INSECT - AND MITE-FREE DRY FOOD MANUFACTURING: IS IT POSSIBLE WITHOUT METHYL BROMIDE?

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Abstract - For over 50 years methyl bromide has been used in ever increasing quantities for broad-spectrum pest control and eradication. In dry food manufacturing its good penetrative properties both into commodities and into the structural complexities of buildings made it a very useful “blanket” eradication fumigation treatment. Some food industry sectors, pre-empting the world-wide concern over the environmental effects of methyl bromide, have worked to find alternatives to traditional fumigation. However, there are many significant importing, processing and manufacturing sub-sectors claiming still to need methyl bromide due to special circumstances and high risk factors. It is clear that these views are often very insular, since the alternatives, at least in general principle terms, are already well established or are being actively developed in other sectors or countries. This paper investigates the possible alternatives to methyl bromide (on the premise that effectively the Montreal Protocol will permit almost no exceptions to its complete withdrawal) by reference to work already established or being undertaken in related food industry sectors. Its main conclusion is that the solutions are already available, although cross-sector collaboration, itself unusual, and probably without significant governmental funding, is needed to transfer the technology and to achieve workable results within the required time scale. The pressures of what is now a political decision will ultimately lead to a much higher standard of more sophisticated pest prevention and control within the human food manufacturing and storage industries which, in turn, will result in far less insect and mite contamination of finished, manufactured food products.
Key words - HACCP, fumigation, risk assessment, pest control

INTRODUCTION

The inevitable phasing-out of methyl bromide as a commodity and building fumigant over the next 5 to10 years is causing concern to many sectors of the food industry. Flour milling, baking, biscuit manufacture and raw and finished products commodity storage are areas where whole building or selected stock fumigations have become the norm over the last 30 or more years, and where a direct replacement gas is generally not available. However, a more careful investigation of the principles of pest prevention and control reveals that many smaller sectors, or even individual companies, have already faced the future by investing in development of existing technology, or have actively developed their own solutions through lateral thinking and application of sound logic.

This paper presents these ideas in a logical progression, to show that there could be significant gains in terms of product quality, particularly in a reduction of insect and mite fragment contamination, and in the ease with which budgeting and pest prevention assessment can be integrated with the normal production and hygiene scheduling. Examples of specific sector problems and solutions are given, and clear guidelines allow for the principles to be utilised in all sectors.

Methyl bromide in fumigation

The changes over the last 100 years, in the occurrence of insect and mites in foods and the public view of these contaminants, has been one of gradual improvements at all stages within the food industry, but with the most dramatic rise in “quality” from the late 1950s onwards. Many older researchers and others involved in extension services might consider the immediate post-war years (at least in Europe, and from a very narrow viewpoint), as the “golden years of infestation”, when government and public concern for less contaminated foods led the need for technically sound solutions.

This period saw an unprecedented development of chemical control methods, including the well known residual insecticide groups, which are themselves now being rapidly overtaken by current safety

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legislation and newer developments. One of the most effective chemical pest control methods for a wide range of situations is fumigation, and for many years the industry could choose from around 15 different fumigants to suit particular problems. This choice narrowed dramatically in the last 20 years and, effectively, we now have either phosphine or methyl bromide for general pest control fumigation. Even this choice is not equal since phosphine cannot easily be used in some circumstances where methyl bromide is best, and methyl bromide has its own drawbacks in selected areas. To add to the rapid rate of change in choice, methyl bromide is scheduled to be withdrawn from all but a very few specific uses over the next 5 years.

Technical questions

Over its 50 or so years of use, methyl bromide has proven itself probably the most useful general disinfestation technique for use with dry food manufacturing. It can be 100% effective in eradication, without leaving unacceptable chemical residues, and can be used for structures and commodities over short treatment times. Nothing is ever perfect, however, and its disadvantages include heavy layering at lower temperatures (a noticeable problem in the UK), bromide residues in some commodities, poor penetration into some structures and, conversely, excellent leakage out of other fumigation situations! However, the realisation that methyl bromide can attack and destroy atmospheric ozone has led to its being listed under the Montreal Protocol for fairly rapid withdrawal. The fine details of the schedule do not concern us here, but the time scale for complete withdrawal leaves the food and pest control industries with about 5 years in which to have satisfactory alternatives ready. Is this feasible, for a sector which has, for the most part, relied very heavily on methyl bromide as a very wide-spectrum pest eradication technique for several decades? Are there sub-sectors for which there are no practical alternatives? Must the public and food safety agencies accept that more insect and mite contamination is inevitable in foods which have, hitherto, been protected by methyl bromide?

Whilst there is no single technical answer, there is a clear response from consumers and politicians alike - contaminated food is not an acceptable trade-off for withdrawing methyl bromide. Somehow the pest control sector and its clients in food storage, manufacturing and distribution must devise methods which offer at least the same degree of control and protection whilst ensuring that the consumer public, the foods themselves and the environment in general are in completely safe hands.

Fumigation situations

Growing crops. For some crops the soil, whether in fields or in glasshouses, is routinely fumigated with methyl bromide to prevent a build-up of noxious weeds or pests. The techniques employed all rely on injection or release of gas beneath covers of more-or-less impermeable plastic sheets. For many growers in many countries this has become a standard treatment and the total quantity of methyl bromide so used is about 80% of all fumigation uses. Airing-off (ventilation) after treatment comprises removing the sheets and allowing the gas to disperse naturally. In enclosed glasshouses collection of gas into charcoal filters has been researched but without true practical benefit. In field situations this is not feasible, although drenching the soil with water does convert some of the gas into a weak organic acid thus reducing the bromide residue and effectively diluting the contamination.

Fresh plant material for export. Once crops are harvested it is rare for the fresh plant material to be fumigated with methyl bromide. However, for certain plant materials in export markets such fumigation may be required by governmental plant health organisations to ensure the eradication of potentially harmful organisms. This quarantine fumigation procedure is very carefully controlled to avoid damage to the living plants and could, at least in theory, be done in a re-cycling mode to prevent the release of the fumigant to the environment.

Stored products exports. For dried food materials, pre-shipment fumigation from exporting countries is very common, though usually to ensure freedom from possible insect pests, rather than to kill known infestations. More technical understanding and care in production, packaging, transport and shipping, with a suitable monitoring strategy and schedule appropriate to the commodity and risks,

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would greatly reduce the incidence of infested goods being transported, perhaps by as much as 95%.

There is an additional problem with export shipment fumigations - it often doesn't work! Factors such as poor technical quality of fumigation, insufficient care between fumigation and loading, and possible cross-infestation during shipment, often combine to remove all credibility from the accompanying fumigation certificates. If this is so, maybe government plant health agencies should insist on accurate and reliable pest monitoring so that real risks would be identified and so dealt with effectively? This itself could reduce fumigation needs in producer countries and ensure that only justified treatments are done on arrival in the importing country.

However, fumigation of dried food exports is commonly done not for plant health quarantine reasons, but to ensure compliance with trade standard agreements. Here is clearly a case for better monitoring at export and import ends. Costs may rise, though probably not significantly, and a higher quality of pest-free export will inevitably mean a better quality of raw material on arrival and a lower incidence of undetected pests being transferred into factories in the manufacturing countries. How many problems in factories are attributable to infested raw materials being brought in unwittingly? Improve the pest detection system at point of production, improve the commodity handling systems, and the result will be a great improvement in quality of commodity on receipt.

Stored products in store. A number of stored food commodities are imported for both production and for market trading. Cocoa beans, for example, are imported into Europe in large tonnages, much of which stays in store for several years as a commodity investment. This increases the risk of infestation and leads to a great deal of fumigation of stacks within warehouses. Commodity storage is a competitive business, but the costs of repeated fumigations within stores does not seem to be a major problem, even when better storage systems and treatment schedules are proposed.

Factories often require commodities received either direct from the docks or via European warehousing, to be fumigated as a guarantee of freedom from insects. These will usually be treated in freight containers en-route to the destination or as stacks in warehouses. The former is commoner, sometimes as containers in transit on-board ship or in a container handling yard. De-stuffing containers to arrange fumigation of the commodity is time-consuming, takes up warehousing space and adds considerably to the cost. On the other hand, bringing into a factory un-fumigated stocks of raw materials is seen as a high-risk action.

Buildings. Over many years a large number of food processing factory sites have been wholly or partially fumigated to remove infestation problems, or to ensure freedom from potential risk. For the last 10 years this number has been reducing, partly because of the cost of fumigation, and partly in response to a desire to minimise pesticide usage. Buildings are inevitably complex constructions, incorporating solutions or compromises to a wide range of often conflicting requirements. Designs to permit easy cleaning are balanced (compromised?) by minimising construction costs, by utilising existing designs and components and by frequently misunderstanding hygiene schedule, methods and the target pests. Infestation prevention and control, as such, are almost never a consideration in the design stages of new buildings and, of course, were never considered in the older buildings which are currently in use for food manufacturing and handling. This leaves certain sectors of the industry feeling that they have special problems in building design which require the use of fumigation to combat the risk of infestation.

Justifying fumigation

In the majority of cases quoted in 5 above fumigation is used as a guarantee of insect- and mite-free food commodities or structures. Because methyl bromide is such a goof fumigant in technical terms, it has been the fumigant of choice for speed, minimum costs and maximum efficacy. It has been popular and effective and, because its drawbacks have been understood, strategies have been devised to overcome its technical problems.

What has been missing, again in nearly all cases, is a true justification for choosing and using fumigation over other methods of pest prevention, control and elimination. Containers of goods are automatically fumigated at sea to comply with customer or importing country requirements. Factories are automatically fumigated at specific times of year because it is an “easy” option to ensure minimum pests. Warehoused stacks are automatically fumigated to “protect” the receiving processing plant. Each time we encounter an assumption that methyl bromide is necessary, even if there are actually no pests present. However, to ascertain that pests are present or absent requires a monitoring system and this is where we are dependent upon having such systems available.

Infestation risk assessment

What can be monitored, and to what level of confidence? Storage pests are understandable and almost entirely predictable. Strategies and schedules for their detection and control can be devised, can be checked for effective working, and can be modified as changes in the influencing parameters occur. For many in the food industry a HACCP system associated with pests signifies combatting microbiological contamination. Developing an effective pest-related HACCP system, therefore, needs a deep understanding of the target organisms, including their possible origins, their physical requirements and behaviour, and their real risk to the situation. Real risk would include an estimate of whether 100% eradication is needed, or perhaps a lesser degree of control because some other action will take place to reduce their significance or to eliminate them. Roasting cocoa beans, for example, may be considered a sufficiently harsh treatment to allow a small number of live beetles or moths to be present in a consignment, providing the roasting is to take place within a set period of days, thus preventing the build-up of larger numbers and possible consequent mass-migration of larvae.

This HACCP-based approach can be taken with every pest risk area. Figure 1, 2, and 3 show the sort of coverage possible for flying insect control, with Critical Control Points in each sub-section, from which detailed estimates of risk for every section of the plant can be made. Risk assessments should be updated on a regular basis and especially when new developments are planned. For example, bringing in new machinery, or formulating new products from trial raw food materials, will change the risk. New suppliers must be included in the risk, and their “value” in risk terms can only be ascertained through a competent pests audit of their premises and chain of association to the factory. Finally, these diagrams can be used to assess success in reducing risk, leading to a self-generating downward pressure on the initial “acceptable” risk estimates.

Planning a pest-free facility

Infestation Risk Assessment allows detailed planning and budgetary justification for: building refurbishment, machine refurbishment, hygiene schedules, pest monitoring, pest prevention, packaging design, and storage specifications. Risks of infestation and associated contamination problems can be assessed on an arbitrary scale of 1 to 10, with 10 being the most disruptive and costly. Any real-time experiences will hone these assessments, though even “guesstimates” are worthwhile, but as a test, try to estimate of the costs and problems involved in a large overseas export consignment rejected for an infestation problem! Some of the questions to ask are: Is the production facility infested with this species?; Is the transport infested (containers, lorries, ships etc.)?; Are the finished goods warehouses infested?; Are the storage facilities dedicated to your products?; How “infestible” is the product concerned?; Is the packaging able to fend of infestation invasion?

A sensitive detailed HACCP-type approach would provide many of the answers through establishing the Critical Control Points through the system. Having set up the Assessment, driving down tolerance levels becomes much easier. Again, it is useful to look at an example. A modern traditional flour mill - pneumatics inside an old building - provides a suitably complex situation where fumigation with methyl bromide would have been routine once or twice a year. The suitability of the building for fumigation can be questioned, since most structures were not designed to retain gas. There will be leakage from poorly-sealed roofing, from windows and doors, and from basements. Walls and silos may also leak, but the efficacy of the treatment is ensured by adding gas to low concentration areas.

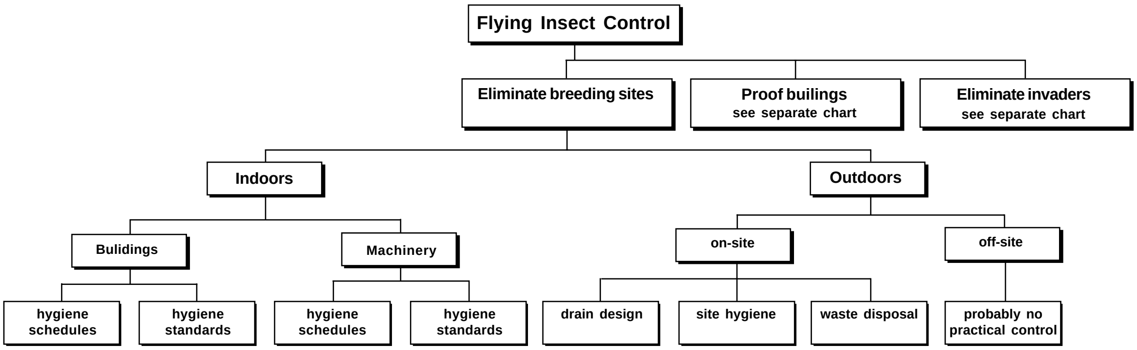


Figure 1. Flying insect control by eliminating breeding sites.

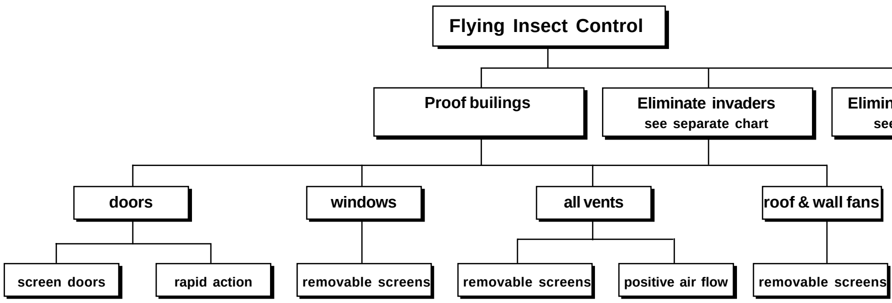
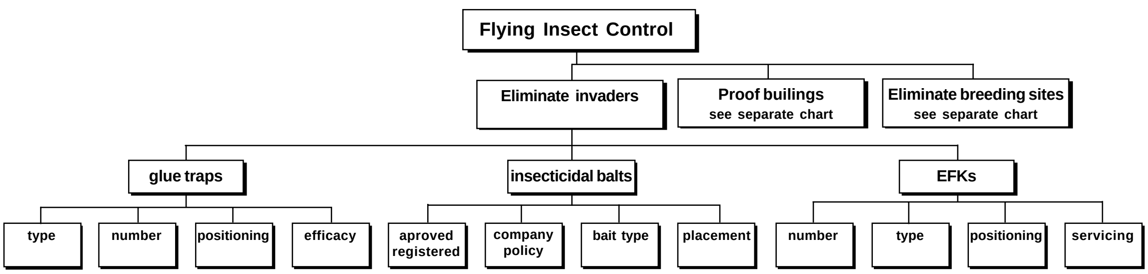


Figure 2. Flying insect control by proofing buildings**.**



How is the efficacy measured? Gas concentration readings multiplied by the exposure period are used to evaluate the theoretical efficacy of a fumigation and can show that, at the places where the gas readings were taken, all stages of the pest insects would have been killed. In practice, though, mills are never made totally pest-free by fumigation (which is not seriously disputed by fumigators) and unless there is some other effective programme in place, there is always a need for a re-treatment some time later. This period may be 6 or 12 months, the revival of the infestation almost never being the result of the arrival of new insects. Exceptions may involve new arrivals of grain weevils and grain beetles, but the mill (flour) moths and flour beetles are not grain pests and are not re-introduced with wheat shipments.

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The cycling of insect infestation populations within food factories has a direct effect on the risk of product contamination. A low level infestation inevitably poses a lower risk to product quality than a high number of insects, though the situation, product type and packaging and many other factors must be considered to establish the real risk. However, if a method of pro-actively seeking sites of infestation and tackling them before significant insect development takes place can be introduced, it is both theoretically and in practice possible to maintain a continuously lower level of infestation, if not total elimination.

Developing an effective non-fumigation infestation control programme must start with a comprehensive assessment of risk. This has been considered in the previous section and is variably complex, depending on the facility; crucial elements of this approach are: understanding the pest spectrum, assessing high risk areas and operations, detailed "proofing" measures to prevent incoming infestation, effective insect , monitoring system for information, rapid reaction control programme, re-assessing risks with every change in procedures and materials.

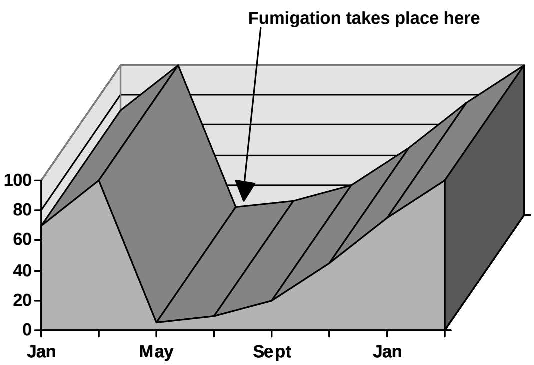

Figure 4. Insect population changes with time in a typical fumigated mill.

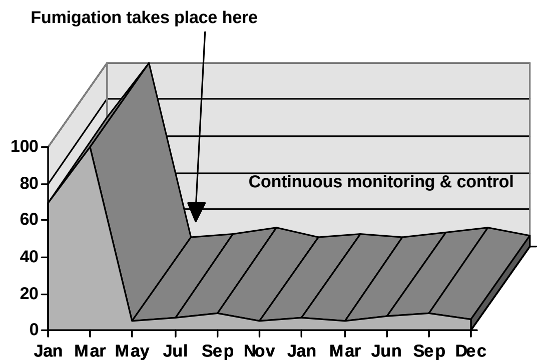

Figure 5. Insect population changes with time with an effective pro-active pest monitoring/control.

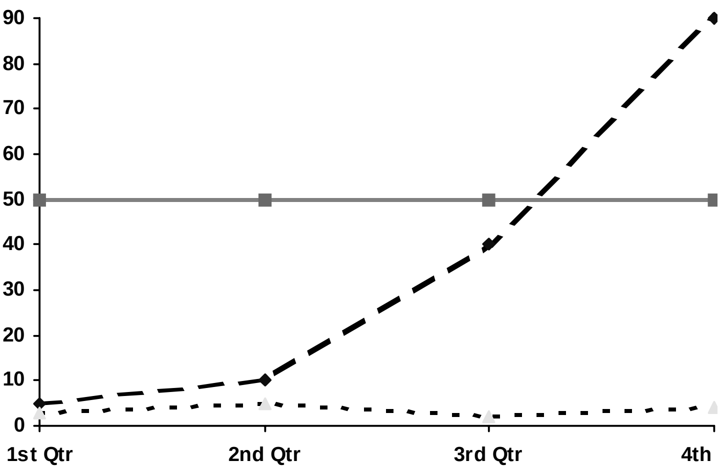

Figure 6. Insect population changes with time and with effective, pro-active, pest monitoring and control in place - in relation to estimated acceptable risk level.

Practical results from infestation risk assessment

How effective can this approach be in eliminating deep seated infestations? There is no single answer, since infestation situations vary considerably. However, practical experience in complex factory structures show clearly that a considerable commitment is required for its success. When the complete infestation risk assessment programme is in place, the practical results come mostly from the elements listed above. Monitoring is the least well developed element throughout the food industry despite its key position in the programme. Without an effective monitoring system, all decision making is based on theory and/or guesswork. Setting standard schedules for hygiene, machinery stripping and maintenance, insecticide treatments and other related activities will be necessary in the first instance, but thereafter these should be modified and adapted to local situations according to an information feedback procedure. This feedback which will trigger actions listed under point v above**.**

The key elements involved in an information feedback system include: staff training to recognise pests, suitable and effective inspection and detection methods, schedules for changing detectors and lures, co-ordination of monitoring results and information, and of actions, assessment of hygiene and pest control actions, and revised monitoring and control operations.

The operation of this loop must be very carefully controlled to maximise effect but the benefits are extremely valuable within the food manufacturing and warehousing industries. An annual fumigation with little in-between control action can give rise to exponentially rising infestation populations, reaching a peak just prior to the fumigation, and creating a real risk of high levels of food contamination from insects and mites, whereas a wholly effective rolling control programme will prevent the build-up of populations and maintain a very low level of product contamination risk.

Whether such a “low risk” is acceptable or not depends on many factors, including local and national food regulations and customer expectations. However, the “routine fumigation” scenario seldom if ever eliminates infestations and is frequently the only real action to be taken throughout the year. Factory hygiene managers may believe that they have in place continuous professional pest control contracts, but in reality such contracts are very seldom suitable for the complex risks within factories.

The benefits referred to above are best seen as the potential to maintain a facility in a virtual pest-free condition. When the programme is running correctly and efficiently, there should be no significant surprises of “new” infestations, nor of discovering unexpected high levels of pests where none were known of before. The monitoring will provide all information for tracking development and spread, for choosing the most appropriate actions and for assessing results. This situation should be contrasted with the annual fumigation plus a routine pest control contract.

What this paper cannot answer is the relative cost of the two approaches, but there are intrinsic differences between their interim and final results which bear strongly on product quality. Fig 4 shows arbitrary levels of population development with time in a facility where the annual fumigation is the only “effective” treatment, and a period when the actual infestation level confers a high risk of insect fragment incorporation into the food products. For management concerned with HACCP-type assessments, exceeding this (arbitrary for this example) level of “risk of incorporation” represents an unacceptable risk, irrespective of the other factors mentioned above.

Alternative control elements

So far this paper has concentrated on conventional pest control based around monitoring. However, two alternatives are available for further development and selective incorporation into the plan. They are the use of high temperatures and the combining of raised (but not high) temperatures with a mixture of carbon dioxide and phosphine. Neither technique has yet been widely adopted and, in historical terms, both are in their infancy regarding technical development for widespread application.

Heat has been used successfully for factory structure disinfestation for many years, though the heat source has varied, and it fell into disuse because methyl bromide was clearly easier and/or better. The careful distribution of the heated air through the facility is necessary (as is the distribution of methyl bromide), accurate temperature monitoring is needed to ensure insect-lethal temperatures are achieved,

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and no structural or machine damage takes place (monitoring of methyl bromide concentrations is done to ensure lethal exposures), and the energy costs can be significant, though with a total absence of chemical residues. Methyl bromide will become much more costly over the next few years and the residue issue is always a consideration. So perhaps heat should be developed, not so much as a total-building treatment, but as a part of a comprehensive strategy - to pre-empt infestation build-up by the application of all feasible techniques as appropriate. Heat applied to selected sections where its characteristics can be used to advantage, where its drawbacks are minimised and where it is the best option.

The combination of raised temperatures, low levels of phosphine and a proportion of carbon dioxide is being actively pursued in the United States primarily by its originator David Mueller of Insects Limited, Inc. Each element is used to achieve an effect, the low phosphine concentrations over an extended period are chosen to kill insects made more sensitive to the gas by the increased temperature and the presence of carbon dioxide, without the normal major drawback of phosphine's corroding action on certain metals such as copper silver and gold.

Evidence of practical trials and real disinfestation programmes so far is encouraging, with successes in many plants in the USA, though there is little enthusiasm for its development and possible adoption in Europe. Again, perhaps it should be developed for selected and specific uses, rather than as a total-building treatment.

CONCLUSIONS

Fumigation is clearly a very useful technique and, in selected circumstances, an indispensable tool for effective pest control. The imminent withdrawal of methyl bromide from routine fumigation work has generated considerable technical effort world-wide to research new or alternative fumigants. However, for whole building disinfestations, the last 40 years have seen methyl bromide become the easy option (if not necessarily the cheap option), with less and less need to investigate alternative treatments, or to develop more sophisticated techniques. A gradual move away from routine insecticide usage to one of targeted and justified use has led to increasingly sophisticated detection and control strategies within certain sectors of the food industry. But for many, methyl bromide's advantages have remained paramount and there is considerable reticence to move to systems which might appear more complicated and less guaranteed of results.

Our contention is that these "more complicated" systems are: more beneficial in product risk and quality terms due to minimal insect numbers over the whole year, less hazardous to operators and product by removing the risk of gas leakage and bromide residues, more able to withstand scrutiny for compliance under "due diligence" requirements, easier to budget for (though maybe not cheaper than annual fumigation costs), easier to monitor for results and therefore to amend control programmes, a more productive way to build a dedicated working partnership between client and contractor, very suitable for "in-house" development without the need for formal certification of staff, more likely to give confidence to purchasers of the facility's products.

Whether a large and complex facility can ever be truly insect- and mite-free depends on the vigour and commitment applied by the management and the pest controller as a team to achieve this effort. It is very clear that fumigation never achieves it, but the principles demonstrated above offer a real opportunity to attempt to gain this valuable prize.

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