Choice of fumigation sheets for use in the tropics (ODNRI Bulletin No. 27)

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ODNRI

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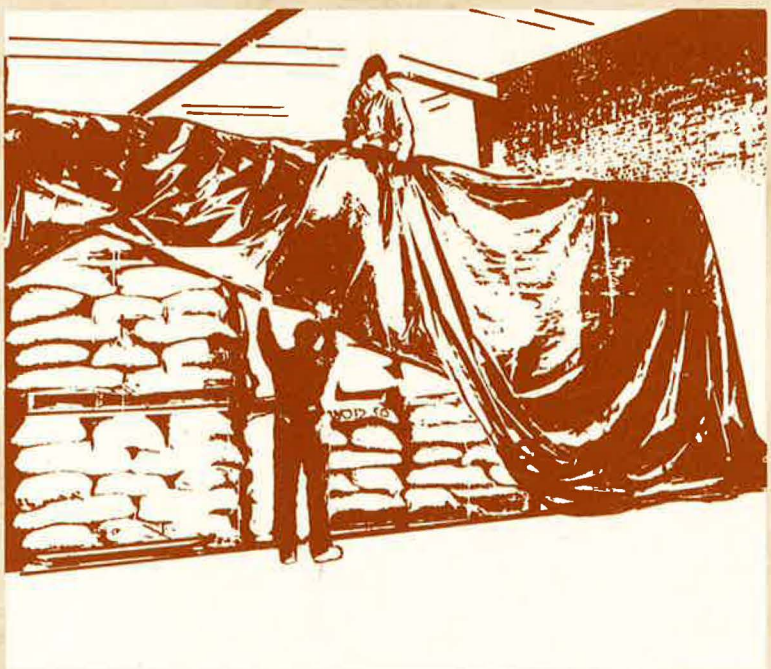

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CHOICE OF FUMIGATION SHEETS FOR USE IN THE TROPICS

R. FRIENDSHIP

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SUMMARY

A successful fumigation requires that an insecticidal concentration of the fumigant is maintained within the fumigation chamber during the exposure period. The demand for fumigation sheets is generally too low for manufacturers to formulate plastic sheets specifically for this purpose. Therefore it is necessary to select the most suitable material from whatever is available. This bulletin gives guidelines to assist in making the right choice.

RÉSUMÉ

Une fumigation couronnée de succès exige que la concentration insecticide du fumigant soit maintenue au sein de la chambre de fumigation pendant le délai d'exposition. La demande pour des toiles de fumigation est généralement trop faible pour que les fabricants envisagent de produire des draps plastiques spécialement conçus à cet effet. Il s'avère donc nécessaire d'établir un choix parmi les matériaux disponibles les mieux appropriés à cet usage. Le document donne des directives en vue d'aider à faire le bon choix.

RESUMEN

Toda fumigación satisfactoria requiere el mantenimiento de concentraciones insecticidas del fumigante dentro de la cámara de fumigación, durante el período de exposición. En general, la demanda de láminas de fumigación es demasiado baja para que los fabricantes produzcan láminas de plástico específicamente para este fin. En consecuencia, se hace necesario seleccionar el material más apropiado de cuantos se dispone. En el presente artículo, se proporcionan sugerencias, que ayudarán a adoptar la selección correcta.

Choice of fumigation sheets for use in the tropics

INTRODUCTION

A fumigation sheet is very different from a conventional tarpaulin or waterproof cover. Basically a fumigation sheet is required for the retention of a gas, the fumigant, to enable it to become dispersed at a sufficient concentration and retained for sufficient time to kill all insects present in a stack covered by the sheet. The particular combination of characteristics required in a fumigation sheet is low permeability to the fumigant(s) to be used, durability, flexibility and ease of handling.

Most public and many large private-sector organizations purchase equipment by public tender and frequently follow the policy of accepting the lowest bid. Members of purchasing boards rarely have the expertise required to take technical factors into account when procuring pest control equipment, and it is, therefore, the responsibility of the user organization to explain their specific requirements. This may mean that the product being offered at the lowest price may not be the most suitable in terms of its immediate performance and longer-term durability. It may in fact be more cost-effective in the longer term to purchase something at a higher initial price. This principle applies particularly to the choice of fumigation sheets when a large number of sheets of a new type are to be purchased, and when there is considerable risk of procuring an unsuitable product which will not give satisfactory performance and service.

In selecting the particular product to be purchased the following factors should be taken into consideration:

- local availability;
- cost;
- intended use;
- permeability to the fumigant(s) to be used;
- weight per unit area;
- size of sheet;
- strength;
- handling characteristics;
- resistance to damage.

These factors are discussed in turn in the following sections.

AVAILABILITY

Many developing countries have their own plastics industries and locally manufactured products are generally protected on the home market by a ban on imports or a high customs tariff. These local products may well include polythene, polyvinyl chloride (PVC) and other sheet materials which, unless totally unsuitable, may have to be used to fabricate fumigation sheets, even though they do not fully satisfy the criteria listed above.

Plastic sheeting is manufactured for a range of purposes of which fumigation is comparatively minor and so constitutes only a small proportion of the total market for such products. Because of low market demand, no manufacturer produces a product specifically designed as a gas-proof fumigation sheet and it is a question of choosing the most suitable from materials which are available. In this context it should be noted that manufacturers may offer tarpaulins for use as fumigation sheets, but specifications for tarpaulins, such as being waterproof, are not the same as being gas-proof. The prospective purchaser must make sure that the sheets he procures are satisfactory, otherwise fumigation failures will occur.

Locally available materials may include the following in ascending order of suitability for fumigation purposes:

- **unsupported polythene film** may only be suitable for a single fumigation because it is susceptible to damage during handling;
- **unsupported polyvinyl chloride (PVC) film** is good initially but loses flexibility with use and tends to crack with age;
- **woven polypropylene** is strong and light in weight but is very easily damaged during handling and by exposure to heat and sunlight;
- **laminated PVC with nylon or terylene scrims** has moderately good performance characteristics in resisting damage during use;
- **multilayer laminates of thin films** have good permeability characteristics but are liable to tear easily;
- **PVC-coated onto nylon or terylene scrims** are very good materials for fumigation sheets combining resistance to damage with low weight and good handling characteristics;
- **nylon cloth coated with neoprene** is very strong and durable but is now little used because of high cost.

Within each of the above categories there is considerable variation in weight, thickness and uniformity of quality, and this must be borne in mind when selecting materials for purchase. In general, only the simplest materials, for example, unsupported polythene and PVC films, are manufactured in developing countries, and others have to be imported for local fabrication into sheets.

COST

The most expensive material for fumigation sheets is nylon or terylene fabric coated with neoprene, followed successively by PVC-coated fabric and scrims, unsupported PVC, high density and low density polythene. However, manfacturers of fumigation sheets frequently give generous discounts for bulk orders and it is well worth while to obtain a number of quotations. Imported sheets will be more expensive because of freight charges, and possibly import duty. There may also be considerable delay between placing an order and taking delivery, as such sheets are not standard stock items.

INTENDED USE

When deciding upon which material to select for fumigation sheets it is important to bear in mind the intended pattern of use. For example, if only a single fumigation is required followed by long-term coverage of the stack, then unsupported polythene sheet of 0.125 mm thickness may be adequate. Unsupported polythene or PVC sheeting of 0.25 mm thickness may be suitable for use on a single storage site where damage during handling and transportation is minimal. Sheets used by mobile fumigation teams serving a number of storage sites will need to be more robust, for example, PVC on a nylon or terylene scrim. Methyl bromide fumigations require sheets with different characteristics to those used for phosphine in that the PVC should be formulated so that it is resistant to the solvent action of liquid methyl bromide. Again, when deciding upon the type of sheet to choose, the handling skill of the pest control operators should also be taken into account. A good team which

handles sheets carefully and protects them against rodent damage may use the same sheet continually for many months compared to a careless team which could damage the same type of sheet beyond repair after only two or three fumigations.

PERMEABILITY

None of the materials used in the manufacture of fumigation sheets is completely gas-tight because such materials are all to some degree permeable to fumigants. The rate at which diffusion through the fabric takes place depends upon the type of material, its thickness and the ambient temperature. Diffusion through the sheet will reduce the concentration of fumigant to which insects are exposed in the stack. If a sheet is highly permeable to methyl bromide there may be uneven distribution of fumigant within the stack to such an extent that in some localities the concentration time product (CT) is insufficient to kill all the insects present. Because a longer exposure period is required for phosphine (five days or more) there is a longer period during which losses due to diffusion will occur. As the ratio of sheet area to stack volume is greater in small compared to large stacks, losses by diffusion would be expected to be proportionally greater in small stacks.

It is possible to carry out permeability tests on candidate sheet materials to determine their relative permeability to the fumigant which is either in use, or it is proposed to use. Winteringham and Harrison (1946) used a laboratory technique to measure the permeability of proofed materials to methyl bromide. They derived a formula to give a value K for permeability. Any material with a K value of 3 or less was considered satisfactory for use as a fumigation sheet for use with methyl bromide.

Permeability of sheet materials is known to increase with use even if the sheets are physically undamaged. Permeability also increases with temperature; for example, the K factor of a woven cloth covered with PVC of 0.25 mm thickness was found to increase from 3.09 at 20 °C to 5.62 at 40 °C.

The value of permeability tests in assessing the merits of candidate materials for use as fumigation sheets needs to be put into perspective. The K factor for a new piece of material may change as the material ages, and a comparison of the K values for a new sheet and after it has been used for some time will give a more accurate indication of the suitability of the material for fumigation purposes.

WEIGHT OF SHEET MATERIAL

Weight is another important factor in deciding the suitability of candidate fumigation sheet materials, this normally being quoted as g/m^2. Examples of the weight per unit area of materials used for fumigation sheets are given below in Table 1.

Table 1

Comparative weights of fumigation sheet materials per unit area

Material	Thickness mm	Weight g/m^2	Weight 18×12 m sheet
Unsupported PVC	0.24	300	64.8 kg
Unsupported PVC	0.16	225	48.6 kg
Neoprene on nylon cloth	0.23	300	64.8 kg
PVC on nylon scrim	0.43	420	90.7 kg

It should be noted that while the above thicknesses are quoted in mm, at least two other units may be encountered – 'gauge' (one hundred thousandth

of an inch) and 'micron' (one millionth of a metre). These may readily be related as follows:

1000 gauge = 0.01 inches = 0.254 mm = 254 microns

Many pest control operators prefer to use lightweight sheets regardless of other properties, because such sheets require less labour and are easier to handle. However, this may be dangerous and there must be a proper compromise between durability, permeability and ease of handling. Appropriate training should be given to teams so that they familiarize themselves with handling these sheets and ensure effective fumigation operations.

SIZE

Any size of fumigation sheet can be manufactured and this is dictated by the stack size in any given situation. For general use the most common size is 18 × 12 m. In manufacturing fumigation sheets a number of lengths have to be joined together, and the recommended method (PIL, 1960) is by high frequency welding, either with a single weld on a half-inch overlap, or a double weld on a one-inch overlap. It is also recommended that edges be folded back at least half an inch and then welded to form a hem.

The maximum size of sheet which should be provided will be dependent upon the gross weight which can be handled by the pest control team. Experience has shown a four-man team can handle sheets of up to 100 kg in weight; the maximum sizes for sheets made from some commonly used materials are shown in Table 2 below.

Table 2

Maximum sizes for fumigation sheets made from commonly used materials

Material	Weight g/m^2	Size of sheet weighing 100 kg/m^2
Unsupported PVC	300	333
Neoprene on nylon cloth	300	333
PVC on a nylon scrim	420	238

In fact properly trained teams can cover large stacks with a number of 18 × 12 m sheets and there is little advantage to be gained in exceeding this size even if the additional weight can be handled by the team. For small stacks sheets measuring 9 × 12 m are a convenient size. In some storage organizations, standard stack sizes are routinely constructed and in such situations fumigation work is facilitated by having standard sheets designed to cover such stacks. In other instances shaped covers may be provided to cover standard-sized stacks.

STRENGTH

The strength of a fumigation sheet may be expressed as its resistance to tearing, perforation and permanent stretching (which can occur when a sheet is pulled over the corner of a stack or any other projection).

In general, coated fabrics are stronger than coated scrims, which in turn are stronger than unsupported sheets. British Standard 3424 (1973 and subsequent additions) provides various tests for measuring breaking strength, tear strength, etc., for coated fabrics, and BS 2782 gives methods for testing sheet materials. Some fabricators of fumigation sheets quote specifications based on British Standards for the range of sheets they offer for sale.

HANDLING CHARACTERISTICS

This section describes how well any particular type of sheet will:

- conform to the shape of the stack it covers;
- lie flat on the floor at the foot of the stack and close to the sides of the stack;
- fold to make gas-tight corners at floor level.

In this context a stiff sheet is less suitable than one which is more flexible, and a sheet with a smooth finish can more easily be pulled over a stack than one with a rough finish. Sheets must be folded in a suitable manner for ease of application, storage and transportation.

Sheets with poor handling characteristics are more liable to receive rough handling from the pest control team resulting in a shorter working life.

RESISTANCE TO DAMAGE

The major causes of damage to fumigation sheets are: mechanical damage during handling and transportation, exposure to high temperatures and ultra-violet radiation (when used for outdoor fumigations).

- **Mechanical damage:** the ability of sheets to resist mechanical damage will, initially, be directly related to the quality of the material from which they are made. If this is unsupported film it will be difficult to prevent damage even with the most careful handling. However, careful handling will minimize such damage.
- **Heat:** much higher than ambient temperatures can occur, particularly at the top of an outdoor stack and permanently sheeted outdoor clamps; this can cause local degradation of the sheet material.
- **Ultraviolent radiation:** sheets which are exposed to sunlight, under sky-lights or out of doors, are liable to damage by ultraviolet light. This can be minimized by incorporation of an inhibitor in the plastic from which the sheet material is manufactured.

A particular problem of fumigation with methyl bromide is the solvent action of liquid methyl bromide on plastics. In well-conducted fumigations all the methyl bromide should be vaporized as it is introduced, but the liquid may accidentally come into contact with the sheet. Plastic materials used for fumigation sheets should be resistant to this solvent action otherwise very rapid degradation of the affected portion of the sheet will take place. The standard test to assess resistance of the sheet material to methyl bromide is immersion of a small sample in the liquid for one minute, during which time it should remain substantially undamaged. An alternative test is to place a small square of sheet material over a crystallizing dish, pour some liquid methyl bromide onto it, and observe if any damage occurs.

SELECTION OF THE RIGHT MATERIAL

While the characteristics of the ideal fumigation sheet in terms of weight, strength, flexibility, impermeability of gases and durability will now be apparent, these characteristics will inevitably have to be compared with local availability and cost. Table 3 below summarizes the options available to a prospective purchaser. Table 4 gives typical specifications for three types of materials commonly used to manufacture good quality fumigation sheets.

CONCLUSIONS

The points to consider in selecting materials for use as fumigation sheets have been discussed above. The ability to carry out precise laboratory tests to assess permeability to fumigants, durability and strength will vary from country to country, but it is essential to eliminate materials which are entirely unsuitable

for use as fumigation sheets, and then to identify those which initially are satisfactory but quickly deteriorate. Locally available sheets may not be as good as imported ones, but because they are relatively inexpensive and easily obtainable their use may be preferred to imported sheets. It should be noted that the characteristics used to describe the ideal sheet are mutually exclusive and not likely to occur.

Table 3

Characteristics of sheet materials

Sheet type	Mechanical strength	UV and heat resistance	Permeability	Weight per unit area	Cost
1 Polyethylene film	–	+ –	+	+ + +	+ + +
2 Unsupported PVC	+	+ +	+ + +	+ +	+ +
3 Laminated PVC on nylon/terylene scrim	+ + +	+ +	+ + +	+ +	+ +
4 Polyethylene-coated woven high-density polythene	+ +	+	+ + when new – with use	+ +	+ + +
5 PVC-coated nylon or terylene cloth	+ + +	+ +	+ + +	+ +	+ +
6 Neoprene-coated nylon or terylene cloth	+ + +	+ + +	+ + +	+ + +	+

Notes: + + + very good
+ + good
+ fair
– poor

Table 4

Typical specifications for three selected types of fumigation sheet

Type	Material	Special properties	Weight of 18×18 m sheet	Tear strength N/50 mm	Remarks
1 General purpose*	460 Decitex nylon scrim fabric coated with tough and flexible PVC on both sides.	Specially formulated plasticisers for hot climates, to resist sunlight and to use with methyl bromide.	92 kg	Warp 350 Weft 170	Standard colour blue/white; excellent handling.
2 Medium weight**	1100 Decitex polyester net fabric coated with tough and flexible PVC on both sides.	Excellent. Flame retardant. Specially formulated plasticisers for hot climates to resist sunlight and to use with methyl bromide.	82 kg	Warp 100 Weft 100	Translucent or standard colours available; excellent handling, very good drape.
3 Light weight†	Tropical quality of PVC with UV-inhibitors. 300 microns quality.	Excellent. Specially formulated plasticisers for hot climates, to resist sunlight and to use with methyl bromide.	68 kg	Warp 45 Weft 82	Limited life due to low strength.

Notes:

* Sheet 1 above is an excellent sheet for phosphine fumigations, but can be damaged by liquid methyl bromide. Using correct application techniques it will last for many years.

** An excellent sheet for all types of sheeted stack fumigations, and it will have a long life if correctly handled.

† PVC sheets must be specially formulated for use with methyl bromide. All types of PVC sheets may not be suitable. In general PVC tarpaulins do not make good fumigation sheets.

(i) Sheets can be supplied in specially made transporting covers which effectively protect the folded sheet from damage.

(ii) Repair kits comprising special adhesive and patches are available and should be specified.

(iii) Fumigation sheets do not require eyelets.

REFERENCES

BRITISH STANDARDS INSTITUTION (BSI) (1987). *Methods of test: coated fabrics*. BS2782 and BS3424, London: BSI.

HURT, A. (1987) *Permeability studies of polythene and plastic-coated film used in fumigation to contain gases (methyl bromide)*. ADAS Agricultural Science Service, Slough, Berks.

PEST INFESTATION LABORATORY (PIL) (1960). Gas-proof sheeting. *Tropical Stored Products Information* (2).

WINTERINGHAM, F. P. W. and HARRISON, A. (1946). The permeability of proofed fabrics to fumigants. *Journal of Science and Chemical Industry*, **65**, 409.

Appendices

APPENDIX 1: A LABORATORY METHOD FOR MEASURING THE PERMEABILITY OF FUMIGATION SHEET MATERIAL

Winteringham and Harrison (1946) used a laboratory technique to measure the permeability of proofed materials to methyl bromide. In this a sample of the material was stretched over the open neck of a fumigation chamber in which the volume of gas concentration was measured over a suitable period of time. It was found that the following formula applied:

$$K = \frac{2.303 \times V(\log C_o - \log C_t)}{At}$$

Where: K (the permeability constant) is the rate of loss of methyl bromide in mg per hour per cm^2 per unit concentration of 1 mg/l and

A = the area of exposed sheet material in cm^2
V = the volume of free space in the fumigation chamber
C_o = the initial concentration of fumigant in mg/l
C_t = final concentration of fumigant in mg/l after t hours.

For methyl bromide, a K of 3×10^{-4}, or less, equivalent to a reduction of 7.2% in concentration in 24 hours is generally regarded as satisfactory. Table A below relates losses of methyl bromide or phosphine from a stack of $10 \times 4 \times 3$ m in dimension covered by a fumigation sheet 18×12 m in size due to sheet permeability alone, that is, ignoring losses due to adsorption onto the commodity and poor sealing.

Table A

Percentage loss of methyl bromide or phosphine over time with different K factors

	K				
Time	1	2	3	4	5
1 hour	0.103	0.206	0.309	0.412	0.515
24 hours	2.45	4.84	7.17	9.44	11.7
120 hours	11.7	21.9	31.1	39.1	46.2

While there is no recognized K value for phosphine, it is suggested that sheet materials should be able to loose not more than 18% of that applied over an exposure period of 5 days. This would imply a maximum K of 1.12×10^{-4}.

Hurt (1987) has described a new laboratory technique which is claimed to be more accurate than that of Winteringham. However it requires the use of equipment which is not likely to be available in developing countries. An adequate assessment of the suitability of materials for use as fumigation sheets can in fact be made using a 200-litre steel drum with a detachable lid as a fumigation chamber, fitted with a sealable access port on the side through which the fumigant can be admitted, and using portable meters to measure fumigant concentrations. Further details are given in Appendix 2.

APPENDIX 2: A FIELD METHOD FOR MEASURING THE PERMEABILITY OF FUMIGATION SHEET MATERIAL

1 From *Permeability* (p. 4) it can be seen that the following information will be required.

- the area of exposed sheet;
- the volume of the free space in the fumigation chamber;
- the fumigant concentrations at the beginning and end of the exposure period; and
- the temperature at which the test was carried out.

2 A sound 200-litre steel drum with a detachable lid secured by a clamp can be used as a fumigation chamber. Calculate the volume of free space in the drum when the lid is in place. The seams of the drum should be painted with polyurethane paint to improve gas-tightness. The drum should be fitted with an aperture (bung hole) either in the side or lid, and this must be placed uppermost during tests. A section of known area should be carefully cut from the lid. The sample of plastic sheet to be tested is stretched tightly over the open end of the drum, covered with the lid and clamped in place. If necessary adhesive tape can be used to improve the seal. During the test, room temperature must remain constant.

3 *Methyl bromide* Methyl bromide can be applied by using a disposable can fitted with a graduated dispenser (0–30 ml). A measured amount of liquid methyl bromide is applied with a nylon tube through the drum aperture into the top of the chamber where it will vaporize. A simple hand-operated paddle will give a good fumigant: air mix. If 30 ml of liquid methyl bromide is used this will give a dosage rate of 75 g/m^3. It is suggested that a 24-hour exposure period is adopted. Methyl bromide concentrations are measured at the beginning and end of the exposure period using a thermal conductivity meter (supplied by AGL Engineering Ltd).

4 *Phosphine* The procedure is to place a tablet (equivalent to 5 mg of phosphine/l) or a pellet (equivalent to 1 mg/l) into a small cloth bag, suspend this in the chamber for 24 hours and then remove the preparation. Phosphine generation will be accelerated by crushing the preparation and increasing the atmospheric moisture in the drum by soaking a cotton wool pad with 3 ml of water and placing this in the drum. The phosphine concentration should be measured immediately after the preparation has been removed from the drum and at 24-hour intervals for the following 96 hours; K factors for 24-hour and 96-hour exposure periods can then be calculated. Phosphine concentrations should be measured with a suitable meter such as the ODNRI conductimetric meter. Gas detector tubes are not accurate enough for this purpose.

APPENDIX 3: SOME UNITED KINGDOM SUPPLIERS OF FUMIGATION SHEETS

1 Claro Plastics Ltd,
Hornbeam Park,
Hookstone Road,
Harrogate,
Yorkshire.

2 Andrew Mitchell & Co. Ltd,
356 Amulree Street,
Glasgow G32 7SL.

3 Fell-Fab Products Ltd,
7 Lenten Drive,
Parkside Industrial Estate,
Leeds LS11 5JW.

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