solution

In the case of an acute infestation in a food plant, it is necessary to have a contingency plan. In this project we have looked at several possibilities and below we describe the most obvious alternatives to methyl bromide. In annex 5 there is a schematic survey of these alternatives with a brief description of other local treatments.

With the present intensive research to find alternatives to methyl bromide, other solutions are likely to be found in the near future. As mentioned earlier IPM is a flexible system - there is no one single patented alternative for the elimination of pests. The solution or solutions must be tailored to the problem.

3.1 **Carbonyl sulphide (COS)**

COS has been examined as a possible alternative to methyl bromide. The focus so far has been on COS as an alternative to MB against pests in grain in stores and silos. At present there is no commercial source.

"Either-or" poison

COS is a colourless liquid with its boiling-point at 50,2°C. COS is well known because of its natural part in the sulphuric cycle. COS is a part of the natural sulphur in soil and moorland areas. It is formed by anaerobic decomposition of organic sulphur material.

Ventilation

COS is like hydrogen cyanide an "either-or" poison, meaning that after a COS poisoning there will be a 100% recovery except for mortal cases.

COS is inflammable, but when used to fumigate the concentrations are far under the explosion limits.
In regards to ventilation it resembles hydrogen phosphide (PH3) and can quickly be blown out of the grain, as it is not absorbed.

COS is very effective against insects and mites in grain. 25 mg/l for 24 hours is enough to kill most insects in all stages, but the rice weevil (Sitophilus oryzae) will require a larger dose or a longer operation time. COS has excellent penetration ability through flour and other closely packed products.

No approval in Denmark

COS is neither tested nor approved in Denmark for fumigation.

If one were to use COS at the present time one disadvantage would be that the gas detecting equipment, used to measure COS-concentrations is not as sensitive as the equipment used to measure Phosphine or Methyl bromide.

3.2 **Hydrogen cyanide (HCN)**

"Either-or" poison

HCN has previously been used to fumigate mills in Denmark. It is a colourless liquid and smells of bitter almonds. It is lighter than air and has its boiling-point at 26°C.

Characteristics

Like COS, it is an "either-or" poison. HCN is inflammable, but when used to fumigate the concentrations are far under the explosion limits.

No approval in Denmark

HCN is very toxic and extremely quick-acting on most living creatures. It does not have the quick effective penetration that MB has and it is easily dissolved in water. This is very important when used as a fumigant, as it will bind with moisture and can be difficult to ventilate.

HCN will have to be approved in Denmark before it can be used again as a fumigant.

3.3 **Chloropicrin (CCl_3NO_2)**

Characteristics

CCl_3NO_2 has been used as fumigant but is now mostly used as a warning agent in MB fumigation. It was also used as a poison gas during World War 1. It is 5,7 times heavier than air and is non-flammable. CCl_3NO_2 has its boiling-point at 112,4°C.

CCl_3NO_2 is heavy and very difficult to use. It is very toxic and quick-acting on insects.

Ventilation

CCl3NO2 is difficult to ventilate and even small amounts in fumigated goods can irritate the eyes for a long time, because of the tear causing effect.

No approval in Denmark

CCl3NO2 is not approved as a fumigant in Denmark.

3.4 **Phosphine (PH_3)**

Approval in Denmark

PH3 is used in the form of pellets, tablets or plates. It is slightly heavier than air, specific gravity 1,21/1,0 - boiling-point at -87°C, in impure form it has a carbide or garlic like odour, but when pure this odour is removed.

PH3 is explosive at concentrations of more than 1,8% in air.

Corrosion risk

By oxidation, phosphoric acid is formed, and there is a risk that combined with sufficient moisture, the fumigant can corrode copper, silver, gold and their alloys and thereby make electronic instruments and systems fail. Potentially, problems can arise when using both magnesium and aluminium phosphine. The corrosion risks involved with phosphine have been tested by FORCE Instituttet, København and published in their report. There are precautions that can be taken to avoid corrosion by phosphine in mills.

Length of treatment

The gas is generated slowly and requires a longer operating time than Methyl bromide. Difficulties can arise when deactivating the powdery

residues of tablets and pellets especially when large quantities are used over a short operating time.

Good permeation

PH_3 has good permeation abilities. It operates slowly but very effectively at low concentrations if the operating time is long enough. The operating time is typically 4 days or more depending on the temperature and target insect species.

At temperatures under 10°C PH_3 should only be used against a selected insect species, exposure times can be more than 14 days in some cases, particularly against Sitophilus spp (grain weevils).

Liquid Phosphine

Liquid Phosphine

Phosphine 2% - carbon dioxide 98%.

Unlike the formulation we know today - solid form e.g. pellets/ plates the new form of phosphine is a 2% liquid formulation with an admixture of carbon dioxide.
The advantages of this formulation are the reduction of phosphine concentration required and a slightly shorter exposure time. And therefore less risk of metal corrosion.

Phosphine generators

Mill fumigation with phosphine has been demonstrated using phosphine supplied from a generator outside the structure.

3.5 **Heat treatment**

Non-chemical pest control

Heat treatment against insects is probably one of the most effective non-chemical methods of pest control.

It is not a new method of controlling pests and has in the past been used with reasonable results, in mills and other places where foodstuff pests appear. 24 hours at 50-55°C is used in many US mills.

Several countries are at present working on improving heat treatment an lowering costs in order to make it a viable alternative to Methyl bromide.

The treatment time is dependent on the temperature generated. Less than one minute at 65°C is mortal for all insects. At lower temperatures more time is necessary. An allowance needs to be made for time taken to heat through solid goods and constructions, to reach insecticidal temperatures.

Heat treatment has been used for many years often with excellent results. Heat treatment is not a new pest control method but has in the past been used, sometimes not very efficiently, in mills and other places where foodstuff pests appear.

Individual infested areas and pieces of machinery may be treatable by spot fumigation after removing product residues. Ethylene dichloride is still in use for this in some countries and some other materials are under development.

3.6 **Carbon dioxide (CO_2), phosphine (PH_3) and heat.**

CO_2 has been used for many years as a fumigant, but is impractical as a whole mill fumigant. The main disadvantage is that it operates very slowly. By combining CO_2 (4-6%) with heat (32-37°C) and PH_3 (low dose 65-100 ppm) tests have shown promising results. The method is said to give good insect pest control over a three day exposure or less.

3.7 **Sulfuryl fluoride (SO_2F_2)**

SO_2F_2 has its boiling-point at -55,5°C. SO_2F_2 is odourless, non-flammable and does not cause unwanted taint.

Because of its physical characteristics SO_2F_2 permeates materials quickly and is completely removed by ventilation.

SO_2F_2 was developed under the name "Vikane" in the 1950's for treatment of houses, churches and other buildings against wood destroying insects.

Laboratory tests

In the later years there has been research into the possibility of using SO_2F_2 as a fumigant in food plants. Laboratory tests are still going on concerning dosage, temperature, exposure time, side effects etc. The product is not approved for fumigation of pests in stored product goods, but has the potential as a whole site treatment of premises from which foodstuffs have been completely removed.

No approval in Denmark

4 Implementation of IPM in a flour processing plant

The project group has visited a number of mills that are members of FDHM and has forwarded questionnaires regarding conditions in the individual mills.
The questionnaires were completed and returned to the project group. Based on these, and together with the project groups own experience with mills, we will try to show how and where to implement an IPM-system.

Quality responsible person

Firstly is important to appoint someone on site to be responsible for quality. This person will be responsible for implementing and maintaining the IPM- system. It is vital that senior management gives the system a high priority in order for it to function effectively.

Practical preparations

A thorough inspection must first be undertaken for pests and general hygiene levels. All cracks, crevices etc. where pests can hide must be removed or sealed.

All windows and doors must be proofed either with insect netting or sluices to prevent pests entering the building.

The factory is divided into zones, with areas of responsibility for personnel under the supervision of the quality controller.

A comprehensive hygiene plan is drawn up for each zone, with details and responsibilities for cleaning and inspection routines and their frequency.

Survey sketches

A sketch of the area showing where insect traps/monitors are to be placed. When placing the traps they must be numbered and dated.

An inspection check list of the area is made. It must be kept up to date by the person responsible and assessed by the quality controller.

Procedure for treatment

If any evidence of pests is observed, action should be taken immediately.

Raw materials

There should be an inspection routine for all incoming raw materials. If pests or evidence of pests are found, then the raw materials must be isolated from other materials,to prevent pests from spreading.
It must be decided immediately whether the raw materials should be discarded, returned or treated.
All incoming raw materials and goods must be checked. Packaging etc. must be inspected for pests or evidence of pests, before it enters the factory.

"First in - first out"

The principle of "first in- first out" should be followed. Materials should be stored about 0,5 metre away from the walls and should be raised off the floor to allow inspection for pests and to remove spillage from damaged packaging.

If the goods are to be stored for longer periods, inspections should be carried out frequently.

If the goods are stored for more than 3 months they should be thoroughly inspected before leaving the store.

Once a week, a visual inspection of the packaging, bags, sacks etc. should take place.

We recommend that cleaning schedules be drawn up for each zone. Guidelines are shown in app 6.

5. Conclusion

This preliminary project outlines some of the experiences, thoughts and ideas that will be necessary in connection with future pest control in Danish mills when Methyl bromide is no longer available from 1.1.98.

Several alternatives - Integrated Pest Management

There is today no single alternative to replace Methyl bromide in all its uses, though the combination of several alternatives may.
This combination of alternatives is called IPM (Integrated Pest Management).

Integrated Pest Management

IPM is a system, a continuous process, with the emphasis being on prevention, not cure.

The system ought to include the following points:

Integrated Pest Management as an alternative

When implementing an IPM-system as an alternative to Methyl bromide, attention must be paid to the following points:
(See section 4 - The start of IPM in a milling)

* A comprehensive survey of the site.

* An assessment of the potential risks.

* A detailed description of the preventive proofing and control needed.

* Access to all areas, and detailed full site plans.

* Knowledge of the material flow through the site.

* Working practices and cleaning routines.

* Structural modifications to “build out” pests.

* Future plans regarding new products, machinery or building alterations.

* Clear lines of communication and responsibility.

The system is built on frequent detailed inspections, including monitoring by traps, to determine and take the necessary action to eliminate any pest problem found together with clear documentation. IPM appears to be effective and the project group is convinced that if used correctly, IPM can be a valid alternative to Methyl bromide. We still need more practical experience in order to determine the systems qualities as regards efficiency, economy and environmental soundness.

Main project

The initial starting point must be with the Danish mills and the attendant change of attitudes which will be necessary in implementing an IPM system.

It is expected that a main project would identify and assess the practical value of such a system, its efficiency-, economy-, and environmental-parameters.

The aims of the system must be clear and visible for everyone involved. The system must be measurable as far as possible and documented both qualitatively and quantitatively concerning:

* Any agreements/contracts between the mill and an outside pest control contractor.

* The number and limits of any hygiene inspections.

* Communication at all levels of the hierarchy within the mill and with outside contractors.

* Training personnel in the recognition of pests / stored product insects, mites and rodents, and their use as indicators of plant hygiene

* Documentation, the content and filing of all reports concerning Integrated Pest Management.

* Quality control

* Testing new methods and assessing existing ones.

* Contingency plans in case of an acute infestation.

Although the above mentioned are all individual points they must be assessed as a whole, to be an alternative to Methyl bromide.

Only in a joint concept - a system - can the best solutions be determined and the system function as one.

The only way to test IPM as an alternative to Methyl bromide in Denmark is to put it into practice.

6 Literature list

1:
Miljøministeriets bekendtgørelse nr. 478 af 3. juni 1994, om forbud mod anvendelse af ozonlagsnedbrydende stoffer.

2:
Arnold Mallis:
Handbook of Pest Control. 7th edition. Franzak & Foster Co. (1990). pp 1037 - 1072

3:
Arnold Mallis:
Handbook of Pest Control. 6th edition. Franzak & Foster Co.
pp 1041 – 1045

4:
J. Richard Gorham:
Ecology and Management of Food-Industry Pests. Association of Official Analytical Chemists (1991) p 595
5:
Henri Mourer, Ove Winding og Ebbe Sunesen:
Vilde Dyr i Hus og Hjem. Gads forlag (1975) pp 56 - 93

6:
Thorkild Hallas og Henri Mourier:
Skadedyr i Levnedsmidler. Polyteknisk forlag. (1984) p 190

7:
E.J. Bond:
Manual of Fumigation for Insect Control. FAO Plant Production and Protection Paper 54 (1984) p 432

8:
The IPM Practitioner, volume IX, number 8. pp 1 - 4 (August 1987)

9:
David Mueller:
Practical use of Fumigants and pheromones, Technical Conference and Workshop, Lübeck, Germany (1993) p 169

10:
G.B. Coates and M.A. Sheard:
The HACCP Concept and Quality Assurance in food Manufacture and Catering. The Society of Food Hygiene and Technology. proceedings of a meeting, Leeds Polytechnic (1985) p 46

11:
Quality in Hygiene Management. The Society of Food Hygiene Technology.
The proceedings of a one day symposium, London (1992) p 49

12:
Thomas J. Imholte:
Engineering for Food Safety and Sanitation. - Technical Institute of Food Safety Inc. USA. (1984) pp 210 - 232

13:
Lise Stengård Hansen:
Status Concerning Alternatives to Methyl Bromide. pp - 38 - 41 in: Alternatives to Methyl Bromide. Tema Nord, Nordic Council of Ministers, Copenhagen. (1995 : 574) p 67

14:
Thorkil E. Hallas, Steen Gyldenkærne, A. Nøhr Rasmussen og Jørgen Jakobsen:
Methyl Bromide in the Nordic Countries. Nord (1993 : 34) p 46

15:
Lise Stengård Hansen:
Biologisk og Microbiologisk bekæmpelse af Skadevoldere. Ansøgning til projekt. (1996)
16:
Rådets Direktiv 93/43/EØF af 14. juni 1993
Om Levnedsmiddelhygiene.
De Europæiske Fællessakbers Tidende

17:
Ole T. Toftdahl Olesen:
Teknologi og Lagring. Forskningscenter Foulum, DK. (1994) p.13

18:
B.W. Bridgeman:
Structural treatment with Amorphus Silica Slurry. Preceedings of the 6th International Working Conference on Stored Product Protection. Vol. 2. (1994) pp. 628 - 630

19:
A. McLaughlin:
Laboratory Trials on Desiccant Dust Insecticides. Proceedings of the 6th International Working Conference on Stored Product Protection. Vol 2. (1994) pp. 638 - 645

20:
UNEP. 1994. Report of the Methyl Bromide Technical Options Committee (MBTOC); 1995 Assessment. United Nations Environmental Programme, Ozone Secretariat. 304 pp.

21:
GAM:
Food Hygiene Code of Practice for the European Flour Milling Industry.
Groupement Des Association Meunieres Des Pays De La C.E.E. (1995) p. 24

22:
Anon:
Alternatives to Methyl Bromide. United states Environmental Protection
Agency. EPA430-R-95-009 (1995)

23:
J.M. Desmarchelier:
Carbonyl Sulphide as a Fumigant for Control of Insects and Mites. 6th International Working Conference on Stored-Product Protection (1994) pp. 78 – 82.

24.:
Anon:
Simple Solution For Ozone Killer. New Scientist. (1993 July)

25:
Michele R. Derrick, Helen D. Burgess, Mary T. Baker and Nancy E. Binnie.
Sulfuryl Floride (Vikane): A Review of its Use as a Fumigant. JAIC 29 (1990) pp. 77 – 90

26:
Ebbe Rislund (Force Institute, Denmark):
Corrosion Aspects of Phosphine Fumigation.
Working Report Nr. 29, 1996. Ministry of Environment and Energy, Danish Environmental Protection Agency (1996) p. 5.

27:
Anon:
Review of Methyl Bromide, British Pest Control Association
RJS / F6 / 1 / 251/ L (1992) p. 22

28:
Dixy Lee Ray:
Truth or Spoof, Thoughts on The Banning of Methyl Bromide. Science and Technology. (1993) pp. 13 - 18

29:
C.H. Bell, B.E. Llewellin, B. Sami, B. Chakrabarti and K.A. Mills:
The use of a Self-Cooled Exothermic Controlled Atmosphere Generator to Provide a Means of Controlling Insect Pests in Grain. Paper presented at the 5th International Working Conference on Stored Product Protection. (1996) pp. 1769 – 1776

30:
A.L. Clifton, C.H. Bell, K.A. Mills, N. Savvidoul:
Control of Grain Pests with Phosphine at Temperatures Below 10°C Project report 105.
Central Science Laboratory, England. (1990) pp. 10 - 21

31:
John Newton:
Carbon Dioxide as a Fumigant to Replace Methyl Bromide in the Control of Insects and Mites Damaging Stored Products and Artifacts. Pater presented at The International Conference on Insects Pests in the Urban Environment.
Cambridge, UK. (1993) p. 16

32:
Michael K. Rust and Janice M. Kennedy:
The Feasibilty of Using Modified Atmospheres to Control Insect pests in Museums. GCI Scientific Program Report. University of California (1993) p. 122

33:
Robert L. Kirkpatrick and Hohn R. Roberts, Jr:
Insect Control in Wheat by use of Microwave Energy. Journal of Economic Entomology, volume 64, number 4. (1971) pp. 950 - 951

34:
David K. Mueller:
A New Method of using Low Levels of Phosphine in Combination with Heat and Carbon Dioxide.
Fumigation Service and Supply Inc. Indiana USA. (1994) pp. 1 - 4

35:
Bo Madsen:
Heat Treatment, an Alternative to Methyl Bromide Fumigation of Mills.
Indlæg ved Nordisk Seminar om Alternativer til Methylbromide. (1994) p. 5

36:
B. P. Saxena, P.R. Sharma, R.K. Thappa and K. Tikku:
Temperature Induced Sterilization for control of Stored Grain Beetles.
Journal of Stored Products Res. Vol 28, No 1.
Pergamon Press (1992) pp. 67 – 70

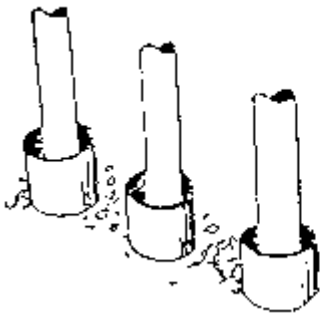
37:
T. Black and J. W. Heaps:
Using Portable Rented Electrical Heaters to Generate Heat and Control Stored Product Insects.
The Pillsbury Company, Minneapolis, USA. (1994)

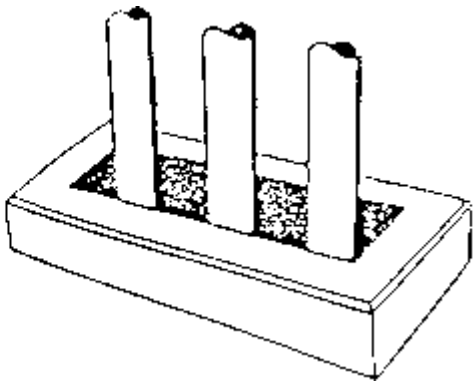
38:
Anon:
Warehouse Sanitation.
GMI Inc. Minnesota USA (1974) p. 6

39:
Anon:
Do Your Own Establishment Inspection.
HHS Publication Nr. (FDA) 82 - 2163 (1980) p. 20

Design:

Pipe entry between floors

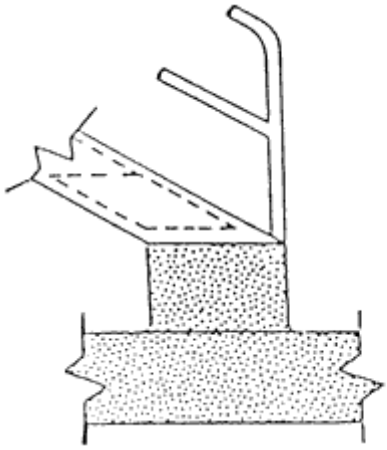


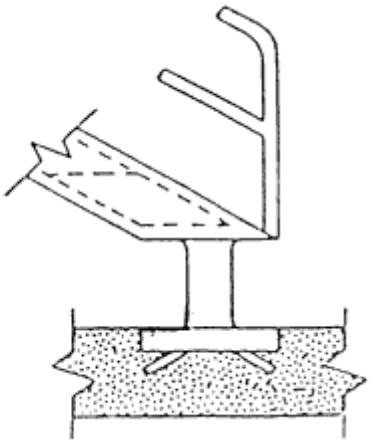


Correct:
enables cleaning
dust e.g. is not accumulated

Wrong:
difficult to clean
dust is accumulated
harborauge for pests

Staircase finish:



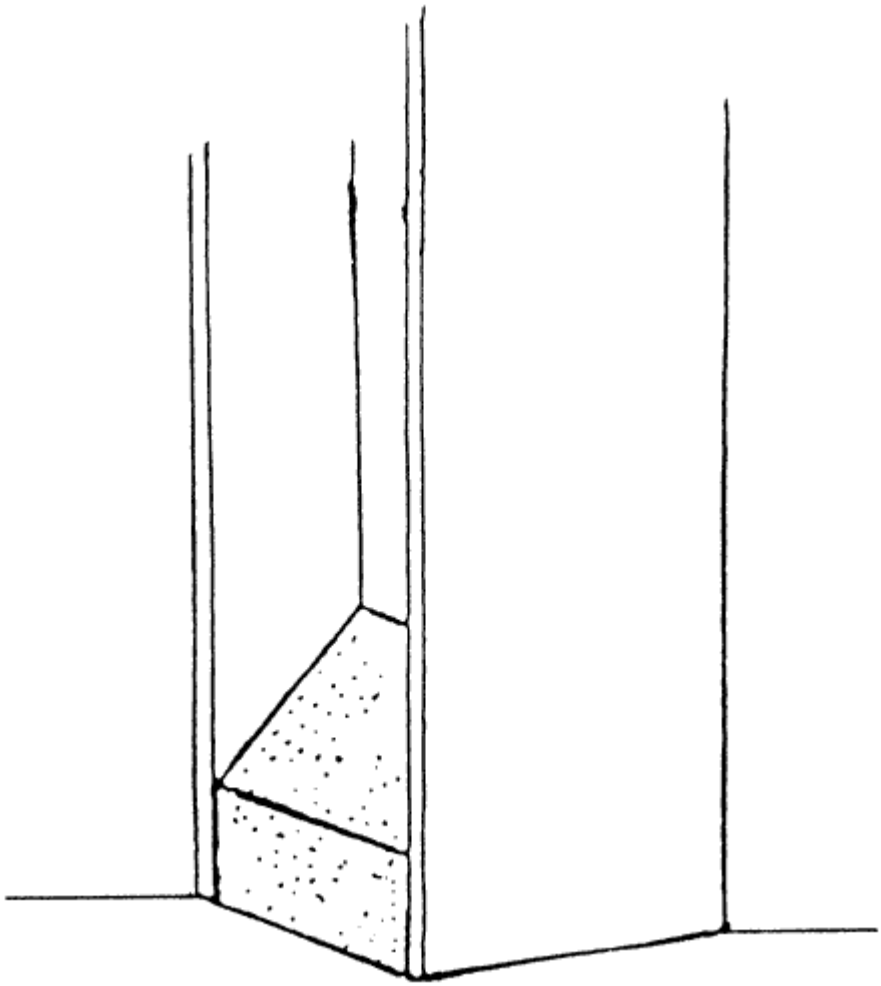


Correct:
easily cleaned
dust e.g. easily removed

Wrong:
difficult to clean
dust accumulates
harborauge for pests

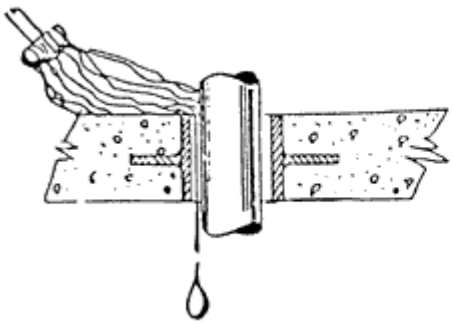
Design:

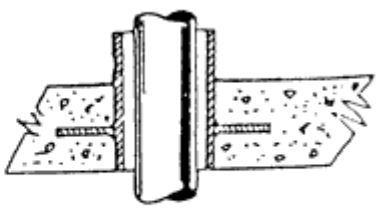
Building construction, filling with cement:



Cement filling
provides easy cleaning and prevents pests

Pipe entry:





Wrong:
impossible to clean
dirty water will accumulate
creating harbourage for pests

Correct:
easy to clean
water does not accumulate

Proposed cleaning plan:

Machinery/ equipment	Frequency	Inspection	Cleaning	Treatment
Weighers	Weekly Monthly	Check surrounding dust for insect tracks	Change cotton filter Remove covers and vacuum thoroughly	 If necessary treat surfaces not coming in contact with flour, with residual product
Packing room	Weekly Monthly	Check accessible surfaces for insect tracks	 Remove barriers and motor shields. Remove spillages. Vacuum	 As above
Vacuum cleaner	Daily Monthly	Check bags for insects	Empty and clean Strip down and clean	 As above
Standby- reserve-machinery	Monthly	Check thoroughly	Vacuum or wipe	As above
Remarks				

Methods to control and monitor pests. January 1996.

Name	Approved in Denmark	Application area	Remarks
Natural pyrethrum	Yes	Space- spray undiluted in silo, storage etc. against flying insects	Pyrethrum is very effective against flying insects, which are killed immediately. There is no long term residual effect. Mostly used to control a local infestation until a residual product becomes active or the area can be fumigated
Chlorpyrifos on water basis	Yes	Used to treat cracks, crevices and barrier/belt method	Chlorpyrifos is used to control insects in and around buildings. It is odourless and has a long term residual effect. Not to be used on surfaces coming into contact with food
Chlorpyrifos Solvent base	Yes	Used to treat cracks, crevices and barrier/belt method, in areas likely to be wet or washed down	Chlorpyrifos lacquer can only be applied by brush. Is of limited value in mills. The advantage over the water based solution is the long term residual action in damp conditions such as basements and floor drains.
Deltamethrin	Yes	For the control of insects on surfaces where insects crawl or land	Deltamethrin is odourless and has a long term residual effect. Not to be used on surfaces where food is handled, apart from the walls and floors of granaries and silos, it is specially useful in old wooden silos, floors etc.
Diatomaceous earth	No	Used against crawling insects in their habitats	Diatomaceous earth can have a long term effect under dry conditions. Can be unsightly and is best used in cavities and non visible undisturbed areas.
Pheromone traps		Used to lure and trap insects for identification and get a general view of the extent of the infestation Can be used to locate an infestation.	The traps are specific for each species and used for indication only but can help reduce the number of insects. Note in the summer they can attract insects from outside and therefore must be used with forethought.

Name	Approved	Application area	Remarks
Sticky traps		Used to trap insects for identification and get a general view of the extent of the infestation	Sticky traps are not species specific and trap all insects coming into contact with the sticky surface. Not all kind of traps are suitable for dusty areas as they become ineffective because of the dust.
Electric insect traps		Where there are flying insects.	Ultraviolet light attracts insects onto a high voltage grill where they are killed. Not to be placed in very dusty areas because of the risk of dust explosions. They can be an excellent supplement in stores, packaging and other less dusty areas.
Biological control with predatory insects		Predatory insects are specific for each species and will e.g. attack the eggs of a certain moth species	At present all insects found in a food factory are considered pests by the authorities and buyers, both pests and so-called utility insects are therefore undesirable. The use of such insects in food factories is now being researched

Possible alternatives to fumigation

Name	Chem. name	Approved	Operating time	Application area	Remarks
Carbonyl-sulphide	COS	No	24 hours	Stores and production buildings, equipment and machinery	Quick-acting, good penetration, qualities, effective. Inflammable at high concentrations. CSIRO, The Stored Grain Research Laboratory in Australia are at present applying for a patent on the gas as a fumigant
Carbon dioxide, Phosphine and heat	CO_2 and PH_3	No	24 - 36 hours	As Phosphine	Quick-acting, good penetration qualities, effective. As less phosphine is required the corrosion and ignition risks are greatly reduced.
Heat	°C		A minimum of 55°C for 10 hours. Heating time depends on the ambient temperature, the buildings construction and content	Stores and production buildings, equipment and machinery	When the temperature is attained: quick-acting and effective. No residues. Several successful trials have been made in mills smaller than about 3000 m^3. At present we do not know whether the results can be applied and viable in large complicated modern facilities with many floors, rooms and passages
Freezing	°C		Dependant on the material and the amount of material	Small valuable consignments	The cold tolerance varies for each species and also for the stage of development. The eggs are often most tolerant. Not all goods are suitable for freezing
Microwave, UV-light, radiation, HTST		No			There have been many tests utilising micro wave radiation etc. At present they can only be used on small quantities of goods. The methods are very specialised and as yet, expensive.

A survey of the practical possibilities of fumigation against insects, in Danish Mills. January 1996

Name	Chem. name	Approved	Operation time	Application area	Remarks
Methyl bromide	CH_3Br	Not after 1.1.98	24 - 48 hours	Stores production facilities, equipment and machinery. Containers and small local fumigations	Quick-acting, effective, good penetration abilities. Non-flammable. No active residues. May be used on some food stuffs such as grain, dry fruit and nuts.
Phosphine	PH_3	Yes	4 - 10 days depending on temperature and air humidity.	Silos, stores, milling equipment and machinery. Small local fumigations	Slow-acting, effective, good penetration abilities. Cannot be used at temp. under 10°C. Inflammable at high concentrations. Residue problems in some countries. Corrosion risk of precious metals under certain circumstances. May be used seed, grain and flour. In large amounts the residues can be difficult to handle
Hydrogen Cyanide	HCN	No	Less than 24 hours	Stores, production facilities, equipment and machinery	Very quick-acting, effective. Inflammable at high concentrations. Extremely poisonous to humans. Easy dissolved in water. Used on dry food such as nuts, grain and flour
Sulfuryl-fluoride	SO_2F_2	No	24 - 48 hours	Stores and production facilities, equipment and machinery	Quick-acting, very good penetration abilities. Non-flammable. Has never been approved for the use on food.

Guidelines for the Inspection of high risk areas:

Area	Frequency	Inspection	Cleaning	Treatment	Remarks
<u>Raw materials:</u> Grain Nuts Dry fruit Chocolate	Control of all incoming goods. Spot checks. Store the goods long enough for hibernating insects to appear	Open 1 of every 50 boxes /bags and inspect		If treatment is necessary e.g. use PH_3 Alternatively store dry at under 14^0C	The mill should ensure that all goods are certified as being pest free.
Storage of raw materials	Store the goods after the principle: "first in - first out"	The area should be inspected weekly	Weekly . Spillage removed immediately	Cold storage or PH_3. Local treatment with insecticides or monitoring with mouse and insect traps	Silos to be inspected and cleaned when empty
Production Cleaning plant		Weekly	Weekly Spillage removed immediately		
Milling rollers		Inside Outside	Weekly		

Area	Frequency	Inspection	Cleaning	Treatment	Remarks
Mechanical transfer systems Screw and bucket		Weekly	Weekly Spillage removed immediately	When needed	Check filters frequently. Change filter bags
Sifters		Surroundings daily. Inside every 2 months	Every 2 months. Spillage removed immediately	When needed	Check tailings
Finished silo		Manhole, inspect the top weekly	Clean when empty	When needed	Silo screw (bottom) should be inspected when empty
Packing room		Weekly	Daily Spillage removed immediately	When needed	

Area	Frequency	Inspection	Cleaning	Treatment	Remarks
Bagged flour tapping		Daily	Daily Spillage removed immediately	When needed	Dust must not collect on edges or cables in dead spaces or trunking
Finished product store	First in - first out	Weekly	Weekly	When needed	
Bulk tankers		When empty	When empty	When needed	Be aware of: Pipe systems Filter bags
Returned goods store		Weekly	Daily	When needed	Returned goods store should be isolated and away from other food materials