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REGIONAL STANDARDS FOR PHYTOSANITARY MEASURES

APPROVAL OF FUMIGATION FACILITIES

APPPC RSPM No. 10

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The Asia and Pacific Plant Protection Commission (APPPC)
FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS
REGIONAL OFFICE FOR ASIA AND THE PACIFIC
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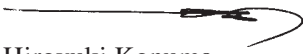
Endorsement

Regional standards for phytosanitary measures are developed and adopted by the Asia and Pacific Plant Protection Commission as part of the plant protection programme of the Commission's contracting parties. This programme makes available to contracting and other interested parties regional standards for phytosanitary measures to support regional harmonization, with the aim to facilitate trade and avoid the use of unjustifiable measures as barriers to trade.

This standard was endorsed by the twenty-eight session of the Asia and Pacific Plant Protection Commission in September 2013.



Hiroyuki Konuma
Assistant Director-General and
FAO Regional Representative for
Asia and the Pacific

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Endorsement

This Asia and Pacific Plant Protection Commission (APPPC) Regional Standard for Phytosanitary Measures was endorsed by the twenty-eighth session of the APPPC held from 23–27 September 2013 in Jeju, Republic of Korea.

Review

APPPC Regional Standards for Phytosanitary Measures are subject to periodic review. The next review date for this standard is 2015. The standard may be reviewed earlier if the APPPC decides this is necessary.

Distribution

APPPC Regional Standards for Phytosanitary Measures are distributed by the Executive Secretariat of the APPPC to all APPPC members, the Administrative Heads of Regional Plant Protection Organizations and the FAO International Plant Protection Convention (IPPC) Secretariat. This standard is available on the APPPC webpage found within the International Phytosanitary Portal: http://www.ippc.int/En/rppo/jsp

INTRODUCTION

Scope

The standard provides guidance to assist NPPOs assess whether fumigators can undertake fumigations effectively and can provide an approved service.

The standard also outlines in appendices the general principles of fumigation and general procedures for fumigation.

References

ISPM 5. *Glossary of phytosanitary terms*. Rome, IPPC, FAO.

ISPM 13. 2001. *Guidelines for the notification of non-compliance and emergency action*. Rome, IPPC, FAO.

ISPM 28. 2007. *Phytosanitary treatments for regulated pests*. Rome, IPPC, FAO.

FAO Manual of Fumigation for Insect Control (1984) FAO PLANT PRODUCTION AND PROTECTION PAPER 54 FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS

Definitions and abbreviations

Except for the definitions below, definitions are from ISPM 5 *Glossary of phytosanitary terms*

enclosure	A gas-proof structure to keep fumigant in contact with the commodity
equilibrium	Even distribution of fumigant where all concentrations readings are within 15% of one another
fumigator	Refers to the person or persons performing the fumigation
PPE	Personal Protective Equipment
SCBA	Self-contained Breathing Apparatus

stack	Any fumigation where the enclosure is created using a fumigation sheet
TLV	Threshold Limit Value
treatment provider	Refers to the company or other entity that provides fumigation treatment services

Outline of requirements

This standard provides guidance to assist NPPOs assess whether fumigators can undertake fumigations effectively and can provide an approved service.

Fumigation treatment providers should be assessed by their NPPO to show the facilities, staff and management are suitable for the scope of the approved treatments. Specific information is required from approved treatment providers before they can be listed by NPPOs. Guidance on the obligations of competent fumigators is provided.

Approved fumigation treatment providers should be subject to regular audits. The approval should be withdrawn if requirements are not met.

NPPO responsibilities include: establishing criteria for competencies; ensuring training meets requirements; establish assessment and audit systems and conduct these; take prompt action upon non-compliance.

Approved fumigation treatment providers should: ensure all treatments meet requirements; ensure documentation is appropriate; cooperate as required with their NPPO.

The principles of fumigation and general procedures for fumigation are attached as appendices.

BACKGROUND

Fumigation is a useful measure to reduce the risk of introduction and spread of regulated pests through the international movement of commodities or regulated articles. However, little guidance has been available to assist NPPOs in assessing whether fumigators have carried out fumigations effectively to allow NPPOs of importing countries to have confidence in the fumigation.

Purpose

The guidelines are to assist fumigators to carry out effective fumigations reliably and NPPOs with guidance on developing appropriate systems for regulating and certifying fumigations to meet importing country requirements.

Acknowledgement

It is acknowledged with thanks that much of the material in this standard is drawn from documentation produced by the Australian Fumigation Accreditation Scheme. For further information refer to: http://www.daff.gov.au/aqis/import/general-info/pre-border/afas

REQUIREMENTS

1. Regulation of fumigation treatment providers

1.1 Approval of fumigation treatment providers

Each treatment provider applying for approval must be assessed by the NPPO to determine if they meet the approval requirements. The treatment provider should be notified in writing if they meet the approval requirements, be allocated an approval number and advised of the date from which their approval will take effect.

If the approval requirements have not been met, the treatment provider should be notified in writing of the reasons why approval was not granted.

1.1.1 Approval assessment

To be eligible for approval by the NPPO, each treatment provider should be able to demonstrate that they have:

- a documented organizational structure that clearly defines the roles and responsibilities of all persons either directly involved in performing the treatments or have managerial responsibility for ensuring that adequate procedures, resources and training are in place to meet requirements

- sufficient suitably qualified and experienced fumigators
- facilities suitable for the scope of the approved treatments
- procedures in place to ensure that fumigations are performed in accordance with the requirements
- appropriate and sufficient equipment available to perform the treatments in accordance with requirements
- record management procedures in place to provide access to all documentation relating to individual treatments for at least two years from the date of treatment
- a commitment to undergo audits to demonstrate compliance.

A documented quality management system that covers their fumigation activities and addresses the requirements would facilitate the approval process by the NPPO.

1.1.2 List of approved treatment providers

The NPPO should establish and administer a list of approved treatment providers containing the following minimum information on each provider:

- approval number
- date of approval
- approval validity period
- company name and contact details
- name and position of persons with management responsibility
- names of competent fumigators employed by the company
- scope of approval e.g. fumigants the provider is qualified to use, phytosanitary verses domestic purposes etc.

1.2 Competency of fumigators

Fumigation treatment provider personnel responsible for managing fumigation must be adequately trained to ensure fumigations are performed safely and effectively. The training should cover the general principles of fumigation, the practical application of these principles in the field, the equipment and facilities needed and the information they need to record to demonstrate compliance.

To be considered competent the treatment provider personnel should be able to demonstrate that they understand and can satisfy their obligations when doing fumigations, such as:

- Selection of suitable sites
- Ensuring the consignment is suitable for fumigation
- Ensuring the enclosure is sufficiently gas-tight to retain the fumigant for the duration of the exposure period
- Applying the correct dosage
- Achieving even gas distribution throughout the enclosure
- Verifying that the fumigant is evenly distributed throughout the enclosure and concentration levels are at or above minimum requirements at the start of the fumigation
- Verifying that fumigant concentration levels at the end of the exposure period are at or above the minimum requirements.
- Ventilation of the enclosure to ensure that the consignment is safe to handle
- Conducting the fumigation in a manner that is safe
- Recording all relevant information on-site and at the time the fumigation is performed.

Refer to appendices 1 and 2 of this Standard for more detailed information about fulfilling these requirements.

1.3 Compliance surveillance

Approved fumigation treatment providers should be subject to regular audits to assess their ongoing compliance with requirements. The audit should determine that:

- management and administrative procedures are in place to ensure that treatment requirements are understood and consistently achieved.
- there are sufficient competent personnel available
- the facilities meet requirements
- equipment is suitable and properly maintained
- sufficient equipment is available and is used in accordance with requirements

- fumigation practices meet requirements
- adequate, accurate documentation is kept to demonstrate compliance.

In addition to formal audits, informal un-announced inspections of fumigations may also be undertaken to verify that requirements are consistently being applied in practice.

1.4 Withdrawal or suspension of fumigation provider approval

The NPPO should withdraw or suspend the fumigation provider's approval if they are not adequately meeting the approval requirements.

2. Roles and responsibilities

2.1 NPPO

The roles and responsibilities of the NPPO include, but are not limited to, the following:

- Establish the criteria for assessing fumigation personnel competency
- Ensure that the training and assessment of fumigation personnel adequately meets the competency criteria.
- Establish and administer systems for the assessment, approval and auditing of fumigation treatment providers.
- Ensure only treatment providers that adequately meet the requirements are approved.
- Establish and maintain a list of all eligible fumigation treatment providers.
- Conduct audits and inspections of approved fumigation treatment providers in accordance with the requirements to determine their level of compliance.
- Take prompt, appropriate action (e.g. withdrawal or suspension of approval), where an approved fumigation treatment provider fails to demonstrate their capacity to conduct effective fumigation treatments.

2.2 Approved fumigation treatment providers

The roles and responsibilities of approved fumigation treatment providers include, but are not limited to, the following:

- Ensure all fumigation treatments are performed according to the relevant requirements
- Ensure all documentation is completed according to the requirements, maintained for a period not less than two years and made available upon request.
- Ensure any company changes that may affect their ability to meet the requirements are promptly reported to the NPPO (e.g. movement of competent persons or changes in address details)
- Cooperate with the NPPO to demonstrate their compliance with the requirements.

Appendix 1

Principles of fumigation

1. Fumigants

A fumigant is a chemical which, at a required temperature and pressure, exists in the gaseous state in sufficient concentration to be lethal to a given pest organism.

An important feature of fumigants is they exist in a gaseous state under normal treatment conditions so they diffuse as separate molecules, enabling them to penetrate into the material being fumigated and to diffuse away afterwards. This is an important distinction from aerosols, which are particulate suspensions of liquids or solids dispersed in air, popularly referred to as smokes, fogs or mists. These are unable to penetrate even a short distance into materials because their particles are deposited at the outer surfaces.

2. Fumigant suitability

Fumigants vary greatly in their mode of action. Some kill rapidly while others kill slowly. In sub-lethal dosages, some fumigants may have a paralysing effect on the pest while others will not allow the pest to recover. Some fumigants have no effect on commodities while others are detrimental even at low concentrations. Commodities vary in their sorption of fumigants and in the effort required to aerate the commodities after fumigation.

There are a number of factors that will determine the suitability of a fumigant to treat a particular commodity and/or pest. These include:

- toxicity
- mode of action
- potential to cause damage to the commodity and/or associated materials
- ability to penetrate into the commodity being treated

3. Fumigant properties

Each fumigant has different properties and characteristics that will affect how it should be applied to consistently achieve an effective fumigation.

3.1 Boiling point

Some fumigants have a relatively high boiling point at normal atmospheric pressure, for example, methyl bromide boils at 3.6ºC. Fumigants with relatively high boiling points can condense back into a liquid as it is being release into the enclosure. A build up of back pressure in the supply system can result in liquid fumigant coming from the supply pipe with the potential to cause damage to the commodity.

The risk of releasing liquid fumigant can be reduced by heating the fumigant using a vaporiser (volatiliser) and by controlling the rate of gas flow through the supply system. The internal diameter of the pipes used in supply system should be the same or increase progressively from the fumigant supply towards the enclosure to minimise potential choke-points that could create sufficient back-pressure to condense the fumigant back to a liquid.

3.2 Rate of diffusion

The rate at which a fumigant will diffuse throughout an enclosure is dependent on a number of factors. The heavier the gas the slower it will diffuse throughout an open space. The rate of diffusion is also directly related to temperature, so that a given gas will diffuse more quickly in hot air than in cold air.

If a gas is heavier than air, it will have a tendency to stratify resulting in lower concentrations in the upper reaches of the enclosure. The use of fans or other means to force thorough mixing of the fumigant with the air will ensure uniform distribution throughout the enclosure.

Once heavier than air fumigants are thoroughly mixed with the air, any tendency to stratification is of no practical importance during normal fumigation exposure periods.

3.3 Flammability

Some fumigants are highly flammable and can present a risk of explosion unless suitable precautions are taken. Dilution of the oxygen content in the enclosure by purging with an inert gas to non-combustible levels, sometimes combined with fumigation under vacuum, plus the removal of any potential source of ignition is commonly used to manage the risk associated with

flammable fumigants. Specific details to manage this risk are described in the appendices for each relevant fumigant.

3.4 Sorption

Sorption is the term used to describe the total uptake of fumigant resulting from the attraction and retention of the molecules by any solid material present in the system. Such action removes some of the molecules of the fumigant from the free space so that they are no longer able to diffuse freely throughout the system or to penetrate further into the interstices of the material.

The amount of fumigant used must be sufficient both to satisfy the total sorption during treatment and also to leave enough free gas to kill the pest organisms.

When the enclosure is ventilated to remove the fumigant from the space and the material, the fumigant slowly diffuses from the material. With the common fumigants and the commodities usually treated, residual vapours are completely dissipated within reasonable periods, although the length of time varies considerably according to the gas used and the material treated.

4. Fumigant concentration levels

To achieve an effective fumigation, the target of the fumigation must be exposed to a sufficient concentration of fumigant for a sufficient length of time to achieve a lethal dose. The amount of fumigant required to achieve the lethal dose is referred to as the dosage rate and is expressed as a function of concentration and time. For example, timber is typically fumigated with methyl bromide at a dosage rate of 48 g/m^3 for 24 hours.

The dosage rate and any minimum retention rate, is set to effectively treat all life stages of the target pest.

Fumigation must be done in enclosures that are sufficiently gas-tight to maintain concentration levels above the minimum requirement over the duration of the exposure period. Typically, there will be a reduction of fumigant concentration in the enclosure over time due to penetration into or sorption by the commodity and leakage from the enclosure. To ensure that the target pest is subjected to a lethal concentration of fumigant over the entire exposure period a minimum final retention rate may be required. The

minimum retention rate is a percentage of the dosage rate concentration which must be met or exceeded at the end of the fumigation exposure period.

Some fumigants, such as phosphine, require fumigant concentrations to be maintained within lower and upper ranges over the fumigation exposure period. This is intended to avoid inducing protective narcosis in the insects which may result in insects surviving the fumigation because they do not take up a lethal dose.

4.1 The effect of temperature on the dosage rate

The most important environmental factor influencing the action of fumigants is temperature as the toxicity of a fumigant depends on the respiration rate of the target organism. Generally, the lower the temperature, the lower the respiration rate of the organism which tends to make it less susceptible. Fumigation at lower temperatures requires a higher concentration of fumigant than fumigation at higher temperatures.

Unless specified otherwise, the minimum expected ambient air temperature within the enclosure during the exposure period should be used to determine any adjustments to the dosage rate.

Some commodities, particularly perishables, require treatment at a specific temperature or within a specific temperature range to ensure the treatment is effective while minimising any adverse effects on the quality of the commodity that may result from increased temperatures. If the treatment requires measurement of the internal or pulp temperature of the commodity then suitable temperature probes must be used. Fumigations that require a specific temperature or temperature range must be performed in a facility capable of heating the commodity to the desired temperature and maintaining it for the duration of the fumigation exposure period.

The expected minimum ambient temperature for fumigations performed outside or in facilities without adequate temperature control should be obtained by checking the official forecast minimum temperature of the nearest locality to the fumigation site.

For practical purposes, it is increasingly difficult to kill insects with fumigants as the temperature is lowered to 10ºC. In general, the effectiveness of fumigants becomes unreliable below 10ºC so, unless otherwise specified,

fumigation is not normally permitted where the temperature is expected to fall below 10ºC during the exposure period. If the ambient temperature is expected to fall below 10ºC, heaters can be used to increase the temperature and maintain it at a satisfactory level for the duration of the exposure period. There will be a gradient within the enclosure where the temperature will progressively decrease the greater the distance from the heat source. The temperature used to determine the dosage rate must be the ambient temperature expected in the coolest part of the enclosure.

Sufficient time must be allowed for the enclosure and the commodity to reach the desired temperature prior to starting the fumigation.

The adjustment of dosage rates to compensate for lower temperatures will vary depending on the fumigant. Any adjustment to the dosage rate must be done before calculating the dosage.

5. Safety

All fumigants are toxic gases which can be harmful to humans if not handled carefully. Appropriate precautions must be taken to avoid exposure to unsafe levels of fumigant by fumigation personnel as well as any other persons in the vicinity. This includes the establishment of an exclusion zone (see Appendix 2, Section 2.7.1).

5.1 Personal protective equipment (PPE)

Fumigation personnel must wear appropriate respiratory protection when inside the exclusion zone while it is in force.

5.2 Full-face respirators

A full-face respirator with a suitable filter canister attached will provide adequate protection against exposure to unsafe levels of fumigant. The filter canister must be appropriate for the fumigant and should be used in accordance with the manufacturer's instructions.

5.3 Self-contained breathing apparatus

Self-contained Breathing Apparatus (SCBA) consists of a full-face respirator attached to a cylinder of breathable air. SCBA provides protection against all

toxic gases and at higher concentrations than a respirator and gas filter is capable of providing protection for.

Personnel must be suitably trained in the use of SCBA.

5.4 Threshold Limit Value

The Threshold Limit Value (TLV) is the maximum concentration of fumigant that the average person can be safely exposed to over a working week (40 hours). The TLV is usually expressed as parts per million (ppm) or parts per billion (ppb).

The TLV is different for each fumigant and may also vary from country to country.

Appendix 2

General procedures for fumigation

1. Site selection

Fumigations are commonly performed at ports, in container terminals or at the exporter's premises. The fumigator should assess the site's suitability to ensure that the fumigation can be done safely and effectively. The site should be away from unprotected personnel, well ventilated, sheltered from high winds (as much as possible) and access restricted to authorised personnel.

If a fumigation sheet is used for the enclosure, the surface must be impervious to the fumigant, flat, clear of stones or other sharp objects that may damage the sheet and free of cracks or joins that will reduce the gas-tightness of the enclosure. There should be sufficient space to set up an exclusion zone around the enclosure.

1.1 Risk assessment

The fumigator needs to conduct a risk assessment of the fumigation site to ensure that the fumigation can be performed safely. They need to consider the prevailing wind direction, proximity of occupied buildings and any unprotected personnel in the vicinity. The fumigator must plan for safe ventilation of the enclosure before the fumigation starts.

The risk needs to be continually re-assessed as it will change depending on the activities taking place and the circumstances at the time.

2. Consignment suitability for fumigation

It is the responsibility of the owner or their agent to present the consignment in a condition that will allow it to be effectively fumigated.

2.1 Adverse effects on the commodity

Some commodities or any other associated materials in the enclosure may be adversely affected by some fumigants. This may include chemical reactions causing undesirable residues, corrosive effects or unacceptable deterioration in quality.

If there is a concern that a commodity may be adversely affected by a fumigant expert advice should be sought regarding its effects or tests conducted on the commodity.

2.2 Free airspace

An important factor in getting good air circulation and therefore even fumigant distribution is the amount of airspace around and between the commodity. The enclosure should be configured to ensure that there is adequate space above, below, at

the sides and throughout the commodity. Putting the commodity on pallets, creating space between the sheets and the commodity and stacking the commodity so there is space between items, will improve fumigant circulation.

Commodities in shipping containers are often packed tightly to utilize as much of the available space as possible. If a container is presented for fumigation without adequate free airspace then it cannot be fumigated effectively unless sufficient space is created by removing some of the commodity which can then be fumigated as a free-standing stack.

3. Penetration into the commodity

In many cases the fumigant must be able to penetrate into the commodity to effectively treat pests (for example, wood borers) that can exist inside the commodity itself. The fumigator should inspect the consignment to verify that it can be treated effectively prior to fumigation. If the consignment cannot be adequately inspected, the fumigator may need to rely on information from the manufacturer/exporter of the goods to ascertain whether there is anything that may prevent the fumigant from penetrating into the commodity to a sufficient degree.

3.1 Impervious surfaces and wrapping

If the commodity is wrapped in materials that are impervious to the fumigant the wrapping should be cut or removed prior to fumigation.

If the commodity has impervious surfaces that will prevent effective penetration of the fumigant then an alternative method of treatment must be used. Where practical, the commodity should be fumigated prior to any impervious surfaces being applied.

3.2 Maximum thickness

The degree of penetration into the commodity will depend on the fumigant used, the nature of the commodity and the exposure period. If there is a maximum depth which the fumigant can penetrate, there may be restrictions on the size of that commodity which can be effectively treated with that fumigant. In general, the maximum thickness of a commodity that can be treated will be twice the penetration depth because the fumigant can penetrate from all sides. If, however, the commodity is partially coated with an impervious surface the maximum thickness from the uncoated surface will be the same as the penetration depth.

4. Fumigation enclosures

Fumigations must be performed in enclosures that are sufficiently gas-tight to retain the required minimum concentrations of fumigant for the duration of the exposure period.

Each enclosure is considered a separate fumigation even if it is for the same consignment and all the requirements apply to each enclosure as a stand-alone fumigation.

4.1 Fumigation chambers

A fumigation chamber is a fixed structure designed for regular use as a fumigation enclosure. The most important characteristic of a chamber is that it can be reliably sealed by simply closing the door. Monitoring tubes, supply pipes and electrical leads enter the chamber through holes in the walls that are sealed to prevent leakage. Chambers should be fitted with a circulation system with an air flow capacity sufficient to move the equivalent of the chamber volume of air every one to three minutes.

They must have an exhaust system to allow safe ventilation of the chamber and complete aeration of the commodity. Ideally the exhaust outlet should extend at least three metres above the chamber or, for chambers situated inside a building, above the building roofline. An air inlet port is necessary to allow fresh air to enter the chamber while it is being ventilated. Better ventilation will be achieved if the inlet port is located at the opposite end from the exhaust port so that fresh air is drawn through the length of the chamber.

Chambers situated inside a building should be in an area that is well ventilated and capable of being isolated from unprotected personnel during fumigation.

Fumigation chambers must pass a pressure test at least every six months. The pressure test must be conducted under normal fumigation conditions, that is, the chamber must be sealed in the same way it would for the actual fumigation.

A pressure decay time from 200 to 100 Pa of 10 seconds or more must be achieved to verify that the chamber is gas-tight. To check this the pressure in the chamber should be raised by 250 Pa and the time taken for pressure to fall from 200 to 100 Pa measured. If the time taken is 10 seconds or more then the chamber can be considered gas tight.

4.2 Vacuum chambers

Some treatments are performed under vacuum which greatly increases the rate of penetration of fumigant into the commodity allowing the exposure time to be reduced accordingly.

The chamber must be capable of achieving the desired vacuum and maintaining it for the duration of the fumigation. At the end of the exposure period normal air pressure is restored to allow the fumigant to be vented and the commodity aerated until it is safe to handle.

4.3 Shipping containers

Fumigations are routinely performed in shipping containers without being enclosed in a fumigation sheet.

The condition of the door seals should be checked and the body of container inspected for any damage that will make it incapable of retaining the fumigant for the required exposure period. If the container is not considered suitable it must be fumigated under a sheet.

Seal the air vents from the outside using tape and install the monitoring tubes and fans. Take care when closing the doors that the monitor tubes are not crushed or kinked which may cause inaccurate concentration readings. The fumigant should be introduced into the container using a metal tube or other suitably rigid material inserted through door seals and withdrawn after dosing is complete. This is easiest at the top or bottom where both doors meet.

It is important to carefully check for leaks around the door seals. It may be necessary to use some temporary sealant to prevent excessive leakage where the tubes and leads enter the container. Leakage from around the doors can usually be fixed by taping along the seals.

The container floor is another potential source of leakage. While the container is on the ground it is not possible to thoroughly leak check the floor. In windy conditions, gas retention can be improved by preventing air flow under the container using sand snakes or other suitable means around the base of the container. If there are leaks in the floor the wind can create pressure differentials, the Venturi effect, that will draw gas from the container.

4.4 Sheeted stacks

Any fumigation that uses a gas-proof sheet to create a fumigation enclosure is considered to be a stack. The ability of a stack to retain sufficient fumigant for the duration of the fumigations is largely determined by the sheet, the fumigation surface and the quality of the seal created between them. If one or more containers are covered by a sheet it is considered a stack fumigation.

4.5 Fumigation surface

The fumigation surface must be impervious to the fumigant and free of cracks (including unsealed expansion joints) and drains or any other opening that will reduce the gas tightness of the enclosure.

The surface should be flat and free from stones and any other sharp objects that may cause damage to the sheet or reduce the gas tightness of the enclosure.

If the fumigation surface is not suitable a gas-proof sheet can be used to cover the surface to create a gas-tight enclosure.

4.6 Fumigation sheets

Fumigation sheets must be impervious to the fumigant being used. They must be able to easily retain sufficient fumigant concentrations for the entire exposure period without the need to add additional fumigant. The ability of the sheets to retain fumigant will deteriorate with use and they should be carefully monitored to ensure their condition is good enough to reliably meet the gas retention requirements.

The sheets must be inspected for any damage before each use. Any tears or holes can be temporarily repaired using cloth or other suitable tape capable of adhering to the sheet material. Permanent repairs should be made to sheets at the first opportunity by heat welding or gluing patches over the damaged area. Patches must not be sewn on as the needle holes will still allow too much gas to escape.

A variety of different materials are suitable for use as fumigations sheets. They range from relatively thin plastic sheets that last for only a few uses to heavier, more durable sheets that will last for many years if handled with care. Thinly coated, woven materials allow too much gas to be lost and are unsuitable for use as fumigations sheets.

4.7 Creating a gas-tight seal

A gas-tight seal between the sheet and the fumigation surface must be created to prevent excessive leakage of fumigant from the enclosure for the duration of the fumigation.

The sheet must be held flat against the fumigation surface to prevent excessive leakage. This is most easily done by the use of sand snakes, flexible tubes filled with sand around 100 mm in diameter and from 0.5–1.5 metres long. Sand snakes should only be filled to 65–75 percent with clean dry sand so they remain flexible enough to bend around corners and lie flat on the ground. A minimum of two rows of sand snakes should be used around the entire enclosure. They should be laid end to end with the second row offset to overlap the joins of the first row in a brick-work like pattern.

Water snakes can also be used. A single continuous water snake should be laid flush against the stack and filled 75–85 percent full. Care should be taken to ensure a complete seal where the ends of the snake meet. The water snake should not start or end on a corner. If water is used to create snakes similar to sand snakes, they should be laid in the same way as sand snakes.

Loose sand or soil can also be used to seal the sheet to the floor. Sufficient sand or soil must be used to create a continuous seal around the entire enclosure.

Fumigation sheets should extend at least 500 mm from the base of the stack to allow more sand snakes, water snakes or the like to be added to improve

the seal between the sheet and the fumigation surface if a leak is detected. The additional snakes should be placed alongside the existing rows rather than on top.

The sheet at the corners of the stack should be folded so the sheet will lay flat against the surface making it easier to get a good seal. Once folded the corners should be secured with clamps or tape to prevent the wind from pulling the sheet apart.

5. Calculating the dosage

The amount of fumigant that needs to be released into the enclosure to achieve the dosage rate concentration is referred to as the dosage.

The dosage is calculated by multiplying the volume of the enclosure by the dosage rate concentration.

$$\text{Dosage} = \text{Dosage rate concentration} \times \text{Volume}$$

5.1 Volume of the enclosure

The volume of the enclosure must be calculated from the measured dimensions. When fumigating stacks the measured external dimensions should be used. The dimensions of stacks should be measured each time because significant variations in volume can occur depending the set-up of the enclosure.

If the enclosure is an un-sheeted container or a chamber, the known internal volume of the enclosure can be used. The volume of any gas circulation equipment external to the chamber must be included in the calculation of the enclosure volume.

No reduction in the volume and therefore, the dosage, is allowed to account for any displacement of air in the enclosure by the commodity.

5.2 Compensating for fumigant mixtures

Some fumigants can be supplied mixed with other gases so the fumigant is diluted to less than 100 percent. For example, methyl bromide is commonly supplied with a mixture of 2% chloropicrin. Methyl bromide is colourless and

odourless at concentrations normally encountered during fumigation so the chloropicrin is added as warning agent.

If the fumigant is mixed with another gas the dosage must be adjusted to compensate for the dilution. The dosage is divided by the percentage of the active fumigant in the mixture to give the total amount of fumigant mix that needs to be released into the enclosure to achieve the specified dosage rate concentration.

6. Even distribution of fumigant

The fumigant must be evenly distributed throughout the enclosure to ensure that a lethal concentration comes into contact with the target of the fumigation over the exposure period. Concentration readings must be taken from different locations within the enclosure to check that even distribution has been achieved. The fumigant can be considered to be evenly distributed when all the concentration readings are within 15 percent of one another. Even distribution of fumigant is called 'Equilibrium'.

Equilibrium is calculated using the following formula:

$$\frac{\text{Highest Reading} - \text{Lowest Reading}}{\text{Lowest Reading}} \times 100 = \% \text{ age distribution}$$

If the result of the calculation is 15 percent or less, then the gas is sufficiently distributed throughout the enclosure. If the result is more than 15 percent, the fumigant requires further circulation until either equilibrium is achieved or the readings falls below any specified minimum concentration level.

In general, equilibrium is only required at the start of the fumigation.

6.1 Placement and number of monitoring tubes

Monitoring tubes must be placed at representative points within the enclosure to allow measurement of the fumigant to check if it is evenly distributed and that concentration levels are at or above any specified minimum amount.

Enclosures smaller than 30 m only require at least one monitoring tube, therefore, equilibrium is not necessary. The monitoring tube should be placed at the top-centre of the commodity.

Enclosures larger than 30 m^3 must have at least 3 monitoring tubes. They should be placed towards the top-back of the enclosure, somewhere around the middle and at the front base. The purpose of positioning the monitoring tubes as recommended is to check that the fumigant is evenly distributed throughout the enclosure. If the configuration of the commodity in the enclosure makes placement of the monitoring tubes at the recommended locations impractical, they can be re-positioned to more accessible locations provided the even distribution of fumigant throughout the enclosure can still be determined.

Fumigation of multiple shipping containers under a fumigation sheet requires at least three monitoring tubes in the enclosure with at least one in each container. If two containers are being fumigated as a stack a monitoring tube must be placed at the top-centre of the commodity in each container with the third monitoring tube placed at the front-base of either container. Three or more containers fumigated as stack sheet require at least one monitoring tube in each container placed at the top-centre of the commodity.

6.2 Fans

One or more fans must be used in each enclosure to force the fumigant to mix thoroughly with the air and circulate throughout the entire enclosure until even gas distribution is achieved.

Fumigations in shipping containers, whether it is a single container or multiple containers in a stack, should have at least one fan placed in each container. The fans should be positioned so that an air current will be created to rapidly disperse the fumigant evenly throughout the enclosure. The capacity and/or number of fans used should be proportional to the volume of the enclosure. The total combined air flow capacity of the fans in each enclosure should be sufficient to move the equivalent of the enclosure volume of air every one to three minutes.

Fans should be turned on 10–15 minutes before releasing any fumigant into the enclosure and continue to run until equilibrium is reached. The time it takes to achieve equilibrium will vary depending on factors such as, how tightly packed the commodity is, the size of the enclosure, the capacity of the fans and the number of supply pipes used to introduce the fumigant. It is a matter of experience to judge how long to run the fans before taking the first readings.

Fans must be turned off prior to taking any concentration readings. Once even gas distribution has been achieved there is no practical benefit in continuing to run the fans so they can be switched off until required for ventilation unless there is a need to add additional fumigant during the exposure period.

6.3 Multiple supply pipes

Using more than one supply pipe in larger enclosures will help to achieve even fumigant distribution more quickly. The supply pipes should be positioned so the fumigant is directed into the free airspace to aid circulation.

Where more than one supply pipe is used the fumigant can be released into the enclosure through the pipes simultaneously if a balanced supply system has been created. A balanced system is where the supply pipes are of equal internal diameter and equal length so an equal amount of fumigant will flow through each pipe. If the multi-pipe supply system is not balanced an equal proportion of fumigant should be released through each pipe in turn.

Fumigations in shipping containers, whether it is a single container or multiple containers in a stack, should have at least one supply pipe placed in each container.

7. Releasing the dose into the enclosure

7.1 Exclusion zone

An exclusion zone should be established around the enclosure by setting up a physical barrier to warn people in the vicinity that a fumigation is taking place. Use tape, rope, bunting or other suitable material held up by stands or bollards to encircle the enclosure at around waist height. Warning signs should be placed so that they are visible on all sides and clearly indicate that the area is potentially dangerous. The warning signs should be large enough to be read from a distance, contain the fumigators contact details, be in more than one language if appropriate and prominently display a readily recognised symbol for danger (e.g. skull and crossbones).

The exclusion zone is in force from the time the fumigator is ready to release the fumigant into the enclosure until the enclosure has been fully ventilated and the commodity is safe to handle by un-protected personnel. While the

exclusion zone is in force, only personnel wearing suitable PPE are allowed inside.

The fumigant supply and the fumigation supply system must be inside the exclusion zone while fumigant is being released into the enclosure.

7.2 Final checks

Before releasing the fumigant into the enclosure do a final check:

- Check the fans are turned on.
- If a vaporiser is used it must be at the required operating temperature.
- Inspect the enclosure for any holes or obvious sources of leaks
- Close any un-used outlets on the supply system
- Ensure all un-protected personnel are outside the exclusion zone.

7.3 Measuring the dosage

The amount of fumigant to be used is usually measured out by weight or volume and slowly released into the enclosure through the supply system. All joins in the system should be connected using suitable clamps or fittings that prevent the joins from coming apart during the dosing process.

Check the joins and connections in the supply system for leaks by releasing a small amount of fumigant into the system. Fix any leaks before applying the full dosage to the enclosure.

The time dosage is fully released into the enclosure must be recorded.

8. Leak detection

Excessive leakage from the enclosure may allow the fumigant concentrations to fall below acceptable levels resulting in an ineffective fumigation.

Carefully check the enclosure for leaks. For stacks check where the sheet meets the fumigation surface around the entire circumference of the enclosure paying particular attention to the corners, where the monitoring tubes and leads exit the enclosure and any cracks or expansion joints in the floor. Check around the door seals of containers used as enclosures without sheeting.

8.1 Leak detection equipment

The leak detection equipment must be sufficiently sensitive to detect fumigant concentrations low enough to find a leak that warrants attention. As a general guide the leak detector should be capable of detecting concentrations down to 20 ppm.

The leak detection equipment must be fit for purpose and properly serviced and maintained in accordance with the manufacturer's instructions.

9. Monitoring fumigant concentrations

Fumigant concentrations must be measured at the start and end of the exposure period to verify that the target of the fumigation has been exposed to the minimum amount of fumigant specified by the treatment schedule. If the concentration readings from all the monitoring tubes are equal to or above the minimum requirement at both the start and end of the exposure period then a sufficient amount of fumigant has been maintained in the enclosure to effectively treat the target of the fumigation.

Additional readings may be required or advisable for fumigations with long exposure periods or where the commodity may warrant it.

9.1 Concentration measuring equipment

Suitable instruments must be available during all fumigations to measure fumigant concentrations as required. The equipment must be fit for purpose and capable of accurately and reliably measuring concentrations in the range typically encountered for the type of fumigation being performed.

Moisture, carbon dioxide and any other filters recommended by the manufacturer must be fitted and the operator must be properly trained how to use and maintain the equipment.

Regular maintenance, servicing and calibration must be done in accordance with the manufacturer's instructions.

9.2 Monitoring tubes

Monitoring tubes should be made of materials that don't absorb or aren't affected by the fumigant and aren't easily crushed or kinked. The monitoring tubes should be sealed between readings. Using monitoring tubes that are long enough to extend outside any exclusion zone or risk area may allow concentration readings to be taken without the need to wear PPE.

The internal diameter of the tubes should not be less than the internal diameter of the sampling probe fitted to the concentration measuring equipment.

10. Topping-up

In some circumstances, it may be permitted to add additional fumigant to the enclosure to prevent the fumigation from failing unnecessarily and avoid the need to retreat the commodity. Depending on the fumigant and the commodity there may be restrictions on the amount of topping-up allowed.

Topping-up of fumigant levels is not permitted to solely compensate for poor fumigation practices or excessive leakage from enclosures.

11. Ventilation

At the end of the exposure period the enclosure must be safely vented to remove the fumigant and aerate the consignment by exposure to fresh air until the concentration of fumigant is below unsafe levels.

Good free airspace and turning the fans on will help to ventilate the enclosure more quickly. The time taken to ventilate depends on a number of factors such as the size of the enclosure, how tightly the commodity is packed, whether there are sorptive materials in the enclosure and the nature of the commodity.

11.1 Risk assessment

The design of fixed or permanent fumigation facilities must allow for safe venting and aeration.

Prior to the ventilation of temporary enclosures, such as containers or stacks, the fumigator must do a risk assessment to plan how to vent the enclosure safely. The fumigator must take into account the direction of the wind,

proximity of occupied buildings and unprotected personnel in the area. The fumigant will disperse rapidly once released into the atmosphere, however, unsafe levels are possible up to 50 metres or more from the enclosure depending on conditions.

11.2 Checking TLV

Ventilation of the enclosure and aeration of the commodity must continue until concentration levels in the enclosure are at or below the TLV. The monitoring tubes positioned in the centre or back of containers can be used to check if TLV has been reached at all points with the container.

The concentration levels in the free airspace will fall relatively quickly compared to the rate of fumigant diffusion back out of the commodity. It is particularly important that the consignment is fully aerated if it is fumigated in a shipping container. Once the container is closed concentrations levels can increase again to unsafe levels as fumigant continues to diffuse out of the commodity. This has the potential for unprotected personnel to be exposed to unsafe levels of fumigant when the container is opened at its destination.

The equipment used to test for TLV must be sensitive enough to accurately and reliably detect concentrations below the TLV.

12. Documentation

The fumigator must keep records with sufficient information to be able to demonstrate that they have been performing effective fumigations.

12.1 Record of fumigation

The fumigator must record all the relevant information for each fumigation. At a minimum the record of fumigation should record:

- Details of the consignment
  - job identification
  - customer name
  - start date of fumigation
  - location of fumigation
  - description of consignment
  - target of the fumigation
  - container number/s or other consignment identifications

- Fumigation details
  - fumigant name
  - type of enclosure
  - specified dose rate
  - exposure period
  - minimum temperature
  - any adjustment to the dose rate
  - volume of the enclosure
  - amount of fumigant used
  - time dosing finished
- Concentration readings
  - location of each monitoring tube
  - concentration readings from each monitoring tube
  - time each reading was taken
  - any top-up amounts added to the enclosure
- Ventilation
  - TLV value measured
  - time measurement was taken
- Fumigator details
  - name
  - signature
  - accreditation number

This information must be recorded on site at the time the fumigation was performed.

12.2 Treatment certificate or report

Treatment certificates or reports must be made available to the NPPO. All details should be legible and free from erasures and non-certified alterations. The treatment certificates or reports should be signed, dated and contain the following details:

- the registration number prominently displayed
- certificate or report number
- description and quantity of goods being treated
- name and address of the shipper/exporter
- country of origin and the port of loading

- name and address of the consignee
- port of entry
- date of treatment
- place of treatment
- fumigant used
- target of the fumigation
- dosage
- exposure period
- minimum ambient temperature during treatment
- date, time and threshold limit value (TLV) at clearance
- date the certificate was issued
- name and signature of the competent fumigator responsible for supervising the treatment.
- any declarations relevant to the treatment

12.3 Phytosanitary certificate

After the treatment provider has completed the fumigation certificates or reports the phytosanitary certificates can be issued by the NPPO in accordance with the requirements of ISPM 12.

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