



Soil MANUAL Fumigation



A NATIONAL PESTICIDE APPLICATOR CERTIFICATION STUDY GUIDE



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Future editions

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INTRODUCTION

The purpose of this training manual is to support state, tribe and territory pesticide applicator certification and training programs. This training manual covers the entry-level knowledge and skills required for reading, interpreting, and following soil fumigant labels and understanding the basic concepts for the effective use of soil fumigants. It does NOT cover the use of other types of **fumigants** (e.g., stored grain or structural) nor is it intended as a how-to manual.

The manual supports state pesticide applicator certification in two ways:

- **Initial Applicator Certification**—provides study material for people seeking certification in the soil fumigation category in their respective states, Indian tribes, or U.S. territories.
- **Label-required applicator training**—for states choosing to offer an examination for **certified applicators**, in

Although this manual provides basic information for certification in the soil fumigation category, you should always read and follow all label instructions for individual fumigants. Requirements may differ from product to product.

lieu of the required **registrant** training. The states providing this “training option” have been approved by EPA and are listed on the EPA soil fumigant training web site: <http://www.epa.gov/fumigantraining>.

Each chapter includes a list of learning objectives describing the material covered in the text. These objectives are the basis of state soil fumigation certification exams. At the end of each chapter,



you will find review questions to help test your knowledge and familiarize you with the style of questions you may find on a state exam. A glossary at the end of the manual defines important terms used in the manual. Words included in the glossary are in bold type when first used in the text.

Because this manual addresses national soil fumigation training requirements, the terms “**private applicator**” and “**commercial applicator**” are used throughout. As used here, “commercial applicator” refers to all certified applicators other than private applicators (states vary in their definitions for certified applicators other than private applicators).

EPA evaluates the risks to **workers**, **bystanders**, and the environment during their registration and reevaluation process. Many of the safety requirements addressed in this manual come from label changes resulting from EPA’s 2009 Reregistration Eligibility Decision (RED) process for:

- Methyl bromide.
- Chloropicrin.
- Dazomet.

- Metam sodium.
- Metam potassium.

In addition, similar label restrictions were included as part of the new registrations for:

- Dimethyl disulfide.
- Iodomethane.

As of 2012, most fumigant labels correspond with the contents of this training manual.

Because 1,3-dichloropropene (1,3-D) was previously reevaluated in 1998 these labels do not have the same label requirements as the other soil fumigants. For example, products with 1,3-D as the sole active ingredient (Telone®II and Telone® EC) do not have labeling on **fumigant handler** tasks, **buffer zones**, posting, fumigation management plans and more. All labels are subject to change.

Additionally, because each product has its own use patterns, toxicity, and potential for exposure, label restrictions and safety requirements vary somewhat across product labels. The label is the law—always read and follow label directions. Labels may change from year to year.



OVERVIEW OF SOIL FUMIGANTS AND SOIL FUMIGATION

LEARNING OBJECTIVES

After studying this chapter, you should be able to:

- Explain the benefits of soil fumigants.
- Explain why fumigants are used.
- Describe the general process of how soil fumigants change from a liquid or solid to a gas.
- Describe the general process of gaseous movement in the soil and into the atmosphere.
- Describe the signs and symptoms of human exposure to fumigants.
- Describe how fumigant exposure can occur for certified applicators, fumigant handlers, field workers, and bystanders.
- Explain the common problems and mistakes that can result in direct exposure to fumigants.
- Explain the importance of reading, understanding, and following fumigant labels.

Soil Fumigants

Soil fumigants play an important role in agriculture, nursery and greenhouse production, and turfgrass management. Yet the chemical properties that make them so effective in managing hard-to-reach and difficult-to-control soil pests also may be hazardous to people who apply the chemicals, people who reenter fumigated fields, and others who may be near the treated area.

Soil fumigation provides benefits to both food consumers and growers. Consumers are able to buy more fresh fruits and vegetables of higher quality since severe pest problems are managed and commodities are suitable for sale. Growers benefit from increased crop manage-

ment flexibility. This includes shorter **crop rotational intervals** (i.e., less time when fields are left fallow) and con-

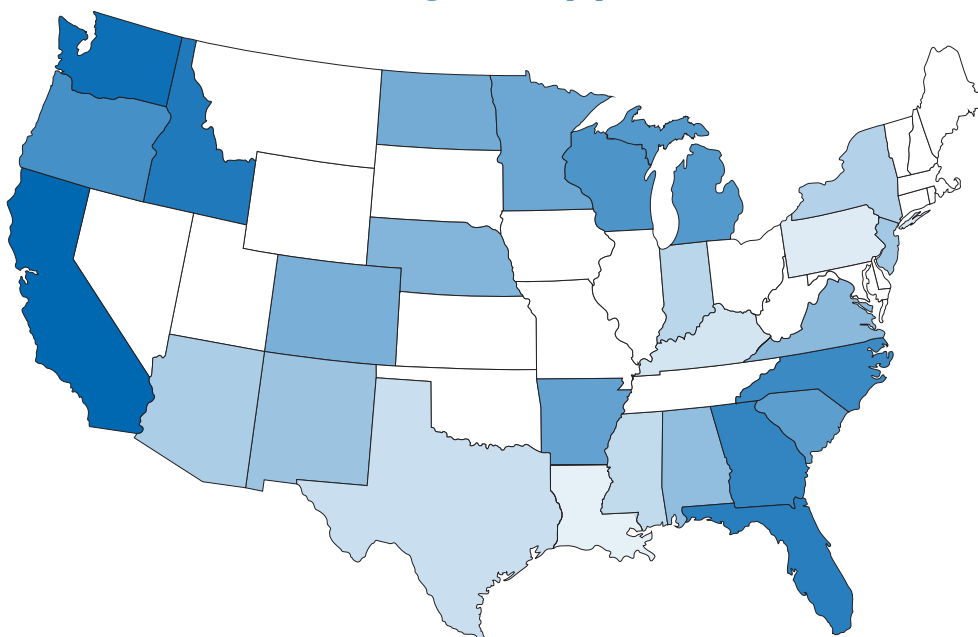
Soil-borne pests targeted by soil fumigants include:

- Insects (e.g., wireworms)
- Nematodes
- Fungi
- Bacteria
- Weed seeds
- Germinating weed seedlings

Soil Fumigant Application

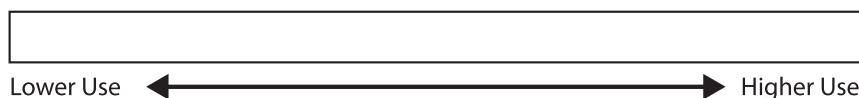
Relative usage of five major fumigants (metam sodium, metam potassium, 1,3-dichloropropene, methyl bromide, and chloropicrin) among the continental United States.

Data adapted from EPA 2006–2008 maps and based on major uses on all field crops.



The use of soil fumigants in the United States is heaviest on:

- Potatoes
- Strawberries
- Tomatoes
- Carrots



sistent management of soil-borne **insects**, **pathogens** (e.g., **nematodes**, **fungi**, and **bacteria**), and weed seeds. Whether fumigation use is beneficial depends on pest pressure (which varies over space and time), product and application expenses, as well as the availability and comparable efficacy of alternative methods.

Use of soil fumigants on fields in the United States that produce major food crops ranges from about 2.0 to 45.5 million pounds per year, depending on the active ingredient. Because of high treatment costs, soil fumigants are usually reserved for high-value crops and sites such as tobacco, vegetables, fruits, golf courses, greenhouses, and plant nurseries. The largest use of soil fumigants in the United States is on potatoes, strawberries, tomatoes, and carrots.

Soil is a complex medium. It provides a refuge for plant pests, including insects, fungi, bacteria, and nematodes that feed on underground plant parts and can vector diseases, along with troublesome weed seeds. These pests live in soil, plant residue, and sometimes even the bodies of certain insects and nematodes. Fumi-

gants are uniquely effective because in their gaseous form they disperse through the soil and some plant residue. Thus, they contact nearly all pest organisms in the treated zone. Fumigants are used to manage soil-borne pathogens (nematodes, fungi, and bacteria), insects, and weeds (both weed seeds and germinating seedlings). Fumigants are especially helpful in resolving problems caused by two or more different organisms. This is because, when properly applied, a single fumigant application often manages both. For example, in vegetables such as tomatoes, fumigants can control both nutsedge (a weed) and soil-borne fungi such as *Phytophthora* (also known as root rot). Without the application of a soil fumigant, separate, target-specific chemicals would be necessary.

Fumigant Volatilization

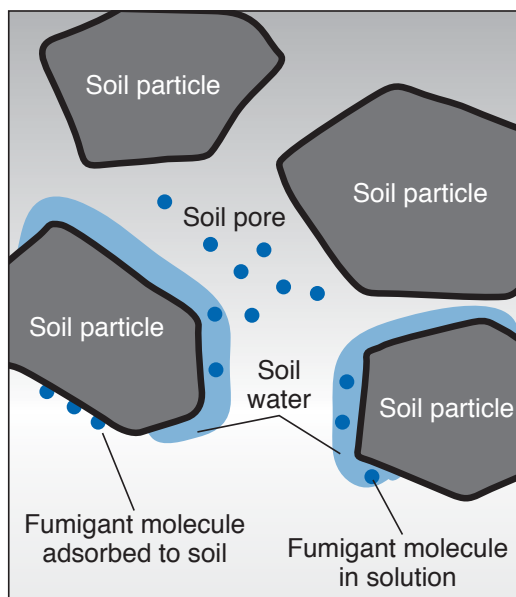
Although applied as a solid, liquid, or liquified gas, soil fumigants rapidly volatilize—become a gas—once in the soil. In gaseous form, the fumigant can disperse

throughout the soil and contact target pests. Soil pests are killed if they:

- Contact a high enough concentration of the fumigant.
- Are exposed to the fumigant for enough time.

As a gas, a fumigant consists of tiny molecules that move through the **soil pores** (air spaces between soil particles). Some molecules also dissolve in the water film or **soil water**—surrounding the soil particles. Pathogens, nematodes, weeds, and weed seeds are killed by absorbing fumigant that dissolves in the water surrounding the soil particles. Insects are controlled by exposure to fumigant in the air spaces between soil particles. Depending on the product, fumigants may move through the soil in the soil pores and/or in soil water.

Fumigants move through the soil profile in multiple ways. Methyl bromide, iodomethane, and 1,3-D disperse through soils primarily as a gas. Sometimes called “**true fumigants**,” these chemicals move thousands of times faster through soil pores than they do in soil water. Because of their **vapor pressure**, true fumigants freely move as a gas via soil pores but also dissolve into soil water.



Soil fumigants simultaneously move through soil pores and soil water

Illustration adapted from Will Sucko, UC Davis

Metam sodium, metam potassium, and dazomet (which are all **methyl isothiocyanate [MITC] generators**) readily move as the parent compound to the zone of the target pest with irrigation water or by mechanical incorporation. After exposure to water, these materials release MITC gas, which kills nearby target pests.

Due to the volatility of all fumigants, there is significant concern for gasses to escape the soil surfaces.

Effects of Fumigants on Humans

Fumigants are among the most hazardous of all pesticides and bear the signal words Danger-Poison, Danger, or Warning. Label precautionary statements note specific human exposure concerns. Generally, very few exposure incidents occur relative to the total number of fumigant applications performed each year. However, when fumigant incidents do occur, especially to field **workers** or bystanders, there are often several people exposed. **Certified applicators** and **fumigant handlers** are at the greatest risk. Incidents involving field workers are more common than incidents with **bystanders**. Chapter 3 addresses some specific concerns of each fumigant active ingredient, but below is a broad overview across the complex of fumigants.

Fumigants can enter the body by multiple routes—skin, eyes, nose, and mouth. A common route of exposure is inhalation, when fumigant vapors are breathed into the lungs. In fact, the major risk for fumigant handlers, workers, and bystanders associated with soil fumigation is from **acute inhalation exposure** caused by fumigant **off-gassing** (escaping the soil). Fumigant labels address respiratory protection through respirator use and air monitoring.

Soil fumigants can also contact the body in other ways. Liquid or gaseous fumigants that touch skin (**dermal exposure**) can cause burning, irritation, and rashes. If fumigants are splashed or

spilled onto clothing or skin, the certified applicator or fumigant handler must act quickly to prevent skin or clothing exposure. Prolonged exposure leads to skin absorption, which can damage internal organs. Pesticide labels state that if clothing gets soiled with fumigant, you must remove the clothing immediately and decontaminate the skin. Some products are corrosive and can physically damage the skin.

Fumigants can also enter the mouth and nose directly, either by inhalation or by splashing. Broken or malfunctioning equipment, such as pressurized lines or leaking tanks, can lead to oral exposure. More often, exposure occurs when contaminated hands or gloves touch the mouth. One example is touching the fumigant container or equipment with gloved hands, removing contaminated **personal protective equipment (PPE)**, and then eating without first properly washing the hands with soap and water.

Eyes are particularly sensitive. They can be seriously harmed by direct exposure to fumigant liquids or granules (ocular exposure). In fact, some fumigants can cause irreversible eye damage. Generally, fumigant handlers are required to wear protective eyewear when handling fumigants. Some fumigants require a specific type of eye protection. Be sure to read the label for the PPE information concerning the fumigant you are using.

Exposure Signs and Symptoms

Fumigants are moderately to highly toxic, and overexposure can cause serious injury. General fumigant exposure symptoms include the following:

- Watery, burning, or irritation of the eyes, nose, or mucous membranes.
- Headache, nausea, or dizziness.
- Tremors, slurred speech, or loss of muscle coordination.
- Skin rash, burning, and/or blistering.
- Cough.

Certified Applicators and Fumigant Handlers

The term certified applicator includes **private applicator** and **commercial applicator**, as defined by federal law. A certified applicator has state-issued credentials and can legally supervise a fumigant application and fumigant handlers—unless the state does not allow a provision for **direct supervision**. This supervising certified applicator is considered the **certified applicator-in-charge**. All people that are part of the fumigation process are considered **handlers** (referred to as “fumigant handlers”). The activities of fumigant handlers are listed on product labels. This includes fumigant handling activities in non-agricultural sites, like golf courses.

Fumigant handlers are the most at risk for exposure to fumigants. Some examples of handler tasks where exposure might occur include: product transfer, maintaining and repairing equipment, removing tarps, and assisting in applications. Fumigant labels provide details about what PPE is required for each handling activity and when it must be worn. This information is crucial to prevent handler exposure.

Certified applicators and fumigant handlers must know what PPE is required for which activities. Fumigant labels provide this information. Furthermore, fumigant handlers and certified applicators can avoid fumigant exposure by staying



Worker Protection Standard (WPS) Trained Handler Exposure Incident

A WPS-trained pesticide handler was checking a shank rig before a fumigant application. As he checked the rig for leaks, he noticed one of the lines had broken from the shank. He immediately turned off the line and returned to inspect and fix the break. While doing so, he put one knee down on the concrete floor and inadvertently kneeled in a puddle. Since he did not feel any skin irritation or burning, he assumed the puddle was water and continued working.

Later, while performing the fumigant application, the handler felt a burning sensation on his knee. He began to suspect that the burning was caused by

fumigant exposure. An investigation revealed that the puddle contained methyl bromide and chloropicrin. He continued working until the fumigation was complete and did not change his clothes until he arrived home. He then noticed the swelling and blistering on his knee and went to the hospital for treatment.

According to the pesticide label, the handler should have decontaminated and changed his clothes immediately after kneeling in the puddle, or as soon as he suspected that his skin had been exposed. Fumigant handlers must receive safety information that highlights the hazards of fumigant applications.

upwind from fumigant activities, assuring that tarps are in good repair, keeping equipment in good working order, and practicing good hygiene. Installing and removing tarps requires specific procedures and equipment, as well as specialized PPE. Improper or premature tarp removal can lead to fumigant exposure by inhaling the off-gassing fumigant.

Bystanders and Field Workers

Bystanders are people who live, visit, and/or work near fumigated fields and may be exposed to fumigant emissions when gases travel offsite. Because most soil fumigation occurs in agricultural settings, farm workers in nearby fields are vulnerable to exposure. For this discussion, “**WPS-trained worker**” refers to workers who are trained according to the federal **Worker Protection Standard (WPS)** and to any agricultural worker who is not involved in the fumigation. This could include farm or contracted employees doing tasks like planting, pruning, irrigation, thinning, or harvesting as well as people in adjacent fields.

Bystanders are most likely to be exposed to fumigants through vapors that get into the eyes, causing irritation, or that are inhaled. Application method, application depth, soil moisture, soil temperature, organic matter levels, use

of water seals or tarps, **soil texture**, weather conditions, soil compaction layers, and other factors influence the amount of fumigant retained in the soil, versus the amount that escapes into the atmosphere. If environmental and physical factors associated with an application and sealing are not managed carefully, off-gassing could occur for several days following a soil fumigation.

Unlike WPS-trained handlers, bystanders (field workers, neighbors) receive little or no safety information or training related to potential fumigant exposure. They are much less likely to attribute injury symptoms to fumigant exposures or to have access to information needed to lessen the effects of the exposure.

Fumigant Labels Change Over Time

EPA conducts human health risk assessments for the soil fumigants as part of their registration process (new products) and reevaluation process (older products). The risk assessments are based on the best available information at that time, including:

- Human and animal toxicity studies.
- Exposures based on monitoring and modeling data.
- Incident reports.

Bystander Exposure Incident

A commercial applicator was making an untarped, shank-injected application of 100% chloropicrin to prepare a field for planting onions. At the end of the workday, the fumigation was not yet complete. The crew pulled the shanks out and stopped the application. That evening, residents about a half mile west of the fumigation site called for emergency assistance after experiencing eye itching and burning. The firefighters who responded could not determine what had caused the residents' eye irritation.

The next morning, workers returned to finish shanking the field and discovered, by their own sensory reactions, that fumigant was escaping from the soil. They tried to solve the problem by lowering the fumigant injection depth by 2 inches, leaving a 50-foot untreated buffer zone at the field margins, purging lines repeatedly before lifting shanks at the ends of rows, and used improper soil-compacting equipment. Nevertheless, residents a quarter mile south of the fumigation site called for help that evening. This time when firefighters arrived, they experienced the same symptoms as the residents. The applicator-in-charge was required to compact the soil immediately using equipment specifically designed for that purpose.

Labels for untarped applications of 100% chloropicrin now carry requirements for specific soil conditions and compaction procedures and equipment that are designed to reduce off-gassing.

The results of the most recent risk assessments showed that there are substantial risks to pesticide handlers, field workers, and bystanders. Bystanders (field workers, neighbors) who live and work near agricultural fields and greenhouses where fumigations occur are at risk of inhalation exposures that exceed EPA's level of concern unless additional mitigation measures are taken. There are also risks of concern for:

- Handlers involved in applications, tarp perforation, and tarp removal.
- Workers who may reenter a treated area or a neighboring area shortly after fumigation or tarp perforation is completed.

All soil fumigants are classified as **restricted-use pesticides (RUPs)**. In addition, labeling for most fumigants now requires **onsite supervision** of fumigant handlers and fumigant applications. Certified applicators—who are in charge of the application—must have additional training before applying or supervising the use of fumigants. Fumigant handlers must receive additional fumigant-specific safety information. This information is in addition to the WPS-required handler training.

Fumigant labels contain use instructions and mitigation measures. In particular to protect handlers, they provide details on:

- Fumigant handler activities.
- Onsite supervision.
- **Entry-restricted period.**
- Posting.
- PPE.
- Tarp perforation and removal procedures.

To protect bystanders, several other restrictions are in place (or soon will be added to labels) including, but not limited to:

- **Buffer zones** and posting.
- Application methods, number of acres treated, and rate.

Good agricultural practices (GAPs) are addressed on labels to ensure maximum performance and minimal off-gassing. Labels also have requirements for emergency preparedness and response, **fumigant management plans (FMPs)**, and **postapplication summaries (PASs)**. Each fumigant label may have slightly different requirements, so carefully read and follow label directions.

Read all labels carefully. Products containing *1,3-D as the sole active ingredient* do not have all the label restrictions found on other fumigant labels.

REVIEW QUESTIONS

- 1. Which of the following pests would NOT be controlled by a soil fumigant?**
 - A. Powdery mildew mycelium.
 - B. Nematodes.
 - C. Weed seeds.
- 2. True or False: The only soil fumigants that become a gas when they are incorporated into the soil are those applied as a liquid.**
- 3. Which is the most common route of human exposure to soil fumigants?**
 - A. Dermal (skin).
 - B. Oral (mouth).
 - C. Inhalation (lungs).
- 4. True or False: Of all the soil fumigants, only methyl bromide and chloropicrin are classified as restricted-use pesticides.**

Answers to Review Questions

- 1. A**—Soil fumigants only control soil-borne pests (powdery mildew mycelium only grows on plant tissue). Fumigants will control nematodes, soil-borne fungi and bacteria, soil insects, and weeds (both weed seeds and germinating seedlings).
- 2. False**—Soil fumigants rapidly volatilize (become a gas) once in the soil, whether they are applied as solids or as liquids.
- 3. C**—Fumigant inhalation is more common than skin or oral exposures.
- 3. False**—All soil fumigants are classified as restricted-use pesticides. This includes metam sodium, metam potassium, dazomet, methyl bromide, iodomethane, 1,3-D, and DMDS.

GENERAL LABEL AND REGULATORY REQUIREMENTS

LEARNING OBJECTIVES

After studying this chapter, you should be able to:

- State who may purchase and use a restricted-use pesticide (RUP).
- Describe the requirements for label-specified training for the certified applicator-in-charge.
- Define fumigant handlers, list their tasks, and explain the safety information that certified applicators are required to provide to fumigant handlers.
- Define the label term onsite supervision of noncertified applicators.
- Define the label term entry-restricted period and interpret entry-restricted period on a label for different tarped and untarped field application scenarios.
- Define water-run and nonwater-run application methods.
- List some good agricultural practices (GAPs) that may be found on fumigant labels.
- List recordkeeping requirements for soil fumigant applications.

This chapter covers the regulatory requirements of EPA and USDA. Be aware that your state may have more extensive requirements.

Not all of the label requirements discussed in this chapter apply to products formulated solely with 1,3-D.

Restricted-Use Pesticides (RUPs)

Because of human safety concerns, EPA designated all soil fumigants as restricted-use pesticides. RUPs can only be purchased and/or applied by certified applicators or persons working under their direct supervision (states vary in their allowances for direct supervision—be familiar with your state laws). States, tribes, and territories currently conduct pesticide applicator certification and training programs. Their requirements for cer-

tification of private and commercial applicators vary, but all meet national standards. This means that anyone who purchases, applies, or supervises the application of a soil fumigant must be a certified applicator, either private or commercial. Throughout this manual, the term “commercial applicator” is used to refer to all state certifications other than private applicator. The certification category or endorsement that is required for



soil fumigators varies depending on the type of applicator certification (private or commercial) and individual state, tribe, or territory requirements.

Fumigant-Specific Certified Applicator-in-Charge Training

Soil fumigant applicators must be certified applicators AND receive EPA-approved fumigant-specific training.

Since all fumigants are RUPs, **all** soil fumigant applicators **must** be certified by their state regulatory agency in order to purchase or use soil fumigants.

In addition, most labels (except 1,3-D only products) require that the certified applicator-in-charge of a soil fumigant application complete an appropriate **soil fumigant training program** listed on the EPA website (<http://www.epa.gov/fumiganttraining>). These EPA-approved training programs include:

- **Registrant** training on a specific soil fumigant active ingredient (every three years), **OR**
- State certification exam in a soil fumigation category that was revised no earlier than 2011, **OR**

Note that all states will not make this option available.

- Newly certified applicator who successfully completed a soil fumigation category exam that was revised no earlier than 2011.

Note that all states will not make this option available.

The training must be completed in the timeframes listed on the website. The Fumigation Management Plan (FMP) must document the date and location where the soil fumigant training program was completed. Certified applicators-in-charge who participate in soil fumigant training are required to show competency when the training is completed. The trainer documents who successfully completed the training and must keep these records. The trainer must also provide a card or certificate to participants who successfully complete the training.

The purpose of the training for the certified applicator-in-charge is to make sure they know how to:

- Apply fumigants correctly.
- Protect handlers and other people.
- Comply with new label requirements.



Fumigant Handlers

Fumigant Handler Tasks

For fumigants, **a fumigant handler includes any person in agriculture or nonagricultural settings, like golf courses, who performs handler activities.** The rules associated with handler protections under WPS apply to all fumigant handlers. Most labels list all fumigant handler activities, such as the following:

- Participating in the application—as supervisors, loaders, drivers, tractor copilots, shovelers, cross ditchers, or other direct application activities.
- Monitoring fumigant air concentrations.
- Cleaning up fumigant spills—this refers to fumigant handlers only and does not include work by outside emergency personnel.
- Handling or disposing of fumigant containers.
- Cleaning, handling, adjusting, or repairing parts of equipment that may contain fumigant residues.

- Installing, repairing, operating, or removing irrigation equipment in an **application block** or buffer zone.
- Entering an application block to perform scouting, crop advising, or monitoring tasks from the **start of the application** until the entry-restricted period ends.
- Entering a buffer zone to perform scouting, crop advising, or monitoring tasks from the start of the application until the **buffer zone period** ends.
- Installing, perforating, removing, repairing, or monitoring tarps until the entry-restricted period ends.
- Performing any handling tasks as defined by the WPS.

Safety Information for Fumigant Handlers

Most soil fumigant labels require that certified applicators provide safety information to fumigant handlers in a manner they can understand; remember, this

Sample label listing fumigation handler activities

Fumigation Handlers

The following activities are prohibited from being performed by anyone other than persons who have been appropriately trained and equipped as handlers in accordance with the requirements in WPS (40 CFR Part 170):

- Monitoring fumigant air concentrations;
- Cleaning up fumigant spills (this does not include emergency personnel not associated with the application);
- Handling or disposing of fumigant containers;
- Cleaning, handling, adjusting, or repairing the parts of application equipment that may contain fumigant residues; and
- Performing any handling tasks as defined by the WPS (40 CFR 170).

The following activities are prohibited from being performed in the application block from the start of the application until the entry-restricted period ends and in the buffer zone during the buffer zone period by anyone other than persons who have been appropriately trained and equipped as handlers in accordance with the requirements in WPS (40 CFR Part 170). (Note: persons repairing and monitoring tarps are considered handlers for the duration listed below). Prohibited activities (except for trained and equipped handlers) include:

- Participating in the application as supervisors, loaders, drivers, tractor co-pilots, shovelers, cross ditchers, or as other direct application participants;
- Installing, repairing, operating, or removing irrigation equipment;
- Performing scouting, crop advising, or monitoring tasks;
- Installing, perforating (cutting, punching, slicing, poking), or removing tarps; and
- Repairing or monitoring tarps until 14 days after application is complete if tarps are not perforated and removed during those 14 days.

includes agricultural and nonagricultural fumigant handlers. Certified applicators must document in their FMPs that their fumigant handlers have received this information within the last year. **Fumigant Safe Handling Information** is available where fumigants are purchased and on the EPA website: <http://www.epa.gov/fumigantraining>.

Information that must be provided **annually** to handlers includes:

1. What fumigants are and how they work.
2. Safe application and handling.
3. Air monitoring and respiratory protection.
4. Early signs and symptoms of exposure.
5. Steps to mitigate exposure.
6. Emergency response.
7. Reporting incidents.

Onsite Supervision

Soil fumigant applications must be made either by a certified applicator or with the certified applicator-in-charge providing onsite supervision, unless a state prohibits supervision of noncertified people. For fumigant applications, onsite supervision means the certified applicator-in-charge must be onsite for the entire application (except for **water-run applications**). This is in contrast to direct supervision, which may be done remotely for non-soil fumigant pesticide use. Soil fumigant labels have different onsite supervision requirements for water-run and nonwater-run applications because some water-run applications occur over a period of several days. Be sure to check and comply with the label for the product you are using.

Onsite supervision requirements for soil fumigants:

- **Nonwater-run applications** (e.g., **shank** or rotary tiller): the certified applicator must be at the fumigation site and in the line of sight of the application and fumigant handlers from the start of the application until the **application is complete**.

- **Water-run applications (metam chemigation)**: the certified applicator-in-charge can leave after starting the application but then must check back every two hours. A fumigant handler may continue monitoring the application by checking back every two hours, as long as he or she can communicate with the certified applicator by cell phone or other means.

Users should check the product label and state laws to ensure whether the fumigant product can be applied by someone other than the actual certified applicator, and to confirm whether the certified applicator must be onsite during the application.

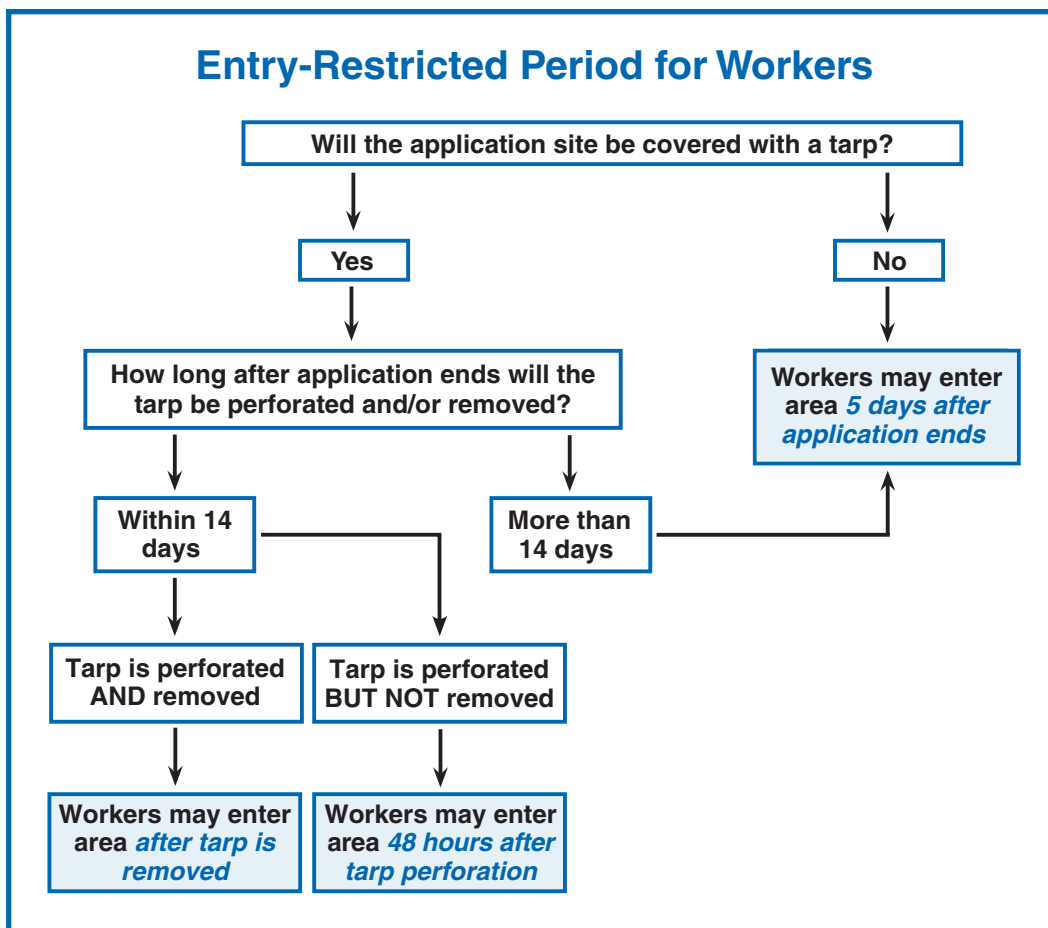
Entry-Restricted Period

Due to the volatile chemical properties of fumigants and the potential for worker exposure, entry into the application block is restricted to fumigant handlers wearing appropriate PPE during the application and the entry-restricted period. The entry-restricted period is a specific amount of time during which entry into treated fields by anyone other than a trained and properly PPE-equipped fumigant handler is prohibited. Entry prohibition includes early entry that would otherwise be permitted under the WPS. **The entry-restricted period starts when the application starts**. The length of the entry-restricted period depends on whether the field was tarped or untarped. Generally, labels have a minimum entry-restricted period of five days, or until after tarps are perforated and removed.

No one other than the certified applicator and fumigant handlers can be in the field once the application has started (i.e., when the fumigant is first delivered or dispensed into the soil). Following are samples of label language for entry-restricted periods:

- **Untarped**: 5 days (120 hours) after the application (and soil sealing) has ended for untarped applications, or

Entry-Restricted Period for Workers



- **Tarped:** After tarps are perforated and removed, if tarp removal is completed less than 14 days after application, or
- **Tarped:** 48 hours after tarps are perforated, if they will not be removed for at least 14 days after the application, or
- **Tarped:** 5 days (120 hours) after application is complete, if tarps are not perforated and removed for 14 days after the application is complete.

It is important to note that the entry-restricted period is different from a **restricted-entry interval (REI)**, a term more familiar to applicators. The REI is the amount of time that must elapse between any pesticide application and the time when a WPS-trained worker (e.g., someone moving irrigation pipe or scouting) can reenter a treated area without wearing protective clothing and equipment. Early-entry exemptions

under WPS do not apply to soil fumigants. Read the label carefully for the PPE required for fumigant handlers who enter fields during the entry-restricted period. Unlike REIs, the entry-restricted period is not listed in the Agricultural Use Requirements section of the fumigant label. It is more restrictive and replaces the REI.

Chemigation

One way fumigants are applied to the soil is through irrigation systems (chemigation). Chemigation applications include any case where fumigants are applied with irrigation water (e.g., wheel line (side roll), center pivot, lateral move, drip (tape), flood, and furrow).

States may have regulations for chemigation practices. If using chemigation for fumigant applications, check with your state about additional laws.

*Chemigation application:
low-release height,
solid-stream system*



Good Agricultural Practices (GAPs)

GAPs ensure that fumigant applications are both effective and protective of fumigant handlers, workers and bystanders. Compliance with GAPs is required for most soil fumigant applications. The GAPs are listed on each fumigant label and are specific to both the product and the application method. GAPs include many factors:

- Weather, including wind speed, and identification of unfavorable weather conditions.
- Soil conditions, including tillage, plant debris, organic matter, soil temperature, and soil moisture.
- Injection depth and application rate.
- Soil sealing, including tarps and prevention of end-row spillage.
- Chemigation requirements, including injection site, irrigation system layout, and flushing.
- System requirements for application rigs, including controls, integrity, **calibration**, setup, repair, and maintenance.

Depending upon the fumigant, there may also be GAPs for planting requirements, spill prevention, and product storage.

Notice to State and Tribal Lead Agencies

Some states, tribes, and territories require that applicators notify them before applying certain soil fumigants. Product labels will include a website that lists each state, tribe, and territory that requires notice, as well as how to provide that notice. Applicators must check the website prior to making an application.

Fumigant Application Records

Certified applicators must keep records of all soil fumigant applications because they are RUPs. In addition, most fumigant labels require certified applicators to prepare and make available written FMPs and PASs for each fumigant application (except for products formulated solely with 1,3-D). These records must be made available to qualifying parties. RUP application recordkeeping requirements fall under United States Department of Agriculture (USDA), EPA, or state regulatory authority depending on the type of certification: private applicator or commercial applicator.

Most, but not all, of the items that are recorded for state and federal application records are also required in FMPs or PASs. (See Chapter 8 for details regarding FMPs and PASs.) However, be aware that simply completing the FMP and PAS does not meet state and federal recordkeeping requirements. You may choose to add the additional federal- or state-required recordkeeping items to the PAS to meet all the recordkeeping requirements with one document.

For a soil fumigant application, completing the FMP and PAS does not meet all of the state and federal application recordkeeping requirements. Know and follow your state laws. A prudent applicator records significantly more information than the minimum requirements.

Elements Required by Federal RUP Recordkeeping Requirements, FMPs, and PASs

(which may differ from your state's requirements), and those items required in FMPs and PASs.

	Private Applicators: Federal Recordkeeping	Commercial Applicators: Federal Recordkeeping	Fumigant Management Plan (FMP)	Postapplication Summary (PAS)
Applicator's Name and Certification #	Y		Y	
Name and Address of Person for Whom Pesticide is Being Applied		Y	Y	
Actual Application Date/Time	Y	Y		Y
Target Application Date/Window			Y	
Brand or Product Name	Y	Y	Y	
EPA Registration Number	Y	Y	Y	
Size of Treated Area	Y		Y	Y
Application Method			Y	
Injection Depth			Y	
Application Rate	Y	Y	Y	Y
Tarp Information and Procedures for Repair, Perforation, and Removal			Y	
Tarp Damage/Repair				Y
Tarp Perforation and Removal Details				Y
Soil Conditions—Texture, Moisture			Y	
Soil Conditions—Temperature			Y	
Weather Conditions			Y	Y
Total Amount of Pesticide Applied	Y			
Location	Y	Y	Y	
Crop or Site	Y	Y		
Target Pest		Y		
Pesticide Disposal		Y		
PPE Requirements for Handlers			Y	
Emergency Procedures			Y	
Posting Procedures			Y	
Communication Plan			Y	
Information for Onsite Personnel			Y	
Air Monitoring Plan			Y	
Good Agricultural Practices			Y	
Hazard Communication Description			Y	
Complaint Details				Y
Description of Incidents, Equipment Failures, or Other Emergency and Procedures Followed				Y
Details of Elevated Air Concentrations				Y
Date of Sign Removal				Y
Description of any Deviation from FMP				Y
Completion Requirements	14 days		Before application	30 days
Record Retention	2 years	2 years	2 years	2 years
Who Retains Records	Private applicator	Person or business making the application	Certified applicator and property owner	Certified applicator and property owner

REVIEW QUESTIONS

1. True or False: To meet the soil fumigant training requirements, both certified applicators and fumigant handlers must pass a written exam.
2. True or False: All soil fumigants are restricted-use pesticides.
3. True or False: For water-run metam applications, the certified applicator can leave after starting the application but then must check back every three hours. A fumigant handler may continue monitoring the application by checking back every three hours, as long as he or she can communicate with the certified applicator by cell phone or other means.
4. True or False: By completing the minimum information required in an FMP and a PAS, you will fulfill federal RUP recordkeeping requirements.

Answers to Review Questions

- 1. False**—Fumigant handlers are not required to pass a written exam. Depending on the EPA-approved training option, some form of assessment is required for certified applicators.
- 2. True**—All soil fumigants are classified as RUPs.
- 3. False**—The check-back requirement is every two hours, NOT every three hours.
- 4. False**—The minimum information required in an FMP and a PAS does not meet federal RUP recordkeeping requirements.

SOIL FUMIGANT CHEMICAL CHARACTERISTICS

LEARNING OBJECTIVES

After studying this chapter, you should be able to:

- Describe the chemical characteristics of each soil fumigant.
- Describe the specific human exposure concerns for each soil fumigant.
- Explain the purpose of chloropicrin in methyl bromide and methyl iodide formulations.
- Name the major groups of pests controlled by each soil fumigant.
- List the application methods commonly used for each fumigant.
- Describe how far the fumigant disperses from the application zone.
- List incompatibility concerns for tanks, hoses, tubing, and other equipment.
- Explain why 1,3-D products have different label requirements than most other fumigants.

Soil Fumigants

The appropriate fumigant, its **application rate**, application method, and timing are determined by:

- The crop to be planted.
- The target soil-borne organism(s).
- Level of pest infestation.
- Soil characteristics.
- Environmental conditions.

For all fumigants, enough concentration and contact time with target pests are required to obtain good results. Some fumigants are more effective on a limited range of soil-borne organisms, while others are broad-spectrum biocides that kill most soil pests. Fumigants manage only

those target pests present in the soil at the time of fumigation and within the treatment zone. Once applied, fumigants have no residual activity and won't control later pest infestations.

Methyl Bromide

Methyl bromide is a broad-spectrum fumigant that controls many weeds and soil-borne insects, nematodes, fungi, and bacteria. However, it does not adequately control all species. Methyl bromide is toxic to all stages of insect life. It is registered for use on a variety of crops, including ornamentals, vineyards, deciduous fruit and nuts, nursery sites, greenhouse soils, peppers, tomatoes, and strawberries.



Tarping for a methyl bromide application

Methyl bromide is a colorless, non-flammable, and odorless gas at ambient temperatures and pressures. Since methyl bromide is very toxic and is virtually odorless, all formulations for use in soil must contain at least 2% chloropicrin as a **warning agent** because of chloropicrin's strong, teargas effect. Most methyl bromide formulations contain a higher percentage of chloropicrin to provide better control of target pests.

Methyl bromide is extremely toxic to mammals, including humans. Without the addition of chloropicrin as a warning agent, certified applicators and/or fumigant handlers may be unaware that they are being exposed. The initial effects of methyl bromide exposure include headache, dizziness, lethargy, fainting, nausea or vomiting, chest and abdominal pain, and irritated eyes, nose, and throat. Severe exposure can result in convulsions, muscular tremors, **pulmonary congestion, cyanosis, delirium**, coma, and death. **Pulmonary edema** is the chief harmful effect of severe methyl bromide poisoning. There may be a delay in the

onset of some symptoms following exposure. In addition, research suggests that long-term exposure to methyl bromide can lead to nervous system disorders. Methyl bromide is corrosive to the skin and eyes, especially when trapped by gloves, boots, or goggles.

For methyl bromide products that contain less than 20% chloropicrin, the label requires the use of a direct-read air-monitoring device.

Since it is a gas at ambient temperatures and pressures, methyl bromide is stored under pressure as a liquid. It is the most highly volatile soil fumigant and changes into an odorless gas when dispensed from a pressurized container. Because methyl bromide has the greatest **volatility**, it also has the greatest soil diffusion capability compared to other fumigants. It can travel up to 36 inches in the soil. After application to the soil, methyl bromide gas moves primarily through soil pores.

The typical application method is to inject methyl bromide into the soil using a shank, then immediately seal the shank

trace using soil compaction and a tarp. It may also be applied with the hot gas method. With this method, methyl bromide is forced through a heat exchanger into perforated tubing under tarps.

Due to its volatility, methyl bromide's effectiveness depends largely on soil sealing with tarps, required for all methyl bromide applications.

Methyl bromide is corrosive to polyvinyl chloride (PVC), nylon, aluminum, or galvanized (coated with zinc) metal.

The **Montreal Protocol** called for the phase-out of all methyl bromide uses by 2005. Critical use exemptions (CUEs), which are granted on a year-by-year basis for an increasingly limited number of uses, are exempt from the 2005 phase-out for the specific year they are granted. Also, quarantine and preshipment uses are not subject to regulation under the Montreal Protocol and are exempt from the 2005 phase-out as well. Finally, existing stocks of methyl bromide, produced before 2005, may still be used on specific non-CUE crops (check label) until those stocks are exhausted. The import or production of new methyl bromide for any other uses is prohibited.

Methyl Iodide (Iodomethane)

Methyl iodide is similar in chemistry to methyl bromide. It is a clear, colorless liquid, with an ether-like odor. As a heavier molecule, it has a vapor pressure that is lower than methyl bromide but still significantly higher than other fumigants. Therefore, it displays good fuming properties in the soil. Methyl iodide offers broad-spectrum activity like methyl bromide, but there is not the concern on impacts to the ozone layer. It is formulated with different ratios of chloropicrin, ranging from 2% to 67%. Again, chloropicrin is added to increase activity.

Methyl iodide is used to control plant pathogens, nematodes, insects, and weeds in crops such as strawberries, tomatoes and peppers, ornamentals, turf, trees, and vines. This fumigant can be applied to raised beds or as a broadcast/flat fume application using tractor-mounted **chisels**. It can also be applied

via drip irrigation. Tarps are required for these applications. In stone fruits, tree nuts, vines, and field-grown ornamentals, methyl iodide can also be applied with a deep injection auger probe.

Methyl iodide exposure symptoms include a burning sensation, coughing, wheezing, laryngitis, shortness of breath, headache, nausea and vomiting, blurred vision, weakness, drowsiness, **ataxia**, confusion, pulmonary edema, and convulsions. It can cause irreversible eye damage and is corrosive to the skin.

Chloropicrin

Chloropicrin is a broad-spectrum fumigant that controls some soil-borne insects, fungi, and bacteria. It provides limited control of some weed seeds and nematodes. Although chloropicrin is often added to other fumigants in low concentrations as a warning agent, it is also added at higher concentrations (up to 75%) to increase the overall spectrum of pest control. Chloropicrin is often formulated with methyl bromide, iodomethane, DMDS, and 1,3-D. It may be formulated as the sole active ingredient.

Chloropicrin is a slightly oily, clear, colorless to amber-colored, nonflammable liquid. It vaporizes slowly when exposed to air at room temperature. It has a high boiling point (233°F) and is only slightly water soluble, so it disperses through the soil largely as a gas. It volatilizes and disperses in the soil more slowly than methyl bromide because of its lower vapor pressure. It provides good movement through well-tilled soil. Chloropicrin is often used in tobacco, tomatoes, peppers, orchard replanting, strawberries, potatoes, and onions.

Chloropicrin is an eye, nose, and throat irritant. It is usually detected through odor and eye sensation within five minutes of exposure. Symptoms of exposure are concentration dependent. Exposure symptoms, such as those resulting from off-gassing of a treated field, include:

- Irritation of mucous membrane and upper respiratory tract.

- Eye irritation, which may include tearing/watering.
- Cough.
- Nausea and headache.
- Possible skin irritation.

Exposure to higher concentrations can cause severe irritation, headache, nausea, and vomiting. These symptoms are temporary and reversible after the exposure has ended. However, they may persist for up to two days after the exposure. At very high concentrations, life-threatening effects, including pulmonary edema, can occur. Severe lung responses can be delayed following onset of exposure. Direct contact with undiluted liquid chloropicrin can cause severe skin irritation.

Chloropicrin is formulated as a pressurized liquid or an emulsifiable concentrate (EC). It is injected beneath the soil surface with a shank or chisel, or is applied through drip irrigation systems. It is also used in tree hole applications when replanting orchards. Chloropicrin moves through soil rapidly and diffuses 6 to 12 inches from the point of injection. For this reason, it is important to seal treated soil to prevent loss of the fumigant from the soil. Postapplication soil-sealing methods include tarps, mechanical soil compaction, and sprinkler irrigation.

When chloropicrin is injected 8 to 10 inches deep—either alone or in combination with methyl bromide—a tarp may be required. When it is formulated in combination with 1,3-D, the methods of application and soil sealing are the same as for 1,3-D.

Chloropicrin is corrosive to many metals. Use fittings made only of brass, carbon steel, or stainless steel. Do not use galvanized, PVC, nylon, or aluminum pipe fittings. All tubing must be made of compatible materials, such as polyethylene or Teflon.

1,3-Dichloropropene (1,3-D)

1,3-D is a colorless or straw-colored liquid that is highly flammable and has

an irritating, sweet, pungent odor similar to garlic. It is highly mobile in soil, especially drier soil.

1,3-D is mainly used to control plant-feeding nematodes, wireworms, and **symphylans**. At higher rates, it is effective on some weed seeds and soil-borne fungi. It can be combined with other fumigants, particularly chloropicrin, to increase the spectrum of pests controlled (e.g., soil-borne fungi and bacteria). 1,3-D is commonly used on potatoes, turfgrass (golf courses), tobacco, mint, and fruit and vegetable crops.

As with the other liquid fumigants, both the liquid and gaseous states are toxic. Exposure can cause severe eye damage, burns, and damage to lungs, kidneys, liver, and the respiratory tract. If inhaled, swallowed, or even absorbed through the skin, the effects can be fatal. **Chronic exposure** can cause systemic damage to internal organs. Acute inhalation exposure can cause mucous membrane irritation, chest pain, nausea, dizziness, fainting, and breathing difficulties. Chronic dermal exposure may result in skin sensitization in humans. EPA has classified 1,3-D as a probable human **carcinogen**.

1,3-D is typically injected into the soil through shanks, knives, or sweep plows. Depending on the cropping system, this can be done either broadcast or in rows. Immediately after application, the soil surface is sealed mechanically, with tarps, or occasionally with a light irrigation. 1,3-D formulated as an EC both with and without chloropicrin may also be applied by chemigation (through surface and subsurface drip irrigation systems). When applied this way, 1,3-D initially moves through the soil with the irrigation water. As the soil dries, 1,3-D volatilizes.

1,3-D is corrosive to aluminum, magnesium, zinc, cadmium, and their alloys. Furthermore, Buna-N, neoprene, and fiberglass may dissolve upon contact with this chemical.

Throughout this training manual, you will note several exceptions to current label requirements for products formulated with 1,3-D as the sole active



ingredient (e.g., Telone®II, Telone®EC). The risk assessments for 1,3-D occurred several years prior to the 2009 review of all other fumigants, which included chloropicrin which is formulated with 1,3-D in Telone®C-17 and Telone®C-35. So products with 1,3-D combined with chloropicrin have all the label requirements discussed in this manual. Products with only 1,3-D, do not have all the label requirements. For example, products with 1,3-D only, do not have the following requirements on their labels:

- Certified applicator-in-charge training.
- WPS fumigant handler safety training.
- Weather restrictions.
- Buffers: 48-hour buffer zone periods, restrictions on overlapping buffers and buffer zone posting.
- **Difficult-to-evacuate sites.**

- Fumigant management plans and postapplication summaries.

However, all of the label requirements discussed in this manual do apply when 1,3-D is formulated in combination with chloropicrin. Read labels carefully.

Dimethyl Disulfide (DMDS)

DMDS is a transparent, light yellow liquid with a strong odor like mercaptan, the odorant in natural gas. Given its high vapor pressure and its level of solubility, **volatilization** followed by movement with soil water is usually the main dispersal pathway for DMDS. The half life of DMDS in air is about one hour. DMDS gradually degrades in the soil environment.

DMDS is toxic to some weeds, soil-borne nematodes, bacteria, and fungi. DMDS is a widespread natural product

1,3-D application with good soil preparation and sealing

and is labeled for use on vegetables (tomatoes, peppers, eggplants), cucurbit crops (cucumber, squash and melons), strawberries, blueberries, field-grown ornamentals, and forest nursery stock.

DMDS is an eye and skin irritant; exposure may cause nausea, headache, or dizziness. It is believed to affect the central nervous system.

There are two formulations of DMDS. The first is a liquid concentrate used only in shank injection applications. Immediately after fumigation, specifically-labeled high-barrier tarps are required to cover the treated area whether you apply DMDS broadcast or in rows for raised bedded fumigation. The second is an emulsifiable concentrate to be used for chemigation through drip irrigation systems **only**. For this type of application, you must bury drip tape under the high-barrier tarp.

Always read and follow the label directions since label requirements for products with this active ingredient may vary from other soil fumigants.

Metam Sodium and Metam Potassium

Metam sodium and metam potassium are broad-spectrum fumigants once they convert into methyl isothiocyanate (MITC) in the soil. They are registered to control soil-borne nematodes, insects, bacteria, fungi, and weeds. They are often used on potatoes and increasingly used on vegetable crops.

These orange to light yellow-green liquid fumigants are nonflammable. MITC degrades into MIC and hydrogen sulfide (toxic compounds) and eventually into sulfur and nitrogen.

MITC is the active phase against pests. For this reason, metam sodium and metam potassium are known as MITC generators. Because of MITC's lower vapor pressure and strong affinity for soil water, it disperses only a few inches through the soil when in its **vapor phase**. Therefore, MITC must be distributed throughout the soil in the parent form (metam potassium or metam sodi-

DMDS shank application





Equipment for shank application

um) before its conversion to MITC. Both metam potassium and metam sodium move more effectively through the soil than MITC.

The MITC form is more acutely toxic than the parent metam sodium and metam potassium material. MITC has a strong rotten-egg odor. Inhaling MITC may cause irritation to mucous membranes and respiratory distress. The earliest symptoms of inhalation exposure include watering of the eyes (tearing) and a runny nose, followed by coughing. These symptoms disappear soon after the victim gets to fresh air. Dermal exposure may cause burns; repeated or prolonged exposure may cause a hypersensitive type of **dermatitis**.

Metam sodium and metam potassium are liquid formulations that are applied by various means:

- Chemigation.
- Tractor-drawn shank injection equipment.
- As a spray followed by mechanical incorporation.
- As a **drench** application to well-prepared seedbeds.

Tractor-drawn applications are carried out with various types of shank soil injection, rotary tiller, and spray blade injection equipment. Seal the soil surface immediately after application using one or more of the following methods:

- Mechanical compaction.
- Covering the treated soil with untreated soil.
- Applying at least $\frac{1}{4}$ -inch of water immediately after application begins.
- Covering the treated area with a tarp.

Using metam potassium or metam sodium is prohibited in greenhouses or any other enclosed structure or confined area. Handheld applications are also prohibited.

Metam sodium and metam potassium move differently in the soil than other fumigants. As the parent compound, they move freely, but once they convert into MITC, movement is greatly reduced. For example, when applied by shank injection, these fumigants often do not move more than 3 inches from the point of injection.

These fumigants are corrosive to aluminum, zinc, galvanized steel, copper, and brass. Assess the tanks, fittings, and clamps on your application equipment and only use application equipment that is made of chemical-resistant materials.

Dazomet

Dazomet is a broad-spectrum, granular soil fumigant that mainly controls germinating annual and perennial weeds. When dazomet is applied to soil, it quickly converts to MITC and also forms formaldehyde, monomethylamine, hydrogen sulfide, and in acid soils, carbon disulfide.

It is registered for use on golf courses, nonbearing orchard crops, berries, flower bulbs, turf and ornamental sites, nurseries, greenhouses, compost piles, potting soils, and—in California—on strawberries and tomatoes.

Dazomet is spread on the soil surface and incorporated into the soil to the depth that control is needed. After application, the soil is sealed, usually by mechanical compaction or with water. Use plastic tarps to seal the soil in small areas or when near-total weed control is desired. Topical application with irrigation works best in areas where tillage is undesirable, such as golf greens, tees, and fairways.

In the presence of soil water, dazomet begins to convert into MITC within 10 minutes after application. MITC does not move far in the soil. For this reason, the effective treatment zone does not extend beyond the reach of the soil water that activates it.

After application, keep the soil uniformly moist for five to seven days. Dazomet breaks down at high temperatures and must not be used when soil temperatures exceed 90°F.

Oral exposure to dazomet may cause nausea, vomiting, cramps, and diarrhea. Serious cases may cause depression of the central nervous system. Skin or eye contact may result in irritation and an occasional allergic reaction. Inhaling the dust or powder may irritate the upper respiratory tract.

Because dazomet is an MITC generator, off-gassing may be detected by a rotten-egg odor. MITC inhalation may irritate the mucous membranes and cause respiratory distress. The earliest symptoms of MITC inhalation include watering eyes and a runny nose, followed by coughing. These symptoms disappear soon after the victim gets to fresh air. Dermal exposure may cause burns; repeated or prolonged exposure may cause dermatitis.

Dazomet is registered for use on golf courses



REVIEW QUESTIONS

- 1. True or False: Soil fumigants have residual activity in the soil lasting longer than 60 days.**
- 2. Why is chloropicrin always added to formulations of methyl bromide and methyl iodide?**
 - A. To make them less volatile.
 - B. So that they can be applied deeper into the soil.
 - C. To act as a warning agent and alert people of the presence of a fumigant.
- 3. Which of the following soil fumigants is a methyl isothiocyanate (MITC) generator?**
 - A. Dazomet.
 - B. Methyl bromide.
 - C. Chloropicrin.
- 4. Which soil fumigant is the most volatile?**
 - A. Metam sodium.
 - B. Methyl bromide.
 - C. Methyl iodide.

Answers to Review Questions

- 1. False**—Soil fumigants have no residual activity and do not control later pest infestations. They control only those target pests present in the soil at the time of fumigation, at the depth of injection and in the treatment zone.
- 2. C**—Methyl bromide and methyl iodide have no or little odor to warn people of exposures. All such formulations must contain at least 2% chloropicrin as a warning agent because of its strong, teargas odor.
- 3. A**—When incorporated into the soil, dazomet is quickly converted into several strong irritant products. One of these is methyl isothiocyanate (MITC), which accounts for most of the fumigant activity. Dazomet is known as an MITC generator. Metam sodium and metam potassium are also MITC generators.
- 4. B**—Methyl bromide is the most volatile of all the soil fumigants. Therefore, it also has the greatest range of diffusion compared to other fumigants. It can travel up to 36 inches in the soil.

SOIL AND PEST FACTORS THAT INFLUENCE FUMIGANT ACTIVITY

LEARNING OBJECTIVES

After studying this chapter, you should be able to:

- List the factors that influence gaseous movement through the soil profile and into the air.
- Describe the influence of important soil factors on fumigant volatility and movement within the soil profile.
- Describe how soil characteristics affect the success of a fumigation operation.
- Describe how to assess soil moisture.
- Describe ways to correct for soil characteristics that might hinder a successful fumigation.
- Explain the importance of knowing which pest is causing the damage.
- Explain the importance of application depth in the soil.
- Explain the importance of application timing.
- Explain the relationship between pest density and application rate.

Soil Factors

Several soil factors influence gaseous movement of fumigants through the soil and can have significant impacts on fumigant volatilization into the atmosphere. These include soil temperature, texture and structure, moisture, tillage, crop residues (quantity and orientation), and sealing method.

Understanding these soil factors and assessing them before application is critical for both effective pest control and minimal volatilization into the atmosphere. These factors also influence the amount of off-gassing that can expose certified applicators, fumigant handlers,

and bystanders (including field workers) to fumigant vapors. Fumigant labels provide use directions related to soil factors.

Soil Temperature

The ideal soil temperature is one where the fumigation results in effective control of target pests and minimal volatilization into the atmosphere. Soil temperature at the time of fumigation depends on the fumigant and the target application depth required to reach the pest organisms. Check the label for the appropriate soil temperature ranges. Most

Check the label for soil temperature requirements. Remember—the label is the law, and labels change over time.

labels list a minimum and maximum temperature for fumigation. The depth at which the soil temperature is measured varies among fumigants—check the label. In general, low soil temperatures prevent the fumigant from moving through the soil as quickly as it would under warmer conditions. Higher soil temperatures generally result in greater dispersion of the fumigant through the soil but also a greater potential for volatilization as well.

Following are examples of fumigant label language regarding soil temperature:

- At the beginning of the application, the **soil temperature at the injection depth** must be between 35° and 90°F.
- If air temperatures have been above 100°F in any of the three days prior to application, then soil temperature must be measured and recorded in the FMP. Record temperature measurements at the application depth or 12 inches, whichever is shallower.

Soil Texture

Soil texture refers to the size of the soil particles and the pore spaces within the soil. It greatly impacts how soil fumigants move. Soil particles are grouped according to their size. Soil texture classification is based on the relative proportion of clay, silt, and sand. The soil texture triangle is a diagram often used to classify soil textures.

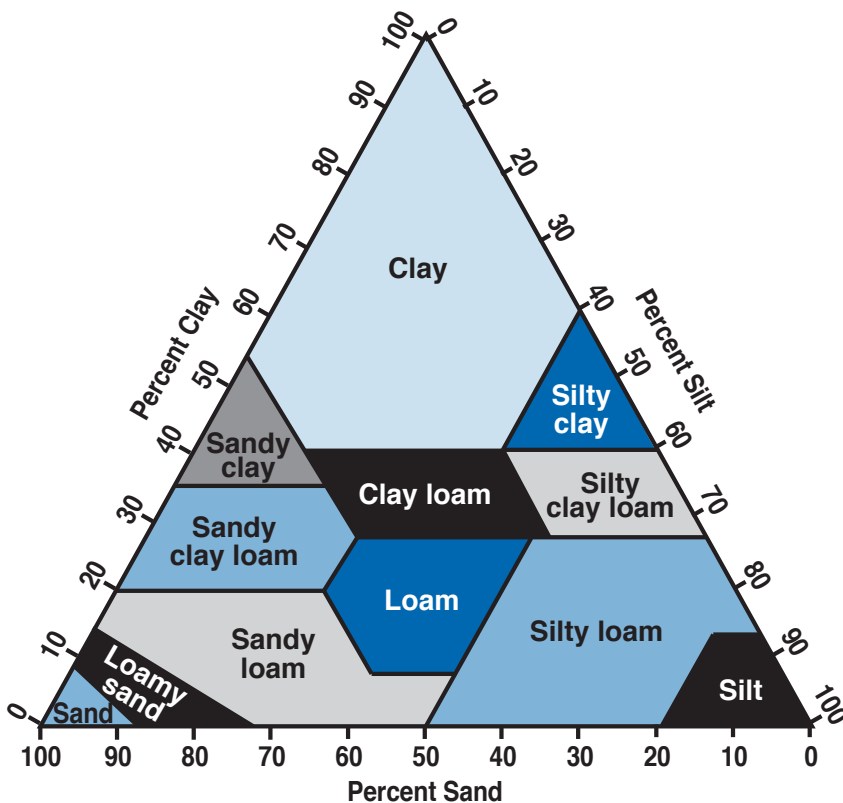
Coarse soils, such as sand and sandy loam, consist of relatively higher percentages of larger soil particles and have larger pore spaces. Fumigants diffuse quickly in coarser soils, moving farther from the point of injection. More finely textured soils, such as clay and silt loam, consist of relatively higher percentages of smaller soil particles and have much smaller pore spaces. This restricts the dispersal of the fumigant. Soil fumigants travel faster in sand and sandy loam soils than in silt loams and clay soils. However, fumigants may escape into the atmosphere more readily from coarse soils.

Soil Moisture

Soil moisture impacts the movement of a fumigant through the soil and off-gassing into the air. Improper soil moisture at the time of application can lead to poor control of target pests and could result in off-gassing. Soil moisture requirements vary depending on the fumigant. Additionally, these requirements may vary depending on a variety of factors, including soil texture, application method, and application depth. Carefully consider soil moisture requirements for the specific fumigant and check the label. Proper pre-fumigation soil moisture management helps to ensure optimal performance and greatly reduces the risk of off-gassing.

To determine soil moisture, use either the United States Department of Agriculture (USDA) feel and appearance method or a tool, such as a **tensiometer**. Fumigant labels explicitly state the amount of soil moisture required for each soil texture and the depths at which the soil moisture is measured. Soil moisture is expressed as a percentage of **available**

Soil Texture Triangle



water capacity. Available water capacity is the amount of soil moisture or water content held in soil after excess water has drained away. Coarse-textured soils typically require higher moisture content compared to fine-textured soils. For fields with more than one soil texture, comply with label statements for the soil moisture content in the lightest textured (i.e., coarsest; most sandy) areas. If there is insufficient moisture at the soil depth indicated by the label before the application, adjust the soil moisture level.

Following are examples of fumigant label language regarding soil moisture:

- The soil moisture in the top six inches of soil must be at 60% to 80% of available water capacity immediately prior to the application, subject to the exception below.
- Exception: In areas where soil moisture must exceed available water



Soil Type, Moisture Levels, Appearance, and Feel

Soil moisture level	Fine sand, loamy fine sand	Sandy loam, fine sandy loam	Sandy clay loam, loam, silt loam	Clay loam, clay, silty clay loam
0 – 25% available soil moisture	Appears dry; will not retain shape when disturbed or squeezed in hand.	Appears dry; may make a cast when squeezed in hand but seldom holds together.	Appears dry. Aggregates crumble with applied pressure.	Appears dry. Soil aggregates separate easily, but clods are hard to crumble with applied pressure.
25% – 50% available soil moisture	Slightly moist appearance. Soil may stick together in very weak cast or ball.	Slightly moist. Soil forms weak ball or cast under pressure. Slight staining on finger.	Slightly moist. Forms a weak ball with rough surface. No water staining on fingers.	Slightly moist; forms weak ball when squeezed, but no water stains. Clods break with applied pressure.
50% – 75% available soil moisture	Appears and feels moist. Darkened color. May form weak cast or ball. Leaves wet outline or slight smear on hand.	Appears and feels moist. Color is dark. Forms cast or ball with finger marks. Will leave a smear or stain and leaves wet outline on hand.	Appears and feels moist and pliable. Color is dark. Forms ball and ribbons when squeezed.	Appears moist. Forms smooth ball with defined finger marks; ribbons when squeezed between thumb and forefinger.
75% – 100% available soil moisture	Appears and feels wet. Color is dark. May form weak cast or ball. Leaves wet outline or smear on hand.	Appears and feels wet. Color is dark. Forms cast or ball. Will smear or stain and leaves wet outline on hand; will make weak ribbon.	Appears and feels wet. Color is dark. Forms ball and ribbons when squeezed. Stains and smears. Leaves wet outline on hand.	Appears and feels wet; may feel sticky. Ribbons easily; smears and leaves wet outline on hand. Forms good ball.

Adapted from the Natural Resources Conservation Service (NRCS) publication “Estimating Soil Moisture by Feel and Appearance.”

capacity to form a bed (e.g., certain regions in Florida), soil moisture content may exceed 80%.

- If appropriate measuring equipment is not used to determine whether the soil moisture in the top six inches of soil is at 60% to 80% available water capacity immediately prior to the application, the *USDA Feel and Appearance Method* test may be used to estimate whether the 60% to 80% soil moisture content requirement is met.

Soil Tilth

Soil tilth is the physical condition of soil. It usually relates to the suitability of soil for planting or growing a crop. Factors include clods, moisture content, degree of aeration, rate of water infiltration, and drainage. The tilth of a soil can change rapidly, depending on environmental factors such as changes in moisture. Relative to soil fumigation, soil tilth is the optimal physical condition to allow the fumigant to diffuse through the soil pore spaces but not escape when the soil surface is sealed properly.

Poor soil tilth—compacted soil layers, clods, or hardpan—interferes with fumigant diffusion. There is less soil pore space available for the fumigant to diffuse, which reduces fumigant spread and effectiveness. Clods and soil debris promote off-gassing. Maximizing soil pore space through good soil management practices promotes proper diffusion of fumigant through the soil to the target pest.

Crop Residues

Soil preparation is critical before any fumigation. Crop residues left in or on the soil may cause problems. Residues may slow movement of the soil fumigant since some fumigants **adsorb** to **soil organic matter**. The orientation of the crop residue may provide avenues for gas to escape from the soil. They may also hamper proper soil sealing. Properly managed crop residue can be a useful tool in preventing wind and water erosion. With shank application, excessive residue (especially long residue) can hang up on the shanks, which may cause plugging. Before making an application, decide how to manage crop residues.



Soil Sealing

Sealing fumigants in the soil with tarps, mechanical compaction, or irrigation allows the fumigant concentration to reach a lethal concentration and for fumigants to remain in the soil long enough to kill target pests. The sealing method depends on the volatility of the fumigant and varies with application method. Covering the soil with a plastic tarp provides a good soil seal and is often done with the more volatile fumigants (e.g., methyl bromide, methyl iodide, and chloropicrin). Less volatile fumigants (e.g., metam sodium and metam potassium) are typically sealed with water or by packing the soil with rollers or drags. Water seals are generally created by a light watering with about ¼-inch of water. See “Soil Sealing” in Chapter 10 for more detailed information.



Very poor soil seal due to inadequate soil preparation and too much crop residue

Pest Factors

Although a fumigant may be effective against many different pest species, the placement (depth), timing, and application rate are not always the same for each. Control efforts are based on the number and types of pests that have occurred in previous years, or on a soil assay for nematodes. Identifying the pest that is causing the damage is a major factor in determining the choice of fumigant, application method, and application depth.

Depth of Pest Organisms

The target pest also influences the application depth of the fumigation. Application depth depends on several factors:

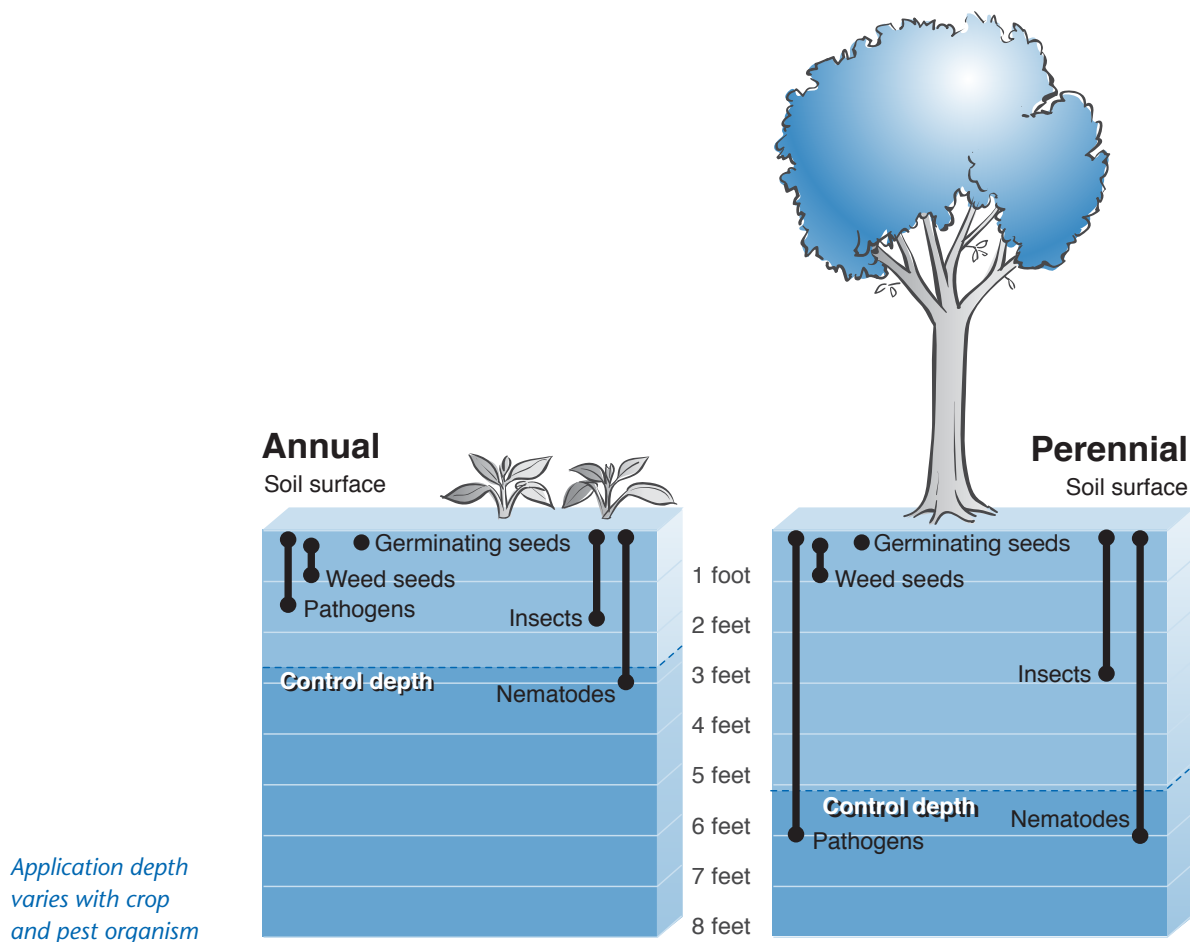
- Type and amount of product to be used.
- Label restrictions on application depth.
- Application method.
- Characteristics of the soil to be treated.
- Crop to be planted.
- Target pests and their location in the soil profile.
- Soil temperature.

Different pest groups inhabit different soil depths. If the application is too shallow, the fumigant will miss target pests that are below the application level. If the application is too deep, the product may not diffuse into the top few inches of soil, where many target pests (particularly weed seeds) are found. For example, lesion nematodes live in the top 6 to 9 inches of soil. In late fall, however, root-knot nematodes may be several feet deep in the soil.

Whether the previous crop was an annual or a perennial may influence pest depth and, therefore, fumigant placement. Pests of **perennial crops** generally live deeper in the soil than pests of **annual crops**. However, insects and nematodes move to search out a food source.

Application Timing

Fumigant applications should be timed to occur when target pests are most sensitive and active. Weather conditions and growth stage of the pest greatly influence pest activity. In general, soil pests are more active when soil temperatures



are higher. Pests that are more metabolically active take up fumigants readily and are therefore more susceptible to them. The insect growth stage determines how effective control measures are. Active insect adults and immature stages (larvae) are easier to kill than the less active life stages (pupae), and hibernating and inactive insects. The more active the pest, the more fumigant it takes up, and the more effective the fumigation. With cooler soil temperatures, allow enough time after an application for the fumigant to diffuse from the soil before you plant.

Application Rate

Higher pest densities and targeting multiple pest species may require using higher fumigant application rates noted

on the label. Furthermore, certain difficult-to-control pests and those with high population densities require using the higher rates. Pest location is also important. For example, it takes more dazomet to control nematodes that feed inside plant roots than outside the roots. Likewise, 1,3-D rates differ depending on whether the target pest is an insect, fungus, bacterium, or nematode, and even by species of organism. Finally, weeds with an impervious seed coating, specifically some perennials, limit fumigant uptake and may require the higher labeled rate.

Different soil textures require varying rates, based on the amount of pore space and amount of adsorption to clay and organic matter. Rates also differ depending on the plants or crops that will be planted.

REVIEW QUESTIONS

1. True or False: Crop residue may impede the movement of fumigants since some fumigants adsorb to soil organic matter.
2. In which soil texture are soil fumigants most likely to escape?
 - A. Silt.
 - B. Clay.
 - C. Sand.
3. Which type of fumigant more commonly uses plastic tarps to seal the soil after fumigation?
 - A. The most volatile fumigants.
 - B. Less volatile fumigants.
 - C. Tarps are required for all fumigant types.
4. Which of the following factors does NOT affect fumigant application rates?
 - A. Soil texture.
 - B. Air temperature.
 - C. Target pest density.

Answers to Review Questions

- 1. True**—Crop residue may impede the movement of fumigants since some fumigants adsorb to soil organic matter.
- 2. C**—Soil fumigants travel faster and more evenly in coarser textured soils, like sand and sandy loam soils, than in silt loams and clay soils. Therefore, fumigants also escape from the soil more readily in coarser soils.
- 3. A**—The most volatile fumigants (e.g., chloropicrin and methyl bromide) require an impervious soil seal, such as a plastic tarp.
- 4. B**—Air temperature is not a factor that directly affects the application rate of soil fumigants.

PERSONAL PROTECTIVE EQUIPMENT AND RESPIRATORS

LEARNING OBJECTIVES

After studying this chapter, you should be able to:

- Interpret label directions for required personal protective equipment (PPE).
- Explain the importance of and proper procedures for selection, inspection, use, care and cleaning, replacement, and disposal of PPE.
- Describe the responsibilities of the certified applicator supervising handlers and fumigant handlers that wear respirators.
- Describe the types of respirators that are required and appropriate when handling specific soil fumigants.
- Explain the need for medical evaluation prior to respirator use.
- Explain the importance of handler training on proper respirator use.
- Explain the importance of fit testing and fit checking respirators.
- Describe a cartridge change-out and disposal schedule.
- List the factors that affect a cartridge's useful life.
- Explain the details of product labeling and laws regarding medical evaluation for respirator use, fit tests and fit checks, training and recordkeeping.

Personal Protective Equipment (PPE)

Fumigants are distinct from many other pesticides in that fumigants are volatile and may result in inhalation exposure. Because of this, the PPE required when handling fumigants often differs from that which is required when handling nonfumigant pesticides that are not volatile. You must know which fumigant you are handling because different products have different PPE requirements. Check the pesticide label for the PPE requirements for each handling activity planned and emergency preparedness. Look for PPE directions in

the Precautionary Statements section of the pesticide label. Review your state's core pesticide safety training manual for basic information on PPE.

Here are examples of PPE requirements for various fumigants that may differ from those of nonfumigants:

- Some fumigant labels require certified applicators and fumigant handlers to wear loose-fitting work clothes when handling fumigants. Tight-fitting clothes can trap certain fumigants next to the skin.



Read the label for proper PPE

- Do not assume that you should wear a chemical-resistant apron or spray suit. Some labels forbid you to wear such items.
- Chemical-resistant gloves or boots are not always allowed when handling fumigants. For example, methyl bromide labels forbid wearing gloves for most handling activities. This is because methyl bromide gas may get trapped next to the skin which can cause severe blistering and burning.
- Some fumigant labels may require wearing cotton gloves; others specify chemical-resistant gloves and footwear for certain tasks.
- Fumigant labels may be very specific about the type of eye or respiratory protection to wear and when you should wear it. For example, methyl bromide labels require handlers that have potential contact with liquid fumigant to wear protective eyewear, such as a full-face shield or safety glasses and specifically prohibit the use of goggles.

PPE requirements for a particular fumigant vary depending on the task. Fumigant labels specify the PPE required for fumigant handlers (including certi-

fied applicators) when performing tasks that will not expose them to contact with liquid fumigant. The labels have a separate set of requirements for fumigant handlers who are more likely to contact liquid fumigant. For example when using methyl bromide, fumigant handlers that are not expected to come in contact to the liquid fumigant must wear a long-sleeved shirt, long pants, shoes, and socks. When handlers are more likely to contact the chemical, they must also wear chemical-resistant gloves, a chemical-resistant apron, protective eyewear (not goggles), and chemical-resistant footwear with socks.

PPE is effective only if it fits correctly and is used properly. Directions for keeping it clean and maintaining it properly are on the pesticide label and in the manufacturer use instructions.

Respirators

Inhaling fumigants can be dangerous—even fatal. Protect your lungs from fumigant vapors by wearing a respirator when needed. Check with your state labor agency for specific respirator requirements that may be more restrictive than fumigant labels or WPS requirements.

Medical Evaluation Before Respirator Fit Testing

Any certified applicator or fumigant handler who may need to wear a respirator is required by the label to be medically evaluated to ensure that their health and lung capacity are suitable for this task. After a preliminary screening, a medical practitioner may determine that a physical exam is required. For example, if the fumigant handler has a heart condition, a medical evaluation is necessary before respirator fit testing. Fumigant handlers must be reexamined by a healthcare professional if their health status, respirator style, or use conditions change. Some people do not medically qualify to wear respirators. Check with your state labor agency to find out where to get a medical evaluation. The medical questionnaire

used for screening can be found on the **Occupational Safety and Health Administration (OSHA)** website.

Respirator Fit and Care

After being cleared by a qualified medical practitioner to wear either an **air-purifying respirator (APR)** and/or a **self-contained breathing apparatus (SCBA)**, all certified applicators and fumigant handlers must be fit tested and trained on how to use each specific respirator they will wear. Fit testing is required by the fumigant label for each respirator and is repeated annually. Follow-up fit testing is required under certain circumstances:

- The style of the face piece has changed.
- The respirator size, model, or brand has changed.
- There is a physical change in the person's face (e.g., weight change or dental work) that would affect fit.
- Fit is unacceptable.
- At request of the user.
- Employer policy.

Check with your state labor agency to find out where to get fit tested.

Conduct a fit check before each use. This test, also called a user seal check, helps you make sure that the respirator forms a complete seal around your face. Be sure to clean your respirator according to manufacturer instructions, inspect it regularly, and store it properly.

Respirator Training

Adequate training is required by the product label and is essential for the safe and effective use of respirators. Before handling a fumigant, seek training on the fit and use of the respirator you may be required to wear, even if it is for emergency response only. Establish a formal respiratory protection program that meets all of the requirements outlined in the OSHA's Respiratory Protection Standard (29 CFR 1910.134) and/or

WPS requirements that include written operating procedures for maintenance, cleaning, and storage of respirators and other PPE.

Respirator Type

Fumigant labels specify the type of respirator to use since the requirements are based on the fumigant's active ingredient. When required for routine handler activities, typically an APR with replaceable organic vapor cartridge or canister (gas mask) is noted on the label. The label will note whether it be a half-face, full-face or **powered air-purifying respirator (PAPR)**. A PAPR is a type of APR that uses a blower to move air through the cartridges. APRs filter contaminants through the cartridge or canister when air passes through them during inhalation. Make sure you have the correct cartridge or canister for the fumigant. For example, a label may require:

- National Institute of Occupational Safety and Health (NIOSH) certified full facepiece air-purifying respirator equipped with an organic vapor (OV, NIOSH approval prefix TC-23C) cartridge and a particulate pre-filter (Type N, R, P, or HE, NIOSH approval number prefix TC-84A).



Air-purifying respirator (APR)





Above: Powered air-purifying respirator (PAPR)

Right: Air-Pak75 SCBA—self-contained breathing apparatus

- Gas mask with a canister approved for organic vapor (NIOSH approval number prefix TC-14G).

Carefully review the respirator requirements on the label to determine:

- Whether you need respiratory protection.
- Correct type of respirator for that fumigant.
- Situations when respiratory protection is needed.

Never substitute another type of respirator that is not consistent with the fumigant label. Always follow the directions on the label regarding the respirator requirements and cartridge type. If using a cartridge respirator, make sure the cartridge brand matches the model and manufacturer of the face piece. Respirator cartridges and face pieces are not interchangeable among manufacturers.

Cartridge or canister life depends on several factors:

- The type of cartridge.
- The size of the cartridge.
- The type and concentration of vapors in the surrounding air.
- The length of exposure.
- The rate of breathing.

- Whether more than one contaminant is present.
- The temperature and humidity at the time of use.

WPS requires that when a cartridge or canister respirator is used that the cartridge or canister be replaced:

- At the first indication of odor, taste, or irritation.
- According to the pesticide label or manufacturer instructions, whichever is more frequent.
- When the end of service life indicator (ESLI) shows a color change indicating the unit has expired.
- In absence of any of the above instructions or indications of service life, at the end of each day's work period.

Some states have regulations that dictate cartridge lifespan or reference OSHA regulations. Never use a cartridge after the expiration date.

SCBA respirators are only used for emergency situations and not permitted for routine handler tasks. They provide a constant source of uncontaminated air from a pressurized cylinder. SCBAs are the only respirators that protect against both deficient oxygen levels and unknown fumigant levels. Handlers that are required to wear an SCBA must be trained and fit-tested.

REVIEW QUESTIONS

- 1. Who must undergo a medical evaluation before using respiratory equipment?**
 - A. Fumigant handlers with known heart problems.
 - B. Fumigant handlers who will be removing tarps.
 - C. Any fumigant handler or certified applicator who might need to wear a respirator.
- 2. Which type of respiratory protection uses a cartridge or canister to absorb contaminants?**
 - A. SCBA.
 - B. Air-purifying respirator.
 - C. Filtering face piece respirator.
- 3. True or False: SCBAs must be worn by methyl bromide handlers during the fumigation operation.**
- 4. What is the end of life service indicator on an APR respirator?**
 - A. A manufacturer-stated period for the life of the entire respirator unit.
 - B. A NIOSH-stated period for the life of the entire respirator unit.
 - C. A color-change gauge that reveals when the cartridge has adsorbed the fumigant.

Answers to Review Questions

1. **C**—Any certified applicator or fumigant handler who might need to wear a respirator must be medically evaluated to ensure that he or she is physically capable of wearing a respirator.
2. **B**—An air-purifying respirator filters contaminants through a cartridge or canister when air passes through it during inhalation.
3. **False**—SCBAs are for emergency response only and are not to be used for routine tasks.
4. **C**—The ESLI is a device on the side of the cartridge that changes color as it adsorbs the fumigant.

PROTECTING PEOPLE

LEARNING OBJECTIVES

After studying this chapter, you should be able to:

- Explain when air concentrations of a fumigant might trigger handlers to wear respirators or leave the work area entirely. Explain where on a label to find this information.
- Interpret labels to determine the number of people and respirators required on site.
- Describe the steps to take if a fumigant handler experiences sensory irritation.
- Explain the purpose of trigger levels, and find them on a fumigant label.
- Describe what air monitoring is, when it is required and where samples are taken.
- Describe the relative sensitivity of air-monitoring devices, including detector tubes, and photoionization detectors (PIDs).
- Describe emergency preparedness/response requirements for neighbor notification or buffer zone monitoring.
- Outline procedures for buffer zone monitoring.
- Describe the situation that initiates an emergency response plan.
- Outline the first aid measures for fumigant exposure.

Most soil fumigant labels require several measures to further protect applicators, fumigant handlers, and bystanders from fumigant gases that may escape from the soil or from under tarps. Read labels carefully to make sure that you follow these protective measures. If exposures occur, it is critical to recognize the signs and symptoms and take appropriate first-aid measures and corrective steps.

Stop Work Trigger Levels and Respiratory Protection

Fumigant labels specify **trigger levels** that require fumigant handlers to

either use a respirator or leave the work area. Trigger levels are based on EPA exposure data and are used to prevent fumigant handlers from being exposed to the **maximum-use concentration (MUC)**. The MUC is the greatest air concentration of a hazardous substance from which a person can expect to be protected when wearing a respirator.

Fumigant labels list trigger levels which prompt fumigant handlers or certified applicators to take action to protect themselves from inhalation exposure. Examples of actions resulting from reaching a trigger level include:

- Putting on an APR.
- Putting on a full-face APR for extra protection when half-face APRs are

Trigger Level

A specified air concentration on a fumigant label initiates the requirement for APRs, or for full-face APRs when half-face APRs are already required by the label.

Required Action

Put on respirators and start air monitoring

OR

Stop work and leave the application block and buffer zone.

required by the label for a particular task.

- Stopping operations and leaving the application block and buffer zone.

Fumigant labels specify how many and which types of respirators are required for each type of application. Following are examples of label statements detailing respiratory protection requirements:

- An APR with the appropriate cartridges or canisters must be available for each fumigant handler who may be required to wear a respirator.
- For methyl bromide formulations with **less** than 20% chloropicrin, fumigant handlers must wear a full-face or gas-mask type APR during all handling activities.
- For methyl bromide formulations with **more** than 20% chloropicrin, 100% chloropicrin formulations, dazomet, metam sodium, and metam potassium, fumigant handlers only need to wear full-face or gas-mask type respirators when they experience **sensory irritation**. If this happens, fumigant handlers must either stop work and

leave the area, or use a full-face APR to complete the task.

- For DMDS, fumigant handlers only need to wear an APR if odor from the product is detected, or they can stop work and leave the area.

For added safety, fumigant labels also establish a minimum number of fumigant handlers and respirators that must be on site for each fumigant. For handling tasks with methyl bromide, DMDS, chloropicrin only, and other products with chloropicrin (including 1,3-D and iodomethane mixed with chloropicrin), labels require:

- At least **two fumigant handlers** must be on site.
- At least **two APRs** must be available.

Metam sodium, metam potassium, and dazomet labels require **only one fumigant handler on site**. APRs must be available for use. **One full-face APR must also be on site**.

Trigger levels and air-monitoring requirements are described on fumigant labels in the “Respiratory Protection and Stop Work Triggers” section.

Examples of action thresholds found in fumigant labels in the “Respiratory Protection and Stop Work Triggers” section

Trigger level

Handlers can remove full-face piece air-purifying respirators or resume operations if two consecutive breathing-zone samples taken at the handling site at least 15 minutes apart show that levels of methyl bromide have decreased to less than 1 ppm and levels of chloropicrin have decreased to less than 0.15 ppm, provided that handlers do not experience sensory irritation. During the collection of air samples, a full-facepiece air-purifying respirator must be worn by the handler taking the air samples. Samples must be taken at the location where the irritation was first experienced.

If at any time: (1) a handler experiences sensory irritation when wearing a full-facepiece air-purifying respirator, or (2) a methyl bromide air sample is greater than 5 ppm or a chloropicrin air sample is greater than or equal to 1.5 ppm, then all handler activities must cease and handlers must be removed from the application block and surrounding buffer zone.

Trigger level

Sensory Irritation

Sensory irritation may occur when people are exposed to fumigant vapors. Sensory irritation is a physical reaction to a certain fumigant air concentration. It can include burning or irritation of the eyes, nose, or mucous membranes. If at any time a fumigant handler experiences sensory irritation, he or she must do one of the following:

- Use an APR to complete the task.
- Stop work and leave the application block and buffer zone.

For some fumigants, such as methyl bromide and iodomethane, fumigant handlers may start tasks wearing a half-face APR. In this case, fumigant handlers who experience sensory irritation must do one of the following:

- Put on a full-face APR.
- Stop work and leave the application block and buffer zone.

Air Monitoring

Whenever a fumigant handler is wearing an APR, **two things can initiate the need for air monitoring to start immediately:**

- Sensory irritation.
- Fumigant label trigger level met or exceeded.

In addition, for labels that require a full-face APR be worn, air monitoring samples must be collected at least every 2 hours in the **breathing zone** of the fumigant handler performing a representative task.

The fumigant handler taking the air samples must wear an appropriate respirator. Samples must be taken at locations specified by the label. Typically, two samples must be taken that indicate vapor concentrations are below the trigger level.

Labels require air samples be collected from the breathing zone of a person performing a **representative handler-**

Number of Handlers and Respirators Required On-site During Handler Activities

Product/ Formulation	Min. # of Handlers	Min. # of Air-Purifying Respirators
Methyl bromide, 100% chloropicrin and other chloropicrin products	2	2
Metam sodium/ potassium and dazomet products	1	1

Fumigant labels establish a minimum number of fumigant handlers and respirators that are required to be on site for each fumigant

task. The breathing zone is the area within a 10-inch **radius** of the nose and mouth.

If a fumigant handler wearing a respirator experiences sensory irritation, or if the air-monitoring sample shows fumigant concentrations above the trigger level, all fumigant handlers must stop work and leave the application block and surrounding buffer zone. If work was stopped due to sensory irritation or concentration of a fumigant above the trigger level, air must be monitored prior to resuming work and/or removing respirators. Fumigant labels provide air monitoring details on:

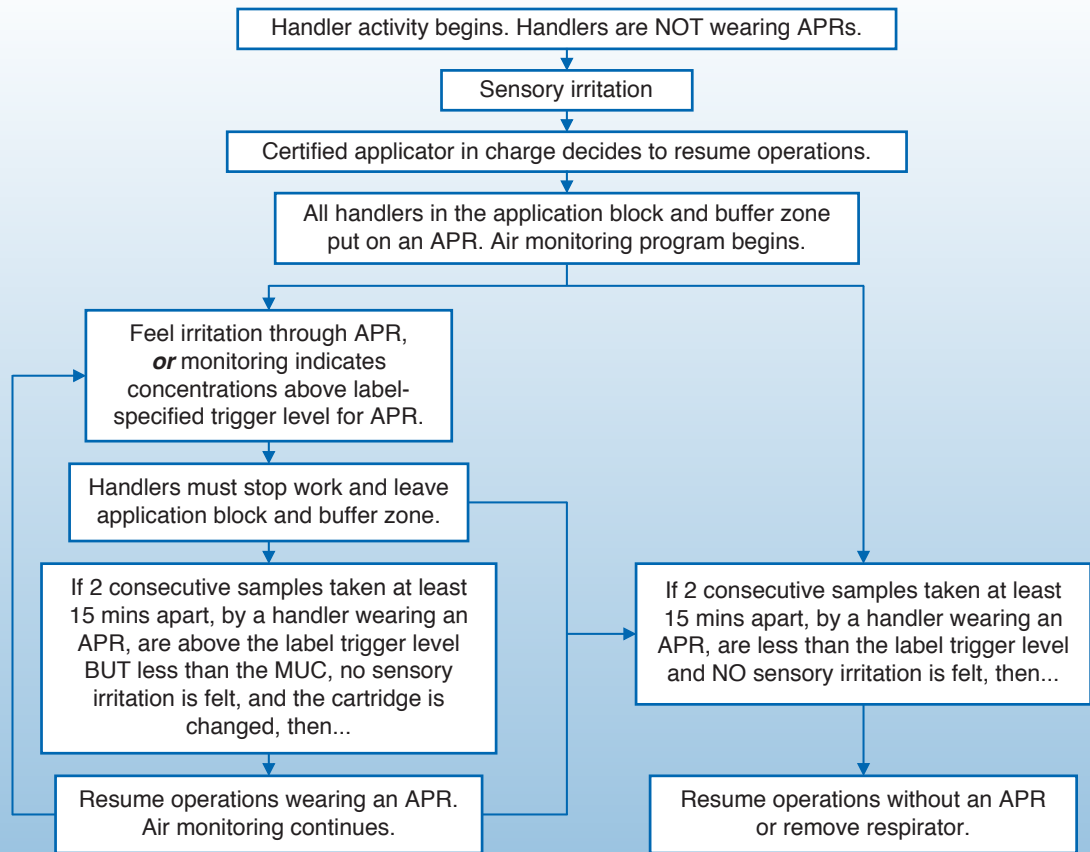
- How often and how many air samples are required.
- When fumigant handlers can resume work with an APR.
- When fumigant handlers can remove APRs.

After a trigger level has forced work to stop, handlers cannot reenter the application site or buffer zone area until:

- Two consecutive air monitoring samples taken in the fumigant handler's breathing zone and 15 minutes apart are below the specified trigger level.
- Fumigant handler does not experience sensory irritation.

Fumigant handlers must comply with label instructions regarding air monitoring and when they may reenter the area and resume work.

When Handlers May Resume Work While Using a Respirator



Monitoring for Fumigant Levels

Most fumigants are sensory irritants that alert fumigant handlers that concentrations are high and immediate action is needed. Sensory irritation can include watering or burning eyes or nose. Labels include requirements for when air monitoring with physical devices is required. For safety reasons, it is essential to be able to immediately determine fumigant concentrations by using the proper detection equipment. If fumigant handlers know the gas concentration to which they are exposed, they can take the proper precautions. Precautions include using respiratory equipment or leaving the site. Even fumigants with strong odors may not be detected by a person with a poor sense of smell.

Consult fumigant label directions for selecting the recommended gas detection device. Be sure the accuracy and range of the gas detector is suitable for the fumigant you plan to use. Some detectors are

more sensitive than others. Make sure you are trained in the proper use of the detector device. Different devices detect different fumigants and concentrations.

Monitoring Representative Handler Activities

If air monitoring is triggered, the places and fumigant handler activities to be sampled must represent each handler's exposure occurring within the application block.

For example, an application operation with a seven-person crew (one tractor driver, one tractor copilot, four shovelers, and one certified applicator-in-charge) requires two breathing zone samples: one for the tractor copilot and one for a downwind shoveler. Results of previous sampling may indicate which tasks and locations pose the greatest concerns and, therefore, are representative of all fumigant handlers.

Air-Monitoring Devices

Gas Detector Tubes

Gas, or colorimetric, detector tubes are sealed, glass tubes filled with an appropriate indicator chemical.

Gas detector tubes (colorimetric tubes) are often more sensitive and more specific than other detectors (e.g., halide detectors). These detectors are easy to use, can detect low concentrations, and are reasonably accurate when used according to directions. The indicator chemical in the tube reacts with a specific fumigant to produce a color change. The amount of color change indicates the air concentration of the fumigant. These devices are disposable and can be used only once. A specific pump is required with these tubes; you must purchase the pump and tubes from the same manufacturer. The equipment is not interchangeable.

Store gas detector tubes in a cool place and out of direct sunlight. Note the following precautions when using these tubes:

- Tubes deteriorate with age. Some tubes have a shelf life of two years when stored at room temperature. Deterioration is more rapid above 86°F.
- Direct sunlight affects the chemical reagents in the tubes.
- At low temperatures—at or below freezing—tubes may not give reliable readings. Warm the tubes to room temperature before use for best performance.
- Tubes may have cross-sensitivity to gases other than their target gas. Seek this information from the manufacturer.

Photoionization Detectors (PIDs) and Flame-Ionizing Detectors (FIDs)

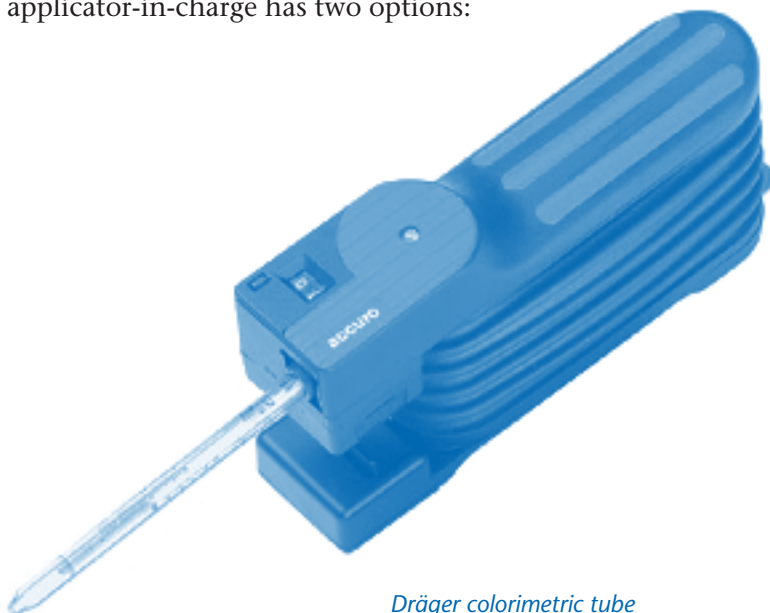
PIDs and **FIDs** are portable gas detectors that react to a variety of organic compounds at very low concentrations. They are handheld, battery operated, and may produce instantaneous readings and operate continuously. They detect the

presence of volatile organic compounds, though not specific ones; unless a chemical-specific response factor is used. Therefore, these detectors do not identify the specific fumigant. However, you can use them in conjunction with another detector to confirm analytical results.

A caution: PIDs and FIDs may give false positive readings for water vapor. Rain may also affect performance. High humidity can cause lamp fogging and decreased sensitivity. They are not as useful as gas detector tubes in a field setting.

Label Requirements for Emergency Preparedness and Response

Most products require monitoring for sensory irritation to ensure that high concentrations of off-gassing fumigant are not moving toward neighbors or other sensitive areas. Fumigant labels (except 1,3-D only formulations) include requirements to help make sure that people living and working near fumigated fields are protected in case of an emergency. One way to reduce risk is to detect an accidental chemical release early and respond appropriately. If homes or businesses are near a buffer zone, the certified applicator-in-charge has two options:



Dräger colorimetric tube and pump gas collector

- **Option 1:** Monitor the buffer zone.
- **Option 2:** Provide response information to neighbors.

The certified applicator may choose which option will work better when circumstances require action. As the buffer zone increases, so does the area of concern that requires Options 1 or 2. **However, if the buffer zone is 25 feet then emergency preparedness measures are not required.**

OPTION 1: Monitor the Buffer Zone. If the certified applicator selects Option 1, he or she (or a fumigant handler under direct supervision) must monitor along the perimeter of the buffer zone and between the buffer zone and the homes or businesses that triggered the requirement. It is necessary to **monitor at least four times each day throughout the buffer zone period:**

- 1 hour before sunset on the day the application begins,
- once during the night,
- once at 1 hour after sunrise, and
- once during the day.

Over the course of the 48-hour buffer zone period, monitoring will occur eight times.

OPTION 2: Provide Emergency Response Information to Neighbors.

Instead of monitoring, certified applicators may choose to provide emergency response information directly to the neighbors. This means providing the following information to neighbors at least **one week** before the application:

- The location of the application block.
- Basic information about the fumigant product.
- Contact information for the certified applicator and property **owner**.
- When the fumigation and the buffer zone period will occur (must not be more than four weeks away).
- Early signs and symptoms of exposure, and what to do if exposure is suspected (call 911 in most cases).

Provide this information using any method that effectively communicates the required material to the neighbors. This may include telephone, door hangers, mailings, or email. It is a good idea to attach a copy of the provided information to the FMP as a record. Provide emergency response information (and all other pertinent details) to neighbors. Be clear and concise about what fumigant will be applied, when and where the application will take place, and whom to contact in an emergency.

Distances that Trigger Air Monitoring or Informing Neighbors

Certified applicators must: monitor the site, OR provide information to neighbors	
If the buffer zone is:	AND residents or businesses are within _____ from the edge of the buffer zone
> 25 feet and ≤ 100 feet	50 feet
> 100 feet and ≤ 200 feet	100 feet
> 200 feet and ≤ 300 feet	200 feet
> 300 feet	300 feet

Following are examples of buffer zone monitoring label language:

- If the buffer zone is greater than 300 feet and there are **occupied structures** (e.g., residences or businesses) within 300 feet of the edge of that buffer zone, the certified applicator must choose between air monitoring between the buffer zone and the occupied structures, or providing information to the neighbors about the application and emergency response procedures.
- If the buffer zone is **75 feet** and there are **no occupied houses** or businesses within 50 feet of the buffer zone, the certified applicator does not have to monitor or provide information to neighbors.
- If the buffer zone is the **minimum 25-foot buffer**, neither option is required regardless of the location of houses or businesses.

If the handler monitoring detects concentrations of concern outside of the buffer zone—either by sensory irritation or through use of a direct-read gas detector device (e.g., Dräger tube)—he or she must put the emergency response plan into action. See Chapter 12 for an explanation of the emergency response plan, as described in the FMP.

Fumigant Poisoning and First Aid

Fumigant poisoning can occur from contact with the skin, eyes, or tissues in the mouth or nose. Seek immediate professional medical attention if anyone experiences an exposure to a fumigant. Employers are responsible for ensuring that their employees are taken to a healthcare professional whenever they exhibit symptoms of pesticide exposure.

The Precautionary Statements section of the fumigant label provides specific first aid information for each product. Note that first aid is the help you are able to give an ill or injured person while

If fumigant handlers experience signs or symptoms of fumigant exposure:

1. Stop work.
2. Leave the area and move upwind.
3. Secure the site and keep unauthorized people out.
4. Inform the supervisor and seek medical attention (if necessary).

waiting for help to arrive. It is not a substitute for professional medical care.

Before assisting a person overcome by a fumigant, call for professional help and put on the appropriate PPE—which would be an SCBA if concentrations were unknown (must be SCBA-trained)—before entering the area. The fumigant that harmed the injured person could also injure you. When assisting, avoid getting fumigants onto your skin, and do not inhale vapors. Also decontaminate the exposed parts of the affected person's body as quickly as possible, including removing contaminated clothing.

Portable decontamination unit



REVIEW QUESTIONS

- 1. If a fumigant handler who is NOT wearing an air-purifying respirator (APR) experiences sensory irritation, he or she has two choices. What are they?**
 - A. Stop working and leave the area or use an APR to complete the task.
 - B. Use an SCBA or take air-monitoring samples from the breathing zone.
 - C. Stop working and leave the area or ask the certified applicator-in-charge to finish the task.
- 2. Labels typically require how many air-monitoring samples show that air concentrations of the fumigant are below the trigger level, and allow fumigant handlers to remove their APRs?**
 - A. 1.
 - B. 2.
 - C. 5.
- 3. How large is the breathing zone around the nose and mouth?**
 - A. 6-inch radius.
 - B. 10-inch radius.
 - C. 24-inch radius.
- 4. What is the best way to detect the presence of fumigant gases at a site?**
 - A. Post the site with warning signs and return 24 hours later.
 - B. Enter the site without respiratory protection to see if you experience any sensory irritation.
 - C. Use an approved colorimetric detector.

Answers to Review Questions

- 1. A**—If a fumigant handler experiences sensory irritation, he or she must EITHER stop work and leave the area OR use an APR to complete the task.
- 2. B**—Two samples must show air concentrations of the fumigant below the trigger level.
- 3. B**—The breathing zone consists of a 10-inch radius around the nose and mouth.
- 4. C**—A pump draws a measured amount of air into the gas coloremtric tube. The fumigant present reacts with material in the tube and causes a color change.

SITE ASSESSMENT AND WEATHER

LEARNING OBJECTIVES

After studying this chapter, you should be able to:

- Identify site characteristics that should prevent fumigant exposure.
- Define and describe a temperature inversion.
- Explain the requirements for forecasting air stability.
- Identify sources of weather information.
- Explain the influences of air stability, air temperature, humidity, and wind currents.
- Find and interpret label statements limiting applications during specific weather conditions.

Site Assessment

The first step in preparing for soil fumigation is to evaluate the suitability of the site. This will help to:

- Protect people and the environment.
- Choose soil management methods, fumigants, and application techniques.
- Maximize fumigant efficacy.

Determine if the proposed application site is near areas where people gather (e.g., residences, businesses, public meeting sites, hospitals, or schools). Nearness to occupied structures does not necessarily preclude fumigation (except for some occupied difficult-to-evacuate sites). However, it does require additional planning.

Evaluate the site's topography (surface features). Under stable air conditions, if fumigant vapors travel offsite, they can collect and concentrate down slope. When making a soil fumigant application, consider the potential offsite movement to surrounding areas due to changes in topography. Take additional precautions

if these areas contain structures occupied by humans or animals, or if you will need to enter them during or shortly after the fumigation. Precautions include wearing appropriate PPE and monitoring for fumigant air concentrations.

Identify and locate field obstacles that may pose risk to the applicator or application equipment.

Soil Characteristics

Environmental and field conditions affect both the success and the safety of the fumigation. Chapter 4 provides a detailed discussion of soil characteristics that impact fumigation success and corrective measures for unfavorable soil characteristics. Be aware that fumigant labels carry specific directions for mandatory GAPs to prepare soil before fumigation. Soil GAPs refer to soil preparation, condition, moisture, and temperature.

Soil characteristics important to successful fumigation:

- Soil temperature
- Soil moisture
- Soil tilth
- Soil type
- Crop residue
- Soil organic matter



Weather Forecast

Check Weather Forecast:

Check weather forecast on the day of the application before starting and daily during the application.

Present and immediate postapplication weather conditions affect fumigant vapors that escape from the soil. These vapors can move offsite and expose nearby people, animals, and plants. This includes both conditions at the start of the application and immediately after the application.

The certified applicator supervising the application must check the National Weather Service (NWS) forecast before a soil fumigation. This will help determine if unfavorable weather conditions may occur when a fumigation is planned—and whether the application should proceed. Check the weather forecast:

- On the day of and preceding the start of the application.
- Each day during the application if the time elapsed from the start of the application until the application is complete is greater than 24 hours.

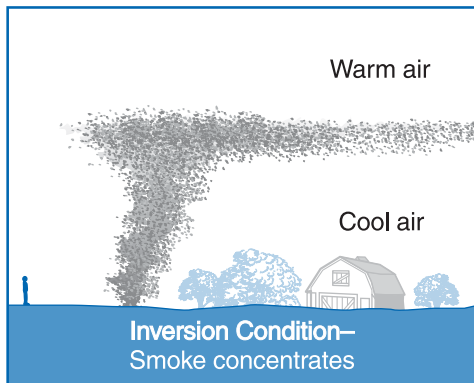
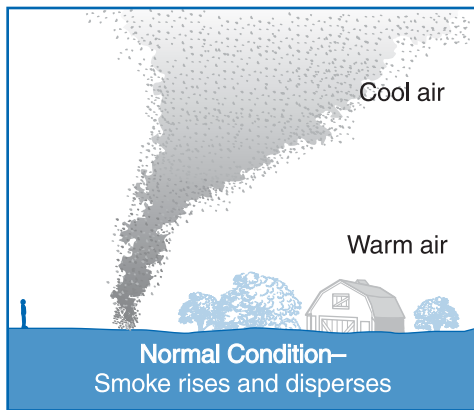
You may obtain detailed NWS forecasts for local weather conditions, wind speed, and air stagnation advisories online at: <http://www.nws.noaa.gov>, on National Oceanic and Atmospheric

Administration (NOAA) weather radio, or by contacting your local NWS forecasting office. You may use other weather forecasts, but these cannot be substituted for the NWS forecast.

Temperature Inversions

Temperature inversions are often to blame for human exposure to fumigants. In an inversion, warmer (lighter) air rises above cooler (heavier) air, which settles near the ground. Under inversion conditions, normal air mixing does not take place; fumigant vapors settle and concentrate near the ground. When this happens, fumigant vapors often move offsite with low-level air movement or settle in low-lying areas. Low-level winds (less than 2 mph) are highly unpredictable in the direction they move. Clues that inversion conditions exist include:

- Road dust that hangs in the air and has little upward or lateral movement.
- Ground fog or smog that remains concentrated with little upward movement.



Adapted from U. of C. The Safe and Effective Use of Pesticides

Dispersion of smoke particles under normal and inversion conditions.

- Smoke from the ground that rises little, flattens out, and moves as a concentrated cloud.

Temperature inversion conditions typically start an hour before sunset and continue past sunrise. They may persist as late as noontime. However, inversions can persist all day long. Inversion conditions are common on nights with limited cloud cover and little to no wind. Look for ground fog, smog, or smoke that flattens out below a ceiling layer and moves sideways in a concentrated cloud. (Note that coastal fog generated by inland movement of sea air masses does not necessarily indicate temperature inversions.)

Air Stagnation Advisory

Most labels (except 1,3-D only formulations) prohibit an application to proceed if an air stagnation advisory issued by the NWS is in effect for the area anytime from the start of application until 48 hours after the application is sched-

uled to be complete. If an air stagnation warning occurs during the application, the application must stop.

Air Stagnation Advisory:

Labels prohibit applications if an air stagnation advisory *is in effect any time from the start of the application until 48 hours after the application* is scheduled to be complete.

Light Winds

Most labels (except 1,3-D only formulations) prohibit an application to proceed if light wind conditions (less than 2 mph) are expected to persist for more than 18 consecutive hours from the time the application starts until 48 hours after the application is scheduled to be complete.

For chemigation applications using lateral moves or center pivots, labels list specific wind speed requirements for two types of systems: **solid stream** systems or other systems. Here are some examples of some metam label statements:

- Wind speed at the application site must be a **minimum of 2 mph** at the start of the application or forecasted to reach **between 5 and 10 mph** during applications:
 - Not using a solid stream type nozzle, **OR**
 - Having a release height or spray height greater than 4 feet, **OR**
 - Having a PSI of 30 pounds or greater at the sprinkler head.
- Wind speed at the application site must be a minimum of 2 mph at the start of the application or forecasted to reach **between 5 and 25 mph** during applications:
 - Using a solid stream, **AND**
 - Having release height and spray height less than 4 feet, **AND**
 - Having a PSI of 29 pounds or less at the sprinkler head.

Light Winds:

Labels prohibit soil fumigant applications if light winds (less than 2 mph) *are predicted for more than 18 consecutive hours* any time from the start of the application until 48 hours after the application is scheduled to be complete.

REVIEW QUESTIONS

1. Which of the following items must you consider during a site assessment?
 - A. Topography.
 - B. Geneology.
 - C. Geology.
2. True or False: During the fumigation, the certified applicator must check the weather forecast every 12 hours from the time the application begins until it is complete.
3. A certified applicator begins a chemigation application on Monday at 6 a.m. The application will run until Wednesday at noon. There is no air stagnation advisory in effect at the start of the application, but one is issued Wednesday at 8 a.m. What is the correct action to take?
 - A. No action is necessary because the application will finish in less than 18 hours.
 - B. The application must be halted.
 - C. If the air stagnation advisory is still in effect at 10 a.m., the application must be halted.
4. What is considered light winds?
 - A. Less than 1 mph, but no more.
 - B. Less than 2 mph, but no more.
 - C. Less than 5 mph, but no more.

Answers to Review Questions

- 1. A**—Evaluate the site’s topography since soil fumigants can move down into low-lying areas.
- 2. False**—The certified applicator is required to check the weather forecast before the application begins and then daily (every 24-hours) during the application.
- 3. B**—When an air stagnation advisory is issued after the start of an application, the application must be stopped.
- 4. B**—Less than 2 mph. If light winds are predicted for more than 18 consecutive hours, soil fumigant applications are prohibited.

FUMIGANT MANAGEMENT PLANS AND POSTAPPLICATION SUMMARIES

LEARNING OBJECTIVES

After studying this chapter, you should be able to:

- Describe the elements of an FMP and resources available for its preparation.
- Specify when an FMP must be in place, how long it must be kept on file, who must receive and keep a copy, where it must be kept during the application, and who must have access to it.
- Describe the purpose and content of a PAS and who must prepare it.
- Identify who is responsible for verifying that an FMP is accurate.
- Identify when the PAS must be completed.

Fumigant Management Plan (FMP)

Preparation and Review

To reduce the risk to bystanders, fumigant handlers, and other workers, soil fumigant labels (except for 1,3-D only formulated products) require preparation of a Fumigant Management Plan. An FMP is a site-specific plan prepared **before any** fumigation begins. An FMP is intended to ensure that all aspects of a safe and effective fumigation have been planned ahead of the actual work. Note that an FMP does not require anything independent of the label. It only captures how a certified applicator is planning to comply with label requirements and serves as a record of compliance.

Anyone may develop the FMP. However, the certified applicator-in-charge of the application must, before beginning the fumigation, review, sign, and date the plan to verify that it is accurate, up-to-date, and complies with the label.

FMPs are intended to:

1. Prevent accidents.
2. Ensure, demonstrate, and verify compliance.
3. Define procedures in case of accidents or unforeseen events.

Contents

You must record all of the following elements in a soil fumigation FMP:

- Certified applicator and owner information.
- General site information.
- General application information.
- Tarp plan (if tarp is used).
- Soil conditions.
- Buffer zones.

- Emergency response plan.
- Posting of fumigant treated area and buffer zone signs.
- Emergency preparedness and response measures (if applicable).
- State and/or tribal lead agency advance notification.
- Communication plan.
- Fumigant handler information, training, and PPE.
- Air-monitoring plan.
- Chemigation and drip application monitoring information (if applicable).
- Good agricultural practices.
- Pesticide product labels and **Material Safety Data Sheets (MSDSs)**.

SAMPLE FMP LABEL LANGUAGE

Fumigant Management Plan—Metam Product

The following is an example of FMP requirements from the label:

Information about the certified applicator supervising the application:

- Name and phone number.
- Pesticide applicator license and/or certificate number.
- Specify if commercial or private applicator.
- Employer name and address.
- Date and location of completing EPA-approved soil fumigant training program.

General site information:

- Application block location (e.g., county; township/range/section quadrant; address; or global positioning system (GPS) coordinates).
- Name, address, and phone number of application block owner.
- Map, aerial photo, or detailed sketch showing:
 - Application block location and dimensions.
 - Buffer zone dimensions.
 - Property lines.
 - Roadways, rights-of-way, sidewalks, permanent walking paths, and bus stops.
 - Nearby application blocks.
 - Surrounding structures (occupied and unoccupied).
 - Locations of buffer zone signs.
 - Locations of difficult-to-evacuate sites with distances from the application block labeled.

General application information:

- Target application date or window.
- Fumigant product name.
- EPA registration number.

Tarp plan (if tarp is used):

- Schedule to check tarps for damage, tears, and other problems.
- Minimum size of damage that will be repaired.
- Factors used to determine when tarp repair will occur.
- Equipment and methods used to perforate tarps.
- Target dates to perforate and remove tarps.

Soil conditions:

- Description of soil texture and moisture in application block.
- Method used to determine soil moisture.
- Soil temperature measurement if air temperatures exceeded 100°F on any of the three days before the application.

Buffer zones:

- Application method.
- Injection depth.
- Application rate from look-up table on label.
- Application block size from look-up table on label.
- Credits applied and measurements taken (if applicable):
 - Tarp brand name, lot number, thickness, manufacturer, batch number, and part number.
 - Organic matter content.
 - Clay content.
 - Soil temperature.
- Buffer zone distance.
- Description of areas in the buffer zone not under the control of the application block owner. If buffer zones extend into areas not under the control of the owner, attach the written agreement and keep it with the FMP.

Record emergency response plan as described in the Emergency Response Plan section.

Posting of fumigant treated area and buffer zone:

- Person or persons (if different) who will post and remove fumigant treated area and buffer zone signs.
- Location of buffer zone signs.

Emergency preparedness and response measures (if applicable):

- Fumigant site monitoring (if applicable):
 - When and where it will be conducted.
- Response information for neighbors (if applicable):
 - List of residences and businesses informed.
 - Name and phone number of person providing information.
 - Method of providing the information.

State and/or tribal lead agency advance notification (if state and/or tribal lead agency requires notice, provide a list of contacts that were notified and date notified).

Plan describing how communication will take place between the certified applicator supervising the application, the owner, and other onsite handlers (e.g., tarp perforators/removers and irrigators) to comply with label requirements (e.g., buffer zone location, buffer zone start and end times, timing of tarp perforation and removal, and PPE):

- Name and phone number of persons contacted by the certified applicator.
- Date contacted.

Handler (including certified applicator) information and PPE:

- Names, addresses, and phone numbers of handlers.

- Names, addresses, and phone numbers for employers of handlers.
- Tasks that each handler is authorized and trained to perform.
- Date of PPE training for each handler.
- Applicable handler PPE, including:
 - Long-sleeved shirts, long pants, shoes, and socks.
 - Chemical-resistant apron.
 - Chemical-resistant footwear plus socks.
 - Protective eyewear (not goggles).
 - Chemical-resistant gloves.
 - Air-purifying respirators:
 - ✓ Respirator make, model, type, style, size, and cartridge or canister type.
 - Other PPE.
- For handlers: Confirmation of receipt of fumigant safe handling information.
- For certified applicator(s) in charge of the application: Completion date and location of the soil fumigant training program listed on the following EPA website: <http://www.epa.gov/fumiganttraining/> for the active ingredient(s) in this product.
- For handlers designated to wear air-purifying respirators:
 - Date of medical qualification to wear a respirator.
 - Date of respirator training.
 - Date of fit testing for the respirator.
- Unless exempted in the *Protection of Handlers* section, verify that:
 - At a minimum, one handler has the appropriate respirators and cartridges/canisters during handler activities.
 - The employer has confirmed that the appropriate respirator and cartridges/canisters are immediately available for each handler who will wear one.

Air-monitoring plan:

- If sensory irritation is experienced, indicate whether operations will cease or operations will continue with use of an air-purifying respirator.
- For monitoring the breathing zone:
 - Representative handler tasks to be monitored.
 - Monitoring equipment to be used.
 - Timing of the monitoring.

Chemigation monitoring (including drip application) (if applicable):

- Record monitoring date(s) and time(s).
- Name of person(s) monitoring.
- Record observations:
 - Is the equipment functioning properly.
 - Description of corrective action (if applicable).
 - Other comments.

Good agricultural practices (GAPs):

- Identify (e.g., list or attach applicable label section) applicable mandatory GAPs.

Pesticide product labels and Material Safety Data Sheets (MSDS):

- Ensure that label and MSDS are on site and readily available for employees to review.

The FMP must be kept on site during all handler activities. It must also be made available to:

1. Fumigant handlers involved in the fumigation.
2. Enforcement personnel upon request.
3. First responders in case of an emergency.

Documentation and Recordkeeping

As stated above, a certified applicator or other worker must prepare and review an FMP before a soil fumigation begins. **The FMP must be kept on site during all handler activities.** It must also be made immediately available to handlers; local, state, federal, and tribal enforcement personnel; and emergency responders.

Both the certified applicator and the property owner must keep a copy of the FMP on file for **two years** from the date of the application.

Farm-Wide FMP

Growers may choose to develop a farm-wide FMP. This allows them to keep the information common to all application blocks on the farm in one document and in one place (for example, in the first section of a binder). A farm-wide FMP might include information about the certified applicator, owner, fumigant handlers, and emergency response plans. It might also include details on the product, tarps, and/or application method. Information unique to each separate application block is recorded in different sections. This might include the location and size of each application block, buffer sizes, application dates, weather, and soil conditions.

Farm-Wide FMPs are optional. They may be helpful to those who manage multiple fields that are treated as separate application blocks.

Postapplication Summary (PAS)

The FMP describes the plan for making the soil fumigation. The postapplication summary serves a different purpose. It describes:

- Any actions that occurred during the application that differed from the FMP.
- Measurements taken to comply with GAPs, if not recorded in the FMP.
- The NWS forecast during application and 48 hours following application.
- Any incidents or complaints.

Labels require that the certified applicator-in-charge complete the PAS within 30 days following the application (except for 1,3-D only products). As with the FMP, the certified applicator and the owner must keep a copy of the PAS for **two years**.

Contents

The following elements (if required) are included in a PAS:

- Application and application block details.
- Weather conditions.
- Tarp damage or repair.
- Tarp perforation or removal details.
- Information on complaints, incidents, equipment failure, or other emergency, and emergency procedures followed.
- Air monitoring results.
- Fumigant treated area and buffer zone posting and removal dates.
- Deviations from the FMP.

Soil fumigant labels require that both the certified applicator and the property owner retain the FMP and PAS for two years. Federal RUP application record retention requirements are also two years; however, state RUP application record retention requirements may be longer.

Several templates and web-based systems exist for preparing FMPs and PASs. These are available from EPA, pesticide registrants, and commercial entities. Some of the commercially-available programs may contain enough information to meet the application record, FMP, and PAS reporting requirements.

Postapplication summaries document:

- 1) deviations from the FMP,
- 2) measures taken to comply with GAPs, if not recorded in the FMP, and
- 3) complaints or incidents.

REVIEW QUESTIONS

1. **True or False: The certified applicator-in-charge of the fumigation is the only person who may prepare a fumigant management plan (FMP).**
2. **During a soil fumigation, how long must the FMP be kept on site?**
 - A. Only while fumigant is being applied.
 - B. Only at the start of the application.
 - C. During all handler activities.
3. **What is recorded in the postapplication summary?**
 - A. The tarp plan.
 - B. Deviations from the FMP.
 - C. Agreements with neighbors.
4. **True or False: Both the certified applicator and the property owner must keep a copy of the FMP on file for two years from the date of the application.**

Answers to Review Questions

1. **False**—Anyone can prepare the FMP. However, the certified applicator-in-charge of the fumigation must review, sign, and date the FMP before the fumigation begins.
2. **C**—The FMP must be on site during all handler activities.
3. **B**—The PAS documents deviations from the FMP.
4. **True**—Both the certified applicator and the property owner must keep a copy of the FMP on file for two years from the date of the application.

BUFFER ZONES AND POSTING REQUIREMENTS

LEARNING OBJECTIVES

After studying this chapter, you should be able to:

- Explain the purpose of buffer zones, and define the buffer zone period.
- Identify who may and may not be in a buffer zone during the buffer zone period.
- Interpret a buffer zone table from the label to determine the size of a buffer zone.
- List the factors that determine the buffer zone credits for a specific scenario.
- Calculate the required buffer zone using those credits.
- Outline the steps to secure permission for buffer zones that include structures or extend onto neighboring land.
- Explain how buffer zone posting and treated area posting differ.
- Explain warning sign placement and what type(s) of sign and wording to use.
- Explain the preapplication and postapplication posting timeframes for buffer zones and treated areas.
- Identify a difficult-to-evacuate site and explain label restrictions for these sites.

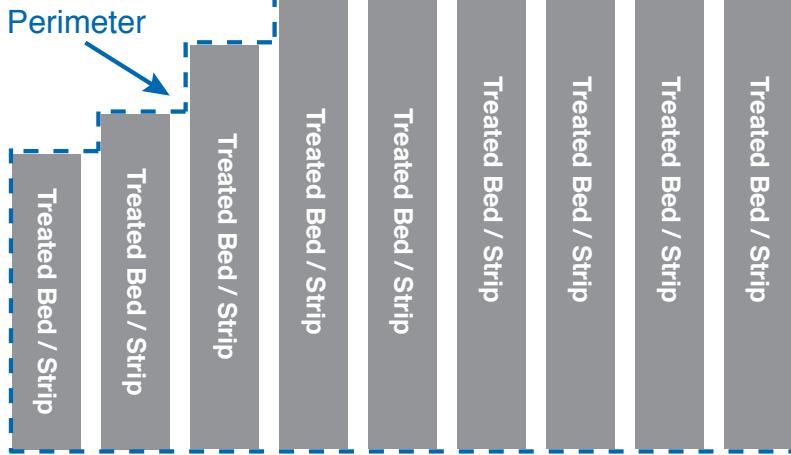
Buffer Zones

Buffer zones are required for most soil fumigations. A buffer zone is a restricted-access area surrounding the fumigant treated area (i.e., application block). It must remain in place both during and after the application is complete: **48-hours after for most products**. Buffer zones are established around fields, greenhouses, and other treated areas (e.g., golf courses). Their purpose is to provide distance between the application site and any bystanders in order to protect them from fumigant exposure.

- Labels have different buffer zone requirements.
- Read labels carefully.

The intent of the buffer zone is to ensure that any fumigant vapors have dispersed before reaching bystanders. **Only fumigant handlers may be in the buffer zone, with the exception of vehicular or bicycle traffic on roadways.**

Application Block



Application Block

The area being treated during the fumigation is defined as the application block. An application block can be a field, contiguous fields, a greenhouse, or a series of beds or planting strips undergoing fumigation. The perimeter of the application block is the border that connects the outermost edges of the total area treated with the fumigant. The size of the application block is the area within the perimeter of the field where the fumigant is applied. Buffer zones are established around the application block and extend outward from the perimeter of the treated area equally in all directions.

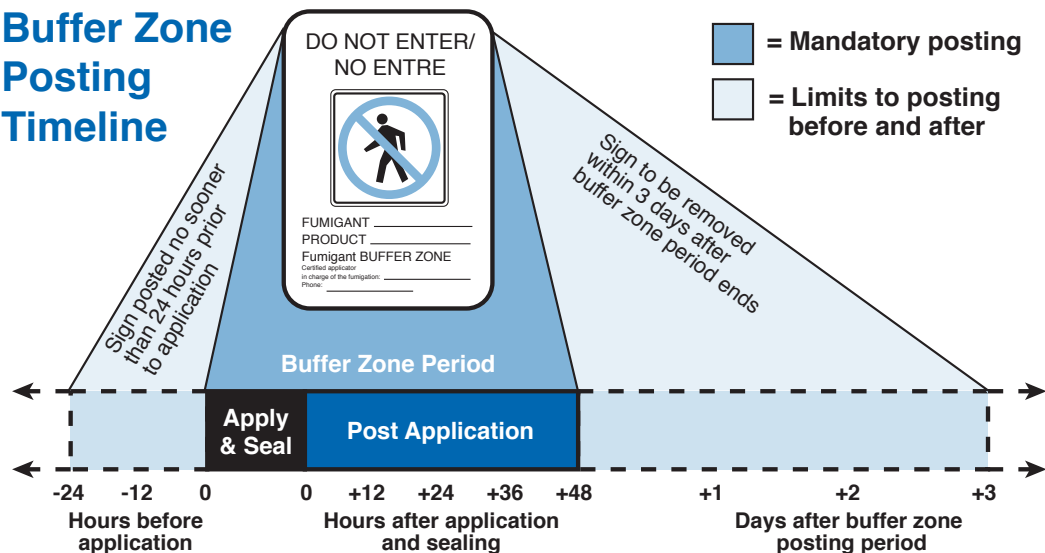
In greenhouse soil fumigations, labels require that buffer zones for pre-plant soil applications are based on the area of the application block, not the perimeter of the greenhouse structure. WPS requirements for greenhouses still apply, which establish ventilation criteria and entry restrictions for greenhouse applications.

Buffer Zone Period

Buffer zones must remain in effect during the buffer zone period. For most fumigants, **the buffer zone period extends from the time that the fumigant application begins (i.e., from the time the fumigant is delivered or dispensed to the application block) until 48 hours after the application ends** (the fumigant is no longer being delivered or dispensed, and the soil has been sealed, and any drip lines have been purged). One exception to the 48-hour period is for products formulated with 1,3-D as the only active ingredient, which have a seven day buffer zone period. Methyl bromide labels require a longer buffer zone period or a second buffer zone for certain tarps. Read labels carefully to make sure you understand buffer zones.

During the buffer zone period, all nonhandlers, field workers, nearby residents, pedestrians, and other bystanders must stay out of the buffer zone. There is

Buffer Zone Posting Timeline



Metam Sodium—Center Pivot by Low Release Height— Solid Stream Buffer Zone Distance in Feet (example only)

		Application Block Size				
		60 acres	80 acres	100 acres	120 acres	160 acres
Application Rate	56 lbs ai/acre	75	125	150	225	625
	80 lbs ai/acre	100	175	200	300	700
	200 lbs ai/acre	425	550	675	800	1200
	250 lbs ai/acre	550	700	850	1000	1400
	320 lbs ai/acre	800	1000	1200	1400	1800

one exception: people in transit (vehicular and bicycle) on roadways may move through the buffer zone.

Buffer Zone Size

Labels of most fumigants include tables showing required buffer zone sizes. These vary depending on the details of the fumigation. **The minimum buffer distance noted on most labels is 25 feet.** Buffer zone size is based on several factors:

- Fumigant being used.
- Application rate.
- Application block size.
- Application method.

Use these tables to determine the size of the required buffer zone. Labels include separate tables for different application methods. Application is prohibited for rates or block sizes that exceed those presented in the buffer zone table.

Buffer Zone Credits

Buffer zone credits on fumigant labels (except 1,3-D only products) allow reductions in buffer zone distance. Certain practices or site conditions that reduce the potential for fumigant off-gassing may earn credits. Buffer zone credits are also gained for conditions such as soil

temperature and organic content as well as for application practices that reduce emissions (such as the use of high-barrier tarps). The size of the buffer zone may be reduced if certain site conditions exist or the certified applicator uses emission-reducing methods. Here are several factors that may earn buffer zone credits:

- Use of specific high-barrier tarps (labels list name of tarp or refer to www.epa.gov/pesticides/tarpcredits).
- Soil conditions (e.g., soil organic matter and soil temperature).
- Use of certain application equipment.
- Application of potassium thiosulfate.

There is a maximum buffer zone reduction that can be earned using these credits, for example:

- **80% maximum credit for methyl bromide, chloropicrin, metam sodium, and metam potassium.**
- **40% maximum credit for dazomet.**

The certified applicator must record certain information on buffer zones in the FMP: the buffer zone distance, any credits (if earned), and any measurements taken to determine the size of the buffer zone.

Here is an example for methyl bromide. A certified applicator will treat 5 acres at a rate of 140 pounds per acre. The look-up table on the label notes a

Check fumigant labels.

Credits vary among fumigants.

$$\frac{100 - \% \text{ buffer zone credit}}{100} \times \text{table buffer zone (ft)} = \text{buffer zone (ft) after credits}$$

$$\frac{100 - 60}{100} \times 125 \text{ ft} = 50 \text{ ft}$$

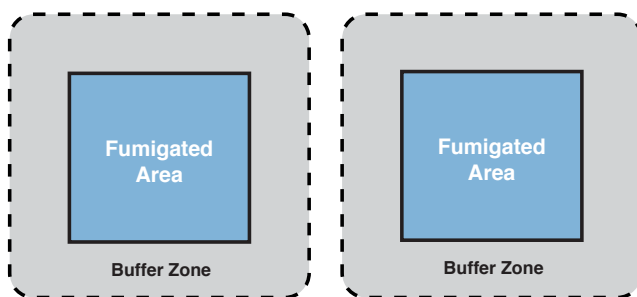
Formula to calculate new buffer zone

buffer zone of 125 feet. The application is by shank injection, broadcast, and tarp.

- Using a high-barrier tarp qualifies for a 40% buffer zone credit.
- The organic matter content of the soil is 2.1% and qualifies for a 20% credit.

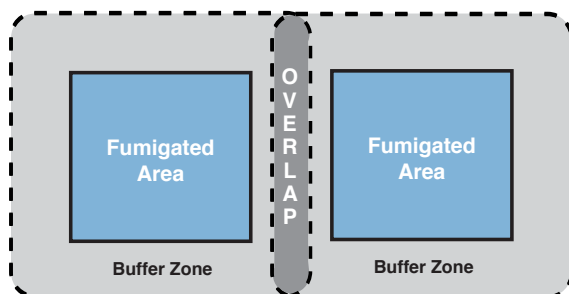
In this case, the total credits gained would be 60% (40+20). If the buffer distance without credits is 125 feet, the buffer zone with credits applied would be reduced by 75 feet (60% of 125 feet). The new buffer is 50 feet. Always make sure the credit is within the maximum credit amount allowed for the specific fumigant you are using. There is a formula for calculating the reduced buffer zone.

Buffer Zone Overlap



ABOVE: Buffer zones do not overlap. No overlap, no issue.

BELOW: Buffer zones overlap – **12 hours must pass** between completion of the first application and the start of the second.



Remember these two important factors about buffer zones:

- If, after applying all applicable buffer zone credits, the buffer zone is greater than a half mile (2,640 ft), then the application is prohibited.
- In all cases where buffer zones are required, the minimum buffer zone allowed is 25 feet. This includes fumigant applications to individual tree holes in the case of selective replant fumigation in orchards.

Overlapping Buffer Zones

Fumigant labels (except 1,3-D only formulations) specify that **buffer zones of multiple application blocks may overlap only if at least 12 hours pass between the completion of the first application and the start of the second**. There is one exception to this requirement: buffer zones may overlap for **low release height—solid stream center pivot applications** of metam sodium/potassium when release height is less than four feet. “Solid stream” is defined as an uninterrupted liquid stream that remains as a coarse flow until contacting the intended target. An example of a solid stream application is Smart-Drop®, also known as a drizzle boom. Note that under this exception, buffer zones may only overlap with those from application blocks that are treated with a different center pivot system. This rig must also be equipped with a low release height—solid stream setup.

Other Buffer Zone Restrictions

Exceptions exist for 1,3-D only formulated products.

Residential and Business Areas

Buffer zones may not include residential areas unless the occupants sign a written agreement to voluntarily vacate the buffer zone during the buffer zone period.

Other Structures

Buffer zones must not include buildings used for storage (such as sheds, barns, and garages), unless both of the following are true:

- The storage buildings are not occupied during the buffer zone period.
- The storage buildings do not share a common wall with an occupied structure.

Roadways, Rights-of-Way, and Transit through Buffer Zones

A buffer zone may include **roadways** and/or rights-of-way only if all three of the following are true:

- The area is unoccupied during the buffer zone period.
- Entry by nonfumigant handlers is prohibited.
- Certified applicators comply with all local laws and regulations.

Only vehicular and bicycle traffic are allowed to travel through buffer zones during the buffer zone period. Bus stops or other areas where people wait for public transportation must not be included in a buffer zone.



Bus stops are not allowed in buffer zones

Publicly Owned or Operated Areas

A buffer zone may include publicly owned or operated areas (such as a public park) if all of the following are true:

- The area is unoccupied during the buffer zone period.
- Nonfumigant handlers are prohibited from entering.
- Certified applicators comply with all local laws and regulations.
- The state or local authorities responsible for the management and operation of the area provide written permission.

Other Agricultural Areas

A buffer zone may include an agricultural area owned by another person if both of the following are true:

- Buffer zones for different fumigations do not overlap.
- The owner or operator provides written agreement that no one will enter the buffer zone during the buffer zone period.

Signage and Posting Requirements

Most soil fumigant labels require two types of postings: Treated Area Posting and Buffer Zone Posting. All require treated area posting according to WPS requirements. Most require buffer zone posting (except 1,3-D only products). Some of the information on these signs is the same: **contact information for the certified applicator and details of the product to be used**. However, they are two different sets of signs with two different posting requirements.

Treated Area Posting

Fumigant treated area signs are posted at the **perimeter of the application block**. They serve to warn fumigant handlers, other workers, and con-

tract employees about the application. Although none of the requirements for posting treated areas has changed, the information on the signage has. Fumigant treated area signs must include the following:

- Skull and crossbones symbol.
- DANGER/PELIGRO.
- Area under fumigation, DO NOT ENTER/NO ENTRE.
- [Name or names of the fumigant active ingredient] fumigant **in use**.
- [Name of the product].
- Date and time of fumigation (start and finish).
- Date and time entry-restricted period is over.
- Name, address, and telephone number of the certified applicator-in-charge of the fumigation.

For soil fumigations, **the fumigant treated area sign replaces the WPS no-entry sign**. Post fumigant treated area signs according to the WPS requirements for location, legibility, text size,

and sign size (40 CFR §170.120). Signs must be at least 14 by 16 inches with letters a minimum of 1 inch.

Fumigant treated area signs must be:

- Posted at all entrances to the application block.
- Posted no sooner than 24 hours before application.
- In place for at least the duration of the **entry-restricted period**.
- Removed within three days after the end of the **entry-restricted period**.

Buffer Zone Posting

Buffer zone signs warn workers and bystanders about the location of the buffer zone, entry prohibition, and other important information. For buffer zones to serve their purpose, bystanders and workers in nearby areas must be informed of the location and timeframe of the buffer zone. They are warned to keep out of the buffer zone area. Buffer zone signs are available at fumigant points of sale. You can also download templates from the EPA's soil fumigant website: <http://www.epa.gov/fumiganttraining/>.



Buffer zone signs must include all of the following:

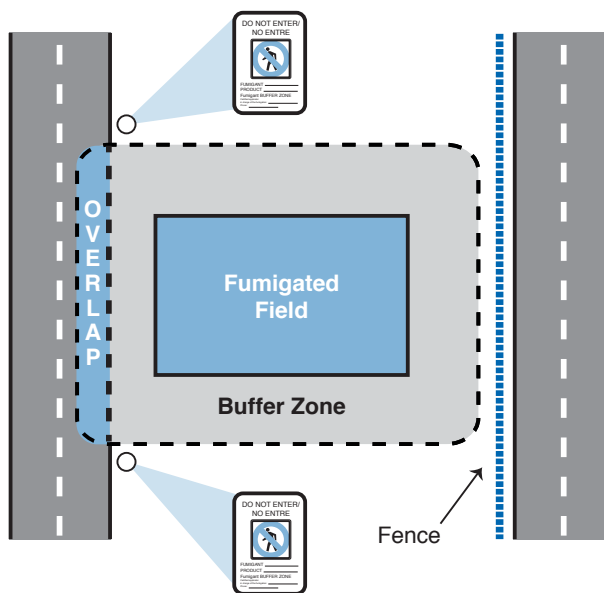
- “Do Not Walk” symbol.
- DO NOT ENTER/NO ENTRE.
- [Name of fumigant active ingredient]; [name of product]; fumigant buffer zone.
- Contact information for the certified applicator-in-charge of the fumigation.

Buffer zone signs must be:

- Posted at all points of entry into the buffer zone and along likely travel routes (roads, sidewalks, walking paths, and bike trails), facing in the direction that people approach the area.
- Legible.
- A minimum of 14 by 16 inches, with letters a minimum of 1 inch.
- Posted no sooner than 24 hours before application.
- In place until end of **buffer zone period**.
- Removed within three days after the end of **buffer zone period**.

Likely routes of approach to a buffer zone might include the area between a roadway and the buffer zone. In the case of a residential area, it might be the area between the houses and the buffer zone. Note that posting buffer zone signs is required at normal access points unless a physical barrier, such as a fence, prevents access.

Buffer Zone Road Signage



Buffer zone signs must be posted at points of entry and along likely travel routes.

Difficult-to-Evacuate Sites

Some sites are difficult to evacuate in cases of an accident or emergency. Most product labels (exception: 1,3-D only formulated product) prohibit fumigant applications near occupied difficult-to-evacuate sites, which include the following:

- Schools (pre-kindergarten through grade 12).
- State-licensed daycare centers.
- Nursing homes.
- Assisted-living facilities.

Fumigant Treated Area and Buffer Zone Posting Time Limit

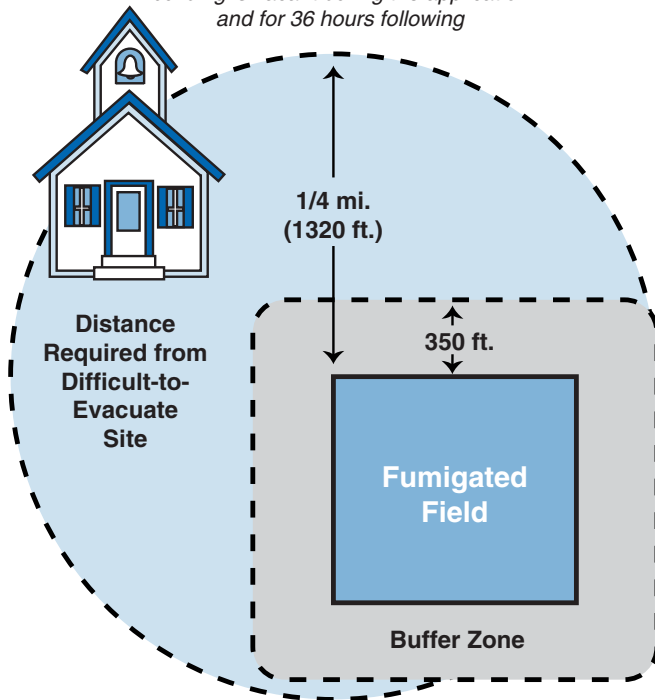
	Fumigant Treated Area Signs	Buffer Zone Signs
Posted – where	At entrances to application block.	At likely points of entry and routes of approach to buffer zone.
Posted – when	No sooner than 24 hours before the start of the application.	No sooner than 24 hours before the start of the application.
Remain	Until the end of the entry-restricted period .	Until the end of the buffer zone period .
Removal	Within three days of the end of the entry-restricted period.	Within three days of the end of the buffer zone period.

Application Prohibitions for Occupied Difficult-to-Evacuate Sites

If the buffer zone is:	The fumigant application is prohibited within the noted distance, if the difficult-to-evacuate site is occupied during the application or within 36 hours afterward.
> 300 feet	within 1/4 mile (1,320 feet)
≤ 300 feet	within 1/8 mile (660 feet)

Fumigation NOT ALLOWED

unless difficult-to-evacuate building is vacant during the application and for 36 hours following



- Hospitals.
- In-patient clinics.
- Prisons.

No fumigant applications are allowed where buffer zones are **greater than 300 feet** if there is an occupied difficult-to-evacuate site **within 1/4 mile of the application block during the application and for 36 hours afterward.**

No fumigant applications are allowed where buffer zones are less than 300 feet if there is an occupied difficult-to-evacuate site **within a 1/8 mile of the application block during the application and for 36 hours afterward.**

For iodomethane, no fumigant applications are allowed if there is an occupied difficult-to-evacuate site **within a 1/4 mile (1/2 mile for California) of the application block during the application and for the duration of the buffer zone period.**

REVIEW QUESTIONS

- 1. The buffer zone period starts when the fumigant application begins (i.e., from the time fumigant is delivered or dispensed to the application block) and continues until:**
 - A. 48 hours after tarp perforation/removal.
 - B. 48 hours after the fumigant has stopped being delivered or dispensed.
 - C. 36 hours after the fumigant has stopped being delivered or dispensed.
- 2. Which of the following are allowed to pass through a buffer zone?**
 - A. Joggers or runners on an established trail.
 - B. People on skateboards at a community park.
 - C. People on bicycles on a roadway.
- 3. What is the maximum buffer zone credit for metam sodium and metam potassium?**
 - A. 20%.
 - B. 40%.
 - C. 80%.
- 4. True or False: You may use fumigant treated area signs to post buffer zones as long as the signs are posted at the usual points of entry and along likely routes of approach to the buffer zone.**

Answers to Review Questions

1. **B**—The buffer zone period starts when the fumigant application begins and extends until 48 hours after the fumigant has stopped being delivered or dispensed.
2. **C**—Only vehicular and bicycle traffic on public or private roadways is allowed to pass through a buffer zone.
3. **C**—80% maximum buffer zone credit for methyl bromide, chloropicrin, metam sodium, and metam potassium; 40% maximum buffer zone credit for dazomet
4. **False**—You must use buffer zone—not fumigant treated area—signs to warn bystanders of the presence of a buffer zone.

APPLICATION METHODS AND SOIL SEALING

LEARNING OBJECTIVES

After studying this chapter, you should be able to:

- Describe the application equipment and methods used to apply fumigants.
- Describe backflow prevention devices (e.g., check valves) and how they work.
- Outline the procedures for fumigating greenhouse and nursery soil and potting mixes.
- Outline a pre-application inspection of the application equipment.
- Describe a step-by-step process for changing fumigant cylinders.
- State the purpose and methods of soil sealing.
- Discuss the factors that help determine which soil sealing method to use.
- Describe the general range of tarps available.
- Explain how to seal tarps.
- Describe the label time requirements for tarp removal and perforation.

Application Equipment and Methods

You can apply fumigants to soil in many different ways. The diverse chemical characteristics of soil fumigants largely determine how the products are applied. However, the application method is also determined by:

- The fumigant formulation.
- The target pest.
- The cost.
- The area or site to be fumigated. (For example, fumigating a field vs. fumigating a mound of potting soil.)

The formulated product varies by fumigant. Methyl bromide is an example of a **liquefied gas**. This means it is a gas

at ambient temperatures and pressures but is stored as a liquid in pressurized cylinders. Chloropicrin, DMDS, iodomethane, 1,3-D, metam sodium, and metam potassium are all **volatile liquids** and readily volatilize to a gas when applied to the soil. Dazomet is an example of a solid that volatilizes when incorporated into the soil.

Shank or Spray Blade Application

For shank soil injection applications, knifelike blades called shanks or chisels are mounted vertically on a toolbar behind a tractor and pulled through the soil to deliver the fumigant. A tube carrying the fumigant runs down the back

Formulations and Application Methods

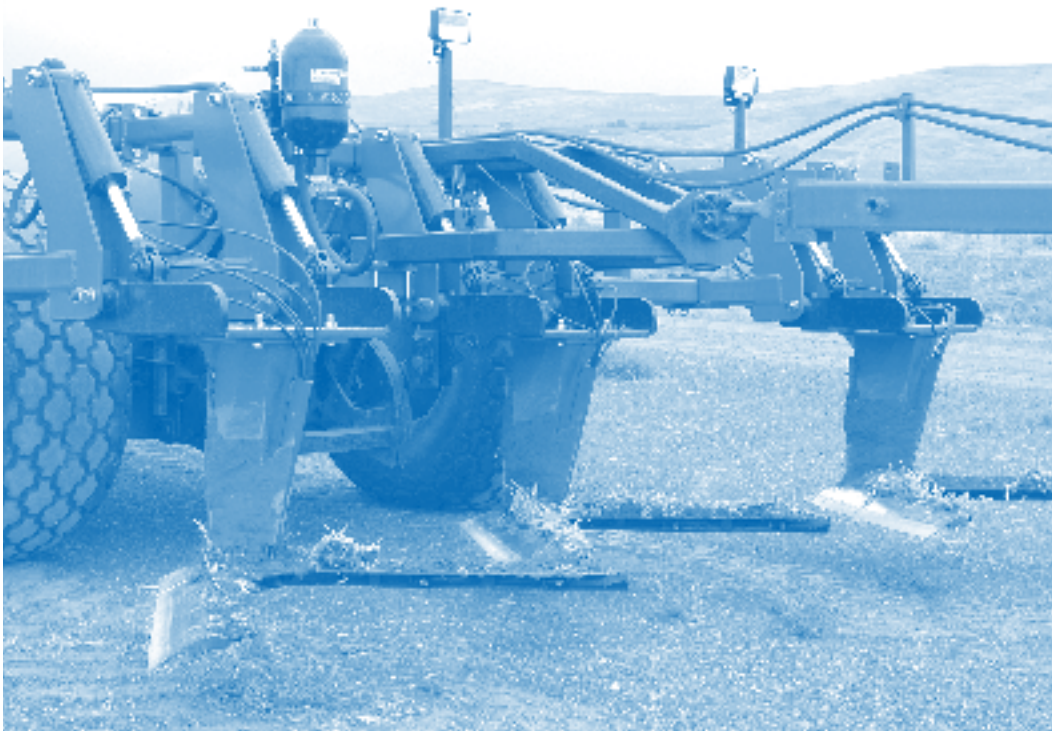
Formulation Type	Chemical	Application Methods
Liquefied Gas	Methy bromide	Ground rig (shank)
		Hot Gas (only 98:2 MeBr:chloropicrin mixtures)
		Tree replant
Volatile Liquid	Metam sodium/ metam potassium	Ground rig (shank, spray blade, or rotary tiller)
		Chemigation
		Tree replant
	Chloropicrin	Chemigation (drip only)
		Ground rig (shank)
		Tree replant
	Iodomethane	Ground rig (shank)
		Chemigation (drip only)
		Tree preplant
	DMDS	Ground rig (shank)
Chemigation (drip only)		
1,3-D	Ground rig	
	Chemigation (drip only)	
Solid	Dazomet	Rotary Tiller
		Tractor-drawn drop spreader



of each shank. Fumigant travels from the tank to the tubing through a pressurized system. Shanks differ in type, size, and shape.

Shank traces (the grooves the shanks make in the soil) are covered with soil. The soil is then sealed immediately, using tarps, water, or a roller to compact the soil. Sealing inhibits the fumigant from escaping from the soil.

Spray blade applications are similar to liquid shank injections except that horizontally positioned spray blades have replaced the injection shanks. Spray blades are designed to cut through the soil horizontally, briefly creating a void under the “wing” of the blade. The fumigant is sprayed into this void or cavity, providing even distribution along the width of the blade at a specific depth. Plows on the toolbar throw soil on top of the treated soil to seal it.



A critical component of shank or spray blade equipment is a blow-out valve on each injection line that allows the fumigant delivery system to be shut off before removing the shank or spray blade from the soil. Proper use of the blow-out valve and timing the shut off prior to removal from the soil greatly minimizes field application exposures.

Shank or spray blade applications can be broadcast or bedded and either tarped or untarped.

Bedded-Tarped Applications. In bedded-tarped applications, a tractor pulls the application equipment (chemical tank, delivery piping, tubing, pump, and shanks or spray blades). The first tractor applies the fumigant to the beds. A second tractor then follows with the sealing equipment. You can also make bedded-tarped applications and lay tarp using one tractor. The sealing equipment has two discs that open small furrows on the sides of the bed. As the tarp is unrolled over the bed, small press wheels insert plastic into the open furrows. Closing discs seal the plastic by throwing soil back into the furrows. At the ends of the rows, manually cover the tarp edge with soil to seal the edges.

Broadcast-Tarped Applications. In broadcast-tarped applications, you apply fumigant across an entire field rather than in rows or beds. For tarping the first application pass, follow the tarping instructions described previously. For the second adjacent pass, replace one of the discs with an adhesive dispenser. During the second pass, one side of the tarp is sealed by adhesive to the tarp applied in the first pass. Repeat this process until the entire field has been fumigated and tarped.

Fumigant injection and tarp deployment are accomplished with a single application rig, where the tarp deploys off a specialized toolbar mounted just after the shank lines.

Untarped Applications. Shank and spray blade fumigant applications can also be untarped. In untarped applications, seal the soil using mechanical compaction equipment or irrigation water (a water seal). When soil is mechanically compacted, a soil-packing device immediately follows the application equipment. In the case of untarped bed applications, soil compaction occurs when these beds are lifted and shaped during fumigant applications. If you plan to

Drip tape shown under an opened tarp



use a water seal, check the label for the amount of water required for the seal.

Power-Mulch or Rotary Tiller Application

Power-mulch or rotary tiller applications are appropriate for either liquid or granular fumigant formulations. They are effective if target pests are in the upper soil profile. Apply the fumigant material to the field surface. Then, immediately incorporate it to the desired depth with a power-mulching device or rotary tiller. For granular applications, drop spreaders are a better choice than broadcast spreaders. This is because drop spreaders have a reduced potential for physical drift and off-target applications. Apply liquid fumigants with a spray boom. Once you have applied and mechanically incorporated the fumigant, seal the soil surface with a plastic tarp or use sprinkler irrigation to apply a water seal. Rotary tiller fumigations are often used as preplant seedbed preparations.

Chemigation Application

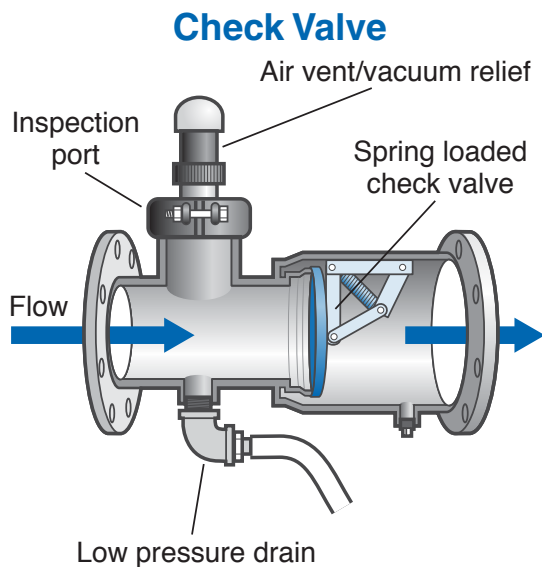
You can apply several fumigants through irrigation systems; however, some

fumigants restrict their use only to drip irrigation (chloropicrin, iodomethane, DMDS, 1,3-D). Liquid fumigant stored in tanks is injected into the irrigation water which is then applied by an irrigation system. Several different systems deliver the treated water to the soil, including:

- Center pivot.
- Lateral move.
- Solid set.
- Sprinkler.
- Drip (in-line and external emitters).
- Drip tape.
- Flood.
- Border furrow irrigation systems.

You can also use drip chemigation (with 100% chloropicrin) to fumigate greenhouse soils.

All chemigation systems must have backflow prevention devices. It is critical that the irrigation system have a standard single check valve, low pressure drain, inspection port, and vacuum relief valve upstream of the injection point to prevent possible contamination of the water source by fumigants.



Tree Replant or Probe Auger Application

You can fumigate tree replant sites similar to other broadcast applications for seed-bed preparation. However, the probe auger application method is sometimes used on small-scale tree replant sites. There are several fumigants that you can directly inject into the soil for this purpose. In these cases, a handheld injector inserts the fumigant deep (18 inches) into the soil and delivers it to a specific site.

Hot Gas Application

The hot gas, no-till application method is used for 98:2 mixtures of methyl bromide and chloropicrin. Heat the fumigant by passing it through a heat exchanger. Then, deliver it to the soil surface through a system of tubing or piping. Lay the delivery tubing on top of the soil to be treated. Cover it with tarps that are sealed on all sides. The hot gas method is used for turf renovation in golf courses. It is the preferred way to treat potting soil mixes and tobacco seedling trays. The hot gas method is also used (via buried drip tape) to treat greenhouse soils.

To treat potting soil by the hot gas method, pile the soil to a depth of 18 inches on a concrete floor or on wet ground. You can also treat piles 2 to 3 feet high if you insert rigid, perforated plastic tubes vertically into the pile at 18-inch intervals to assist penetration.

You may also treat potting mixes in flats and tobacco seedling trays with this method. Arrange the flats or trays in loose, crisscross stacks that are no more than 5 feet high. Then, cover and seal the stacks with a tarp. Introduce the fumigant at the top and in the center of the stack. Use one injection point for each 100 cubic feet of volume. Note that when treating potting mixes, the tarp must be at least 4 millimeters thick. Seal tarp edges by burying, covering with moist sand or soil, or using sand snakes.

Preapplication Equipment Inspection

Before each use, inspect application equipment to make sure that it is in good repair and that all necessary pipe, tubing, and coupling connections are secure. Make sure none of your equipment is incompatible with the fumigant being used (see Chapter 3). Clean and check all filters or screens in the application equipment. Make sure that all outlets are delivering a uniform amount of liquid. Specifically:

- For ground equipment used to apply liquids, first fill the tank with a suitable liquid (water or diesel) and check for leaks in tubing and fittings.
- For chemigation applications, run water through the irrigation system. Check for even flow distribution and leaks in piping, hoses, and fittings, and missing or malfunctioning nozzles/sprayheads. Insure distribution uniformity and adjust if needed.
- For granular applications, make sure that the hopper is free of debris that might clog equipment.
- For gas applications, check the system with compressed air or gas. Check all fittings, valves, and hoses for leaks using a soap solution.

Changing Fumigant Cylinders and Filling Application Tanks

Changing fumigant cylinders and filling application tanks are high risk activities and care must be taken. Always assume that hoses on your equipment contain fumigant or are contaminated with residue. Make this assumption even after the lines have been purged. Take appropriate protective measures to prevent exposure. Be sure to wear appropriate PPE as specified on product labels.

When a fumigant cylinder *is empty*, first prevent inadvertent fumigant discharge by closing the cylinder shutoff valve. Use nitrogen or other inert gas or dry compressed air to purge the cylinder. Use this gas to purge any residual fumigant out of the fumigant lines into the soil. Next, disconnect the empty fumigant cylinder from the application rig. Install the new cylinder. Connect and secure all tubing. Slowly open the compressed gas or air valve. Slowly open the fumigant cylinder valve, always watching for leaks. Increase the pressure to the desired level.

The same care must be taken when working with liquid fumigants in large volumes, like metam sodium. Inspect the shuttle tank for integrity. Double-check all connections, lines, and pumps for leaks. Always assume the material is present. Follow all label PPE requirements.

Soil Sealing

Methods and Selection

As noted earlier, the soil is sealed after applying a fumigant for several reasons, including to:

- Prevent the fumigant from off-gassing and unintended exposure to humans, plants, and animals.
- Keep the fumigant in the soil in high enough concentrations and for long enough to control target pests.

Sealing is accomplished using tarps, mechanical compaction (disking, rolling, or dragging), covering treated soil with untreated soil, or by irrigation (water seal).

The soil-sealing method depends on the target pest, volatility of the fumigant applied, and the application method.





Fumigant labels specify which soil-sealing methods to use for specific application techniques. In general, fumigants that are less volatile and those that are applied deeper in the soil are effectively retained in the soil using a water seal or by soil compaction. Alternately, fumigants that readily volatilize (such as methyl bromide) typically require tarps that limit vapor escape, especially after shallow applications. Deep applications (18 to 30 inches) may not require surface treatments other than soil compaction, depending on the target pest.

Tarps

Tarps differ by thickness, density, and permeability. They may also differ by tolerance to ultraviolet (UV) light, stretching, color, and price. The broad categories of tarps used for soil sealing are:

- Low-density polyethylene (LDPE).
- High-density polyethylene (HDPE).
- Semi-impermeable film (SIF).
- Virtually impermeable film (VIF).
- Totally impermeable film (TIF).
- Metalized film.

Tarps are also categorized by permeability and density. Here, permeability refers to the ability of the fumigant gas to pass through the tarp. Density refers to the compactness of the material used to make the tarp. The two main types of tarps used in soil fumigation are HDPE and LDPE. Except for VIFs and TIFs, there is a strong relationship between tarp thickness and permeability, regardless of tarp density. Tarp composition is as important as thickness with respect to permeability. Labels reference an EPA web site for the tarps that qualify for buffer zone credits.

Tarps used to cover raised beds that remain in the field through the growing season must have an UV stabilizer for exposure to sunlight. This will prevent their disintegration. Tolerance to sunlight is not important for tarps that are removed within a few weeks of application.

Stretching properties are important for ease of tarping. Film flexibility is especially important when covering raised beds. However, tarps used on flat ground also should be flexible to avoid tearing during application.

Tarps come in a variety of colors: usually black, brown, white, and clear.

Tarp thickness is measured in mils—
1 mil = 0.001 inch.

Different tarp colors help control soil temperature, suppress weeds, or repel insects. For example, clear or white tarps heat the soil better than black tarps. However, clear standard tarps do not control weeds while opaque tarps prevent seed germination.

You can seal tarps along their sides in two ways:

- Inserting the tarp edge into a furrow and then closing the furrow over the tarp.
- Using adhesive to seal the edge of the tarp to an adjacent strip of tarp.

No matter which method you use to seal the edges, seal the tarp at the ends of each row by manually shoveling soil over the edge of the tarp.

Tarp Perforation and Removal

Most labels state that tarps can be **perforated no sooner than five days** after a soil fumigation is complete. Tarps

may be **removed two hours after the perforation** is complete. The application is complete under both of the following conditions:

- The fumigant is no longer being delivered or dispensed.
- The soil has been sealed, and—if applicable—irrigation system has been purged.

The requirement to wait two hours following perforation before removing the tarp is to ensure that any remaining fumigant has dissipated.

Labels also state that if tarps are **not** removed after perforation, planting can begin under either of the following conditions:

- **48 hours** have elapsed since perforation was complete.
- Tarp perforation occurred more than **14 days** after the application. In this case, planting or transplanting can occur at the same time tarps are perforated.

Tarp perforation





There are two exceptions to the tarp removal and perforation requirements noted on labels:

1. **Early tarp removal** is allowed for tarps used in broadcast applications if a weather condition exists (e.g., high wind, hail, or storms) that may compromise the integrity of the tarp and the tarp poses a safety hazard.
2. **Early tarp perforation** is allowed for flood prevention activities. In bedded-tarped applications, when tarps are perforated in cross-ditching to allow water between beds to drain, the tarp must be retucked and packed after removing the soil.

Tarps must be perforated (cut, punched, poked, or sliced) **mechanically**. However, there are three situations where tarps may be manually perforated:

- At the beginning of each row when a coulter blade (or similar device) is used on a motorized vehicle such as an ATV.
- In fields that are 1 acre or smaller.
- During flood prevention activities.

For broadcast applications, there are three additional perforation requirements:

1. Each tarp panel must be perforated.
2. Perforation must be completed before noon.

3. Tarps must not be perforated if rain-fall is expected within 12 hours.

Common Soil Fumigation Problems

The most common problems with fumigation performance are:

- Poor calibration of the fumigant delivery rate and errors in calculations.
- Improper soil moisture (too much or too little).
- Poor soil preparation.

See Chapter 4 for details on these soil characteristics and their impact on fumigation. Poor seedbed leveling is also another factor. Fumigation problems also arise when equipment malfunctions (such as tubing coming loose). Always inspect application equipment before making an application. *Double check* your calculations before starting a soil fumigation application.

Additional problems cited by EPA in exposure incidents include:

- Applying fumigants despite adverse weather conditions.
- Certified applicator carelessness and/or not planning the fumigation process.
- Not following label use directions.

Early tarp removal is allowed in some cases of severe weather. Early tarp perforation is permitted for flood prevention activities.

REVIEW QUESTIONS

1. **Why are chemigation irrigation mainline check valves used in irrigation systems?**
 - A. To prevent fumigant from flowing backward into the water supply.
 - B. To meter water flow to make sure the capacity of the pump is not exceeded.
 - C. To meter the flow of fumigant into the irrigation system.

2. **True or False: When changing fumigant gas cylinders, you should always assume that the lines are full of fumigant even though they have been purged.**

3. **In normal situations (no adverse weather and no flooding), what are the time limits for tarp perforation and removal?**
 - A. Three days for tarp perforation, then two hours after perforation for removal.
 - B. Five days for tarp perforation, then two hours after perforation for removal.
 - C. Two days for tarp perforation, then five hours after perforation for removal.

4. **When may tarps may be manually perforated?**
 - A. Any time by fumigant handlers wearing respirators.
 - B. During flood prevention activities.
 - C. In fields that are 10 acres or less.

Answers to Review Questions

1. **A**—Chemigation line check valves will prevent backflow of fumigant into the water supply.
2. **True**—Always assume that some fumigant may remain in the lines when changing fumigant gas cylinders.
3. **B**—In normal situations, tarps may be perforated five days after the fumigation is complete and then removed two hours after the perforation is complete.
4. **B**—There are three scenarios when tarps may be manually perforated: at the beginning of each row when a coulter blade (or similar device) is used on a motorized vehicle such as an ATV, in fields that are 1 acre or less, and during flood prevention activities.

CALCULATIONS AND CALIBRATION

LEARNING OBJECTIVES

After studying this chapter, you should be able to:

- Calculate the area of a rectangle, circle, triangle, and an irregularly-shaped site.
- Calculate the circumference of a circle and the revolution time of a center pivot.
- Calculate the amount of product required for a specific treatment area.
- Calculate the row acre application rates for bedded or strip applications.
- Calculate the broadcast equivalent rate for bedded or strip applications.
- Outline the basic techniques for calibrating soil fumigation application equipment.

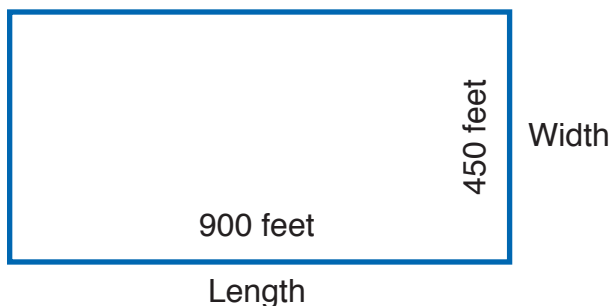
Area Calculations

In order to correctly apply a soil fumigant, you must know the size of the treatment area. Included here are directions for calculating the area of variously shaped fields. The discussion that follows explains how to manually calculate area. Note, however, that there are web-based tools that use global positioning system (GPS) input to calculate field areas. When doing the calculations for area, make sure to measure each number in the same unit (e.g., feet). If the measurements are in two different units, convert to the same unit of measurement. For example, to find the area for a nursery bed that is 100 yards long and 4 feet wide, first convert the 100 **yards** to 300 **feet**. Then multiply 300 **feet** by 4 **feet** for a total of 1,200 square feet.

Area Equivalents

1 acre = 43,560 square feet (ft²)

1 acre = 4,849 square yards (yd²)



Square and Rectangle


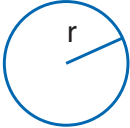
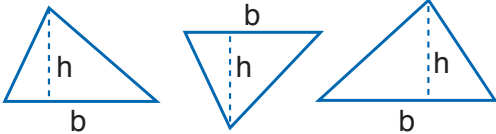
To calculate the area of a square or rectangle, multiply its width by its length.

- Area = $w \times l$
- Area = 450 ft x 900 ft
- Area = 405,000 square feet or 405,000 ft²

Because fumigant labels state application rates per acre, convert the area from square feet to acres. To do this, divide the total square feet by 43,560 (the conversion rate to acres).

$$405,000 \text{ ft}^2 \div 43,560 \text{ ft}^2/\text{acre} = 9.3 \text{ acres}$$

Area Formulas

To calculate the are of a...	Use the formula...	Where...
Square and Rectangle 	$A = w \times l$	w is the width and l is the length.
Circle 	$A = \pi \times r^2$	π is the constant 3.14 and r is the radius.
Triangle 	$A = \frac{1}{2} \times b \times h$	b is the base and h is the height.

Circle

To calculate the area of a circle, measure the length of the circle's radius. The radius is half the length of the **diameter**, which is the length of the longest possible straight line across a circle.

Area = $\pi \times r^2$ where π is a constant with the value 3.14 and r is the length of the circle's radius

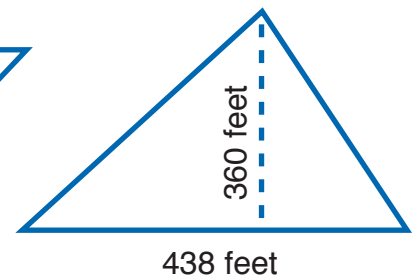
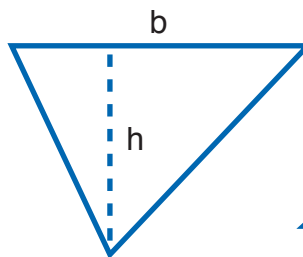
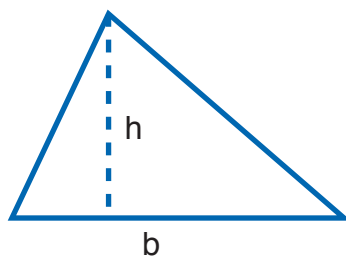
- Area = $\pi \times r^2$
- Area = $3.14 \times 750 \text{ ft}^2$ or
- Area = $3.14 \times 750 \text{ ft} \times 750 \text{ ft}$
- Area = 1,766,250 ft^2

Next, convert this value to acres using the appropriate conversion constant:

$$1,766,250 \text{ ft}^2 \div 43,560 \text{ ft}^2/\text{acre} = 40.5 \text{ acres}$$

Triangle

To calculate the area of a triangle, measure the length of the triangle's base and height.



Area = $\frac{1}{2} \times b \times h$ where b is the length of the base and h is the height of the triangle.

In this example, calculate the area of a small triangular-shaped field where the base is 438 feet across and the height is 360 feet:

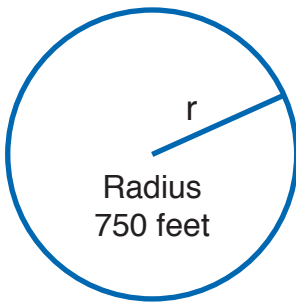
- Area = $\frac{1}{2} \times b \times h$
- Area = $0.5 \times 438 \text{ ft} \times 360 \text{ ft} = 78,840 \text{ ft}^2$

Convert this value to acres:

$$78,840 \text{ ft}^2 \div 43,560 \text{ ft}^2/\text{acre} = 1.8 \text{ acres}$$

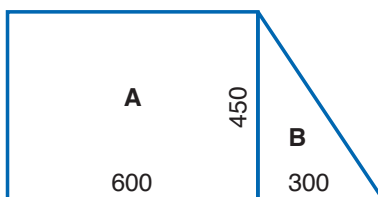
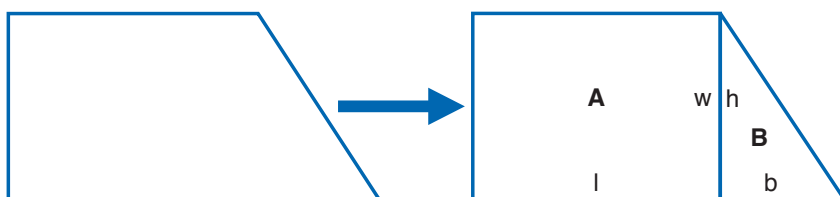
Irregularly-Shaped Sites

To calculate areas for irregularly-shaped fields and beds, break the shape into the shapes discussed above and figure the area for each part. In the first example, you can divide the field into a rectangle and a triangle.

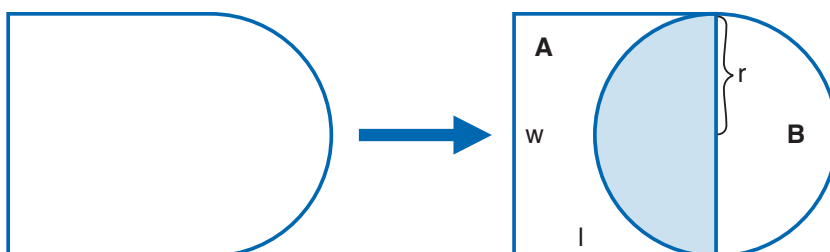


Example 1—The area of the field is the sum of the area of rectangle A and triangle B. In this example, if rectangular area A measures 600 feet by 450 feet and the base of triangular area B is 300 feet, the total field area is:

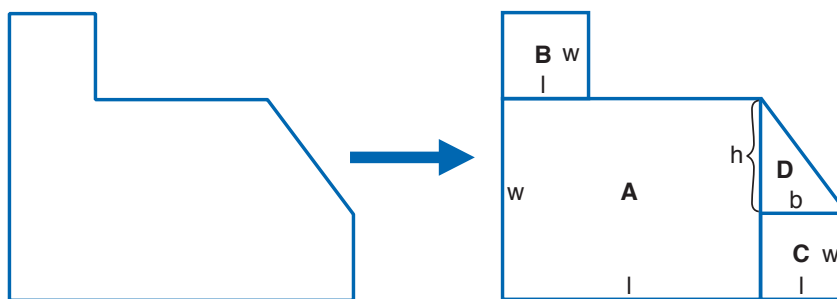
- Area of A = $w \times l = 450 \text{ ft} \times 600 \text{ ft} = 270,000 \text{ ft}^2$
- Area of B = $\frac{1}{2} \times b \times h = 0.5 \times 300 \text{ ft} \times 450 \text{ ft} = 67,500 \text{ ft}^2$
- Total area = area of A + area of B = $270,000 \text{ ft}^2 + 67,500 \text{ ft}^2 = 337,500 \text{ ft}^2$
- Total area in acres = $337,500 \text{ ft}^2 \div 43,560 \text{ ft}^2/\text{acre} = 7.75 \text{ acres}$



Example 2—In the second example, the field contains both a rectangular and a half-circle section. To calculate the area, break the shape into a rectangle and a circle. The field area is the sum of the area of rectangle A and **one half** the area of circle B.



Example 3—The last example is for a field with irregular borders on two of the four sides. To calculate the total area of the field, add the areas of rectangles A, B, and C to the area of triangle D.



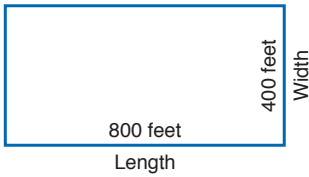
Sample Calculations of Amount of Fumigant Needed for Treatment Area

When preparing for a soil fumigation, first determine the application method you will use. Then figure the application rate and the size of the target area. Once you know these factors, calculate the amount of fumigant needed for the application. Following are sample calculations.

Broadcast Shank Injection

In this example, calculate the amount of chloropicrin needed to fumigate a field that will be planted to eggplant. The field is 400 feet wide and 800 feet long. First, calculate the area of the field in acres:

- $A = w \times l$



- $A = 400 \text{ ft} \times 800 \text{ ft} = 320,000 \text{ ft}^2$

Convert the area from square feet to acres:

$$320,000 \text{ ft}^2 \div 43,560 \text{ ft}^2/\text{acre} = 7.35 \text{ acres}$$

According to the label for a broadcast shank injection application that will be tarped, the application rate is 300 to 350 pounds per acre. In this case, we will apply the chloropicrin at the lower rate of 300 pounds per acre. Calculate the amount of chloropicrin needed for this application:

- $300 \text{ pounds/acre} \times 7.35 \text{ acres} = 2,205 \text{ pounds chloropicrin}$

Center Pivot

To calculate the amount of fumigant needed to do a center pivot chemigation, you need the following information:

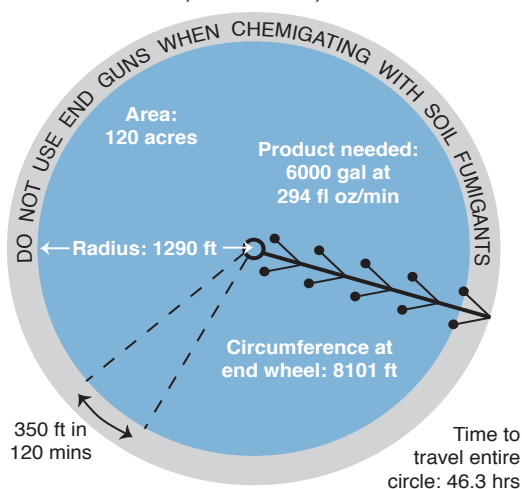
- **Circumference** of the treated area (circle).
- Time necessary for a full revolution of the treated area (revolution time).
- Area of the treated circle.
- Injection rate for the fumigant.
- Speed of the pivot.
- Depth of water application.

First, calculate the circumference of the treated circle:

- $C = 2 \times \pi \times r$

Center Pivot Calculations

(not to scale)



Next, calculate the revolution time for the pivot. To do this, time how long it takes the pivot to move a predetermined distance. Alternatively, you can figure the revolution time by measuring the distance it takes the pivot to travel a predetermined time. Using this information, estimate the time it takes the pivot to travel the circumference of the center pivot. Lastly, calculate the area of the entire treatment zone (area of a circle = πr^2) and the required injection rate for the fumigant.

Note that soil fumigant labels **prohibit the use of end guns** on any irrigation system. This includes center pivots. Do not include the area covered by the end gun in the circle radius. Always make sure end guns are turned off when chemigating with soil fumigants.

In this example, the application rate for metam sodium is 50 gallons per acre. The center pivot covers up to 1,290 feet (radius) with the end gun turned off. Calculate the area that the center pivot covers:

- $A = \pi \times r^2$
- $A = 3.14 \times 1,290 \text{ ft} \times 1,290 \text{ ft} = 5,225,274 \text{ ft}^2$

Convert the area from square feet to acres:

$$5,225,274 \text{ ft}^2 \div 43,560 \text{ ft}^2/\text{acre} = 120 \text{ acres}$$

Calculate the revolution time as follows: the predetermined distance is 350 feet and it takes the pivot 2 hours to complete that distance. Next, determine revolution time. If it takes two hours to travel 350 feet, how long does it take to travel around the entire circle?

- End wheel circumference ($2 \times \pi \times r$) = $2 \times 3.14 \times 1,290 \text{ ft} = 8,101 \text{ ft}$
- Set up a ratio calculation to determine end wheel revolution time:

$$\frac{2 \text{ hours}}{350 \text{ ft}} = \frac{x \text{ hours}}{8,101 \text{ ft}}$$

$$x \text{ hours} = \frac{2 \text{ hours} \times 8,101 \text{ ft}}{350 \text{ ft}}$$

$$x = 46.3 \text{ hours}$$

Time required to travel around the entire circle = 46.3 hours.

The application rate for metam sodium is 50 gallons per acre. Calculate the quantity of fumigant needed:

$$50 \text{ gals/acre} \times 120 \text{ acres} = 6,000 \text{ gallons}$$

Calculate the required fumigant flow rate for the application:

- 6,000 gallons of fumigant must be delivered over 46.3 hours (2,778 minutes)
- $6,000 \text{ gals} \div 2,778 \text{ min} = 2.2 \text{ gals/min}$

Convert to ounces per minute:

$$2.2 \text{ gals/min} \times 128 \text{ oz/gal} = 282 \text{ oz/min}$$

Row Acres

Another useful calculation for determining the treated area for bedded/row applications is the row-acre calculation. The term **row acre** or **plastic acre** is the number of linear feet of row that equal one acre of ground. You need to calculate the number of linear feet in a row (knowing the spacing between rows) that equal an acre. Simply divide the area of an acre (43,560 square feet) by the distance between beds (width of row spacing) to find the linear feet of treated area in one acre of ground. Following is an example for a vegetable field composed of 100 plastic mulch-covered rows and uncovered row spacing. Each row is 1,000 feet in length. If the plastic covered rows are 3 feet wide and the row spacing is 6 feet, calculate the row acres present in the field:

- Calculate the linear feet in one acre of ground.
 - $43,560 \div 6 \text{ feet row spacing} = 7,260 \text{ linear feet of row acres.}$
 - 7,260 linear feet of rows equals an acre of ground.
- You need to treat 100 rows that are 1,000 feet long.
 - $100 \text{ rows} \times 1,000 \text{ ft} = 100,000 \text{ linear feet of row.}$
- Divide the number of linear feet per row by the linear feet in one acre of ground, calculated above.
 - $100,000 \div 7,260 = 13.77 \text{ row acres.}$
 - 100 rows is equivalent to 13.77 acres.



The use of **end guns** is prohibited when making fumigant applications via chemigation.

Broadcast Equivalent Rate

When fumigant is applied in bedded or strip applications, a portion of the acreage in the application block is treated (i.e., the area of the treated beds or strips) and other areas within the application block are not treated. The **broadcast equivalent rate** is the application rate for the fumigant applied to the entire application block based on amount of fumigant applied in beds/strips and the size of untreated areas. The application block includes untreated areas between the rows and any in-field ditches or roadways. The broadcast equivalent rate is essentially the total amount of fumigant applied to the treated area (in gallons or pounds) divided by total land area in the application block in acres (subtracting the area for in-field ditches and roads). Product labels may specify maximum application rates in terms of amount of fumigant applied in beds/strips or the broadcast equivalent rate. However **all labels specify the buffer zone distances based on broadcast equivalent rate**. You must report the broadcast equivalent rate in the FMP for buffer zone distances and buffer zone credits.

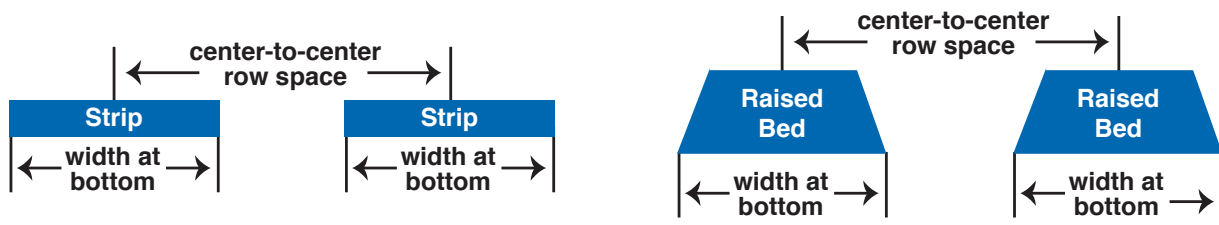
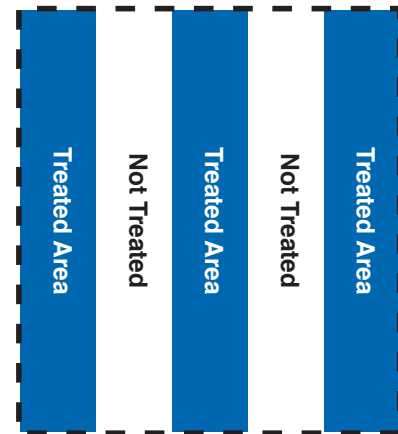
To calculate the broadcast equivalent rate for bedded or strip applications, you need the following information:

- Application block size (acres)—the area within the perimeter of the fumigated part of the field with the acreage of normally untreated portions of the field (roadways, ditches) subtracted.
- Pounds (or gallons) of product per treated acre—rate of product applied in the bed.

Broadcast Equivalent Rate Calculation

Information Needed

- ▶ **Application block size** (area within perimeter of fumigated portion of a field, including furrows, ditches, roadways; perimeters indicated by dashed line in illustrations at right and at bottom)
- ▶ **Amount of product per treated acre** (ratio of **total product applied** to size of **total area treated**; for bedded or strip applications, **total area treated** is summation of area of each treated bed or strip, as indicated by solid color areas in illustrations; untreated areas between strips or beds are not factored into total area treated; in example at right, if total block were 1 acre, treated areas would be 0.6A or 60% of the application block area)
- ▶ **Strip or bed width at bottom** (as illustrated below)
- ▶ **Center-to-center row spacing** (as illustrated below)



$$\text{Broadcast Equivalent Rate (lbs or gals product/acre)} = \frac{\text{Strip or Bed Bottom Width (inches)}}{\text{Center-to-Center Row Spacing (inches)}} \times \left(\frac{\text{IF APPLICABLE* Area of Strips or Beds + Row Spacing}}{\text{Application Block Size}} \right) \times \text{Product/Treated Acre Applied in Strip or Bed (lbs or gals)}$$

*This calculation included if there are ditches, waterways, drive rows and/or other non-fumigated areas within application block.

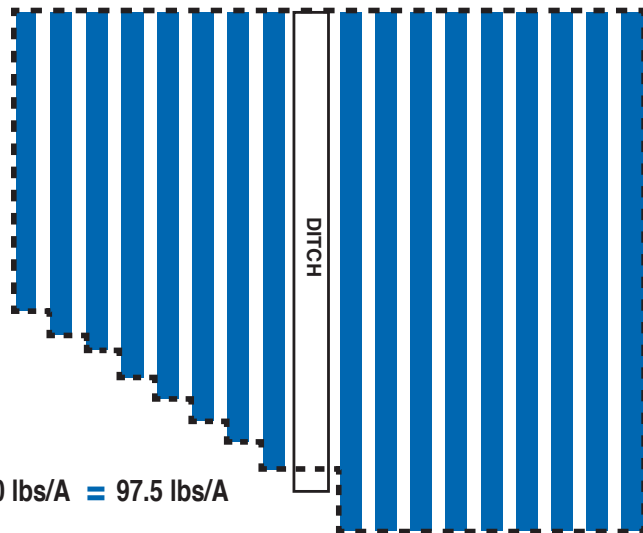
Sample Calculation

The graphic at right represents a shank-bedded field with the following parameters:

- bed width (at bottom) = 30 inches
- row spacing (center-to-center) = 60 inches
- product per treated acre in beds = 200 lbs
- application block size = 10 acres
- ditch is 0.25 acres
- area of beds + row spacing = 9.75 acres

Using calculation formula above, the Broadcast Equivalent Rate is **97.5 lbs product/acre**.

$$\frac{30 \text{ in.}}{60 \text{ in.}} \times \frac{9.75 \text{ A}}{10 \text{ A}} \times 200 \text{ lbs/A} = 0.5 \times 0.975 \times 200 \text{ lbs/A} = 97.5 \text{ lbs/A}$$



- Total treated area (measured)
 - Strip or bed bottom width (inches).
 - Center-to-center row spacing (inches).

For example, the application rate is 200 pounds per treated acre and the application block size is 10 acres. There is a 0.25 acre ditch; thus, 9.75 acres with treated beds and untreated furrows. The width of the bottom of the treated bed is 30 inches and the distance between the centers of two adjacent beds is 60 inches. By using the calculation in the illustration, the broadcast equivalent rate is 97.5 pounds per treated acre. Applying 200 pounds per treated acre of bed equates to a broadcast equivalent rate of 97.5 pounds per acre for the application block as a whole.

Equipment Calibration

Application equipment must be correctly calibrated before making a soil fumigation application so the recommended amount of fumigant is applied to the treatment area (application block). If equipment is not properly calibrated, the fumigant may be underapplied, overapplied, or applied inconsistently. If you apply too little fumigant or apply it unevenly across a field, expect poor or variable pest control. This is an expensive mistake because it jeopardizes crop quality or yield, and possibly necessitates retreatment. Too much fumigant increases the risk to handlers and bystanders; threatens the environment; and may lead to **phytotoxicity**. It also wastes product and is an unnecessary expense!

With the computer controls and flow meters that are available for application equipment, calibration is done electronically with a rate controller system with a flow meter, control valve, and GPS guidance and mapping systems. Make sure you have the use instructions for your application equipment and become

Useful Conversions for Calibration

1 acre = 43,560 feet (ft²)

1 gallon (gal)

= 4 quarts (qt)

= 8 pints (pt)

= 128 fluid ounces (fl oz)

= 3,785 milliliters (ml)

1 fl oz = 29.57 ml

1 cubic foot of water = 7.481 gal

1 acre inch of water = 27,156 gal

1 pound (lb)

= 16 oz

= 453.6 grams (gm)

1 mile per hour (mph)

= 88 feet per minute

= 1.467 feet per

second (ft/sec)

Circle *circumference* = $2 \times \pi \times r$

r = radius of circle

$\pi = 3.1417$

Circle *area* = $\pi \times r \times r$

r = radius of circle

$\pi = 3.1417$

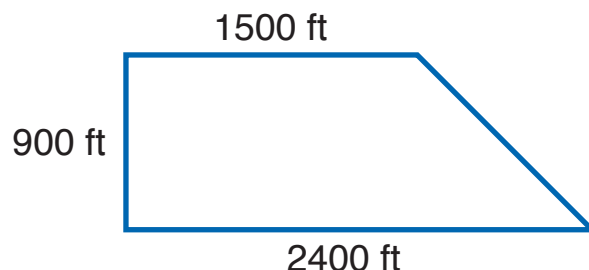
familiar with how it operates to ensure you achieve an accurate fumigation.

Flow meters are a tool that controls the volume of soil fumigant being applied. A flow meter measures the volume of fumigant that passes through equipment per unit time. Although flow rate is usually calculated in gallons per minute, most flow meters indicate flow rate as a percentage of their maximum output (% flow rate).

If your equipment does not have flow meters and computer controls, determine the output rate per area. This can be accomplished by measuring the amount of fumigant applied over a known area, or for a predetermined time. Realize that handling the fumigant for a calibration exercise greatly increases risk of exposure to the certified applicator and fumigant handler.

REVIEW QUESTIONS

1. What is the area, in acres, of the irregularly-shaped field shown? Given: The base of the field is 2,400 feet, the width of the field is 900 feet, and the field measures 1,500 feet across the top. (1 acre = 43,560 feet²)



- A. 3.4 acres.
- B. 34.4 acres.
- C. 40.3 acres.

2. How many row acres are in a field that contains 300 rows, each 450 feet long, each covered with a 3-foot wide film of plastic spaced 6 feet apart?

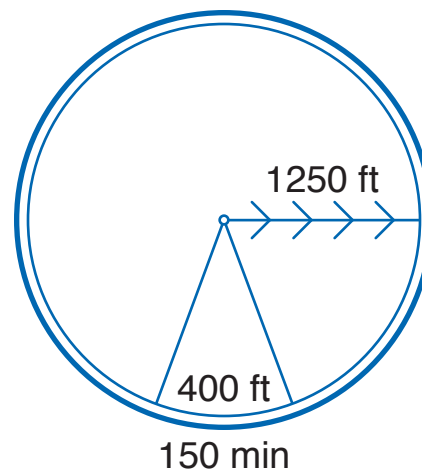
- A. 6.39 acres.
- B. 12.25 acres.
- C. 16.90 acres.
- D. 18.60 acres.

3. True or False: If application equipment is not properly calibrated and it delivers too little fumigant to the field, you should expect poor or variable pest control.

4. A center pivot system covers 1,250 linear feet. In 150 minutes, the pivot end wheel travels 400 feet. How many hours will it take the pivot to complete one revolution?

Given: Circumference = $2 \times \pi \times r$, area = $\pi \times r^2$, and 1 acre = 43,560 ft².

- A. 16.3 hours.
- B. 24.5 hours.
- C. 49.1 hours.



Answers to Review Questions

- 1. C**—To find the area, first break the field into two shapes: a rectangle and a triangle. The rectangle measures 1,500 feet long and 900 feet wide. The remaining part of the field is a triangle with a base of 900 feet and a height of 900 feet. The area of the field is the sum of the area of the rectangle and the triangle.
 - The rectangle area = $w \times l = 900 \text{ ft} \times 1500 \text{ ft} = 1,350,000 \text{ ft}^2$
 - The triangle area = $\frac{1}{2} \times b \times h = 0.5 \times (900 \text{ ft} \times 900 \text{ ft}) = 405,000 \text{ ft}^2$
 - The area of the field is the sum of the two = $1,350,000 \text{ ft}^2 + 405,000 \text{ ft}^2 = 1,755,000 \text{ ft}^2$
 - Convert to acres:
 $1,755,000 \text{ ft}^2 \div 43,560 \text{ ft}^2/\text{acre} = 40.3 \text{ acres}$
- 2. D**—To figure the row acres:
 - $43,560 \div 6 \text{ foot row spacing} = 7,260 \text{ linear feet of row acres.}$
 - Treating 300 rows 450 feet long
 - $300 \times 450 = 135,000 \text{ linear feet of row}$
 - $135,000 \div 7,260 = 18.60 \text{ row acres}$
- 3. True.**
- 4. C**—To figure the revolution time for the pivot, you must know the end wheel circumference:
 - $C = 2 \times \pi \times r$
 - $C = 2 \times 3.14 \times 1,250 \text{ ft}$
 - $C = 7,850 \text{ ft}$
 - Set up a ratio to calculate the revolution time:
$$\frac{150 \text{ minutes}}{400 \text{ ft}} = \frac{x \text{ minutes}}{7,850 \text{ ft}}$$
 - $x = (150 \text{ min} \times 7,850 \text{ ft}) \div 400 \text{ ft}$
 - $x = 2,943 \text{ minutes}$
 - $2,943 \text{ minutes} \div 60 \text{ minutes/hour} = 49.1 \text{ hours}$

TRANSPORTATION, STORAGE, DISPOSAL, SPILL RESPONSE, AND EMERGENCY RESPONSE PLANS

LEARNING OBJECTIVES

After studying this chapter, you should be able to:

- Describe and interpret label requirements for transportation, storage, spill cleanup, and emergency response for soil fumigants.
- Explain how to safely dispose of fumigant containers and contaminated soil.
- Describe how to manage empty containers.
- Explain what information is found on a Material Safety Data Sheet (MSDS) and how to locate it.
- Locate spill response information and procedures for specific products in the *Emergency Response Guidebook*.

Soil fumigant labels include information and requirements on safe and legal transport, storage, disposal, spill cleanup, and emergency procedures. As a certified applicator, you must read, understand, and follow all label directions.

Your state's, tribe's, or territory's core pesticide laws and safety manual includes the basic regulations and safety precautions for proper handling of fumigants. Be aware that your state, tribe, or territory may have additional laws for handling fumigants that are more restrictive than the label. These laws may also cover transportation, storage, disposal, spill cleanup, and emergency procedures. As always—know and follow applicable laws.

Transportation

As you would with any pesticide, take special care when transporting fumi-

gants. However, accidental leaks and spills are sometimes beyond your control. Spilled materials may cause serious harm, both to people and to the environment. Chemicals that spill onto roads may wash into ditches, streams, or rivers. This may contaminate groundwater and pollute surface water, causing fish kills. Pesticide spills may also contaminate vehicles, occupants, and cargo.

Use common sense and take the following precautions to prevent accidents:

- Do not use public transportation (subways, buses, trains, or taxis) to transport fumigants.
- Do not transport fumigants through tunnels without the permission of your state department of transportation.
- Read the label and Material Safety Data Sheet (MSDS) to determine the **placarding** requirements for trans-

Always read, understand, and follow label directions. The label is the law.



Always keep pesticides and their empty containers out of the reach of children.

porting each fumigant. Contact the fumigant manufacturer or distributor for more information on placarding for transportation.

- Mount cylinders so they are protected from rear-end collision.
- Do not remove protective valve covers on fumigant containers until just before use.

Always follow federal and state transportation regulations when transporting fumigants and/or their containers, including placarding requirements. Refer to the U.S. DOT website, <http://www.dot.gov>, for information on the proper transport of fumigants.

Storage

Storage of fumigants poses unique hazards. Some products are stored for short periods of time in the field (bulk) and some are stored in buildings (cylinders). Typically fumigants are purchased just before use to shorten the storage period. When large quantities of fumigant are needed, they are delivered to the field location in bulk tanks.

For products that are stored indoors, a separate building that is well ventilated or has a mechanical exhaust system is the best choice. If there is no separate storage area for fumigants, isolate fumigants within the pesticide storage area. This reduces the chance of vapors contaminating other pesticides. Be sure that

all fumigant storage areas are locked and posted as pesticide storage. Further, warning signs should indicate the presence of fumigants. Follow these guidelines:

- Post additional warning signs on each entrance to the storage area that clearly indicate fumigants are stored inside.
- Ventilate the storage area before entering.
- Inspect fumigant containers regularly. Fumes can escape from faulty valves or corroded containers.
- Keep metal fumigant containers off the ground to reduce exposure to moisture, which can lead to rusting.
- Protect containers from temperature extremes.
- Never store fumigants in employee work areas.

The National Fire Protection Association places certain limits on the storage of flammable and combustible goods based on location, size and type of container, and the physical nature of the product; make sure you comply with their requirements. Check with your state, tribe, or territory for any storage laws specific for fumigants. Check each fumigant label for specific storage requirements—they vary by chemical. For example, you should tightly seal containers of dazomet. This chemical reacts with moisture and quickly releases fumigant vapors.

Disposal

Consult the product label for information about how to dispose of unwanted fumigant. You can also seek guidance from your county or regional disposal agencies. The label will tell you how to handle empty containers. In addition, you can ask the supplier about disposal or recycling of empty fumigant containers. Never handle fumigant containers or residues in a manner that contaminates water supplies.

Typically, empty fumigant containers require different handling than emp-

ty nonfumigant containers. Some small fumigant containers that are damaged and punctured during the application may be allowed to aerate until all fumigant residue has volatilized. You can then dispose of those containers in a sanitary landfill. For large bulk containers and any plastic containers, consider participating in a plastic recycling program. Contact the Agricultural Container Recycling Council, your dealer, or your state, tribe, or territory pesticide officials for more information.

Most fumigant containers are returned to the distributor or manufacturer. Cleaning fumigant containers before refilling is the responsibility of the refiller. Even partly filled cylinders are returnable under certain circumstances (check with the manufacturer). Identify partially full or defective containers.

Spill Response

A call to *CHEMTREC's* emergency phone number is generally the first call for spill response: 800-424-9300. Many fumigant labels also have a 24-hour spill hotline. Fumigant labels and their MSDSs provide both general and detailed instructions on how to respond to pesticide spills or leaks. For example, the label will state:

- Whether the use of PPE is required during spill response.
- Whether the material can be salvaged.
- What actions to take to minimize the risks to others.

An indoor spill requires complete aeration of a building before allowing anyone to enter without wearing a respirator. Additionally, your state regulatory agency that deals with hazardous material spills may have specific pesticide spill reporting requirements.

Inform your local fire department about what chemicals are in storage. If there is a fire, burning fumigants will likely produce toxic gases. Firefighters must recognize the need to evacuate

structures and have the proper respiratory equipment to protect themselves.

An outdoor spill often means contaminated soil. Requirements for disposing of fumigant-contaminated soils vary widely from state to state. Consult your local regulatory agency for guidance.

MSDS and the *Emergency Response Guidebook*

The MSDS provides valuable facts about the hazards of a particular pesticide. Manufacturers (registrants) prepare these informational sheets for each pesticide product. MSDSs must be provided to every person selling, storing, or applying fumigants. They do not take the place of the fumigant label.

The MSDS describes the chemical characteristics, safety and handling precautions, and hazards of the pesticide ingredients. It is product specific. Storage information and emergency spill or leak cleanup procedures are also included. If requested at the time of purchase, an MSDS must be provided at the point of sale. Otherwise, MSDSs are available for downloading or printing on various websites. Check the registrant's web page or other label and MSDS sites. Two examples include:

- Crop Data Management Systems: <http://www.cdms.net>.
- Agrian: <http://www.agrian.com>.

Because of the dangers of handling soil fumigants, certified applicators and fumigant handlers should be familiar with the information about the chemical properties and hazards found in MSDSs and other reference texts. A good source of emergency response information is the *Emergency Response Guidebook*. The latest version of this guide is available online, courtesy of the U.S. Department of Transportation, at <http://www.phmsa.dot.gov/hazmat/library/erg>. Before an emergency occurs:

- Be aware of the chemical properties of the specific fumigants that you use.



- Be familiar with the correct emergency response actions to take in case of a spill or leak.

Have both the MSDS and the *Emergency Response Guidebook* on hand to help you plan for emergencies and—when needed—respond to an emergency. Remember: the time to plan for an emergency is before it happens.

Emergency Response Plan

Accidents may happen when handling or applying fumigants. This is true even if you work carefully under the most controlled conditions. Fumigant emergencies may result from broken equipment, spills, fires, theft, misapplication, or carelessness in storage or handling. Learn to recognize emergencies and know how to respond to them quickly. Many fumigant labels have 24-hour emergency assistance numbers.

Fumigant applications require emergency preparedness because of the dangers involved and the complexity of fumigation operations. Preparing for a fumigation includes:

- Learning about possible fumigant emergencies.

- Knowing and being able to carry out the correct response procedures.
- Having the necessary tools to respond.

Product manufacturers have prepared field fumigation emergency responder guides. Consider obtaining this useful information.

As previously discussed in Chapter 8, fumigant labels require the preparation of a Fumigant Management Plan. This includes documenting the plan for responding to emergencies that might arise any time from the start of the application through the entry-restricted and buffer zone periods, or through tarp perforation and removal. FMPs are site-specific plans prepared **before** fumigation begins. They ensure that all aspects of a safe and effective fumigation have been planned ahead of the actual work. An FMP includes emergency procedures, communication plans among key parties, and hazard communication procedures. See Chapter 8 for detailed information about FMPs.

All people who help store or apply fumigants—or who might be in the area where fumigants are stored or applied—must be trained in emergency recognition and response. A checklist can help you prepare for emergencies. Have the fumigant label, FMP, emergency PPE, and appropriate communication devices on hand at all times.

CHECKLIST: PREPARING FOR PESTICIDE EMERGENCIES	
<ul style="list-style-type: none"> <input type="checkbox"/> Be prepared for an accident. When accidents happen, the best response is a quick response. <input type="checkbox"/> Develop an emergency response plan for pesticide exposures and accidents (spills, leaks, and fires). <input type="checkbox"/> Train all of your handlers how to handle emergencies. <input type="checkbox"/> Obtain first aid supplies and keep a set in each truck or work place. Keep them updated. <input type="checkbox"/> Be sure to have adequate clean water for routine washing during the work period, emergency washing of the entire body, and eye flushing. 	<ul style="list-style-type: none"> <input type="checkbox"/> Obtain information about the pesticides you are using, including copies of all labels and MSDSs for each pesticide you use and put them in the truck or at the workplace. Contact the National Pesticide Information Center (www.npic.orst.edu) for more pesticide information. <input type="checkbox"/> Take training on first aid procedures, including rescue breathing and CPR. <input type="checkbox"/> Locate and make arrangements for emergency medical care for you and your employee handlers before you need emergency care. <input type="checkbox"/> Post the name, location, emergency telephone number, and address of the emergency care facility in your vehicle and at your workplace.

REVIEW QUESTIONS

- 1. What is the BEST source for storage requirements for a particular fumigant?**
 - A. State environmental quality agency.
 - B. The Department of Transportation website.
 - C. The pesticide label.
- 2. Which of the following could you find on the pesticide label?**
 - A. Container disposal requirements.
 - B. Placarding requirements for transporting fumigants.
 - C. Installation procedures for ventilation devices in fumigant storage areas.
- 3. Which of the following could you find in the *Emergency Response Guidebook*?**
 - A. Placarding requirements.
 - B. Emergency spill and response information.
 - C. PPE requirements for each fumigant.
- 4. Which of the following is the best way to clean up a spilled fumigant?**
 - A. Cover it with kitty litter and sweep it into the garbage.
 - B. It depends on the fumigant; consult the fumigant label.
 - C. Do not clean up the spill; call the appropriate authorities.

Answers to Review Questions

- 1. C**—The pesticide label provides explicit instructions on how to properly store the fumigant. However, your state regulatory agency may have additional requirements. The MSDS is also an excellent source of information.
- 2. A**—The pesticide label includes requirements for proper disposal of empty pesticide containers.
- 3. B**—Emergency spill and response information for fumigants is detailed in the *Emergency Response Guidebook*.
- 4. B**—Spill cleanup procedures vary for different fumigants and are explicitly stated on the label.

GLOSSARY

Acute Inhalation Exposure. An exposure to a single dose of a pesticide that is inhaled.

Adsorb. When one particle physically binds to the exterior surface of another (e.g., a fumigant binds to a soil particle or to the material in a respirator).

Air-Purifying Respirator (APR). Respirators that filter contaminants through a cartridge or canister when air passes through them upon inhalation. The cartridge or canister fits on a facepiece and are specific for one type of chemical (e.g., organic vapors). Air-purifying respirators are also called gas mask/canister combinations.

Annual Crop. A crop that completes its life cycle in less than 12 months.

Application Block. Area within the perimeter of the fumigated part of a field or greenhouse (including furrows, irrigation ditches, and roadways). The perimeter of the application block is the border that connects the outermost edges of the total area treated with the fumigant product.

Application Is Complete. The time at which the fumigant is no longer being delivered or dispensed into the soil and the soil has been sealed and/or drip lines have been purged.

Application Rate. The ratio of fumigant mass applied compared to the soil surface area (e.g., pounds of product per acre). The amount of pesticide that is applied to a known area.

APR. See Air-Purifying Respirator (APR).

Ataxia. Failure of muscular coordination; irregularity of muscular action.

Available Water Capacity (field capacity). The amount of soil moisture or water content held in soil after excess water has drained away. It varies depending on soil type.

Bacteria (singular: **Bacterium**). Single-celled microorganisms that can cause plant diseases. Bacteria damage plant tissues and cause symptoms such as wilt, necrosis, and soft rot.

Breathing Zone. Area within a 10-inch radius of the nose and mouth. Labels require that handler air-monitoring samples be collected in the breathing zone outside any respiratory protection equipment.

Broadcast Equivalent Rate. The rate of fumigant applied to the fumigated part of the field (i.e., rate within the bed or strips). Calculate for bedded and strip applications.

Buffer Zone. A restricted-access area established around the perimeter of each application block. The buffer zone must extend outward from the edge of the application block perimeter equally in all directions. Nonhandlers must stay out of the buffer zone during the buffer zone period.

Buffer Zone Credits. Credits that may be earned for certain practices or site conditions that reduce the potential for fumigant off-gassing. These include having high soil organic matter and using high barrier tarps. Buffer zone credits may reduce the size of a buffer zone.

Buffer Zone Period. A timeframe that begins at the start of the application and lasts for at least 48 hours after the application is complete. Nonfumigant-trained handlers must stay out of the buffer zone during the buffer zone period.

Bystander. A person who may be near a fumigation but is not involved in it. Bystanders live, work, or otherwise spend time near fumigated fields and may be exposed to fumigant emissions that travel offsite. They include field workers, neighbors, and people passing nearby.

Calibrate. To properly adjust equipment to deliver soil fumigant at a specific rate.

Carcinogen. A cancer-causing substance or agent.

Certified Applicator. A person certified through a federal, state, tribe, or territory agency who is qualified to apply or supervise the application of restricted-use pesticides. Includes both commercial and private applicators.

Certified Applicator-In-Charge. The person responsible for the entire fumigation application, buffer zones, monitoring and supervision of handlers.

Chemigation. The process of applying a pesticide through an irrigation system (e.g., center pivot, drip tape, lateral move).

Chisel. A strong, heavy, tractor-drawn tillage tool with curved points used to stir soil deeply without turning it.

Chronic Exposure. Continuous or repeated exposure to a substance over a long period.

Circumference. The distance around the edge of a circle (or any curvy shape); the perimeter of a circle.

Commercial Applicator. All nonprivate certified applicators.

Crop Rotational Interval. The period between harvesting one crop and planting another.

Cyanosis. Blue or purple coloration of the skin or mucous membranes due to lack of oxygen in the tissues near the skin surface.

Delirium. Acute onset of disorganized behavior or confusion. Delirium is not a disease but rather a set of symptoms caused by an underlying condition (such as overexposure to fumigants).

Dermal Exposure. Exposure to a substance by contact with the skin.

Dermatitis. Inflammation, itching, or irritation of the skin, or a rash occurring after exposure to a chemical.

Diameter. A straight line going through the center of a circle connecting two points on the circumference.

Difficult-to-Evacuate Sites. Certain facilities (e.g., schools, state-licensed daycare centers, nursing homes, assisted living facilities, hospitals, in-patient clinics, and prisons) that are difficult to evacuate in an emergency.

Direct Supervision. The oversight by a certified applicator of any restricted use pesticide application made by noncertified people. The specific requirement for direct supervision varies by state, but in all cases the certified applicator is ultimately responsible for the application. For soil fumigants, “onsite supervision” is required, which means the certified applicator-in-charge is physically present during the entire application, except water-run applications.

Drench Application. An application with high volumes of water that nearly saturate the soil.

End Gun. A high-pressure sprinkler located at the terminal of a lateral move or center pivot.

End of Service Life Indicator (ESLI). A device found on an air-purifying respirator that changes color as the filter media absorbs the fumigant. The service life of the filter is expired when the color change fills the indicator window.

Entry-Restricted Period. The interval after a fumigation in which entry into the application block is restricted to any person other than fumigant handlers wearing appropriate PPE. It begins at the start of the application and ends when the tarps are perforated and removed (if tarps are used). The end time is variable depending upon whether the application was sealed with tarps or not. Check the label for specific end times.

ESLI. See End of Service Life Indicator.

FID. See Flame-Ionizing Detector (FID).

Field Capacity. See Available Water Capacity.

Flame-Ionizing Detector (FID). A portable gas detector that reacts to a variety of organic compounds.

FMP. See Fumigant Management Plan (FMP).

Fumigant. A type of pesticide that is either applied as a gas, or once applied, forms a gas that is toxic to plants, animals, and microorganisms.

Fumigant Handler. A person trained and equipped in accordance with the requirements of the WPS (40 CFR Part 170) who performs handling tasks as listed on product labels, including both agricultural or nonag uses. For fumigants, most labels list all fumigant handler activities. Fumigant handlers must receive fumigant-specific safety information before being able to work with fumigants.

Fumigant Management Plan (FMP). A written plan for a specific fumigation that is prepared before the start of the fumigation.

Fumigant Safe Handling Information. Information that must be provided annually to handlers that must include the following: (1) what fumigants are and how they work, (2) safe application and handling of soil fumigants, (3) air monitoring and respiratory protection requirements for handlers, (4) early signs and symptoms of exposure, (5) appropriate steps to take to mitigate exposures, (6) what to do in case of an emergency, and (7) how to report incidents. Examples of this information may be provided where fumigants are purchased and on EPA's soil fumigant toolbox website.

Fungi (singular: **Fungus**). Plant pathogens that invade plant tissue, causing plant disease.

GAPs. See Good Agricultural Practices (GAPs).

Gas Detector Tubes. Single-use, disposable glass tubes used for air monitoring. They can detect specific fumigants at lower levels than other gas detectors.

Good Agricultural Practices (GAPs). A collection of principles for on-farm production processes that result in safe and healthy food and nonfood agricultural products. GAPs encourage economic, social, and environmental sustainability. Fumigant labels specify mandatory GAPs.

Handler. A person who directly works with pesticides (e.g., during mixing, loading, transporting, storing, disposing, and applying, or while working on pesticide equipment).

Insect. Arthropods characterized by a body composed of three distinct regions, three pairs of legs, and one pair of antennae.

Liquefied Gas. A gas that is maintained as a liquid by cooling or by storing under pressure.

Low Release Height—Solid Stream Center Pivot Applications. An uninterrupted liquid stream released less than four feet above the ground, where the stream remains generally as a coarse flow until contacting the intended target. An example of a solid stream application is Smart Drop®, also known as drizzle boom. Any application system that employs sprayheads or nozzles with moving parts that produce a rotating or oscillating spray pattern (e.g., rotators, spinner, nutators, and wobblers) or that otherwise break up the stream into droplets does not qualify as a solid stream nozzle.

Material Safety Data Sheet (MSDS). A factsheet that provides basic information on a material or chemical product. It contains information intended to provide workers and emergency personnel with procedures for handling or working with that substance in a safe manner, and includes information such as toxicity, health effects, first aid, protective equipment, storage, disposal, spill-handling procedures, and physical data (melting point, boiling point, flash point, reactivity).

Maximum-Use Concentration (MUC). The greatest air concentration of a hazardous substance from which a person can expect to be protected when wearing a respirator.

Methyl Isothiocyanate (MITC). A degradate of some soil fumigants (metam sodium, metam potassium, dazomet) that is the volatile and active form of the fumigant.

Methyl Isothiocyanate (MITC) Generator. Fumigant chemicals that convert to methyl isothiocyanate when exposed to water. MITC generators include metam sodium, metam potassium, and dazomet.

MITC. See Methyl Isothiocyanate (MITC).

Montreal Protocol. An international treaty intended to reduce emissions of ozone-depleting chemicals (including methyl bromide).

MSDS. See Material Safety Data Sheet (MSDS).

MUC. See Maximum-Use Concentration (MUC).

National Institute for Occupational Safety and Health (NIOSH). The federal agency responsible for conducting research and making recommendations for the prevention of work-related injury and illness.

Nematode. Microscopic, slender, colorless roundworms that live in soil or water or as parasites of plants, animals, or fungi.

NIOSH. See National Institute for Occupational Safety and Health (NIOSH).

Occupational Safety and Health Administration (OSHA). The federal agency responsible for regulating and enforcing labor laws, including the safe use of hazardous chemicals in the workplace.

Occupied Structures. Buildings that contain people or where people may enter intermittently. These include residences, businesses, equipment buildings, barns, sheds, and other structures.

Off-Gassing. The release of a gas previously dissolved, trapped, frozen, or absorbed in some material. In this manual, it refers to the movement of a fumigant from the soil into the atmosphere.

Onsite Supervision. The oversight by a certified applicator-in-charge of a fumigant application where the certified applicator remains onsite for the entire application (except for water-run applications).

OSHA. See Occupational Safety and Health Administration (OSHA).

Owner. Any person who legally possesses an agricultural establishment (such as a farm). A person who has both leased a farm to another person and granted that same person the right and full authority to manage and govern the use of the farm is not an owner. See the definition of owner in WPS (40 CFR §170.3).

Ozone. A colorless, odorless reactive gas that is found naturally in the earth's stratosphere. Ozone absorbs ultraviolet radiation that could be harmful to life on earth.

PAPR. See Powered Air-Purifying Respirator (PAPR).

PAS. See Postapplication Summary (PAS).

Pathogen. A bacterium, virus, or other microorganism that can cause disease.

Perennial Crop. A crop that completes its life cycle in more than 12 months (e.g., mint, grapes, and apples).

Personal Protective Equipment (PPE). Protective clothing, respirators, eyewear, or other devices designed to protect the wearer's body from chemical exposure.

Photoionization Detector (PID). A portable gas detector that reacts to a variety of organic compounds.

Phytotoxicity. Chemical injury to plants.

PID. See Photoionization Detector (PID).

Placard. Diamond-shaped signs required by the U.S. Department of Transportation for vehicles that are transporting hazardous materials.

Plastic Acre (row acre): The number of linear feet of row that would fit in one acre of ground.

Postapplication Summary (PAS). A postapplication record of data collected for a specific fumigant application. It documents any deviations from the FMP, any incidents or complaints, measurements taken to comply with GAPs, and a summary of the weather forecast.

Powered Air-Purifying Respirator (PAPR). Respiratory equipment that uses a blower to move contaminated air through one or more purifying filters.

PPE. See Personal Protective Equipment (PPE).

Private Applicator. A person certified by a state agency who can purchase, use, and supervise the use of restricted use products on their own or an employer's property (nurseries, greenhouses) for the purposes of producing an agricultural commodity.

Pulmonary Congestion. Excessive accumulation of blood or other fluid in the lungs.

Pulmonary Edema. Fluid accumulation in the lungs.

Radius. The distance from the center to the edge of a circle. It is half of the circle's diameter.

Registrant. A chemical company that registers pesticides for use.

REI. See Restricted-Entry Interval (REI).

Representative Handler Tasks. During air monitoring, the locations and handler activities sampled must represent each handler's exposure occurring within the application block.

Restricted-Entry Interval (REI). The time specified in the pesticide label's Agricultural Use Requirements section which states the time period immediately following a pesticide application during which entry into the treated area is restricted.

Restricted-Use Pesticide (RUP). A pesticide that can be purchased only by certified pesticide applicators and used only by certified applicators or persons under their direct supervision. Not available for use by the noncertified people because of high toxicity and/or environmental hazards.

Roadway. The part of a street or highway that is designed and used for vehicular travel. It does not include the sidewalk or shoulder. The term “roadway” can also refer to two or more separated roadways.

Row Acre (plastic acre): The number of linear feet of row that would fit in one acre of ground.

RUP. See Restricted-Use Pesticide (RUP).

SCBA. See Self-Contained Breathing Apparatus (SCBA).

Self-Contained Breathing Apparatus (SCBA). Respiratory equipment that supplies fresh air from an outside or portable source. Air enters a mask that tightly covers the entire face.

Sensory Irritation. A physical reaction to a certain fumigant air concentration. It can include burning or irritation of the eyes, nose, or mucous membranes. Sensory irritation may occur when people inhale fumigant vapors.

Shank. The curved iron bar that connects the working point of a cultivator to its beam or crossbar. Different types of working points can be attached to each shank.

Soil Fumigant Training Program. Certified applicator training that provides information on:

- 1) How to correctly apply the fumigant, including how to comply with label requirements.
- 2) How to protect handlers and bystanders.
- 3) How to determine buffer zone distances.
- 4) How to complete a fumigant management plan and the postapplication summary.
- 5) How to determine when weather and other site-specific factors are unfavorable for fumigant application.
- 6) How to comply with required GAPs, and how to document compliance with GAPs in the FMP.
- 7) How to develop and implement emergency response plans.

Soil Organic Matter. The part of the soil that includes plant and animal residues at various stages of decomposition.

Soil Pores. The part of the soil space that holds air and water; the air spaces between soil particles.

Soil Texture. Relates to the size and type (i.e., clay, silt, and sand) of the soil particles and the pore spaces within the soil.

Soil Tilth. The physical condition of soil relative to its suitability for a fumigant application or fitness as a seedbed.

Soil Water. The water held within the soil pores that makes up part of the soil solution. Soil water supplies nutrients to growing plants.

Solid Stream. An uninterrupted liquid stream that remains as a coarse flow until contacting the intended target. An example of a solid stream application is SmartDrop®, also known as a drizzle boom.

- Start of the Application.** The time at which the fumigant is first delivered or dispensed into the soil in the application block.
- Symphylans.** Soil-dwelling arthropods also known as garden centipedes.
- Tensiometer.** An instrument that measures soil moisture.
- Trigger Level.** The air concentration of a fumigant that triggers the requirement for a fumigant handler or certified applicator to use specific respiratory protection in order to continue working in the area being fumigated.
- True Fumigants.** Certain fumigants (e.g., methyl bromide, 1,3-dichloropropene, methyl iodide, and chloropicrin) that move through the soil as a gas.
- Vapor Phase.** The state in which a liquid or solid fumigant becomes a gas (vapor).
- Vapor Pressure.** A measure of how quickly a chemical liquid will evaporate.
- Volatile Liquid.** Liquid that readily becomes a gas.
- Volatile Solid.** Solid that readily becomes a gas.
- Volatility.** The degree to which a substance changes from a liquid or solid state to a gas at ordinary temperatures when exposed to air.
- Volatilization.** The change from a solid or liquid to a gas or vapor. Fumigants by their nature are likely to volatilize.
- Warning Agent.** A chemical, such as chloropicrin, that is added to other chemicals because of its strong smell and irritant qualities. Warning agents alert people when they are being exposed to fumigant vapors.
- Water-Run Application.** The process of applying metam products through an irrigation system.
- Wireworms.** Soil-dwelling larvae of click beetles.
- Worker.** As defined in relation to soil fumigations, a worker is a person who is working in an agricultural field, greenhouse, nursery, or golfcourse and has no fumigant handling responsibilities. It includes people working in nearby fields. They are considered bystanders if near a fumigant application.
- Worker Protection Standard (WPS).** A federal regulation designed to protect agricultural workers (such as farm workers) and pesticide handlers (people mixing, loading, or applying pesticides, or doing other pesticide-related tasks). The WPS requires agricultural employers to provide protections to workers and handlers, including, but not limited to: safety training, posting of application sites, and decontamination supplies.
- WPS.** See Worker Protection Standard (WPS).
- WPS-trained worker.** An agricultural worker who is trained according to the federal Worker Protection Standard (WPS).

