

Training Manual: Aluminium Phosphide Fumigation Procedure



**Prepared for PACT
By
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PREFACE

The practice of pest control is becoming increasingly specialized and requires professional personnel who are familiar, not only with the pest and the pesticide, but who also have a good knowledge of the many factors related to pest infestation and control.

With increased public concern over the adverse effects of pesticide chemicals on human health and the environment, greater emphasis is being given to methods that can circumvent the use of pesticides. Nevertheless, the need for chemical pesticides, particularly the fumigants, is likely to continue for many years to come. In modern terminology a fumigant is a chemical which, at a required temperature and pressure, can exist in the gaseous state in sufficient concentration to be lethal to a given pest organism. The manual deals primarily with the use of fumigants as insecticides. This manual will apply primarily to Phosphide gas (fumigants) for the treatment of pests where other non-fumigant pesticides do not act satisfactorily.

A general guidelines and checklists include basic knowledge on fumigants and fumigation procedures. This aspect in itself is very broad. Training facilitators/ expert should read and follow the Standard Operating Procedure (SOP) while explaining basic knowledge on fumigation. The Operation Manual contains all necessary information, procedures and instructions to ensure the safe fumigation operations. The training's manual explains what has to be in the plan: you must document **who, what, when, where, how & why**. 5W1H is a method of asking questions about a process or a problem taken up for improvement. Also, the section in Part 3 on **Fumigation Operational Procedures and Documentation** must be regularly consulted until a certain procedure is completely mastered. These guidelines include requirements under existing legislation.

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Training Design and Curriculum for ALP Fumigation at a glance

Day	Training Session	Sub-topics	Time frame	Facilitation methods	Training Materials	
1 st Day	1stSession:*** Registration, Opening- Introduction Evaluation	<ul style="list-style-type: none"> • Introduce participants & resource persons • Explore participant's expectations for the training • Share training objectives • Pre- evaluation 	1 hour 30 minutes	Discussion Q & A	<ul style="list-style-type: none"> • Folder with pen/participant • Meta cards& marker pen • Soft board & pins • Pre- test 	
	2nd Session: Basic information on fumigation	<ul style="list-style-type: none"> • Introduction on fumigation & fumigants • Limitations of fumigation • Fumigation chamber and how it works • Possible effects of fumigants • Responsibilities • Requirement 	1 hour 30 minutes	Lecture Discussion Q & A	<ul style="list-style-type: none"> • Meta cards & marker pen • Power point slides 	
	Lunch Break					
	3rd Session: Description of Fumigation and Types & Nature of Fumigants	Types of Fumigation: <ul style="list-style-type: none"> • Space Fumigation ❖ Chamber fumigation ❖ Others types of fumigation ❖ Tarpaulin Fumigation ❖ Vehicle or Truck Fumigation • Soil Fumigation Types & Nature of Fumigants: <ul style="list-style-type: none"> • Methyl bromide • Aluminum phosphide 	1 hour 30 minutes	Lecture Discussion Q & A	<ul style="list-style-type: none"> • Meta cards & marker pen • Power point slides 	
4th Session: Effects of Phosphine on Plant Life its advantages & disadvantages and Factors affecting effectiveness	<ul style="list-style-type: none"> • Effects on plant life • Advantages & Disadvantages of Fumigation • Factors that Modify Fumigant Effectiveness: <ul style="list-style-type: none"> ○ Proper understanding of temperature, humidity relationships and C X T relationship ○ Structure area fumigated ○ Method of application 	1 hour 30 minutes	Lecture Discussion Q & A	<ul style="list-style-type: none"> • Meta cards & marker pen • Power point slides 		

Day	Training Session	Sub-topics	Time frame	Facilitation methods	Training Materials
2nd Day	5th Session: Emergency action plan and different Fumigation response method	Review of the previous day. <ul style="list-style-type: none"> • General Precautions • Preparedness for emergency • Safety Measures • Additional Tips on safety Measures and recommendations • Respiratory protection • Precautions at pre-fumigation stage • Precautions during application • Precautions after application • First Aid measures 	1 hour 30 minutes	Lectures Brainstorming Q & A Demonstrations Observation Discussions in small groups Practical Exercises	<ul style="list-style-type: none"> • Meta cards & marker pen • Power point slides • First aid material demonstratin
	6th Session: Fumigation Management Plan	Fumigation management Plan: <ul style="list-style-type: none"> • What is FMP • Purpose of FMP • Steps for preparation of a written fumigation management plan • Preliminary Planning and Preparation • Site Preparation • Personnel • Notification • Sealing Procedures • Application and Period of Fumigation • Monitoring • Post Application Operations • Emergency Response Plan • Checklist for Developing a FMP 	2 hours	Lecture Discussion Question & answer Demonstration Discussion in small groups	<ul style="list-style-type: none"> • Meta cards & marker pen • Power point slides
	Lunch Break				
	7thSession: Types and techniques and process of fumigatin	<ul style="list-style-type: none"> • Gas fumigation • Solid fumigation: • Liquid fumigation Fumigation Methods <ul style="list-style-type: none"> • Direct Application to Commodities • Fumigation Using Probe 	1 hour 30 minutes	Lecture Discussion Question & answer Demonstration Discussion in small groups	<ul style="list-style-type: none"> • Meta cards & marker pen • Power point slides

Day	Training Session	Sub-topics	Time frame	Facilitation methods	Training Materials	
		<ul style="list-style-type: none"> Recirculation methods (for bulk storage) 				
	8th Session: Fumigation method and Storing, Handling, & Disposing of Fumigants	<ul style="list-style-type: none"> Method of fumigation general background Storage and Handling instructions Disposal Instructions National regulations 	1 hour 30 minutes	Lectures Brainstorming Q & A	<ul style="list-style-type: none"> Meta cards & marker pen Power point slides 	
3rd Day	9th Session: Understanding of Phases of Application	<ul style="list-style-type: none"> Review of the previous day work Pre-application (Before Fumigation) During Fumigation (Fumigation Period) Post-application (After Fumigation) 	1 hour 30 minutes	Lectures Brainstorming Q & A	<ul style="list-style-type: none"> Meta cards & marker pen Power point slides 	
	10th Session: Application procedure duration Calculation of Chamber Volume and Dose Uses	<ul style="list-style-type: none"> Calculation of Fumigation Chamber Volume/Fumigation Enclosure/Container Calculating Phosphine Fumigant Dosage (Use Rates) Correct / recommended dosage of fumigant 	1 hour 30 minutes	Lectures Brainstorming Q & A Demonstrations	<ul style="list-style-type: none"> Meta cards & marker pen Power point slides 	
	Lunch Break					
		11th Session: Detection and Fumigation Operation Procedures and equipment	<ul style="list-style-type: none"> Preparing the Chamber/Container Loading the chamber Key factors to consider when loading a chamber/container Sealing the chamber/container Fumigation Placards Determination of Fumigation Temperature Introducing Phosphine into Chamber/Container Exposure Period Detecting gas leakages/ Gas Retention Testing/Testing for Leaks Using Two Trained Applicators Monitoring Fumigant Concentration Threshold Limit Value 	3 hours	Lectures Q&A Demonstrations Observation Discussions in small groups Brainstorming Practical Exercises	<ul style="list-style-type: none"> Meta cards & marker pen Power point slides Fumigation Placards Sealing materials

Day	Training Session	Sub-topics	Time frame	Facilitation methods	Training Materials
		<ul style="list-style-type: none"> Phytopsanitary system security 			
	12th Session: Using Phosphine Generator and gas detection cont..	<ul style="list-style-type: none"> Introduction Phosphine recirculation fumigation technology Operation principle the phosphine generator Phosphine recirculation fumigation technology Phosphine generators in combination of gas distribution system Operation of the phosphine generator Reaction and filtration container Controllers 	3 hours	Lecture Discussion Q & A Practical exercises in small group	<ul style="list-style-type: none"> Phosphine Generator PH₃ Other required equipment and materials
4th Day	13th Session: Using Phosphine Generator (Contd)	<ul style="list-style-type: none"> Review of previous day work. Carbon dioxide supply valve and flow meter Reagent container Safety devices in the phosphine generator Technical parameters of phosphine generator Technical parameter of carbon dioxide supply valve Recirculation Fan Phosphine concentration monitors Phosphine alarm 	Whole Day	Lecture Discussion Q & A Practical exercises in small group Demonstration	<ul style="list-style-type: none"> Phosphine Generator PH₃ Other required equipment and materials
5th Day	14th Session: Using Phosphine Generator (Contd)	<ul style="list-style-type: none"> <i>Practical Course</i> 	Whole Day Practical (Practical Day)	Practical Training	<ul style="list-style-type: none"> Phosphine Generator PH₃ Required equipment and materials
Lunch Break					
6th Day	15th Session: Completion of Fumigation	<ul style="list-style-type: none"> Review of the previous day Degassing/Aeration/Ventilation Waiting period Reentry Unloading the Chamber 	1 hour 30 minutes	Lecture Discussion in small group Q & A Practical exercises Demonstration	<ul style="list-style-type: none"> Meta cards & marker pen Power point slides Testing/Monitoring Equipment

Day	Training Session	Sub-topics	Time frame	Facilitation methods	Training Materials
		<ul style="list-style-type: none"> Residues Testing/Monitoring in Foodstuffs/Others Treatment Records and Documentation Issuance of <i>Fumigation Certificate</i> Fumigation Failure 			
	16th Session: Auditing & Communication	<ul style="list-style-type: none"> Responsibilities of Fumigation Operator Responsibilities of the traders or exporter/importer: Reporting of Fumigation Activities: Review Mechanism for further improvement 	1 hour 30 minutes	Lecture Discussion in small group Q & A Practical exercises Demonstration	<ul style="list-style-type: none"> Meta cards & marker pen Power point slides
Lunch Break					
	17th Session: Training Evaluation and Feedback Collection	Four levels Evaluation using post-test <ul style="list-style-type: none"> Reaction Learning Behavior Results <i>Gathering Feedback</i>	1 hour 30 minutes	Examination	<ul style="list-style-type: none"> Post-evaluation questionnaires
	Closing Ceremony	<ul style="list-style-type: none"> Presentation of Training-Program Results Distribution of Certificates Concluding Remarks Refreshment 	1 hour	Reports Certificates	

***. Session plan can be adjusted as per the demand requirement of the participants

PART I: Understanding Basic Concepts

Module 1: Introduction

Session 1: Basic information on fumigation

Thrust of this session should be to provide knowledge on fumigants and what they are how they act...

OBJECTIVES

By the end of this session, participants will be able to:

Gain Knowledge on:

- Know in detail about the fumigants and fumigation.
- Identification of fumigants. Understand the key steps for differentiating the fumigation from other aspects of pest control. Know the merits and demerits of using fumigants in the treatment of different commodities. And also the scope of this training and training manual.
- Understand and discuss the needed information to be known before starting the fumigation.

Performance:

- Develop introductory modules on fumigation.

Attitude:

- Appreciate the basic knowledge about the fumigants and importance of fumigation operation in expansion of agricultural trade supporting the SPS and Quarantine Compliance.

CLARIFY KEY WORDS, DEFINITIONS AND RELATED CONCEPTS

Step 1

Welcome the participants and share them the objectives of the first module of the training. Provide them a blank sheet of paper and ask them to write down what they understand/know about fumigants. Then, you define fumigants and its importance in Quarantine. Steps and information required to ensure the correct and proper use of phosphine fumigation, their physical and chemical properties, safety precautions to be followed while handling fumigants, modes of action of fumigants, and also appropriate use of fumigants and safety equipment.

Step 2

Clarify key topics and related concepts of fumigants. It is necessary to understand the principles of fumigants. Start by asking the participants what they understand by Fumigation, Fumigants, SPS requirements, why Phosphine, etc.

Step 3

Hand out of the teaching material should be prepared in advance, however, it should be given to the participants only at the end of the session only. The discussion material and mater given in the hand out should be tallied. The reference material should cover the following areas.

Proper definition of the fumigation, difference between fumigants and fumigation, what are the advantages of Phosphine fumigation, responsibilities of fumigation operators and precautionary measures that need to be observed. Further, the participants should be clear about the Quarantine compliances, certification system.

This module helps to understand the basic knowledge on fumigation and the participants will develop confidence towards its practical application. It creates inquisitiveness among the farmers on fumigation. In addition, the participants will must be familiar with and comply with applicable federal, state/province and local regulations.

Step4

Exercise- Divide participants into small groups. The participants should remain in their respective groups. Each group should be provided with writing pad and pens to write the definition of fumigation and fumigants. Once the task is complete, ask the groups to read their respective answer/s. Ask the groups if any member faced a problem understanding the definition of the fumigants. If so, respond accordingly.

Step 5

While the groups are working, move from group to group to assist if necessary. Encourage prompt discussion and debate. The higher the trust, cohesion, and commitment of group members, the better the output from healthy and hot debate. Now start explaining the unclear points on the first lesson of the fumigation. Provide them the reference materials also and how to use it.

ORGANIZATION OF REFERENCE MATERIALS

1. Scope of this manual

Introduction review of the past documents on fumigation shows that historical available documents on basic principles of fumigation for insect control was “Manual of Fumigation for Insect Control” by H.A.U. Monro, FAO Agric. Studies No. 79, 1969 and the second by E.J. Bond, F.A.O. Plant Production and Protection Paper No. 54 published in 1984. Both documents are of similar type. But now in the form of research articles, leaflets, seminar proceedings, and treatment schedules are available in many online references. In Nepalese case, though fumigation in Chamber is new area though references on general fumigation are available and use of both Phosphine and methyl bromide gas has been since early 70’s era. Present Manual and SOP is prepared based on the information available in other countries.

The manual deals primarily with the use of phosphine fumigants within the atmospheric chamber. This manual provides specific guidance on dosage, duration, type of equipment and other aspects deemed essential for the application of the treatment procedures to be applied in the atmospheric chamber through safe handling of fumigants tools. The manual is primarily for employers and fumigators/fumigation technicians to help them comply with the,” SOP for Aluminum Phosphide in Fumigation Chamber” developed by NPQP when carrying out fumigation activities

Operational guidelines for conducting fumigation chamber treatments, the procedures and treatment schedules in this manual are administratively authorized for use by NPQP to prevent the movement of agricultural pests into or outside the country.

2. Fumigant:

“Fumigants are similar to the infamous mustard gases used on the allies in World War I”.

A fumigant is a chemical which, at a required temperature and pressure, can exist as a vapor or gas that, when released, penetrates objects or enclosed areas in concentrations that are lethal to pest organisms.

Fumigants are used to exterminate exotic pests in a wide range of environments such as:

- Ship holds;
- Grain stores;
- Shipping containers;
- Whole buildings;
- Food processing equipment

It is also used to protect many types of goods and objects, including:

- Commodities;
- Goods that require treatment for import or export control; and
- Smaller objects such as museum items that need preserving without damage
- A range of gases is used according to the type of fumigation, their labelled requirements and the regulations in each country.

There are different types of fumigation: Some of these are listed down.

- Chamber fumigation

- Vacuum chamber fumigation
- Vehicle fumigation: railroad car, truck or van
- Tarpaulin fumigation
- Spot fumigation
- Structural fumigation
- Empty building fumigation: warehouse, grain elevator, food processing plant, mill, restaurant
- Shipboard, in transit ship or fumigation
- Farm grain storage fumigation
- Rodent burrow fumigation
- Fumigation of beehives, supers and other beekeeping

3. Fumigation

Fumigation is a method of pest control that distributes fumigant to exterminate pests in an enclosed space. The space is sealed to prevent the gas escaping to areas that are not being treated, for environmental and public safety, and to keep the gas at the required concentration for the appropriate time to be effective.

Fumigation operations can occur in a variety of situations, including in purpose built fumigation or sterilization chambers, outside, in temporarily created containment, in suitably prepared buildings, on ships or other structures.

Why phosphine fumigation

- Easy to handle and government approved for use as approved fumigants. Provided safety precautions are followed while handling it
- Use in chamber is comparatively easy and safe and safety equipment

Treatment Objectives

The objective of the fumigation is for complete control of all stages of all species of pest so that resistance to the fumigant does not develop.

4. Fumigation Responsibilities

Responsibilities of Fumigation unit/personnel

- Hold a valid registration certificate granted by the NPQP and a license to purchase, stock and use of restricted pesticides granted by the Department of Agriculture;
- Be technically competent to perform relevant treatment to meet the quarantine requirements;
- Perform fumigation operations always under the supervision of accredited fumigation operator;
- Advise the client on stocking of consignment for carrying out effective treatment;
- Advise the client about the time requirements for complete and successful treatment of consignment;
- Seek from the client any specific conditions attached to the treatment of consignment;

- Inform the client of any other factors that affect treatment of commodity such as impervious package or sportive nature of commodity;
- Ensure adopting right fumigation practices and follow safety precautions, while undertaking treatment operations;
- Maintain proper records on stock/use of fumigants;
- Issue fumigation certificates after ensuring fumigations are carried out in effective manner;
- Follow the guidelines stipulated in the standard and abide by instructions issued by NPQP from time to time;
- Ensure not to undertake fumigation in forbidden places unsafe to public and animal life or of forbidden commodities;
- Submit the information to NPQP regarding change of address, transfer, retirement, resignation or death of fumigation operator;
- Submit monthly report of various activities of agency including stock and use of restricted pesticides.

The fumigation companies are responsible to:

- Ensure fumigation complies with the relevant laws, security or licensing codes within the jurisdiction of the fumigation area;
- Ensure the fumigation is according to standard;
- Ensure only certified fumigator is allowed to conduct fumigation under this scheme;
- Ensure all items are suitable for AIP fumigation before conducting the fumigation;
- Assist NPQP for any enquiries pertaining to the procedures or consignments inclusive under this scheme;

Responsibilities of Fumigation Operator

- Not to undertake fumigation in residential areas where animal/human life exists;
- Display warning signs and take adequate safety precautions during fumigation;
- Ensure safety of workers during fumigation operations;
- Undertake supervision of all fumigation operations;
- To monitor and detect gas leakage and take appropriate measures to seal leakage, monitor gas concentration and aeration of fumigated commodities;
- To monitor/repair essential fumigation /safety equipment;
- To dispose of empty containers of fumigants in safe manner as per the Pesticide Act and Rules;
- To maintain appropriate record related to fumigation.

5. Requirements

Apply requesting for fumigation

An application for requesting the fumigation treatment operations of Plant and Plant products should be made by the client. The client could be the owner of the commodity; an agent; a warehouse manager; an agent representing buyer; an exporter or importer. Along with the application, the fumigation requirements of the commodity, the type, volume and composition of consignment and where applicable import requirements need to be provided by the client.

Eligibility of Fumigation Operator

A fumigator (or fumigation technician) is the person involved in the fumigation operation and a fumigator-in-charge is the person who directs the fumigation operation. Fumigators and fumigators-in-charge should only be involved in a fumigation operation if they are competent and have been properly trained. This includes training in the safe use and disposal of the fumigant they are going to use, the required safety precautions and what to do if there is an emergency.

Educational Qualifications

The fumigation operators seeking accreditation with the NPQP should possess the educational qualifications namely: B. Sc. Degree in Agriculture or Bachelor Degree in Life Science.

Refresher Training Requirements

Due to the risks involved in fumigations, operators should be given basic training before being allowed to handle fumigants, fumigant-generating substances or articles that may have been contaminated. The eligible operators shall be required to undergo training for a period of at least one week at any of the training institute accredited by the NPPO and working knowledge of MS Word, MS Excel and internet on computer. The training program shall be as per the guidelines prescribed by the NPQP and should be structured to impart technical skills and competency in performance of effective fumigation operations with Aluminum Phosphide.

Organization & Personnel

The fumigation unit must have an organizational chart with clear job descriptions. At minimum level, it shall have Officer –in- charge or equivalent, who shall have authority and resources to carry out assigned administrative jobs for up-keep of the office and a SMS officer (fumigation operator), who shall be responsible for all fumigation technical activities. The fumigation unit must have sufficient number of technical personnel to carry out its activities. A minimum of two persons shall be required to carry out each fumigation activity including an accredited fumigation operator. The agency will arrange training to its personnel in carrying out Alp fumigation treatment.

Facilities

Fumigation unit must have its own website, computer, mass storage device, camera for photo and videography. Both, the management of fumigation agency and the accredited fumigation operator must be aware of all the regulatory requirements including the licensing requirements regarding use of fumigants and the operational requirements outlined in the Aluminium Phosphide standard developed by

NPQP. They must be aware of their responsibilities and the need to acquaint everyone associated with fumigation treatment procedure.

The exposure period

It is the time required for a specific dosage of fumigant to kill target pests. For practical purposes, the exposure period does not start until monitoring shows that the concentration of fumigant gas inside the fumigation enclosure has reached an effective concentration (for example, 0.05 g/m for phosphine). Sealing is the process of making a fumigation enclosure gastight:

- To make sure that fumigant gas loss (leakage) is minimized so that sufficient gas is available over the full time of the required exposure period.
- It is recognized that a certain amount of leakage will occur, even from well-sealed enclosures, but this must be reduced to the lowest practical point.

Leakage: is loss of fumigant gas from a fumigation enclosure and Permeations loss of fumigant gas from a fumigation enclosure through ‘gas-proof’ sheets, which are seldom completely impermeable.

Diffusion (dispersion): is the process whereby a fumigant gas moves from an area of high concentration to an area of lower concentration, ending with an equilibrium concentration. Fumigant gases are dispersed inside fumigation enclosures by air currents generated by (i) density differences, (ii) natural air movement

Concentration: describes the amount of fumigant in the air/atmosphere inside a fumigation enclosure during the exposure period, or in the workspace around a fumigation enclosure, and is an expression of the weight or volume of fumigant gas in a given volume of air. The units of concentration are usually: grams per cubic meter (g/m³), milligrams per liter (mg/L) or parts per million (ppm). With fumigants, ppm describes the volume of fumigant gas per million volumes of air, e.g. liters per million liters (or micro liters per liter). Measurements of fumigant gases in the workspace are usually given in ppm because they are not affected by changes in temperature and pressure.

Monitoring: is the process of measuring the concentration of fumigant gas inside a fumigation enclosure and in the area surrounding a fumigation enclosure? Monitoring gas concentrations inside a fumigation enclosure allows the fumigator to: •check if the correct quantity of gas has been introduced into the fumigation enclosure

Sorption (absorption and adsorption): is uptake of fumigant gas by the product being fumigated. Sometimes this can be so great that the amount, or concentration, of fumigant gas available inside a fumigation enclosure is reduced to less than the minimum effective concentration. When this happens, it becomes impossible to kill the target pests. If this situation is not corrected by addition of more gas (called ‘topping-up’ or ‘dosage correction’), the treatment will fail.

Best fumigation practice involves (i) being aware of commodities and products known to sorb large quantities of fumigant gases (for example grains and oilseeds with a high oil and/or moisture content), and (ii) considering the use of an alternative fumigant that is either not sorbed or sorbed to a lesser extent. Fumigants with high boiling points (methyl bromide, for example) tend to be sorbed more than fumigants with low boiling points (phosphine, for example). There are two types of sorption, physical and chemical, the latter giving rise to residues in the treated commodity. Whereas chemical sorption is reduced at low

temperature, physical sorption is increased, and to a much greater extent. This, in addition to increased pest tolerance, is a reason why dosages must be increased when fumigations are done at low temperatures. It requires fumigators to understand all the processes that can influence sorption and formation of

Desorption: is the reverse of sorption. It is the release of sorbed fumigant gas from the product that was fumigated. Desorption generally occurs at the end of a fumigation exposure, as the fumigant escapes or disperses out of the product during the

Aeration or ventilation stage of a fumigation treatment. Fumigants with high boiling points (e.g. methyl bromide) tend to be sorbed more and remain as residues for longer times than fumigants with low boiling points (e.g. phosphine).

Desorption can take a long time after a product has been fumigated at a low temperature, but is more rapid in products fumigated at high temperature and/or moisture content. Desorption can be accelerated by increasing the flow of air through and around products that have been fumigated. This can be done at the end of the exposure period when the fumigation enclosure is opened and aerated, and may involve: •use of fans to speed up air movement •opening doors and windows to allow a free flow of air into and out of the warehouse. The amount of residual fumigant gas left in a product after fumigation depends on: •the conditions when the fumigation was done •the length of the aeration period. If excessive residual fumigant gas is left in a treated product, it can be dangerous for workers and other people if they come into contact with the desorbing gas.

Residues: are the very small quantities of chemicals left in a product after it has been fumigated. Residues include one or more of the following:

- Chemicals from which fumigant gases are generated (for example, Aluminium phosphide formulations)
- Fumigant gas (for example, unchanged PH₃ after a fumigation done at low temperatures)
- Any new chemical compound formed when a fumigant gas reacts with the product being fumigated (for example, PH₃ residues after a fumigation with PH₃). International limits have been established for the maximum acceptable amount of residues that may be left in many products, particularly grains and foodstuffs.

Aeration (airing or ventilation): is the process at the end of the exposure period, after the fumigation enclosure is unsealed, when fumigant gas desorbs and diffuses out of:

- the product that was fumigated
- the fumigation enclosure. Aeration can be speeded-up by increasing the flow of air through and around the product that was fumigated by:
 - opening warehouse doors and windows
 - using fans to accelerate air movement. After the concentration of fumigant in both the fumigation enclosure and the product that was treated has been shown by monitoring to have fallen to, or below, the TLV, it becomes safe for people to handle the product. Only when this stage is reached may clearance be issued.

Fumigant should be used only in accordance with the instructions provided on the label. If no label is attached to a fumigant container, it should not be used until the supplier can provide one. Failing that, further information should be sought from the relevant national agricultural chemicals registration agency.

6. Quarantine compliance

Plant protection Act 2064, recognizes the obligation that Nepal government has to comply with in international trade of Agricultural commodities. PPA has provisioned Plant Quarantine Committee to make advice and suggestions to the Government of Nepal on policies on the quarantine of plants or plant products. Similarly, the Government of Nepal may, by notification in the Nepal Gazette, designate any central level office related with plant protection as the National Plant Protection Organization which is responsible for making all SPS related compliances.

Fumigation company /agency should ensure that the fumigants and the services provided are been used safely and complies with necessary legislation and import requirements of importing country.

The fumigator needs to know where to find quarantine requirements for a particular commodity so the appropriate quarantine treatment can be performed with doses, temperature maintained and time duration.

7. Fumigation Certification

Each assessed fumigation agency with accredited fumigation operator shall be issued a certificate of approval in the prescribed format by NPQP. Each fumigation operator after successful assessment shall be issued recognition Accreditation Certificate valid for a period of 1 (one) year initially and thereafter it can be renewed after every two years. Accredited fumigation operators are required to apply for renewal at least 45 days prior to the expiry of accreditation along with original accreditation certificate, with revalidation fee as prescribed in legislation, detail activities undertaken in the past one or two years as the case may be, in the format prescribed by NPQP. After verification of provided information with the detail of activities forwarded on e-mail id, the accreditation of the agency shall be renewed before expiry of validity failing which, its accreditation will be deemed to be renewed automatically for a period of another two years if not found any non-compliance otherwise.

Presentation techniques

- Lectures
- Ask questions, get answers
- Demonstrations
- Observation
- Discussions in small groups
- Brainstorming
- Practical Exercises

Evaluation

Knowledge Acquisition

You never learn much until you really want to learn.

Knowledge is knowledge only when it takes a shape, when it can be put into words, or reduced to a principle.

What you should say: A better answer is asking a question that demonstrates an understanding of the questions.

Focus on Timing

- Structure interaction time into all your sessions
- Keep your session on track. Start on time and finish on time

Session 2: Description of phosphine

This session is about basic knowledge on Phosphine fumigant. Training facilitators/ expert read and follow the Standard Operating Procedure (SOP) while explaining basic knowledge on fumigation. The purpose of using fumigation as a Phytosanitary measure is to manage pest risk by achieving a specified level of pest mortality.

OBJECTIVES

By the end of this session, participants will be able to:

Gain Knowledge on:

- Properties of Phosphine, what it is and how it should be treated what is its alternative name .
- Understand the different terminology used in fumigation, and importance of fumigation from other aspects of pest control. They will also understand using Fumigants in the treatment of different commodities.
- Understand the Five W's and One H about Phosphine fumigant
- Understand and discuss the needed information to be known before using the Phosphine fumigants

Presentation:

- Developed modules on Phosphine fumigation

Approach:

- Appreciate the basic knowledge about the fumigants and importance of knowing the properties of phosphine fumigants to treat agricultural commodities supporting the SPS and Quarantine Compliance
- Mode of Poisoning of the Phosphine, when not to use the fumigants
- Clarify key words, definitions and related concepts; e.g. Plant and plant products, Quarantine, Pest Risk analysis, Phytosanitary certificate etc.

Step 1

Welcome the participants and share with them the objectives of this session. Find out to what level the participants are exposed with chamber fumigation and phosphine fumigation, their physical and chemical properties, safety precautions to be followed while handling it, modes of action of fumigants, and also appropriate use of fumigants and safety equipment.

Step 2

Clarify key topics and related concepts of fumigants. It is necessary to understand the principles of fumigants. Start by asking the participants what they understand by Fumigation, Fumigants, SPS requirements, why Phosphine, etc.

Step 3

Exercise- Ask the participants to review the whole session and jot down in bullet form what they have learnt individually in this session. Once the task is complete, ask the groups to read their respective answer/s. and respond accordingly.

Step 4

Encourage prompt discussion and debate. Provide them the reference materials also and how to use it.

Organization of Reference Materials

Trainers or facilitators must prepare hand out of the teaching material in advance; however, it should be given to the participants only at the end of the session. The discussion material and mater given in the hand out should be tallied. The reference material should cover the following areas.

Proper definition of the fumigation, difference between fumigants and fumigation, what are the advantages of Phosphine fumigation, responsibilities of fumigation operators and precautionary measures that need to be observed. Further, the participants should be clear about the Quarantine compliances, certification system.

This module helps to understand the merits and demerits of Phosphine fumigants especially when not to use this fumigant. They will also know the fumigation and will develop confidence towards its practical application. In addition, the participants will must be familiar with and comply with applicable federal, state/province and local regulations regarding the Phosphine fumigation. Using the Five W's and One H Approach i.e. **who, what, when, where, how, and why** is a method of asking questions about the knowledge that is to be grasped by the participants?

1. Characteristics and Effects of Fumigants

a. Physical Characteristics

Solid, dark gray material (granules, or powder); molecular weight 134.70; material must be protected from moisture in the atmosphere in air-tight containers; contact of the solid material with moisture in the air, or with water, or acids releases phosphine, a highly toxic gas. Upon inhalation of the gas toxicity of phosphine initiate action.

b. Environmental Characteristics

Magnesium phosphide reacts with moisture or water to release phosphine gas, which eventually dissipates into the atmosphere. The resulting material from the reaction is magnesium hydroxide, a relatively inert and innocuous material, which is a constituent of clay. Exposure (monitoring data) and related information are required to help assess the margins of safety for applicators and workers exposed to phosphine gas.

c. Ecological Characteristics

Phosphine is a highly toxic gas to a wide range of living organisms. Indoor uses pose no risk to non-target organisms outside of the site to be treated. Outdoor end use products (i.e. rodent and mole control) must bear special precautionary labeling to protect endangered species. Manufacturing use products must bear environmental hazard statements for wildlife.

2. How Fumigation Works?

Fumigation is a method when applied completely fills an area with gaseous pesticides—or fumigants—to suffocate or poison the pests within. It is used to control pests in buildings (structural fumigation), soil, grain, and produce, and is also used during processing of commodities to be imported or exported to prevent transfer of exotic organisms.

Fumigation generally involves the following phases: First the area intended to be fumigated is usually covered to create a sealed environment; next the fumigant is released into the space to be fumigated; then, the space is held for a set period while the fumigant gas percolates through the space and acts on and kills any infestation in the product, next the space is ventilated so that the poisonous gases are allowed to escape from the space, and render it safe for humans to enter. If successful, the fumigated area is now safe and pest free. There are no residual chemicals after the gas evaporates.

3. Properties of Phosphine

Alternative name: hydrogen phosphide

Odour	Carbide or garlic-like odour may be due to impurities
Chemical formula	PH ₃
Boiling point	-87.4°C
Freezing point	-133.5°C
Molecular weight	34.04
Specific gravity gas (air = 1)	1.214°
liquid (water at 4°C = 1)	0.746(-90)
Latent heat of vaporization	102.6 cal/g
Lowest explosion point	1.79% by volume in air
Solubility in water	26 cc/100 ml at 17°C (very slightly soluble)
Method of evolution as fumigant	From preparations of aluminium and magnesium phosphide
Pertinent chemical properties	Reacts with copper and precious metals.

4. Advantages of Phosphine fumigants

- Toxic to insects, rodents, birds, and mammals
- Some are toxic to weed seeds, nematodes, and fungi can be applied by several methods
- Penetrate into cracks, crevices, burrows, partitions, soil, commodities, and equipment
- Applied without disturbing the commodity,
- Usually available and economical to use.

5. Disadvantages of Phosphine fumigants

- Highly toxic to humans, apply with proper protective equipment,
- Required trained applicators,
- Area or commodity treated must be enclosed,
- May injure seed germination,
- May leave excessive residues that exceed tolerances
- May alter the taste or odor of the fumigated product
- It will not prevent re-infestation after the fumigation.

6. When to use and when not to use phosphine as a fumigant

Phosphine gas is explosive under vacuum conditions. Do not apply either fumigant in vacuum chambers. Therefore, its use is restricted to atmospheric fumigation with or without a tarpaulin or cover. Cloth or canvas tarpaulins are not suitable for fumigation purposes. Polyethylene, or vinyl-coated films or tarpaulins are satisfactory when properly sealed to the floor or base surface to prevent gas leakage.

Phosphine — is gas that is highly corrosive to certain metals that it contacts. These metals include gold, silver, and most importantly, copper. Electrical appliances, wiring, lighting, and especially electronic equipment with integrated circuits, computer chips, and similar devices with copper and other conductors of electricity are at risk of being damaged under phosphine fumigation and may not work properly after the fumigation.

Fans and blowers used with phosphine products should be manufactured from materials resistant to the fumigant

7. Remove or protect the following items prior to fumigation:

- Batteries and battery chargers
- Brass sprinkler heads
- Communication devices
- Computers
- Electric motors
- Electronic or electrical equipment
- Fork lifts
- Smoke detectors
- Switching gears
- Temperature monitoring systems

8. Phosphine may be used:

- when a commodity is required in not less than 7 days
- when *Trogoderma granarium* is present and use of MB is not compulsory
- when oilseeds, expeller cake and meals are to be treated
- where germination is important
- where commodities have been treated previously with MB
- where taint may be a problem if MB is used (eg. On flour)
- processed foods
- grains and grain products
- nuts, seeds and tobacco
- cocoa and coffee beans
- bulk animal feeds (including dog food)
- feathers and raw wool
- many processed foods
- phosphine is also preferred for fumigating malting barley

ALP has become one of the preferred fumigants used for treating seeds/grains in bulk because phosphine has no adverse effects on seed germination at normal dosages.

9. Phosphine must not be used:

- when there is no trained, qualified and properly protected fumigation team
- In unsealed enclosures
- Where resistance is known to exist in an insect population
- When the temperature is below 15°C
- When a rapid treatment is required, i.e. less than 7 days
- In areas immediately adjacent to workspaces and places where people live

10. Toxicity

Aluminum phosphide (ALP) is a cheap solid fumigant and a highly toxic pesticide which is commonly used for fumigation. Phosphine is very toxic to all forms of animal life; hence exposure of human beings even to small amounts should be avoided. Poisoning can result from ingestion or inhalation; however, the gas is not absorbed through the skin.

Phosphine ranks as one of the most toxic fumigants of stored product. It is a slow acting poison that is effective at very low concentrations if the exposure time is long enough. Usually, exposure times of four or more days are required to control insects, depending on temperature. The toxicity of phosphine to insect declines as the temperature falls to 5°C, so that longer exposure times are required for it to exert its effect. It is not recommended for use below 5°C. The exposure time cannot be shortened by increasing the dosage; in fact, high concentrations can have a narcotic effect on insects thereby reducing mortality (Winks, 1974a).

Phosphine has an inhibitory effect on insect respiration and is unique in that it is only toxic to insects in the presence of oxygen - in the absence of oxygen it is not absorbed and is not toxic to insects (Bond et al 1967, 1984). However, the action of phosphine is potentiated by carbon dioxide and the exposure time can be reduced when both gases are present (Kashi and Bond, 1975).

Phosphine exposures can occur through the ingestion of metal phosphides or through the inhalation of phosphine gas. If ingested, metal phosphides generate highly toxic phosphine gas through interaction with hydrochloric acid in the stomach. Toxicity following exposure to phosphine gas depends on the concentration and duration of exposure. Symptoms (irritation, nausea, vomiting, headache, dizziness) occur rapidly at high concentrations. Death can occur within hours, usually from dysrhythmias, cardiovascular collapse or pulmonary dysfunction

The fatal dose for a 70 kg adult is 150–500 mg. Permissible exposure limit (PET) is 0.3 ppm over an 8 h shift (for factory stuffs). The range of short term exposure limit (STEL) is 1 ppm and immediate danger to life and health would be 200 ppm. For lethal dose in 30 min, the range of 400–600 ppm (10 mg/Kg ALP) has been determined.

11. Epidemiology

Although fumigation with phosphine is a simple technique, results, in terms of insect mortality, are often unsatisfactory. This is because complete insect control can only be achieved if an insecticidal concentration of phosphine is maintained for a sufficient length of time. Where multiple fumigations with phosphine have failed to meet these criteria insect resistance to phosphine has become established.

The emergence of strong resistance has made phosphine ineffective for insect control in many areas. The cause of insect resistance to phosphine covers fumigation using improper sealing and inefficient fumigation, particularly in the, inadequate exposure period, higher target concentration, leakages, temperature.

Plan presentation techniques

- Lectures
- Ask questions, get answers
- Demonstrations
- Discussions in small groups
- Brainstorming

Evaluation

Knowledge Acquisition

Knowledge acquisition is a very general term that may be defined as the process of identifying and eliciting knowledge from existing sources from domain experts or from documents and subsequently encoding that knowledge so that it can be utilized. Encourage the participants to ask questions until they have enough information to explain the related questions which are as follows:

- 1 What are Advantages and disadvantages of Phosphine Fumigants?
- 2 When to use and when not to use phosphine as a fumigant

Focus on Timing

- Structure interaction time into all your sessions
- Keep your session on track. Start on time and finish on time

Session 3: Fumigation risk areas

The following are general guidelines and checklists for running session on fumigation risk areas. Standard Operating Procedure (SOP) and label instructions on the product are useful guidelines which need to be referred.

OBJECTIVES

By the end of this session, participants will be able to:

Knowledge:

- Understand fumigating and fumigation risk areas
- Understand the different criteria for a successful fumigation in chamber
- Understand the Five W's and One H Approach to clarify the subject matter related to the fumigation risk areas.
- Understand the action to be performed before starting the fumigation

Attitude:

Appreciate the importance of systematic approach to be taken in fumigation operation from initial planning to final clearance of fumigant.

Step 1

Welcome the participants and share with them the objectives of the session. Emphasize here the risk areas in every type of fumigation and measures required to ensure safe and successful fumigation.

Step 2

Ask and clarify key words and definition related to successful fumigation. It is necessary to understand the concept of successful fumigation. Start by asking the participants what they understand by risk areas and how to mitigate them to have a successful fumigation. Link the role of risk in Fumigation Management Plan and discuss.

Step 3

Exercise- Ask the participants to write down what they understand by a Risk area in fumigation. For this, each individual should be provided with writing pad and pens. Give them 15 minutes' time and let the participants turn by turn present their understanding and then discuss and clarify accordingly.

Step 4

While the participants are working, assist where necessary. Encourage prompt discussion and debate. Compare your handouts with your objectives for the session, to make sure that you'll achieve them. Distribute the handouts and discuss. Make them understand that handouts are for reference purpose. Make them habit of surfing in the websites and getting the desired information.

Organization of Reference Materials

Prepare handout based on SOP and training manual as well as surfing from the Net. After discussion the hand out and reference material should be given to the participants for future references while carrying out the fumigation. Basically, Participants will learn about the precautions that need to be taken in all stages of the fumigation i.e. from planning to a completion successful fumigation. Fumigators 'Confidence level for running chamber fumigation will be high.

1. Phosphine fumigants and risk area

Fumigation in a gas-tight chamber, is a comparatively safe and easy than in other types of structures. A chamber is modified but air tight enclosed cabin fitted with necessary gadget for releasing, extracting the desired fumigants, along with temperature, humidity and pressure control mechanism. The chamber comes equipped with vacuum release valve, a side-hinged door, a stainless steel (SS) pan, and two removable aluminum shelves each with twelve 7/8" (22 mm) holes.

Modifications to the chamber serve to allow connection to the manifold, introduction and sampling of the fumigant, air circulation inside the chamber, installation of a vacuum gauge, and the addition of an air inlet facility during the aeration period following the exposure period of the treatment schedule. This facility may also be modified to allow for the use of a needle syringe to inject the fumigant into the chamber at the proper dose, a circulation fan or piping system to assure even distribution of the fumigant inside the chamber and throughout the load, and an exhaust fan and piping system to flush the chamber with fresh air at the end of the exposure period and for the safe removal of the fumigant.

Further, fumigation chamber is a purpose-built structure, normally containing solid walls, used primarily to conduct fumigations. Chambers are normally fitted with built-in circulation and extraction equipment. A fumigation chamber must be pressure tested every 6 months to ensure it is still fit for purpose.

In Nepal prior the construction of fumigation chamber at Kirtipur there was no system of fumigation in chamber. Fumigation under Tarpaulin cover, Metal drum and concrete silos were common fumigation practices. Similarly, at presently, phosphine, is most commonly used only fumigants. Now, none of the fumigants such as hydrogen cyanide, carbon disulfide, ethylene dibromide, and carbon tetrachloride including methyl bromide are in use because of adverse effects to human health as well as to environmental condition. Under the Montreal Protocol, because of its ozone-depleting effects, methyl bromide was phased out in 2005 in developed countries and by 2015 in developing countries.

Globally, Aluminum and magnesium phosphide has been accepted to be used to eliminate insect infestations in a variety of commodities, including animal feed and feed ingredients, corn, cottonseed, grass seed, millet, oats, peanuts, pecans, popcorn, rye, sorghum, soybeans, wheat, fruits and vegetables. They may be used for a variety of processed foods as long as the residue dust does not get in direct contact with the product. They can be used on some non-food commodities including straw and hay, cotton, feathers, tobacco, dried plants, and flowers, and on seeds. Phosphine fumigants may be used in a variety of structures including grain bins and silos, rail cars, warehouses, and flat storage structures.

When to use and when not to use phosphine when a commodity is required in not less than 7 Days-No

- when *Trogoderma granaries* is present and use of methyl bromide is not allowed

- when oilseeds, expeller cake, and meals are to be treated -No
- where germination is important
- where commodities have been treated previously with methyl bromide
- where taint may be a problem if methyl bromide is used; for example, on flour.

2. Defining the risk areas in fumigation

Fumigation act as poisons when they are breathed in, or through suffocation, or by the lethal biocidal effect of the fumigant on the surface of the target organism. So, if not used correctly and safely, fumigation can be even fatal to those applying the fumigants or to others in the vicinity,

Fumigation operations can be done in chambers, in open field but covered and sealed with tarpaulin like appropriate material, temporarily created or, in suitably prepared buildings, on ships or other structures used as warehouse.

Broadly risk can be anticipated in all major stages of fumigation operations from preparation stage to post-fumigation stage. Thus, only trained Fumigators and fumigation-in-charge should only be involved in a fumigation operation. In addition, Fumigators carrying out work in cargos arriving into the country from outside may encounter products which have previously been fumigated, and so they need to be aware of the health effects associated with such chemicals and the necessary precautions.

The purpose of the risk assessment is to determine the risk of fumigators and others through exposure to fumigants. So that steps can be taken to prevent or adequately control any exposure. Simple, low-risk situations may require little attention, but high-risk, complex situations need to be critical. It also varies depending upon the type or form of fumigant being used (e.g. methods of application) and on the location being fumigated.

Two time periods are used: long term (eight hours), and short term (15 minutes) and concentrations of hazardous substances in the air that people breathe, averaged over a specified period of time referred to as a time-weighted average (TWA).

The risk area is all areas or spaces where the fumigant has been applied and any other areas where the gas may move to, therefore posing a danger to fumigators and others. An example of this is where there are structures connected to the area or space which has been fumigated and where the fumigants may travel.

The fumigation area must always be sealed from other areas and made as gas tight as possible. No one should enter into it during a fumigation period, except in a serious emergency, such as a fire, and then only by agreement with the fumigator in-charge of the fumigation operation.

The risk area comprises all adjacent spaces where it is considered that concentrations of the fumigant above appropriate level could occur. In whole building fumigation if the Cavity roof spaces or false ceiling spaces above tiles are particularly susceptible and often difficult to seal off fully. But in chamber there will not be such problem.

A Successful Fumigation:

- Controls the target pests effectively.
- Has low toxicity to non-target organisms.
- Has low use hazard.

- Is noncorrosive, nonflammable, and nonexplosive
- Does not react with fumigated products.
- Has no undesirable odor
- Vaporizes readily.
- Penetrates rapidly to location of target pests.
- Has low sorption on wood and other building materials
- Has low solubility in liquids.
- Can be monitored easily.
- Can be aerated readily.
- Is packaged for convenient storage, transport, and disposal.

3. Requirements for a successful fumigation

The fumigation and its success depends not only on technical knowledge and skill but largely depends on fumigation in-charge's capacity to manage the system. Successful fumigation is the result of administrative, regulatory and technical skills. To most it may look a simple procedure of injecting fumigants, in an airtight container and killing the pest but it is more than that and is complicated. It needs careful planning and an understanding of the process by all parties involved. Before starting fumigation, all parties must be satisfied that they are aware of their responsibilities and have complied with all guidelines and codes, so that the fumigation can be performed by the fumigator with confidence, applying best fumigation practice.

The fumigators must be properly trained and qualified. They must hold a valid license or certificate with the skills and competencies needed to undertake specified fumigation treatments, e.g. quarantine treatments. The unit must maintain and update all necessary tools and functional and safe equipment with which to undertake fumigation treatments, including equipment required to accurately apply the correct dosage of fumigant, measure fumigant levels in the fumigation enclosure.

Thorough checkup of the commodity to be fumigated before loading it to the chamber is the first step to take. Before each fumigation fumigator must:

- Advise customers how to prepare the commodity for effective ,
- Ask the customer about any specific conditions attached to the treatment,
- Tell the customer how much time is needed to successfully complete fumigation using the fumigant selected for the treatment,
- Tell the customer about any situation that could make the fumigation treatment impossible or unsuccessful – for example, if a commodity is stored in a way that would prevent a successful fumigation treatment, or where there is insufficient time to do a fumigation treatment using the long exposure periods required for treatments with phosphine,
- Issue all necessary notices and certificates relating to the treatment, aeration, and occupational safety involved with the fumigated commodity,
- Advise all relevant local authorities, e.g. police, fire brigade, and the nearest hospital.

- Fumigators need to make right choice of fumigant and right dosage that has no or below allowable sorption and formation of residues. e.g. Fumigants with high boiling points (methyl bromide, for example) tend to be sorbed more than fumigants with low boiling points (phosphine,).
- There are high chances that insects will develop resistance to the fumigant when its repeated use is high,
- The fumigation operator must make sure that sufficient time is available to perform an effective fumigation and meet the requirements of a specific treatment (for example, a treatment to kill all life stages, including the diapausing larvae, of *Trogoderma granarium* (Khaprab beetle) like insect,
- To prevent contamination: do not allow phosphine-generating products or their breakdown products (spent residues) to come into contact with any food or feed commodity.

4. Good Fumigation practices

To make fumigation successful it is essential to make a practical combination of all procedures strictly executed during fumigation treatment. The unit chief must make all to follow the SOP and technical recommendations strictly. The fumigation is said safe and successful when it makes:

- All people and environment in the area around the fumigation treatment area remain safe and are not harmed,
- All life stages of all target pests are killed,
- Commodity, product, or equipment being treated inside the fumigation enclosure is not damaged in any way,
- Release of sorbed fumigant gas from the product that was fumigated is fast. Desorption generally occurs at the end of a fumigation exposure, as the fumigant escapes or disperses out of the product during the aeration or ventilation stage of a fumigation treatment.,
- Similarly, fumigants with high boiling points (e.g. methyl bromide) tend to be sorbed more and remain as residues for longer times than fumigants with low boiling points (e.g. phosphine). It affects only the target pest.
- This is because core parts of the fumigation technique essential for a successful result are not applied.
- If any of the conditions essential for safety cannot be met, then fumigators and people will be endangered. Conditions for best practice include
- Fumigators must always make sure that they are properly equipped science behind fumigation' should be the basic thinking by the fumigators. Trained personnel available in adequate number (licensed or registered where required)
- Fumigators must have proper respiratory protective equipment and Personal-protection equipment available
- Method of monitoring workspace concentration is available
- No connection (pipes, drains, ducts) between fumigation enclosure and a non-target area in case of general type of fumigation.

- Sufficient time available for post-exposure ventilation
- Fumigant acceptable to product end user
- Commodity not damaged by fumigant
- Adequate supply of fumigant and adequate time for exposure period is available
- For phosphine: temperatures between 15 and 35°C. is maintained for safety and also to kill all life stages of target pests.
- Always maintain fumigation monitoring equipment in good-as-new condition, because if you fail to have gas-monitoring equipment calibrated regularly (and in accordance with the manufacturer's instructions) this may be the cause of a fatal accident

5. Warning signs

- Always put warning signs (in appropriate languages) around the danger area at a fumigation site. Include an emergency telephone contact number on the signs.
- The signs must be at places where people are most likely to see them.
- Guards must be used if required by government (or other) regulation.
- Containers (tins, canisters) of phosphine-generating products must always be opened in the open air, because concentrations of gas may build up in them.
- To avoid inhaling the gas, fumigators must make sure that containers are pointed away from them when they open such containers.
- Do not eat, drink or smoke at any time when doing a fumigation with phosphine, especially while handling and distributing phosphine-generating products.
- To prevent spontaneous ignition of phosphine-generating products (tablets, pellets, sachets etc.) do not place phosphine-generating products on wet grain or wet surfaces
- Do not heap tablets or pellets when distributing them

There are many conditions that make up best fumigation practice and it is not possible to list them here the experience capacity to make good judgement and commonsense of the fumigators plays crucial role in making the fumigation a success.

Plan presentation techniques

- Lectures
- Ask questions, get answers
- Demonstrations
- Discussions in small groups
- Brainstorming

Evaluation

Knowledge Acquisition

To acquire knowledge walk around the thing studied. The thing is not only what you touch, what you see; it has many other sides, many other conditions, many other relations which you cannot know until you study it from all angles. Current best practice includes assessment which is aligned to learning goals which focus not only on content knowledge but also on process and capabilities.

Starting with following convergent questions helps discussion participants to establish a base of shared knowledge and builds participant confidence,

- How do you define the risk areas in fumigation?
- What are the requirements for a successful fumigation?
- What are warning signs? And what do you understand "Don't Ignore the Warning Signs"

Focus on Timing

- Structure interaction time into all your sessions
- Keep your session on track. Start on time and finish on time

Session 4: Effects of Phosphine gas on plant life and the storage pest

OBJECTIVES

By the end of this session, participants will be able to:

Knowledge:

- Understand and learn about the effect of phosphine on plant life and also on the pest.
- Acquire broad ideas on the various life stages of the insect pest.
- Understand factors that modify the effectiveness/ toxicity and potential residue on food products.

Performance:

- Observe and know the steps to be taken during the fumigation so that there is no adverse effects of fumigants on the plants and plant products..

Attitude:

- Develop positive attitude towards effects of PH₃ gas on plant life and the storage pests and develop confidence in performing the job.

Clarify key topics and related concepts

Step 1

Welcome the participants, and share with them the objectives of the meeting and it helps the participant focused on what he or she wants to achieve. Emphasize and explain different aspects of fumigants especially on plants and plant products.

Step 2

Explain them how the Phosphine fumigants works and its effects on plant and plant products. Highlight the different pest in Post-harvest system

Step 3

Gradually discuss about the role of a biotic factors affecting the effectiveness of the fumigants.

The training programme should be structured to impart technical skills and competency in performance of effective fumigation operations with Aluminium Phosphide.

Organize Reference Materials

1. Post-harvest insect pest and the effectiveness of fumigation

Pest Identification It is important before any pesticide application. In order for you to identify these pests an understanding of their biology is critical to their control.

Therefore, before fumigating the commodity need to identify what insect pest and what stage of the pest is there in the commodity to be treated, accordingly adjust the dosage and duration of exposure to the dosage. Most storage pest are cosmopolitan type, however some pest are location and commodity specific and they may require special care during treatment time. It is very important the basic taxonomic knowledge of the pest should be known to the fumigation in charge.

2. Possible effects of fumigants

The ideal fumigant should not change or impair the treated commodity in any way, nor should it leave any residue which could be hazardous during processing or harmful to the consumer. The quantity of a fumigant to be applied in sealed buildings, vacuum chambers, rail cars, and to packed commodities under tarpaulins is determined by the volume (cubic feet) of the space. In most cases, no allowances are made for the space occupied by the commodities. In grain silos or bulking bins, the quantity of a fumigant to be applied is calculated per ton of grain.

The residues resulting from the use of phosphine fumigants may be of three types: reaction products of the formulation, unchanged phosphine absorbed in commodity or products formed by chemical combination of phosphine with components of the commodity.

Formulations of aluminium or magnesium phosphide leave mainly an inert residue of the metallic hydroxide. In formulations of aluminium phosphide, a small amount of unreacted material may also remain, and hence precautions should be taken to avoid hazards from the unspent formulation. When processed foods are fumigated, or when space fumigations are carried out, residue from the formulation should be collected and properly disposed of.

Residue from magnesium phosphide in the plate preparations remains in the plastic matrix in which it is embedded as magnesium hydroxide. The reaction with water vapour is substantially complete, so that no unreacted material remains, and elimination of the residue simply involves collection and disposal of plastic trays at approved sites. However, in the chamber fumigation the tablets do not directly come into contact with the commodities it is only the generated gas that is injected into the chamber.

Unchanged phosphine does not remain in fumigated commodities in appreciable amounts. Tolerance levels of 0.1 mg/kg for raw grains and 0.01 mg/kg for processed foods have been established by many agencies and numerous investigations have shown that the gas desorbs rapidly during aeration to levels well below the tolerances (see review by Dietrich et al, 1967). It is interesting to note, however, that minute but detectable traces of phosphine can remain in fumigated commodities for very long periods of time. Dumas (1980) detected phosphine desorbing from fumigated wheat 220 days after the treatment. Quarantine treatments by phosphine (PH₃) gas have been performed to replace methyl bromide (MeBr) for export cut flowers and imported nursery plant in Korea.

(https://www.ippc.int/.../1195228067900_2007_TPPT_115_New_Zealand_Phosphine_s...)

3. Effects on Plant life

Like Methyl Bromide, Phosphine may be used safely on a wide range of living plants without producing harmful effects. However, before using this fumigant especially on vegetables and fruits, careful attention should be paid. Some of the observation are as followings.

Physiological

Nursery Stock and Living Plants

- Stimulation of growth
- Retardation of growth
- Temporary injury and subsequent recovery
- Permanent injury, usually followed by death

Seeds

- Stimulation of germination
- Impairment or total loss of germination

Fruit and Vegetables

- Visible lesions
- Internal injury
- Shortening of storage life
- Delay of ripening
- Stimulation of storage disorders

Pest and beneficial organisms

- Death
- Stimulation of growth or metamorphosis
- Stimulation of symptoms of disease

Physical and chemical effects on non-living materials

- Production of foul or unpleasant odours in furnishings or materials stored in premises.
- Chemical effects that spoil certain products.
- Reaction with lubricants followed by stoppage of machinery
- Corrosive effects on metals (phosphine reacts with copper, particularly in humid conditions).

4. Effects on plant products

Phosphine has been used for many years to control insects in a wide range of plant products throughout the world. To date there has been no report of appreciable adverse effects from recommended treatments.

A normal fumigation with phosphine has no effect on vitamins, particularly vitamins A and B2 (riboflavin), in a group of important foods which are a regular dietary source of these vitamins. Fumigation of wheat with phosphine under normal conditions has no adverse effect on the baking quality of flour, made from it (Neitzert, 1953; Lindgren et al, 1958; Mayr, 1974; Matthews et al, 1970a, b). Phosphine can also be used to control insects (Nelson, 1970; Vincent and Lindgren, 1971) and mites (Cangardel and FleuratLessard, 1976) in dried fruit.

Tests on fresh fruit and vegetables show that insects such as fruit flies can be controlled using gas generated from a magnesium phosphide preparation without injury to the produce. Seo et.al, (1979) found no injury on papaya, tomato, bell pepper, eggplant or banana fumigated with dosages that eliminated eggs

and larvae of the fruit flies *Dacus dorsal* Hendl. and *Ceratitiscapitata* Wied. Ten varieties of avocado, although not injured by the treatment, did ripen more quickly than fumigated avocados. Grapefruit and tomatoes have also been fumigated without injury at concentrations sufficient to kill fruit flies (von Windeguth et al, 1977; Spalding et al, 1978).

The use of phosphine for bulk grain fumigation is age old long practice and so far there has been no adverse effect observed in.

PH3 is an accepted grain treatment and is increasingly being used for a greater range of commodities such as fruit, cut flowers and branches (including foliage), dried foodstuffs (including herbs, dried fruit, coffee, cocoa), nursery stock (plants intended for planting other than seed), seeds (intended for planting), cotton and other fibre crops and products, tree nuts (almonds, walnuts, hazelnuts etc.) and buildings with quarantine pests (including elevators, dwellings, factories, storage facilities where sensitive components can be isolated).

Phosphine has been used to fumigate oranges in Australia to control larvae of Queensland fruit fly (Williams et al. 2000). The disinfection of Californian walnuts in storage is carried out using phosphine from a cylinder (Banks, 2003). Other products disinfected using phosphine include dried fruit, nuts, cocoa, coffee, and bagged rice (Bell & Katan, 2000).

In China, aluminium phosphide has been used successfully to treat chestnuts without residual toxicity (Li et al., 1989). Phosphine has also been used to control pest problems in potatoes, onions, cashew nuts, dates, cloves, lettuce, grapefruit, papaya, avocado, tomato, bell pepper, eggplant, and banana (Seo & Akamine, 1979).

5. Factors that modify fumigant effectiveness/Factors affecting toxicity

Effect of Moisture

Adequate moisture is required for release of the actual toxicant, phosphine. At relative humidity below 25%, or grain moisture below 10%, release of phosphine requires more time. Excessive moisture may interfere with fumigant action by reducing fumigant concentration within a commodity, or by retarding aeration during soil fumigation.

Tarpaulin fumigation using a gas proof sheet or cover is more effective than sealing a building with paper or tape and holding a fumigant within structural walls. Tarpaulin fumigation has the advantage of reaching the exterior wood areas (doors, sills, etc.) which may be infested. Ideally, a fumigant should not change the quality of or damage the treated commodity in any way, or leave any hazardous residue during processing of the commodity that could be harmful to the consumer.

In fumigation, as in any other pesticide treatment of a raw agricultural commodity or packaged food product, the "tolerance" must be considered. The tolerance, or tolerated residue, is the amount of the pesticide's active ingredient that is considered safe to consume and is legally permitted to remain in the commodity. Tolerances are expressed in parts per million, which is the same value as milligrams per kilogram (1,000 grams).

Effect of Temperature

Temperature has far-reaching effects on all the factors governing the successful outcome of fumigation:

- Fumigant labels generally warn not to use the product at temperatures below 40° F (5° C)
- Adsorption is the most important physical factor modifying the penetration of fumigants. The amount of gas physically adsorbed increases as the temperature is lowered, and it is necessary to add progressively more fumigant to sustain concentrations free to act on the insects. Furthermore, because of this inverse effect, at low temperatures diffusion of the gas into the material is slower during the treatment, and there is a corresponding decrease in the rate of desorption afterwards.
- Fumigation at temperatures at which the insects are not active may be advantageous in some quarantine treatments.
- If seeds or live plants in dormant condition are being fumigated, the risk of injury is reduced by avoiding the possible stimulating effects of higher temperatures on physiological mechanisms. Secondly, if the infesting insects are active fliers, their chances of escape from the material awaiting treatment in a cool environment are greatly reduced.
- With highly sorptive materials, on the other hand, low temperature fumigation may not be advisable because increased adsorption of the gas by the commodity may interfere with penetration. Also, under some conditions, the material may be hazardous for handling because the adsorbed fumigant is held longer at low temperatures.

Effect of Humidity

From the present knowledge of insect toxicology, it is not possible to make any general statements about the influence of humidity on the susceptibility of insects to fumigants. Variations in response at certain humidity have been observed not only between different species subjected to different fumigants but also between stages of the same species exposed to a single fumigant. However, variations due to humidity are not as important in practice as those due to temperature.

Effect of Carbon Dioxide

Carbon dioxide, in certain concentrations, may stimulate the respiratory movements and opening of spiracles in insects. A number of authors have shown that addition of carbon dioxide to some of the fumigants may increase or accelerate the toxic effect of the gas (Cotton and Young, 1929; Jones, 1938).

Major pest of post-harvest and storage

- The Weevils – rice weevil, maize weevil, and granary weevil
- The Lesser Grain Borer
- The Angoumois Grain Moth
- Saw-Toothed Grain Beetle
- Red Flour Beetle and Confused Flour Beetle
- Flat Grain Beetle and Rusty Grain Beetle
- Merchant Grain Beetle
- Foreign Grain Beetle
- Surface-Feeding Caterpillars
- Indian meal Moth

Plan presentation techniques

- Lecture
- Brainstorming
- Q & A
- Observation
- Discussions in small groups

Evaluation

Knowledge Acquisition

Explain that for this session they need to answer the following questions to confirm understanding

- When will the fumigation not work?
- What are the abiotic factors affecting the effectiveness of the fumigants?
- What are the Physical and chemical effects on non-living materials and living things give some examples?
- There shall be a post training evaluation to assess adequacy of skills of fumigation operator through practical work.

Focus on Timing

1. Structure interaction time into all your sessions
2. Keep your session on track. Start on time and finish on time.

Session 5: Emergency Action Plan for successful fumigation

The following are general guidelines and checklists for running session on Emergency Action Plan for successful fumigation. Standard Operating Procedure (SOP) and label instructions need to be referred.

OBJECTIVES

By the end of this session, participants will be able to:

Knowledge:

- Understand fumigation and emergency action plan for phosphine fumigation and its execution status.
- Understand the need to held a weekly meeting on the status of emergency plan and safety measures and inspection of critical areas
- Understand the Five W's and One H Approach to clarify the subject matter related to the emergency action plan.
- Understand the importance of post fumigation operations and detail steps to undergo in case of emergency

Attitude:

- Appreciate the importance of safety measures and emergency action plan to be designed in every fumigation operation.

Clarify key topics and related concepts of emergency plan.

Step 1

Welcome the participants and share with them the objectives of the session. Emphasize here the emergency action plan and importance of action plan to ensure safe and successful fumigation.

Step 2

Ask and clarify key words and definition related to safety measures. Start by asking the participants what they understand by safety measure to have a successful fumigation. Link the role of risk in Fumigation Management Plan and areas where necessary precautions need to be taken.

Step 3

Exercise- Get all the participants ready for the practical class and ask the participants to wear the different PPE and especially the face mask. Ask the participants to jot down their experience using the safety equipment's. Give them 15 minutes' time and let the participants turn by turn present their understanding and then discuss and clarify accordingly. This exercise is to develop confidence of the personnel working the fumigation unit to be well aware of the safety measures.

Step 4

Provide the participants with the handouts you have prepared with objectives of the session. Distribute the handouts and discuss. Make them understand that handouts are for reference purpose. Make them habit of surfing in the websites and getting the desired information.

Organization of Reference Materials

Prepare handout based on SOP as well as surfing from the Net. After discussion the hand out and reference material should be given to the participants for future references while carrying out the fumigation. Basically, Participants will learn about the precautions that need to be taken in all stages of the fumigation i.e. from planning to a completion successful fumigation. After this session the fumigators 'Confidence level for running chamber fumigation will be high.

The first level of safety is to understand that fumigants are toxic to humans as well as to insects.

In charge of the Fumigation unit and the operator must know the properties of phosphine gas. Know in details the fumigation chamber. Read the instruction carefully as the shape, size and type of construction of each particular structure create special problems in achieving and maintaining the concentrations required for the control of the pest and most importantly know the level of concentration above which it is not safe to subject workers.

Threshold Limit Value-Time Weighted Average (TLV-TWA), i.e. the time weighted average concentration for a normal eight-hour work-day or 40-hour work-week, to which nearly all workers may be repeatedly exposed, day after day, without adverse effects should be regularly. The most immediate concern is for the health and well-being of persons in and around the area. Call 101 for fire/rescue squad to obtain medical assistance for injured or contaminated persons. Post Important Phone Numbers to be contacted during emergencies in places where everybody can see it; e.g.

Organization/Associations	Contact Number
1 Police (Emergency)	100
2 Ambulance, Bishal Bazaar	4244121
3 Bir Hospital	221988
4 Patan Hospital (Lagankhel)	4522278
5 Teaching Hospital (Maharajgunj)	4412707/4412505/4412808
6 B & B Hospital (Gwarko)	4351930/4533206
7 Teku Hospital (Teku)	4253396
8 Blood Bank	4225344
9 Ask me	4427806
10 Night Taxi	4224374
11 Tribhuvan International Airport (TIA)	4472256/4472257

Action in emergency

- Location specific or fumigation specific emergency preparedness plan should be prepared. All staffs working in the site must be fully aware of precautionary measures and become fully acquainted with site and commodity to be fumigated;
- Use the checklist as an outline for a more detailed operating procedure in case of emergency;
- General layout of the structure, connecting structures, adjacent structures, and escape routes, above and below ground;
- Once in a week the emergency response chief should call office staffs meeting and discuss thoroughly the preventive and safety measures and check the critical areas in and around the office periphery and report the status to the chief and NPPO;
- Check over safety equipment to ensure that it is in good condition;

- Check all spouts, conveyers, conduit heat pipes or other possible openings leading from the area to be fumigated;
- It is necessary to follow exactly the label recommendations concerning specific protective equipment and clothing for each fumigant product
- Number and identification of persons who routinely enter the area to be fumigated;
- The specific commodity and its biological properties;
- The commodity's treatment history, if available, to be aware of possible food residues;
- Accessibility of utility service connections;
- Location of the nearest telephone or other communication facility;
- Location of the emergency shut-off stations for electricity, water, and gas;
- Post current emergency telephone numbers, i.e., Fire, Police, Hospital, and Physician;
- Make sure that employees actively taking part in fumigation are in good physical condition;
- Instruct all personnel in first aid and other emergency procedures, including personal decontamination;
- Select a fumigant or combination of fumigants, registered by Pesticide Registration and Management Division (PRMD)/Plant Protection Directorate for the work involved.

Safety precautions

- Inform corresponding authorities before fumigation (Management officials of, NPQP);
- In addition to warning signs, the entrances of the fumigated object have to be marked with safety tape;
- Never allow people/employees without special training to use fumigants;
- Fumigators should wear protective equipment and never open fumigants in a place which is flammable and also avoid contact with water;
- Prior entering the chamber make sure the following activities completed and then only enter or start taking out the treated commodities for delivery to respective destination or agency;
- After the fumigant is applied in the closed chamber, the circulating fans are operated for 15 to 30 minutes. With many commodity treatments, this initial circulation will suffice. When continuous or intermittent circulation is required, as for some fruit and plants;
- The period of exposure to gaseous-type fumigants begins when the discharge of the fumigant is completed. With liquids and discs, the exposure should be timed from the moment the door is firmly closed;
- The exposure periods for the various kinds of treatment at atmospheric pressure are given in the fumigation schedules. Fruit, vegetables, plants, bulbs and nursery stock are exposed usually for 1.5 to 4 hours; seeds and plant products, for 16 to 24 hours. For particularly sorptive commodities that may substantially deplete fumigant concentration, some allowance for this depletion may be necessary (see Thompson, 1970);
- The Flammability Limit of Pure Phosphine-Air Mixtures at Atmospheric Pressure is another important area that needs to be considered seriously during the handling of Phosphine gas fumigation;
- Ventilate the rooms and measure the residual concentration before using the rooms again;

- Do not open Alp containers with any sharp metallic device as contents may catch fire due to friction;
- Protective clothing like hand gloves and special respirator with reaction type canister must be worn during fumigation with aeration;
- Odour of the fumigant should not be relied upon as an indication of poisonous concentration of the fumigant;
- Phosphine detector strips or tubes are used before allowing workers entry into the fumigated premises;
- Smoking or eating at any time during fumigation should be strictly prohibited;
- Persons with punctured ear drums must not be employed for fumigation work;
- Although most formulations are designed to delay liberation of PH₃ from Aluminium Phosphide tablets, they liberate highly toxic Phosphine gas on opening the container. All fumigation work should, therefore, be planned so that operation of placing the tablets, covering with fumigation covers and closing doors and ventilators should be completed within shortest possible time but not more than 30 minutes;
- Before entering to place where phosphine fumigation has been done one need to wear respirators but it is equally important to have a thorough physical check of the condition of respirators before using it. Check if the canister in fresh enough condition to give the protection desired;
- If a person has not worn a mask before, a regular daily drill should be undertaken to rehearse the proper procedure and movements. This drill should be continued until the new fumigator can demonstrate full familiarity with the correct handling and use of the respirator;
- After the respirator is put on for actual use with a fumigant, the final check on tightness and proper fit is most important. Place the hand lightly over the air intake at the bottom of the canister and take a deep breath. If the respirator is properly adjusted, a strong draught of air will be felt as it enters the canister;
- Respirators need not be worn when tablets or pellets are being dispensed under conditions where the operator does not breathe the vapors' of phosphine. Under normal conditions, there is a delay in evolution of the fumigant from the formulations described in this manual. Respirators equipped with a canister designed for protection against phosphine (see above) or other appropriate respiratory equipment should always be on hand in case of emergency;
- Odour of the fumigant cannot be relied upon as an indication of whether or not the operator is breathing poisonous concentrations. Detection equipment such as glass detector tubes or other detectors should be used to monitor concentrations of the gas and to determine when an area is free of fumigant after a treatment;
- Do not smoke or touch food at any time during the application of this insecticide;
- Any spaces adjoining silo bins or close to other structures undergoing treatment with phosphine should be kept continuously aired by leaving windows open or by providing artificial ventilation by means of fans or blowers;

- All persons working, or likely to work, in any place near the fumigation area must be notified that fumigation is in progress. Warning notices should be posted to prevent exposure of employees or the public at large to the gas;
- When the fumigation is completed and the grain is turned, or aeration of a structure is undertaken, full precautions must be undertaken to ensure that no person is exposed to residual vapours of the fumigant;
- Regularly exposed to phosphine as a result of inattention, negligence, failure to follow proper procedures or some other reason and, may result, symptoms consisting of fatigue, ringing in the ears, nausea, or pressure in the chest appear, s/he should go immediately into the open fresh air. Phosphine gas is not absorbed through the skin. There is no evidence of cumulative effects from intermittent, low level exposure of 10 ppm or less. At higher concentration, inhalation of Phosphine may produce symptoms including nausea, vomiting, diarrhea, headache, chest pain and massive accumulation of fluids in the lungs before death;
- Symptoms of poisoning by a small quantity of phosphine will normally disappear when a person is removed to the fresh air. However, despite the seeming insignificance of even mild cases of poisoning with symptoms as described above, first aid measures are absolutely imperative before and until the arrival of a doctor;
- Under no conditions should an affected person resume work during the next 48 hours, particularly work dealing with fumigation, as it takes time for the body to eliminate the poison completely. Complete abstinence from alcoholic beverages after any poisoning is strongly recommended;
- For personal protection against the vapours of phosphine at concentrations above the threshold limit, a respirator, gas blouse or other similar equipment for supplying uncontaminated air must be used. Respirators with a special canister for phosphine vapours will give protection up to 0.5 percent phosphine by volume in air (Kloos et al, 1966). Above this concentration, air must be supplied by an air-line or self-contained breathing equipment. Appropriate detection equipment for measuring concentrations of phosphine in air should be used in conjunction with respiratory protective devices to ensure adequate protection;
- Make sure that employees actively taking part in a fumigation are in good physical condition. They all must have a physical examination at least once a year and more often if health conditions require such;
- Fumigation businesses should maintain up-to-date health records for each employee should abstain from alcoholic beverages and medical or recreational drugs for 24 hours before or and 24 hours after a fumigation job;
- Should NOT participate in a fumigation if they have colds or other respiratory problems that make breathing difficult;
- Make sure fumigators understand the use of specific antidotes, first aid procedures, and a symptomatic relief measures;

- Instruct employees to report any accidents immediately to the employer or supervisor. Caution personnel to report all indications of illness or physical discomfort regardless of their apparent minor nature;
- Make sure employees understand the hazards that may be encountered because of carelessness or misuse of fumigants;
- Teach employees in the selection, operation, and maintenance of all protective equipment and safety procedures required by the fumigant;
- Storing, Handling, & Disposing of Fumigants Store all fumigant products in a locked, dry, well-ventilated place away from heat;
- Post as a pesticide storage area;
- Do not risk contamination of water, food, or feed by storing these products in the same area as other pesticides.

Preparing for fumigation

As first step in phosphine fumigation operation, is to notify the local police and Fire prior initiation of fumigation at least 24 hours ahead of the fumigation operation. Any particular precautions which should be taken regarding entry into confined spaces should be addressed. The confined space may be the whole or part of the intended fumigation area, risk area and/or other work area and there may be hazards other than those associated with release of fumigant.

Safety precautions

Pre-fumigation

Before fumigation begins, the fumigator must ensure that the following precautions are taken:

- the fumigation area should be evacuated (removing and securing any non-target animals, plants etc.) with only the fumigator allowed into the risk area
- other absorbent solids (other than those intended to be fumigated) should also be removed from the fumigation area;
- fires and naked lights including pilot lights should be extinguished, other sources of ignition should be removed from the fumigation and risk areas
- any unnecessary electrical supply should be disconnected from the fumigation area
- the risk area should be secured against unauthorized entry;
- warning notices should be placed at the fumigation area and all points of access to the risk area

During fumigation

- Employers should ensure that: fumigation is carried out effectively and safely. This may be achieved by managing the temperature, improving the sealing and/or extending the duration of fumigation;

- Should wear proper respiratory protection, care should be taken to avoid direct exposure. Warning signs that indicate the type of fumigant in use and the date of the treatment should be put in appropriate places. They should be removed after the treatment is completed;
- Check, if necessary, repair of any leaks from the fumigation area or the application equipment and piping outside the fumigation area is carried out, especially at joints and couplings;
- An electronic detector or other detection device should be used;
- If leaks are detected, they must be dealt with by a fumigator wearing RPE, before the fumigation can continue. If it is not possible to seal a leak, the fumigation and risk areas should be extended.

After application of fumigant

- Once the fumigant has been applied, phosphine gas generator should properly shutdown and monitoring of the level of required concentration of gas should be initiated and surveillance need to be carried out.
- In the chamber fumigation though the chances of skin and hair contaminated is minimum but necessary precaution need to be taken after work and before stay in open air area where aeration is good but smoking, washing, eating or drinking or going outdoors in the rain should be avoided.
- Only after adequate aeration of the treated area, gas detection equipment should be used to ascertain that all fumigant has been removed.

If Emergency

In best fumigation practice, the response to emergency situations with fumigants is made using emergency procedures. As said earlier fumigation be allowed to be done only by the trained persons who understands the requirements for fumigation with phosphine under gas-proof sheets and can carry out all tests needed to ensure the fumigation will be successful. This means that the fumigator-in-charge or his associate understands what is needed to done and most importantly is aware of the dangers associated with the use of phosphine.

Before the fumigation starts, the fumigator-in-charge is responsible for:

- Planning how the treatment will be done, including the aeration after treatment;
- Explain the fumigation plan to –assistant fumigators –the owners of the commodity – any other parties involved in the fumigation;
- obtaining all materials and equipment needed to do the fumigation;
- marking the danger area around the site of the fumigation
- putting up warning notices to show people where the danger area is before starting the fumigation;
- making sure that nobody except the fumigators is in the danger area;
- monitoring gas concentrations during the exposure and ventilation period.

At the end of the exposure period, the fumigator-in-charge is responsible for:

- certifying, after aeration is complete and the gas concentration is at or below the TLV, that the danger area is safe to enter;
- supervising the collection and safe disposal of any spent fumigant-generating products and contaminated packaging materials;
- removing all warning signs and barriers;
- informing Officer in charge and concerned agencies that the fumigation has been completed;
- The danger (exclusion, hazard or risk) area wherever a fumigation is done, there is an area surrounding the fumigation enclosure into which a fumigant gas may escape in concentrations that are dangerous to the people doing the fumigation;
- May harm the environment. This area is called the danger (exclusion, hazard or risk) area;
- It is essential to ensure that people who are not directly involved in the fumigation process do not enter this area;
- Warning notices must be placed around the outer limits of the danger area, indicating:
 - the name of the fumigant (e.g. phosphine)
 - the name and address of the fumigator-in-charge
 - emergency telephone numbers (including those of the fumigation
 - charge, and the nearest hospital, fire brigade, and police station.
- The extra demands of phosphine fumigation arise because (in most cases) the dosages used with phosphine kill the larval and adult life stages of insects. –the ‘susceptible life stages’. However, the ‘tolerant life stages’ may not be killed and may require some more time, them to grow and develop into the next susceptible life stage [eggs to larvae, and pupae to adults] while they are inside the fumigation enclosure. This is why long exposure periods of up to 7–8 days (sometimes longer) are required when fumigations are done with phosphine. In fumigation practice, the concentration of phosphine inside the enclosure must be held at a toxic level for long enough to allow eggs and pupae to develop through to larvae and adults;
- enclosures made with fumigation sheets must be sufficiently gastight to allow phosphine to be held at these concentrations for up to 7–8 days but fumigation treatments where most gas is lost by about the fifth day will fail;
- Remember Repeated fumigation failures (treatments where eggs and pupae have not been killed) have already led to the development of resistance to phosphine in some insects, in some countries;
- Further, the properties of phosphine as a fumigant may be sorbed by commodities and has great penetrative capacity. At normal dosages, phosphine appears to have virtually no effect on the germination of seeds held at safe moisture contents, but it may slightly reduce the vigour of subsequent seedlings. There is some evidence that phosphine may reduce germ inability if applied to high-moisture grain;

- Odour Pure phosphine is odorless at concentrations up to 200 ppm. At concentrations down to less than the TLV of 0.3 ppm (0.4 µg/L or 0.42 mg/m³), phosphine generated from metal phosphide preparations has a ‘garlic’ or ‘fishy’ smell. It must be noted that this smell may be sorbed by the commodity or product being fumigated;

Venting (aeration)

- The fumigation area and risk area should be ventilated at the end of the fumigation period. Fumigation gases and solid fumigation particles are heavier than air. Where possible, when venting fumigated buildings, the starting point should be the top of the structure to minimize the risk of the fumigant coming into contact with fumigators or others. Where it is necessary to enter the fumigation area to carry out the ventilation, eg to open doors or windows, RPE appropriate to the fumigant must be used. Areas such as cellars, enclosed vessels and other similar confined spaces that should use forced ventilation to remove the fumigant;
- The fumigator-in-charge, wearing RPE, should test the atmosphere until the concentrations of fumigant have fallen below safety level or other appropriate level, to ensure that all areas are safe;
- Materials in the fumigation area may continue to release gas after the end of the fumigation operation and so should be considered;
- At the end of the treatment, venting should be commenced by opening the exhaust port or valve and starting the fan. The chamber door should be opened slightly to allow fresh air to flow in. At least 10 or 15 minutes should elapse before the door is fully opened. The time of this interval will depend on a number of factors, but the door should not be fully opened until the operator is assured by appropriate chemical tests, instrumental tests, or from long experience, that it is safe to enter the chamber to begin unloading;
- First aid kits and gas masks should be available and in good condition at all times;
- Allow enough time and use enough fans to ventilate and aerate in accordance with structural limitations;
- Turn on all ventilating or aerating fans where appropriate;
- Before re-entry, use a suitable gas detector to determine fumigant concentration so that appropriate precautions may be taken;
- Check for gas concentrations in areas that aerate slowly;
- Phosphine is very corrosive to certain metals, such as copper wiring, brass sprinkler heads, and electronic equipment for safety reasons, the person doing the fumigation should be the only one who has a key to the building being fumigated;
- The chamber can be kept open to use next lot of treatment;
- Gas-proof sheeting should be aired until it is free of fumigant before being folded, rolled, transported and stored for future use;

- At the end of some fumigation processes, such as phosphine, the remaining residues may contain undecomposed metal phosphides, which will continue to decompose and generate fumigant. If this is the case, the residues should be removed from the fumigation and risk areas and rendered safe for disposal;
- Any contaminated clothing and equipment should be removed and aired;
- Where confined spaces or enclosed vessels are involved, the certificate of clearance should clarify that it may no longer be safe to enter without further ventilation if the confined space or enclosed vessel is resealed, as traces of gas may release slowly and accumulate;
- Aeration must be done in stages, to avoid sudden release of large amounts of fumigant;
- Respiratory protection Fumigators and other persons at risk from inhaling excessive quantities of phosphine must be provided with either a full-face canister respirator or an open-circuit, self-contained breathing apparatus with a full face mask;
- A full-face filter respirator or self-contained breathing apparatus must be worn if concentrations exceed 0.3 ppm;
- Self-contained breathing apparatus should be used for operations, such as breakdowns, when longer exposures at higher concentrations may occur.
- Respiratory protection must be worn whenever tests of the atmosphere reveal concentrations of the gas greater than the hygienic standard (currently 0.3 ppm v/v in most countries);
- Masks and filter canisters must be issued on a personal basis, and a register of use maintained by the fumigator-in-charge. Canister respirators must never be worn for entry into the fumigation enclosure itself. If this is ever necessary, self-contained breathing apparatus must be worn;
- In the event of an emergency during fumigation, e.g. if a delivery pipe breaks or becomes disconnected, or containment measures, such as sheeting, become damaged and leakage of fumigant occurs, the fumigator should wear RPE and move to open Space. Depending upon the types of fumigation the leakage checking and other operation measures should be taken.

First Aid Kit essential

- Scissors Tweezer, Irrigation syringe, Gauze Adhesive Tape, Thermometer, Oral dehydration solution Kidney tray. Prescribed drugs if you know the medical history. Dettol Crepe bandage and sling. Regular bandage etc.
- A self-contained unit, using compressed air, carried on the person in one or more small cylinders (bottles);
- A type of self-generating apparatus whereby the oxygen is evolved from a special Check for Gas Tightness

Safety Rules

- Read and follow instructions on the label, including the SOP. Phosphine fumigants are valuable tools as long as they are used properly.

- Keep careful inventory so each container and package is accounted for. If you discover that any fumigant has been stolen, you are required to report the theft immediately to your local law enforcement authorities. Make sure the storage area is properly placarded as a pesticide storage area.
- After a fumigation, fumigators must wash thoroughly and change their clothes immediately.
- Clothing contaminated with dust produced by phosphine generating products must be aired overnight in an open area before it is washed.
- Do not leave contaminated clothing, shoes and other equipment in confined areas such as motor cars, cupboards or rooms.
- Dirty clothing worn by fumigators must be washed separately from other clothes, especially infants' clothes

Additional Tips on safety Measures

- Always read the label before use and follow the manufacturer's instructions also;
- Obtain a safety data sheet (SDS) from your chemical supplier which gives information about treatment and symptoms of phosphine poisoning, as well as chemical data;
- Wear correct respirator and protective clothing;
- Have an observer standing by who should have access to respiratory protection;
- Monitor the atmosphere around fumigation using a hand pump and gas detector tube; concentration should not be higher than 0.3 ppm;
- Never increase dosage to have a 'better kill' of insects.

Canister respirators

- Canister respirators must be fitted with a filter canister designed for protection against phosphine;
- Each time a respirator of this type is put on or use, the facial fit must be tested by closing the inlet to the canister with the palm of the hand and inhaling deeply; the vacuum so created must cause the face-piece to adhere to the face for about 15 seconds. With this type of respirator, it is essential that the filter canister be used within its stated shelf life;
- The filter canister must always be replaced before either its shelf life has expired or the recommended usage time has been reached;
- The expiry date of a filter canister may easily be calculated since each is marked with the date of manufacture and its shelf life. Filter canisters must be stored in a cool, dry, well-ventilated place away from contamination by any fumigants. The following precautions must always be observed;
- When the canister is attached to the respirator face-piece after the top seal is removed, record the date;
- This is best done by writing the date on a small, adhesive label which must be affixed to the canister. This label can be used as a 'log' to record exposure of the canister to the fumigant.

Before using the respirator, remove the cap and the seal over the air inlet valve of the canister. Again, at this time mark the date on the 'log' label. Once this seal is removed, even if there is no Self-contained breathing apparatus Self-contained breathing apparatus must be available for all uses of phosphine above 15 ppm. The facial fit of this type of apparatus may be tested in the same way used for canister respirators, except that the cylinder valve is closed before deep inhalation. Skin protection Gloves, preferably cotton, must always be worn when phosphine generating tablets, pellets, or sachets are handled. Cotton gloves are less likely to cause sweating than are plastic gloves. Cotton gloves must be washed after use.

First Aid measures

First aid is one of the most important and basic life skills that one should learn. First aid must be started at once. If possible, one person should begin treatment while another calls a **physician**.

Measures in Emergencies to be taken before arrival of a physician

Inhaled poisons

- Carry patient (do not let him walk) to fresh air immediately;
- Open all doors and windows;
- Loosen all tight clothing;
- Apply artificial respiration if breathing has stopped or is irregular.
- Prevent chilling (wrap patient in blankets);
- Keep patient as quiet as possible;
- If patient is convulsing, keep him in bed in semi dark room; avoid jarring or noise;
- Do not give alcohols in any form.

Skin contamination

- Drench skin with water (shower, hose, faucet);
- Apply stream of water on skin while removing clothing;
- Cleanse skin thoroughly with water; rapidity in washing is most important in reducing extent of injury.

Eye contamination

- Hold eyelids open, wash eyes with gentle stream of clean water (running) immediately. Delay of a few seconds increases extent of injury;
- Continue washing until physician arrives;
- Do not use chemicals; they may increase extent of injury.

Strain and sprains

Overstretching muscles tissues resulting in tearing and bruising. While tending to this first check how much you can move the limb and if you can feel the sensation, put the strained limb in rest to limit its movement.

Wound Management

- Use ice or water to cool the strained or swollen muscle a use bandage or cloth wrap the limb and compress it. Check circulation, sensation, and motion. Then elevate the muscle and keep it at higher level than your heart and take rest;
- Wound bleeding, can be open and closed. In case of open bleeding put direct pressure on the wound with a clean cloth or gauge or pad and elevate it. If the bleeding is heavy put multiple gauge over the wound with enough pressure so that the bleeding is stopped. Once the bleeding stops remove the pad slowly irrigate the last one attached to the wound if necessary. Wounds need to be cleaned and dried to heal it faster. Use gauge dipped in Dettol or betadine solution to disinfect the wound if these are not available then use at least the clean water;
- Clean the wound and get medical help as quickly as possible.

Burns

Put the affected area in cool water and clean the wound do not keep the wound open so apply thin bandage over the area. Seek medical help but very best thing to do is stay calm and not panic.

Choking / Airways Obstruction

- Choking is state when some foreign material gets obstructed in the tracheal and affects normal breathing and ;
- First encourage the injured to cough forward and cough. If you are alone start coughing as much as you can.

Unconsciousness/fainting

Unconscious/faint follows the CAB (circulation –Airway – Breathing) rule. Check the pulse first follow by airway and breathing. The normal respiratory rate for adult is 10-20 per minute whereas heart rate is 50-100 per minute. Reposition their head by tilting chin up if airways comprised.

First Aid with Rescue Breathing

If a person has stopped breathing, don't delay. Give first aid immediately. Ask someone else to get medical help.

Is the person breathing then, place him flat on his back and put your ear close to his mouth? If s/he is breathing, you will feel his breath and see his chest rise and fall. 2. Open the airway. If the person has stopped breathing, lift up his neck with one hand and push down on his forehead with the other. This opens the airway and the person may start to breathe. If he doesn't, begin RESCUE BREATHING at once.

Rescue Breathing

Keep one hand under the person's neck so that his head is tilted backward with his chin up. Pinch his nostrils shut with the fingers of your other hand. Take a deep breath and cover his mouth completely with yours. Blow air into his mouth. When his chest moves up, take your mouth away and let his chest go down by itself. Repeat this procedure every 5 seconds. Do not stop until the person starts breathing or medical help comes.

Phosphine gas Poison symptoms

Mild Poisoning

Any discomfort can be an indication of mild poisoning or some other sickness. Individuals who are exposed to poison and who experience the following symptoms should be aware that more serious indications may follow. Headache, fatigue, skin irritation, loss of appetite, dizziness, weakness, nervousness, nausea, perspiration, diarrhea, eye irritation, insomnia, thirst, restlessness, irritation of nose and throat, loss of weight, soreness of joints, changes of mood.

Moderate Poisoning

Nausea, trembling, muscular incoordination, excessive saliva, blurring of vision, feeling of constriction in the throat and chest, difficulty in breathing, flushed or yellow skin, abdominal cramps, vomiting, diarrhea, mental confusion, twitching of muscles, weeping, excessive perspiration, profound weakness, rapid pulse, cough. Severe Poisoning Vomiting, loss of reflexes, inability to breathe, uncontrollable muscular twitching, constriction of pupils (to pinpoint pupils), convulsions, unconsciousness, severe secretion from respiratory tract, fever, intense thirst, increased rate of breathing

According to the amount of phosphine inhaled, symptoms may occur immediately or several hours after exposure. Slight or mild poisoning may give a feeling of fatigue, ringing in the ears, nausea, pressure in the chest and uneasiness. All of these symptoms will normally disappear in fresh air. However greater quantities will quickly lead to general fatigue, nausea, gastrointestinal symptoms with vomiting, stomach ache, diarrhoea, disturbance of equilibrium, strong pains in the chest and dyspnoea (difficulty in breathing). But very high concentrations rapidly result in strong dyspnoea, cyanosis (bluish-purple skin colour), agitation, ataxia (difficulty in walking or reaching), anoxia (subnormal blood oxygen content), unconsciousness and death.

Death can be immediate or occur several days later due to oedema and collapse of the lungs, paralysis of the respiratory system or oedema of the brain. Disturbances of kidney and liver functions (hoematuria, proteinuria, uraemia, jaundice) and cardiac arrhythmia may occur.

For Physicians' reference

From manufacturer's note.

- Make sure fumigators understand the use of specific antidotes;
- In its milder forms, symptoms of poisoning may take some time (up to 24 hours) to make their appearance, and the following measures are suggested: Complete rest for one or two days, during which the patient is kept quiet and warm;
- If the patient suffers from vomiting or increased blood sugar, appropriate intravenous solutions should be administered. Treatment with oxygen breathing equipment is recommended as is the administration of cardiac and circulatory stimulants;
- In cases of severe poisoning intensive care in a hospital is recommended where pulmonary oedema is observed, steroid therapy should be considered and close medical supervision is recommended. Blood transfusions may be necessary;

- In case of manifest pulmonary oedema, venesection should be performed under vein pressure control, and intravenous administration of glycosides (in case of haemo concentration, venesection may result in shock). On progressive oedema of the lungs, perform immediate incubation with constant removal of oedema fluid and establishment of oxygen positive pressure respiration, as well as any measures required for shock treatment. In Case of kidney failure, extracorporeal haemodialysis is necessary. There is no specific antidote known for this poison;
- Suicide may be attempted by taking solid phosphides by mouth. In such a case, empty the stomach by inducing vomiting and flush it with a dilute potassium permanganate solution or a solution of magnesium peroxide until the flushing liquid ceases to smell of carbide. Thereafter, administer medicinal charcoal;
- Scientific research has shown that phosphine poisoning is not chronic; the action of phosphine is reversible and symptoms will disappear by themselves;
- Instruct employees to report ail accidents immediately to the employer or supervisor. Also report all indications of illness or physical discomfort regardless of their apparent minor nature.
- Fumigators: — should have a physical examination at least once a year and more often if health conditions require such

Plan presentation techniques

- Lectures
- Ask questions, get answers
- Demonstrations
- Observation
- Discussions in small groups
- Brainstorming
- Practical Exercises

Evaluation

Knowledge Acquisition

Evaluation is the gathering of information to ascertain the effectiveness of the training and this measures the degree to which participants acquired the intended knowledge, skills and attitudes as a result of the training.

Ask frequent open-ended questions to confirm understanding. It encourages them to explore their own experience, and understand information in ways that resonate with them. As a result, they can retain information – and apply it – more effectively.

This can also be completed as a pre- and post-event evaluation, or only as a post-evaluation. You should confirm the performance of the trainees in the workplace.

Ask the participants to discuss Questions or discuss questions in group

- What are safety precautions to be taken before, during and after the fumigation?
- What are safety rules to be taken before, during and after the fumigation?

- What are measures in emergencies to be taken before arrival of a physician?
- What is Phosphine Gas Poison Symptoms?

Focus on Timing

- Structure interaction time into all your sessions
- Keep your session on track. Start on time and finish on time

Module 2: Fumigation Management Plan

Session 6: Fumigation Management Plan and Components

OBJECTIVES

By the end of this session, participants will be able to:

Knowledge:

- Understand the purpose of FMP
- Understand the Fumigation Management Plan (FMP) and identify the key steps of FMP
- Understand the Five W's and One H Approach for FMP
- Understand and discuss the needed information to be known before starting the fumigation

Performance:

- Develop FMP

Attitude:

- Appreciate the importance of systematic planning and conduct of every steps of a fumigation operation from initial planning to final clearance of fumigant. to support Quarantine Compliance

Clarify key topics and related concepts

Step 1

Welcome the participants and share with them the objectives of the meeting. Emphasize here the detailed FMP and the steps and components of FMP information required to ensure the correct and proper PH₃ fumigation.

Step 2

Before preparation, clarify key topics and related concepts on FMP. It is necessary to understand the concept of FMP. Start by asking the participants what they understand by FMP. Link their responses with the Fumigation Management Plan Steps and Components and explain its key components.

Step 3

Exercise- Divide participants into small groups. The participants should remain in their respective groups. For this meeting, each group should be provided with writing pad and pens to prepare components of Fumigation Management Plan. Make the participants the next 30 minutes on an exercise where they are to prepare a FMP for PH₃ fumigation. Once the task is complete, ask the groups to refer to current answers to the problem. Ask the groups if any member faced a problem in developing the FMP. If so, respond accordingly.

Step 4

While the groups are working, move from group to group to assist if necessary. Encourage prompt discussion and debate. The higher the trust, cohesion, and commitment of group members, the better the output from healthy and hot debate. Now start explaining FMP and all components of FMP by group by group.

Organization of Reference Materials

Compare your handouts with your objectives for the session, to make sure that you'll achieve them. Handouts showing session structure are listed below for reference.

What is Fumigation Management Plan?

This is an organized, written description of the required steps involved to help ensure a safe, legal and effective fumigation. The FMP is intended to ensure the safety of the applicators, site employees, the surrounding community, and the environment. The FMP is intended to ensure a safe and effective fumigation. The written plan that summarizes all the steps will be taken **before, during, and after** the fumigation. It makes sure that the fumigant is applied effectively and safely by forcing you to think about all the steps beforehand.

This FMP provides as a guide for preparation of the required plan. The FMP must be written prior to every treatment. Before a FMP is developed the product pesticide label and Standard Operating Procedures (SOP) must be carefully read and reviewed. The application must follow all label directions and follow any restrictions noted in these documents. In addition, the applicator must be familiar with and comply with applicable federal, state/province and local regulations. The success of the fumigation is not only dependent on your ability to do your job but also upon carefully following all rules, regulations and procedures required by governmental and related private agencies. The certified applicator supervising the fumigation must ensure that nearby residents and business owners/operators have been provided the response information at least one week prior to fumigant application. A FMP must be prepared for each fumigation that is made.

The training's manual explains what has to be in the plan: you must document **who, what, when, where, how, and why**. 5W1H is a method of asking questions about a process or a problem taken up for improvement. For example,

Using the Five W's and One H Approach

Who

- Who should be told about the fumigation because they might be accidentally exposed to phosphine gas during the fumigation
- Who should be notified in case of emergency? Include the Phone numbers of the nearest fire department, police department, hospital, and your physician.
- Also, who will conduct the fumigation?

What

- What commodity will be fumigated?
- What type of structure will be fumigated? Can it be sealed? If not, it shouldn't be fumigated.

When

- When will you begin the fumigation/
- When will you end the fumigation?
- When will it be safe to use the commodity?

Where

- Indicate places where people might be accidentally exposed to phosphine gas.
- Think about where phosphine gas can escape
- Where you need to seal potential leaks?

How

- How will the structure be sealed?
- How will accidental exposure be prevented?
- How will you monitor gas concentrations?
- How will you apply the aluminum phosphide pellets or tablets?
- How will you aerate the structure?

Why

- Why was the fumigation necessary?

Steps for preparation of the required written fumigation management plan

The required parts in creating a FMP are:

Purpose of FMP

A Fumigation Management Plan (FMP) is an organized, written description of the required steps involved to help ensure a safe, legal, and effective fumigation. It will also assist you and others in complying with pesticide product label requirements. The guidance that follows is designed to help assist you in addressing all the necessary factors involved in preparing for and fumigating a site. By following a step-by-step procedure, yet allowing for flexibility, safe and effective fumigation can be performed. A Fumigant Management Plan (FMP) must be written PRIOR to all applications.

Checklist Guide for FMP

A simple tool that helps to prevent these mistakes is the checklist. A checklist is simply a standardized list of the required steps developed for a repetitive task. So make checklists for your common work tasks.

The objective of these checklists is to assist you in the planning, implementation, and internal auditing of your activities. Many of us have repetitive tasks to complete. Often we find that if we don't have any guidance, we may forget certain steps in a process. Sometimes even with simple steps involved we can get distracted and forget one or more of the required procedures. Based on the compliance requirements for an activity, the operators should develop a checklist for the audit.

This checklist is provided to help you take into account factors that must be addressed prior to performing all fumigations. It emphasizes safety steps to protect people and property. It is to be used as a guide to prepare the required plan. Each item must be considered.

The FMP and related documentation, including monitoring records, must be maintained for a minimum of two years or longer as directed by Government recordkeeping requirements. The FMP includes the following components:

Preliminary Planning Facility, Commodity Details and Preparation

- i. Determine the purpose of the fumigation
 - Elimination of insect infestation

- Elimination of rodent/vertebrate pests
- Plant pest quarantine.
- ii. Determine the type of fumigation, for example
 - Space; tarp, warehouse
 - Transport Vehicle; truck, van, container
 - Commodity; raw agricultural, processed foods or non-food
 - Type of storage; vertical silo, farm storage, flat storage e. Vessels or ships
- iii. Fully make personnel aware of or familiar with the site, structure and commodity to be fumigated to determine its suitability for fumigation, including:
 - Understand the structure and draw or have a drawing or sketch of the structure highlighting main features.
 - The number and identification of persons who routinely enter the area to be fumigated
 - The commodity to be fumigated
 - Identify telephone and other means of communication and mark them on drawing.
 - List emergency telephone numbers of local Health, Fire and Hospital
 - Exposure time considerations.
 - Product (Tablet or Pellet) to be used
 - Temperature, humidity and wind speed
 - Measured and recorded commodity temperature and moisture content
 - Exposure time-Fumigation duration as defined and described in the use directions of the SOP
 - Aeration requirements
 - Cleanup requirements
 - Deactivation
 - Determination of dosage

Consider the type of structure and its size, temperature, humidity, how well the structure can be sealed, label restrictions, and the sorption of the fumigant.

- Cubic footage or other appropriate space/location calculations
- Dosage rates used (Maximum Allowable Dose Rates)
- Temperature humidity and wind
- Structure sealing methods
- Label recommendations
- Past history of fumigation of structure
- **Personnel -Training, safety and Notification**
 - Tell all fumigation staff:

- how the fumigation will be done
 - how to leave the fumigation area safely in case of emergency
 - what to do if any person breathes in phosphine gas
 - what to do if any person breathes in or comes into contact with dust produced by phosphine-generating product
- Make sure all fumigation staff:
 - know what first aid action to take in case anyone is injured
 - are equipped with, and know how to use personal-protection equipment appropriate for fumigation with phosphine (self-contained breathing apparatus, gas masks)
 - understand that gloves must be worn while (i) opening and handling containers of generating product, and (ii) dispensing the product by hand.
 - Confirm in writing that all personnel in and around the structure and/or area to be fumigated have been notified before starting fumigation.
 - Instruct fumigation personnel on the hazards as well as selection of personal protection devices including detection equipment
 - Confirm that all personnel are aware of and know how to proceed in case of an emergency situation
 - Should NOT participate in a fumigation if they have colds or other respiratory problems that make breathing difficult
 - Instruct all personnel in first aid and other emergency procedures, including personal decontamination
 - Instruct all personnel on how to report any accident and/or incidents related to fumigant exposure.
 - Make sure two trained persons will be present at all times during the fumigation.

Never give or sell fumigants to untrained persons

Notification of Authorities

- Confirm the appropriate local authorities (fire police, etc.) have been notified as per label instructions or instructions of the client
- Prepare written procedure ("**Emergency Response Plan**") which states clearly and in detail about instructions, names, and telephone numbers so as to be able to notify local authorities if phosphine levels are exceeded in an area that could be dangerous to bystanders and/or domestic animals leaving no room for confusion or doubt.

Sealing Procedures

- The sealing must be adequate to maintain gas concentration and control the pests. Care should be taken to insure that sealing materials would remain intact until the fumigation is complete

- If the structure has been fumigated before, review the previous FMP for previous sealing information.
- Warning Placards must be placed on every possible entrance to the fumigation site.

Application and Fumigation Phases

- Apply Phosphine as per label requirements
- Confirm the required safety equipment is in place and the necessary manpower is available to complete a safe and effective fumigation.
- When entering into the area under fumigation, always work 2 or more people under the direct supervision of certified applicator using the proper respiratory equipment.
- Make a final check to clear all personnel and non-target animals from the space to be fumigated
- Confirm the area is secure or provide watchmen to prevent entry into the fumigation site by unauthorized person
- Turn off any electric lights and all nonessential electric motors in the fumigated area of the structure

Monitoring

Safety

- Monitoring of phosphine concentrations must be conducted to confirm that nearby workers and bystanders are not exposed to levels above the allowed limits.
- Monitoring must be conducted during aeration and corrective action must be taken if gas levels exceed the allowed levels in an area where bystanders and/or nearby residents or domestic animals may be exposed.
- Document where monitoring will occur.

Efficacy

- Phosphine readings should be taken to insure proper gas concentrations. If the phosphine concentrations have fallen below the targeted level, the fumigators may reenter the structure, following proper entry procedures
- All phosphine readings should be documented

G Post Application Operations

- Provide watchmen when the fumigation structure cannot be secured from entry by unauthorized persons during the aeration process.
- Ventilate and aerate as per structural requirements and use fans where appropriate
- Consider temperature when aerating
- Use a suitable gas detector before reentry into a fumigated structure to determine fumigant concentration

- Keep written records of monitoring showing completion of aeration
- Remove warning placards when aeration is complete

Plan presentation techniques

Lectures

- **Ask questions, get answers**
- **Demonstrations**
- **Observation**
- **Discussions in small groups**
- **Brainstorming**
- **Practical Exercises**

Evaluation

Knowledge Acquisition

Evaluation is the gathering of information to ascertain the effectiveness of the training and this measures the degree to which participants acquired the intended knowledge, skills and attitudes as a result of the training.

Ask frequent open-ended questions to confirm understanding. It encourages them to explore their own experience, and understand information in ways that resonate with them. As a result they can retain information – and apply it – more effectively.

This can also be completed as a pre- and post-event evaluation, or only as a post-evaluation. You should confirm the performance of the trainees in the workplace.

Ask the participants to discuss Questions or discuss questions in group

- What did you like most about this training?
- What is a fumigation management plan?
- What are Five W's and One H approach for fumigation?
- Do I have to prepare fumigation?
- What aspects of the training could be Improved?

Focus on Timing

- Structure interaction time into all your sessions
- Keep your session on track. Start on time and finish on

PART 2: General Fumigation

Module 3: Fumigation Types and Methods

Session 7: Types, Techniques and Processes of Fumigation

OBJECTIVES

By the end of this session, participants will be able to:

Knowledge:

- Understand and learn about the types, techniques and processes of Fumigation

Performance:

- Know how to perform the processes of fumigation to ensure the proper application of quarantine treatments through different types and techniques of fumigation

Attitude:

- Appreciate discussing enthusiasm during the training by Chamber Fumigation, Tarpaulin Fumigation and Vehicle or truck Fumigation and different techniques of fumigation

Clarify key topics and related concepts

Step 1

Welcome the participants and share with them the objectives of the meeting. Emphasize here the importance of knowing types of fumigation, different techniques of fumigation and processes to ensure the proper application of quarantine treatments.

Step 2

Divide participants into 3 groups and tell them they will have group presentation on types of fumigation, different techniques of fumigation and processes. Make the participants 30-45 minutes they are to prepare said topics. It encourages them to explore their own experience, and understand information in ways that resonate with them. As a result they can retain information – and apply it – more effectively.

Step 3

Write the word Chamber Fumigation on the left side of the board, Tarpaulin Fumigation on the centre of the board and Vehicle or Truck Fumigation on the right side of the board. Ask participants what they understand by these terms and note key words from their responses under the word Chamber Fumigation, Tarpaulin Fumigation and Vehicle or Truck Fumigation.

Once the task is complete, ask each group to elaborate their group findings and note suggestions on the board.

- Conclude this discussion by referring the participants to the handout describing the terms, and explaining the terms as given in the handout.



Organize Reference Materials

1. Types of Fumigation

Let's now go over the different types of fumigation so you have a better idea of what's out there to use to help rid your pest problem away. The major types of fumigation and their methods currently in use are listed below:

Space Fumigation

The ability to carefully control Chambers used for fumigation may be either the atmospheric or vacuum type.

Chamber and vault fumigation

Chamber fumigation refers to fumigation treatment carried out within a specifically designed chamber. Maximum results with a minimum amount of fumigant can best be achieved by chamber fumigation. Atmospheric fumigation chambers are easy to operate. In these fumigations, the material to be treated is loaded into the chamber (vault) not exceeding 75% of the available space. Fumigation chambers allow simplified use of fumigants and do not require SOPhisticated application techniques. The single most characteristic of a chamber is that it holds enough poison gas fumigant for a required period of time to affect a kill on all stages of insects or other pests. Through atmospheric conditions, the aluminum phosphide product releases hydrogen phosphide or phosphine (PH₃) gas. This section of the training manual will discuss the general use of this type of treatment, chamber fumigation.

An atmospheric chamber can be any airtight structure under **normal air pressure**. It is usually small building located away from other structures. Atmospheric chambers should not be within or connected to other structures where fumigant passage may occur. When fumigation operations are to be carried out in chambers, the chambers should be fitted with a ventilating system which either discharges the fumigant outside, away from any areas where people may be present, or is designed to recover the used fumigant. The meaning of vault is safe and secure place for storing items of value.

Since environmental conditions can be carefully controlled and monitored, chamber fumigation is a superior method for fumigating many materials. Using a chamber will allow only small amounts of a commodity to be fumigated at a time because of the limited size of the chamber. However, the limited space can be an advantage, because the fumigant is confined, saving the time it takes to seal and saving the amount of fumigant used. Atmospheric chambers are useful for fumigating materials that might be damaged in a vacuum chamber.

Chambers working under atmospheric pressure are highly economic because investment cost is low in comparison to pressure chambers. On the other hand the treatment period is definitely longer than in pressurized chambers.

It is important to then ensure gas-tight, sealable chamber/enclosure are maintained before fumigating to ensure they remain gas-tight and continue to perform as an effective fumigation chamber. Before a chamber is used for fumigation, the manometer is used for pressure leakage test as a measure of tightness.

Introduce the required dosage of fumigant and check with a monitoring device to determine that no leakage is occurring during fumigation.

Little leaks cause big problems.

Vacuum chamber fumigation

These require special designs, which take into account the vacuum pressure exerted on the materials of construction. Vacuum chambers provide the quickest and most thorough fumigation and are best for finely divided items such as flour. Applying a vacuum increases the penetration of a fumigant and shortens fumigation time. However, some materials may be damaged by vacuum and require special precautions.

Tarpaulin Fumigation

The material(s) to be fumigated should be stacked on an airtight surface and covered with a tarpaulin that is of sufficient size to provide a gas distribution dome and also allow for sealing the tarpaulin to the floor. Aeration should proceed as follows: if fumigation is being conducted inside a closed structure, all doors and windows should be opened to provide cross-ventilation. The tarpaulin should be opened on one end to allow the stack to aerate for at least 30–60 min before removing the tarpaulin completely. If the fumigation is conducted outside a structure, the aeration should be conducted in steps as above with monitoring of the immediate surrounding vicinity for safety.

Tarpaulin fumigation involves placing a gas-tight material over the commodity or structure to be fumigated. The tarps must be specially made for fumigation, such as impregnated nylon or sheet polyethylene. The tarpaulin method provides thorough protection from insect damage at practical cost. Done in place, it permits fumigation without the expense of moving huge stores of commodities. Tarpaulin fumigation can effectively and economically free material such as bagged grain, dried fruit, stacked lumber and other commodities from insects. Tarpaulin fumigation may be done in the open, on loading docks, or in areas of buildings that allow safe aeration when the tarpaulin is removed. However, sites must also be checked for possible hazards in securing the fumigated area from humans and animals as well as for adequate sealing. Workers should not be allowed into areas containing taped fumigated materials unless there is adequate ventilation and regular monitoring.

If the fumigation is done with phosphine, and the tablets or pellets have to be placed on the floor along the sides of the stack because they cannot be put under a stack, make sure not to spill them out of their trays when putting sand snakes along the sides of the stack.

Vehicle or Truck Fumigation

Fumigation in a well-sealed vehicle or truck trailer is a type of chamber fumigation. Numerous pests find their way into various kinds of vehicles – some by natural means, some brought in by humans. Most common are wood boring insects, carpet beetles.

Items shipped in rail cars or in large truck trailers are often fumigated after they are loaded into the vehicle. This prevents pests from being transported to other locations and protects shipped products from pest damage during transport. Most vehicles, depending on their condition and on the type of commodity being fumigated, require tarping or other sealing to confine the fumigant. Obtaining a good seal is not always easy. Monitoring the fumigation is the only way to know if the seal is good. Even cargo on truck or in

container, which comes from overseas can be fumigated and aerated without danger in a quite short period of time.

Pests controlled by rail car and truck fumigation include beetles and moths that infest flour, grains, nuts, dried fruits, and other agricultural products. Some insect pests may hide in empty vehicles, feeding on residues from previous cargoes. Unless controlled by fumigation or removed by thorough cleaning, these pests can infest future loads.

Containers, trucks, vans and other transport vehicles loaded with bulk raw agricultural commodities or other commodities approved for direct addition are treated in essentially the same way as any other flat storage facility. The dose may be scattered over the surface after loading has been completed or may be probed below the surface. Bags are easily applied in vehicles on the boards.

Because fumigated rail cars or trailers may contain residues of a fumigant after aerations, the vehicles need to be monitored with appropriate detection equipment once they reach their destination and before they are unloaded. To prevent injury, notify people who will open the vehicle (fumigated loads) at its destination that they must wear respiratory protection and any other protective equipment required by the fumigant label. Instruct them not to unload the vehicle until fumigant levels have been monitored again and are determined to be in the safe range.

Soil Fumigation

- Field, nursery, greenhouse and seed or transplant bed soils
- Non-tarp fumigation by injection

Note: Soil Fumigation will not be described here

2. Different Techniques of Fumigation

Gas fumigation

In this technique they release the chemical in its gas form in an enclosed structure or space. They will enclose the area with a gas proof covering that will protect the outside environment from the chemicals being used. Some of the common gases used are Methyl bromide and Sulfuryl fluoride.

Solid fumigation

Some popular solid fumigation chemicals are **Aluminium phosphide** and Calcium cyanide. Synonyms for phosphine include hydrogen phosphide and phosphorated hydrogen. Commercial names include Phostoxin, Gastion, Detia, Gas XT, Fumitoxin, quickphos, celphos, and others. Its ease of handling and effectiveness have made it the most important fumigant in the world. Its formulation is solid and usually is concentrated in tablets weighing 3 grams each. Most cans contain 168 tablets or 6 tubes with 28 tablets each.

This type of fumigation is released as pellets, and tablets in the measured amount of necessary for handling the particular size pest problem. This method is less harmful to the environment and much easier and safer to use than the gas form.

Liquid fumigation

Most of these types of fumigants are toxic to humans and are highly flammable. Liquid fumigation acts quicker than solid fumigation. This type of fumigation is usually performed outside or in an enclosed area.

Typical chemicals that are used in this form are carbon disulfide, ethyl acetate, chloroform, carbon tetrachloride, sulfuryl fluoride, ethylene dichloride and methyl bromide

3. Processes of fumigation

Fumigation operation is effective and a better option than any other methods of pest control because in fumigation process the fumigant circulates and spreads to all areas of infestation whereas spraying operation or other methods of pest control will be less effective. The process of fumigation is the creation of a sealed gas-tight environment structure into which a concentration of the fumigant will be held at a suitable temperature and for an appropriate time to kill the invisible pests within this sealed area. These conditions, when achieved correctly, effectively control and kill the pests at all development stages and in adult form. When the treatment is completed, and after the fumigant has been safely ventilated, no residual effect remains.

Plan presentation techniques

- Lectures
- Q & A
- Discussions in small groups
- Brainstorming

Evaluation

Knowledge Acquisition

Animals have knowledge. But only men can reason. The better you can reason the farther you separate yourself from animals. Explain that for this session they need to answer the following questions to confirm understanding

1. What do you understand by Fumigation in Atmospheric Chamber? Describe it
2. What do you understand by Vacuum chamber fumigation? Describe it
3. What do you understand by Tarpaulin Fumigation? Describe it
4. What do you understand by Vehicle or Truck Fumigation? Describe it
5. What are Different Techniques of Fumigation?
6. What is the fumigation process?

Focus on Time

- Structure interaction time into all your sessions
- Keep your session on track. Start on time and finish on time

Session 8: Fumigation methods

OBJECTIVES

By the end of this session, participants will be able to:

Knowledge:

- Understand and learn about the Fumigation Methods on Direct application to Commodities, Application using Generator, Application using Probe and Recirculation of Phosphine

Performance:

- Observe first hand many of the principles and practices and know the operating procedures listed above

Attitude:

- Demonstrations plus active individual participation in performing the various procedures involved in fumigation are considered to be essential parts of course of instruction.

Clarify key topics and related concepts

Step 1

Welcome the participants, and share with them the objectives of the meeting and it helps the participant focused on what he or she wants to achieve. Emphasize and explain here the importance of knowing the Fumigation Methods on Direct Application to Commodities, Application using Generator, Application Using Probe and Recirculation of PH₃ for Bulk Storage.

Step 2

Write words Direct Application to Commodities, Application using Generator, Application Using Probe and Recirculation of PH₃ for Bulk Storage on the board or brown paper and ask participants what they understand by these terms listed above and note their responses below the word Direct Application to Commodities, Application using generator, Application Using Probe and Recirculation of PH₃ for Bulk Storage. Conclude this discussion by referring the participants to the handout and explaining the different types of fumigation methods.

Step 3

In order to deepen participants' understanding of Fumigation Methods on Direct Application to Commodities, Application using generator, Application Using Probe and Recirculation of PH₃ for Bulk Storage and to the learning anchor and practice to fumigation plant after the training, organize the participants into groups of three to four. Ask each group to select one Fumigation Method for practical exercise and make participants the next special session on an exercise. Rotate each group to perform another type of method. Inform the participants about the steps for operation or instructional guidelines for use of Phosphine Generator. The facilitator demonstrates fumigation practices and facilitates group interactions on specific problems and issues related to fumigation operations.

Step 4

In the interest of time, each group presents first their practical information. This may take about 40 minutes. Once the groups are ready, facilitate a plenary discussion so that you are sure every participant is on track.

Step 5

The training programme should be structured to impart technical skills and competency in performance of effective fumigation operations with Aluminium Phosphide. Tell the participants that handholding period of at least four months shall be considered for operator.

Organize Reference Materials**1. Fumigation Methods****Direct application on commodities**

The use of tablets and pellets is not limited to any particular type of storage. They can be applied in silos, bins, warehouses, containers, vehicles. Application may be made either by hand or by inserting the tablets or pellets into the commodity. When fumigating silos or bins, the tablets or pellets may be added to the commodity during the filling procedure.

Depending upon temperature and humidity, tablets and pellets release phosphine gas slowly upon exposure to moisture from the air. Due to the smaller size of the pellets, decomposition is more rapid than with the tablets. Phosphine gas readily penetrates many kinds of packing material as well as densely packed commodities and can control all developmental stages of pests.

When fumigating packaged commodities under gas-proof sheets the tablets or pellets can be spread out on trays to lay under the sheet before it is secured. In warehouses, after the structure is adequately sealed, the tablets or pellets are spread out on trays or sheets of Kraft paper so that residual material can be easily collected at the end of the treatment. The tablets or pellets should never be piled on top of each other or in a mass.

During fumigation the commodity will be exposed to a certain concentration of the fumigant (which exists as a gas) for a certain period of time in a closed system in order to kill the pests.

Fumigation Using Probe

The use of tablets and pellets is not limited to any particular type of storage. They can be applied in silos, bins, warehouses, railcars, containers, barges or ships. Application of may be made either by inserting the tablets or pellets into the commodity using a probe.

The fumigant is usually applied by probing into the grain. Probes specially designed for the purpose are used to insert the fumigant into the grain. The number of tablets or pellets used per probe is determined by dividing the total amount of fumigant to be used by the number of probing to be made. In most storage units where there is considerable air space above the grain bulk, or when it is considered that significant loss of fumigant may occur above the load, it is advisable to cover the entire mass with gas-proof sheets.

Aluminum phosphide are mainly used in protecting bulk grains and needs to be evenly distributed to provide adequate fumigant levels. Special probes are used for applying pellets/tablets below the surface of bulk grain. Pellets should be inserted deeply within the grain mass, at least five feet, and no more than 50 pellets or 20 tablets should be inserted per probe. Applicators should also wear cotton gloves so that perspiration doesn't contact the aluminum phosphide, releasing the phosphine gas. The applicator not making the probes should periodically monitor fumigant (hydrogen phosphide / phosphine) levels.

Recirculation methods (for bulk storage)

It is permissible and sometimes desirable to re-circulate the PH₃ gas in certain bulk storages. This method may be used in various types of flat storage and vertical storage bins. Recirculation usually involves the application of fumigant to the surface of the commodity. The PH₃ gas is then continuously or intermittently drawn out of over space and blown into the bottom of the storage using specially designed low volume fans and duck work. This method facilitates the quick and uniform penetration of phosphine throughout the commodity. In some instances a reduced dosage may be used.

Phosphine Gas Generator

Amongst the different devices which are available at the international market the Phosphine Generator has been chosen to be described in this manual because it has been procured by PACT to be used in the project's practical training programme. The design of the facility in Kirtipur is to be based on the use of Phosphine Generator which shall generate phosphine using Aluminum Phosphide tablets 56% which are already registered and available in local market of Nepal and used widely. Phosphine-producing materials have become the predominant fumigants used for the treatment of bulk-stored grain throughout the world. It is available in solid formulations of aluminum phosphide. When exposed to heat and moisture the formulations release phosphine, a highly toxic gas.

The facility available in the building design consists of four chambers of about 33 cubic meters volume capacity (1165.38 cubic feet volume capacity) each which is leak proof and suitable for fumigation. The proper use of phosphine generator reduces the fumigation treatment time and one can also ensure uniform treatment of material.

The 4 chambers in a unit alternate with each on a weekly basis and show the usage for the fumigation chambers which ensures one chamber of material being fumigated daily. Normal fumigation time using a phosphine generator is about 72 hours for temperature above 20 degrees centigrade.

2. Phosphine Generator Features

Outdoor Application

The generator is operated outside of the storage structure (i.e. open to the outside environment) and the phosphine gas is introduced into the structure, either directly through the gas distributor or through recirculation system which has a recirculation fan. The operator in the warehouse outside put the aluminum phosphide into the carbon monoxide (gas cartridge) in a fully sealed environment. The operators do not actually touch the PH₃ and that can prevent incidents from occurring or happening and protect the operators from harmful effects from the gas.

Synergistic fumigation

The synergistic fumigation (Mixture of CO₂ and phosphine) can increase the fumigant toxicity or the insecticidal effect, which effectively maintain the storage good quality and save about 50% of the dosage.

Computer control

The generator is controlled by a computer. The computer controls the pesticide spray rate and reaction temperature and this mechanism can help to ensure safety and avoid/prevent condensation.

Steel brushes

Steel brush is in the pesticide cartridge as cleaning device and all tablets or pellets are used up without any remaining.

Setting of the structures

The whole structure is set up by vertical and horizontal arrangement. The reactor and the filter container with heavy weight are arranged in a horizontal position and the cartridge and the mixing cylinder which is light in the weight, are arranged vertically above the reactor and the filter. This kind of arrangement has been made to ensure that the machine will not tilt and keep it in a safe manner to prevent movement of structures. The design techniques are useful/ beneficial for input dose and easily converted into a mixed gas output.

Drive motor and Reducer

The drive motor and reducer in the phosphine generator are all aluminum alloy shell and integrated in one installation and well assembled with good appearance.

Other Special Features

The generator will automatically stop work, if:

- There is insufficient flow of carbon dioxide;
- the pressure in internal chamber is excessive;
- the temperature in the reaction chamber becomes too high or too low;
- there is a malfunction in the power supply.

Should any of these conditions develop, an audible alarm will sound and the phosphine generator should be stop work at once.

3. Generator technologies

The phosphine generator technology is based on the combination of carbon dioxide and phosphine for fumigation. After mixing phosphine produced by phosphine generator with carbon dioxide in a steel cylinder, the gas is conveyed into the treated premises.

The phosphine gas produced is pumped into the object being fumigated either directly or through the generator's self-contained recirculation system. It is first flushed with carbon dioxide to remove air from its internal plumbing. They are carried automatically to the reaction chamber where the phosphine gas is generated. Then the gas is pumped into the object being fumigated. The phosphine generator can be used

for fumigation of stored products in situations with unfavorable conditions of temperature and/or humidity which delay gas production from the solid material. Operations are regulated by a control system.

Part of equipment

The first part of the equipment is the phosphine recirculation system that is composed of the following five parts:

- i. Phosphine generator;
- ii. Recirculation fan;
- iii. Aeration pipe on the bottom of the granary (building which is used for storing grain) ;
- iv. Recirculation pipe on the surface of grain and under plastic sheeting;
- v. Recirculation pipe on the outside wall of granary

Fumigant generator and distribution system

Phosphine recirculation fumigation technology

- Phosphine recirculation fumigation technology has been regarded as an effective and feasible way for pests control in warehouses.
- It could make phosphine uniform distribution by recirculation fan and recirculation pipe. By virtue of its effect on pest control, people usually took this as a simple and safety practices, more economic and effective in the workplace.
- Before fumigation, we should be familiar with the air tightness of the commodity storage to be fumigated. This is the key factor in the success of the recirculation fumigation.

Functional principles of the phosphine generator

The Phosphine Generator is a device for rapid production of phosphine (PH₃) gas to be introduced into chamber from outside of a fumigated structure. The aluminum phosphide (ALP) tablets are used as raw material and the content of effective constituent of aluminum phosphide in pesticide tablets or pellets is 56%.

The Phosphine Generator requires power, continuous water and air supply (whether it be a recirculation supply line from the fumigated structure or ambient supply) at the site of application as well as a carbon dioxide source. The generator is operated with a special formulation of ALP provided in sealed flasks which react inside the reactor chamber.

The generator is operated outside of the storage structure and when the recirculation fan is activated, the gas mixture of phosphine and carbon dioxide from phosphine generator is conveyed to the outlet of recirculation fan. The air flow carries the mixture gas into the ventilation system on the bottom of commodity. By using the recirculation fan the phosphine gas is introduced into the stored grain. Through the ventilation pipeline the phosphine gas can be uniformly distributed. The fast developing gas is blown through pipes directly into the commodity to be fumigated. A schematic diagram of work (Work Flow) is given below (Figure 1):

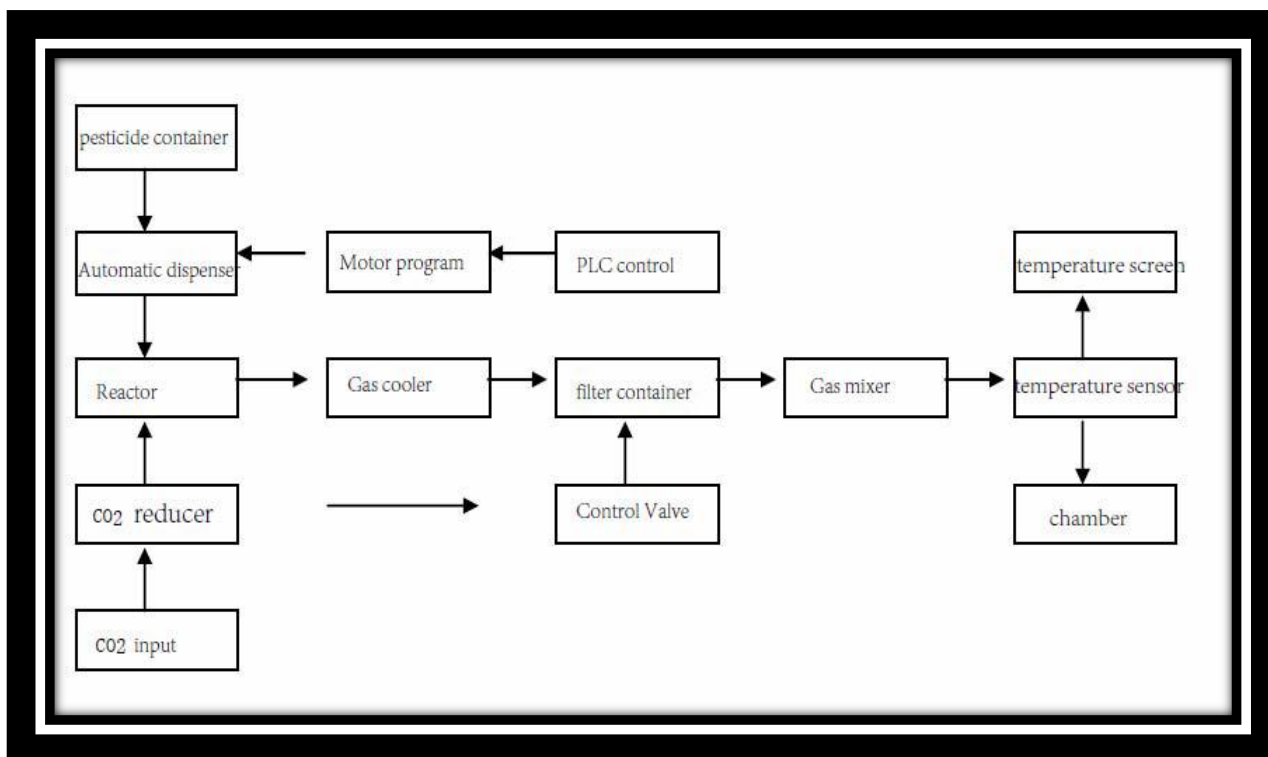


Figure 1. Schematic diagram of work

Performance Parameters

One time dosage (ALP Tablet or Pellet)	≤8 kg
Reactor water injection	90 kg
Filter water injection	50 kg
Regular work pressure	2-15 kpa
Designed pressure for the whole tank	0.25Mpa
Designed pressure relief valve	0.23Mpa
Ventilation temperature limitation (adjustable)	Setting as 450C when in manufacture
Voltage and rated power	AC 220V

Composition of the structure

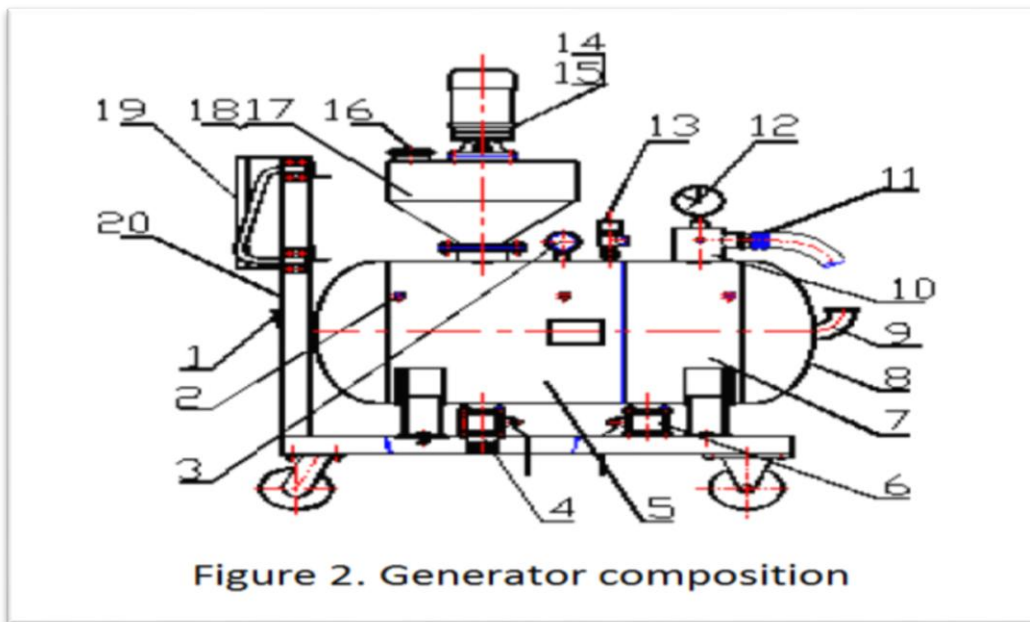
The composition of the structure of the outdoor phosphine generator composition is shown in Figure 2. The tank, item 8, is partitioned by the reactor 5 and the filter with function of coolers 7, 5 and 7 connected by special designed stainless steel tubing. Index for the inlet and outlet of the Nozzle, diameter (connecting thread) and the role of the table is given below:

Index for the inlet and outlet

No.	Function	Diameter	Remark
1	1 Reactor water intake	φ 50	Water input and Water Limitation
2	CO2 inlet	φ 8	with φ 12 x 8 hose
4	Reactor drainage	Φ 60	
6	Filter drainage	φ 60	
9	Filter water intake	φ 50	Water input and Water Limitation
11	Vent of mixing gas for ph3 and Co2	Vent of mixing gas for G2 "	Vent of mixing gas for with φ 50 hose
12	Pesticide infusion inlet	φ 76	

Full components of the structures

1. Reactor water intake	7. Filter with function of cooler	13. Safety valve
2. CO2 inlet	8. Tank as pressure cabinet	14. Motor
3. Stainless steel pressure gauge (measure the pressure in reactor)	9. Filter water intake	15. Reducer
4. Reactor drainage	10. Gas Mixing tube (PH ₃ +CO ₂)	16- ALP dosage input
5. Reactor	11. Vent of mixing gas for pH ₃ and Co ₂	17 Pesticide cartridge
6. Filter drainage	12. Digital thermometer (mixing gas out Measurement)	18 Pesticide sprayer controller
19 - Electric control box	20 - Portable trolley	



Electronic control box

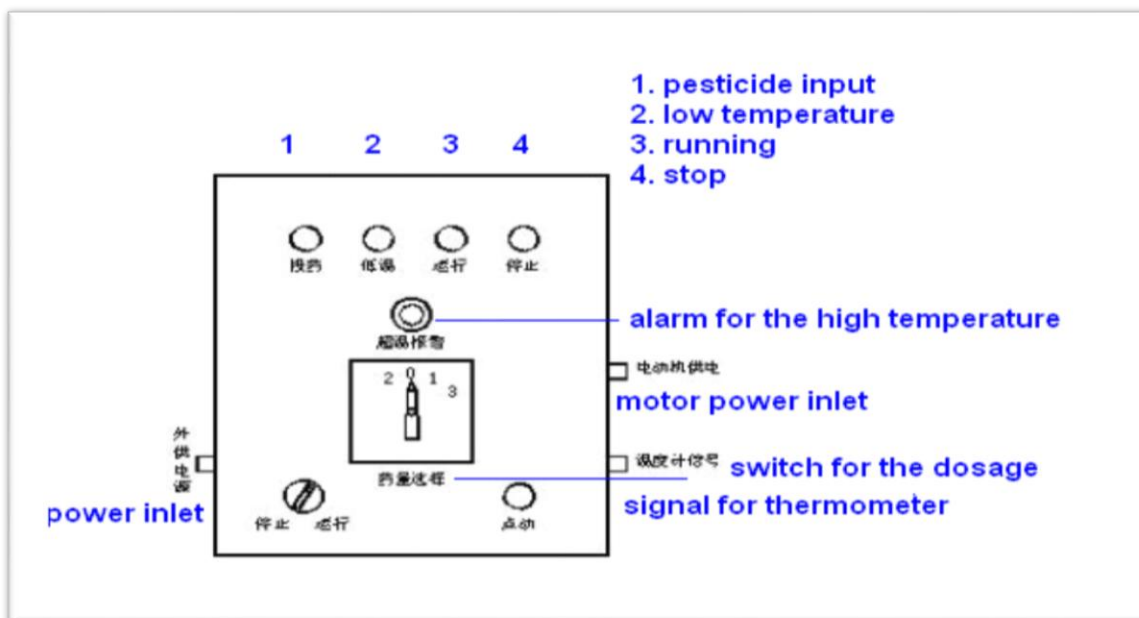


Fig. 3: Electronic control panel

Phosphine recirculation fumigation technologies under plastic film

It is possible to apply phosphine recirculation fumigation in commodity bulks under plastic film after commodity surface is covered by plastic film, and recirculation pipes are installed in the commodity surface and connected to ventilation pipes. Sealing by plastic film, could prevent phosphine leaking and keep effective concentration for a long time.

Phosphine generators in combination of gas distribution system This system is composed by A. Phosphine generator and B. Gas distributor. The gas distributor is mainly composed of 5 unit gas flow meters which are specially used for regulating the gas flow of carbon dioxide. Adjusting the 5 unit gas flow meters, the mixture of phosphine and carbon dioxide can be divided into proportional 5 pipes. This set up enables fumigation of several warehouses or several stacks or several containers at the same time.

4. Instructional Guidelines for Use

Operation of the Phosphine Generator

An aluminum phosphide formulation, preferably containing 56% of the active ingredient, is used for phosphine gas generation for fumigation. The present method is directed to a rapid generation of phosphine gas, which ensures that the required amount of phosphine gas is released in a short interval of time of less than two hours. The capacity of the PH₃ generator was 8 kg of ALP tablets, is limited and required “time-out” to prepare additional batches where required. Operations are regulated by a control system. A feed-back loop allows the rate of water addition to be ‘fine tuned’ by monitoring the phosphine concentration in the air stream and adjusting the water flow to achieve the desired concentration.

During the process the phosphine being developed is mixed with an air-carbon dioxide mixture that is exchanged with air inside the sealed structure being fumigated via an internal recirculation fan. By taking air out of the structure and exchanging it with the air-gas mixture, pressure changes inside the structure are negligible. This process aids in the rapid distribution of high concentrations of phosphine

Operation preparation

- Prepare the suitable amount of phosphide agent calculated on basis of the warehouse capacity, air tightness, ambient temperature and type of insects.
- Usage ratios: per 1Kg of phosphide agent matched with a cylinder (25Kg) CO₂ dose preparation. While CO₂ should not be less than 2 cylinders (50Kg),
- Maximum weight of aluminum phosphide in once fumigation process needs ≤8 kg Aluminum Phosphide (tablets or pellets),
- No matter how much fumigant it contains or quantity of the dosage for the fumigation each time

Equipment inspections

The thermometer is highly sensitive to local air pressure, so the temperature shows a deviation. It should be calibrated thermometer before operation. The common thermometer can be used as reference for measuring output of gas and record any deviation of temperature from the reference thermometer and modify the set figure in the temperature sensor; Example:

- Suppose the factory setting : 45⁰C

- Temperature sensor before calibration: 25⁰C,
- The measured ambient temperature: 23 ⁰C, and then, the figure should be set to 47 °C (add difference 2⁰C to the factory setting).

Power supplies

Not all power supplies that don't have a 220 V switch are auto range so check the power supplies voltage. A bad power supply can be the root of many problems.

Check the air tightness

An Air Tightness Test sometimes referred to as an Air Pressure test is required to measure the amount of uncontrolled air leakage. So check each connection place, such as nozzle, the valve seal, any loose, leakage, check the reactor. See if it contains any dirt, debris, or matted dust. Also check the mixture air outlet and the warehouse connector connected hose remain intact. The work can be started if the all of technical standard procedures have fulfilled and confirmed all formal requirements.

Water injection

Water injects from the two water intake and keeps injecting until there is water overflow. After that, it should be closed tightly.

Connect CO₂ cylinder and pre-open CO₂ gas for 10 minutes. Outlet pressure of pressure reducer should be set as 0.1 ~ 0.2Mpa and the flow rate of CO₂ should be not less than 120 L / min.

Dosage input

After 10 minutes of pre-CO₂, close the CO₂ cylinder valve, release the pressure regulator handle. Open the pesticide cartridge cap and place a predetermined amount of tablets or pills, into the cartridge. The charge should not exceed 8Kg at one time. Tighten the cap after loading. Open the CO₂ cylinder valve, tighten the pressure regulator handle to ensure that the outlet flow of the reducer is not less than 120 L / min, and continue to pass CO₂.

Operation by a computer board

The Phosphine Generator can produce about 2.66 kg of phosphine gas in 2 h. The generator is operated by a computer board with a password protected multi-function touch screen.

Flushing carbon dioxide

Before the generator begins to work, air from its internal chamber should be removed by flushing with carbon dioxide.

Timing motor device

The tablets or pellets of aluminum phosphide are automatically supplied through a timing motor device to a reaction chamber that contains water. The phosphine gas is produced and then carried by carbon dioxide into the storage. Since the phosphine concentration is maintained below 2% in air, there is no fire hazard.

Controlling by a computer

The generator is controlled by a computer. Once programmed, the generator will operate automatically, until the 8 kg aluminum phosphide is processed. The machine operates automatically with the exception of reloading the ALP until the desired results have been achieved.

Fumigating by two trained persons

Although the generator is developed to operate automatically, it cannot be operated without the presence of at least two trained, certified operators for safety reasons. Fumigation should only be carried out by trained staff operating under proper supervision. The operators can manually control several functions. For example, production of phosphine can be paused, stopped completely or started again at any desired moment by the operator.

Hydroxylation reaction

During the generator operation, the aluminum phosphide and water are brought into contact a hydrolyzation reaction takes place to produce the phosphine gas in per unit time under the control of the reaction temperature, reaction pressure, and the dosage of aluminum phosphide. Aluminum phosphide is automatically supplied (through a timing motor device) into a reaction chamber that contains water. In this reaction the gas phosphine is generated immediately, and then it is carried by carbon dioxide into the commodity storage.

Weight ratio of carbon dioxide and phosphine

The phosphine is flammable and explosive, it should be mixed with carbon dioxide by weight ratio of 98% carbon dioxide and 2% phosphine before the phosphine is released into air. According to the amount of phosphine generated in unit time, mixing an amount of carbon dioxide with it at the same time, controlling both proportion between phosphine and carbon dioxide can be realized. Weight ratio between phosphine and carbon dioxide has been proved to be safe by practice.

The cone-shaped container can hold 8 kg aluminum phosphide (tablets or pellets). A timing motor is located on the top of the container and its spiral device rotation speed can be controlled by the phosphine generator.

The spiral device supplies aluminum phosphide into the reaction container that can hold 100 kg water. User can adjust the carry speed by touch screen on the controller of phosphine generator.

The speed of ALP tablets immersed into the water in reaction container range 12~72 g/min (adjustable range). One gram of aluminum phosphide (tablets or pellets) can produce about 0.33 g phosphine, so the capacity of pure phosphine is 4 ~24 g/min. Three grams of tablets produce approximately one gram of phosphine gas which corresponds to 700 ppm (0.7g) in one cubic meter (35.3 cubic feet).

If the immersed speed of the aluminum phosphide into water in reaction container is 72 g/min, after 111 minutes 8 kg aluminum phosphide is consumed, and the total capacity of phosphine generated in one cycle of fumigation is 2.66 kg. The aluminum phosphide tablets contain some wax that causes delay in its hydrolyzation reaction. After the total aluminum phosphide is immersed into the water the function of

the reaction container is terminated, but carbon dioxide is blown for at least 60 minutes, until the hydrolyzation reaction can be nearly completed.

Reaction and filtration container

Before fumigation, water is added into the reaction and the respective filtration container. During the whole process in one cycle of fumigation, the capacity of the reaction container is 100 kg water for reaction reagent, and the capacity of the filtration container is 80 kg water. The water of the filtration container is used for filtration of the foam generated in reaction container; and also for cooling the phosphine and carbon dioxide mixture gas.

When the aluminum phosphide is added into reaction container, it reacts with water at once and generates the gas phosphine immediately. A certain amount of carbon dioxide gas is supplied to mix with the gas phosphine in the reaction container, and then the mixture of the two gases is conveyed into the filtration container. After cooling and filtration, the cool and pure mixed gas can be released into the site to be fumigated or into the gas recirculation pipe.

Phosphine gas is generated by agitating a reaction mixture of a metal phosphide and water with agitation air in a reaction container of a phosphine gas generator. The resulting phosphine gas is then diluted with dilution air to produce a fumigant phosphine gas which is directly delivered to a commodity for fumigation. The reaction container does not have any rotating means such as agitators, rotors, or stirrers. The generator provides on-site generation of phosphine gas in a rapid manner improving the fumigation efficiency for a commodity. The generator has a built in deactivation system for the unused metal phosphide and phosphine gas.

Phosphine Alarm

Phosphine alarm is a specially designed pocket sized instrument to protect workers from the hazards of phosphine gas inhalation during the fumigation process. After the automatic dosing is completed, the alarm box will alarm and the red and green lights will be lit at the same time to remind the operator of the safe handling after the operation. Each time when fumigation is completed, the run / stop switch should be turned to "stop", the switch should be turned to "0" and the power of the control box should turn off.

If the concentration of phosphine around the work site is over 0.3 ppm, it will sound and light the alarm. If the temperature inside reaction container is exceeded, the controller of phosphine generator can give an alarm. The working temperature is 35 to 60°C, depending on the gas generation rate and environment temperature.

Controllers

The work of the phosphine generator is controlled by a microcomputer inside the controller of phosphine generator. The working parameters can be set and displayed on a touch screen.

The temperature sensor can detect the temperature inside reaction container, which is from 35°C to 60°C. If the normal values of these parameters are exceeded, the controller of phosphine generator can send an audible alarm. Any abnormal sound, no matter how faint, must never be ignored. In case of an unusual sound, the engine should be immediately stopped and find out the troubling issue. Never panic in such situation.

User can set the rate of aluminum phosphide to be immersed into the water inside reaction container, and the required carbon dioxide gas flow displayed on touch screen.



Fig: Configuration of the phosphine generator

Carbon dioxide supply valve and flow meter

Providing enough carbon dioxide is the key to ensure the safety of fumigation process. Usually the carbon dioxide loaded in steel cylinder is as gas sources for the phosphine generator. The carbon dioxide supply valves are set on the steel cylinder.

The maximum capacity of one carbon dioxide supply valve is 120 L/min (240 g/min)., According to the phosphine generator rate and the quantity of carbon dioxide, the user can decide how many carbon dioxide steel cylinders should be used. For example, if the phosphine generator rate is 72 g/min, the output speed of pure phosphine is 24 g/min, each carbon dioxide cylinder can supply 120 L/min (240 g/min) carbon dioxide gas, user should be using five carbon dioxide cylinder, which can supply 600 L/min (1200 g/min) carbon dioxide, so that the weight proportion between phosphine and carbon dioxide is 2:98.

Frost and ice is usually formed when carbon dioxide is released from carbon dioxide cylinder through a supply valve. Therefore, electric heating is applied on carbon dioxide supply valve to avoid such a phenomenon.

The carbon dioxide gas has another two more functions. One is agitation in the reaction container to ensure aluminum phosphide hydrolyzing reaction is complete in the water. The other one is in adjusting the temperature of the mixed gas at the outlet of phosphine generator.

Reagent containers

After the hydrolyzation reaction of aluminum phosphide in water, two kinds of materials are produced: aluminum hydroxide and phosphine. The chemical formula is: $\text{AlP} + 3\text{H}_2\text{O} = \text{Al}(\text{OH})_3 + \text{PH}_3$. So the waste

liquid includes aluminum hydroxide [Al (OH) 3] and the residual water that looks like a watery mud in the reaction container.

Because aluminum phosphide includes a little wax, sometimes the hydrolyzation reaction is not complete, so the waste liquid includes an amount of phosphine. Before releasing the waste liquid from the reaction container, the phosphine gas in the waste liquid must be cleared. During normal operation, the fully-reacted waste products are contained within the reaction chamber and are removed at the completion of the fumigation for safe disposal at an approved site.

To eliminating the residual phosphine in the waste liquid a special reagent in the reagent container is used for processing waste liquid after processing the waste. After processing the waste liquid can be changed into a non-poisonous liquid which is safe. It can be disposed of by the normal route for industrial waste. The special reagent is composed of nitric acid (HNO₃), perchloric acid (HClO₄) and copper sulphate (CuSO₄), at a ratio of 1000 ml, 500 ml, and 70-100 g, respectively.

Nitric acid is mainly used to neutralize ammonia in the waste liquid. Secondly, as the oxidant, nitric acid can oxidize low valence phosphorus. Perchloric acid is mainly used as the oxidant which can oxidize low valence phosphorus. Secondly it is also used to neutralize ammonia in the waste liquid. As the catalyst, copper sulphate (CuSO₄) is used to catalyze the reaction between perchloric acid and low valence phosphorus. After adding perchloric acid into copper sulphate (CuSO₄), the reaction between perchloric acid and low valence phosphorus can be accelerated.

5. Precaution

- Gas supply must be guaranteed throughout the fumigation process. Prior to loading, CO₂ gas must be input at least 10 mins and expel Oxygen in a pipe and containers
- The water leverage in the reactor and cooler must keep the same level with the overflow.
- Operators keep alert and observe the operation of the machine all the time and check if there is any leakage with the tool of phosphine alarm. In case, timely action is taken to prevent the worse situation.
- In case of power failure, should immediately open standby power or self power generation.
- Recommend fumigation special pressure reducer equipped by factory (optional) (150L/min).
- Fumigation should avoid direct solar insulation to the machine, or electric control box was excluded from rain.
- Relief valve shall not bear any external attack or distortion.
- After the first dose (standard dosage of 8Kg), if need to add dosage or continuous fumigation for another location. Total amount dose in two times.



6. Advantages

The major advantages of the Phosphine Generator are listed below:

- There is no need to apply solid phosphine products and to remove their solid residues from the fumigated object. Contact hazards are minimized as the fumigant is introduced into the machine via a sealed flask.
- The application can be made with a lower number of staff than using standard solid phosphine formulations. This is why also less safety equipment is required.
- Only 8 kilograms Aluminum Phosphides are needed to produce 2.66 kilogram of phosphine gas (tablets or pellets)
- The speed of phosphine generation is not dependent on ambient temperature and relative humidity.
- Quick production of high concentrations of phosphine increases efficacy of the treatment and may result in shorter fumigation periods.
- Phytotoxicity is no longer a concern using the phosphine gas produced in the generator.
- In case more phosphine is required during the course of a fumigation additional gas can easily be added.
- Multiple container can easily be conducted from one central location using a gas distribution manifold system.
- Pressure increases within a fumigated structure due to gas development are no longer a concern because excess air is exchanged within the machine via a recirculation pump.
- The generator can easily be connected to a re-circulation system.
- At the end of the fumigation no deactivation of degassed carrier material is required.

Plan presentation techniques

- | | |
|-----------------------|-----------------------------|
| • Lectures | Brainstorming |
| • Q & A | Demonstrations |
| • Observation | Discussions in small groups |
| • Practical Exercises | |

Evaluation

Knowledge Acquisition

Explain that for this session they need to answer the following questions to confirm understanding

1. What do you understand by Direct Application to Commodities?
2. What do you understand by application using Generator?
3. What do you understand by application using Probe?
4. What do you understand by Recirculation of PH₃ for Bulk Storage?
5. What are the instructions for use and preparation before operating the outdoor phosphine generator?

There shall be a post training evaluation to assess adequacy of skills of fumigation operator through practical work.

Focus on Timing

- Structure interaction time into all your sessions
- Keep your session on track. Start on time and finish on time

PART 3: Fumigation Operational Procedures and Documentation

Module 4: Application procedures and completion

Session 9: Calculation of chamber volume and dose uses

OBJECTIVES

By the end of this session, participants will be able to:

Knowledge:

- Understand and learn about the volume of the chamber to be fumigated
- Understand and learn about the appropriate fumigant dosage

Performance:

- Know the technique/method how to measure volume of the chamber and calculate the dosage rates to be fumigated.

Attitude:

- Encourage participants to know and get chamber volume done now, and fumigant dosage rate calculated now before fumigation, not later

Clarify key topics and related concepts

Step 1

Greet the participants enthusiastically and tell participants what you're going to cover. Introduce your session with a brief overview of the training subject's main points.

Step 2

Use as much hands-on training as possible. The most effective training uses all the senses to affect learning. Demonstrate and apply teaching points to create greater understanding and knowledge of the subject.

Step 3

Also ask participants to share their experiences with the training topic on fumigation chamber, fumigant dosage and exposure time. Many participants are experienced personnel who have valuable information to contribute. All participants will get more out of sessions by hearing about their co-workers' experiences with the subject—and not just the trainer's lecture points. Hearing different voices also keeps sessions varied and interesting.

Step 4

Repeat questions before answering them. This practice ensures that all participants know what the question is so they can make sense of the answer

Step 5

Show the practical example of measuring the fumigation chamber and calculating the fumigant dosage

Step 6

Ask each group to work on fumigation chamber and fumigant dosage calculation. As they are working on this, move from group to group and assist them if necessary. When everyone is finished ask each group to share their presentations on fumigation chamber and fumigant dosage calculations.

Step 7

Tell participants another conception of philoSOPhy "What We Learn When We Learn by Doing"

Organize Reference Materials

Calculation of Fumigation Chamber Volume/Fumigation Enclosure

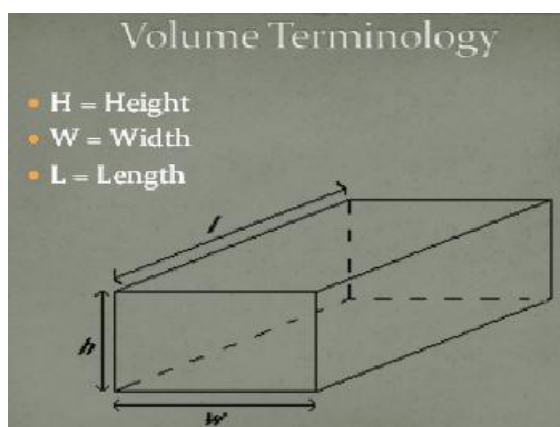
The volume of the fumigation chamber or enclosure needs to be calculated accurately, so that the correct dosage to be applied can be determined. For the purposes of sheet fumigation, the volume of an enclosure is all of the space enclosed under the gas-proof sheets.

The volume of the space to be fumigated is the volume of the total space enclosed for fumigation. Measure the length, width and height of the chamber. Multiply the three measurements together to find the volume in cubic feet or meter.

Formula for calculating volume

The following calculation may be used to determine the volume of the chamber in cubic feet (ft³)

Total chamber volume (ft³) = Chamber Height (ft) x Chamber Length (ft) x Chamber Width (ft)



Produce Temperature Measurement

i. Fruits and Vegetables

The Fumigator shall measure the flesh temperature of one centre fruit or vegetable and one outer fruit or vegetable from each pallet of bulk bin.

For un-palletized fruit and vegetables, a minimum of one outer and one inner fruit or vegetable from every twentieth package shall be sampled.

Temperatures shall be taken from each lot of fruit or vegetables in the load. A minimum of three temperature readings shall be taken from for each lot to be fumigated.

ii. Live Plants and Plant Products

The Fumigator shall take sufficient temperature readings from each lot to be fumigated to determine the minimum and maximum temperatures of the load. Temperatures shall be varied between the top middle and bottom and from outer and inner packages of each lot. A minimum of three temperature readings shall be taken from each lot to be fumigated.

In this fresh fruit fumigation method, pure phosphine free from ammonia is used at low temperature for the control of pests. The gas is applied in fumigation chambers, cooling chambers or controlled atmosphere chambers.

It was determined that this can be done successfully, if the fumigation is carried out at a temperature between $-1,5$ and 6 °C with a concentration of pure phosphine free from ammonia, between 1,000 and 2,000 ppm in a sealed enclosure, with an exposure time between 24 and 72 hours, depending on the pest. The main condition to avoid damage to the fruit during the fumigation period is to maintain the temperature low, not warming up the fruits.

The best way to do the treatment with phosphine is to fumigate the fruit and vegetables directly in the cooling chambers, where the fruit is stored after the selection process, and leaving the cooling system working during the whole fumigation period.

No changes in taste, smell, texture, color or shelf life of the fruit, if fumigation has been conducted at low temperature. There are no residues after fumigation on the fruits and no product residues that have to be deactivated and disposed after fumigation.

iii. Produce Temperature Records

The Fumigator shall record each temperature reading and the maximum and minimum produce temperatures of the load on the Fumigation Treatment Record.

Calculating Phosphine Dosage Rates¹

Dosage describes the amount of fumigant gas that must be introduced into a fumigation enclosure and the length of the exposure period. A dosage is always expressed in two parts:

- (i) a statement indicating the amount of fumigant gas required and
- (ii) a statement giving a period of time (the exposure period).

The amount of fumigant gas required may be presented in two ways:

- as an amount of fumigant gas per unit of volume of space/ enclosure, usually given as grams per cubic feet or metre, which is abbreviated as g/ft^3 or g/m^3
- as an amount of fumigant gas per unit of weight of commodity, usually given as grams per tonne, which is abbreviated as g/t .

Concentration-Amount of fumigant present in a known volume

- High concentrations are usually expressed in as weight per unit of volume-grams per cubic meter (g/m^3)
- Lower concentrations as **-parts per million (ppm)**

Formula for Dosage calculation

In order to calculate dosage, you must have the following information:

1. Treatment schedule
2. Volume of the fumigation chamber (**ft^3 or m^3**)
3. Temperature of commodity and air ($^{\circ}C$ or $^{\circ}F$)

¹ **Dosage rates are discussed in detail in the Standard Operating Procedure.** In this document the symbol g/ft^3 or g/m^3 means grams per cubic feet or grams per cubic meter.

Refer to the specific treatment schedule to determine the dosage rate (g/ft³)-**Refer to Standard Operating Procedure (SOP)**. Once the chamber volume has been determined the number of fumigant/weight of fumigant required should be calculated using one of the following formulas:

$$\text{Dosage (gms.)} = \text{volume (ft}^3\text{)} \times \text{dosage rate (gms./1,000 ft}^3\text{)}$$

$$= \frac{\text{volume ft}^3 \times \text{dosage rate (gms)}}{1000 \text{ ft}^3}$$

EXAMPLE: A Chamber requires 20 grams of phosphine per 1000 ft³ for 72°F (22.2°C) (air and commodity temperature). The size of the chamber is 100' x 75' x 50'. To determine the number of Fumiphos tablets and pellets to introduce, use the following procedure:

Size of the Chamber: 100 x 75 x 50 = 375,000 ft³

Step 1:

$$(20 \text{ g} \times 375,000 \text{ ft}^3) / 1000 \text{ ft}^3 = 7,500 \text{ g}$$

Step 2:

$$\text{Tablets: } 7,500 / 1.0 = 7,500 \text{ Tablets}$$

$$\text{Pellets: } 7,500 / 0.2 = 37,500 \text{ Pellets}$$

Tablets are up to five times larger than pellets

Another Formula

Calculate dosage by doing the following

$$\text{Amount of fumigant (g)} = \frac{\text{Volume of Chamber (ft}^3\text{)} \times \text{Dosage (g/ft}^3\text{)}}{\% \text{ Fumigant Release} \times 1000}$$

For Tablet Calculation:

Volume of the Chamber (Enclosure): 100 x 75 x 50 = 375,000 ft³

Dosage: 20g/ft³

Amount of Phosphine (Fumiphos Tablets) release (% Fumigant): 1.0 g of phosphine

$$\text{Amount of fumigant (g of Tablet)} = \frac{375,000 \times 20}{1 \times 1000}$$

$$\text{Amount of fumigant (g)} = \frac{7500000}{1000} = 7500 \text{g (Tablets)}$$

For Pellets Calculation:

Volume of the Chamber (Enclosure): 100 x 75 x 50 = 375,000 ft³

Dosage: 20g/ft³

Amount of Phosphine (Fumiphos Pellets) release (% Fumigant): 0.2 g of phosphine

$$\text{Amount of fumigant (g of Pellets)} = \frac{375,000 \times 20}{0.2 \times 1000}$$

$$\text{Amount of fumigant (g)} = \frac{7500000}{200} = 37500 \text{g (Pellets)}$$

Remember also that dosage recommendations consist of two parts (i) the amount of phosphine generating formulation that must be put into the fumigation enclosure and (ii) the length of the exposure period.

Read the label carefully then carefully select and calculate the dosage in accordance with the instructions on the label. Do not exceed the maximum allowable rate.

Record keeping

All details relevant to the dosage applied during a fumigation must be recorded on an appropriate 'record of fumigation'. These must include:

- the dosage chosen for the treatment
- the calculations made to decide on the total amount of phosphine required for the treatment

Plan presentation techniques

- Lectures
- Brainstorming
- Q & A
- Demonstrations
- Observation
- Discussions in small groups
- Practical Exercises

Evaluation

Knowledge Acquisition

Share your own ideas (as relevant), but the focus should be on participants creating their own knowledge and understanding.

Ask the small group at the end of the session to write their responses to the following questions

1 How to measure fumigation chamber and enclosure?

2 How to calculate fumigant dosage rates?

Focus on Timing

- Structure interaction time into all your sessions
- Keep your session on track. Start on time and finish on time

Session 10: Application procedures and duration of fumigation

OBJECTIVES

By the end of this session, participants will be able to:

Knowledge:

- Understand and learn about the procedures for Fumigation and exposure period

Performance:

- Participants know the techniques for operating the Phosphine Fumigation Before Fumigation (Pre-fumigation), During Fumigation Period (Application Operations during Fumigation) and after the fumigation (post-fumigation)
- Relate skills development to operate the phosphine fumigation

Attitude:

- Appreciate the importance of fumigation duration to support and assure adequate control of insects and other pests
- Develop self-reported confidence, attitudes and skills in practical procedures among participants

Clarify key topics and related concepts

Step 1

After greeting the participants and explain the activities (Pre-Fumigation, Application Operations during Fumigation and Post-Application Operations) for the day, do a quick review of method how to measure the fumigation chamber/enclosure and how to calculate the dosage rates of fumigants. Also recall with the participants that in previous discussions on exposure period. These simple discussions also lead a fumigation procedure, which is a tool that allows the systematic assessment of all fumigation factors that can positively or negatively affect the fumigation performance.

Step 2

The facilitators explain on the following points in details:

Demonstrations plus active individual participation in performing the various procedures involved in fumigation are considered to be essential parts of fumigation course of instruction. The practical training should demonstrate with step-by-step directions how to carry out various procedures. Similarly, it should emphasize the importance of systematic planning and conduct of every stage of a fumigation operation from initial planning to final clearance of fumigant. Planning should include the following steps:

- a. Preliminary inspection of facilities to be fumigated.
- b. Arrangements with officials and personnel, plus notification of appropriate authorities - fire, police departments, etc.
- c. Materials required for the fumigation.
- d. Duties to be performed by each individual of the fumigation crew.

- e. Preparation of the facility to be treated.
- f. Pre-application procedures.
- g. Fumigant application and operations to be performed during the treatment (surveillance for gas leaks, analysis of concentrations).
- h. Aeration and post-fumigation procedures.

Step 3

The fumigator should describe one complete fumigation cycle, from loading the product into the enclosure to removing the product after fumigation. Also describe all measures taken to minimize emissions of the fumigant during and after the fumigation cycle.

Step 4

A check list that gives a record of all equipment required and all duties to be performed should be made. Explain the reasons why participants take it seriously. The facilitators should provide enough experience to allow the new fumigator to use fumigants effectively and safely and to adapt his treatments to the varying situations that he may encounter

Step 5

Then, start a discussion on Pre-Fumigation, Fumigation and Post-Application Operations. Divide participants into three groups, for example, Pre-Fumigation, Fumigation Period and Post-Application Operations and ask them to discuss for 20-25 minutes in their groups.

Step 6

Share your own ideas (as relevant), but the focus should be on participants creating their own knowledge and understanding. Encourage them to work together. Ask participants of each group to brainstorm some actions under the sub-sections of the topic and note the group findings on the paper. Use the following questions to guide the discussion and make sure that operational procedures are introduced:

- a. What do you understand by FMP?
- b. Why should I seal the structure?
- c. How do I seal the structure?
- d. Should I use tablets or pellets?
- e. How much aluminum phosphide do I need?
- f. How do I apply the fumigant?
- g. How long does it take to fumigate?

Also provide blank Fumigation Dosage Chart to all participants for professional skill test

Ask if there are any more questions or issues to be discussed. Review the meeting and remind the participants of the next meeting.

Organize Reference Materials

1. General principles of fumigation

Application is defined as the time period covering the opening of the first container, applying the appropriate dosage of fumigant and closing up the site to be fumigated. Aluminum phosphide has achieved a key status in the International market. Nepal is entirely dependent on phosphine as the fumigant for disinfecting grain stacks, as it is low-priced, easy to apply and does not affect the quality even after repeated applications. Effective fumigation requires that phosphine gas at lethal concentration is held in stacks long enough to kill all stages of the target pests. Loss of measurable phosphine gas results due to absorption by grain, penetration through fumigation sheets and leakages through holes and gaps. **The recent phase out of methyl bromide has left phosphine as the only economically and environmentally viable fumigant for the industry.**

Now-a-days, phosphine resistance is documented in every part of the world due to poor fumigation practices. The resistance to phosphine occurs because of improper application of phosphine pellets/tablets, exposure of insect populations to sub-lethal dosages or due to poor fumigation covers. The best way to prevent resistance is to use phosphine correctly — in a gas-tight, sealed chamber/enclosure.

2. Application Phases

Before performing fumigation, the applicator needs to understand clearly about Application Phases. The FMP is a part of these procedures to ensure minimum human exposure and assure adequate control of insects and other pests.

a. Pre-Fumigation (Pre-application)

Before any application is undertaken, applicator is required to create a fumigation management plan by law. This is part of the paperwork carried around by your fumigation team on the way to the site.

Pre-fumigation is a copy of the signed statement containing the information required by item this section. It observes the application of the fumigant formulation to verify that the dosage, method of application, sealing of the space, and the placement of warning placards etc are as specified in this check lists.

b. Fumigation Periods (Application Operation)

Fumigation is a method of using a lethal gas to exterminate pests within an enclosed space. There are two methods of performing fumigation. One is to seal the structure with plastic, tape or other sealing materials, and the other is by enclosing the structure in a “tent” of vinyl-coated nylon tarpaulins.

This means whole-structure fumigation with fumigant according to label directions or applicator manual (SOP).

Fumigation is the process of adding a fumigant to a fumigation chamber/enclosure with the specific objective of killing pests. Best fumigation practice is the process that provides a successful treatment and results from a practical combination of all the procedures required during a fumigation treatment to ensure that:

- the people doing the fumigation remain safe and are not harmed,
- all people in the area around the fumigation treatment area remain safe and are not harmed,

- the environment is not harmed,
- all life stages of all target pests are killed,
- the commodity or product being treated is not damaged in any way.

Each of these five objectives, which make up a successful fumigation, will happen when best fumigation practice is followed wherever a fumigation treatment is done.

c. Post-fumigation (Post-Application Operations)

To restore the correct profile the component will be required to be:

- kept FMP for 2 years after completion of the fumigation
- completed and recorded information in the post application summary and kept with the FMP.

3. Fumigation Check Lists

a. Pre-fumigation

Here's everything you need to know about fumigation preparation.

- A written, site-specific fumigation management plan (FMP) is required before fumigation begins.
- At least two certified and trained applicators
- Applicators trained in use of safety equipment
- What is the reason for fumigating? (What are the pests?)
- Grain characteristics known:
 - Temperature _____
 - Moisture _____
- Dosage calculated before fumigation
- Safety equipment inspected or tested
- Two approved gas masks and canisters or two SCBA.s on site or available
- Proper gas-detection equipment available
- Fumigation practiced
- Escape plan practiced
- Inspection of facility
- Locks or lockouts available
- Sealing material and plastic sheeting available
- Electrical, gas, and water cut-offs identified
- Determine time required to fumigate
- Determine number of certified persons available (2 is the minimum)
- Check structure to make sure no one is present except the applicators
- Seal structure
- Post areas to be treated immediately before fumigation. Placarding (Place warning signs) should be bilingual if workers or neighbors do not read English
- Turn off electrical power

b. Fumigation Period (During)

Here's everything you need to know about application procedure for fumigant.

- Record who is doing fumigation
- Record date and time of fumigation
- Record rate of fumigant used
- When fumigating, consider prevailing wind and other factors that may affect the fumigation
- Applicators sign fumigation record log sheet
- Record time fumigation was started
- Self-Contained Breathing Apparatuses (SCBA.s) or gas masks and their canisters must be on site if phosphine levels will go above 0.3 ppm during application
- All applicators know the evacuation plan
- Practice every step of the fumigation in sequence before beginning
- Establish communications from the inside to the outside of structure
- Provide watchman if necessary
- Begin fumigation

c. Post Fumigation

Here's everything you need to know about post fumigation.

- Properly dispose of empty fumigant containers
- Wait the appropriate time before aerating the facility
- Remove tarps or plastic from the top of the grain
- Allow enough time to ventilate and aerate in accordance with structural limitations.
- Before re-entry, use a suitable gas detector to determine fumigant concentration so that appropriate precautions may be taken. Most fumigants do not provide adequate odor warning.
- Record level monitored
- Record what air-monitoring device you used
- Remove warning signs when aeration is complete.
- Turn on electrical power
- Remove lockouts
- Remove sealant tape
- Description of Incidents
- Dispose of empty containers and used canisters
- Record date and time of fumigation completion
- Ensure aeration is complete before treated vehicle is allowed onto public roads

4. Application Procedures and Duration of Fumigation

a. Fumigant Application

Fumigation is the application of fumigant within a measured space that is enclosed by tarpaulins or otherwise sealed. Fumigant Application is the process of introduction of a specific toxic gas or a chemical releasing toxic gas into the commodities or product or to part or all of a structure to be treated and its enclosure. Fumigation is only practical way to kill internal insects or insects deep within the grain mass. The primary purpose of fumigation is to obtain quarantine control of the pests in all stages of development in, on, or with the product being fumigated. The objective of fumigation, therefore, is to introduce a killing

concentration of gas into the commodities or product or to part or all of a structure and to maintain that concentration long enough to kill all stages of target organism(s)/pests present.

Fumigation is the application of fumigant within a measured space that is enclosed by tarpaulins or otherwise sealed. The fumigant must be confined for a time and at a concentration sufficient to kill the target organism. At these concentrations, the fumigant is hazardous to human beings. Best fumigation practice is the process that provides a successful treatment and results from a practical combination of all the procedures required during a fumigation treatment to ensure that:

- the people doing the fumigation remain safe and are not harmed all people in the area around the fumigation treatment area
- remain safe and are not harmed the environment is not harmed all life stages of all target pests are killed the commodity or product being treated is not damaged in any way. Each of these five objectives, which make up a successful fumigation, will happen when best fumigation practice is followed wherever a fumigation treatment is done.

b. What methods are used for fumigation?

There are really only a few types of methods for fumigation. The first method is to completely seal the structure off with a sealant such as tape or plastic to ensure the fumes to kill the pest stay in that particular area you desire to rid the pest from.

The second method consists of concealing the building in a nylon tent. Once the process of fumigating is done, and the chemicals have dissipated them and plastic or nylon tent would be removed.

c. What is technique of fumigation?

Solid fumigation: This type of fumigation is released as powder, pellets, and tablets in the measured amount of necessary for handling the particular size pest problem you have. They say that this method is less harmful to the environment and much easier and safer to use than the gas form. Some popular solid fumigation chemicals are Aluminium phosphide and Calcium cyanide.

d. Why Fumigate?

The great advantage of structural fumigation over other methods of pest control is that all target pests are killed within the fumigated space, regardless of their location. Fumigants follow all the physical laws of gases; therefore, their molecules diffuse freely through air and infiltrate the minutest of spaces. The disadvantage of fumigation is the lack of residual activity to protect the fumigated space from subsequent infestation.

5. Preparing, Loading and Sealing the Chamber

a. Preparing the Chamber

Chamber means a permanent or tarped enclosure made from gasproof material specifically designed for the purpose of fumigation. The Fumigator shall check the chamber for damage and possible leak sites prior to the chamber being loaded. Before any fumigant is released, the building/chamber should be checked to ensure it is clear of people, non-target animals and plants and to ensure that no unauthorized person can gain access until the building has been vented and declared safe by the fumigator-in-charge.

Any damage (eg damaged door seals or holes or tears in chamber walls) shall be made good prior to loading. The Fumigator shall check chamber circulation and ventilation systems are operating correctly and ensure all vents are closed and sealed prior to the chamber being loaded.

When working inside the building, fumigators should wear RPE, unless tests with detection equipment show that concentrations of fumigant do not exceed the WEL or other appropriate level.

The building should be made as gas tight as possible. All windows, doors and other openings from the building should be sealed with masking tape or other suitable material, unless the building is to be enveloped completely by fumigation sheets of low permeability.

At the end of the fumigation period, the fumigators, wearing RPE, may break the seals and open doors and other openings accessible from outside the fumigation area and then withdraw beyond the risk area for the ventilation period.

When buildings are to be occupied by people, they should not be allowed back into the building until suitable monitoring equipment shows that the area contains gas levels below the WEL or other appropriate level for that fumigant.

At the end of the ventilation period, all piping and application equipment used for fumigation should be disconnected, dismantled and removed from the fumigation area and risk areas.

A certificate of clearance should be issued after the fumigator-in-charge has tested the atmosphere in all floors or sections and is satisfied that it is safe for people to enter without RPE.

Loading the Chamber

- Before fumigation, the commodity should be loaded into the fumigation enclosure in a manner that ensures sufficient space for adequate circulation of the fumigant. To ensure fumigant penetration into the commodity, separators such as pieces of wood should be used.
- Prior to stuffing of the containers, each empty container is fully inspected on the exterior and interior to check for the presence/absence of pest
- The condition of commodities (Raw materials, agricultural and other primary products as objects of large-scale trading) and their moisture level
- Produce may be fumigated either unpacked, in bulk bins or following packing.
- The Fumigator shall ensure produce packaged or covered with impervious materials such as plastic bags or waxed paper are opened, cut or removed to allow adequate penetration of the gas.

Key factors to consider when loading a container include:

- Weight Distribution- The weight of the goods should be spread evenly over the entire length and width of the floor of the enclosure.
- Goods Variation & Compatibility- Weight, size, density, and properties such as solid **or liquid, and even odors of commodities are factors to be considered when loading your cargo into a container.**

Loading rates within the chamber must be –

- For fruit and vegetables – not less than 30% or more than 50% of the volume of the chamber when empty.
- For all other plants and plant products – not more than 50% of the volume of the chamber when empty.

b. Introducing Phosphine into Chamber/Enclosure

- Before starting to introduce phosphine into chamber or enclosure, it is important to:
- plan how the phosphine-generating formulation will be distributed inside the enclosure
- plan how the enclosure will be ventilated safely at the end of the exposure period
- take action to protect any materials and equipment (electrical apparatus, computers, machines etc.) containing copper that may be damaged by exposure to phosphine gas during the exposure period and ventilation process
- measure the chamber/enclosure or stack to be fumigated, work out the volume, then calculate the dosage based on its volume (which is more effective than dosages based on weight of commodity)
- mark out the danger area around the fumigation enclosure
- put warning signs on the enclosure and around the danger area.

c. Sealing the Chamber

Once all of the produce has been placed in to the chamber, the Fumigator shall ensure the chamber is gas tight by closing all vents and access pints and checking all possible leak sites such as doors and joints.

Sealing the structure before fumigation is the law

d. How do I seal the structure?

The structure to be fumigated must first be inspected to determine if it can be made sufficiently gas tight. Careful sealing is required so that adequate gas levels are retained. Various materials are available, including plastic (4 mil or thicker is best), duct tape, expanding foam, and caulk. If you think you will need to fumigate, seal all cracks and crevices before you load the commodity into the structure. Every step you take to seal potential leaks and allow the gas to be distributed throughout the enclosure will improve effectiveness. All windows, doors and other openings from the building should be sealed with

masking tape or other suitable material, unless the building is to be enveloped completely by fumigation sheets of low permeability. The building should be made as gas tight as possible. Good sealing is necessary for an effective fumigation.

After the building is sealed, it is a good idea to check it for leaks before beginning fumigation. Check for leaks by using thermal smoke generators against the walls and sealed openings inside the building. A person on the outside can mark the areas where smoke escapes, so they can be resealed. Proper sealing of chamber/ enclosure or bagged stacks is the most important factor for both 100 % kills of insects in the commodity and optimal workers safety in the surroundings.

e. Why should I seal the structure?

The most important aspect of a successful fumigation with any fumigant is the degree to which the space is sealed. Good sealing is necessary for an effective fumigation. **DO NOT FUMIGATE A STRUCTURE THAT CANNOT BE SEALED SUFFICIENTLY GAS TIGHT**

- If you don't, the gas will probably leak before it reaches a high enough concentration to kill all the insects.
- Unsealed or poorly sealed structures are hazards.

f. Equipment Required

- Appropriate personal-protection equipment, including gas masks and canisters suitable for use with phosphine, or self-contained breathing apparatus (SCBA), rubber gloves, and overalls must be available for all staff.
- Enough phosphine-generating preparation to make up the required dosage.
- Cardboard or plastic trays (about 30 × 30 cm) into which to place the tablets or pellets.

g. Placard fumigated site

- Placard fumigated site entrances
- Site security, locked entrances, sometimes extra guards

h. During Fumigation

How Does Fumigation Work?

Step 1: The area to be treated is covered with tarp (known as “tenting”) then all ventilation holes and slats are taped shut to ensure the fumigation chemicals are trapped inside.

Step 2: After all humans and animals have exited, pesticide vapors are pumped into the tent structure where they seep into wood, upholstery, and all elements of the structure to kill hard-to-reach pests.

Step 3: The chemicals are allowed to steep for a set period of time, usually between 24-72 hours, then the area is de-fumigated and the tent is removed.

Step 4: A pest control professional will manually check all areas of concern in the property to ensure the pest infestation is under control. Continued follow-up spot treatments may be necessary.

Calculation of Fumigant Dosage

The first step in deciding how much fumigant must be released to achieve the desired concentration is to measure the length, width and height of the area to be treated and figure its volume. (Volume measurements on fumigant labels are given in cubic feet.).

All fumigant labels provide information on the recommended dosages required to effectively treat commodities. Using less fumigant than is recommended can result in too low a concentration of gas to be effective. Using more fumigant than recommended is illegal, adds cost, and may not increase efficiency. Always read and follow label instructions. Physical or environmental conditions may influence the amount of fumigant that must be applied to achieve the required dosage.

Once the dosage recommended for the conditions of your fumigation have been identified from the label chart, you only need to calculate the number of Tablets or pellets to be treated to determine the total fumigant dosage. The number of Tablets or pellets in enclosure may be calculated using the formulas as already mentioned above.

How much aluminum phosphide do I need?

The applicators manual recommends different amounts for different structures. The maximum dose is 725 pellets or 145 tablets per 1,000 cubic feet. Dosage depends not only on the volume of space to be fumigated but on the temperature, the commodity, the moisture content of the commodity, and how well the structure is sealed. **It is important to be aware that a shortened exposure period cannot be fully compensated for with an increased of PH₃.**

Dosage Guidelines for Fumigations with Phostoxin

Product	per 1000 cu.ft
Pellets	100 - 725
Tablets	20 - 145

These dosages are not to be exceeded. Always read the product label to confirm recommended application rates.

Application Rates for Phosphine Tablets

STORAGE CAPACITY		NUMBER OF TABLETS REQUIRED
TONNES WHEAT	CUBIC METRES	
1	1.3	2
50	65	100 (1 tin)
100	130	200 (2 tins)
200	260	400 (4 tins)
300	400	600 (6 tins)

Fumigation Dosage Chart

Chamber Identification:.....

Business

Tablets release about five times more phosphine gas than pellets release

Name:.....

IP Number:.....

Facility Address:.....

Dosage Chart

Concentration (g/m ³)	Calculated Quantity of ALP (gms) (required to achieve indicated concentration)
16	
24	
32	
40	
48	
56	
1 Cubic meter=35.3147 Cubic feet	

This chart is to be located in close proximity to each Fumigation Chamber

Prepared by: (Fumigators Name).

Signature: Date:

Should I use tablets or pellets?

A standard among all aluminum phosphide fumigants is that they are all prepared in two spherical shapes. The rounded tablets weigh approximately 3 grams and release 1 gram of hydrogen phosphide gas when fully reacted. They are 16mm in diameter and are bulk packaged in re-sealable aluminum flasks containing 100 or 500 tablets each. The pellets weigh approximately 0.6 grams and release 0.2 grams of hydrogen phosphide gas. They are about 10mm in diameter and are also packaged in re-sealable flasks containing about 1660 or 2490 pellets. Aluminum phosphide is also packaged as granules in a sachet or small, porous bag.

At high temperatures, it may be safer to use tablets because they break down slower than pellets. If you are fumigating a raw agricultural commodity, you can use tablets or Pellets, without removing the residue.

Different formulations of Aluminum phosphide

Tablets	3 g, releases 1 g of phosphine
Pellets	0.6 g, releases 0.2 g of phosphine
Sachets	34 g, releases 11 g of phosphine
Linear gas generation until 80%, then the generation becomes nonlinear	
Gas release differences among formulations	Pellets > tablets > sachets

Using Tablets

The application rate for phosphine is 52.9 grams per cubic feet (1.5 grams per cubic metre, which in Tablet form equates to three Tablets per 70.6ft³ (2m³).

Remember: 35.3 Cubic feet= 1 Cubic metre

Application of Fumigant

i. Sealed System

The Fumigator calculated the required amount of fumigant. After the required amount of fumigant has been calculated and introduced into the chamber. After the required material or amount of fumigant is placed in the fumigation chamber or introduced into the chamber the opening is sealed. If test insects are used, care should be taken in selecting representative samples for reliable results.

ii. *How do I apply the fumigant?*

The SOP provides tips for how to fumigate chamber, transport vehicles, tarped commodities, and in-transit ship holds. This includes where and how to place the fumigant. Too much aluminum phosphide in any one spot can lead to fires and explosions.

The first step is to find out what the situation is, and secondly decide what to do about it.

The proper introduction of a fumigant into an enclosed area is often referred to as "shooting" or "shooting the fumigant." This introduction is essential to the success, safety and economy of fumigation. It is imperative that the fumigator understand the principals involved as well as the conditions that exist for introducing the fumigant on each job. Remember no two are alike. Methods of application, or shooting, vary according to the type of fumigant used, what is being fumigated, and where the fumigation takes place. The way fumigants are applied in any situation, however, influences the degree of control of the target pests. Incorrect application or improper introduction of the fumigant can damage the area, damage the commodity, or injure people.

Pure phosphine is 1.17 times heavier than air. However, when applied at the concentrations required for fumigation, the phosphine–air mixture is not much heavier than air. This is because it mixes very rapidly with air and very rapidly penetrates large stacks of grain and tightly packed materials.

For this reason it is not necessary to:

- distribute phosphine-generating preparations on top of a stack
- use fans to distribute the gas inside a sheeted enclosure, if required or necessary

When fumigating packaged commodities under gas-proof sheets the tablets or pellets can be spread out on trays to lay under the sheet before it is secured. In warehouses, after the structure is adequately sealed, the tablets or pellets are spread out on trays or sheets of Kraft paper so that residual material can be easily collected at the end of the treatment. Apply the fumigant on the floor through the center of the warehouse. The amount of fumigant applied is usually expressed in weight per volume (for example, grams per cubic meter). Refer to the SOP as well as fumigant label for dosage information.

As soon as the fumigant is placed in the center of the warehouse, everyone should leave through the escape door, which should then be sealed tightly. Phosphine gives off a warning odor similar to carbide or garlic. Just before phosphine is released from the product, an ammonia-like odor will be released to warn the applicator(s) to leave the area at once. This usually occurs about 10 minutes before phosphine is released. The tablets or pellets should never be piled on top of each other or in a mass.

When tablets or pellets are used, they must be placed in cardboard or plastic trays so that:

- The commodity is not contaminated by spent residues (the dust left after phosphine has been released)
- The spent residues can be collected and disposed of safely. Trays containing tablets or pellets must be distributed evenly around the base of the stack. Where a stack is built on pallets, they can be placed under the pallets.
- Where no pallets are used, they may be placed along the sides of the stack. It is not necessary to place tablets at the top of the stack, or in the spaces between bags.
- When placing tablets or pellets in trays, it is important to make sure they are evenly spread out on the tray, in a single layer just to remove piled or heaped up condition during fumigation.
- Oxygen must be present for phosphine to be toxic. It is not recommended to use phosphine in combination with low oxygen controlled atmosphere treatments that would reduce the efficacy of the gas.

Posting of Fumigated Areas the applicator must post all entrances to the fumigated areas with signs bearing, in Nepali and English:

- The signal word DANGER and the SKULL and CROSSBONES symbol.
- The statement, “Area under fumigation, DO NOT ENTER”.
- The date of fumigation.
- Name of fumigant used.
- Name, address, and telephone number of the applicator.

The longer the fumigation time, the more effective the fumigation

iii. Exposure Period

The exposure period is the time required for a specific dosage of fumigant to kill target pests. The exposure period must be long enough for the fumigant gas to reach a toxic concentration in the atmosphere surrounding the target pest. The length of the exposure period differs, depending on the:

- fumigant being used
- most tolerant stage or physiological state (diapausing or active) of the target pest
- temperature of the commodity or product that has to be fumigated
- rate of respiration (breathing) of the target pest
- dosage of fumigant applied into the fumigation enclosure.

The time taken for a fumigant gas to diffuse depends on its density. The lighter the gas, the faster it diffuses. Thus, phosphine diffuses more rapidly than methyl bromide, which is heavier than phosphine. Exposure time should be lengthened to allow for penetration of gas in all parts of storage areas. It is generally true that the liberation of the gas and its toxicity increase as the temperature rises.

Some insect species and life stages are harder to kill than others. It is important that target pest(s) are known and understood. For example, overwintering dormant larva may be more difficult to kill than an active larva of the same species. Use of the maximum duration and concentration of Phosphine is recommended when possible. The following table may be used as a guide in determining the minimum length of the exposure period at the indicated temperatures:

Minimum length of exposure periods for fumigation

Temperature to which fumigant or insects are exposed (Air Temperature)	Minimum Exposure Periods	
	Pellets(0.6 g)	Tablets(3 g)
Below 40°F (5°C)	Do not fumigate	Do not fumigate
41°-53°F (5-12°C)	8 days (192 hours)	10 days (240 hours)
54°-59°F (13-15°C)	4 days (96 hours)	5 days (120 hours)
60°-68°F (16-20°C)	3 days (72 hours)	4 days (96 hours)
above 68°F (20°C)	2 days (48 hours)	3 days (72 hours)
As a rule- of- thumb a minimum of one day should be added to the exposure time listed above		

iv. How long does it take to fumigate?

Do not rush the fumigation. You must give the gas time to build up to the concentration needed to kill insects. Respiration rates of insects are much slower than those of humans, especially in cooler temperatures. Only minutes of exposure of a given concentration of phosphine can be very dangerous to humans while the same concentration may take days to kill insects.

Phosphine has an inhibitory effect on insect respiration and is unique in that it is only toxic to insects in the presence of oxygen - in the absence of oxygen it is not absorbed and is not toxic to insects. However, the action of phosphine is potentiated by carbon dioxide and the exposure time can be reduced when both gases are present.

An applicator should also consider how various life stages of the pest respond to fumigation. For instance, many insects are relatively non-susceptible to fumigants or other insecticides during their egg and pupal stages. Phosphine gas concentration also depends on temperature. It takes at least 2 days for the pellets to break down when the temperature in the structure is above 68 degrees F. It takes about a day longer if you are using tablets. The cooler it is, the longer it takes. Then, it can take up to 2 days to aerate the product after the fumigation.

The length of time required for fumigation varies. A fumigation can take anywhere from six hours to one week or more depending on the type of infestation, dosage, temperature, size of the structure and other factors. There's a general relationship for most fumigants between concentrations and time: high concentrations require shorter exposure time and low concentrations require long exposure to achieve comparable kill.

Exposure Limits

Chemical	Safe Level
Metal Phosphide	0.3 ppm
Methyl Bromide	5.0 ppm
Carbon Dioxide	10,000 ppm

v. *Testing for Leaks*

Once the fumigation has commenced, the Fumigator shall test the chamber for leaks using leak detectors. Any leaks detected shall be repaired immediately. If leaks are detected that cannot be repaired during the treatment, the fumigation must be aborted and the chamber repaired before further use.

The advantages of leak testing are twofold:

- First, it is extremely beneficial to perform a leak test on a component or system prior to it being put into service.
- Secondly, if a leak is suspected in a system, performing one of the leak test methods can help determine leak locations for repairs.

Leaking systems can adversely impact on the environment, system performance and/or a agency's/company's finances due to the loss of product and significant downtime.

**Fumigation must never be done by just one person, which requires added labor.
Always work in pairs**

vi. *Using Two Trained Applicators*

Recent regulations and changes in warning statements on labels now require the presence of two trained applicators during hazardous stages of fumigant application. This strengthens long-standing recommendations to always work in pairs. Two applicators are to work together whenever the application or gas-monitoring requires entry into or work within the confined space where a fumigant is applied.

a. **Monitoring Fumigant Concentration**

Effective fumigation is dependent on maintaining a satisfactory level of fumigant within the chamber during the fumigation. Monitoring of fumigant concentration is not mandatory for every fumigation, however this is preferred practice. Fumigators may elect to monitor gas concentration during fumigations. Where monitoring indicates that the required concentration will not be achieved the Fumigator shall vent of all fumigant, ensure gas freedom and then inspect the chamber for the possible cause. When the cause has been rectified the produce must be re-gassed at the specified rate. See the session no. 10 for details.

b. **Threshold Limit Value**

The Threshold Limit Value (TLV) for phosphine are as follows:

- Single exposure for continuous daily 8-hour exposure: 0.3 ppm or TLV for on 8-hour per day exposure is 0.3 ppm.
- Short-term exposure limit (STEL): 1 ppm or 1 mg/m³
- The threshold level of odor to the human nose is considered to range from 0.005 to 0.5 ppm.
- The maximum concentration for a single exposure for animals should not exceed 50 ppm.

Gas Retention Test Certificate

Operator of Fumigation Chamber					Interstate Produce No:		
Facility Address:					Chamber Identification:		
					Date of Test:		
Chamber Dimensions (internal):	Length: <i>ft or m</i>	Width: <i>ft or m</i>	Height: <i>ft or m</i>	Chamber Volume:	<i>Ft³ or m³</i>		
Fumigator's Printed Name:					External Ducting (if applicable)	<i>Ft³ or m³</i>	
Fumigator's Licence No:				Expiry Date:	/ / /	Total Chamber Volume:	<i>Ft³ or m³</i>
Test Number	Fumigation Rate g/ft ³ (g/m ³)	Quantity of ALP added (g)	Time Fumigation Completed	Gas Concentration at Monitoring Point(s) after 20 minutes	Gas Concentration at Monitoring Point(s) after 2 hours	Time Venting Commenced	Percentage of ALP retained after 2 hours
The fumigation chamber described above has been tested in accordance with requirements of Operational Procedure Fumigation with ALP and has been shown to achieve at least 50% retention of ALP gas after 2 hours fumigation period							
Fumigators Name:		Signature:				Date: / /	
Inspectors Name:		Signature:				Date: / /	

Plan presentation techniques

- Lectures
- Ask questions, get answers
- Demonstrations
- Observation
- Discussions in small groups
- Brainstorming
- Practical Exercises

Evaluation

Knowledge Acquisition

Ask the small group at the end of the session to write their responses to the following questions

1. What does fumigation mean?
2. Why fumigation checklist ("to do list") is important?
3. How to prepare for fumigation?
4. What do I need to do before fumigation day?
5. Where and when will warning placards be placed?
6. The dosage for phosphine is based on the amount of commodity in the chamber. Is this a correct statement?
7. How much aluminum phosphide do I need?
8. How long does it take to fumigate?
9. Are fumigations safe?
10. Asked to perform a group Practice Exercise for Phosphine Application

Focus on Timing

1. Structure interaction time into all your sessions
2. Keep your session on track. Start on time and finish on time

Session 11: Detection of the phosphine gas and different equipment

OBJECTIVES

By the end of this session, participants will be able to:

Knowledge:

- Understand the purpose of detection of fumigants and different tools and equipment available for the purposes.
- Understand the needed information to be known before entering the fumigated area.

Performance:

- Gas detection skills developed and use of correct instrument known

Attitude:

- Appreciate the importance of gas detection with appropriate instrument is developed among the officials of the fumigating unit.

Clarify key words, definitions and related concepts

Step 1

Welcome the participants and share with them the objectives of the meeting. Emphasize here the importance of gas detection before entering the fumigation chamber, or making it ready to use for next lot for fumigation. Information required to run the gas detector is also discussed.

Step 2

Before preparation, clarify key topics and related concepts on gas detection technique. It is necessary to understand the concept of residue in the commodity treated. Start by asking the participants what they understand by gas detection and how it can be done. Link their responses with the Fumigation Management Plan Steps and Components and explain its role while preparing the Fumigation Management Plan.

Step 3

Exercise- Get various types of detection equipment available in the office and explain them on its use. Where possible prepare the chamber ready for detection giving them practical experience. After completing the practical gather in the lecture room and ask every participant to explain on what they have learnt and what difficulty they faced and now how confident are they in using the gas detector. Then respond accordingly.

Step 4

While the groups are working, move from group to group to assist if necessary. Encourage prompt discussion and debate.

Organization of Reference Materials

1. Monitoring Phosphine

Phosphine Monitoring critical and so is essential to measure to know the level of the concentration of fumigant gas in the treated commodity inside a chamber as well as in the area surrounding the chamber to be sure those workers and other people near the fumigation site are safe.

The distribution of gas inside the enclosure and the success of the fumigation involve measuring insecticidal (or fumigation) concentrations of fumigant gases which range between:

- 0.1 and 5.0 g/m³ (70 and 3500 ppm) for phosphine
- 2 and 100 g/m³ (515 and 25,700 ppm) for methyl bromide.

During the fumigation period the warehouse where the fumigation takes place should be checked regularly and it has to be ensured that no unauthorized persons enter the warehouse. The sealing of the chamber/stack should be checked as well. Gas readings to ensure workers safety should be performed in different locations while fumigating, i.e. at four points close to the stack and in other critical points away from the stack in the warehouse.

Exposure to hydrogen phosphide gas may not exceed 0.3 ppm, measured as an eight hour time-weighted average (TWA), for applicators and workers during application. If the fumigator's exposure exceeds the eight hour TWA of 0.3 ppm, approved respiratory protection must be worn

Gas monitoring is essential:

- During application
- During fumigation
- After fumigation

The standard of fumigation can be improved if gas monitoring is practiced. It needs to be mandatory requirement. Monitoring is necessary to ascertain:

- application of correct dosage;
- to ascertain even distribution of gas; and
- Achievement of target concentration.

Who needs to use monitoring equipment?

Anyone entering a fumigated site

- Employees applying fumigant
- Anyone who may enter a possible fumigation site
- Anyone who is responsible for daily gas readings during fumigation

2. Monitoring equipment

A wide variety of equipment is available for measuring phosphine concentrations. The equipment used must be suitable for monitoring in the concentration ranges for concentrations involved in the workplace and also the insecticidal concentrations reached during fumigation treatments.

Instruments for monitoring are available that can measure fumigant gas at: low concentrations only – for workplace safety (TLV) measurements whereas at high concentrations only – for checking the progress of fumigation exposures. Low and high concentrations – from the low safety concentrations to the high fumigation concentrations. The range of concentrations over the whole of the exposure period – a process called dosimetry. Dosimeters are instruments that measure fumigant gas concentrations over the whole of the exposure period. Such instruments can provide an indication of the likelihood of the success of a fumigation treatment. Dosimeters are placed inside fumigation enclosures before they are gassed then removed at the end of the exposure period after clearance has been issued. Dosimeters are available for use with phosphine (as tubes) and provide an indication of the total fumigant dosage achieved (as ppm hours or g hours/m³) during the exposure period. Because the fumigant is absorbed passively, there is no need for pumps. However, it is essential to ensure that these instruments are properly calibrated when specific end-point concentrations are required.

The range of instruments available extends from single-use gas detector tubes (for use either at safety or fumigation concentrations and dosimetry) to multipurpose electronic instruments.

Measuring fumigant concentrations in the health and safety range. Measuring phosphine in the health and safety range (that is, around the TLV, which is 0.3 ppm for phosphine, is much more difficult than measuring the high concentrations found inside enclosures during fumigation treatments. More importantly, there is a risk to human health if inaccurate measurements are made. When making measurements of fumigant gas concentrations in the health and safety range, fumigators must use:

- Detector tubes that have been stored at the correct temperature (normally 5–25°C) for no longer than the ‘shelf life’ printed on their storage container(s).
- Electronic (and other) gas-detection meters that are regularly and properly calibrated.
- Measurements of gas concentration during the exposure period tell the fumigator.
- If enough gas has been added to the enclosure.

When the gas inside the fumigation enclosure is evenly distributed (in equilibrium) and when to start timing the exposure period:

- If gas is leaking out of the enclosure;
- To look for and repair leaks, if safe;
- To top up the dosage, if necessary and safe;
- If the treatment has succeeded or failed.

A critical time to measure the concentration of gas inside the enclosure is at the end of the exposure period, because this is the time when fumigators find out if the treatment has succeeded or failed.

It is best fumigation practice to monitor the concentration of fumigant gas inside the enclosure regularly during the exposure period.

When to measure phosphine concentrations

When using phosphine, it is essential to measure the concentration of gas inside the enclosure:

- six to twenty-four (6–24) hours after dispensing aluminium phosphide formulations and just for information two to four (2–4) hours after dispensing magnesium phosphide formulations

- thirty to sixty (30–60) minutes after dispensing phosphine from cylinders or generators
- This needs to be done to find out: – if the gas is evenly distributed (in equilibrium) inside the enclosure – when to start timing the exposure period.
- at least once every two days until the end of the exposure period to: – make sure gas is not leaking from the enclosure –top-up the gas if the concentration falls below a critical level, if this can be done safely (not towards the end of the exposure period)
- Always use leak-detection equipment to check that the workspace is safe and the enclosure is well-sealed
- Repeated small exposures to phosphine can be dangerous. Always plan ways to minimise unprotected exposure to phosphine.
- If anyone gets sick during fumigation, with symptoms of or similar to phosphine poisoning, do not take chances. Take the person to a doctor and let the doctor decide the cause of the illness
- at the end of the exposure period to find out if the treatment has been a success or a failure.

Refer FAO Manual for Fumigation if need to fumigate with other fumigants.

Gas detector tubes: Gas detector tubes, and associated pumps, are available from several manufacturers. Each brand has its own equipment and specific set of instructions for use.

- Always read and understand the instructions for the pump and tubes you use
- Make sure that you do not contaminate grain or other commodity with the glass tips that are broken off the tubes used to make a test.
- It is important to understand the following general points to obtain correct readings with all types of detector tubes.
- Make sure the tube is calibrated for the gas you are working with.
- Make sure it is in-date (or cross-calibrated with an in-date tube).
- Make sure it measures in the range for the planned use (safety or fumigation).

Always use a pump made by the manufacturer of the tube – because pumps from other manufacturers can give false readings

- Make sure the pump does not leak.
- Always purge every sampling line before taking a sample of gas.
- Make sure the sampling line is not blocked or broken.
- Always use the correct number of pump strokes for the tube you are using.

3. Electronic gas-measuring equipment

Electronic instruments to measure concentrations of phosphine are available from several manufacturers. Each brand has its own equipment and specific set of instructions for use. However, the results obtained from such instruments are only as reliable and accurate as their calibration and ability to remain calibrated. Because of this the manufacturer's recommendations for calibration must always be followed.

4. Maintenance of electronic monitoring equipment:

Monitoring equipment requires regular calibration and maintenance to ensure that it operates effectively. This must always be done according to the manufacturer's specifications. Some instruments have

moisture absorbers and carbon dioxide (CO₂) absorbers fitted to them. The fumigator-in-charge must check and renew absorber or filter materials regularly to ensure that the instrument works properly and accurately.

Using electronic gas detectors always read the instructions for use before using an instrument.

- Some sensors might be damaged when used under pressure or vacuum.
- Always check that the instrument is 'in calibration' Always check the battery
- Always make sure the gas-sampling line is not blocked or broken.
- In emergencies, where a person becomes disabled in a fumigation enclosure or the risk area, the rescue team must include one person who does not enter the enclosure or risk area. This person has one job only – to go for more help
- Safety rules for fumigators using phosphine Fumigation is a precise operation requiring considerable expertise, and it cannot be undertaken without proper preparation. It is important that management and their fumigators-in-charge understand this, and ensure that proper planning is carried out before a fumigation treatment is done.
- Store phosphine-generating products in a cool, dry, well-ventilated and locked area, out of reach of children or unauthorized persons, and away from all dwellings. Keep phosphine-generating products away from water and liquids, which can cause immediate release of phosphine and may result in fire or explosion. Keep phosphine-generating products away from naked flames, because high concentrations of phosphine are explosive. For the same reason, while fumigating with phosphine do not use any equipment that may cause sparks. The product must never be used under conditions that would allow the gas concentration to reach the lower limit of flammability, which is 1.8% by volume (17,900 ppm or 24.9 µg/L or 24.9 mg/m³).

Plan presentation techniques

- Lectures
- Ask questions, get answers
- Demonstrations
- Observation
- Discussions in small groups
- Brainstorming
- Practical Exercises

Evaluation

Knowledge Acquisition

For many of our participants, there may be a significant gap between training and carrying out panel work. If training is to be effective it has to be retained long enough to be taken into the workplace or real-life situation – in our case, into the panel situation, give out a 'Reactionaries' straight after the training has finished and evaluate key learning outcomes. So, encourage the participants to ask questions until they have enough information to explain the related questions. Facilitators most often ask lower-order, convergent questions that rely on participants' factual recall of prior knowledge rather than asking higher-

order, divergent questions that promote deep thinking, requiring participants to analyze and evaluate concepts.

Ask participants the following questions and discuss answers with the group

1. Why gas monitoring is essential?
2. What are mandatory requirements for standard fumigation?
3. When to monitor the concentration of gas inside the chamber?
4. Do you know the standard concentration of gas inside the chamber?

Focus on Timing

- Structure interaction time into all your sessions
- Keep your session on track. Start on time and finish on time

All gas reading records have to be documented properly.

Session 12: Completion of fumigation

OBJECTIVES

By the end of this session, participants will be able to:

Knowledge:

- Understand and learn about the procedures on completion of fumigation

Performance:

- Participants know the techniques for operating the Phosphine Fumigation after the fumigation (post-fumigation)
- Relate skills development to operate the phosphine fumigation after the fumigation

Attitude:

- Appreciate the importance of fumigation duration to support and assure adequate control of insects and other pests

Clarify key words, definitions and related concepts

Step 1

Welcome the participants, and share with them the objectives of the meeting. Make sure that all participants have their handbooks with them.

Step 2

Tell the participants that you would like them to spend some time discussing their experiences on post-fumigation. Use the following questions to guide the discussion and make sure that some key post-fumigation concepts and terminologies are introduced:

- Ask the participants to mention Aeration/Ventilation
- Ask the participants after fumigation what to do
- Ask the participants to discuss why operators do understand the waiting period after fumigation.
- Ask the participants when to release the commodity

When this discussion is done, ask each group to share what was discussed.

Step 3

Summarize the discussions by stating again that what the steps to be done after fumigation are. Repeat this process until all the ideas are shared. Sum up the key points and remind participants about the next meeting.

Organization of Reference Materials

1. Completion of Fumigation

Following things need to be considered after application of fumigation;

- Once the fumigant has been applied, application equipment and surplus fumigant that is no longer required should be removed from the site
- where applicable, cylinder valves should be closed, and valve caps and cylinder caps placed in position;
- all equipment should be ventilated and inspected for solid residues by the fumigator wearing appropriate RPE and PPE, before it is loaded into transport or placed in store; and any contaminated clothing and equipment (including RPE) should be removed and aired in a well-ventilated place for a minimum of two hours or until free of fumigant, whichever is the greater.
- If skin and hair become contaminated, they should be brushed free of any solid residues in a well-ventilated place after work and before smoking, washing, eating or drinking or going outdoors in the rain

2. Aeration/Ventilation

When fumigation is completed, the fumigant must be completely dissipated by aeration before allowing access to anyone inside enclosure or before vehicles can be moved. On completion of the fumigation, first of all windows, doors and aeration flaps of the warehouse should be opened by the fumigation team and the space aerated for at least 1-2 hours.

Measure the fumigant level before entering the fumigated area, and wear protective equipment until the fumigant has dispersed. To prevent injury, notify people who will open the chamber/enclosure and vehicle at its destination that they must wear respiratory protection. After this the sheet can be removed completely from the stack.

3. Waiting period

The storage areas can be used only when monitoring instruments show that gas concentrations have fallen to, or are below, the toxic level value (TLV) set for phosphine.

Fumigated areas must be aerated to 0.3 ppm hydrogen phosphide or less prior to reentry by unprotected workers. If the concentration is still above this level aeration must continue. A written gas-free certificate must be issued at the end by the fumigator in charge.

4. After aeration (Venting)

If it is ever necessary to enter a structure when it is under fumigation, enter with a partner and the proper respiratory protection. After aeration, do not occupy fumigated premises until the fumigation supervisor has tested the fumigated area with the proper equipment and has announced the premises clear and safe to enter.

Fumigation's effectiveness can easily be checked by placing test cages of live target insects in various parts of the building, area, or commodity to be fumigated.

Retrieve test cages after fumigation for a mortality count of the insects.

5. Reentry

If the area is to be entered after fumigation, it must be aerated until the level of hydrogen phosphide gas is 0.3 ppm or below. The area or site must be monitored to ensure that liberation of gas from the treated commodity does not result in the development of unacceptable levels of hydrogen phosphide. Do not allow reentry into treated areas by any person before this time unless protected by an approved respirator.

6. Unloading the Chamber

Unloading of the chamber may commence after the Fumigator has released the produce. The ventilation system should be kept running during this process. Use the following table to determine when to release the commodity

Table: Determine when to release the commodity

If the gas concentration level is:	Then
0.3 ppm or less	Release the commodity
0.4 ppm or more	1. Continue aeration and take concentration readings until the concentration level is 0.3 ppm or less
	Then
	2. Release the commodity

7. Aeration of Produce

Treated produce shall be given sufficient time to air after treatment to allow adequate dispersal of the fumigant out of the produce and ensure that the Exposure Standards of 0.3 ppm of ALP and any applicable maximum residue limits are not exceeded.

8. Residues in Foodstuffs

Unchanged phosphine does not remain in fumigated commodities in appreciable amounts. Tolerance levels of 0.1 mg/kg for raw grains and 0.01 mg/kg for processed foods have been established by many agencies and numerous investigations have shown that the gas desorbs rapidly during aeration to levels well below the tolerances.

9. Identification and Control of Treated and Untreated Produce

The Business/organization shall have adequate procedures in place, which prevent mixing of treated and untreated produce at the facility.

10. Handling un-aerated Commodities

Workers must not be exposed to hydrogen phosphide in excess of 0.3 ppm during moving, storage or processing of incompletely aerated commodities.

11. Fumigation Certification

Each assessed fumigation agency with accredited fumigation operator shall be issued a certificate of approval in the prescribed format

Summary

- Always read and follow the label directions.
- Fumigants are DEADLY. Treat them with care and respect.

- Plan and prepare for each step of the fumigation process.
- Know and use proper safety precautions.
- Properly store and maintain PPE and detection devices.
- Use a checklist to ensure all requirements are complete.
- Keep accurate and complete records.
- Never make assumptions. If you don't know, ask.

Plan presentation techniques

- Lectures
- Ask questions, get answers
- Demonstrations
- Observation
- Discussions in small groups
- Brainstorming
- Practical Exercises

Evaluation

There are numerous types of knowledge, but the most important distinction is between declarative and procedural knowledge. Declarative knowledge refers to one's memory for concepts, facts, or episodes, whereas procedural knowledge refers to the ability to perform various tasks to be done after fumigation.

Discuss following questions in your group:

- What is post-fumigation?
- How will you aerate the structure?
- What should I do if physical discomfort is experienced immediately following fumigation?
- Do we have to wash our clothes after fumigation?
- What do you understand the exposure standards of 0.3 ppm of ALP?
- Do you agree this statement "do not attempt to re-enter fumigated areas or structures before final clearance is given"

Apprenticeship

A period of on-the-job training with an experienced fumigator will enable the participants to observe first hand many of the principles and practices described above. A period of at least four months, but preferably six months, should provide enough experience to allow the new fumigator to use fumigants effectively and safely and to adapt his treatments to the varying situations that he may encounter

Focus on Timing

- Structure interaction time into all your sessions
- Keep your session on track. Start on time and finish on time

Session 13: Record Keeping

This session is to give the participants knowledge on how record keeping of the phosphine fumigant is done and how long this record should be maintained. How the record will help to solve the problem if at all any accident (poisoning) takes place so that timely precautionary measures and first Aid can be provided. Training facilitators/ expert read and follow the Standard Operating Procedure (SOP) while explaining basic knowledge on the above topics.

OBJECTIVES

By the end of this session, participants will be able to:

To get knowledge on:

- purpose of record keeping
- information on fumigation records
- how long record data should be kept and maintained
- Five W's and One H about fumigants record keeping and precautions that need to be taken areas on which information on precautionary measure to be known before starting the fumigation

Presentation:

- Discuss and use five W and one H method to understand more about record keeping and

Attitude:

- With the use of 5W and one H method participant master in record keeping areas easily.

Clarify key words, definitions and related concepts on record keeping

Step 1

Welcome the participants and share with them the objectives and its importance through 13th module of the course. Steps and information required to understand the purpose of record keeping, information on fumigation records and how long record data should be kept and maintained

Step 2

Clarify key topics related concepts. It is necessary to understand the principles of record keeping. Start asking the participants what they understand by record keeping and the areas of record keeping, SPS requirements, General Precautions etc... and accordingly clarify them where required.

Step 3

Exercise: Ask all participants to participate in the discussion to disc. Ask each member to go to the board and write one area which need to be documented while performing the chamber fumigation to explain in the area they are assigned and find out if the assigned topics is dealt correctly or not wherever there is need for improvement intercept. Ask the groups if any member faced a problem understanding topic. If so, respond accordingly. Remember the higher the trust, cohesion, and commitment of group members, the better the output from healthy and hot debate.

Step 4

Now provide them the reference materials also and how to use it.

Organization of Reference Materials

Hand out of the teaching material should be prepared in advance; however, it should be given to the participants only at the end of the session only. The discussion material and mater given in the hand out should be tallied with SOP. The reference material should cover the following areas.

1. Overview of treatment record keeping

Fumigation entities should keep records. These records should be provided to the NPQP in which the fumigation is conducted or initiated for auditing and verification purposes or trace back. Appropriate records for fumigation as a phytosanitary measure should be kept by the fumigation entity for at least one year to enable the trace-back of treated lots. The fumigation entity should keep all records for every treatment. Test records and data need to be kept to validate the data requirements and should upon request be presented to interested parties, for example the NPPO of the importing country, for consideration in establishing an agreed commodity treatment.

All gas reading records have to be documented properly.

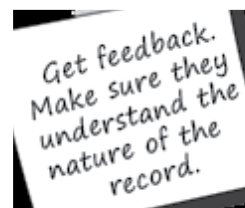
2. Record keeping

Fumigation operators should keep records. These records should be available to the NPQP for auditing and verification purposes or trace back. Appropriate records for fumigation as a Phytosanitary measure should be kept by the fumigation entity for at least one year to enable the trace-back of treated lots.

Practice of keeping fumigation records (Test records and data)

Information that should be recorded includes:

- identification of enclosure and fumigation entity –
- enclosure leakage testing records (as appropriate) –
- equipment calibration records –
- commodity fumigated –
- target regulated pest –
- packer, grower and place of production of the commodity –
- fumigation lot number –
- lot size and volume, including number of articles or packages –
- identifying markings or characteristics –
- date of fumigation –
- any observed deviation from the treatment schedule –
- air and commodity temperature records –
- fumigant dose and concentration records –
- fumigant volumes (dose rate) calculated and added throughout fumigation.



All those procedures should be appropriately documented and records, including those of monitoring inspections made and phytosanitary certificates issued should be maintained for at least one year. In cases of non-compliance or new or unexpected phytosanitary situations, documentation should be made available to importing country on request and for emergency action.

The fumigation agency must report to the In-charge of NPQP/RPQO on monthly basis regarding the stock/use of fumigant and the details of all the fumigation operations carried out.

Plan presentation techniques

- Lectures
- Ask questions, get answers
- Demonstrations
- Observation
- Discussions in small groups
- Brainstorming
- Practical Exercises

Evaluation

Knowledge Acquisition

Starting with convergent questions helps discussion participants to establish a base of shared knowledge and builds student confidence. The goal is to follow a logical order rather than jump around when asking questions. Use the following questions to help participants begin reflective practice.

1. What is a recordkeeping system?
2. How long I must keep records
3. Who is responsible for managing records?
4. What is the significance of keeping complete and accurate records before, during and after fumigation?

Focus on Timing

- Structure interaction time into all your sessions
- Keep your session on track. Start on time and finish on time

Session 14: Auditing and communication

This session is to expose the participants on need of Auditing & Communication on efficient running of fumigation chamber and also to guide how the technical auditing and communication system auditing should be should implemented It also tells the Training facilitators/ expert to read and follow the Standard Operating Procedure (SOP) while facilitating the participants on the respective topics.

OBJECTIVES

By the end of this session, participants will understand the:

- purpose of technical Auditing and importance of communication
- Participants will understand the need of effective management of the fumigation system by NPPO in coordination with NPQP manage regularly to conduct technical auditing of the fumigation unit and ensure that the SOP is adopted properly and communicate with new developments in fumigation system /technique. And also the responsibilities of Fumigation Operator, traders.
- Reporting of Fumigation Activities to the concern in right time and in right manner
- Five W's and One H about auditing and communication system in running fumigation chamber efficiently

Presentation:

- Discuss and use five W and one H method to understand more about Auditing and communication

Attitude:

- With the use of 5W and one H method participant will fully understand the importance of technical auditing.

Clarify key words, definitions and related concepts on Auditing and communication

Step 1

Welcome the participants and share with them the objectives and importance of auditing for Smooth implementation of Fumigation chamber;

Step 2

Clarify key topics related concepts. It is necessary to understand the principles of record keeping. Start asking the participants what they understand Auditing and communication and the areas of record keeping, SPS requirements, General Precautions etc and accordingly clarify them where required.

Step 3

Exercise: Ask all participants to participate in the discussion and ask each participant to go to the board and write one area which need to be audited regularly to show that the fumigation chamber is running efficiently and safely. Ask the groups if any member faced a problem understanding topic. If so, respond accordingly.

Step 4

Now provide them the reference materials also and how to use it.

Organization of Reference Materials

Hand out of the teaching material should be prepared in advance; however, it should be given to the participants only at the end of the session only. The discussion material and mater given in the hand out should be tallied with SOP. The reference material should cover the following areas.

The Auditor / team need to carry out detailed physical inspection/ audit/ assessment of the fumigation facility especially focusing the, HR status, whether duties and responsibilities are carried out as envisaged in SOP or not. The team should in detail discuss the status of execution of the SOP by the operators and officer in-charge. The situation report should be submitted to NPPO. NPPO accordingly should take necessary action.

Similarly, standard operational procedure is documented in line with the provisions of the standard established by the NPPO of Nepal. The fumigation Unit must ensure that the records and documents relating to supervising, monitoring and testing of compliance with the procedures are maintained in prescribed format and kept up to date.

Auditors/team should audit considering the followings areas whether these have been put into execution or not;

1. For Smooth implementation of Fumigation chamber;

- Adequate qualified fumigation operators are there or not and also their transfer been done within the Quarantine program.
- Check if the new comer have /had the fumigation training prior joining the unit, or not. The level of knowledge and skill of the persons working there.

2. Fumigation Operator level

- Level of adoption of the SOP and instructions issued by the NPPO/NPQP from time to time
- Proper records on stock and use of fumigant status record
- System of display warning signs and take adequate safety precautions during fumigation.
Safety Measure of workers adopted during fumigation operations.
- Supervision of all fumigation operations.
- Practice of monitor whether gas leakage detection equipment's are there or not whether the problem has been addressed properly taking appropriate measures to seal leakage, monitor gas concentration and aeration of fumigated commodities.
- Status of essential fumigation /safety equipment's.
- System or mechanism of disposal of empty containers of fumigants in safe manner as per the Insecticides Act and Rules.
- Registration status of Fumigation Operator at NPPO
- Issue fumigation certificate after ensuring that fumigation has been carried out effectively

3. The traders or exporter/importer level:

- Whether the traders have given full information on the commodity to be treated especially regarding any specific conditions of the consignment.
- informed any other factors that affect treatment of commodity such as impervious package or sportive nature of commodity to ensure adopting correct fumigation practices and follow safety precautions, while undertaking fumigation treatment operations
- ensuring not to undertake fumigation if proper safety measures are not followed
- Regularity of Report sending to NPPO/ NPQP of various activities concerned in relation to fumigation in the unit including stock and use of pesticides in the prescribed format /RPQS

4. Fumigation Certification:

Audit how the fumigation certification is being issued. Whether the Fumigation Operator, before issuing Fumigation Certificate, has:

- monitor the fumigation treatment to ensure that correct dosage of fumigant is applied and appropriate concentration of fumigant is maintained to make it effective and proper documentation being done.
- affix an official stamp on the fumigation certificate with an accreditation number assigned
- Record all the details of fumigation
- Medical Certificate of Fumigation Operator and Fumigation Assistants is updated
- Calibration Certificate of Equipment
- ALP Stock Register & Attendance Register

5. Educational Qualifications

As mentioned in Chapter 1. subsection 1.14.2.1 of SOP

6. Training Requirements

The practice of pest control is becoming increasingly specialized and requires professionals who are familiar, not only with the pest and the pesticide, but who also have a good knowledge of the many factors related to pest infestation and control and a working knowledge of the principles of fumigation is very essential. It is to be remembered that just by having idea of insect's pest and chemical properties of the chemical would not of much value in safe handling of the fumigants. It requires both theoretical and practical experience in handling the fumigants. Thus all technicians under Plant Protection and Plant quarantine may not be capable of handling the fumigation.

7. Equipment & facilities

- The operators shall be required to undergo training for a period of at least 7 days organized by the NPQP or by the agencies authorized by NPPO. The Course and duration should be As mentioned in 1.14.2.2.

- Status of the essential equipment and accessories that are required for undertaking Aluminium Phosphide treatments and their working condition, availability of a separate secured place for stocking fumigant, proper upkeep and maintenance of safety equipment's (gas masks) and calibration of measuring equipment's and gas detection equipment etc.

8. Documents of Fumigation:

The following records and documents relating to supervision, monitoring and testing of compliance with the due procedure for ALP fumigation if are maintained or not will be audited.

- Stock and Issues Register for fumigant (ALP)
- Monthly report of various activities of agency including stock and use of Aluminium Phosphide in the prescribed format
- Record of Servicing of Equipment & Replacement of Accessories
- Test Report of sheet permeability provided by the manufacturer
- Personal Health Records of Fumigation Operators & Co-workers
- Details of personnel trained in First Aid
- Record of Accredited Fumigation Operators
- Copy of Job order
- Fumigation Certificates
- Equipment stock register
- Monthly Report - fumigation certificate wise

9. Reporting of Fumigation Activities:

- The Chief of the fumigation unit must report to NPPO and respective NPQP on monthly basis regarding the stock / use of Aluminum Phosphide fumigant and the details of all the fumigation operations carried out in the preceding month.

10. Detectors for Alp:

- Paper strip detectors sensitive to 0.3 ppm.
- Detector tubes sensitive to 0.01 mg PH₃.

11. Check if the recommended safety measures are properly exercised and if the required detection device are updated and ready to use condition.

- Some fumigants react with components of commodities to form new compounds. Ethylene oxide can combine with the chlorides and bromides in food to form toxic chlorohydrins and bromohydrins (Scudamore and Heuser, 1971). Methyl bromide is decomposed in wheat to form several non-toxic derivatives (Winteringham et al, 1955) and hydrogen cyanide can combine with sugars in dried fruit to form laevulose cyanohydrin (Page and Lubatti, (1948). Other fumigants may also react with materials being fumigated.

- In addition to residue from the fumigant, some by-products from formulations such as aluminum phosphide and calcium cyanide can leave residue on food materials. An ash-like residue of aluminum hydroxide, along with a small amount of undecomposed aluminum phosphide, is left after phosphine is generated. Calcium cyanide leaves a residue of calcium hydroxide after hydrogen cyanide is released.
- The residues remaining in treated materials after a fumigation may be of significance both as an occupational hazard to workers and others exposed to desorbing gas and as a hazard to consumers eating treated foods.
- Although desorbing fumigant may not be considered a residue in the usual sense, appreciable amounts can remain for long periods of time and create hazards for personnel in the immediate vicinity. When treated goods are kept in confined spaces, such as airtight bins or a chamber, the residual fumigant can be of considerable consequence. There is great concern over the possibility of long-term effects that may develop from exposure to desorbing fumigant.
- Some fumigant may remain in food materials and reach the ultimate consumer. Attention has been focused on residues of pesticides in food in recent years because of the harmful effects they may have on human beings. Concern over toxic chemicals in food has been heightened by sensitive detection methods that show traces of residue not previously suspected. The significance of very low levels of some compounds is not known. However, it is believed that the human body can tolerate small amounts without adverse effects.
- Good fumigation practice will normally require that treatments should be conducted in such a way as to keep residues to the lowest possible level

12. Records of Fumigation:

Minimum information that may be required to be recorded includes, however, as per the requirements and working strategy some additional documentation may be further added.

- The names of all personnel engaged either on commodity handling or fumigation work during the application of fumigant, and the nature of their duties;
- The location of treatment;
- The type of produce treated;
- The quantity of produce treated;
- All temperatures measurements taken prior to fumigation;

Volume of enclosure;

- The total quantity in grams of fumigant released in the fumigation;
- Results of gas tightness test;
- The date and time of commencement of fumigant application;

- The fumigation dosage rate used (expressed preferably in grams per ft³ or m³ or tablets, pellets, and exposure time;
- The completion time of the fumigation;
- Length of airing period;
- Record of Servicing of Equipment's & Replacement of Accessories;
- Test Report of sheet permeability provided by the manufacturer;
- Personal Health Record of Fumigation Operators & Co-workers;
- Record of Accredited Fumigation Operators;
- Details of any incidents or accidents;

13. Storage of Document

Documentation of the whole activity related to fumigation as supporting evidence describing official controls treatments and this information upon the requested by the importing country/ies for the traceability of the products all the information as mentioned above need to be documented at the office of NPQP chief, NPPO and Fumigation units. Hard copy need to be maintained at Fumigation unit. The information if required by the NPPO of importing country should be made available through the NPPO only.

14. Record Keeping

Information on the treatment should include to the extent possible:

- scientific name of pest and commodity
- date of treatment made and name of operator, time and concentration of the PH₃ used
- Date of certification
- references, if any
- additional information, of pest occurrence on the commodity,
- Reports of new occurrences of pests should also include information on any measures taken, and such reports made available on request.
- Procedures
 - The NPPO should maintain guidance documents, procedures and work instructions as appropriate covering every aspect of the certification system.
 - control over issuance (manual or electronic)
 - identification of issuing officers
 - inclusion of additional declarations
 - completion of the treatment section of the certificate

Records

In general, records should be kept concerning all activities mentioned in this SoP. A copy of each fumigation certificate should be retained for purposes of validation and “trace back”. For each consignment for which a fumigation certificate is issued, records should be kept as appropriate on. The

NPPO should be able to retrieve these records when required, over an appropriate period of time. The use of secure electronic storage and retrieval is recommended for standardized documentation of records.

- any inspection, testing, treatment or other verification which was conducted on a consignment basis
- the names of the personnel who undertook these tasks
- the date on which the activity was undertaken
- the results obtained
- any samples taken.
- Traders name
- Export country

Consignment tracing

- Consignments and their certification should be traceable as appropriate through all stages of production, handling and transport to the point of export. If the NPPO becomes aware after certification that an exported consignment may not have complied with the importing country's phytosanitary requirements, the importing country's NPPO should be so advised as soon as practicable.

Communication

The NPPO should have procedures in place for timely communication to relevant personnel and to industry concerning changes in:

- importing country phytosanitary requirements
- pest status and geographical distribution
- -operational procedures.
- The NPPO may put in place, for non-conforming consignments, a procedure which enables rapid communication to all affected industry parties and certification personnel.

Outside the exporting country

The NPPO should: liaise with the nominated representatives of relevant NPPOs to discuss fumigation requirements

- make available a contact point for importing country NPPOs to report cases of non-compliance
- liaise with the relevant Regional Plant Protection Organizations and other international organizations in order
- to facilitate the harmonization of fumigation measures and the dissemination of technical and regulatory information.

15. Review Mechanism

System review

- The NPPO should periodically review the effectiveness of all aspects of its fumigation system and implement changes to the system if required. effectiveness of Phytosanitary measures, auditing

the activities of the NPPO and authorized organizations or persons, and modifying the Phytosanitary legislation, regulations and procedures as required

Incident review

- The NPPO should establish procedures for investigating reports from importing countries of non-conforming consignments covered by a Phytosanitary certificate. If requested, a report of the outcome of the investigation should be supplied to the importing country.
- The NPPO should have procedures in place to review cases of non-compliance and emergency action. Such a review may lead to the adoption or modification of Phytosanitary measure

Means of Communication

The NPPO should ensure that it has communication procedures to contact:

- importers and appropriate industry representatives
- NPPOs of exporting countries
- the Secretariat of the IPPC
- the Secretariats of the RPPO(s) of
- The relevant documents, supporting information and associated records should be kept for at least
- one year after the date of treatment. Electronic record keeping should be maintained.
- Facility records and traceability
- Packers and treatment facility operators should be required to keep records. These records should be available to the NPPO for review, e.g. when a trace-back is necessary.
- Appropriate treatment records for should be kept for at least one year to ensure traceability of treated lots. The operator should keep all records for every treatment.

Reporting of Fumigation Activities

The fumigation agency must report to the NPPO on monthly basis regarding the stock/use of fumigant and the details of all the fumigation operations carried out as per the agreed format. Keep all treatment records at the treatment facility for one year after treatment. The facility must also maintain a record of all problems and/or breakdowns and any maintenance performed on the chamber. All the records listed above must be made available to the NPPO official upon request.

Plan presentation techniques

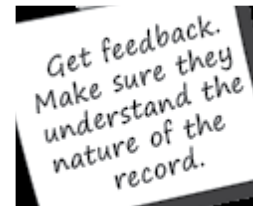
- Lectures
- Ask questions, get answers
- Demonstrations
- Observation
- Discussions in small groups
- Brainstorming
- Practical Exercises

Evaluation

Knowledge Acquisition

Starting with convergent questions helps discussion participants to establish a base of shared knowledge and builds student confidence. The goal is to follow a logical order rather than jump around when asking questions. Use the following questions to help participants begin reflective practice.

- What is Auditing and communication systemg system?
- What is the responsibility of NPPO?
- What is the significance of keeping complete and accurate records before, during and after fumigation?



Focus on Timing

- Structure interaction time into all your sessions
- Keep your session on track. Start on time and finish on time

References

Reference listed below are a few that were referred while preparing the SOP and this training Manual. However, it is suggested that the expert while discussing on the module need carry further web surfing and get updated information and discuss in the class.

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