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CONTROLLED ATMOSPHERE AND OTHER ALTERNATIVES FOR CURRENT USES OF METHYL BROMIDE IN THE NETHERLANDS

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ABSTRACT

Current uses of methyl bromide (MB) in The Netherlands are restricted to quarantine applications and fumigation of durables and structures. In 1991, soil sterilisation was banned. In accordance with the Montreal Protocol the policy of the Dutch government is to further reduce MB use in the future. A basic necessity for an effective reduction scheme is the availability of reliable use figures. Since 1992, notifying a central registry of fumigations with MB has been required. From the resulting database, developments in the use pattern of MB in The Netherlands have been analysed.

A major necessity for use reduction is the availability of effective alternatives. Research has been focused on identifying alternatives suitable for the Dutch situation. Controlled atmospheres seem to be a promising alternative for the two major products currently treated with MB, e.g. groundnuts and cocoa beans. Pilot tests with two different systems for creating low-oxygen atmospheres have enabled companies to amass basic knowledge in this field. Further development is still required.

Heat treatment has been tested for two consecutive years by a large commercial flour mill as a whole-site disinfestation method. The working protocol for this method is improving with every single treatment. Although not always fully effective, the company is now using heat instead of fumigation with MB as a central curative pest-control method.

Control of MB emissions at the permanent fumigation facility of the flower auction in Aalsmeer was achieved by installation of an activated charcoal filter. Chemical analyses have shown a very high removal efficiency resulting in a 99.9% reduction of MB emissions.

INTRODUCTION

Since 1991, methyl bromide (MB) has been reported to possess ozone depleting properties. Because of this potential, the production and use of MB is being controlled within the framework of the so-called Montreal Protocol. In 1994 the ozone depleting potential (ODP) of MB was finally established at 0.6, in comparison to the baseline reference ODP of 1.0 of CFC-11.

The designated parties of the Montreal Protocol have decided upon a differentiated use reduction and phase-out scheme. The current target was agreed upon during the most recent meeting in Vienna, in December 1995. For developed countries, it is a total phase-out in 2010, with intermediate reduction steps of 25% in 2001 and 50% in 2005, in comparison to the baseline use level of the year 1991. For developing countries, currently only a freeze of the use of MB at the average level of the years 1995–1998, to be achieved in 2002, has been agreed upon. In 1997 possible further reduction steps will be discussed.

The European Union has speeded up this reduction scheme by agreeing (in October 1994) to a use reduction of 25% based on the 1991 reference level, to be achieved in 1998.

The Ministry of Environment of The Netherlands has established, within the framework of a multi-year policy plan on hygiene and material protection, a specific action plan for stored-product protection and MB. This plan is designed to reduce the negative environmental consequences of the use of MB. Specific aspects of this plan include, among other actions, the reduction of MB emissions to the atmosphere and stimulation of research on alternatives to the use of MB.

Within the framework of this action plan, the Ministry of Environment has asked TNO to carry out an investigation into alternatives for MB that already are available or will shortly become available for practical implementation. The project started with an inventory which included a survey of current uses of MB in The Netherlands and listed potential alternatives that could be considered for further examination in pilot tests. The second phase of the project was focused on setting up a number of practical pilot tests with selected alternatives in order to explore their potential for future use as a replacement for MB in The Netherlands. This paper gives a concise overview of the results of both phases of the project.

OVERVIEW OF CURRENT USES OF METHYL BROMIDE

Data collection

Since the use of MB for soil sterilisation was banned in 1992, MB is currently used only for fumigation of durables and for structural and preshipment treatments. Following the Montreal Protocol these use categories are also subject to a reduction scheme.

Registration of use-figures is essential for the implementation of any effective reduction scheme. Since 1990 fumigation companies have been obliged to notify a central register of any intended fumigation. Notification time depends on the size of the fumigation. Fumigations of objects with a volume larger than 2,500 m^3 have to be announced at least 7 d in advance; small-scale fumigations up to volumes of 500 m^3 may be announced only 6 h prior to fumigation. Companies have to indicate, among other things, the following data:

1. Date, time and location of the fumigation
2. Type and amount of product being fumigated
3. Type and volume of structure intended to be fumigated
4. Quantity of MB that will be used

5. Quantity of MB used (announced after the fumigation)
6. The necessity for a fumigation

Because it is collected at a central place, this register provides a database that, after a few years of data registration, has enabled trends in the MB use pattern to be analysed.

Use pattern

Table 1 gives an overview of the total amount of MB used in the years 1990 to 1995. The first row indicates the amount of MB of which fumigation companies have given advance notice. The second row shows the actual use figures that were determined afterwards from the adminstration of fumigation companies. The total amount used decreased from 64,471 kg in 1990 to 17,038 kg in 1995. In this last year, a major use reduction of 60% was thus achieved in comparison to the reference level (43,008 kg in 1991 as per the EU reduction scheme). For comparison, the amount of MB used worldwide for applications other than soil fumigation is approximately 15,000 t, which constitutes approximately 22% of total MB consumption worldwide.

TABLE 1
Total quantities of MB (in kg) notified ahead and actually used in The Netherlands in the years 1990–1995

Category	1990	1991	1992	1993	1994	1995
Notification ahead	50,154	42,413	37,452	28,571	26,851	13,707
Actually used	64,471	43,008	38,366	29,495	27,269	17,038

In Fig. 1 the seasonal trend of total MB use (in kg) is shown. The strong reduction in 1995 can be attributed especially to lower use in the summer months. In 1992 peak levels, up to 10,000 kg per month, could be observed, whereas the summer of 1995 actually had the lowest use figures. The total number of fumigations did not decrease but in fact went up from 833 in 1992 to 1,078 in 1995.

Major products

Table 2 specifies MB use per product category over the years 1993 to 1995. For all years, the major products have been — and still are — groundnuts (peanuts) and cocoa beans; both are bagged commodities mainly stored in the ports of Rotterdam, Amsterdam and Vlissingen. However, significant reductions for both products were achieved last year.

Using the notification forms as a guide, the environmental inspection authorities have increased their activities in both 1994 and 1995, focusing on the necessity of fumigations as well as on possibilities for reduction of their size. This increase of activity has probably contributed significantly to the major use-reduction achieved in 1995.

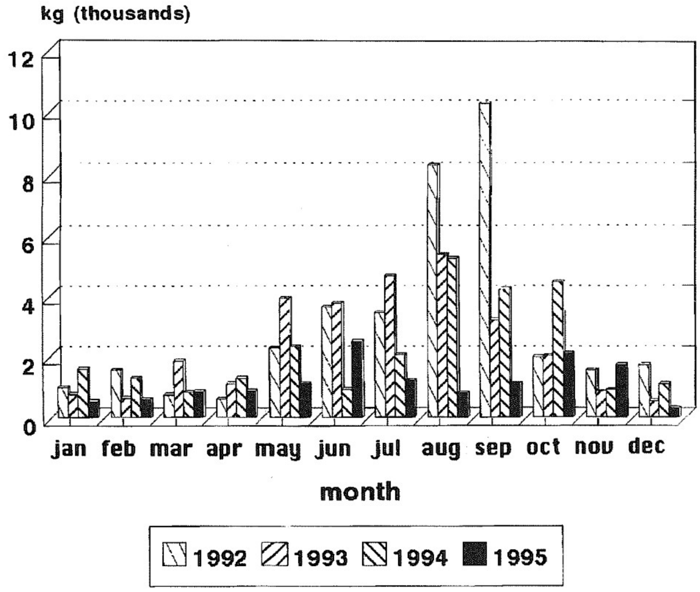

Fig. 1. Seasonal trend in MB use in The Netherlands during the years 1992 to 1995.

TABLE 2
Major products and current MB use (kg) in the years 1993–1995

	Year		
Products	1993	1994	1995
Groundnuts	10,720	9,583	2,906
Cocoa beans	4,910	5,827	2,328
Containers (*Sirex*)	–	3,616	2,774
Structures	2,666	2,507	1,991
Nuts/Seeds	691	1,363	1,303
Rice	1,430	1,575	718
Coffee	704	815	451
Pet food	1,167	505	424
Grain	3,021	40	65
Others	3,262	1,020	747
Total	28,571	26,851	13,707

Because of increased inspection, fumigation companies may have been persuaded to carry out bag-stack fumigations rather than warehouse fumigations after the necessity for this had been demonstrated. Isolation of stacks of infested produce under plastic covers eliminates a lot of empty space and thus reduces the initial dose required. The average size of a fumigation, based on quantity of MB used, was reduced from 46 kg in 1992 to 12 kg in 1995, and this indicates the shift to smaller fumigations.

Groundnuts, as well as cocoa beans, are stored in bags of approximately 50 kg piled up to 8 to 10 m high in stacks in large warehouses. During the last years there has been an increase of available cooled storage facilities in various ports. Cooled storage at temperatures below 10°C may effectively prevent insect populations from further development. An increase of the amount of produce being stored at low temperatures may also have contributed significantly to use reduction of MB. Whether this shift has indeed taken place (and can partly explain the large use reduction) is not clear.

Container fumigation is a very important use category. This is apparent from specific use figures collected in the last 2 years: more than 3,600 kg in 1994 and almost 2,800 kg in 1995 (see Table 2). These quantities were used to meet the Australian quarantine regulations with regard to possible *Sirex* woodwasp infestation in the dunnage or wooden floors of containers. The logistic process at container terminals in The Netherlands nowadays is fully adapted to a fast-acting disinfestation procedure which, until now, can only be accomplished by fumigation with MB.

Fumigation of empty structures (primarily buildings like flour mills or silo bins) is a significant use category for which, in 1995, a 20% reduction was achieved.

A striking phenomenon seen in Table 2 is the very large reduction in MB use for fumigation of grain in the years 1994 (40 kg) and 1995 (65 kg) in comparison to 1993 (over 3,000 kg). This could be due to a great reduction in grain tonnage stored in The Netherlands. Nowadays, The Netherlands no longer has any strategic stocks of grain. Replacement of MB by other pest control measures, such as phosphine (PH_3) or sprayable insecticides, might provide another explanation for the great use reduction.

In the United Kingdom the most common fumigant for use in stored grain is PH_3. Although this substance is registered in The Netherlands as well, it is not commonly used. Until March 1996 no advance notification was required for a fumigation with PH_3, so central use figures on this fumigant are not available. Thus, a possible shift from MB to PH_3 cannot be established. Similarly, a possible shift to increased use of sprayable insecticides cannot be established either.

USE REDUCTION AND ALTERNATIVES

From the environmental point of view, the best option for MB use reduction is the application of hygienic and preventive measures on a larger scale. Visits to warehouses and current application sites of MB, as well as contacts with responsible authorities, have indicated that there is room for improvement in such measures. Specific methods of improvement may vary with different types of products and different storage and processing conditions, as well as with logistic and economic factors. Cooled storage, by preventing pest populations from building up to damaging levels, can be considered a basic component of a preventive approach.

After identification of potential alternatives in the first inventory phase, the major objective of the second phase was to set up, in collaboration with interested parties, pilot tests that would increase the level of knowledge about practical application of alternatives and might also demonstrate the feasibility of some selected alternatives. The initiatives of fumigation companies and other interested parties were stimulated and, where appropriate, experimental protocols were set up by mutual agreement.

Data from recent literature suggested four categories of alternatives that could potentially replace — at short term — part of the current use of MB: e.g. controlled atmosphere treatments, physical control methods, other fumigants and sprayable insecticides.

Among the fumigation companies there was high interest in the development of controlled atmosphere (CA) treatments as an alternative for MB. This was because CA applications are not subject to any distance requirements and registration is expected to be much easier and far less costly than that for toxic chemical methods. The use of carbon dioxide (CO_2) for pest control is already exempt from registration.

The two largest product categories (groundnuts and cocoa beans) for which MB is currently used are usually stored for periods of up to several months. Because the need for disinfestation varies, a fast-acting method is not always absolutely necessary, although currently it is still the option preferred by the interested parties, e.g. buyers, suppliers, warehouse managers and insurance companies. In principle, however, average storage periods of up to several months open opportunities for alternative treatments that require long treatment times, for instance those based on CA's.

PILOT TESTS

On the basis of both the use pattern figures and the preferences of participating companies, it was decided that pilot tests would be focused on possible alternatives for treatment of groundnuts and cocoa beans and on alternative structural treatments.

Pilot tests were carried out with CA treatment of groundnuts and cocoa beans, heat treatment for disinfestation of a flour mill, application of inert dust in grain storage and flour mills and disinfestation of rice by treatment with microwaves.

An additional test focused on emission control, determining the ability of an activated carbon filter, installed at a permanent fumigation facility, to recapture MB.

ISOGEN burner gas system

The tests using the ISOGEN burner gas system for maintaining an effective CA regime ($<2\%$ O_2, 12% CO_2, balanced by N_2) to disinfest groundnuts have demonstrated the technical feasibility of the system. Three separate tests were carried out in a 400-m^3 climatized cell. Energy and fuel consumption were determined, composition and flow of outlet gas and temperature were monitored continuously and the effects on various insect species were investigated. Effective treatment times depended on ambient temperature but were generally much longer than those of MB. Tests were conducted during a period of high average temperature (29–31°C), and effective exposure times of 7.5–8 d were found. A preliminary assessment of running costs revealed that this treatment is probably less expensive than fumigation with MB.

In Italy the system is in commercial use in large feed mills to treat a variety of products and also for treatment of stored grain in silos, indicating the economic feasibility of the technique. To enable this system to work on a larger practical scale in The Netherlands, a follow-up developmental program has recently been started.

Carbon-dioxide fumigation

Fumigation of infested commodities like groundnuts, cocoa beans, maize or rice with CO_2 is an effective technique already used in practice in developing countries like Indonesia. Effective treatment times range from 10 to 20 d, depending on the temperature. Pilot tests in The Netherlands for treatment of bags of infested cocoa beans with CO_2 at 20°C were not successful. Basically, the same technique was used, creating a high CO_2 (>40% v/v) and low O_2 (<2% v/v) atmosphere using CO_2 from cylinders.

Small bag-stacks (about 2 t) of cocoa beans were sealed in plastic enclosures with and without floor sheeting. Temperature and gas concentrations were monitored continuously. The failures could be attributed mainly to the inappropriate equipment with which the CA regime was applied. Flushing the bag-stacks with N_2 prior to CO_2 application in order to accelerate the build up of a low O_2 atmosphere did not improve the performance of the system. All sealed bag-stacks were pressure tested before starting. Despite this, a stable low O_2 atmosphere could not be maintained for a period long enough to achieve any biological effect.

Basically, however, the technique lends itself to disinfestation of bagged commodities like cocoa beans which, in The Netherlands, are usually stored for longer periods of time. Further investigations with improved equipment are required to determine the potential of this technique in The Netherlands.

Heat treatment

Pilot tests were carried out by the Meneba company in Rotterdam. Meneba has set up a very detailed working protocol listing all the activities that have to be carried out, including the cool-down period after the treatment, in relation to the implementation of the treatment. Special care must be taken to prevent insects from escaping from the heated areas to cooler areas (where they might survive and start to build up a new population) and to prevent any damage to materials and electronic equipment by heat or low humidity.

A steam boiler was used for generating heat, and hot air was circulated through the ventilation system of the building. Target air temperature was 55–60°C to be reached as quickly as possible but with a maximum temperature increase of 6°C per hour. The target temperature had to be maintained for at least 24 h. Cooling down afterwards was similarly done at a maximum rate of 6°C per hour.

During both large scale trials (in 1994 and 1995), sufficient insect mortality was in general achieved. At some particular spots, however, live insects were still found shortly after the end of the heat treatment, demonstrating the existence and location of so-called cool spots.

The costs for installation of the equipment required for effective heat treatment were quite high. Judging from the experience of Meneba, however, the energy costs for a heat treatment are reasonable and the costs for sealing and preparation of the building are less than those for a fumigation with MB. The shut-down period for a heat treatment is the same as that for a fumigation with MB.

Overall, the experience obtained so far indicates that heat treatment is a viable option when it is considered as a general disinfestation method for a building, but it is not a substitute for good housekeeping and proper sanitation and preventive measures. In the future, heat treatment may be a central curative method that, supplemented with various other control methods, can replace part of the current MB use for structural fumigation.

Inert dust

Inert dust or diatomaceous earth can be considered a physical control method due to its mode of action: it causes desiccation in insects. Its efficacy is highly dependent on ambient temperature and relative humidity. In laboratory experiments at 20°C and 65–70% r.h., the recommended dosages were found to be insufficiently active to act as a stand-alone method for the control of grain weevils and confused flour beetles.

When applied to floors in a flour mill, however, inert dust was found to have a very clear effect in retarding and sometimes preventing new populations of flour beetles from building up. As a complementary treatment to other control measures, application of inert dust may certainly contribute to improved pest control. In this respect the regulatory status of inert dust in The Netherlands should receive special attention.

Microwave treatment

Experiments with microwave treatment of rice conducted by a private company in The Netherlands have shown that, in principle, this method could be a viable option for fast and effective disinfestation of flowing bulk products. However, a substantial amount of work related to technical scale-up and assessment of economic parameters remains to be done.

Emission control

A filter installation based on activated carbon has been installed at a permanent fumigation chamber at the flower auction in Aalsmeer. A series of measurements was carried out to determine the removal efficiency and the effective lifetime of this filter during normal operation procedures. Gas concentrations were measured before and directly after passing the carbon filter during the first phase of ventialtion of the chamber. For up to approximately 75 fumigations, the filter appeared to be very effective in removing MB from a passing gas stream. Typical concentrations before and after passing the filter were 18 g/m^3 and <2 mg/m^3, respectively, resulting in a removal efficiency of more than 99.9%.

In fact, the installation was found to remain highly effective in recapturing MB from an air stream during its full time of operation. This means that more than 99.9% of the former MB emission from this facility can now be prevented. Saturated filter material is dispatched to a high temperature incinerator in which bromine is ultimately recaptured as a salt in the flue gas scrubber.

The permanent fumigation facility in Aalsmeer is in use for quarantine treatment of a large variety of agricultural products. Expansion of similar recapturing systems to other fumigation facilities may contribute to further prevention of MB emissions.

CONCLUSIONS

The use of MB in The Netherlands for stored-product protection and structural fumigation has shown a drastic decline from 43,000 kg in 1991 (the reference year in international reduction plans) to 27,000 kg in 1994 and 17,000 kg in 1995. The reduction of 60% obtained in 1995 is far greater than the intended reduction schemes of both the Montreal Protocol (25% reduction in 2001) and the European Union (25% reduction in 1998).

Major causes for the reduction achieved are probably the implementation and improvement of an obligatory notification system, increased inspection activities of the environmental inspection authorities, a shift from warehouse fumigation to bag stack fumigation resulting in strong dosage reductions, increasing facilities for cooled storage and reduction in the amount of produce (grain) being stored in The Netherlands.

Major use categories for MB applications in The Netherlands currently are as follows: groundnuts (2,900 kg), cocoa beans (2,300 kg), structural fumigations (2,000 kg) and fumigation of containers (about 2,800 kg).

Prevention, proper sanitation and other hygienic measures may contribute significantly to use reduction of MB. Cooled storage can prevent the build up of pest populations to damaging levels. Structural integration of cooling equipment in storage facilities can contribute to further reduction of MB use in stored-product protection.

For effective treatment of commodities like groundnuts and cocoa beans, CA is a viable option. Systems using CO_2, N_2 and burner gas for generating and maintaining CA regimes are at different stages of development.

Heat treatment of buildings, although not always fully effective or applicable to every building, can partly replace the use of MB for structural fumigation. Additional treatment of so-called cold spots with contact insecticides and complementary use of inert dust at inaccessible sites or void spaces inside the building may help to suppress the build-up of new pest populations.

Currently, the registration requirements for CA applications for the purpose of pest control are not clear. In The Netherlands at present, the use of CO_2 for control of pests is exempt from registration whereas other types of CA treatments are not. Clarification of this regulatory status will help to provide a better perspective on the future role of CA treatments in the replacement of MB.

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