

# Unit 8. Common Fumigants

## Learning Objectives

For each fumigant discussed in this unit, the reader will be able to

- Describe basic application and aeration techniques.
- Understand its mode of action.
- Use it safely and effectively.
- Know which detection equipment best measures its concentration.
- Dispose of its residues and empty containers in a safe and legal manner.

This unit discusses some of the most common fumigants used to treat soil and raw commodities. By reading it, you will understand how each of these fumigants works and how to use them effectively. This unit will explain basic application and aeration procedures. You will learn the risks each chemical poses. You will discover how to protect yourself and others from exposure. Selection and use of detection equipment is discussed. This unit will also outline how to properly dispose of fumigant residues and empty fumigant containers.

## Terms to Know

**Bonnet** – The cap that covers the valve and safety cap on a fumigant cylinder. The bonnet protects the valving system from damage and prevents accidental release of the fumigant.

**Chemigation** – The application of a pesticide through an irrigation system.

**Corrosive** – Able to weaken or destroy something gradually.

**Deactivate** – To make something ineffective. For example, by deactivating fumigant residue, you would neutralize its toxic effects.

**Emulsifiable Concentrate (EC)** – A liquid pesticide formulation that helps you apply an active ingredient(s) that does not readily dissolve in water. The water-insoluble active ingredient(s) is dissolved in an organic solvent with an “emulsifier.” The emulsifier disperses the formulated product into tiny droplets when added to water.

**Exposure Period** – The period of time after fumigation during which the fumigant is allowed to diffuse through the material being treated in order to maximize “exposure” of the target pest(s) to the fumigant.

**Formulation** – The specific mixture of active ingredient(s), other additives, and a carrier in which a pesticide is offered for sale to the user. Examples include emulsifiable concentrations, pellets, etc.

**Germination** – The process by which a spore or seed begins to grow or sprout.

**Inert** – Having no chemical activity. Not reactive.

**Liberate** – To set free. To release.

**Prepac** – Aluminum phosphide fumigant tablets that are packed in a gas-permeable material.

**Residue** – Traces of fumigant that remain after treatment.

**Sprigging** – Transplanting pieces or “sprigs” of grass.

**Threshold Limit Value (TLV)** – The maximum amount of fumigant that can be in the air before conditions are considered unsafe. The TLV is expressed in parts per million (ppm). It is used to monitor short-term exposure.

**Threshold Limit Value-Time Weighted Average (TLV-TWA)** – The average concentration of fumigant for a normal 8-hour workday and a 40-hour workweek to which workers may be repeatedly exposed without adverse effect. The TLV-TWA is expressed in parts per million (ppm). It is used to monitor long-term exposure.

There are a limited number of fumigants on the market. Each has its own advantages, disadvantages, uses and limitations. This unit does not intend to indicate a preference toward any one fumigant. You must make your own choice based on the label information, the pest and the commodity or soil that is infested. Since there is some overlap between soil and raw commodity fumigants, we will not attempt to divide them into these two categories. Instead, we will discuss the many uses of each chemical.

# Common Fumigants

## Disclaimer

Just because a fumigant appears in this manual does not mean that it is legal to apply. Laws and regulations governing pesticides change often. Fumigants described here may no longer be legal. Always check current laws and regulations before using any **fumigant for any purpose. For example**, at the time of this writing, methyl bromide has been labeled an ozone-depleter. As a result, this widely used fumigant may soon be banned. Keep up-to-date on the state and federal laws and regulations that apply to you.

## Sulfuryl Fluoride

Sulfuryl fluoride (ProFume® or Vikane®) is a colorless, odorless and tasteless toxic gas. It is heavier than air and tends to initially settle in low areas. It is nonflammable. However, heaters, pilot lights and open flames must be extinguished, as temperatures above 752°F will cause decomposition products to be formed which can be corrosive and can etch glass and metal. Refer to ProFume and Vikane fumigation manuals and labels before usage and for any changes in use that may have occurred from the registration process. **Sulfuryl fluoride is toxic to most living organisms including humans.** In case of over exposure, get medical attention immediately.

## Formulations

Sulfuryl fluoride comes in pressurized cylinders (containers). ProFume and Vikane are restricted use products. Cylinders are under pressure, 303 psi @ 90°F, and must not be stored near heat or open flame. Exposure to temperatures above 158°F will cause a fusible plug to melt and the contents will be released. Always store and transport cylinders in a secure upright position. Cylinders of sulfuryl fluoride should be stored in a dry, cool, well-ventilated, secure and locked area. Post as pesticide storage area.

## Uses

This fumigant is very effective against insect larvae and adults, but requires higher doses for insect eggs. Do not use for insect control when temperature at the site is below 40°F.

## Sulfuryl fluoride at a glance:

### Required clothing:

- Use splash-resistant goggles or full-face shields when handling the liquid, such as opening the cylinder to introduce gas into a structure. Liquid sulfuryl fluoride can freeze the eye tissue.
- Wear loose-fitting or well-ventilated long sleeve shirt, long pants, shoes and socks.
- Do not wear gloves.
- Do not wear rubber boots.

### Respiratory protection:

- For ProFume use in commodities, concentrations of 1 ppm or less require no respiratory protection. Concentrations above 1 ppm require NIOSH/MSHA approved SCBA or combination air-supplied respirator/SCBA, such as those manufactured by Ranger, Survivair, Scott or MSA.
- For Vikane use in structures, concentrations of 5 ppm or less require no respiratory protection. Concentrations above 5 ppm require NIOSH/MSHA approved SCBA or combination air-supplied respirator/SCBA required, such as those manufactured by Ranger, Survivair, Scott or MSA.
- If (emergency) re-entry into a structure under fumigation, prior to complete aeration, with sulfuryl fluoride is required, the proper respiratory protection (SCBA) must be used.

## ProFume Uses

- What – For control of insects pests for the commodities listed on label, such as confused flour beetle, red flour beetle, sawtoothed grain beetle, warehouse beetle, Indianmeal moth, Mediterranean flour moth, codling moth, navel orangeworm, granary weevil, rice weevil and other moths and beetles as well as rodents. Area around fumigation must be monitored using a detection device such as INTERSCAN gas analyzer or MIRAN vapor analyzer to ensure that workers without respiratory protection are not exposed to

concentrations of sulfur dioxide exceeding **1 ppm**.

- Where – Non-residential structures (for the food commodities listed on the label) such as mills, warehouses, stationary transportation vehicles (railcars, trucks, etc., excluding aircraft and passenger railcars), temporary and permanent fumigation chambers and storage structures. For use in food-processing establishments containing only those commodities listed on the label. Not for use in other food-handling establishments.
- Do not use ProFume without the Fumiguide Program for ProFume Gas Fumigant. The ProFume Fumiguide is part of labeling for ProFume and must be used to calculate the dosage. Never allow untrained individuals to apply ProFume gas fumigant.
- **Read product label for any usage changes and further definition of uses or prior to fumigation.**

## Vikane Uses

- What – Control of existing infestation of insects and related pests such as (or including) drywood termites, Formosan termites, powderpost beetles, death watch beetles, old house borers, bedbugs, cockroaches, clothes moths, rodents (rats, mice) and the larvae and adults of carpet beetles (except egg stage), oriental, American and brownbanded cockroaches.
- Where – Dwellings (including mobile homes), buildings, construction materials, furnishings (household effects) and vehicles including automobiles, buses, surface ships, rail car, and recreational vehicles (but not including aircraft). Area around fumigation must be monitored using a detection device such as INTERSCAN gas analyzer or MIRAN vapor analyzer to ensure that workers without respiratory protection are not exposed to concentrations of sulfur dioxide exceeding **5 ppm**.
- **Read product label for any usage changes and further definition of uses or prior to fumigation.**

## Application

Sulfur dioxide does not adversely react with other compounds. However, all flames, including pilot lights, must be extinguished. All electrical heating elements must be turned off or unplugged. Temperatures above 752°F will cause

decomposition products to be formed which can be corrosive and etch glass and metal.

Because sulfur dioxide is odorless, colorless and tasteless, chloropicrin must be used as a warning agent when using Vikane. Pour chloropicrin (one ounce per 10,000 to 15,000 cubic feet) onto some cotton in a shallow pan. Do not use evaporation containers or application equipment made of magnesium, aluminum or their alloys, as chloropicrin may be severely corrosive to such metals. Place the pan in front of a fan. Allow 5 to 10 minutes for the chloropicrin to circulate before introducing the sulfur dioxide. When adding chloropicrin to evaporation containers, do not dispense more than 3 fluid ounces per container. Use one chloropicrin introduction site per 45,000 cubic feet to be fumigated.

Introduce sulfur dioxide from the outside through tubes. Use polyethylene, polypropylene or strong nylon tubing with an internal diameter of 1/8 to 1/4 inch. The tubing should have a minimum burst pressure of 500 pounds per square inch (PSI). The rate of fumigant released through larger tubing would be too great for good gas distribution. Place fans throughout the fumigation area. Run the fans during introduction and for at least 60 minutes afterward. For ProFume, Dow recommends leaving the fans running for the duration of the fumigation. Fans aid in the introduction, distribution and the aeration process for sulfur dioxide. Fans will circulate the gas ensuring good distribution. If desired, use a remote shut-off such as a timer to turn off the fans.

Do not use sulfur dioxide at temperatures below 40°F. To prevent damage, do not apply sulfur dioxide directly to any surface.

## Precautions

If the concentration of sulfur dioxide is unknown or exceeds 1 ppm for ProFume or 5 ppm for Vikane, all persons in the exposed area must wear a self-contained breathing apparatus (SCBA) or a combination air-supplied/SCBA respirator.

Always wear (safety) splash resistant goggles or a face shield while releasing sulfur dioxide. However, you **should not wear rubber boots or gloves** when introducing sulfur dioxide. These may trap the liquid against your skin and cause injury.

When fumigating with Vikane any food, feed or drug item must be placed in Nylofume bags or removed before fumigation. Because the gas can get into frost-free refrigerators and freezers,

you must either bag the contents of these appliances or remove their contents from the fumigated space. Additionally, open or remove items that might slow fumigant aeration, such as waterproof mattress covers. Do not use sulfuryl fluoride on living plants.

In transit fumigation, including aeration, of any vehicle is prohibited on public roads or waterways.

Product labels require that the structure be posted with specific warning signs on all entrances and all sides during the exposure and aeration period until the building is cleared for reentry by the fumigator.

## Aeration

Aeration is rapid. Sulfuryl fluoride desorbs quickly. Follow the aeration procedures in the label information to determine your aeration time.

## Detection

Use the Fumiscope® (a thermal conductivity analyzer) to monitor sulfuryl fluoride levels during application. The Fumiscope® can detect sulfuryl fluoride at levels greater than 240 ppm.

When measuring gas concentrations for reentry, however, you will need to use a different type of gas detector. Only approved detection devices of sufficient sensitivity, such as specific types of gas analyzers or infrared detection systems (ambient air analyzers), can be used to confirm a concentration of sulfuryl fluoride of 1 ppm or less. At the time of this writing, the sulfuryl fluoride product label requires the use of an INTERSCAN or MIRAN analyzer, or similar approved device to measure gas concentrations for reentry.

## Disposal

When a sulfuryl fluoride cylinder is empty, close the valve, screw the safety cap onto valve outlet and replace the protection bonnet. Return the empty cylinder promptly to the distributor. Do not use the cylinder for any other purpose.

**As with any Restricted Use Pesticide, carefully read and follow all label instructions. When using ProFume Gas Fumigant, the fumigator must also read and follow the ProFume Gas Fumigant Fumigation Manual as it is part of the label. All persons desiring to use sulfuryl fluoride, as Vikane or ProFume, must comply with Dow AgroSciences product stewardship policies.**

# 1,3-Dichloropropene

## 1,3-Dichloropropene at a glance:

### Required clothing:

#### Outside an enclosed tractor cab:

- Coveralls over a short-sleeved shirt and short pants.
- Chemical-resistant gloves as listed in the label information.
- Chemical-resistant footwear plus socks.
- Face-sealing goggles, unless a full-face respirator is worn.
- Chemical-resistant headgear for overhead exposure.
- Chemical-resistant apron when performing direct contact tasks.

#### Inside an enclosed tractor cab:

- Coveralls.
- Shoes and socks.
- Face-sealing goggles, unless a full-face respirator is worn.
- Additional clothing for direct contact activities must be immediately available and must be worn if the handler leaves the enclosed cab to perform any direct contact activity.

### Respiratory protection:

#### Outside an enclosed tractor cab:

- A National Institute of Safety and Health (NIOSH)-approved respirator with a canister approved for pesticides or an organic-vapor-removing cartridge with a prefilter approved for pesticides.

#### Inside an enclosed tractor cab:

- A NIOSH-approved, half-face respirator with a canister approved for pesticides or an organic-vapor-removing cartridge with a prefilter approved for pesticides.

#### In high concentration conditions (large spill cleanup, poor ventilation):

- A NIOSH-approved supplied-air respirator or self-contained breathing apparatus (SCBA).

### Uses:

- What: Soil.
- Where: Agricultural fields. Not for use in greenhouses or other enclosed areas.

1, 3-dichloropropene (1, 3-D) usually comes as a colorless to straw-colored liquid with a pungent, sweet, penetrating odor. It is flammable, highly mobile in soil and toxic to many organisms, including aquatic organisms and humans.

## Formulations

Products that contain only 1,3-D are over 90 percent pure. These mixtures are formulated as emulsifiable concentrates (ECs) and non-emulsifiable concentrates (Non-ECs). Application of 1,3-D as an EC is restricted to use with drip irrigation systems. You can also combine 1,3-D with chloropicrin to create a multipurpose fumigant. Non-EC formulations are packaged in pressurized cylinders of varying sizes. Most come in large “mini-bulk” containers.

## Uses

1,3-D is used for soil fumigation only. It is most often applied to control plant-parasitic nematodes. However, it will also control or suppress certain insects and diseases. Read the label to be sure 1,3-D will control the pest or disease you wish to target.

## Application

You can apply 1,3-D products as row treatments or by broadcasting them over entire fields. The most common formulation of 1,3-D is the non-EC. Use “ripper-bedders” for row application of non-ECs. A ripper-bedder is a subsoil shank followed by two bedder disks. Together, these are attached to a toolbar and perform a single operation. The shank fractures the hardpan in the soil, while the disks throw a mound of soil over the slit left by the shank. For broadcast fumigation, use chisel or bottom plows. Apply non-ECs through equipment that moves the product from a tank into the soil via pressure from a cylinder of nitrogen gas or from a pump – power take-off (PTO), electrical (explosion-proof) or ground-driven. During application, maintain operating pressures between 10 and 50 pounds per square inch (psi).

Apply EC formulations of 1, 3-D through a surface or buried drip irrigation system for each row. Space drip emitters 12 to 24 inches apart on the driplines. Cover each treated row with tarp for at least 14 days after application.

## Precautions

1,3-D products should only be used to treat soil. Do not use them in confined spaces such as

greenhouses or in areas where fumes can enter nearby dwellings.

Do not use 1,3-D products with equipment that contains aluminum, magnesium, zinc, cadmium metals or their alloys, or galvanized materials. 1,3-D is highly corrosive to these materials. Polyvinyl chloride (PVC), ethylene propylene diene monomer (EPDM), Buna-M, neoprene and fiberglass may also dissolve upon contact with products that contain 1,3-D. Finally, do not use 1,3-D with rubber.

During application of 1,3-D, be sure that:

- Sight gauges on all application tanks have shut-off valves
- All tank fittings are fumigant-resistant (brass or nylon)
- All seals are made of Viton®
- Transfer systems are the dry-disconnect type

Do not allow smoking within 50 feet of containers or equipment that contains 1,3-D. A full eyewash bottle and at least 5 gallons of clean water should be available to each person who handles 1,3-D. Restrict entry into the fumigated area until five days after treatment. Notify workers of an application verbally, as well as by posting warning signs at the entrances to treated area.

Check and replace hoses, check valves, strainers, tanks and seals in soil fumigation equipment regularly. Before application, flush your equipment with diesel fuel or water to check for leaks or other problems. If you use water, pump out or drain the water before filling the equipment with fumigant. Flush application equipment with diesel fuel after each use. Dispose of flush material according to local, state and federal regulations. Fill any pumps with new motor oil or a 50 percent motor oil/fuel oil mixture before storing them. Store application equipment in a location that protects it from sunlight and weather.

## Aeration

Exposure periods for 1,3-D should range from 7 to 14 days. At the end of the exposure period, delay planting for at least one week for each 10 gallons of 1,3-D-containing product that you use per acre. Read the label to determine how long to aerate the treated area. Allow longer exposure and aeration periods when the soil is cold and wet. You can speed up aeration by cultivating the soil to the depth of the treatment zone.

## Detection

Detection devices are not normally used with soil fumigants such as 1,3-D.

## Disposal

Products that contain 1,3-D are sold in refillable containers. Return these containers to the distributors after use.

## Chloropicrin

Chloropicrin is a colorless, nonflammable, liquid fumigant. It is toxic to fungi, insects, mites and rodents in commodity storage sites. It will also control or suppress plant-parasitic nematodes and certain bacterial pathogens, soil fungi and soil-infesting insects. Chloropicrin is a

powerful tear gas. Its strong odor and irritating effects warn people of its presence.

You can use chloropicrin alone and with other fumigants. At a concentration of 2 percent or less, chloropicrin acts as a warning agent. At higher levels, it can enhance the activity of other fumigants.

*NOTE: Personal protective equipment (PPE) requirements and other use information differ depending on how you use chloropicrin, as a warning agent (low concentrations) or as a pesticide (higher concentrations). This manual covers information for chloropicrin when it is used as a pesticide only. This manual does not cover information for chloropicrin used as a warning agent. Always consult the label information before using any fumigant for any purpose.*

## Formulations

Chloropicrin products are nearly 100 percent pure. They come in a variety of containers and amounts:

- 1-pound bottles
- 3.5 pound and 13.5-pound plastic containers
- Nonpressurized cylinders that contain 2 to 70 pounds of product
- Pressurized cylinders that contain up to 375 pounds of product

## Uses

As a warning agent, chloropicrin can be used in dwellings (emptied of food products), empty structures (warehouses, grain bins, greenhouses, poultry houses, mushroom houses), and empty bags, boxes and crates. However, do not use chloropicrin near living plants or in dairy, cheese or meat factories. When used as a warning agent with sulfuryl fluoride in structural fumigations, chloropicrin is introduced before the actual fumigant is released. Methyl bromide structural fumigants are typically premixed formulations that contain chloropicrin as a warning agent.

As a pesticide, chloropicrin is limited to use in empty potato storage structures and the sub-floor aeration spaces below empty grain bins. Because it is nearly six times heavier than air, chloropicrin will sink down into the plenum area of bins with false floor aeration systems without the help of fans.

You can use chloropicrin to treat soil and agricultural fields. It will control or suppress soil insects and plant disease-causing organisms such as nematodes, bacteria and fungi.

### Chloropicrin at a glance:

#### Required clothing:

- Loose-fitting or well-ventilated shirt and long trousers.
- Shoes and socks.
- Full-face shield or safety glasses with brow and temple shields.
- Do not wear goggles.
- Do not wear jewelry.
- Do not wear gloves, rubber protective clothing or boots.
- Do not wear contact lenses.

#### Respiratory protection:

- Concentrations less than 0.1 ppm: no respiratory protection required.
- Concentrations greater than 0.1 ppm and less than 4 ppm: NIOSH-approved air-purifying respirator approved for organic vapors.
- Concentrations greater than 4 ppm or unknown concentrations: NIOSH-approved supplied-air respirator or SCBA.

#### Uses:

- What: Empty structures.
- Other: As a warning agent with other fumigants.
- What: Soil.
- Where: Agricultural fields and soil media in greenhouses or other enclosed structures.

Do not use chloropicrin alone or mixed with methyl bromide to treat foods, fresh fruits or vegetables. Products containing chloropicrin, even as a warning agent, are no longer labeled for direct application to stored grain.

## Application

When fumigating soil, apply chloropicrin through a closed system. Pressurize the system with dry, nonflammable compressed nitrogen gas at pressures between 30 and 120 psi. To be safe, use only equipment with parts that can withstand pressures above 150 psi. In addition, be sure your equipment is made of brass, copper, stainless steel, black carbon steel or polyethylene. Do not use aluminum, magnesium or any of their alloys (PVC, Neoprene, Buna-M, EDPM or rubber). Be sure all gaskets and threading sealants are made of compatible materials such as Teflon™.

Do not use chloropicrin when soil temperatures are below 50°F. Ideally, temperatures should be between 60°F and 85°F.

Chloropicrin moves through soil rapidly. For this reason, it is important to tarp treated soil to prevent premature loss of the fumigant from the soil.

To treat small areas or volumes of soil, potting mix or mushroom casing with chloropicrin, use a probe-type injection device. Release the product 6 to 8 inches below the soil surface in a grid pattern. Space your injection points 12 inches apart.

## Precautions

Handle chloropicrin in well-ventilated conditions with the applicator upwind. If the air concentration of chloropicrin exceeds 0.1 ppm, all persons in the exposed area must wear an air-purifying respirator approved for organic vapors. When treating soil inside a greenhouse or other enclosed structure, restrict entry for 48 hours after fumigation and until the concentration of chloropicrin is less than 0.1 ppm. If chloropicrin air concentrations are above 4 ppm or are unknown, all persons in the exposed area must wear a supplied-air respirator or an SCBA. If you detect a strong odor or your eyes start to tear, the mask is leaking. Leave the area and do not reenter unless you are wearing an SCBA. If necessary, supplement the SCBA with an air hose to provide air from an outside source.

However, you should only use this as an emergency backup supply in case the SCBA runs out of air. Regardless of the fumigant concentration in the work area, respiratory protection must be available at the fumigation site.

When handling and applying chloropicrin, be sure to wear a full-face shield or safety glasses with brow and temple shields. You should also wear loose-fitting, full-body clothing, shoes and socks. Do not wear goggles, gloves, rubber protective clothing or boots. If liquid chloropicrin splashes on your clothes, shoes or socks, remove them immediately. Place them outdoors until they aerate completely. Discard any absorbent items that have been drenched or heavily contaminated.

To be safe, use only fumigation equipment with parts that can withstand pressures above 500 psi. In addition, be sure your equipment is made of brass, copper, stainless steel, black carbon steel or polyethylene. Do not use galvanized pipe, aluminum, magnesium or any of their alloys (PVC, Neoprene, Buna-M, EDPM or rubber). Be sure all gaskets and threading sealants are made of compatible materials such as Teflon™. Fumigation “rigs” should include a filter to remove any particulates and a check valve to prevent backflow contamination of the pressurizing cylinder.

Chloropicrin is corrosive to most metals (for example, magnesium, aluminum, etc.). Take care to protect metal surfaces and equipment during treatment.

Chloropicrin should be stored in upright containers in a cool, dry, well-ventilated area under lock and key. Be sure to completely close the cylinder valve to reduce leaks and potential damage to metal. Do not store chloropicrin near people, animal feed, food or seed.

## Aeration

Long aeration periods may be needed to remove chloropicrin’s strong odor and “tear gas” effect. Follow the aeration procedures in the label information to determine your aeration time.

## Detection

You can use several devices to detect chloropicrin. Examples include color diffusion detector tubes and infrared detection systems (ambient air analyzers).

## Disposal

Dispose of excess product according to the label information. Return reusable cylinders to the manufacturer or distributor. Always triple-rinse plastic containers before recycling or reconditioning them. If you are not able to recycle a container, rinse and puncture it before disposing of it in a landfill, burning it or incinerating it.

## Controlled Atmospheres (CAs)

Controlled atmospheres (CAs) are low-oxygen mixtures of relatively inert gases such as nitrogen (N<sub>2</sub>) and carbon dioxide (CO<sub>2</sub>). CAs have three major advantages over other fumigants.

1. CAs leave no harmful residues on the treated commodities.
2. If a CA leaks from a treatment area, it will be diluted by normal air and reach nontoxic levels quickly.
3. CAs do not change the end-use processes (for example, baking, brewing, germination, etc.) or biochemical properties (for example, taste, odor, etc.) of commodities.

As a result, CAs have fewer government regulations than do other fumigants.

Unfortunately, CAs also have several disadvantages. The biggest problem is cost. Fumigation with CAs is usually more expensive than with other fumigants. It may not be cost-effective in many situations. Other disadvantages with CAs include the long exposure times and high concentrations required for effective control of many stored product pests. CAs also become much less effective at lower temperatures. Sixty degrees Fahrenheit is the lower limit for adequate pest control. Although CAs are often thought of as nontoxic, low-oxygen atmospheres are very hazardous to humans. They can cause unconsciousness and death quickly. Even when diluted with oxygen, CO<sub>2</sub> has some toxicity, as evidenced by an Occupational Safety and Health Administration (OSHA) worker exposure limit of 10,000 ppm (1%) during an 8-hour time-weighted average (TWA).

Because the atmospheric gas most commonly used as a fumigant is CO<sub>2</sub>, this manual discusses only CO<sub>2</sub> fumigation.

## Carbon Dioxide (CO<sub>2</sub>)

### Carbon dioxide at a glance:

#### Required clothing:

- None

#### Respiratory protection:

- Entry into any CO<sub>2</sub>-treated areas: NIOSH-approved supplied-air respirator or SCBA.

#### Uses:

- What: Raw agricultural commodities such as cereal grains.
- Where: Silos, trucks, trailers, bins, tanks and sealed railroad cars and ships.

CO<sub>2</sub> is a colorless, odorless and tasteless gas. It is about 1.5 heavier than air, and it is non-combustible. Although it is safer than other fumigants, a single breath of CO<sub>2</sub> in the high concentrations used for fumigation can cause a person to faint or fall. The main advantage of CO<sub>2</sub> is that it leaves no toxic residues and no odors or flavors. CO<sub>2</sub> also does not affect the germination of seeds.

## Formulations

CO<sub>2</sub> is commonly stored and transported as a liquid at 0°F and under a pressure of 300 psi. One pound of CO<sub>2</sub> produces 8.7 cubic feet of gas.

For most fumigants, you will need a large amount of CO<sub>2</sub>. Bulk containers range from 4 to 50 tons. These amounts are usually delivered by tanker truck and transferred to an on-site receiver. The liquid CO<sub>2</sub> is then vaporized and passed as a gas through the stored commodity. The CO<sub>2</sub> supplier is usually involved in the delivery and vaporization of CO<sub>2</sub>.

## Uses

You can also use CO<sub>2</sub> to treat raw commodities in bins, concrete soils, storage bins, tanks and railroad cars if you are able to seal the structures tightly enough to contain the fumigant. At high concentrations, CO<sub>2</sub> triggers increased respiration in insects. This can cause dehydration and death. The most effective concentration of CO<sub>2</sub> is about 60 percent. Lower than 60 percent, CO<sub>2</sub> levels are less effective.

Concentrations higher than 60 percent provide little or no added benefit.

Do not use CO<sub>2</sub> as a pesticide on fresh produce. Insecticidal concentrations are too high and may damage the produce.

CO<sub>2</sub> may also be useful for organic operations.

## Application

There are two methods available for treating stored products with CO<sub>2</sub>:

1. The top-down purge method.
2. The lift method.

The top-down purge method adds CO<sub>2</sub> at the top of a structure. The CO<sub>2</sub> displaces the air in the structure as it settles downward. The lift method adds CO<sub>2</sub> at the bottom of the structure. In this case, the CO<sub>2</sub> displaces the air in the structure as it moves upward.

The application method you choose will depend largely on the type of structure you intend to treat. Use the top-down purge method in concrete commodity elevators where you can place the injection hose in the top of a well-sealed tank. Bottom injection (the lift method) works best in stand-alone steel bins where major leaks occur at the top around eaves and hatches. In either application, you must vent the storage during the initial purge so that air pressure will allow the normal air to escape.

To determine when the purge is complete, measure CO<sub>2</sub> concentrations at the commodity surface or headspace (for the lift method) or at the base of the commodity mass or aeration floor (for the top-down purge method). When CO<sub>2</sub> levels reach 60 percent, seal the structure to prevent leaks and outside air from entering. Make additional injections of small amounts of CO<sub>2</sub> when concentrations within the commodity have dropped below 50 to 60 percent. Because CO<sub>2</sub> is heavier than air, it can settle into the bottom of the storage. You can use recirculation systems to improve the efficiency of CO<sub>2</sub> fumigation.

CO<sub>2</sub> application in commodity storages requires a pressure regulator to drop pressures from 300 psi in storage tanks to 10 to 40 psi at the injection hose. Use a flowmeter and globe valve to measure and set the flow of CO<sub>2</sub> to the desired rate, usually measured in pounds per hour. You will also need a vaporizer to speed the conversation of CO<sub>2</sub> from liquid to gas.

The effectiveness of CO<sub>2</sub> depends on several factors. Principal among these are commodity temperature and the insect species you target. Adjust the duration of treatment accordingly. If commodity temperatures are less than 60°F, CO<sub>2</sub> fumigation is usually not effective because fumigation times become extremely long. As commodity temperatures increase, however, fumigation time drops. For example, when grain temperatures are near 80°F, most insects that live outside of the grain kernel will die if they are exposed to CO<sub>2</sub> for 4 to 5 days. Internally developing insects, such as weevils, require longer exposure periods of 10 to 14 days.

*NOTE: While insect eggs are often resistant to chemical fumigants, they are more susceptible to CO<sub>2</sub> and other CAs.*

## Precautions

While CO<sub>2</sub> leaves no toxic residues in treated commodities, it is poisonous at high concentrations in enclosed spaces. The concentration of CO<sub>2</sub> in the atmosphere is about 0.03 percent. The threshold limit value (TLV) for CO<sub>2</sub> exposure is 1.0 percent. When concentrations of CO<sub>2</sub> reach 2 percent, human breathing rates increase by 50 percent above normal. At 5 percent CO<sub>2</sub>, human breathing is three times more rapid than normal. Such levels can cause strain, fatigue and exhaustion. High concentrations of CO<sub>2</sub> not only reduce available oxygen, they also trigger additional respiratory stress.

Always monitor CO<sub>2</sub> concentrations when applicators enter a fumigated structure. Also check enclosed work areas adjacent to the structure.

Gas mask/canister respirators do not provide protection in high-CO<sub>2</sub>, low-oxygen atmospheres. Although the canister may absorb the fumigant, it cannot supply the necessary oxygen. Only an SCBA or supplied-air respirator provides adequate protection.

As a rule, do not enter an area undergoing fumigation with CO<sub>2</sub> except under emergency conditions. Then, you must wear an SCBA or supplied-air respirator.

## Aeration

Structures fumigated with CO<sub>2</sub> must be aerated before unprotected workers may enter. CO<sub>2</sub> is known to sorb into commodities and may desorb slowly. Read the label information for specific aeration instructions.

## Detection

Check CO<sub>2</sub> concentrations throughout the treatment process. Monitor low concentrations of CO<sub>2</sub> to provide information for worker safety. Monitor high concentrations of CO<sub>2</sub> to determine the need for continued injection of CO<sub>2</sub> into the structure. Use vacuum pumps and tubing to draw gas samples during fumigation. Test these samples with gas detector tubes. Use separate tubes to detect low and high levels of CO<sub>2</sub>. Thermal conductivity sensors capable of measuring a range of CO<sub>2</sub> concentrations are also available.

## Disposal

Dispose of CO<sub>2</sub> containers according to the label information.

## Dazomet

Dazomet is formulated as a nonflammable white or yellowish solid with a characteristic odor. If it contacts damp soils, dazomet decomposes into the active ingredient methyl isothiocyanate (MITC). MITC is toxic to many organisms, including aquatic organisms and humans. Dazomet is insoluble in water.

### Dazomet at a glance:

#### Required clothing:

- Coveralls over a short-sleeved shirt and short pants.
- Chemical-resistant footwear plus socks.
- Waterproof gloves.

#### Respiratory protection:

- A NIOSH-approved air-purifying respirator is required for application in greenhouses or other enclosed areas. A NIOSH-approved half-face respirator may be worn if face-sealing goggles are used.

#### Uses:

- What: Soil and compost.
- Where: Compost piles, golf greens/tees, fairways, potting soils, seed and propagating beds, soil heaps and piles, soil media, ornamental beds and soil media in greenhouses or other enclosed structures.

## Formulations

Currently, dazomet is sold only as a granular product containing 99 percent active ingredient and 1 percent inert ingredients.

## Uses

As a soil fumigant, dazomet will control most weeds, nematodes and plant diseases caused by soil-borne pathogens. However, it is not registered for the control of soil insects. You can use dazomet to fumigate soil for interplanting within existing orchards, berry fields and similar areas. It will also kill grasses and weeds in lawn and turf areas before renovation.

## Application

There are several ways to apply dazomet. These include:

- Incorporation With Tarping – incorporating dazomet into the soil and then tarping the soil to seal in the fumigant
- Incorporation Without Tarping – incorporating dazomet into the soil and then rolling and irrigating the soil to seal in the fumigant
- Topical Application With Irrigation – applying dazomet to the top of the soil and then using irrigation to seal in the fumigant

### Incorporation With Tarping

To apply dazomet via the “Incorporation with Tarping” method, use scoops, shakers, drop-type fertilizer spreaders or other suitable equipment to spread the product as evenly as possible. Do not use rotary spreaders. Immediately after spreading, incorporate the granules uniformly to a 4-inch depth using a C-shaped tine rototiller or spading machine. After incorporation, seal the treated soil by covering it with a polyethylene sheet.

Maintain soil moisture at 50 percent of field capacity for 5 to 14 days before treatment and during treatment. In addition, be sure soil temperatures are between 43°F to 68°F. Record the soil temperature in your treatment log.

Unfortunately, tarping soils can be expensive. For this reason, the “Incorporation with Tarping” method is usually reserved for smaller areas.

## **Incorporation Without Tarping**

For large areas, the labor and disposal costs associated with tarping may be undesirable. In these cases, you can seal in an incorporated fumigant by compacting and irrigating the soil. First, apply and incorporate dazomet as described in the “Incorporation with Tarping” section. Then, instead of covering the soil with a tarp, compact the soil surface with a roller and add moisture to form a crust on the soil surface. Keep the treated soil wet but not waterlogged for 72 hours after treatment. If treated soils are untarped, moisten them frequently for 5 to 7 days after treatment. This will minimize cracking of the soil surface. Cracks may allow fumigant to escape before the target pests are completely controlled.

## **Topical Application With Irrigation**

Topical application with irrigation works best in areas you do not want to till, such as golf greens, tees and fairways. This method uses water instead of tillage to draw dazomet into the soil. First, prepare the target area. If weeds are present, apply a nonselective herbicide. Then, mow the area close to the ground and remove as much debris as possible. Apply dazomet with a drop spreader at the label rate. Irrigate the treated area. Keep the soil surface wet but not waterlogged for at least 72 hours after application. Then moisten the treated area frequently for 5 to 7 days after treatment. Conduct a seed germination test with lettuce seed or cress seed before planting, seeding or sowing. See Unit 5 for more information about this test.

For all application methods, waiting periods between application of dazomet and planting or seeding depend on soil temperature and moisture. Higher moisture levels and lower soil temperatures usually require a longer wait.

Thoroughly clean your application equipment with a strong detergent or a commercial sprayer cleaner before and after treatment.

## **Precautions**

Do not apply dazomet when air temperatures are over 103°F or when wind might blow product granules away from the target area. Keep the product 3 to 4 feet from growing plants and no closer than the dripline of trees and large shrubs. Do not apply dazomet to any area where surface water is present or likely to occur, or any area that is subject to runoff. After treating orchards, berry fields and similar areas, do not harvest produce for one full year after application.

Notify workers verbally and by posting fumigant warning signs outside entrances to the treated area. Do not drink alcoholic beverages before, during or after working with dazomet.

Fumigation with dazomet can reduce the nitrification of fertilizers. You can decrease this risk by using fertilizers that contain a high percentage of nitrogen. It also helps to fumigate several months before planting.

Do not apply manures, fertilizers or lime with dazomet.

## **Aeration**

Aerate treated soil no sooner than 5 to 7 days after application. At that time, loosen treated soil thoroughly to the depth of incorporation by tilling it with a disk, power tiller or hand implement. To avoid crop injury, be sure that all dazomet residues are gone from the soil before planting or seeding. Keep in mind that soils with high levels of organic matter will take longer to aerate. Read the label information to determine how long to wait between treatment and planting, seeding or transplanting. You can also conduct a seed germination test with lettuce seed or cress seed that will indicate whether treated soil is safe for planting. See Unit 5 for more information about this test.

## **Detection**

For applying dazomet outdoors, detection devices are not normally used. For treatments in enclosed structures, read the label to determine what reentry standards to use.

## **Disposal**

Dispose of excess dazomet wastes according to the label information. Always triple-rinse plastic containers before recycling them. If you are not able to recycle a container, rinse and puncture it before disposing of it in a landfill, burning it or incinerating it.

## **Metam Sodium**

Metam sodium is a nonflammable, amber to yellow-green, water-soluble liquid. It has a characteristic odor of rotten eggs. Metam sodium readily decomposes into the active ingredient MITC. Metam sodium is toxic to many organisms, including aquatic organisms and humans.

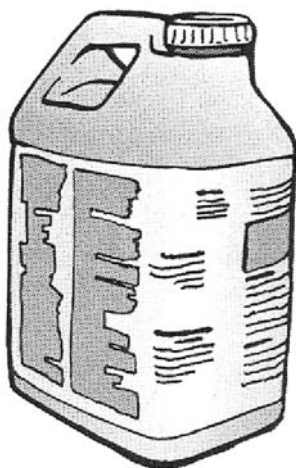
## Formulations

Metam sodium is available as a 42 percent liquid solution. It is available in a variety of containers and amounts, including:

- 55-gallon drums
- Mini-bulk containers, 250 to 300 gallons
- Trailerloads, 4,500 gallons
- Railcars, 18,500 gallons

## Uses

As a soil fumigant, metam sodium will control most weeds, nematodes, and plant diseases caused by soil-borne pathogens. Metam sodium is registered for use on all crops for the treatment of soil or agricultural fields. It will also kill grasses and weeds in commercial sod, turf and ornamental flower farms before seeding or sprigging. Read the label information to be sure that metam sodium will control the pest or disease you wish to target.



Metam sodium container

## Application

There are many ways to apply metam sodium. The most common methods used are soil injection, chemigation and rotary tiller or power mulcher application.

### Soil Injection

This method uses injectors (shanks, blades, fertilizer wheels, plows, etc.) to apply metam sodium below the soil surface. A bed shaper, roller press wheel or similar device follows behind the injection equipment to immediately seal the fumigant into the soil. You can also seal the injection zone by covering it with an adequate amount of soil. Light watering (1/2 inch of water is usually best) or tarping after rolling also helps to reduce gas escape.

### Chemigation

Chemigation applies pesticide through an irrigation system. The two most common types

## Metam sodium at a glance:

### Required clothing:

#### Outside an enclosed tractor cab when performing direct contact tasks:

- Coveralls over a long-sleeved shirt and long pants.
- Chemical-resistant footwear plus socks.
- Face-sealing goggles, unless a full-face respirator is worn.
- Chemical-resistant headgear for overhead exposure.
- Chemical-resistant apron.

#### Inside an enclosed tractor cab:

- Coveralls.
- Shoes and socks.
- Additional clothing for direct contact activities must be immediately available and must be worn if the handler leaves the enclosed cab to perform any direct contact activity.

#### Early entry of the treated area:

- Coveralls over a long-sleeved shirt and long pants.
- Waterproof or chemical-resistant gloves.
- Chemical-resistant footwear plus socks.
- Face-sealing goggles, unless a full-face respirator is worn.

### Respiratory protection:

#### Outside an enclosed tractor cab when performing direct contact tasks:

- A NIOSH-approved air-purifying respirator with a canister approved for pesticides or an organic-vapor-removing cartridge with a prefilter approved for pesticides.

#### Inside an enclosed tractor cab:

- A NIOSH-approved air-purifying respirator with a canister approved for pesticides or an organic-vapor removing cartridge with a prefilter approved for pesticides.

#### Early entry of the treated area:

- If a pungent, rotten-egg odor can be detected, a NIOSH-approved air-purifying respirator must be worn with either a canister approved for pesticides or an organic-vapor-removing cartridge with a prefilter approved for pesticides.

### Uses:

- What: Soil.
- Where: Agricultural fields. Not for use in greenhouses or other enclosed areas.

of irrigation used to apply metam sodium are sprinkler irrigation and drip irrigation.

Sprinkler chemigation requires 1 to 1 1/2 inches of water. Start by pre-irrigating the field five to seven days before application to stimulate biological activity. Then, apply metam sodium in a minimum of 1 acre-inch of water. Continuously meter the fumigant into the irrigation system throughout the application period. Be sure to apply a 1/2 inch water seal. If the soil surface dries quickly, reseal it with 1/2 inch of water once the next day. Use only sprinkler systems that produce large water droplets. This will reduce evaporation and drift. Operate the system at the lowest pressure possible.

When applying metam sodium with drip irrigation, first pre-irrigate the field as described for sprinkler irrigation. Check the drip tape for uniform distribution. Then, apply the fumigant using enough water to thoroughly wet the treatment zone. Inject metam sodium continuously into the drip line as close as possible to the treatment area. You may need two or more lines per bed to ensure full coverage.

### **Rotary Tiller or Power Mulcher Application**

This method sprays dilute metam sodium in front of a tiller or mulcher, which incorporates the fumigant into the soil. A bed shaper, roller press wheel or similar device follows behind the tiller or mulcher to immediately seal the fumigant into the soil. You can also seal the treatment zone by covering it with an adequate amount of soil.

Immediately after all methods of application, you must seal the soil in order to retain the fumigant. Several options are available, including:

- Water sealing with irrigation systems (1/2 inch of water is usually recommended)
- Tarping the soil
- Compacting the soil with rollers or similar devices
- Covering the treatment zone with soil that has not been affected by the application

Consult the label information for specific sealing recommendations that apply to your crop.

In lighter soils, you can often apply metam sodium 14 days before planting. In heavier soils with high levels of organic matter, however, you

will need to wait 21 days or longer after application before planting a new crop. This will allow the product to dissipate from the treated soil.

When applying metam sodium, soil moisture should usually be between 50 percent to 80 percent field capacity down to 24 inches. Proper moisture is essential to stimulate pest activity before and during treatment. It will also help ensure the distribution and retention of the fumigant within the treatment zone. Soil temperatures must range between 40°F to 90°F. Metam sodium works best at 60°F to 90°F. For more specific information, read the label information for the method you intend to use and crop(s) you intend to target.

In most cases, air temperatures should be below 90°F (mandatory for application by chemigation) and wind speeds should be no more than 7 mph. Early mornings tend to offer the best combination of weather conditions for application. Avoid applying metam sodium when ground fog is present.

Metam sodium moves differently in the soil than many other fumigants. Specifically, it does not travel far from the point of injection. For example, when you apply metam sodium by shank injection, it is likely to stay within 3 inches of the point of injection. More limited movement means that metam sodium is more likely to remain within the treatment zone for a longer period. This can increase the exposure period and improve pest control. However, you must adjust your equipment to compensate for the slower movement. The best way to do this is to increase the total number of application points. For example, when using soil injection to apply metam sodium, space the shanks no more than 6 inches apart, horizontally and vertically. Double drip lines for wide-bed drip irrigation can be helpful for the same reason.

### **Precautions**

Metam sodium products should only be used to treat soil. Do not use them in confined spaces such as greenhouses or in areas where fumes can enter nearby dwellings. Be sure to leave a 3-foot buffer between treated soil and desirable plants, shrubs and trees. Always use metam sodium products promptly after mixing them with water. Do not store diluted product or allow a solution that contains metam sodium to stand overnight.

Do not apply metam sodium with equipment that contains fittings that are zinc coated, galvanized or made from copper or brass. Metam sodium is corrosive to these metals as well as to aluminum. It may also soften or discolor iron. Be sure that pump impellers are not made from brass or galvanized material. Try to keep hose lengths on application equipment as short as practical and pointed away from the operator. Use a dry-disconnect transfer system rather than compressed air to transfer product.

**Do not apply** metam sodium through irrigation systems that are connected to public water systems.

## Aeration

When using tarps to seal an area treated with metam sodium, leave the tarps in place for at least 48 hours. Five to seven days after application, begin frequent shallow cultivation to aid aeration. Repeat cultivation as necessary, but be careful not to introduce untreated soil from below or around the treated area.

Wait at least 21 days between fumigation and planting. If you think the treated soil contains metam sodium residues after 14 to 21 days, conduct a lettuce seed or transplant test. See Unit 5 for more information about these tests.

## Detection

Since metam sodium is only used outdoors, detection devices are rarely used.

## Disposal

Read the label information to determine how to dispose of metam sodium wastes properly. Always triple-rinse (or equivalent) containers and bulk storage tanks before disposing of, recycling or reconditioning them.

For more information about metam sodium, contact the Metam Sodium Task Force. Your Extension agent or product manufacturer can help you get in touch with this organization.

## Methyl Bromide

Methyl bromide is a colorless gas at standard temperatures and pressures. At normal concentrations, it is odorless, tasteless and has no irritating qualities to indicate its

presence. However, at concentrations higher than those normally used in fumigation, methyl bromide has a sickly sweet odor. Methyl bromide is toxic to all stages of insect life, as well as to many microorganisms and weeds. It is usually stored under moderate pressures so that it can be handled as a liquefied gas.

When injected into soil, methyl bromide vapor diffuses through the soil and dissolves in soil water, where it attacks target pests. When used above ground, methyl bromide gas is 3.3 times heavier than air and tends to stratify, settling out in low places. In such cases, you will need fans to ensure thorough mixing of the gas with air. With fans, methyl bromide penetrates most commodities well.

### EPA Alert

At the time of this printing, methyl bromide is believed to contribute to the depletion of the earth's ozone layer. For this reason, the EPA has initiated action under the Clean Air Act to phase out the production and use of this fumigant. A 70 percent reduction in production was mandated by January 1, 2003. The complete phaseout of production was scheduled for January 1, 2005. The Environmental Protection Agency (EPA) is amending the regulations governing the phaseout of methyl bromide (MeBr) to allow for exempted production and import beyond the phaseout date of January 1, 2005, for critical uses and to address sales of pre-January 1, 2005 stocks of methyl bromide for critical uses. This rule makes approximately 8,942 metric tons of methyl bromide available for critical uses in 2005, which is 35 percent of the U.S. methyl bromide 1991 consumption baseline. The 1991 consumption baseline was established in the 1993 rulemaking, to cap and phase out methyl bromide production and import. An additional 2.5 percent of baseline was recently authorized for 2005 critical uses by the Parties to the Montreal Protocol at their meeting on November 26, 2004. EPA is beginning the notice-and-comment rulemaking process on the supplemental amounts to make them available for critical uses as quickly as possible. It is your responsibility to keep up-to-date on any changes that affect the legal use of products you intend to use.

## Methyl bromide at a glance:

### Required clothing:

- Loose-fitting or well-ventilated long-sleeved shirt and long pants
- Shoes and socks
- Full-face shield or safety glasses with brow and temple shields when performing direct contact tasks
  - Do not wear goggles.
  - Do not wear jewelry.
  - Do not wear gloves, chemical protective clothing or rubber boots.
  - Do not wear contact lenses.

### Respiratory protection:

- Air concentrations less than 5 ppm: no respiratory protection required
- Air concentrations greater than 5 ppm or when air concentrations are unknown: NIOSH-approved SCBA or combination supplied-air/SCBA respirator required

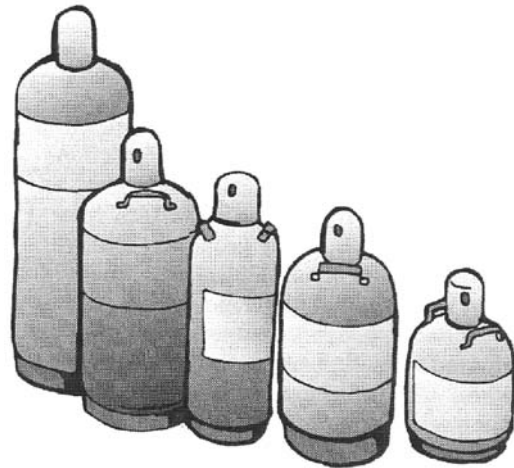
### Uses:

- What: Soil and potting mixes, baled cotton and tobacco, feed and other raw agricultural commodities, forest and plant products, beehives and beekeeping equipment and miscellaneous nonfood cargo. Entire structures and dwellings, bags, boxes, crates (empty), furniture, lumber and wood products
- Where: Structures that contain commodities: warehouses, grain elevators and other buildings storing raw products. Chambers and vaults: vacuum chambers, tarpaulin fumigation, box-cars, trucks, vans, ships and trailers. Agricultural areas: outdoor seedbeds, fields and orchards. Other: piles of soil or planting mixes in greenhouses or other enclosed structures. Structures – warehouses, grain elevators, food processing plants, restaurants and other empty buildings.

## Formulations

For commodity fumigation, you can use formulations that contain 100 percent methyl bromide. When treating soil, however, you must use formulations that contain 2 percent or more of chloropicrin. Chloropicrin improves plant disease control. Chloropicrin also serves as a warning agent for the otherwise undetectable methyl bromide.

Methyl bromide is available as a compressed liquid in 1 1/2-pound cans or in cylinders that contain from 50 to 1,500 pounds.



Cylinders of Methyl Bromide

## Uses

Use methyl bromide to control pests in processed food or feed. There are established tolerances for methyl bromide residues on many commodities. Pure methyl bromide is not labeled for use in empty structures. It is strictly for the treatment of raw or processed commodities and some nonfood products. When mixed with chloropicrin, do not use methyl bromide on processed foods; in dairy, cheese or meat plants; or where there are living plants. Instead, apply these mixtures to control termites and powder-post beetles. You can also use them to treat empty grain bins and warehouses.

There are several materials that should not be exposed to methyl bromide. Some react with the gas and create long-lasting odor problems. Others may be damaged by the gas. Do not use methyl bromide to treat the following items:

- Iodized salt
- Full fat soya flour

- Items that may contain reactive sulfur compounds such as some soap powders, some baking sodas, and some salt blocks used for cattle licks
- Sponge rubber
- Foam rubber, as in rug padding, cushions, and mattresses
- Reclaimed rubber, such as rubber stamps
- Furs
- Horsehair
- Pillows (especially feather pillows)
- Leather goods (particularly white kid or any other leather goods tanned with sulfur processes)
- Woolens
- Viscose rayons (rayons produced or manufactured by a process that uses carbon bisulfide)
- Paper (especially silver polishing paper and writing paper cured by the sulfide process)
- Photographic materials used in darkrooms
- Cinder blocks

It is also important to remove all charcoal products before fumigating with methyl bromide. Charcoal can absorb methyl bromide, reducing its effectiveness.

Methyl bromide is most often formulated with chloropicrin for use in soil fumigation. It will control plant-parasitic nematodes, soil microorganisms that cause important root and stem diseases, many broadleaf weeds and grasses and some soil insects. These methyl bromide-chloropicrin mixtures often provide better control of target pests compared to methyl bromide alone. Beware, however, chloropicrin is not safe for many items that methyl bromide, by itself, can be used to treat. For example, when mixed with chloropicrin, do not use methyl bromide:

- On or around food
- Where there are living plants

Always read the label information of both fumigations before using the mixture for any purpose.

In addition to soil pests, you can also use methyl bromide to control pests in raw foods (including grains, fruits and vegetables), animal feed, cotton and tobacco. There are established tolerances for methyl bromide residues on many commodities.

Methyl bromide is registered for fumigation of plants, bulbs, corms, tubers, rhizomes and

roots. These types of applications are usually reserved for quarantine situations. However, plant materials are, in general, intolerant of this product. Read and follow the label information carefully. You may also want to contact the manufacturer for specific instructions when fumigating living plants. Also remember that chloropicrin is poisonous to plants. Never use methyl bromide containing chloropicrin on live plants.

## Application

### Soil Fumigation (formulations that contain at least 2 percent chloropicrin)

Small cans (1 1/2 pounds) of methyl bromide that contain at least 2 percent of chloropicrin are ideal for tarpaulin jobs that treat small areas. These applications may include outdoor plant or seedbeds, piles of manure, decomposed compost or potting mix, ant colonies in soil or small quantities of a commodity.

When using cans to treat small, tarped areas you must use evaporation pans or combination opener-evaporating pans.

Evaporation pans are plastic or metal (not aluminum) shallow pans used to hold liquid methyl bromide during application. To use them, place the pans under the tarp. Anchor one end of a polyethylene tube in each evaporation pan with tape or a suitable weight. Attach the other end of each tube to a methyl bromide container located outside the tarp. The polyethylene tube directs the liquid methyl bromide from the cans to the pans. The liquid fumigant will volatilize in the pans.

Combination opener-evaporating pans, such as a Simplex tray, allow you to place both the pan and the fumigant container under the tarp. Each trap can hold several cans of methyl bromide. Spikes on the bottom of the tray will puncture the bottom of the cans. Once punctured, the liquid methyl bromide flows into the pan where it evaporates. You do not need tubing with the combination opener-evaporating pans.

For most soil treatments and for larger amounts of commodities, you will need to use cylinders (50 to 1,500 pounds) of methyl bromide.

When treating soil with cylinders of methyl bromide, you will often use the injection method. This involves application equipment that is mounted on a tractor. A cylinder of nitrogen gas

pressurizes the equipment. This helps it to deliver a consistent quantity of fumigant to the soil. To adjust the amount of fumigant you apply, use a flowmeter or a constant pressure system combined with orifice plates. Liquid methyl bromide/chloropicrin flows through a tube from each cylinder to shank/chisel type injectors. These injectors place the fumigant 6 to 8 inches below the soil surface. Once in the soil, the fumigant changes into a gas.

You can apply methyl bromide to soil in many ways, including:

- As a broadcast treatment to entire fields
- As a row or strip treatment
- As an individual treatment to sites where single trees will be replanted.

In many of these cases, you will have to cover the treated area with a tarp as you apply the fumigant. Follow the label information for each type of application method.

### **Commodity Fumigation (formulations of 100 percent methyl bromide)**

To treat raw products with methyl bromide, first seal the space in which the commodity is stored. Then release the fumigant in one of several ways depending on the location of the commodity. If the commodity is in a chamber or vault, introduce methyl bromide by:

- Releasing it in front of a blower or fan
- Passing it through a vaporizer
- Allowing it to evaporate from a shallow pan

Keep all controls outside the treatment chamber.

For vacuum fumigation, release methyl bromide through an appropriate heating unit. This will ensure vaporization of the product as it travels to the treatment chamber. When treating commodities in vehicles, containers and buildings use “shooting lines” (polyethylene tubing or other compatible tubing) to introduce methyl bromide.

Since methyl bromide is 3.3 times heavier than air, it can settle in low places. This can cause stratification during commodity fumigation. Use nonsparking fans to speed up and maintain uniform gas distribution.

Methyl bromide works quickly. Exposure times of 24 hours or less are normal. Read the label to find out what the required exposure time is for your application.

## **Precautions**

If the concentration of methyl bromide is unknown or exceeds 5 ppm, each person in the exposed area must wear an SCBA or combination supplied-air/SCBA respirator. When applying formulations that contain chloropicrin, you must wear an SCBA if the air concentration of chloropicrin is greater than 0.1 percent. Regardless of the fumigant concentration, respiratory protection must be available at the treatment site in case it is needed.

If the cylinders are outdoors, you do not need to wear a respirator while introducing methyl bromide unless a leak develops and the air concentration of methyl bromide is greater than 5 ppm. Check the label for specific requirements. Always have an SCBA ready and available.

Never transport methyl bromide containers in the passenger section or trunk of a vehicle.

Do not wear jewelry, gloves, goggles, tight clothing, a chemical protective suit or rubber boots when using methyl bromide. The gas can be trapped inside your clothes and cause skin damage. If liquid methyl bromide splashes on your clothes, shoes or socks, remove them immediately. Place them outdoors until they aerate completely. Discard any absorbent items that have been drenched or heavily contaminated. Leather will absorb methyl bromide and may aerate slowly.

Check soil fumigation equipment, filters, tubes or hoses, chisels and orifice plates for debris and obstructions before use. Be sure the entire system is pressurized with nitrogen. Use a soap solution to check for leaks. Do not use equipment that contains aluminum, magnesium, zinc and alkali metals to apply methyl bromide. Contact with these metals many cause corrosion and release of toxic gases, as well as fire and explosion hazards. Make sure that all fittings are made of brass or stainless steel and that hoses are made of Teflon™ or Teflon™-lined steel braid. Do not use galvanized pipe. Be sure that soil fumigation “rigs” include:

- A filter to remove debris from the methyl bromide
- A check valve to prevent backflow of the product into the nitrogen cylinder that pressurizes the system
- Components with a pressure rating of at least 500 psi

Nitrogen cylinders are kept at a pressure of about 2,000 psi. Be sure to check and maintain regulators that reduce the pressure during application on a regular basis. If a regulator fails, the system may overpressurize. This could cause the methyl bromide cylinder to rupture.

Do not use methyl bromide to control insects in/on a commodity when the temperature of the commodity or the space is less than 40°F. Do not use methyl bromide to control rodents or other warm-blooded pests when temperatures are below 20°F. Heat the fumigant when temperatures are below 60°F.

Methyl bromide is not a fire hazard. In fact, it once was an ingredient in fire extinguishers. Still, you must extinguish all open flames and pilot lights before using methyl bromide. It produces corrosive acid when it reacts with moisture near a heat source. In addition, while methyl bromide does not corrode most metals, it can react with aluminum or magnesium in the absence of oxygen to form an explosive mixture. Therefore, never connect aluminum or magnesium tubing to a methyl bromide cylinder. Be sure neither metal is present during vacuum fumigation with methyl bromide.

There are several materials that should not be exposed to methyl bromide. Some react with the gas and create long-lasting odor problems. Others may be damaged by the gas. Be sure to read the label information before treating any item with methyl bromide.

## **Aeration**

After fumigating soil with methyl bromide, delay use of the treated area according to label directions. This will allow the product to break down in the soil and escape into the atmosphere. If you tarp the soil, begin aeration by breaking the seals around the edges of the cover. Cultivate the soil, usually no sooner than 7 to 10 days after application, to speed the aeration process.

To aerate fumigated commodities, open doors and windows and/or remove the tarp to allow air exchange. You may use fans to speed the exchange of air. During fumigation with methyl bromide, commodities may contain inorganic bromide residues. Aeration does not remove these compounds. After repeated treatments, residues may exceed legal tolerances. The Food and Drug Administration (FDA) may seize

the product. If this occurs, the last fumigator may be held responsible. Always check past fumigation records before treating any product. Be sure your treatment will not increase residue levels past legal limits. For help, contact the fumigant manufacturer.

## **Detection**

You can measure methyl bromide concentrations in air with halide gas detectors, color diffusion detector tubes and thermal conductivity analyzers (TCAs) such as the Fumiscope®. More sophisticated detection systems now include infrared, photoionization, flame ionization and electron capture detectors. Always consider the sensitivity of the detection device when making your selection. For example, the halide gas detector and Fumiscope® only provide an indication of methyl bromide presence. They do not indicate concentration. Use these devices to detect leaks. Halide detectors and TCAs do not read low enough to detect gas levels for reentry purposes. To check fumigant levels before reentry, use color diffusion detector tubes.

Always read the label information to be sure you select the appropriate detection device. Follow all detection device instructions.

Detection devices are rarely used for outdoor soil applications of methyl bromide.

## **Disposal**

Dispose of methyl bromide containers according to label directions. Return empty or partial cylinders to the manufacturer. Cans are not returnable. Aerate empty cans in a well-ventilated, secure location for 12 hours before disposal. If local authorities allow, you may be able to recycle the cans. Otherwise, dispose of them according to local regulations.

## **Phosphine**

### **Aluminum Phosphide and Magnesium Phosphide**

There are two main types of phosphine fumigants: aluminum phosphide and magnesium phosphide. These “metal phosphides” are formulated as solids that react with moisture in the air to produce hydrogen phosphide (phosphine gas). Phosphine also comes as a bottled product (phosphine dissolved in liquid carbon dioxide).

## Aluminum phosphide and magnesium phosphide at a glance (also called hydrogen phosphide and $\text{PH}_3$ ):

### Required clothing:

- Dry cotton gloves if you contact the pellets, tablets or dust

### Respiratory protection:

- Respiratory protection is required if exposure is likely to exceed the 8-hour TWA of 0.3 ppm during application, or is above 0.3 ppm at any time after application is complete
- Concentrations less than 0.3 ppm: no respiratory protection required
- Concentrations 0.3 to 15 ppm: NIOSH-approved full-face gas mask and hydrogen phosphide canister
- Concentrations 15.1 to 1,500 ppm: NIOSH-approved full-face gas mask and hydrogen phosphide canister for escape only
- Concentrations greater than 15 ppm or when concentrations are unknown: NIOSH-approved SCBA or supplied-air respirator

### Uses:

- What: Raw agricultural commodities such as grains, nuts, seeds, cotton, wool and tobacco. Animal feeds and feed ingredients, processed foods and non-food items
- Where: Boxcars, containers, ships and other transport vehicles, bins, silos, barges, under tarpaulins, in small sealable structures and enclosures, mills, food processing plants, and warehouses.

Phosphine gas is colorless and highly toxic to all stages of insect and animal life. It has a distinct garlic or carbide odor that is readily detectable at levels below worker protection limits (0.3 ppm). The odor is due to an impurity rather than the phosphine gas itself. However, odor is not a reliable indicator of the presence or absence of phosphine. This is especially true when phosphine has been in contact with a commodity for a considerable length of time.

## Formulations

Both aluminum phosphide and magnesium phosphide fumigants are available in a number of formulations. These include pellets, tablets, Prepacs, bags and plates. Since metal phosphide fumigants react readily with moisture, they must be packaged in gastight containers. Phosphine can also be applied from cylinders that contain phosphine in liquid carbon dioxide.

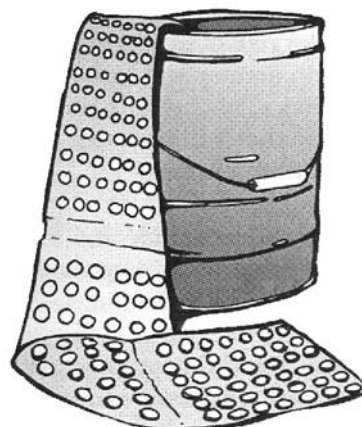
Most aluminum phosphide formulations yield about 1/3 of their weight in phosphine. Aluminum phosphide is available in 0.6-gram pellets and 1.0-gram tablets.

Magnesium phosphide comes as Prepacs and in polyethylene plates and strips.

**Pellets:** Pellets weigh 0.6 gram. They yield 1/3 (0.2 gram) of their weight in phosphine. They are available in resealable flasks.

**Tablets:** Each tablet weighs 3 grams and releases 1 gram of phosphine. Tablets are available in resealable flasks. Tablets are also used in Prepacs and Prepac Ropes.

**Packaged Fumigants:** Packaged fumigants are available in several forms. These include bags, Prepacs and plates. In all cases, the metal phosphide is encased in a gas-permeable material, which is overpacked in gastight containers. Bags that contain a powdered aluminum phosphide formulation are also available. Each bag will release 11 grams of phosphine. Many of these packaged fumigants are not resealable. Once opened, you must use the entire contents.



Phosphine Prepacs

## Uses

Use metal phosphides to treat raw agricultural commodities such as grains, nuts, seeds, cotton, wool and tobacco. You can use metal phosphides to treat spaces and commodities and to control certain burrowing pests. Commodities treated with phosphine include processed foods, nonfood items, animal feed and feed ingredients.

Aluminum phosphide is the main form used to treat raw commodities. Magnesium phosphide is more reactive than aluminum phosphide. It is preferred when rapid release is desired and when treatment is performed at lower temperatures and humidities.

## Application

One advantage of metal phosphide products is that they are easy to use. Start by calculating the cubic volume of the space you intend to treat. (See Appendix B for information on calculating volume.) Then, count out the required number of pellets, tablets, plates, Prepacs or bags. Always wear gloves when handling phosphide tablets or pellets. Packaged metal phosphides such as bags and Prepacs do not require gloves. Place the pellets, tablets or bags onto a tray or sheet of cardboard. Slip the tray under the fumigation tarp or inside the fumigation chamber or structure. The moisture in the air will liberate phosphine in about one day, depending on the temperature and humidity.

To treat raw commodities such as grain, scatter phosphide tablets or pellets over the surface of the grain. Spread the fumigant evenly over the surface. You can also use a probe to insert the tablets or pellets directly into the grain stream as the grain is moved into storage or as it is “turned” (recirculated).

Fumigation with phosphine takes time. Buildup of the fumigant is slow. It may take 12 to 48 hours to reach the desired concentration of gas. If the atmosphere or commodity is very dry, the process may take even longer. In areas where the relative humidity is low, you can increase the speed of gas liberation by placing a pan of water under the fumigation tarp. You can also spray water onto the floor or dirt. Be very careful. Do not to allow any water to contact the phosphine. An explosive mixture may result.

Normal exposure periods can take 3 to 5 days. If gas concentrations are lower than required after 72 hours, extend the fumigation period.

Magnesium phosphide releases phosphine faster than does aluminum phosphide. Therefore, you are more likely to need respiratory protection when applying magnesium phosphide.

Phosphine is not effective at temperatures below 40°F. Be sure to keep aluminum phosphide and magnesium phosphide products dry during storage. Since magnesium phosphide is more reactive than aluminum phosphide, it is usually recommended for fumigation in cool and/or dry conditions.

Pure phosphine is about 17 percent heavier than air. However, since it is given off slowly, it does not tend to stratify. Fans are not needed to ensure even distribution except when treating bulk commodities. Because of its low sorption and good penetration capacity, phosphine tends to leak from bins that are not gastight. Phosphine will go where the airflow goes.

## Precautions

Phosphine does not accumulate within body tissues as do other fumigants. Any phosphine gas entering the body will be eliminated within 48 hours. Even so, phosphine is very toxic to humans. The TWA is only 0.3 ppm. This means the gas is about 60 times as toxic as methyl bromide. However, because of the way phosphine is liberated and because of its distinct odor, it is far safer to handle than most other fumigants.

Always wear approved respiratory protection if the concentration of phosphine in the work area is likely to exceed an 8-hour TWA of 0.3 ppm. A gas mask/canister combination may be used at concentrations up to 15 ppm. Above this level, or when the concentration is unknown, you must wear an SCBA.

After the application, you must wear a respirator whenever the concentration of phosphine is unknown or exceeds 0.3 ppm. The TWA applies only during application. “Application” is the period covering the opening of the first container, applying the appropriate dosage of the fumigant and closing the site to be fumigated. At all other times, anyone exposed to fumigant concentrations exceeding 0.3 ppm must wear respiratory protection.

Always wear gloves when handling aluminum phosphide pellets, tablets, and the residue that remains after fumigation. Air out used gloves and other contaminated clothing in a well-ventilated area before washing them.

Wash your hands thoroughly after handling phosphide materials.

Phosphine is extremely flammable. Never open metal phosphide containers near an open flame or in a flammable atmosphere. Fire or an explosion can occur if the phosphine concentration is too high. It is better to open containers outdoors or near a fan. Phosphine may also ignite spontaneously at concentrations above 18,000 ppm. If you conduct the fumigation properly, however, concentrations will not approach this level. Phosphine is also explosive under vacuum conditions. Never use it for vacuum fumigation. Finally, do not stack or pile phosphine pellets or tablets. This can create a fire hazard.

To reduce the risk of fire, some phosphine products contain ammonium carbamate in their formulation. This helps to produce a gaseous mixture that will not burn or explode at normal application rates.

Both aluminum phosphide and magnesium phosphide can react violently if they contact water.

Never allow aluminum or magnesium phosphide or their residues to directly contact any processed food. To prevent this, place phosphide pellets or tablets on a tray or use packaged phosphine such as Prepacs, bags or plates. Do not add metal phosphide directly to any processed food. Aerate foods and feeds that have been treated with phosphine for 48 hours before giving them to the consumer.

Phosphine gas, especially at high temperatures and humidities, will corrode silver, copper and copper alloys. Copper-containing equipment, such as computers, telephones and other electrical devices, may be severely damaged. Protect or remove items that contain these metals during treatment.

## Aeration

Areas treated with phosphine aerate quickly. To be safe, open all doors and windows first to assure good ventilation. Then, while wearing respiratory protection, open the fumigated space or remove seals from the edges of a tarp. Some aerations will be complete in one to two hours. Others will require much longer aeration periods. Take gas readings to be sure concentrations are below 0.3 ppm.

## Detection

Several reliable gas detectors are available to measure phosphine gas. Glass detector tubes are the most common. Two types of glass tubes are available. The first measures low levels of gas (~0.1 to 40 ppm). Use this type of detector to determine worker exposure levels and to locate leaks. The second type of detector measures high levels of gas (~50 to 2,000 ppm). Use it to determine if phosphine levels during treatment are high enough to kill the target pest.

## Disposal

Metal phosphide fumigants leave a white powdery residue. This residue contains a small amount of unreacted phosphide that may or may not need to be deactivated. The deactivation process differs somewhat for aluminum phosphide and magnesium phosphide.

*NOTE: If the fumigant residue is grayish green, the metal phosphide is only partially spent. Extend the fumigation period until the residue turns white, or use extreme care during the deactivation process.*

To deactivate unreacted and partially reacted aluminum phosphide, prepare a deactivating solution. Fill a small to large container with water. Fifty-five-gallon drums work well for large amounts of aluminum phosphide. Add enough nonsudsing detergent to create a 2% solution. Fill the container to within a few inches of the top with the deactivating solution. Then, stir in the phosphide residue. Do not add more than about 45 to 50 pounds of phosphide to 15 gallons of water-detergent mixture.

To deactivate unreacted and partially reacted magnesium phosphide, no detergent is needed. Instead, fill a container to within a few inches of the top with water **ONLY**. Add the phosphide residue until it sinks to the bottom. Because unreacted or partially reacted magnesium phosphide reacts vigorously with water, be sure to add the residue slowly.

Always deactivate metal phosphide fumigants outdoors. Wear the appropriate respiratory equipment. Never place residue in enclosed containers. It could cause a fire hazard. After deactivating phosphide residues, dispose of the rinsate in a storm sewer, landfill or by other approved methods. Always check with local authorities for disposal regulations. Where permissible, bury the solid or spread it out on the ground.

## Test Your Knowledge

**Q. Name a fumigant that should not be used to treat food products.**

A. Chloropicrin.

**Q. Which fumigants do not have an odor at normal treatment concentrations?**

A. Methyl bromide and sulfuryl fluoride.

**Q. Which of the fumigants described in this unit are used for soil fumigation?**

A. 1,3-D, chloropicrin, dazomet, metam sodium and methyl bromide.

**Q. Which of the fumigants described in this unit are used to treat raw agricultural products?**

A. CO<sub>2</sub>, methyl bromide, sulfuryl fluoride and phosphine.

**Q. Which of the fumigants described in this unit can you apply via chemigation?**

A. 1,3-D and metam sodium.

**Q. What type of equipment should you use to apply non-EC formulations of 1,3-D?**

A. “Ripper-bedders” are recommended for row application of non-EC formulations of 1,3-D. A ripper-bedder is a subsoil shank followed by two bedder disks. Together, these are attached to a toolbar and perform a single operation. The shank fractures the hardpan in the soil, while the disks throw a mound of soil over the slit left by the shank. For broadcast fumigation, use chisel or bottom plows. Apply non-ECs through equipment that moves the product from a tank into the soil via pressure from a cylinder of nitrogen gas or from a pump – power take-off (PTO), electrical (explosion-proof) or ground-driven.

**Q. Which of the fumigants described in this unit are flammable?**

A. 1,3-D, and phosphine.

**Q. What fumigant is commonly added to methyl bromide and sulfuryl fluoride (sulfuryl fluoride or Vikane used in structures) to warn workers of its presence?**

A. Chloropicrin.

**Q. Describe how you would treat a small area or volume of soil with chloropicrin.**

A. Use a probe-type injection device to release the product 6 to 8 inches below the soil surface in a grid pattern. Space your injection points 12 inches apart. Tarp the treated soil to prevent premature loss of the fumigant from the soil.

**Q. Name three advantages of CO<sub>2</sub> fumigation.**

- A. 1. CO<sub>2</sub> does not leave harmful residues on treated commodities.  
2. If CO<sub>2</sub> leaks from a treatment area, it will be diluted by normal air and reach nontoxic levels quickly.  
3. CO<sub>2</sub> does not change the processing or biochemical properties of commodities.

**Q. How is CO<sub>2</sub> commonly stored and transported?**

A. As a liquid at 0°F and under a pressure of 300 psi.

**Q. What is the most effective concentration of CO<sub>2</sub>?**

A. 60 percent.

**Q. Describe the two methods available for treating stored products with CO<sub>2</sub>. When should you use each method?**

- A. 1. The top-down purge method adds CO<sub>2</sub> at the top of a structure. The CO<sub>2</sub> displaces the air in the structure as it settles downward. Use this method in concrete grain elevators where you can place the injection hose in the top of a well-sealed tank.

2. The lift method adds CO<sub>2</sub> at the bottom of the structure. In this case, the CO<sub>2</sub> displaces the air in the structure as it moves upward. Bottom injection (the lift method) works best in stand-alone steel bins where major leaks occur at the top around eaves and hatches.

**Q. Which two fumigants described in this unit decompose into the active ingredient methyl isothiocyanate (MITC)? How are each of these fumigants formulated?**

- A. Dazomet and metam sodium. Dazomet is formulated as a solid. Metam sodium is formulated as a liquid.

**Q. Describe three ways to apply dazomet to soil.**

- A. 1. Incorporation With Tarping: This method incorporates dazomet into the soil and then tarps the soil to seal in the fumigant.
2. Incorporation Without Tarping: This method incorporates dazomet into the soil and then rolls and irrigates the soil to seal in the fumigant.
3. Topical Application With Irrigation: This method applies dazomet to the top of the soil and then uses irrigation to seal in the fumigant.

**Q. Which application method would you select to treat a golf green with dazomet? Why?**

- A. Topical application with irrigation. This method uses water instead of tillage to draw dazomet into the soil.

**Q. If you have to fumigate a field with dazomet shortly before planting, how might dazomet affect the fertilization of the crop? How can you prevent this from being a problem?**

- A. Fumigation with dazomet can reduce the nitrification of fertilizers. You can decrease this risk by using fertilizers that contain a high percentage of nitrate nitrogen.

**Q. When applying metam sodium, at what percent of field capacity should the soil moisture be?**

- A. 50 to 80 percent.

**Q. What is the waiting period between fumigation and planting for metam sodium?**

- A. At least 21 days.

**Q. Which of the fumigants discussed in this unit is being phased out? Why? When might this occur?**

- A. At the time of this printing, methyl bromide is believed to contribute to the depletion of the earth's ozone layer. For this reason, the EPA has initiated action under the Clean Air Act to phase out the production and use of this fumigant. A 70 percent reduction in production was mandated by January 1, 2003. The complete phaseout of production was scheduled for January 1, 2005. The Environmental Protection Agency (EPA) is amending the regulations governing the phaseout of methyl bromide (MeBr) to allow for exempted production and import beyond the phaseout date of January 1, 2005, for critical uses and to address sales of pre-January 1, 2005 stocks of methyl bromide for critical uses. This rule makes approximately 8,942 metric tons of methyl bromide available for critical uses in 2005, which is 35 percent of the U.S. methyl bromide 1991 consumption baseline. The 1991 consumption baseline was established in the 1993 rulemaking, to cap and phase out methyl bromide production and import. An additional 2.5 percent of baseline was recently authorized for 2005 critical uses by the Parties to the Montreal Protocol at their meeting on November 26, 2004. EPA is beginning the notice-and-comment rule-making process on the supplemental amounts to make them available for critical uses as quickly as possible. It is your responsibility to keep up-to-date on any changes that affect the legal use of products you intend to use.

**Q. List several things you should NOT wear when working with sulfuryl fluoride, methyl bromide or chloropicrin.**

A. Goggles, jewelry, gloves, contact lenses or rubber boots.

**Q. What detection device is sensitive enough to check levels of methyl bromide before reentry into the treatment area?**

A. Glass detector tubes.

**Q. Which of the fumigants described in this unit are odorless at normal treatment concentrations?**

A. CO<sub>2</sub>, sulfuryl fluoride and methyl bromide.

**Q. Describe the difference between aluminum phosphide and magnesium phosphide.**

A. Aluminum phosphide is the main form of metal phosphide used to treat raw commodities. Magnesium phosphide is more reactive than aluminum phosphide. Magnesium phosphide is preferred when rapid release is

desired and when treatment is performed at lower temperatures and humidities. In addition, when deactivating phosphide residues, nonsudsing detergent is required for aluminum phosphide, whereas you only need to use plain water to deactivate magnesium phosphide.

**Q. What is responsible for liberating phosphine gas from its solid form?**

A. Moisture in the air (humidity).

**Q. What detection device is sensitive enough to check levels of sulfuryl fluoride before reentry into the treatment area?**

A. Only approved detection devices of sufficient sensitivity, such as specific types of gas analyzers or infrared detection systems (ambient air analyzers), can be used to confirm a concentration of sulfuryl fluoride of 1 ppm or less for Profume or 5 ppm for Vikane. At the time of this writing, the sulfuryl fluoride product label requires the use of an INTERSCAN or MIRAN analyzer, or similar approved device to measure gas concentrations for reentry.