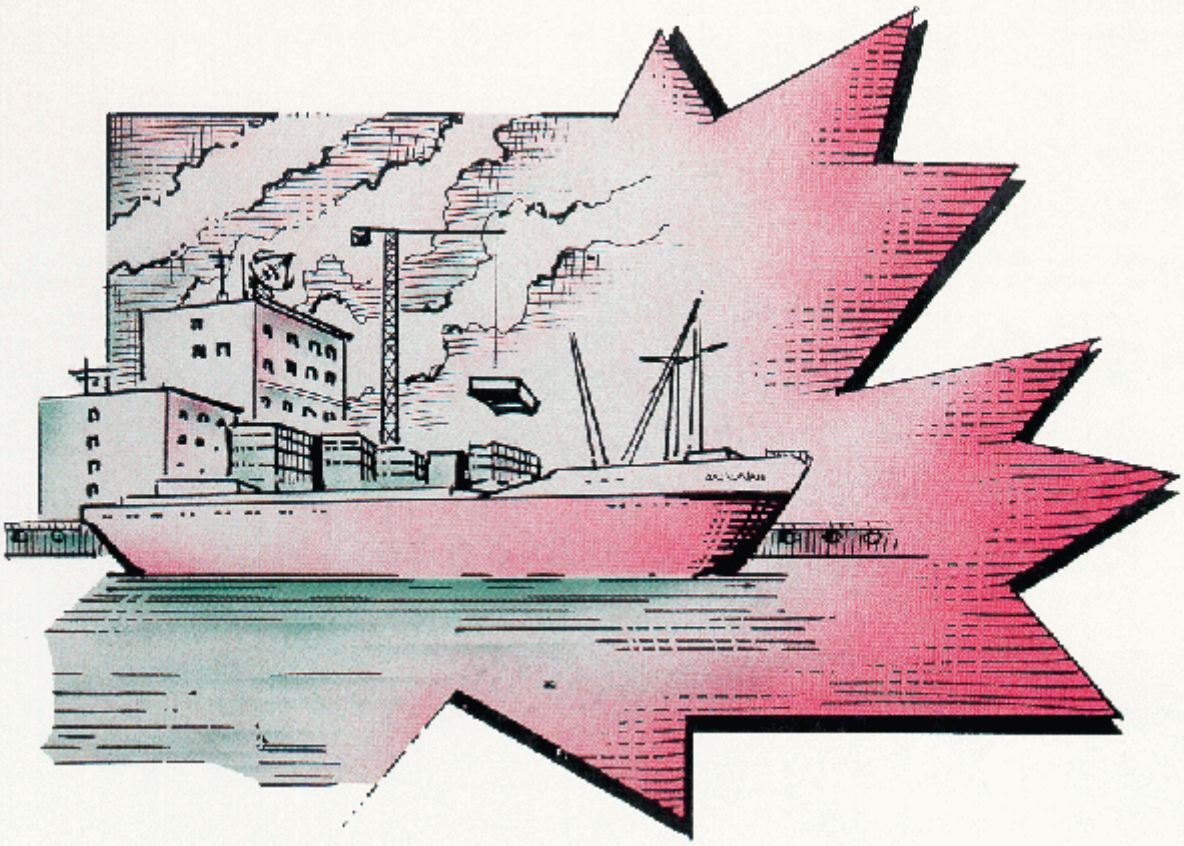

FUMIGATION MODULE | **MODULE – FUMIGATION**

BASIC KNOWLEDGE REQUIREMENTS FOR PESTICIDE EDUCATION IN CANADA

CONNAISSANCES FONDAMENTALES REQUISES POUR LA FORMATION SUR LES PESTICIDES AU CANADA

CAPCO

Health Canada Santé Canada

FUMIGATION MODULE

BASIC KNOWLEDGE REQUIREMENTS

FOR

PESTICIDE EDUCATION IN CANADA

AUSSI DISPONIBLE EN FRANÇAIS

Prepared by the National Task Force on Pesticide Education, Training and Certification

If you would like additional information on the Standard for Pesticide Education, Training and Certification or to be on our mailing list, please write to:

Health Canada
Standard for Pesticide Education,
Training and Certification
Publications
Ottawa, Ontario
K1A 0K9

Catalogue Number: H50-4/7-1995E
ISBN: 0-662-22812-X

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The final draft of the fumigation module has been endorsed by the Canadian Pest Control Association.

The dedication and commitment of Lois Lemieux, Health Canada, for word processing is gratefully acknowledged.

BASIC KNOWLEDGE REQUIREMENTS
FOR PESTICIDE EDUCATION IN CANADA
FUMIGATION MODULE

The Fumigation category includes the use of fumigants for soil fumigation, within enclosed structures or under sheets. This category also includes fumigation in grain bins and elevators, buildings, rail cars, trucks and closed vaults.

The knowledge requirements described in this module are additional to the knowledge requirements detailed in the Applicator Core, common to all certification categories. This module adds details to sections of the Core, where it is necessary to include Fumigation specific information. An outline of the knowledge requirement for the Fumigation module is presented on the following page. This outline shows which sections of the Core have been expanded in this module.

The knowledge requirements provided here is the information a trainer would use to provide training to an applicator on the responsible use of pesticides. It is targeted to the trainer for teaching purposes and is not intended as an applicator manual.

In addition to the Applicator Core, modules of knowledge requirements have been developed for the following ten pesticide applicator categories:

Aerial
Agriculture
Aquatic Vegetation
Forestry
Fumigation
Greenhouse
Industrial Vegetation
Landscape
Mosquito and Biting Flies
Structural

FUMIGATION MODULE

CONTENTS

Category: FUMIGATION

Concept: HUMAN HEALTH - MEDICAL FITNESS OF FUMIGATORS

General Objective: To ensure that appropriate health and safety procedures are developed.

COURSE OUTLINE	INSTRUCTIONAL OBJECTIVES	LEARNING OUTCOMES
Medical Fitness		
All persons engaged in fumigation should have regular medical examinations. The examining physician should be aware of the nature of work being done. This will enable the physician to inform the worker of any medical condition such as respiratory or heart disease which may preclude the use of respiratory protection. Such medical conditions should be brought to the attention of the employer and/or supervisor.	**Understand that regular medical fitness examinations are in the best interests of the worker.**	**Identify the need for regular medical examinations.**

Category: FUMIGATION

Concept: PESTICIDE SAFETY - SAFETY PROCEDURES

General Objective: To understand the concept of threshold limits and to appreciate their importance in providing a safe workplace.

COURSE OUTLINE	INSTRUCTIONAL OBJECTIVES	LEARNING OUTCOMES
Threshold Limits		
Threshold limit values refer to air-borne concentrations of substances in parts per million (PPM) which represent conditions under which it is believed that nearly all workers may be repeatedly exposed, via inhalation, without adverse affects. Because of the wide variation in individual susceptibility, a small percentage of workers may experience discomfort at concentrations near to or even below the threshold limit. Refer to product labels and material safety data sheets for further information.	**Understand the concept of threshold limits and that these limits are to be used as guidelines for a safe workplace.**	**Describe threshold limit values.**
Two threshold limit values are used: TLV-TWA and TLV-STEL.		
Threshold limit value-time weighted average (TLV-TWA) represents 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.	**Know what TLV-TWA means.**	**Define and describe TLV-TWA.**
Threshold limit value - short term exposure limited (TLV-STEL) is the maximum concentration to which workers can be exposed for a 15 minute period continuously without suffering from irritation, chronic or irreversible effects or to materially reduce safety alertness. A maximum of 4 exposures are permitted per day with at least 60 minutes between exposures. The TLV-TWA concentration must not be exceeded during the maximum of 4 consecutive exposures.	**Know what TLV-STEL means.**	**Define and describe TLV-STEL.**
Routes of Entry		
There are four main routes whereby fumigants may enter the body. These routes include oral, dermal, inhalation and ocular.	**Know the routes of entry for fumigants.**	**List the routes of entry for fumigants.**
The threshold limit values (TLV) mentioned earlier are for inhalation exposure only. The limits do not include intake via oral, dermal and ocular routes.	**Understand that TLVs are a measure of inhalation exposure only.**	**Identify that TLVs are a measure of inhalation exposure.**

Category: FUMIGATION

Concept: PESTICIDE SAFETY - PRECAUTIONS FOR THE HANDLING AND USE OF FUMIGANTS

General Objective: To know how to manage fumigants during preparation, application, exposure period, and post treatment.

COURSE OUTLINE	INSTRUCTIONAL OBJECTIVES	LEARNING OUTCOMES
General Safety Procedures		
In addition to general safety procedures, the following items need to be addressed when preparing to do a fumigation: **- product knowledge;** **- knowledge of application technique;** **- safety equipment in good repair;** **- application equipment in good repair;** **- site information;** **- site operational plan;** **- development of emergency response plan;** **- storage requirements;** **- transportation safety;** **- disposal techniques.**	**Know the safety information that must be obtained in preparation for a fumigation.**	**List the safety information that must be obtained before a fumigation operation is carried out.**
Preparation		
During preparation for fumigation, the site should be fully inspected. Escape routes need to be identified. Security of the site must be established and maintained. Specific individuals should be assigned well understood tasks.	**Know the tasks that must be completed during preparation for fumigation.**	**Describe the tasks that must be performed during preparation for fumigation.**
Application		
Respiratory protection is absolutely essential during a fumigation procedure. Attention should be taken to ensure that fumigant formulations do not come in contact with the skin. Always check the product label to determine if specific protective clothing requirements are identified.	**Know what protective clothing and equipment is necessary for fumigation activities.**	**Describe the protective clothing and equipment requirements for fumigation.**

Category: FUMIGATION

Concept: PESTICIDE SAFETY - PRECAUTIONS FOR THE HANDLING AND USE OF FUMIGANTS

General Objective: To know how to manage fumigants during preparation, application, exposure period, and post treatment.

COURSE OUTLINE	INSTRUCTIONAL OBJECTIVES	LEARNING OUTCOMES
Persons with punctured ear drums should take extra precautions when using fumigants. The fumigant can enter the respiratory system via the punctured ear drum. Poisonous concentrations can build up within the ear in such circumstances. Complete protection can be obtained by using cotton ear plugs that have been covered with oil.	**Understand the safety risk of using fumigants if the applicator has punctured ear drums.**	**Identify the safety risk to applicators with punctured ear drums.**
	Know how to protect punctured ear drums.	**Describe how to protect punctured ear drums.**
Contact lenses should not be worn during a fumigation procedure. Gas can become trapped behind the lens if an accident occurs.	**Understand why contact lenses should not be worn during a fumigation.**	**Identify the safety risk to applicators wearing contact lenses.**
If clothing or footwear becomes contaminated, it should be removed immediately. The affected areas of the skin should be washed with soap and water.	**Know the procedure to follow if protective clothing becomes contaminated.**	**Describe the procedure to follow if protective clothing becomes contaminated.**
A buddy system must always be used. A fumigator is not to work alone.	**Understand that the buddy system must always be used.**	**Identify the need for always using the buddy system.**
Security		
For the fumigant to be effective, the gas must be contained within the treatment area for a specified period. Avoid exposure to escaping fumigants present due to leakage. Ensure that unauthorised entry to the treatment site is prevented. The site is to be posted with appropriate warning signs. Check with Provincial/Municipal authorities to determine if there are specific security requirements.	**Know where fumigants can escape from a treatment site. Know how to reduce exposure to both applicators and bystanders.**	**Describe how to reduce the possibility of exposure to applicators and bystanders.**
Post-treatment		
After adequate aeration of the treatment site, gas detection equipment should be used to ascertain if the fumigant is still present. Since desorption can vary greatly among fumigants, different commodities, and various environmental conditions, gas detection is important to ensure that harmful levels of gas do not accumulate where people could subsequently be exposed.	**Understand that dangerous conditions continue to exist even though the actual fumigation has been completed.**	**Identify that dangerous conditions continue to exist after the fumigation has been completed.**
	Know how to evaluate a site to ensure that fumigant has dissipated.	**Describe how to evaluate a site to determine if the fumigant has dissipated.**

Category: FUMIGATION

Concept: PESTICIDE SAFETY - FUMIGATION PROTECTIVE EQUIPMENT

General Objective: To ensure that a fumigator is able to select, fit and maintain respiratory equipment.

COURSE OUTLINE	INSTRUCTIONAL OBJECTIVES	LEARNING OUTCOMES
Respirators		
Respiratory equipment must fit properly and must be equipped with canisters that are certified to provide protection for the fumigant being used. All fumigants require a minimum of full face protection.	**Know how to select the respirator that is appropriate to the fumigation being planned.**	**Describe the features that are important in obtaining proper respiratory protection.**
All respirators used in fumigation work should have an approval from a recognized government safety organization. Examples include NIOSH (National Institute for Occupational Safety and Health) and MSHA (Mine Safety and Health Apparatus). The safety approval extends only to the complete assembly. If a certain respirator is purchased, the canisters used with it must come from the same manufacturer. Check before each fumigation to ensure that the canister on the respirator is the correct one for the gas or mixture of gases being used.		
For fumigation work, the full face respirator provides the minimum acceptable level of inhalation protection for most fumigants. These can be supplied with a canister that attaches to the body by means of a belt. Generally, canister-type respirators give protection from gases that do not exceed 2% by volume in air (0.5% for phosphine).		**Identify and describe the minimum level of inhalation protection.**
For some fumigants (e.g., methyl bromide), a self contained breathing apparatus (SCBA) is required. Ideally, SCBA should be the inhalation protection method of first choice for fumigation.		**Identify the ideal apparatus for inhalation protection.**
Cartridge respirators with one or two cartridges attached to the face piece should never be used in any phase of fumigation work. These respirators are commonly referred to as half mask respirators.	**Know that half mask cartridge respirators should not be used.**	**Identify that half mask cartridge respirators should not be used.**
Men with beards cannot fit respirators/gas masks tightly enough to provide sufficient protection against fumigants. Also, a similar condition may occur if several hours have passed since the face was shaven.	**Understand why applicators must be clean shaven.**	**Describe the need to be clean shaven.**

Category: FUMIGATION

Concept: PESTICIDE SAFETY - FUMIGATION PROTECTIVE EQUIPMENT

General Objective: To ensure that a fumigator is able to select, fit and maintain respiratory equipment.

COURSE OUTLINE	INSTRUCTIONAL OBJECTIVES	LEARNING OUTCOMES
Canisters		
The function of the canister is to remove toxic gases from the air that is being breathed by the fumigator. Fumigant gases are removed by canisters designed for that particular fumigant.	**Understand the function and limitations of canisters and know when they should be replaced.**	**Identify the function of canisters.**
Canisters have a number of limitations, such as maximum gas concentrations for effectiveness, exposure life, gas specific removal and shelf life limitations. Different sized canisters provide varying length of protection.		**Describe the limitations of canisters.**
Always record the start and stop times of canister use. Discard the canister after the maximum usage time has been reached.		**Identify when canisters should be replaced.**
Canisters have a limited shelf life even if they have never been used. Always check the expiry date on a canister before using it.		
Always start a fumigation program with a new canister. Never use a canister where the seal has previously been broken.		
A canister should always be discarded following a fumigation operation. Canisters should be replaced when the indicator changes colour or when the duration of exposure exceeds the life expectancy indicated on the canister. A new canister should be used for the aeration process.		
Canisters should be immediately replaced if: **- there are indications of external damage;** **- increased resistance to inhalation is detected;** **- face mask lens remains fogged;** **- liquid enters interior of canister;** **- expiry date has passed.**		
Upon disposal, canisters should be rendered unfit for further used. Puncturing and crushing will usually suffice.	**Know how to dispose of used canisters.**	**Describe how to dispose of used canisters.**

Category: FUMIGATION

Concept: PESTICIDE SAFETY - FUMIGATION PROTECTIVE EQUIPMENT

General Objective: To ensure that a fumigator is able to select, fit and maintain respiratory equipment.

COURSE OUTLINE	INSTRUCTIONAL OBJECTIVES	LEARNING OUTCOMES
Safety Check for Respirator		
Always go through the following check list before starting a fumigation program: **- Is the correct canister being used?** **- Is the gas concentration below the protection limits prescribed for the canister?** **- Is there sufficient oxygen in the atmosphere of the treatment area to support respiration?** **- Are there other noxious or poisonous gases in addition to the fumigants which could pass through the recommended fumigant canister?** **- Read and follow instructions provided by manufacturer.**	**Know the respiratory safety checks which should be completed prior to starting a fumigation job.**	**List the respiratory safety checks which must be completed prior to a fumigation job.**
The check for gas tightness of the respirator can be done as follows: **Place hand over intake and inhale. If mask is fitted properly, no air movement should be noted. Mask should collapse and compress against the face.**	**Know how to check gas tightness of the respirator.**	**Describe how to test for gas tightness of a respirator.**
Additional information on fitting procedures is provided by the manufacturer. This information should be followed precisely.	**Know the source of additional information on fitting procedures.**	**Identify that additional fitting procedures are provided by the manufacturer.**
Storage and Cleaning		
Respirators should be cleaned following each use. Generally warm water and soap are sufficient. Read and follow the instructions provided by the manufacturer.	**Understand when and how respirators should be cleaned.**	**Identify when respirators should be cleaned.** **Describe how to keep respirators clean.**

Category: FUMIGATION

Concept: PESTICIDE SAFETY - FUMIGATION PROTECTIVE EQUIPMENT

General Objective: To ensure that a fumigator is able to select, fit and maintain respiratory equipment.

COURSE OUTLINE	INSTRUCTIONAL OBJECTIVES	LEARNING OUTCOMES
Body Protection		
Coveralls generally provide adequate body protection while applying fumigants. However, caution should be exercised in wearing gloves for some fumigants (i.e., gloves should not be worn when using methyl bromide and gloves should be worn when using aluminum phosphide). Always check the label to determine proper protective clothing and equipment recommendations.	**Understand that different fumigants may have different protective clothing/equipment requirements.**	**Identify that different fumigants have different protective clothing/equipment requirements.** **Identify that the label is a source of recommendations for proper protective clothing and equipment.**

Category: FUMIGATION

Concept: PESTICIDE SAFETY - DETECTION OF FUMIGANTS FOR THE PURPOSE OF APPLICATOR SAFETY

General Objective: To provide the applicator with information on ways of determining the presence of fumigants.

COURSE OUTLINE	INSTRUCTIONAL OBJECTIVES	LEARNING OUTCOMES
Fumigant Detection Methods		
Some fumigants possess little or no odour and are thus difficult to detect. Even for those with an odour, the sense of smell may not always provide the level of warning required.	**Understand that proper detection equipment is essential for safe fumigation activities.**	**Identify that proper detection equipment is needed for safe fumigation activities.**
For safety purposes, it is essential to have detection equipment that will provide reliable and immediate readings on fumigant levels. Detection equipment includes the following:		
Detector Tubes		
Gas detector tubes consist of sealed glass tubes which contain an indicator chemical that will react with a particular gas and give a colour reaction. Graduated scales on the outside of the tube provide an easy way to read the ambient fumigant gas level. Extension tubes are available for the gas detector tubes.	**Know the components of a gas detector tube.**	**Describe gas detector tubes.**
Detector tubes can be used to measure worker exposure and fumigant concentrations both within and outside the treatment area.	**Know the uses of gas detector tubes.**	**Describe how gas detector tubes can be used.**
Long duration gas detector tubes are available for monitoring exposure throughout a normal working day. Results from these detectors can be used to determine time-weighted average (TWA) of exposure.	**Know when long duration gas detectors are used.** **Know that the results from these can be used to determine TWA of exposure..**	**Describe the function of long duration gas detectors.**
The following limitations apply to gas detection devices: **- tubes will deteriorate with age and should be replaced on a regular schedule according to manufacturer's instructions;** **- exposure to direct sunlight can affect the performance of the tube;** **- at or below freezing, readings may not be reliable;** **- tubes may show cross-sensitivity in that other gases may cause a colour change in the indicator.**	**Know the limitations that apply to gas detectors.**	**List and describe the limitations that apply to gas detectors.**

Category: FUMIGATION

Concept: PESTICIDE SAFETY - DETECTION OF FUMIGANTS FOR THE PURPOSE OF APPLICATOR SAFETY

General Objective: To provide the applicator with information on ways of determining the presence of fumigants.

COURSE OUTLINE	INSTRUCTIONAL OBJECTIVES	LEARNING OUTCOMES
Halide Leak Detector		
The halide leak detector is used to detect the presence of halogenated fumigants (e.g., methyl bromide). It can be used as a leak detector or as a safety device around fumigation sites.	**Know the uses of the halide leak detector.** **Know that halide detectors only work with halogenated compounds.**	**Identify the uses of halide leak detectors.**
Infra-red Analyzers		
Fumigants have characteristic infra-red absorption spectra which allow both identification and quantitative analysis using an infra-red analyzer. These units can easily be operated in the field for on-the-spot analysis.	**Understand the principle of how the infra-red analyzer works.** **Know the advantage of this unit.**	**Describe how the infra-red analyzers identify and measure fumigants.** **Identify the advantage of this unit.**
Thermal Conductivity Meters (Fumiscope)		
Fumiscopes are probably the most frequently used fumigant detector. They operate on the basis of comparing the known concentration of a gas with that which is being sampled. Advantages include reasonable cost, reliability and portability.	**Understand the principle of how the thermal conductivity meter works.** **Know the advantages of this meter.**	**Describe how the thermal conductivity meter measures the concentration of a fumigant.** **List advantages of this meter.**
Portable Gas Chromatographs		
Portable Gas Chromatographs represent state of the art instrumentation for fumigant detection. These instruments are able to provide fumigant detection approaching parts per billion. Portability, ruggedness and high capital cost are factors to consider before purchasing.	**Understand that portable gas chromatographs provide very sensitive measurements.** **Know the factors to consider before purchasing this unit.**	**Identify that portable gas chromatographs provide very sensitive measurements.** **List the factors to consider before purchasing this unit.**

Category: FUMIGATION

Concept: PEST MANAGEMENT - WEEDS

General Objective: To understand pest management principles required to carry out effective fumigation.

COURSE OUTLINE	INSTRUCTIONAL OBJECTIVES	LEARNING OUTCOMES
Weed Characteristics		
A weed is a plant growing where it is not wanted.	**Know what a weed is.**	**Define what a weed is.**
Weeds are pests when they compete with crop plants for light, water or nutrients.		
Weeds are classified according to how long they live.	**Know the weed classification according to how long the weed lives.**	**Describe how weeds are classified according to how long they live.**
Annual weeds complete their life cycle within one year. Most annuals produce many seeds to ensure their survival. Annuals can be divided into two groups: summer annuals which germinate in the spring, and winter annuals which germinate in the fall.	**Know the difference between annual, biennial and perennial weeds.**	**Describe the difference between annual, biennial and perennial weeds.**
Biennial weeds live more than one year but less than two years. They grow from seed which usually germinates in the spring. The first year they store food, usually in short fleshy roots. Usually the foliage is only a rosette of leaves. Next season the plant uses the stored food and grows vigorously. It produces seed in the summer or fall and then dies.		
Perennial weeds live more than two years. Often no seed is produced the first year; thereafter seeds may be produced every year for the life of the plant. Most perennial weeds spread by seed. Many also spread vegetatively by producing creeping stems or roots, rhizomes and bulbs. There are shallow-rooted and deep-rooted perennials.		

Category: FUMIGATION

Concept: PEST MANAGEMENT - WEEDS

General Objective: To understand pest management principles required to carry out effective fumigation.

COURSE OUTLINE	INSTRUCTIONAL OBJECTIVES	LEARNING OUTCOMES
Weed Management Methods		
An integrated pest management approach should be used to manage weeds. The various weed control methods include sanitation, cultural control, mechanical control, biological control, and chemical control (herbicides). Often, a combination of weed management methods are used. When fumigants are used, they should be part of an integrated pest management program.	**Know weed management methods.**	**List weed management methods.**
An effective Integrated Pest Management program involving fumigation would consist of: **- exclusion of the pest;** **- inspection procedures;** **- good housekeeping and sanitation;** **- physical, mechanical and environmental controls;** **- chemical control.**	**Understand the components of an IPM program involving fumigation.**	**List the components of an IPM program involving fumigation for weed control.**
The ultimate goal in the management of pests should be to improve resource management to the point where the need for fumigants will be reduced.		

Category: FUMIGATION

Concept: PEST MANAGEMENT - INSECTS AND MITES

General Objective: To understand pest management principles required to carry out effective insect and mite control.

COURSE OUTLINE	INSTRUCTIONAL OBJECTIVES	LEARNING OUTCOMES
Insect and Mite Characteristics		
Insects are a group of animals that have 6 legs, an exterior skeleton, and 3 body sections (head, thorax and abdomen) in the adult stage. Many adults have wings.	**Know basic features of insects and mites.**	**Describe basic features of insects and mites.**
Mites are members of a group of animals that include spiders and ticks. They also have an exterior skeleton but are extremely small (0.1 - 1 mm in length), have no wings, generally have 8 legs and one main body section.		
There are many different insects and mites. Only a few are pests. Insects and mites are only pests when they damage property, crops, food, feed and livestock, and when they carry diseases affecting man or animals.	**Know when insects or mites are pests.**	**Identify when insects and mites are pest.**
Often insects that become pests are present in low numbers for most of the time until conditions become right for their populations to expand rapidly. In such cases, they may multiply so fast that for a while, natural enemies such as birds, predator insects, and diseases cannot contain the population levels. After several years, their natural enemies increase and usually reduce the pest population to low numbers again.	**Know why native species of insect or mite populations occasionally increase to become severe pests.**	**Describe why native species of insect or mite populations occasionally increase to become severe pests.**
Sometimes insect pests are introduced species. Their populations expand rapidly because they have been transported from other geographical areas and in the new location there may be no natural enemies to contain them.	**Know why an introduced insect species may be a significant pest.**	**Describe why an introduced insect species may be a significant pest.**
Insect and Mite Life Cycles		
Insects and mites change as they grow. Insects go through 3 or 4 different stages. Two common sequences of insect stages are:		
1. Egg to young to adult (gradual development). The young are similar in appearance to the adult but are wingless and lack reproductive organs; for example, aphids and grasshoppers.	**Know the most common sequences of growth that insects may go through.**	**Describe the most common sequences of growth that insects may go through, and provide an example of each.**

Category: FUMIGATION

Concept: PEST MANAGEMENT - INSECTS AND MITES

General Objective: To understand pest management principles required to carry out effective insect and mite control.

COURSE OUTLINE	INSTRUCTIONAL OBJECTIVES	LEARNING OUTCOMES
2. Egg to larva to pupa to adult (complete metamorphosis). The larva is very different from the adult (e.g., caterpillars, loopers, grubs, maggots); the pupa is a non-feeding stage during which complete change of shape occurs; the adult is the reproductive stage and is usually winged. Examples: mosquitoes, moths, beetles, and flies.		
Mites generally go through three stages: egg to nymph to adult.	Know the stages of growth that mites generally go through.	List the growth sequence that mites go through.
Control Measures		
The best control is usually achieved during the early stages: young, nymph, or larva. Egg and pupa are not affected by most insecticides and miticides.	Know the stages of growth during which the best control is usually achieved.	Identify when best control is usually achieved in the life cycle of insects and mites.
Control of these pests involves one or more of the following methods: exclusion, cultural, mechanical, biological, and chemical. An IPM program should be implemented if possible.	Know the control methods for insects and mites.	List and describe the control methods for insects and mites.

Category: FUMIGATION

Concept: PEST MANAGEMENT - DISEASES AND NEMATODES

General Objective: To understand pest management principles required to carry out safe and effective disease control.

COURSE OUTLINE	INSTRUCTIONAL OBJECTIVES	LEARNING OUTCOMES
Diseases		
Plants may be diseased when their appearance or function is not normal.	Know when plants are diseased.	Describe how you know when plants are diseased.
Disease symptoms are caused by environmental stress or infection by microorganisms. Similar symptoms may be caused by insect damage (e.g., gall forming insects) or herbicide damage. It is important to correctly identify the cause of the symptoms so that an effective diagnosis and treatment can be chosen.	Know what can cause disease symptoms. Understand why it is important to correctly identify the cause of disease symptoms.	List the major causes of disease symptoms. Identify other things that could cause similar symptoms. Describe why it is important to correctly identify the cause of disease or disease-like symptoms.
Environmental Stress		
Unfavourable environmental conditions that stress plants and cause abnormal growth or disease-like symptoms include extremes of light, temperature, water or nutrients, and toxic chemicals (e.g., air pollutants). Plants weakened by environmental stress are more likely to be infected by pests. Recognizing and relieving the stress will help prevent infectious diseases.	Know environmental conditions which can stress plants and cause abnormal growth or disease-like symptoms. Understand why it is important to recognize and relieve stress on plants.	List the environmental conditions that could stress plants and cause abnormal growth or disease-like symptoms. Describe why it is important to recognize and relieve environmental stress.
Diseases caused by environmental stress cannot be spread from plant to plant.	Realize that diseases caused by environmental stress cannot spread from plant to plant.	Identify that diseases caused by environmental stress cannot spread from plant to plant.
Infection by Microorganisms		
Microorganisms can cause diseases. Pest microorganisms include fungi, bacteria, viruses and nematodes. These organisms are usually too small to see. Identification is usually based on the symptoms that can be seen, or on laboratory investigations.	Know pest organisms which can cause diseases. Realize disease identification is based on symptoms and laboratory investigations.	List types of organisms that can cause diseases. Describe how a disease can be identified.
Diseases caused by microorganisms (pest infection) are called infectious diseases. These diseases can spread from plant to plant.	Know what an infectious disease is. Realize that diseases caused by microorganisms can spread from plant to plant.	Define infectious disease. Identify that diseases caused by microorganisms can spread from plant to plant.
Microorganisms are pests when they damage desirable plants.	Know when microorganisms are pests.	Identify when microorganisms are pests.

Category: FUMIGATION

Concept: PEST MANAGEMENT - DISEASES AND NEMATODES

General Objective: To understand pest management principles required to carry out safe and effective disease control.

COURSE OUTLINE	INSTRUCTIONAL OBJECTIVES	LEARNING OUTCOMES
Fungi are the largest group of organisms which cause plant diseases. They are organisms which feed on living or decaying organic matter. This group includes moulds, mushrooms, and rusts.	**Know about fungi that cause plant diseases.**	**Describe what a fungus is.** **List organisms that are considered fungi.**
Most fungi reproduce by tiny spores. When spores germinate, they usually produce threadlike filaments which can infect the host, absorb nutrients, and give off toxins that cause disease symptoms.	**Know how fungi reproduce and cause disease symptoms.**	**Describe how fungi reproduce and cause disease symptoms.**
The life cycles of many fungi follow a similar sequence. An example of the sequence is: The fungus stays on a diseased leaf over winter. As the weather becomes warmer in spring, the fungus becomes active and produces spores. The spores are released into the environment and they are moved by wind or water. Some land on healthy parts of a plant. If environmental conditions are poor for spore germination the spores may die, be washed off by rain, or remain dormant. Spores are fairly resistant to fungicides during this stage. If environmental conditions are good, the fungus spores will germinate. The fungus is most vulnerable to fungicides or unfavourable growing conditions between germination and infection. Infection begins when the fungus is able to enter the plant tissues.		**Describe the life cycle of a typical fungus.**
When the plant responds to infection by growing abnormally it is said to be diseased. Inside the plant the fungus is protected and difficult to control. A systemic fungicide may control the disease, if applied before the infection is too severe. Some fungi (e.g., rusts) need 2 different hosts to survive and reproduce. Fungi are spread by spores or tiny pieces of the fungus. Movement of infected plants, plant parts and soil may also spread the fungus.		
Some symptoms that may be caused by fungi include cankers, dieback, galls, leaf spots, rots, rusts and wilts.		**List symptoms of a disease that could be caused by a fungus.**

Category: FUMIGATION

Concept: PEST MANAGEMENT - DISEASES AND NEMATODES

General Objective: To understand pest management principles required to carry out safe and effective disease control.

COURSE OUTLINE	INSTRUCTIONAL OBJECTIVES	LEARNING OUTCOMES
Bacteria cause serious plant diseases. Bacteria are one-celled organisms which can only be seen with a microscope. They usually enter a plant through openings or wounds. Under favourable conditions, bacteria reproduce very quickly, using the plant as a source of food.	Know about bacteria.	Describe what a bacteria is. Describe how bacteria can infect plants.
Bacteria are spread by wind and rain, ground or surface water, or by contact with contaminated animals or equipment.	Understand how bacteria are spread.	List ways bacteria could be spread.
Some blights, galls and rots are caused by bacteria.	Know about the bacterial diseases in your province.	Describe bacterial diseases in your province.
Viruses are extremely small. They cannot be seen with an ordinary microscope. Viruses cause diseases which often reduces plant vigour and crop yields.	Know about viruses.	Describe what a virus is.
Viruses reproduce only when they are in living cells.	Know how viruses reproduce and spread.	Describe how viruses reproduce.
Viruses can be spread by mechanical means (e.g. during pruning or harvesting), in propagation material (seeds, tubers and other plant parts) or by vectors (insects, mites, nematodes, fungi).		List ways viruses can be spread.
Mosaics, ringspot and leaf roll are examples of diseases caused by viruses.	Know about the diseases caused by viruses in your province.	Describe diseases caused by viruses in your province.
No pesticides are available to control viruses directly. However, some pesticides may be used to control virus vectors.	Know that there are no pesticides to control viruses.	Identify the fact that pesticides can not be used to control viruses.
Nematodes are very small "worm-like" organisms which may feed on plant root, stems, and leaves. They can affect the movement of water and nutrients in a plant and they create wounds which may allow fungi or bacteria to enter.	Know about nematodes.	Describe what nematodes are.
Nematodes multiply by producing eggs.		Describe how nematodes reproduce.
Nematodes spread by movement of infected plants, animals, and seeds, contaminated soil and water.		Describe how nematodes spread.
Some symptoms that can be caused by nematodes are wilting, stunting, lack of vigour, and growth deformities.		List symptoms that may be caused by nematodes.

Category: FUMIGATION

Concept: PEST MANAGEMENT - DISEASES AND NEMATODES

General Objective: To understand pest management principles required to carry out safe and effective disease control.

COURSE OUTLINE	INSTRUCTIONAL OBJECTIVES	LEARNING OUTCOMES
Approaches to Disease Management		
Three things must be present for infectious disease to develop. They are:	**Know the three things necessary for an infectious disease to develop.**	**List the three things necessary for an infectious disease to develop.**
1. A disease causing organism (pathogen).		
2. A host susceptible to the disease.		
3. An environment favourable to the disease organism.		
Taking away or changing any one of these 3 things will control or avoid the disease. For example, a disease problem can be prevented by: keeping the organism out of an area, using strains of plants that are resistant or are not affected by the disease, reducing the population of disease causing organisms, or by manipulating the environment to favour the host but not the pathogen.	**Understand how diseases can be controlled.**	**Describe how diseases can be controlled.**
Fungicides		
Fungicides are often described according to how they work (mode of action).	**Know how fungicides work.**	
Protectant fungicides provide a protective film of fungicide on or around the host to prevent fungus spores from germinating. Protectant fungicides must be used before the fungi reach the infectious stage. After the plant is infected the fungicide normally will not kill the fungi inside the plant but it can protect the plant from more infection. New plant growth which appears after application is not protected. Therefore reapplication is required. Protectants can be applied to seeds, foliage, flowers, fruit, or to roots.		**Describe how protectant fungicides work.**
Eradicant fungicides kill fungus organisms that have infected but not become well established within the plant. Eradicant fungicides have limited value for fungi that are well established within plants.		**Describe how eradicant fungicides work.**

Category: FUMIGATION

Concept: PEST MANAGEMENT - DISEASES AND NEMATODES

General Objective: To understand pest management principles required to carry out safe and effective disease control.

COURSE OUTLINE	INSTRUCTIONAL OBJECTIVES	LEARNING OUTCOMES
Systemic fungicides are absorbed by plants and move within them. They may act as protectants, eradicants, or both. Once inside the plant, systemics move to new areas of plant growth.		Describe how bactericides work.
Bactericides		
Bactericides are chemicals that are toxic to bacteria. They kill bacteria on contact and must be used before the bacteria infect a plant.	Know how bactericides work.	Describe how bactericides work.
Nematicides		
Nematicides are chemicals that move through the soil as a gas or in soil water. The presence of spaces between the soil particles is important for their movement. Nematicides may be applied as liquid or granular formulations. They may act by direct contact with nematodes or systemically so that nematodes feeding on or in the diseased plant acquire a lethal dose.	Know what pesticides are used for nematode control and how they work.	Identify the formulations of pesticides used for nematode control. Describe how nematicides work.
Fumigants		
Fumigants are chemicals that when in a gaseous state are lethal to pest organisms. The fumigants may move through air spaces between soil particles (soil fumigation) or through air in structures (space fumigation).	Know what a fumigant is.	Define a fumigant and describe how it works.
Factors Affecting Fungicide/Bactericide Effectiveness		
Timing of Application - the fungicide/bactericide should be on or in the plant (in effective concentration) prior to or during the infection period of the fungus/bacteria.	Know factors affecting fungicide/bactericide effectiveness.	Describe how timing of application can affect the effectiveness of fungicides/ bactericides.

Category: FUMIGATION

Concept: PEST MANAGEMENT - DISEASES AND NEMATODES

General Objective: To understand pest management principles required to carry out safe and effective disease control.

COURSE OUTLINE	INSTRUCTIONAL OBJECTIVES	LEARNING OUTCOMES
Fungus/Bacteria Life Cycle and Weather - the frequency of applications varies depending on the type of fungus/ bacteria, the fungicide/bactericide, and the weather. If the fungus/bacteria has a short life cycle and if there are good conditions for it's growth, it can have many infection periods and many applications may be needed. If the conditions are poor for its growth, few applications may be needed. Moisture, rate of plant growth, and type of fungicide/bactericide also affect the frequency of applications. If the fungicide/bactericide is washed off, if new leaves grow or if the fungicide/bactericide breaks down quickly, applications may need to be repeated.		**Describe how the weather and fungus/ bacteria life cycle can affect the effectiveness of fungicides/bactericides.**

Category: FUMIGATION

Concept: PEST MANAGEMENT - PHYSICAL AND CHEMICAL PROPERTIES OF FUMIGANTS

General Objective: To understand the physical and chemical properties of fumigants that are the bases of effective fumigation.

COURSE OUTLINE	INSTRUCTIONAL OBJECTIVES	LEARNING OUTCOMES
Definition of a Fumigant		
A fumigant is a chemical which, at a specific temperature and pressure, can exist in the gaseous state in sufficient quantities to be lethal to a pest organism. As such, a fumigant is primarily effective in the gaseous state. **Fumigants diffuse as separate molecules. This enables them to penetrate into material to be fumigated and to disperse afterwards.** **Aerosols are particulate suspensions of liquids or solids in air commonly known as fogs, smokes or mists.**	**Know the distinction between fumigants and aerosols.**	**Define the term fumigant.** **Describe fumigants and aerosols.**
Desirable Characteristics		
Desirable characteristics of a fumigant include: **- low flammability;** **- high toxicity to pest;** **- excellent penetrability;** **- poor absorption;** **- minimal residues after aeration;** **- no reaction with treated commodities;** **- rapid rate of diffusion and dispersion;** **- no acute/chronic effect to workers exposed to low concentrations;** **- low corrosiveness;** **- low reactivity.**	**Know the desirable characteristics of fumigants.**	**List the desirable characteristics of a fumigant.**
Fumigation Uses		
Soil fumigation is used in either greenhouses or fields for control of insects, diseases, nematodes and weeds.	**Know where fumigants are used.**	**Describe the types of fumigation.**

Category: FUMIGATION

Concept: PEST MANAGEMENT - PHYSICAL AND CHEMICAL PROPERTIES OF FUMIGANTS

General Objective: To understand the physical and chemical properties of fumigants that are the bases of effective fumigation.

COURSE OUTLINE	INSTRUCTIONAL OBJECTIVES	LEARNING OUTCOMES
Enclosed space fumigation under sheets to control insects or plant disease organisms in food commodities or plant material. Sheets are made of polyethylene or other durable material, which is impermeable to the fumigant.		
General space fumigation to control pests within enclosed spaces such as aircraft, buildings, ships, grain bins, etc. Such structures must be made gas-proof. Commodities may be contained within the space designated for fumigation.		
Utility pole treatment where fumigants are released into the pole for the purpose of controlling wood boring pests.		
Vacuum fumigation where goods are introduced into chambers capable of withstanding reduced internal pressures. Fumigant gases are introduced into a partially vacuated chamber. Do not use aluminum phosphide for vacuum fumigation.		
Physical and Chemical Properties of Fumigants		
Fumigants are described according to various physical and chemical properties:		
Boiling Point		
Fumigants may be divided into two main groups according to whether they boil above or below room or moderate outdoor temperature (20E-25EC). The lower the boiling point, the greater the rate at which the fumigant volatilizes.	**Understand the importance of boiling points relative to rate at which the fumigant volatilizes and relative to its molecular weight.** **Know how fumigants are grouped according to their boiling points.**	**Describe how the boiling point of a fumigant is related to its rate of volatilization and its molecular weight.** **Describe how fumigants are grouped according to their boiling points.**
Generally, the boiling point rises with increases in molecular weight. The low boiling point fumigants, such as methyl bromide, are known as gaseous-type fumigants.		

Category: FUMIGATION

Concept: PEST MANAGEMENT - PHYSICAL AND CHEMICAL PROPERTIES OF FUMIGANTS

General Objective: To understand the physical and chemical properties of fumigants that are the bases of effective fumigation.

COURSE OUTLINE	INSTRUCTIONAL OBJECTIVES	LEARNING OUTCOMES
Those fumigants with high boiling points are described as the liquid or solid type of fumigants. Chloropicrin is an example of this group.		
Maximum Concentrations		
The maximum amount of a fumigant that exists as a gas in a given space is dependent upon the molecular weight of the fumigant and the temperature of the space being fumigated. The practical aspect of this is that it is useless to attempt to volatilize into an empty chamber more fumigant than can exist in the vapour form. Fumigants with low boiling points may be released in large amounts whereas the opposite is true for high boiling point fumigants.	**Know there are limits to the amount of fumigant that can be added to the empty space within a fumigation chamber.**	**Identify how the molecular weight of a fumigant, its boiling point and the temperature of the space being fumigated affect the amount of fumigant that will exist as a gas.**
Latent Heat of Vaporization		
As liquids evaporate, the remaining liquid loses energy which results in a fall in temperature of the liquid. The energy lost in forming the vapour is known as the latent heat of vaporization. This factor varies from one fumigant to another.	**Know that the latent heat of vaporization can lead to problems in dispersing fumigants when they cool below their boiling point.**	**Describe latent heat of vaporization.**
The practical aspect of this is that some fumigants, while being vaporized, can cool below their boiling point. The result is that gas ceases to be generated. Liquid fumigants being dispersed in metal or rubber tubing can "freeze", preventing further passage of the fumigant.		**Identify problems which are caused by the latent heat of vaporization.**
Law of Diffusion		
The rate at which a gas diffuses through an empty space is inversely related to its density. Densities in turn are proportional to molecular weights.	**Know the Law of Diffusion. Know how the rate of diffusion of a gas into an empty space is related to the density and molecular weight of the gas and related to the temperature of the space.**	**Describe the Law of Diffusion. List and describe the factors that influence the rate of diffusion of a fumigant within a treatment area.**
Therefore, a heavier gas will diffuse more slowly through an empty space than would a lighter one. The rate of diffusion increases with increasing temperature.		

Category: FUMIGATION

Concept: PEST MANAGEMENT - PHYSICAL AND CHEMICAL PROPERTIES OF FUMIGANTS

General Objective: To understand the physical and chemical properties of fumigants that are the bases of effective fumigation.

COURSE OUTLINE	INSTRUCTIONAL OBJECTIVES	LEARNING OUTCOMES
Specific Gravity and Distribution		
Specific gravity of a fumigant indicates whether the fumigant is heavier or lighter than air at a certain temperature and pressure.	**Know the importance of specific gravity in affecting the distribution of a fumigant.**	**Define specific gravity and describe its importance in affecting distribution of a fumigant.**
Many of the fumigants are heavier than air. When introduced in a chamber, they sink to the bottom resulting in what is known as stratification.		
Fumigants will stratify due to density differences in the same way as found with liquids that do not mix.		**Describe how fumigants stratify and how this can be avoided.**
Mixing of the fumigant with air in the chamber can be achieved by fans or a ducting system.		
Once a proper air fumigation mix has been achieved, further stratification is usually not a problem.		
Sorption		
When a gas is released into any environment, some of it becomes bound to the surface of solid materials by either physical or chemical means. This is known as adsorption.	**Know the concept of sorption.**	**Describe the concept of sorption and its importance in a fumigation program.**
In contrast, the movement of a gas into the tissue of plants, animals or microorganisms or into the soil is known as absorption. For the purpose of fumigation, these processes are combined under the term sorption.		
In fumigation, sorption has the effect of reducing the effective level of fumigant gas within the treatment area.		
Increases in sorption run parallel to increases in the amount of solid material in the treatment area.	**Know the factors which affect the degree of sorption.**	**Describe the factors which affect the degree of sorption.**
The degree of sorption is also fumigant specific. In general, the degree of sorption increases with those fumigants that possess higher boiling points.		

Category: FUMIGATION

Concept: PEST MANAGEMENT - PHYSICAL AND CHEMICAL PROPERTIES OF FUMIGANTS

General Objective: To understand the physical and chemical properties of fumigants that are the bases of effective fumigation.

COURSE OUTLINE	INSTRUCTIONAL OBJECTIVES	LEARNING OUTCOMES
Physical sorption varies inversely with temperature and is greater at lower temperatures. This is one reason why dosages have to be increased at lower temperatures. **Sorption may also be influenced by the moisture content of the commodity being fumigated. At higher moisture levels, more fumigant can be sorbed. However, the overall effect is not great.**		
Desorption **Desorption is the reverse of the sorption process. When fumigation is complete and the system is being ventilated, gases sorbed to solid material are released or desorbed to the environment. The length of the desorption period depends upon the fumigant used and the solid material treated. Lower temperatures retard the desorption process. Higher humidities facilitate the desorption process. Desorption is also speeded up by increasing the flow of air around solids that have sorbed fumigants.**	**Understand desorption.** **Know the factors which affect the length of the desorption period.**	**Describe desorption and identify factors which affect the length of the desorption period of fumigants.**
Chemical Reaction **Attention to residue formation is important when conducting fumigation of food or food processing/handling equipment. If a chemical reaction occurs between a fumigant and the material, new compounds are frequently formed. Such reactions are usually characterized as being specific and irreversible. Permanent residues are formed. These residues may occur in the form of corrosion of metal, electrical wire, and electrical components.** **This corrosion may render the device unusuable/unsafe. The intensity of the chemical reaction to form residues varies directly with temperature.**	**Know that chemical reactions may result in permanent residues being formed.**	**Identify that permanent residues may be formed from chemical reactions.**

Category: FUMIGATION

Concept: PEST MANAGEMENT - PHYSICAL AND CHEMICAL PROPERTIES OF FUMIGANTS

General Objective: To understand the physical and chemical properties of fumigants that are the bases of effective fumigation.

COURSE OUTLINE	INSTRUCTIONAL OBJECTIVES	LEARNING OUTCOMES
It is important to recognize that residues can be formed during the fumigation process. Product labels provide detailed information on application techniques and dosage rates, which are designed to minimize the formation of residues.	**Understand the effect of temperature on the intensity of a chemical reaction.** **Know where to find information on how to minimize chemical reactions.**	**Describe the effect of temperature on the intensity of a chemical reaction.** **Identify sources of information on how to minimize chemical reactions.**
Non-Target Effects **There are a number of undesirable effects that must be considered when selecting a fumigant or when deciding whether or not to use fumigation as a method to control pests. Some of these effects are:** **- effects on nursery stock and living plants;** **- stimulation of growth;** **- retardation of growth;** **- temporary injury, recovery;** **- permanent injury, death;** **- effects on seed germination and growth;** **- stimulation of germination;** **- impairment of germination;** **- poor growth of seedling;** **- effects on fruit and vegetables;** **- visible lesions;** **- internal injury;** **- shortening of storage life;** **- delay of ripening;** **- stimulation of storage disorders;** **- effects on infesting organisms;** **- stimulation of growth or metamorphosis;** **- delay in development;** **- stimulation of disease effects;** **- initiation of aestivation and protective narcosis;**	**Know non-target effects.**	**List non-target effects.**

Category: FUMIGATION

Concept: PEST MANAGEMENT - PHYSICAL AND CHEMICAL PROPERTIES OF FUMIGANTS

General Objective: To understand the physical and chemical properties of fumigants that are the bases of effective fumigation.

COURSE OUTLINE	INSTRUCTIONAL OBJECTIVES	LEARNING OUTCOMES
- physical and chemical effects on non-living materials; **- production of foul or unpleasant odours in fumigated material;** **- chemical effects that spoil certain products;** **- reaction with lubricants followed by stoppage of machinery;** **- corrosive effect on metals.**		
It is important to review product labels, technical bulletins, etc., for information on the reactivity of the particular fumigant under consideration.	**Know where to obtain information on non-target effects of a particular fumigant.**	**Identify where to obtain information on non-target effects of a particular fumigant.**

Category: FUMIGATION

Concept: PEST MANAGEMENT - EXAMINATION OF FACTORS AFFECTING FUMIGATION

General Objective: To understand the factors affecting fumigation.

COURSE OUTLINE	INSTRUCTIONAL OBJECTIVES	LEARNING OUTCOMES
Factors affecting the success of a fumigation include: **- temperature;** **- humidity;** **- protective narcosis;** **- pest susceptibility;** **- pest resistance.**	**Know the factors affecting fumigation.**	**List the factors affecting fumigation.**
Temperature Effects		
Temperature plays a significant role in affecting all factors governing fumigation.	**Understand the effect of temperature in influencing a fumigation program.**	**Identify the effects of temperature on a fumigation program.**
The concentration of a fumigant required to kill a given pest species decreases as temperature rises. This is due mainly to increased metabolic rate of the pest. Also, the physical sorption of the fumigant decreases as temperature increases. This leaves proportionately more fumigant for pest control. Conditions for successful fumigation generally improve with increases in temperature.		
Temperature of Pest Prior to Fumigation		
A fumigator should have some knowledge of the previous temperature history of the pest population. Fumigating at temperatures considerably above prior pest temperature conditions can contribute to poor results. Frequently the metabolic rate for the pest will reflect the prior temperature history and not the one being used for fumigation.	**Understand that pre-fumigation temperatures may affect the degree of pest control.**	**Describe how pre-fumigation temperature of a pest can affect degree of pest control.**
Some insects may enter a stage known as protective narcosis when subjected to sharp increases in temperature. Dosages and exposure times for insects in this state need to be considerably higher and longer.		
Humidity		

Category: FUMIGATION

Concept: PEST MANAGEMENT - EXAMINATION OF FACTORS AFFECTING FUMIGATION

General Objective: To understand the factors affecting fumigation.

COURSE OUTLINE	INSTRUCTIONAL OBJECTIVES	LEARNING OUTCOMES
Commodity moisture content and relative humidity levels are generally not considered as important in influencing the outcome of a fumigation program. However, they are important in influencing the "quality" of the commodity being fumigated.	**Understand how humidity levels affect fumigation.**	**Describe how humidity levels affect fumigation.**
Pest state/stage effects include the following: **- protective narcosis;** **- changes in pest susceptibility;** **- species and life cycle susceptibility;** **- pest resistance.**		
Protective Narcosis		
Some fumigants can produce a paralysing or protective effect when the insect is exposed to sublethal concentrations before the full concentration is applied. This is known as protective narcosis. This protective effect reduces the effectiveness of the fumigant. A similar effect can occur when specific fumigants are applied at excessive concentrations.	**Understand insect protective narcosis and its importance to fumigation.**	**Describe protective narcosis and how it effects a fumigation program.**
Changes in Pest Susceptibility		
Pest populations can exhibit fluctuations in susceptibility to a given fumigant. Two major factors appear to be seasonal climate effect and level of nutrition of the pest population. The former is primarily a temperature effect. In the latter case, starvation may cause the pest to be more resistant to the fumigant.	**Understand the factors that influence pest susceptibility.**	**List and describe the factors that may lead to varying pest susceptibility to fumigants.**
Species and Life Cycle Susceptibility		

Category: FUMIGATION

Concept: PEST MANAGEMENT - EXAMINATION OF FACTORS AFFECTING FUMIGATION

General Objective: To understand the factors affecting fumigation.

COURSE OUTLINE	INSTRUCTIONAL OBJECTIVES	LEARNING OUTCOMES
There is a great variation in susceptibility of different pest species to the various fumigants. The successive stages of a single pest species may also vary greatly in response to any particular fumigant. **It is important to note that fumigation treatments are frequently prescribed for a specific pest species or their stages or in some cases to a clearly defined group of pests. Successful fumigation programs are built on recognition of the limits of a particular fumigant as it applies to pest species and life cycle stage.**	**Understand that pest response to a particular fumigant may vary with species and stage of development.**	**Identify that a pest's susceptibility to a fumigant may vary with species and stage of development.**
Pest Resistance		
Resistance of pest species to fumigants is a major concern because of: **- the unique physical characteristics of fumigants, such as effectiveness as a gas, which are not found in other pesticides;** **- the very limited number of chemicals presently registered for use as fumigants.**	**Understand the concern for pest resistance to fumigants.**	**Identify the concern for pest resistance to fumigants.**

Category: FUMIGATION

Concept: PEST MANAGEMENT - FUMIGANT RESIDUES

General Objective: To recognize that residues can be formed during or following fumigation.

COURSE OUTLINE	INSTRUCTIONAL OBJECTIVES	LEARNING OUTCOMES
The type and form of residues remaining after fumigation are dependent on the following factors: **- type of fumigant;** **- type of commodity;** **- concentration and exposure period;** **- moisture content and humidity;** **- temperature.**	**Know the factors that affect the type and form of residues remaining after fumigation.**	**List the factors that affect the type and form of residues remaining after fumigation.**
The residues remaining in treated materials following fumigation may be hazardous to workers and others who may come in contact with the desorbing gas. There is also the possibility of a hazard to bystanders and to those who consume food products that have been fumigated.	**Know the hazards of residues remaining in treated materials.**	**Identify the hazards of residues remaining in treated materials.**
The amount of residue present in fumigated material is determined by the conditions during fumigation and the subsequent treatment of the material.	**Understand the factors which affect residue formation.**	**Describe the factors which affect residue formation.**
Type of Fumigant **Fumigants with higher boiling points tend to be sorbed more readily and remain as residues for longer times than those compounds with lower boiling points.**		
Type of Commodity **Some materials will sorb and retain more fumigant than others. Materials high in oil content are especially vulnerable.** **Care must be taken to ensure that the fumigant does not react with the material or structure being fumigated. For example, at high humidity levels materials containing copper or copper salts may be corroded by phosphide gas to form undesirable residues. The product label will indicate materials that are reactive with the fumigant.**		
Concentration and Exposure Time		

Category: FUMIGATION

Concept: PEST MANAGEMENT - FUMIGANT RESIDUES

General Objective: To recognize that residues can be formed during or following fumigation.

COURSE OUTLINE	INSTRUCTIONAL OBJECTIVES	LEARNING OUTCOMES
The amount of residue formed can be influenced by the dosage of fumigant applied and by the length of the exposure. Generally, increases in either factor result in higher residue levels.		
Moisture Content and Humidity **Fumigation residues tend to increase when either the moisture content or the humidity of the treatment area increases.**		
Temperature **The rate of desorption usually increases with temperature. However chemical reactivity increases with temperature. The net result in residue formation is a balancing of these two factors.**		

Category: FUMIGATION

Concept: APPLICATION TECHNOLOGY - DOSAGE AND CONCENTRATION OF FUMIGANTS

General Objective: To understand the general application of dosage and concentration calculations.

COURSE OUTLINE	INSTRUCTIONAL OBJECTIVES	LEARNING OUTCOMES
Calculations for fumigations need to include the following steps: **- determining dosage and concentration of the fumigant;** **- determining C x t product (concentration x time).**		
Dosage and Concentration		
Dosage is the amount of fumigant applied per unit volume. It is either expressed as volume of fumigant per unit volume treated or as weight of fumigant per unit volume treated.	**Understand the difference between dosage and concentration.**	**Describe dosage and concentration.**
Dosages are calculated prior to the start of the fumigation process.		**Identify when dosages are calculated.**
As soon as a fumigant gas enters a treatment area, some is lost by the process of sorption or by actual leakage from the treatment area.		**Identify when fumigant concentration can be determined.**
As a result of sorption, and leakage, the initial calculated dosage level is reduced and will continue to decline until the system stabilizes. The new level of fumigant in the treatment area is referred to as the fumigant concentration. The concentration can only be determined by taking actual measurements after the start of the fumigation procedure.		
Dosage calculations are based upon the total internal volume of the structure. For irregularly shaped buildings, calculate the size of each unit then add together. If the building has a peaked roof, be sure to add in the volume enclosed by the roof.	**Know how to determine volume calculations.**	**Describe volume calculations.**
Weight per volume		
Dosages are most often expressed as weight per volume. This can be grams per cubic metre for the metric system or as pounds (ounces) per 1000 cubic feet for the British system.	**Understand that dosages can be expressed as weight per volume, parts per volume or percent by volume.**	**List ways that dosages are expressed.**

Category: FUMIGATION

Concept: APPLICATION TECHNOLOGY - DOSAGE AND CONCENTRATION OF FUMIGANTS

General Objective: To understand the general application of dosage and concentration calculations.

COURSE OUTLINE	INSTRUCTIONAL OBJECTIVES	LEARNING OUTCOMES
Parts or percent by volume **In some cases dosages may be expressed as parts per volume (e.g., parts per million) or as percent by volume (% by volume).** **Volume or weight per area** **Dosages for soil fumigation may be expressed as L/ha or kg/ha.** **Calculations to convert from weight per volume to parts per volume**		
Simple calculations can be used to convert from weight per volume to parts per volume. These calculations provide approximations but are accurate enough for fumigation purposes. To convert weight/volume to parts per volume: **(1) Divide the weight/volume (WV) value by the molecular weight (MW) of the fumigant, then multiply by 24.** $\left(\frac{WV}{MW} \times 22.4 = \text{parts per volume}\right)$ **(2) If parts per million are required, multiply the answer from (1) by 1000.** $\left(\frac{MV}{MW} \times 22.4 \times 1000 = \text{parts/million}\right)$ **(3) If percentage by volume is required, divide the answer from (1) by 10.** $\left(\frac{MV}{MW} \times 22.4 \div 10 = \%\ \text{by volume}\right)$	**Know how to convert from weight per volume to parts per volume.**	**Describe how to convert from weight per volume to parts per volume.**
To convert parts per million (parts per volume) to grams per cubic metre:	**Know how to convert parts per volume to weight per volume.**	**Describe how to convert parts to volume to weight per volume.**

Category: FUMIGATION

Concept: APPLICATION TECHNOLOGY - DOSAGE AND CONCENTRATION OF FUMIGANTS

General Objective: To understand the general application of dosage and concentration calculations.

COURSE OUTLINE	INSTRUCTIONAL OBJECTIVES	LEARNING OUTCOMES
(1) Divide the parts per million by 1000 to give the number of cubic centimetres of gas per litre. **(2) Multiply the answer from (1) by the molecular weight (MW) of the gas.** **(3) Divide (2) by 22.4. The answer will be expressed as milligrams per litre.** **(PPM x MW ÷ 22.4 = milligrams/litre)** **1000**		
To convert percentage per volume of gas to weight per volume: **(1) Multiply the percentage (%) by 10 to give the number of cubic centimetres of gas per litre of air.** **(2) Multiply the answer from (1) by the molecular weight (MW) of the gas.** **(3) Divide answer from (2) by 22.4. The answer can be expressed as mg/L.** **(% x 10 x MW ÷ 22.4 = milligrams/L)**	**Know how to convert percentage per volume to weight per volume.**	**Describe how to convert percentage per volume to weight per volume.**
Concentration x time (C x t) products **Most fumigation treatments are presented as a dosage of fumigant per unit volume or per unit weight of commodity to be fumigated. This dosage is followed by a statement of the length of the treatment in hours as well as the temperature at which the dosage and time factors apply.**	**Understand that an effective dose consists of a predetermined amount of poison administered over a specified time, at a specified temperature.**	**Describe the factors that must be considered in determining a fumigation treatment.**
In order to kill 99% of a certain species of pest, a specific concentration of fumigant (C) must be maintained for a specified time (t). This is known as the concentration x time product (C x t product) and is expressed as milligram hours per litre (mg h/L).	**Understand the need to maintain gas concentrations during a fumigation.**	**Describe why it is important to maintain gas concentrations during fumigation.**

Category: FUMIGATION

Concept: APPLICATION TECHNOLOGY - DOSAGE AND CONCENTRATION OF FUMIGANTS

General Objective: To understand the general application of dosage and concentration calculations.

COURSE OUTLINE	INSTRUCTIONAL OBJECTIVES	LEARNING OUTCOMES
By taking readings of concentration, action can be taken (i.e., addition of fumigant, increasing the exposure time), to compensate for fumigant loses due to leakage, sorption, and chemical reactions, which can significantly reduce the level of free fumigant.		
The (C x t) product method cannot be used for aluminum phosphide. Certain minimum gas concentrations are required for an aluminum phosphide fumigation.	**Know that the C x t product method cannot be used for aluminum phosphide.**	**Identify that the C x t product method cannot be used for aluminum phosphide.**

Category: FUMIGATION

Concept: APPLICATION TECHNOLOGY - SPACE FUMIGATION

General Objective: To understand the various fumigation methods that apply to space fumigation.

COURSE OUTLINE	INSTRUCTIONAL OBJECTIVES	LEARNING OUTCOMES
Space fumigation is the release of a fumigant into an enclosed space for the purpose of controlling pest populations in a stored commodity or for the control of pest populations that are infesting the actual enclosure.	**Know what space fumigation refers to.**	**Describe a space fumigation.**
Sealing the Space		
It is important to properly seal the treatment area to retain the fumigant for sufficient time to ensure that the pest receives an adequate dose of fumigant. Structures of all sizes and shapes can be fumigated if properly sealed. Narrow cracks and small holes can be sealed with masking tape, expanding styrofoam, heavy kraft paper or similar material. For sealing larger openings, refer to the fumigant label for specifics on acceptable sheeting materials. **Proper sealing can only be accomplished when care is taken to ensure that all joints are carefully taped or sealed.** **A leak from the fumigation space can make the difference between the success or failure of the program.**	**Know how to properly seal spaces to be fumigated.**	**Describe how to properly seal spaces to be fumigated.**
Types of Space Fumigation		
Space fumigation includes the following: **- fumigation chambers;** **- fumigation under sheets;** **- fumigation of buildings;** **- fumigation of buildings under sheets.**	**Know the types of space fumigation.**	**List the types of space fumigation.**
Fumigation Chambers		
To conduct fumigation of commodities on a routine basis, it may be advisable to construct a fumigation chamber. Check labels to determine acceptable building materials.	**Know when a fumigation chamber is used and know how to make it relatively gas-proof.**	**Describe the construction and use of a fumigation chamber.**

Category: FUMIGATION

Concept: APPLICATION TECHNOLOGY - SPACE FUMIGATION

General Objective: To understand the various fumigation methods that apply to space fumigation.

COURSE OUTLINE	INSTRUCTIONAL OBJECTIVES	LEARNING OUTCOMES
A major criteria for construction is that the chamber be relatively gas-proof.		
The commodity to be fumigated should be placed on racking or pallets on the floor. Space between the stack of goods and any wall/ceiling should be at least 30 cm.	**Know how a fumigation chamber must be loaded to allow for circulation of the fumigant.**	**Describe how to load a fumigation chamber.**
Temperature reading should be taken for both the material and for the free air within the chamber. To select the correct dosage of fumigant it is best to use the lowest temperature recorded. Temperatures should be 15EC or higher.	**Know how to select the correct dosage of fumigant.**	**Describe how to select the correct dosage of fumigant.**
Dosage information is given on the product label either as (C x t) product or as mg/L.		
Prior to the start of the fumigation cylinders valves should be "cracked open" and immediately closed. This procedure is necessary to ensure that the cylinder valve is operating properly and should be done outside in case of a mishap with the valve. The cover cap and protective sleeve should be replaced before the cylinder is moved inside.	**Know how to check that the cylinder valve is operating properly.**	**Describe how to check that the cylinder valve is operating properly.**
Once the chamber has been closed, gaseous-type fumigants are discharged from pressure cylinders located outside the chamber. To obtain the correct dosage, cylinders are placed on a scale and weighed. The cylinder weight after the release of the correct dosage is also calculated. Fumigant is released until the calculated cylinder weight has been attained.	**Know how to release the amount of fumigant required for a chamber.**	**Describe how to release the amount of fumigant required.**
When using heavier-than-air fumigants, air circulation should be done following the start of fumigation. Specific information on air circulation will be provided on the product label.	**Know that there is a need for air circulation when using heavier-than-air fumigants.**	**Identify the need for air circulation when using heavier-than-air fumigants.**
The period of exposure for gaseous-type fumigants begins when the discharge of the fumigant is completed.	**Know when the exposure period begins.**	**Identify when the exposure period begins.**

Category: FUMIGATION

Concept: APPLICATION TECHNOLOGY - SPACE FUMIGATION

General Objective: To understand the various fumigation methods that apply to space fumigation.

COURSE OUTLINE	INSTRUCTIONAL OBJECTIVES	LEARNING OUTCOMES
At the end of treatment, aeration should be started by opening the door only slightly. The doors should only be opened fully when it is determined by testing that the chamber is safe to enter. Use of protective clothing and equipment is essential.	**Understand that aeration should take place slowly and under controlled conditions.** **Know that protective clothing and equipment is essential.**	**Describe the aeration process.**
Fumigation Under Sheets		
Sheets capable of retaining fumigant gases may be used to cover infested material while the fumigation process is taking place. **Sheets made of polyethylene or polyvinyl chloride are suitable to place underneath and to cover the items to be fumigated. Sheets should be at least 0.1 mm (4 mil) in thickness.** **In preparing for sheet fumigation, it is important to ensure that the fumigant does not leak downward from the treatment site. If possible, plastic sheeting should be placed on the ground or floor.** **Material to be fumigated should be piled so as to allow for movement of the fumigant within the pile.** **If possible, use one large sheet instead of several small ones to cover a pile. Allow at least 1/2 metre of extra sheeting along the edge to allow for sealing of the sheet to the floor.** **If sheets have to be joined, allow at least 1 metre of overlap which can then be rolled to form a satisfactory joint.** **Edges of sheets are best sealed to the floor by means of plastic tubes filled with sand or water. These tubes make an effective seal when laid over the sheet.** **Once the release of the fumigant has been completed, the covering sheets should be checked for leakage along all joints and at the floor.**	**Know how to fumigate under sheets.**	**List the major steps in sheet fumigation.**

Category: FUMIGATION

Concept: APPLICATION TECHNOLOGY - SPACE FUMIGATION

General Objective: To understand the various fumigation methods that apply to space fumigation.

COURSE OUTLINE	INSTRUCTIONAL OBJECTIVES	LEARNING OUTCOMES
Aeration should be started by lifting the cover sheet from each corner of the pile.		
When it has been shown by testing that the site is free of fumigant gas, all sheets may be removed from the pile.		
Fumigation of Buildings		
Fumigation of buildings require that the structure be made relatively air tight. Brick and cement buildings are usually quite air tight and only require attention to external openings such as windows, doors, vents, and chimneys. Doors and windows should be taped to ensure an adequate seal.	Know how to make buildings and other structures relatively air tight.	Describe how to make buildings and other structures relatively air tight.
Fumigation procedures for cargo ships, railway cars, transport trucks and aircraft follow the same basic procedures as set forth for fumigation of buildings.		
It is always advisable to check design drawings to locate internal compartments. For example, bilge space in ships or bulkhead space in aircraft. These areas are frequently sealed and thus should be opened to allow for the free movement of the fumigant.	Understand importance of checking for closed compartments within the area being fumigated.	Identify the importance of checking for closed compartments within the area being fumigated.
Pre-fumigation Actions		
The structure should be thoroughly checked for unusual features or potential problems that could influence the outcome of the fumigation program.	Understand the need to check the structure for unusual features or potential problems.	Identify the need to check the structure for unusual features or potential problems.
Always prepare a check list of the various activities that should be done prior to, during and following the fumigation. Never trust to memory. Mistakes or oversight of important details can result in serious accidents.	Know that a check list of the various activities must be prepared.	Identify the need to prepare a check list.
Ensure that the program complies with provincial and local regulations.	Know provincial and local regulations.	Identify provincial and local regulations which apply.

Category: FUMIGATION

Concept: APPLICATION TECHNOLOGY - SPACE FUMIGATION

General Objective: To understand the various fumigation methods that apply to space fumigation.

COURSE OUTLINE	INSTRUCTIONAL OBJECTIVES	LEARNING OUTCOMES
Regulations may include advance notification requirements. If they do not, be sure to at least inform emergency response officials in the area.	Understand that emergency response officials must be notified.	Identify the need to notify emergency response officials.
Security of the site is always necessary. Guards should be present during the entire procedure including preparation and aeration procedures.	Know that site security is necessary.	Identify that site security is necessary.
Warning notices must be placed on all sides of the fumigation site. These signs must provide sufficient information to warn the reader that they must not enter the fumigation area. All exterior doors must be locked.	Know the requirements for site posting and for preventing entrance to the structure.	Describe the requirements for site posting. Identify the need to have all exterior doors locked.
Warning signs should be illuminated at night. Local and provincial authorities may have requirements for site posting.		
While fumigating a larger structure, workers should always work in pairs. In complex structures, lacking exit signs, directional signs should be used. Provisions for radio communication among the applicators is advisable during the entire operation.	Know when it is important that fumigators work in pairs. Know when directional signs and radio communication should be used.	Identify when it is important that fumigators work in pairs. Identify when directional signs and radio communication should be used.
It is important to pre-plan the location of fumigant release points. Fumigant cylinders or other containers should be placed throughout the structure in a manner which allows for systematic release of the fumigant.	Understand the importance of pre-planning the location of fumigant release points.	Identify the need to pre-plan the location of fumigant release points.
When the fumigant is to be released, always start at the release point furthest away from the exit. Always work toward the pre-arranged exit point. Applicators should never have to pass through a space where fumigation has already started.	Know where applicators must start and move through the treatment area.	Describe where applicators must start and the route to be followed through the treatment area.
Workers should only fumigate for a limited time before having a rest away from the work area. In general applicators should not be releasing fumigant into a building for more than thirty minutes, however, large fumigations often take more than 30 minutes. Proper pre-planning should avoid the occurrence of situations where the applicator releases fumigant for more than the time interval considered as safe.	Know that applicators should only release a fumigant for a limited time.	Identify that applicators should only release a fumigant for a limited time.

Category: FUMIGATION

Concept: APPLICATION TECHNOLOGY - SPACE FUMIGATION

General Objective: To understand the various fumigation methods that apply to space fumigation.

COURSE OUTLINE	INSTRUCTIONAL OBJECTIVES	LEARNING OUTCOMES
Final Check		
Prior to the start of gas release a final check should include: **- elimination of all sources of ignition including switching off of all electrical equipment;** **- ensure that warning signs are properly placed;** **- locate an outside telephone that can be used in an emergency situation;** **- check that sufficient security personnel are present and understand their role;** **- check every part of the structure to ensure that all people have left. The person in charge should enter every room and call in a loud voice a warning such as "Everyone Out, poison gas fumigation about to begin". Also check with building authorities to determine if anyone normally present in the building has a hearing disability.**	**Know the points to cover in a final check prior to the start of gas release.**	**List the points to cover in a final check prior to the start of gas release.**
During Fumigation		
Once fumigation starts all personnel within the treatment area must wear respirators except for those working outside where there is sufficient breeze to dilute any escaping fumigant.	**Know when respirators are needed.**	**Identify when respirators are needed.**
The structure should be checked for leaks once gas release has started.	**Know that the structure should be checked for gas leaks.**	**Identify that the structure should be checked for gas leaks during fumigation.**
During the fumigation, gas samples should be taken and checked for concentration. If levels fall below recommendations, additional fumigant must be added.	**Understand why gas samples should be taken during fumigation.**	**Identify why gas samples should be taken during fumigation.**
Aeration		
Upon completion of the fumigation, the aeration process can start. Instrument checks are to be conducted to determine when gas levels are low enough to allow re-entry and re-use. In cold weather, it may be necessary to heat the building up and aerate again to eliminate any remaining fumigant.	**Understand the proper airing out procedure.**	**Describe the proper airing out procedure.**

Category: FUMIGATION

Concept: APPLICATION TECHNOLOGY - SPACE FUMIGATION

General Objective: To understand the various fumigation methods that apply to space fumigation.

COURSE OUTLINE	INSTRUCTIONAL OBJECTIVES	LEARNING OUTCOMES
Fumigation of Buildings Under Sheets		
Sometimes it is difficult and costly to completely seal a building for fumigation purposes. **An alternative is to cover the building with sheets and proceed with techniques used for fumigation under sheets.** **Due to the possibility of wind damage, covering sheets must be very durable. Seams or joints must be clamped. Rolling together is not sufficient.** **In larger structures, covering sheets may billow because of the expansion of air trapped in the building or due to the forces of the wind. Large fans situated to suck air out of the building can be used to reduce the billowing effect. Since the covering is fairly air tight, the concentration of fumigant within the structure should not change appreciably when the fans are operated.** **Fumigant monitoring should be conducted along sheet seams and at selected sites within the structure. Additional fumigants may have to be added if the concentration drops below the recommended levels.**	**Know how large structures can be fumigated using the sheet techniques.**	**Describe how large structures can be fumigated under sheets.**

Category: FUMIGATION

Concept: APPLICATION TECHNOLOGY - VACUUM FUMIGATION

General Objective: To understand the general concept of vacuum fumigation.

COURSE OUTLINE	INSTRUCTIONAL OBJECTIVES	LEARNING OUTCOMES
Vacuum Fumigation		
Vacuum fumigation is a specialized form of chamber fumigation.	**Understand the concept of vacuum fumigation and why it is a valuable technique.**	**Describe the process of vacuum fumigation.**
In vacuum fumigation, a reinforced chamber is used to hold the commodity to be fumigated. Once closed, air is withdrawn from the chamber. A vacuum up to one atmosphere is created. Fumigant gases are then released into the chamber.		
Because of the vacuum created, the fumigant gas penetrates the commodity more rapidly. Fumigation time can be reduced by as much as 75% in some instances. The technique is also valuable in situations where the commodity to be fumigated is packed very tightly.		**Identify the advantages of vacuum fumigation.**
Care must be exercised to ensure that the commodity is not damaged by being placed in a vacuum. Always check the product label to determine if the proposed fumigant is safe to use in vacuum fumigation. Do not use aluminum phosphide for vacuum fumigation.	**Know the limitations of vacuum fumigation.**	**Identify the limitations of vacuum fumigation.**

Category: FUMIGATION

Concept: APPLICATION TECHNOLOGY - FUMIGATION OF BULK STORAGE COMMODITIES

General Objective: To provide basic information on fumigation procedures for bulk storage.

COURSE OUTLINE	INSTRUCTIONAL OBJECTIVES	LEARNING OUTCOMES
As with any other type of fumigation, the storage area must be made gas tight. If gases are allowed to escape during fumigation, control results will be erratic.	Understand the importance of sealing the storage area.	Identify the need to make the storage area gas tight.
Direct Mixing		
Direct mixing of a fumigant is used when: - the pest infestation is found throughout the commodity; - when there is direct access to the commodity during transfer from one holding facility to another.	Understand the process of direct mixing as a means of fumigation.	Identify when direct mixing is used for fumigation of bulk storage commodity.
The technique is to meter the fumigant into the commodity as it is moved from one bin to another.		Describe the process of direct mixing.
Dosage rates are based on the amount of commodity to be treated assuming that the bin will be relatively full when the transfer has been completed.		
Extreme care should be taken when adding fumigants to commodity streams. Fumigant vapours may be given off before the commodity enters the storage area.	Know the safety hazards associated with the direct mixing process.	Identify the hazards associated with direct mixing.
Surface Application		
This technique is used primarily for flat or horizontal storage units, where it is very difficult to turn the commodity or to transfer it to another bin.	Understand the process of surface application.	Identify when surface application is used.
In surface application, the fumigant is applied directly on the commodity. The gas slowly evolves and diffuses down through the commodity. To facilitate even distribution of the fumigant, the surface of the commodity should be levelled prior to application of the fumigant.		Describe the process of surface application.
Application of the fumigant should take place from the outside of the storage bin to minimize applicator exposure.		

Category: FUMIGATION

Concept: APPLICATION TECHNOLOGY - FUMIGATION OF BULK STORAGE COMMODITIES

General Objective: To provide basic information on fumigation procedures for bulk storage.

COURSE OUTLINE	INSTRUCTIONAL OBJECTIVES	LEARNING OUTCOMES
If the bin is large, applicators may have to enter the bin and apply the fumigant directly onto the commodity. Applicators applying fumigant in this manner should wear air-line or self-contained breathing equipment (SCBA). Fumigant levels can easily exceed the levels where a respirator and canister do not provide adequate protection.	Understand the need for protective equipment when entering a large bin to apply the fumigant.	Identify the protective equipment needed when fumigating from within a bin.
Fumigants such as methyl bromide can be used in "fumigation under sheets" where the commodity is covered with a gas-proof sheet. Methyl bromide is injected under the sheet and allowed to diffuse into the commodity.		
Prepacks, ropes and tablets (pellets) can be used to treat stored commodities. The advantage to these is that the fumigant is pre-measured and packaged thus reducing potential applicator exposure. Closed-loop air circulation systems can be used to circulate the fumigant as it is being released from any of the pre-packaged fumigant formulations. Degesch has a patented "J-System" which facilitates gas circulation within enclosed containers such as silos, grain bins and ship holds.	Understand how prepacks, ropes and tablets are used to treat stored commodities.	Describe how prepacks, ropes and tablets are used to treat stored commodities.
Tablets or pellets of aluminum phosphide can be used to treat stored commodities. Pipes are inserted into the pile at pre-determined intervals. Pre-measured fumigant tablets, or pellets, are dropped into the tubes. After the tubes are removed, the tablets release fumigant gas into the commodity.	Know how tablets can be used to treat stored commodities.	Describe how tablets can be used to treat stored commodities.
The total amount of fumigant to use is determined by the volume or weight of commodity to be treated.	Know the calculations.	Describe how to calculate the amount of fumigant required when using pellets or tablets.
The number of tablets to use per tube is determined by dividing the total amount of fumigant to be used by the number of holes to be made.		
If there is considerable air space over the storage or if a considerable gas leakage problem is anticipated, the bin should be covered by gas-proof sheets.	Know when a bin should be covered by gas-proof sheets.	Identify when a bin should be covered by gas-proof sheets.

Category: FUMIGATION

Concept: APPLICATION TECHNOLOGY - FUMIGATION OF BULK STORAGE COMMODITIES

General Objective: To provide basic information on fumigation procedures for bulk storage.

COURSE OUTLINE	INSTRUCTIONAL OBJECTIVES	LEARNING OUTCOMES
In cases where infestation is localized, treatments can be designed for that specific area only. These spots can usually be recognized and defined by an increase in temperature in the zone of infestation. Solid fumigants can be injected into their areas. Due to the need for complete pest control, it is expedient to treat an area larger than the actual size of the infestation.	**Understand when to use spot treatments.**	**Identify when to use spot treatments.**

Category: FUMIGATION

Concept: APPLICATION TECHNOLOGY - SOIL FUMIGATION

General Objective: To know how soil fumigation works.

COURSE OUTLINE	INSTRUCTIONAL OBJECTIVES	LEARNING OUTCOMES
Soil fumigation is used to kill weeds, weed seeds, insects and disease-causing organisms, including nematodes, which live in the soil.	**Understand when soil fumigation can be used.**	**Identify when soil fumigation can be used.**
Factors Affecting Performance		
The basic principle is to apply a fumigant to the soil and to allow it to diffuse through the soil. Several factors influence movement of fumigants within the soil. These include: **- water content;** **- soil compaction;** **- soil temperature;** **- organic matter.**	**Know the factors which influence the movement of fumigants within the soil.**	**List the factors which influence the movement of fumigants within the soil.**
Soil Moisture		
If the soil is too wet, there is not enough air space within the soil to allow the gas to move about freely. If the soil is too dry, there will be too little moisture around the soil particles to absorb the fumigant. Also, the fumigant will readily escape through the soil and into the air above the soil.	**Understand the relationship between soil moisture and fumigation effectiveness.**	**Describe the relationship between soil moisture and fumigation effectiveness.**
Soil moisture should be sufficient that a handful of soil, when squeezed, just retains its shape but should crumble when touched. For drier soils or sandy soils, moisture may have to be added to the soil.	**Know how to determine if the soil has sufficient moisture.**	**Describe how to determine if the soil has sufficient moisture.**
Soil Compaction		
Heavy or compacted soils are not suitable for fumigation. These soils must be cultivated before they are fumigated. Light or sandy soils exhibit the opposite response. The fumigant escapes too quickly to allow sufficient residence time for the effect to occur.	**Understand that soil compaction or very loose soil affects fumigation effectiveness.**	**Describe how soil compaction or very loose soil affects fumigation effectiveness.**

Category: FUMIGATION

Concept: APPLICATION TECHNOLOGY - SOIL FUMIGATION

General Objective: To know how soil fumigation works.

COURSE OUTLINE	INSTRUCTIONAL OBJECTIVES	LEARNING OUTCOMES
Soil Temperature		
When soil temperatures are below 4EC (at a depth of 15-20 cm) the fumigant converts slowly to a gas. Diffusion also occurs at a very slow rate. At temperatures approaching 25EC and beyond, the fumigant is converted rapidly to a gas and leaves the soil quickly. Residence time for the gas is insufficient to achieve effective pest control. **Soil temperature at a depth of 15 to 20 cm should be in the range of 10 to 20EC.**	**Understand how soil temperatures affect the effectiveness of soil fumigation.**	**Describe how soil temperatures affect effectiveness of soil fumigation.**
Organic Matter		
Organic matter can bind the fumigant and prevent it from diffusing through the soil. Where organic material or crop residues are high, additional fumigant may be required to achieve effective pest control.	**Understand how organic matter reduces the effectiveness of the fumigant.**	**Describe how organic matter reduces the effectiveness of the fumigant.**
Application Timing		
The optimum time to apply soil fumigants is generally late summer or early fall, which allows sufficient time for the fumigant to be in the soil. Also, there is sufficient time for fumigant residues to disappear before planting in the following spring.	**Know the optimum time to apply soil fumigants.**	**Identify the optimum time to apply soil fumigants.** **Describe why timing of the fumigant application is important.**
Types of Soil Fumigation		
There are three types of soil fumigation namely: **- fumigation under sheets;** **- tractor mounted injectors;** **- soil incorporators.**	**Know the types of soil fumigation.**	**List the types of soil fumigation.**

Category: FUMIGATION

Concept: APPLICATION TECHNOLOGY - SOIL FUMIGATION

General Objective: To know how soil fumigation works.

COURSE OUTLINE	INSTRUCTIONAL OBJECTIVES	LEARNING OUTCOMES
Fumigation Under Sheets		
For small areas such as greenhouse soil or seed beds, the technique of fumigation under sheets can be used as described earlier. Liquid fumigants can be applied with an injector or with hand held sprayers. A light sprinkling of water should then be sprayed over the treated area to prevent release of the fumigant.	**Know how to fumigate small areas under sheets.**	**Describe how to fumigate small areas under sheets.**
Tractor Mounted Injectors		
For larger areas fumigants are usually applied from tractor drawn equipment. Tractor-mounted chisel injectors (also planter shoe injectors and plough injectors) are frequently used. As the chisel moves through the soil, it creates an opening 15 cm to 20 cm deep. The injector, located immediately behind the chisel, releases measured amounts of fumigant. After the injector passes, soil falls back and closes the opening. Immediately after application, drag the soil to remove chisel marks. Roll the soil to further reduce the release of fumigant. For very volatile fumigants the treated area is covered with a gas-proof film such as polyethylene. Edges are sealed with soil to prevent the release of the fumigant.	**Know how to fumigate soil using tractor mounted injectors.**	**Describe how to fumigate soil using tractor mounted injectors.**
Soil Incorporators		
Soil incorporators can also be used when applying low volatile fumigants. The fumigant is sprayed on the field and is immediately cultivated (15 cm or less). The field is then compacted with suitable equipment. An alternative to compaction is to irrigate the field following fumigation. Fumigants diffuse through water at a slow rate.	**Know how soil incorporators can be used for soil fumigation.**	**Describe how soil incorporators can be used for soil fumigation.**
Aeration After Soil Fumigation		

Category: FUMIGATION

Concept: APPLICATION TECHNOLOGY - SOIL FUMIGATION

General Objective: To know how soil fumigation works.

COURSE OUTLINE	INSTRUCTIONAL OBJECTIVES	LEARNING OUTCOMES
In those cases where the use of volatile fumigants require sheet sealing of the treatment area, care must be taken when aerating the treated area. Always wear a full face canister respirator when aerating a site. **Start by lifting the corner of the sheet to allow for gradual release of the fumigant. After 30 minutes, the entire sheet can be removed. No one should work in the treated area until virtually all the fumigant is gone.**	**Know the precautions to take when aerating the treated area.**	**Describe the precautions to take when aerating the treated area.**

Category: FUMIGATION

Concept: APPLICATION TECHNOLOGY - HANDLING OF FUMIGANT CYLINDERS

General Objective: To know how to handle fumigant cylinders.

COURSE OUTLINE	INSTRUCTIONAL OBJECTIVES	LEARNING OUTCOMES
Safe Handling of Cylinders and Application Equipment		
When the fumigant is contained in a cylinder, follow safe handling and installation procedures.		
During transport, ensure that cylinders are securely fastened using suitable strapping or webbed material. Cylinders must be securely fastened to application equipment. Frequently check brackets for damage.	**Know how to transport fumigant cylinders.**	**Describe how fumigant cylinders should be transported.**
Always check delivery lines, metering devices before the start of each fumigation. Ensure that delivery lines are protected from possible damage or rupture from other parts of the application equipment.	**Be able to prepare an application equipment check prior to starting a fumigation.**	**Describe the check list which is prepared prior to a fumigation.**
Equipment Maintenance		
Equipment should be thoroughly washed with water. Be sure to flush all parts of the system.	**Know procedures for cleaning fumigation equipment.**	**Describe the procedures for cleaning fumigation equipment.**
Once the system has been flushed with water, a final cleaning may be necessary. Check product label for specific instructions.		
Be sure to wear a proper respirator when cleaning the application equipment because fumigant residue may still exist.		
Because of the very volatile nature of fumigants, both storage and disposal must be done with care. The storage area should be partitioned off from other sections of a building. The storage facility must remain locked at all times and only be opened by authorized personnel.	**Know the proper storage of fumigants.**	**Describe how fumigants should be stored in a storage facility.**

Category: FUMIGATION

Concept: EMERGENCY RESPONSE - DEVELOPMENT OF ROUTINE EMERGENCY RESPONSE PROCEDURES

General Objective: To ensure that fumigation personnel are appropriately trained in emergency response procedures.

COURSE OUTLINE	INSTRUCTIONAL OBJECTIVES	LEARNING OUTCOMES
First Aid Training		
All fumigation personnel should be thoroughly trained in first aid procedures. Special emphasis is to be placed on artificial respiration procedures for gas poisoning.	**Know the first aid and other emergency response procedures for fumigation.**	**Identify emergency response procedures which are applicable to fumigation.**
Hospital/Poison Control Centres		
Hospital emergency departments and Poison Control Centres should be provided with information on fumigants that are being used. This information should be as detailed as possible. Supporting information should include label, product information and material safety data sheet.	**Know what information on fumigants to supply to hospitals and poison control centres.**	**Identify the information on fumigants to be supplied to hospitals and poison control centres.**
Emergency Response Plan		
For each fumigation, an emergency response plan should be prepared. This plan should include: **- notification of emergency response authorities;** **- fire fighting procedures;** **- location of telephone;** **- location of first aid equipment;** **- adjacent land use;** **- adjacent building occupancy;** **- site security;** **- MSDS;** **- extra safety equipment;** **- product distributor.**	**Know how to prepare an emergency response plan.**	**List the components of an emergency response plan.**