PESTICIDE APPLICATION COMPENDIUM 9

Field Fumigation

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3. Explain how local regulations may be more restrictive than the label and importance of communicating with the agricultural commissioner.
4. Explain what a nonattainment area (NAA) is and how it affects the application of fumigants.
5. Describe reporting requirements for the various types of fumigant applications and the roles of the county agricultural commissioner and DPR.
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Fumigants are gaseous pesticides used to control pests in agricultural fields as well as in structures, stored products, and other sites. Applying fumigants poses many risks to people and the environment. Fumigants are general biocides, chemicals that have the potential to injure or kill most living organisms they come in contact with. They can be also classified as volatile organic compounds (VOCs), which have been identified as significant contributors to smog.

To mitigate air quality problems, new regulations regarding the use of fumigants used as field soil treatments went into effect in California in January 2008. These regulations do not affect the use of fumigants on structures, stored or harvested commodities, containerized soil, or individual tree and vine replant sites. For agricultural fields, the regulations limit the amount of fumigant that can be used in certain areas of the state, set specific requirements on how applications can be made to reduce emissions, and set tighter restrictions on fumigant application methods and reporting in certain areas of the state that have the most serious air pollution problems (nonattainment areas).

The new regulations also established a new licensing subcategory (O) for commercial field fumigation applicators. The rules specify that field fumigations carried out by licensed pest control businesses must be supervised by an applicator certified in the field fumigation subcategory. This rule applies statewide. However, private applicators are not required to have this certification to perform field fumigations.

LICENSING REQUIREMENTS FOR FIELD SOIL FUMIGATION, SUBCATEGORY O

This book is the study guide for people applying for the field fumigation qualified applicator license or certificate (QAL or QAC) in California. To obtain the license or certification after January 1, 2009, the applicator will need to pass an exam in the field fumigation pest control subcategory and also pass the Laws and Regulations exam. This chapter will primarily highlight the regulations specific to field fumigation in California. Pesticide laws provide general guidelines and regulations provide the specifics for how to comply. Copies of the complete laws and regulations regarding field fumigation are available on the California Department of Pesticide Regulation (DPR) website at http://www.cdpr.ca.gov/. General

information on laws and regulations for pesticide applicators is available in the *Laws and Regulations Study Guide* available from DPR. Additional information is contained in Chapter 4 of *The Safe and Effective Use of Pesticides*, UC ANR Publication 3324, the general study guide for persons preparing for California pesticide applicator certification and other pesticide use-related licenses.

In addition to knowing the laws and regulations related to pesticide use, applicators are expected to know how to properly handle and apply the pesticides they use and know about human health and environmental risks and how to avoid problems. This book includes information on fumigant materials (Chapter 2), site preparation considerations (Chapter 3), and application and soil sealing procedures (Chapters 4 and 5), as well as details on hazards, procedures for protecting people and the environment, and responding to emergencies (Chapters 6, 7, and 8). Applicants for the California field fumigation license or certificate will be tested in all of these areas. Knowledge Expectations shown at the beginning of each chapter list the information that applicators will need to know to pass the exam. Use the review questions at the end of each chapter to test your knowledge. As for other California pesticide applicator certifications, a minimum of 20 hours of continuing education every 2 years will be required to renew the certificate or license.

UNDERSTANDING PESTICIDE USE REQUIREMENTS

Pesticide laws and regulations can be confusing and sometimes may appear to be in conflict with each other. It is important to review and understand all pertinent laws and regulations and the pesticide label before applying a pesticide. This includes federal and state laws and regulations and any local use requirements noted in a restricted materials use permit issued by the county agricultural commissioner. All field soil fumigations require a permit. Any conflicts among federal, state, permit, or label restrictions must be resolved by always following the strictest requirements.

Table 1-1 lists regulatory requirements for fumigant applications and refers to sections of the California Food and Agricultural Code and the California Code of Regulations where they are discussed in more detail. This table can be used as a checklist to ensure that all requirements are met prior to an application. Information regarding many of these regulations is contained in this book, especially Chapters 7 and 8 and the sections below. All applicable laws and regulations are available on the DPR website.

Pesticide Labeling and Other Legal Use Requirements

California law requires that pesticides be used according to the registered container label and any supplemental labeling. The label contains use directions, requirements, restrictions, protections against health and environmental hazards associated with use, what to do in case of emergencies, and required personal protective equipment (PPE) for handling the pesticide. Labels also include registered application settings or treatment sites and approved methods of application.

In some cases labels refer to Technical Information Bulletins (TIBs). The TIB and any other supplemental written or graphic materials referred to in the label are also considered labeling. However, you should not rely only on labeling for assuring legal and safe applications.

You are also required to know the California pesticide laws and regulations, as well as the restricted materials permit conditions. Remember, you must follow the stricter of any conflicting requirements found in law, regulation, use permit conditions, and labeling covering each use situation. You cannot use two or more pesticides together, including fumigants, unless you can meet all of the labeling and other requirements for each pesticide.

TABLE 1-1

Checklist of California Regulations or Laws that Should Be Reviewed Prior to Carrying Out a Field Fumigation.

Requirement	Code *	Requirement	Code *
Pest control business (and equipment) registered in county	11732	Accident Response Plan at worksite	6780 (d)
Registered label available at use site	6602	Backflow prevention—air gap	6610
Notice of Intent submitted	6434, 6447.1 (a) (1)	Safe equipment	6742
Restricted materials use supervised	6406	Closed system used	6746
Fumigation handling activities	6445	Containers secure/under control	6670
Field fumigation licensing requirements	6445.5	Pesticide containers (including service containers) properly labeled	6676, 6778
Complies with permit conditions (aeration, reentry, site, rate, buffers, PPE)	12973	Proper pesticide transport	6682
Complies with labeling (aeration, reentry, site, rate, buffers, PPE)	12973	Methyl bromide: general requirements, buffer zones, methods, notification, posting, worker safety	6447, 6447.1, 6447.3, 6784
Personal protective equipment	6738	1,3-D: general requirements, methods	6448, 6448.1
Suitable methods/manner/climate	6600	Chloropicrin: general requirements, methods	6449, 6449.1
Accurate measurement	6604	Metam sodium, metam potassium, dazomet: general requirements, methods	6450, 6450.1, 6450.2
Protection of persons, animals, property	6614	Sodium tetrathiocarbonate: general requirements, methods	6451, 6451.1
Handlers trained	6724	Pesticide use reports, method (NAA)	6624, 6624 (f)
Emergency medical care posting	6726	Respiratory protection	6739
Decontamination facility, eyewash	6734	Field entry after pesticide application	6770
Field posting	6776, 6784 (a)	Limited work hours and workdays (methyl bromide)	6784 (b)
Gas concentration controlled & monitored	6780 (a,b)		

* Laws from Ca forn a Food and Agr cu tura Code (nd cated by 5-d g t numbers) and Regu at ons from the Ca forn a Code of Regu at ons (nd cated by 4-d g t numbers) as of Nov 14 2008 See the DPR webs te http://www cdpr ca gov

Nonattainment Areas

A major concern with field fumigants is their contribution to poor air quality, especially in some areas of the state where air pollution has caused human and environmental health concerns. Field fumigants are considered volatile organic compounds (VOCs) that contribute to air pollution. VOCs react with other compounds in the air in the presence of sunlight to form ozone. Ground-level ozone (smog) is the nation's most pervasive air pollutant. It can damage lung tissue, cause respiratory illness, and harm farm crops.

The California Air Resources Board has identified several air basins in California that do not meet the ozone standards set by the U.S. EPA. DPR must track and reduce pesticide VOC emissions in five of these ozone nonattainment areas (NAAs): Sacramento Metro, San Joaquin Valley, Southeast Desert, Ventura, and South Coast (Figure 1-1). DPR has responded to the need to reduce VOC sources by adding regulations that restrict the use of certain fumigants within the NAAs. These regulations include restricting total poundage of materials allowed, methods of application, and time of year that certain applications can be made, and increasing use-reporting requirements. These regulations may change over time and are available from the DPR website. Applicators must be aware of current regulations regarding the use of fumigants in the nonattainment areas they work in.

FIGURE 1-1

Federal nonattainment areas for field fumigants, January 2008. From DPR.

Restricted Materials Permit Conditions

California regulations list field fumigants as restricted materials, requiring property operators to possess a restricted materials use permit to possess, use, or store these pesticides. The county agricultural commissioner issues the restricted materials permit to the property operator and must include the name of the pest control business applying the material, as well as the name of the qualified applicator license holder responsible for the application. Use permits can impose use requirements that are stricter than those found in labeling or state regulation. These restrictions will vary according to certain criteria such as the restricted material, the location of the treatment site, the areas surrounding the treatment site, and the time of year.

An example of a use condition is a site-specific requirement placed on a permit to protect the public or the environment. Site-specific conditions might require an extended setback around a school or sensitive wetland or limit application times to periods when people are not present. These conditions are issued and enforced by the county agricultural commissioner. The applicator must be careful to observe all of the conditions. Simply following the label will lead to violations in cases where local site conditions are more stringent. Always get a use permit from the agricultural commissioner's office in the county of application and know all local requirements for fumigant use.

Pesticide Use Reporting

As with all pesticides used for the production of agricultural commodities, field fumigants fall within California's 100% pesticide use reporting requirements. In addition, for any field fumigant applied within an NAA, the pesticide use report must include the specific method of application as outlined in the regulations. Use reports are filed with the county agricultural commissioner.

Notification and Posting

Because of the potential for injury to people or crops in areas surrounding or near a fumigation, there are many regulations requiring that neighbors be notified of an impending fumigation. Workers often also must be notified. These regulations vary according to material, site, and locality. Some notification requirements are listed in state regulations, others on labels, and others are conditions of a restricted-use permit. In many cases, warning signs must be posted at the treated site to notify employees and the public about the date and time of the fumigation. In other cases, oral notification is a requirement. Chapter 7 provides additional information about notification and posting.

STEWARDSHIP PROGRAMS

In addition to the restrictions placed on a field fumigant's use by the label, laws and regulations, and permit conditions, the fumigant registrant may have a stewardship program that further restricts the actual use of their product. Stewardship programs are typically designed by registrants to gain better control and understanding over who buys and uses a fumigant, and how much is used. The most common components of stewardship programs involve specialized training and recordkeeping, and restricting product distribution. The goals for these programs are to ensure safety for handlers and other workers, the public, and the environment. In some cases, the registrant may restrict the distribution of the product to certain dealers to assure that applicators that have completed the training program. Check with registrants or their dealers for more information on stewardship programs. Stewardship programs are not part of federal, state, or county regulatory programs and are not regulatory requirements. County agricultural commissioners and DPR do not enforce their use. However, a county agricultural commissioner can condition a restricted materials permit so that handlers covered by the permit must complete a stewardship program before handling a fumigant.

CHAPTER 1: REVIEW QUESTIONS

1. **Who must have a subcategory "O" QAL or QAC?**
   a. anyone carrying out a field fumigation for hire
   b. only the person supervising the field fumigation for a licensed pest control business
   c. private applicators and qualified applicators doing field fumigations
   d. anyone carrying out a field fumigation in a nonattainment area
2. **A good source of information for finding out the current regulations regarding field fumigation methods is**
   a. the pesticide label
   b. the California Department of Pesticide Regulation website
   c. University of California study guides for pest control professionals
   d. all of the above
3. **When the label, the use permit, and DPR regulations conflict about permissible uses of a fumigant,**
   a. follow the strictest requirements
   b. follow the DPR regulations
   c. follow the label
   d. check with the manufacturer of the product
4. **In nonattainment areas,**
   a. fumigants can never be used
   b. a licensed QAL or QAC is always required when fumigating a field
   c. methyl bromide cannot be used
   d. methods of application are restricted for some fumigants
5. **Who must be notified when fumigants are applied?**
   a. all neighboring property owners
   b. all workers
   c. a & b
   d. it varies according to material and site
6. **DPR regulations regarding pesticide use reporting now require that method of application be reported**
   a. for all field fumigations
   b. for field fumigations in nonattainment areas
   c. for field fumigations by QALs or QACs
   d. when required as part of a stewardship program
7. **Stewardship programs**
   a. are now required for fumigant applications as part of the regulations to reduce VOCs
   b. are always voluntary for users of a designated product
   c. allow manufacturers to restrict use of their product to people who have been trained to safely handle their product
   d. allow users to forego use requirements in nonattainment areas if the stewardship program is carefully followed

Chapter 2: Fumigants

Knowledge Expectations

1. Describe and contrast true fumigants and less volatile products, including the mode of transport and distribution in the soil.
2. Describe the relative volatility, warning agents, the solubility and ability to move in water, movement in soil, persistence, the boiling point and appropriate uses (including application methods and target pests) of the following active ingredients:
   a. methyl bromide
   b. chloropicrin
   c. 1,3-dichloropropene (Telone II)
   d 1,3-dichloropropene emulsifiable concentrate (Telone EC, Inline)
   e. MITC generators
      metam sodium (Vapam, Sectagon)
      metam potassium (K-Pam, Sectagon-K)
      dazomet (Basamid)
   f. carbon disulfide liberators (Enzone)
3. Describe the toxicity and hazards associated with the active ingredients listed above.

Fumigants are chemicals that are pesticides in their gaseous state. Although applied as a solid or liquid, soil fumigants rapidly volatilize once in the soil to kill pests. A number of soil fumigants are currently available, and several others may come on the market in the future.

Fumigants can be roughly classified according to their ability to disperse through soils through fuming action of their vapors. Methyl bromide, chloropicrin, and 1,3-dichloropropene (1,3-D) disperse through soils primarily in the vapor phase. Sometimes called “true fumigants,” these materials move 2000 times faster via open air spaces in the soil than they disperse in the water films surrounding soil particles. True fumigants move as a gas via soil passageways, simultaneously dissolving into water films when they reach their target pest.

In contrast, methyl isothiocyanate (MITC) generators and carbon disulfide liberators are generally moved to the vicinity of target pests with irrigation water or through soil incorporation. After exposure to water, these materials release fuming agents which kill target pests within short distances.

The fumigants described in this chapter differ in the pests they control, their ability to reach and penetrate the target pest, and their potential to move off-site. See Sidebar 2-1 for definitions of important chemical properties of fumigants and their effects on fumigation. Tables 2-1 through 2-3 list various chemical properties of each fumigant. The two most important properties to consider when evaluating a fumigant’s ability to move within the soil are its Henry’s Constant value and its half-life in soil (Tables 2-2 and 2-3). However, to determine efficacy or usefulness of a material to control a pest, you will need additional information regarding biological activity. Likewise, information on fate in the soil and other factors must be considered to understand the potential for a fumigant to move off-target. Fumigant applicators must be attentive to many parameters to assure the best balance of field performance and environmental stewardship.

SIDEBAR 2-1

Chemical Properties and Their Importance in Fumigation

Vapor pressure is the pressure of a vapor in equilibrium with its nonvapor (liquid and solid) phases at a specific temperature. Fumigants with a high vapor pressure, such as methyl bromide, are more volatile and penetrate quickly, while compounds with a lower vapor pressure diffuse more slowly.

The **boiling point** of a chemical is the temperature at which the liquid stage boils under specific atmospheric conditions to become a gas. Fumigants that have low boiling points are gases at normal temperatures and pressures and are usually stored as liquids in high-pressure canisters. Fumigant materials with high boiling points, on the other hand, are liquids or solids at normal temperatures and pressures.

Henry's Constant is the ratio of the concentration of a chemical substance in air to its concentration in water solution at equilibrium. It is considered to be the most valuable indicator of a fumigant's movement through the soil under field conditions. The lower the numerical value of Henry's Constant, the more likely the material will be in the vapor phase and less likely it will be dissolved into the soil–water matrix. The higher values indicate the tendency of the fumigant to be held within soil water films, significantly limiting its movement through the soil profile.

Solubility in water is the maximum amount of a chemical that dissolves in water at a specific temperature and pH. Solubility affects the ease of movement through soil. In general, the higher the solubility value, the greater the likelihood for movement into water films.

Half-life in soil is the time required for a pesticide to degrade to one-half of its previous concentration. Half-life is an indicator of persistence of the chemical in the soil: the longer the half-life, the slower the pesticide degrades and the more persistent it is.

TABLE 2-1

General Properties of Fumigant Formulations[1].

Fumigant Material	Example Trade Names	Movement through Soil Under Field Conditions	Warning Indicators	Pests Controlled
Methyl bromide	Methyl bromide	Excellent	None; odorless, but must be formulated with chloropicrin in California	Broad spectrum
Chloropicrin	Chloropicrin	Good in well-tilled, low-moisture soil	Strong eye irritant, strong penetrating odor	Best for fungi and bacteria but some control of other pests
1,3-Dichloropropene	Telone	Good in dry soil, poor in moist soil	Sweet, pungent, garliclike odor	Primarily nematodes but also other pests
Methyl isothiocyanate generators	Vapam, Sectagon, K-Pam, Sectagon-K, Basamid	Limited, although moves well with water in coarse soils	Horseradish, garlic, or rotten-egg odor	Broad spectrum
Carbon disulfide liberator	Enzone	Limited, although moves well with water in coarse soils	Rotten-egg odor	Broad spectrum

[1] The general properties of field fumigants and their behavior under field conditions depend on soil temperature, soil moisture, soil organic matter, soil texture and preparation, material placement, and the physical properties of the formulated active ingredients found in Table 2-2. In general, cold, wet field conditions will retard a product's movement, as well as slow its decomposition.

TABLE 2-2

Physical Constants of Active Ingredients.

Fumigant Material	Example Trade Names	Henry's Constant[1]	Boiling Point (°F [°C])	Vapor Pressure[2] (mm Hg at 20°C)	Solubility in Water[3] (% w/w at 20°C)
Methyl bromide	Methyl bromide	3.8	39 (4)	1420	1.34
Chloropicrin	Chloropicrin	13	233 (112)	18	0.20
1,3-Dichloropropene	Telone	~19 (cis) ~30 (trans)	219 (104)	34	0.22
Methyl isothiocyanate	Vapam, Sectagon, K-Pam, Sectagon-K, Basamid	170	246 (119)	13	0.76
Carbon disulfide	Enzone	1.5	115 (46)	300	0.20

[1] See Sidebar 2.1 for definition of terms.

[2] mm Hg = millimeters of mercury

[3] % w/w = % by weight of total mass of mixture with water

TABLE 2-3

Persistence in Soil in the Field[1].

Fumigant	Half-life in Soil (persistence)[2]	% Dissipating Daily in Soil at 1-ft Depth at 25°C[3]
Methyl bromide	30–55 days (moderately persistent)	2–3%
Chloropicrin	1 day (nonpersistent)	20%
1,3-Dichloropropene	10 days (nonpersistent)	10–12%
Methyl isothiocyanate	7 days (nonpersistent)	20%
Carbon disulfide	1 day (nonpersistent)	50%

[1] Persistence in the soil in the field is influenced by temperature, soil type, moisture levels and microbial activity. These values are relative.

[2] Data source for half-life is Oregon State University Extension Pesticide Properties Database http://npic.orst.edu/ppdmove.htm

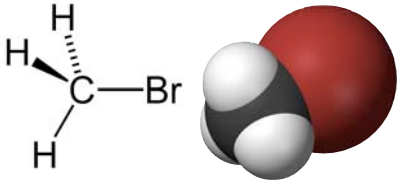
[3] Data from M. McKenry, Nematology, UC Riverside.

Fumigation products may be formulated as a mixture of active ingredients to control a broader range of pests. For instance, although a low concentration (0.5 to 2%) of chloropicrin is commonly added to other fumigants as a safety factor because of its distinct odor, it also can be added at higher concentrations (up to 50%) to increase the overall spectrum of pest control.

Registration status of fumigants is likely to change with regulatory concerns and as new products are developed and approved. Most of the discussion in this book applies to the five fumigant chemicals

registered in California at the time of publication. Sidebar 2.2 notes four unregistered chemicals that may come on the market in the future.

METHYL BROMIDE



Methyl bromide, also called bromomethane, has been a preferred preplant soil fumigant in the United States, particularly in California, since its registration in 1961. It is an excellent broad-spectrum fumigant, effective for managing many insects, nematodes, weeds, vertebrates, bacteria, and fungi. However, methyl bromide does not adequately control a number of pests, including some soilborne bacteria, fungi, and certain weed seeds. Some formulations contain 30 to 50% chloropicrin to broaden the range of plant pathogen pests that can be controlled.

The 1992 Montreal Protocol listed methyl bromide as an ozone depleting compound, requiring a phase-out of import and manufacture of methyl bromide worldwide by 2005, except for essential and critical use exemptions. There is an international ban on its use after 2015.

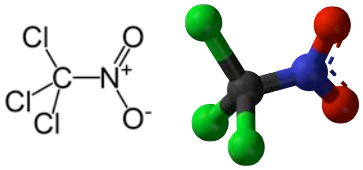
Under normal temperature and pressure, methyl bromide is a colorless, nonflammable gas, generally odorless but with a slight chloroform odor at higher concentrations. In California, low concentrations (0.5 to 2%) of chloropicrin, which has a strong odor and is an eye irritant, must be added to methyl bromide formulations to alert victims to poisoning. In the field, methyl bromide quickly vaporizes since its boiling point is very low, only 39°F (4°C). After application to the soil, methyl bromide gas moves primarily through air pores, and its rate of diffusion via the soil–water interface is negligible by comparison. Maximizing the continuity of the soil air–space network will promote diffusion of methyl bromide through the soil to the target pest.

As with all fumigants, sufficient concentration and contact time of methyl bromide with target pests are required to obtain control. The fumigant has moderate persistence in the soil (half-life in soil is estimated to be 55 days at 77°F [25°C]). However, its volatilization half-life in soil, when applied 10 inches beneath an unsealed field surface, is estimated to be only 5 to 12 hours. For this reason, the effectiveness of methyl bromide applications largely depends on sealing the field surface with tarpaulins or plastic films, or by placement at adequate depths to delay its escape to the atmosphere.

Methyl bromide for field fumigation is available as a liquid stored in pressurized cylinders. The typical method of application is to inject the liquid methyl bromide into the soil behind a shank and immediately seal the shank path. In most applications, the soil surface is sealed by tarpaulin or mechanical compaction. It can also be applied as a chemigation via a hot gas injection method with drip lines under tarpaulins.

Methyl bromide is acutely toxic to humans, but there may be a delay in the onset of some symptoms of poisoning. Without the addition of chloropicrin as an odorizing agent, the victim may be unaware of being poisoned. However, all methyl bromide products used in California must contain chloropicrin so victims will be alerted by the eye and throat irritation and strong odor characteristic of chloropicrin exposure. The initial effects of methyl bromide poisoning include headache, dizziness, nausea or vomiting, chest and abdominal pain, and irritated eyes, nose, and throat. Research suggests that long-term exposure to methyl bromide may lead to nervous system disorders.

CHLOROPICRIN



Chloropicrin, also known as trichloronitromethane, has been used as a fumigant since the 1920s. It generally provides excellent control of some fungal and bacterial pathogens but is considered to give less than adequate control of weed seeds and nematodes. Although it is registered

for field use alone, chloropicrin is usually formulated with methyl bromide or 1,3-dichloropropene to broaden the range of pests that can be controlled and at very low rates as a warning agent when added to the odorless methyl bromide.

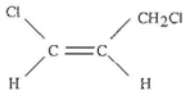
Chloropicrin is a slightly oily, clear, colorless, nonflammable liquid. It has a strong, penetrating and offensive odor and irritates the eyes, causing them to water at very low concentrations. These characteristics are the reason it is widely used as a warning agent in blends with other odorless fumigants. With a high boiling point and only slight water solubility, chloropicrin disperses though the soil largely as a gas. It vaporizes and disperses in the soil more slowly than methyl bromide because of its lower vapor pressure. It is considered nonpersistent in soil, degrading rapidly at a rate estimated at 20% per day at 77°F (25°C).

Chloropicrin is typically formulated with either methyl bromide or 1,3-dichloropropene and is usually shank or chisel injected beneath the field surface. It may also be applied through drip irrigation systems. Post-treatment soil surface treatments include tarpaulins, mechanical soil compaction, or sprinkler irrigation.

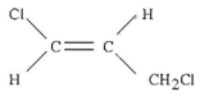
This fumigant is acutely toxic and can damage the eyes and respiratory tract in very low concentrations. Research has not shown evidence of chronic toxicity or cancer related to long-term exposure to low concentrations of chloropicrin.

1,3-DICHLOROPROPENE

1,3-dichloropropene (1,3-D) was discovered in 1943 and has been used since the early 1950s for preplant nematode control. It is also available as a mixture with chloropicrin, which extends its control to include several fungal and bacterial plant pathogens.



Cis-1,3-D



Trans-1,3-D

1,3-D is a straw-colored liquid with a sweet, pungent odor. Like chloropicrin, 1,3-D is only slightly soluble in water and has a high boiling point. The vapor pressure of 1,3-D is nearly double that of chloropicrin, thus providing adequate dispersion through the soil principally as a gas. The fumigant has a short persistence and dissipates in the soil at a rate of about 12% a day at 77°F (25°C).

1,3-D can be applied to the soil through shank injection immediately followed by sealing the field surface mechanically, with tarps or with irrigation. Adequate soil moisture is essential for optimal effect.

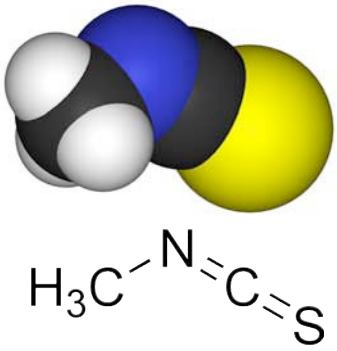
1,3-D plus choropicrin is also available as an emulsifiable concentrate under the trade name InLine. Registered only for chemigation through surface and sub-surface drip irrigation systems, the 1,3-D plus chloropicrin formulation initially moves through the soil with irrigation water, and then as soil dries, vaporizes. In California, drip irrigation applications of 1,3-D plus chloropicrin must be made beneath sealed films or tarpaulins.

1,3-D is a severe skin and eye irritant, and toxic amounts can easily be inhaled, particularly in closed environments. Chronic effects of exposure include systemic damage to internal organs and cancer.

METHYL ISOTHIOCYANATE GENERATORS

Methyl isothiocyanate (MITC), is a soil fumigant that has been used primarily for weed and nematode control but also to manage some plant pathogens and insects, all with variable effectiveness. Although generally more toxic than methyl bromide, MITC has poorer fuming ability and doesn't disperse as well through the soil, thus providing less reliable control. It is applied to the soil as what is referred to as an "MITC generator," a chemical that degrades in the soil to form MITC as one of its breakdown products. Three different MITC generators are currently available. Metam sodium (Sectagon or Vapam) and metam

potassium (Sectagon-K or K-Pam) are water-soluble concentrates, and dazomet (Basamid) is a granular formulation.

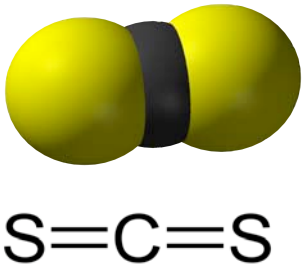


MITC itself is a colorless solid (melting point 88°F [31°C]), with a low vapor pressure and low solubility in water. Because of its lower vapor pressure and strong affinity for soil water, MITC disperses only a few inches through the soil when it is in its vapor phase. Therefore, the product must be distributed throughout the soil while still in the form of a MITC generator (e.g., metam sodium or metam potassium) that move more effectively. MITC has a short persistence and dissipates in soil at a rate of about 20% per day at 77°F (25°C).

Metam sodium and metam potassium are liquid formulations that may be applied through shanks, as a spray followed by mechanical incorporation, as a drench to well-prepared seed beds or through drip or flood irrigation systems. Granular dazomet is dropped or broadcast onto the soil surface and then mechanically incorporated to the depth of desired control or watered in with overhead irrigation. For each of these chemicals, it is best to remember that the zone of effective treatment will not extend beyond the reach of the water that carries or activates it.

MITC has a horseradishlike odor and is an eye and skin irritant. Acute toxicity symptoms include running nose, dizziness, cramps, nausea, vomiting, and disturbances to the nervous system.

CARBON DISULFIDE LIBERATORS



Carbon disulfide (CS_2) has historically been used at very high rates to manage nematodes, Armillaria root rot and grape phylloxera, often with variable results. Carbon disulfide has a very low auto-ignition point and can be ignited by a spark during application, making it extremely dangerous to transport and handle.

The current product on the market is Enzone, a deep amber-colored solution of sodium tetrathiocarbonate, which “liberates” carbon disulfide gas as it breaks down. Enzone is registered as a preplant fumigant and a postplant fumigant but is used primarily postplant in established orchards or vineyards for control of nematodes.

Carbon disulfide is a volatile liquid. Like MITC, the fumigant will be effective only where the sodium tetrathiocarbonate liberator is distributed. Carbon disulfide has a very short half-life in soil (about one day at 77°F [25°C]) and is considered nonpersistent.

Sodium tetrathiocarbonate is available as a water soluble concentrate for application with flood, furrow, or low-volume irrigation. Its short half-life, combined with need for saturating soils to successfully deliver the chemical to target pests, limits its effectiveness except in coarse-textured soils with water content at field capacity.

Sodium tetrathiocarbonate is a severe skin and eye irritant and may be toxic if inhaled or ingested. Acute toxicity symptoms include irritation of the eyes, nose, throat, and digestive tract, nausea, vomiting, dizziness, and fluid in the lungs. Its tendency to self-ignite also makes any handling activity extremely hazardous.

SIDEBAR 2-2

Products that May be Registered in the Future

Methyl iodide, or iodomethane, is similar in chemistry to methyl bromide. As a heavier molecule, it has a vapor pressure that is lower than methyl bromide, but still significantly higher than the other fumigants, so it displays good fuming properties in the soil. It can kill pests as well as methyl bromide can, but it is not an ozone-depleting compound. Registration for methyl iodide is being pursued under the trade name Midas, a product that also contains a substantial chloropicrin component.

Dimethyl disulfide (DMDS), a preplant soil fumigant that can control nematodes, weeds, and soilborne plant pathogens, is currently being evaluated for registration under the trade name Paladin. DMDS is a ubiquitous natural product, common in the global sulfur cycle and a metabolite in numerous biological processes. It is broadly toxic to organisms and has a strong odor. It is a widely used solvent in various manufacturing processes. Its behavior in the soil is not well documented, but many of its chemical properties are similar to MITC.

Propargyl bromide is a fumigant that was briefly registered in the 1960s under the trade name Trizone. It is currently being investigated as an alternative to methyl bromide. Current research shows propargyl bromide to be an excellent fungicide, nematicide, and herbicide, with good fuming properties and a satisfactory half-life in the soil. Further research is required before propargyl bromide is ready to begin the registration process. The product will require addition of carriers to nullify its explosive qualities.

Sodium azide is undergoing research trials as an alternative to methyl bromide for control of nematodes, fungi, and weeds in annual crops. It does not penetrate or kill remnant root systems. Applied as a granular product that is mechanically incorporated or in water solution through drip irrigation, it shows promise as a broad-spectrum fumigation material. Further research is required before sodium azide is ready to begin the registration process.

CHAPTER 2: REVIEW QUESTIONS

1. **Fuming pesticides that move through soil primarily as a gas through soil passageways are often referred to as**
   a. carbon disulfide liberators
   b. ozone depleters
   c. volatile organic compounds
   d. true fumigants
2. **Tarping or soil sealing is essential for effective use of methyl bromide because**
   a. it has a very short half-life in soil
   b. it moves rapidly in air
   c. it has a very unpleasant odor
   d. it dissolves easily in water
3. **Which fumigant is often added to formulations of other fumigants to alert applicators of possible leaks?**
   a. metam sodium
   b. carbon disulfide
   c. methyl bromide
   d. chloropicrin

4. When used alone, 1,3-dichloropropene is applied primarily for control of

a. nematodes

b. weeds

c. insects

e. plant pathogens

5. Emulsifiable concentrate formulations of 1,3-dicloropropene are applied

a. as shank injections

b. by drip irrigation

c. through sprinkler systems

d. with spray nozzles

6. Metam sodium and metam potassium are effective

a. only against weeds

b. only against nematodes and plant pathogens

c. only within soil areas where the fumigant has been moved or activated with water

d. only when applied through irrigation systems

7. A soil fumigant that is applied as a granular formulation is

a. dazomet

b. Enzone

c. InLine

d. diazinon

8. Sodium tetrathiocarbonate (Enzone) is most effective

a. in clay-loam soils

b. in coarse soils at field capacity

c. in dry soils

d. in soils with a lot of organic matter

9. Persons exposed to chloropicrin are likely to show the following symptoms

a. nausea and vomiting

b. cancer

c. eye and respiratory tract irritation

d. none of the above

Chapter 3: Preapplication Considerations

Knowledge Expectations

1. Locate the preapplication section on a sample soil fumigation label.
2. For chemigation, soil injection, soil incorporation, and other types of applications,
   a. Identify site soil texture, tilth, and plant debris conditions that impact fumigant volatilization and loss to the atmosphere.
   b. Describe how to recognize when site soil texture, tilth, and plant debris conditions are conducive (or not conducive) to satisfactory control and reduced volatilization.
   c. Describe procedures that can be taken to correct unsatisfactory soil tilth or plant debris conditions to achieve satisfactory control and reduced volatilization.
   d. Describe soil moisture requirements for satisfactory control and reduced volatilization and how to measure soil moisture at various depths to determine if conditions are satisfactory.
   e. Describe soil temperature requirements for satisfactory control and reduced volatilization and how to measure temperature at various depths to determine if conditions are satisfactory.
   f. Explain measures that can be taken to correct unsatisfactory soil moisture or temperature conditions.
3. Explain the concepts of buffer zones and setbacks as they apply to field fumigation, and list potential site conditions that can affect them.
4. Describe where to find the current requirements for buffer zones and setbacks.
5. Explain the process of filing a "Notice of Intent."
6. Describe procedures to ensure that persons will not enter a treated field before the restricted entry interval expires.
7. Describe the posting requirements for field fumigation sites.
8. Explain the importance of identifying inhabited structures nearby.
9. Describe the site conditions and application methods that favor satisfactory control of the following pest groups:
   a. bacteria, fungi, and water molds; b. weeds; c. nematodes; d. insects
10. Describe life cycles of pests in the groups above that fumigants are used to control, how these pests are damaging to plants, and any life stages resistant to certain fumigants.

Before applying a soil fumigant, you must gather critical information about the application site. Knowledge about field conditions and the target pest is essential for protecting the environment, choosing management methods and application techniques, and maximizing fumigant efficacy.

Reviewing the preapplication and field preparation sections of a soil fumigant label is a good first step. This section of a label typically lists information on

- application method, rate, and timing
- target pest and required depth of treatment

- optimal soil characteristics and preparation
- soil temperature and moisture requirements
- phytotoxicity

The appropriate fumigant, its application rate, method of delivery, and timing are determined by the crop to be planted, target pest, soil texture, and environmental conditions. Soil preparation and other environmental conditions affect how well the fumigant controls the target pest. Many fumigants are nonselective and can be phytotoxic to crop plants growing near the fumigated area or planted before the soil has been adequately ventilated. This chapter discusses each of these factors in more detail.

SITE CONDITIONS FOR SUCCESSFUL FUMIGATION

The success and safety of soil fumigation and chemigation rely on proper field and environmental conditions during the time of treatment. Applicators must assure that soil, moisture, and temperature conditions are appropriate for an application since these site conditions influence the quality and degree of fumigant dispersal in the soil, as well as emissions into the environment. If modifications cannot be made to correct problems, the application may need to be delayed.

The best time to fumigate in California varies with crop and location. September until mid-November is typically best for perennial crops, when soil moisture and temperature are more likely to be optimal for fumigation. The goal with perennial crops is deep delivery throughout the new rooting zone where the crop will be planted, and good site preparation is essential for delivery, which can be as deep as 5 feet. The optimal time for fumigation of annual crops is several weeks or months prior to planting when the soil is warm and dry enough for fumigant dispersal. If there is too much moisture or temperatures are low, a greater effort is needed to prepare the soil prior to treatment.

Soil Texture

Soil texture affects fumigant movement through the soil, and this influences the needed application rate. Various soil textures have different mixtures of clay, silt, and sand (Figure 3-1). Sand is a coarse-textured soil and has large air spaces (pores) between the large particles (Table 3-1). This lets fumigants and water move more quickly through sandy soils than other soils. It also means that coarse textured soils are easier to prepare for fumigation. Silt describes a medium-textured soil with smaller soil particles than sand and, therefore, smaller pore spaces between particles. While medium-textured soils have smaller pores, there are more of them and the net effect is greater total pore space compared to the same volume of sandy soil. Clay soils are fine-textured soils and have even smaller pores between smaller particles compared to silt soils. The smaller pores and greater total pore space in medium- and fine-textured soils enables them to hold more moisture than sandy soils, with clay soils holding even

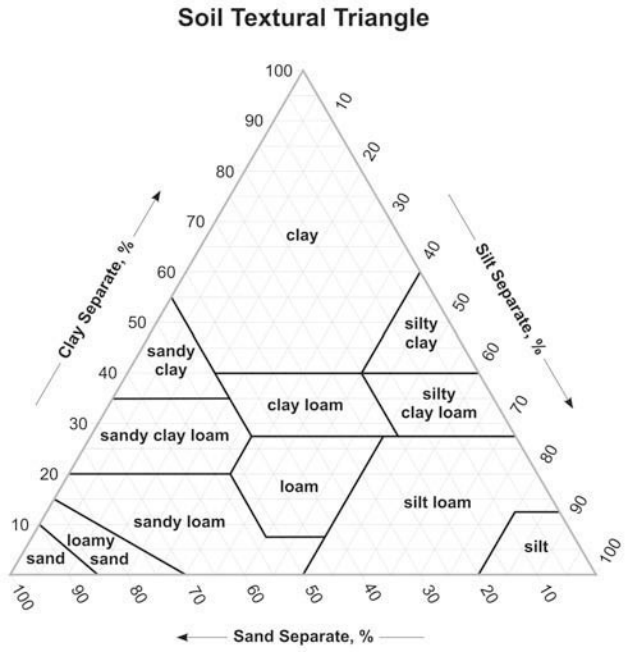


FIGURE 3-1

The USDA Soil Texture Triangle shows the proportion of different-sized soil particles for each soil texture. From USDA.

more moisture than silt soils. This retention of water in the pore spaces can impede fumigant movement. As a result, as soil particles get smaller (i.e., the soil texture gets finer), the application rate often must be increased and chisel spacing reduced to effectively fumigate to the same depth of soil.

Soil Moisture

Proper soil moisture is essential for effective fumigation. If the soil is too dry and fumigation is shallow, fumigants volatilize rapidly to the surface, reducing efficacy and increasing the potential for drift. On the other hand, too much moisture can reduce the efficacy of the fumigant. Application through sprinkler irrigation with too much water can wash away fumigants in the upper two feet of soil. Soil with high water content will impede fumigant movement by closing off pore spaces. Too much water is especially a problem with chemigation, where saturated soil will cause the water carrying the fumigant to pool at the surface and not penetrate deeper into the soil.

TABLE 3-1

Particle Diameter (mm) of the Soil Separates.

Soil Separate	Diameter of Particles (Millimeters)
Clay	< 0.002
Silt	0.002–0.05
Very fine sand	0.05–0.10
Fine sand	0.10–0.25
Medium sand	0.25–0.50
Coarse sand	0.50–1.00
Very coarse sand	1.00–2.00

The proper moisture level for soil fumigation may vary according to the regulations for emission reduction, pest, and type of crop planted. For example, if your target pests are weed seeds, they are less susceptible to fumigation when the soil is dry. Dry soil is best for fumigant delivery to deeper soil pests such as nematodes in perennial crops. However, regulations may require, especially in nonattainment areas (NAAs), higher soil moisture than suggested for greatest efficacy in order to reduce emissions.

Chemigation treatments generally require higher soil moisture levels than soil injections. For soil injections, high moisture levels greater than field capacity can seriously impede delivery. Chemigation, on the other hand, is best applied when soil moisture is at field capacity or 30 centibars throughout the zone to be treated. Most fumigant materials applied via injection should be applied when soil moisture is at 50 to 80% of field capacity, but this number varies according to fumigant and soil type. Check labels for actual requirements.

When fumigating fields for annual crops, fumigants may volatilize too rapidly from the field surface if the soil is too dry at the surface. This effect is increased if there is excessive moisture deeper within the soil profile, which can prevent the fumigant from moving deeper into the soil where pests are located. This situation occurs in fields with soil in “moist seed-bed condition” or with 30 centibars of moisture tension. The goal of fumigation for perennial crops is to reduce pest numbers as deep as possible and for as long as possible. This, along with the deeper rooting depth of perennials, necessitates deeper delivery than with annual crops. Deep delivery of the fumigant may require deep-drying of soils, which can take up to a year between tree or vine removal and replanting. Deep delivery also requires different soil preparation, such as deeper soil ripping and dry soil. For effective pest control in perennial crops, the most favorable soil moisture conditions for different soil textures throughout the surface five feet are

- sandy to loamy sand soil—2 to 6% moisture
- fine sandy loam soils—less than 12% moisture
- clay loam soil—less than 12% moisture

Regulations may require higher moisture content at the site of application to reduce fumigant emissions. A higher moisture requirement than listed above for pest control efficacy is especially important in NAAs. Currently, regulations specify use of the “feel method,” which is discussed below to

determine if moisture content is adequate for minimizing fumigant emissions. Check the regulations to determine soil moisture content requirements since they may change over time.

Estimating Soil Water Content

Soil water content can be determined by using the "feel method" or specialized instruments. Tensiometers can be used to estimate water content relative to field capacity. Soil should be tested at the depth where the target pest is located to be sure water content is adequate.

To use the "feel method," you will need to pull up a soil sample at the depth of treatment using an auger, soil probe, or soil sampling tube (typically used to sample soil for nematodes). You can then perform a simple test of soil moisture by squeezing a soil sample with your hand to form a round ball. Depending on the soil texture, the ability of the soil to retain the ball shape will determine its suitability for treatment. Table 3-2 applies this technique for determining adequate soil moisture for different soil textures.

Water content can also be measured in terms of soil capacity, or the amount of water the soil can hold that is readily taken up by plant roots. This is the amount of water, after an irrigation, which remains in the soil after it has drained. If you want to measure soil capacity, you will need to use a tensiometer (Figure 3-2).

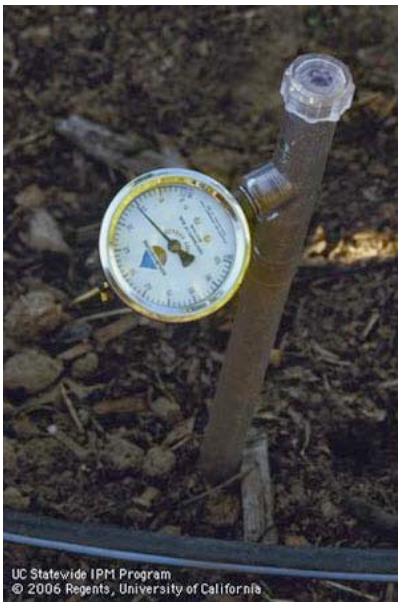


FIGURE 3-2

A tensiometer can be used to estimate soil moisture.

Available in lengths ranging from 6 to 72 inches, tensiometers can be purchased that measure soil moisture at the depth of the fumigant application. Tensiometers provide accuracy only within the zones where they are placed. A tensiometer is buried in the soil and is composed of a closed tube with a porous, water-filled cup at the bottom. Water is wicked from the cup as the soil dries. The loss of water creates a vacuum that is measured by a gauge. The unit of measure for tensiometers is centibars (cb), which range from 0 to 100. Saturated soil will measure 0 centibars. Dry soil will have readings of 70 to 80 centibars. Soil at field capacity (the amount of water remaining in the soil after excess water has drained) will have a reading of 25 to 35 centibars.

Moisture levels for deep treatments such as in perennial crops can be obtained most accurately by bagging soil from each foot down to the appropriate depth and quantifying the moisture content. The moisture content can be quantified by weighing the soil before and after heating in the microwave on high power for 15 minutes. Subtract the weight of the soil after heating from the weight of the soil before heating. Divide this number by the weight of the soil after heating and multiply by 100 to get the percent moisture on a dry weight basis.

$$\text{percent soil moisture} = \left(\frac{\text{soil weight before heating - soil weight after heating}}{\text{soil weight after heating}} \right) \text{X } 100$$

Soil Moisture Modifications

For annual crops with sandy soils, soil moisture can be adjusted by sprinkler or drip irrigation to achieve the recommended soil moisture levels. If soil moisture is available 6 inches below the field

surface, disking or plowing before the fumigant application can bring available moisture to upper soil levels. Perform tillage as close to the time of fumigation as possible to retain soil moisture, but not too late or clods will develop in finer-textured soils.

If soil moisture is too high, withhold irrigation and/or wait until the soil is dry. Leaving the previous crop in the ground a bit longer can pull moisture from the soil. During spring, in northern California, with

TABLE 3-2

The "Feel Method" to Determine Soil Moisture Requirements. From USDA NRCS.

Soil texture	**Soil moisture is adequate when soil:**	**Photo example**
Coarse Texture – fine sand and loamy fine sand	• forms a weak ball • loose and aggregated sand grains remain on fingers • darkened color • moderate water staining on fingers • will not ribbon	
Moderately Coarse Texture – sandy loam and fine sandy loam	• forms a ball with defined finger marks • darkened color • very light soil/water staining on fingers • will not stick	
Medium Texture – sandy clay loam, loam, and silt loam	• forms a ball • darkened color • very light water staining on fingers • pliable, forms a weak ribbon between thumb and forefinger	
Fine Texture – clay, clay loam, and silty clay loam	• forms a smooth ball with defined finger marks • light soil/water staining on fingers • ribbons between thumb and forefinger	

fine-textured soils, if winter rains are unusually high, the soil may contain too much deep moisture for a fall fumigation. In anticipation of these events, crops such as sudan grass, safflower, or winter wheat planted with slight irrigation can be helpful in deep-drying of soils. Do not return crop refuse to the soil. In the San Joaquin Valley or desert regions, deep ripping before fumigation can slowly reduce soil moisture content of clay loam soils, particularly if there are prevailing winds.

Soil Tilth

Compacted soil layers or clods within the fumigation zone will interfere with fumigant dispersal. Prepare the soil prior to treatment to improve conditions for fumigant activity. Thoroughly work the soil to break and bury large clods. Hard pans, clay pans, or plow pans can also impede fumigant penetration within the soil profile. Backhoeing, ripping, or deep plowing the soil can eliminate these boundaries, allowing the fumigant to penetrate the soil profile uniformly. However, do not work the soil when it is wet, since this will increase compaction and, therefore, reduce fumigant penetration.

Temperature

Check the label to determine the temperatures where the fumigant is most effective and fumigate only in that range. Most fumigants will list a minimum temperature below which application is not recommended. For most fumigants the soil temperature at a depth of 12 inches should be between 55° and 85°F (13° to 29°C).

If soil temperatures are too low, volatilization of the fumigant is reduced. The fumigant will be slow to attain sufficient concentrations and less effective at reducing pests. In cold soil,more fumigant binds with water in the soil, resulting in reduced fumigant dispersal. Due to the slower rates of movement and decreased pest respiration, higher dosages (concentration by time) are required for effective control of pests in colder soils. Low soil temperatures also result in reduced degradation and so more fumigant remains in the soil, resulting in delayed planting or phytotoxicity (see section below on avoiding phytotoxicity). Low air temperatures slow fumigant movement in application equipment and can affect the rate of application.

If temperatures are too high, volatilization of the fumigant occurs too rapidly and not enough will remain in the soil to control pests. Excessive temperature (greater than 85°F measured 12 inches deep) may cause the fumigant to degrade before it reaches the target pest. High soil temperatures (exceeding 90°F [32°C]) cause evaporation of the product, especially with chemigation or shallow applications.

It is best to measure soil temperatures at the 12-inch depth where daily temperature differences are more stable. Measure soil temperature using a calibrated hand-held steel thermometer after digging the first six inches as a pilot hole.

Plant Debris

An abundance of plant debris in the soil can interfere with fumigant efficacy. Organic matter from decomposing plant debris, particularly if the organic matter is still green to brown in color, can dramatically absorb soil fumigants, rendering them ineffective. In some cases, plant debris can form air spaces in the field surface where the fumigant moves up to rapidly escape into the atmosphere. Plant matter may also interfere with application equipment and penetrate sealing films.

Pests harbored within plant debris may not be controlled by fumigation. Plant debris from the previous crop should be worked into the soil and time allowed for debris to decompose before fumigating. In orchards and vineyards, remove old stumps and roots where possible.

Avoiding Phytotoxicity

Fumigants are nonspecific and can kill or injure any plants that are in or near the fumigated area during, and for some time after, the fumigation event. Materials that injure plants are termed phytotoxic.

Fumigants can be phytotoxic in several ways but particularly when applied at the wrong time of year to cold and wet soils. Wet soils can concentrate and hold fumigants within the soil for a longer period of time. The greatest risk associated with treating soils below 40°F (4°C) is the chance for phytotoxicity.

Another way phytotoxicity can occur is with the use of fumigants that typically degrade rapidly such as carbon disulfide generators and chloropicrin. These fumigants will degrade much slower than expected in soils at cool temperatures. As a result, more will remain at planting time and phytotoxicity can result. On the other hand, warm temperatures over 90°F (32°C) may cause grape, citrus, and *Prunus* species (almonds, peaches, prunes, and plums) injury when carbon disulfide generators are applied at the higher label rates. Before planting the crop, allow the fumigant to dissipate according to the time period stated on the fumigant label.

Fumigation reduces soil nitrification, the process of changing ammonia to nitrate by soil bacteria, and this, in combination with other factors, can lead to an increase in ammonium nitrogen and soluble ammonium salts that cause phytotoxicity. Ammonium is more likely to accumulate where high rates of fumigant and fertilizer are applied to soil that is acidic, cold, or with a high organic content. In soils with high organic matter, avoid the use of fertilizers containing ammonium salts until the crop is well established and the soil warms.

Always obey the label regarding use of fumigants for tree replants. Fumigation within three feet of the dripline of existing trees may result in slight plant injury if treating only on one side, but severe injury will likely occur if the tree receives treatment on both sides. Additionally, age of the crop can influence phytotoxicity. For example, carbon disulfide generators and other fumigants may cause phytotoxicity in grapevines that have been in the field for less than a year.

PREAPPLICATION REGULATIONS AND SAFETY

There are a number of safety issues and regulations to consider before you fumigate. This section briefly describes preapplication issues such as buffer zones, notice of intent, and field posting. You will find more detail about these subjects in Chapter 7. To better understand statewide regulations, contact the California Department of Pesticide Regulation (DPR) and check with the county agricultural commissioner's office for local information.

Application Buffer Zones and Setbacks

Buffer zones are untreated areas between occupied structures or other sensitive sites and the area where the fumigant will be applied. As you plan your application, be sure you have allowed for sufficient untreated land to satisfy buffer requirements. Leave buffer zones where the treated area adjoins a sensitive area, such as sites where applications might expose nontarget organisms, people, or occupied structures to the fumigant.

Generally, the buffer zone will vary according to application equipment, weather conditions, fumigant, and adjoining area. For most sensitive areas, the distance of the buffer zone depends on the number of acres treated and application rate.

For methyl bromide, regulations state that two buffer zones (an inner and outer) are to be established with size and duration dependent on treatment area, fumigant rate, and application method. A document describing buffer zones can be found on the DPR website or contact the county agricultural commissioner's office to find out information about buffer zones and setbacks.

Notice of Intent

The Notice of Intent to Apply a Restricted Material (NOI) is the second part of the restricted-use pesticide permit. Since restricted-use pesticide permits are often issued for a year, the NOI serves to notify the agricultural commissioner that you intend to apply a certain fumigant on a specific date. In most instances, file the NOI with the agricultural commissioner's office at least 24 hours (48 hours for methyl bromide) prior to fumigant treatment, however, some materials or local permit conditions require a longer notification period so check with the county agricultural commissioner.

Submitting the NOI lets the county agricultural commissioner review the fumigant to be used. The agricultural commissioner's office may inspect the proposed application site and surrounding areas to determine if there are additional concerns and, if necessary, may apply more restrictions.

Depending on the fumigant, if an unanticipated delay occurs (e.g., an application needs to be postponed due to weather or equipment failure), you may have up to four days after the date on the NOI to begin the application. File a new NOI if more than four days have passed. However, for methyl bromide the NOI is date specific, and if the application does not take place on the intended day, a new NOI must be submitted.

Field Posting

Prior to application, warning signs must be posted at treated areas to notify employees and the public about the date and time of the fumigation. Posting requirements may differ depending on the fumigant to be applied and the location.

Field posting requirements include the type of material the signs are made of and the language, signal words, and symbols to be used. For example, signs must be made of a durable material and printed in English and Spanish. They must contain a skull and crossbones symbol and the word "danger." You should also determine how many signs are required and where they are to be posted. There will be instructions about when they should be put up prior to application and when they can be safely removed. Field posting requirements may differ for fumigation and chemigation.

You can find additional information on field posting for fumigation and chemigation by contacting DPR and the county agricultural commissioner's office.

TARGET PESTS AND THEIR LIFE CYCLES

A number of soil inhabiting pests and diseases can be controlled by fumigants. Plant pathogens (including bacteria, fungi, and water molds), weeds, nematodes, and arthropods are the major pest groups that live in the soil and cause crop losses. Proper identification of the pest or disease is essential for determining if a fumigant is necessary. Many pests can be controlled with alternative management tools and some pests require fumigation only when their populations reach specific levels.

Fumigants such as metam sodium, metam potassium, methyl bromide, chloropicrin, and 1,3-dichloropropene (1,3-D), are thought to be a prime source of volatile organic compounds (VOCs), which may contribute to air quality issues in California. Fumigate only as a last resort when other management strategies have not been successful or are not available. Some alternatives to fumigation that may be effective for some pests are listed in Sidebar 3-1. Variable rate applications are also becoming more feasible to minimize chemical usage.

In California, only a few major pests are managed with fumigation. For those pests, knowing which one is causing the damage to the crop will be a factor in determining the choice of fumigant and application method. For instance, nematodes occur deeper in the soil than most soilborne pathogens (Figure 3-3). This necessitates greater attention to soil conditions. The following sections describe the major categories of pests targeted by fumigants. Within each major category, life cycles are described for

the main pests for which fumigants are applied in California crops. Table 3-3 lists major crops in California where fumigation is used.

SIDEBAR 3-1

Nonchemical Alternatives to Fumigants

Soil solarization has been successfully used as a field disinfection technique against weed seeds and shallow-dwelling plant pathogens since the 1970s. A polyethylene tarpaulin is applied to the field surface during the hot summer months, and 30 to 45 days of soil temperatures above 122°F (50°C) provide good control of several plant pathogens, including *Phytophthora, Pythium, Fusarium* and *Verticillium.* Solarization also appears to be effective against some nematodes and seeds of many common California weed species located within the top 6 to 8 inches of soil. For further information, see UC ANR Publication #21377, *Soil Solarization: A Nonpesticidal Method for Controlling Diseases, Nematodes and Weeds*.

Soil steaming is a technique of slowly injecting steam underneath a heat-stable tarp. It is effective in controlling many plant pathogens, depending on temperature, depth of delivery, and duration of treatment. Because of energy costs, steam treatment use is generally limited to nurseries or greenhouses.

Biofumigation relates to the addition of biological agents that have demonstrated effectiveness against plant parasites and pathogens applied under a tarp. These include manures, agricultural processing wastes, fish processing waste, allelopathic compounds, green manure crops, and antagonistic organisms. The manures and wastes typically release nitrogen compounds that can be effective against some pathogens. Of particular interest are the members of the genus *Brassica*, which have been shown to produce allyl isothiocyanate (AITC) during decay. AITC is chemically very similar to MITC and has demonstrated effective control of insects, nematodes, and plant pathogens in several research trials but effectiveness is limited to the depth of their placement.

Cultural practices as alternatives to chemical fumigation include crop rotation with plant species or cultivars that will naturally disrupt the plant parasites or pathogens. An example is the rotation of nematode-resistant varieties of tomatoes, dry beans or cotton to reduce certain root knot nematodes, including *Meloidogyne incognita, M. javanica*, and *M. arenaria,* prior to planting susceptible tomatoes.

Plant breeding and selection programs can provide effective resistance or tolerance to certain pathogens or nematodes in specific crops. Disease- or nematode-resistant cultivars of tomato, cotton, bean, grape, peach, and pistachio are examples.

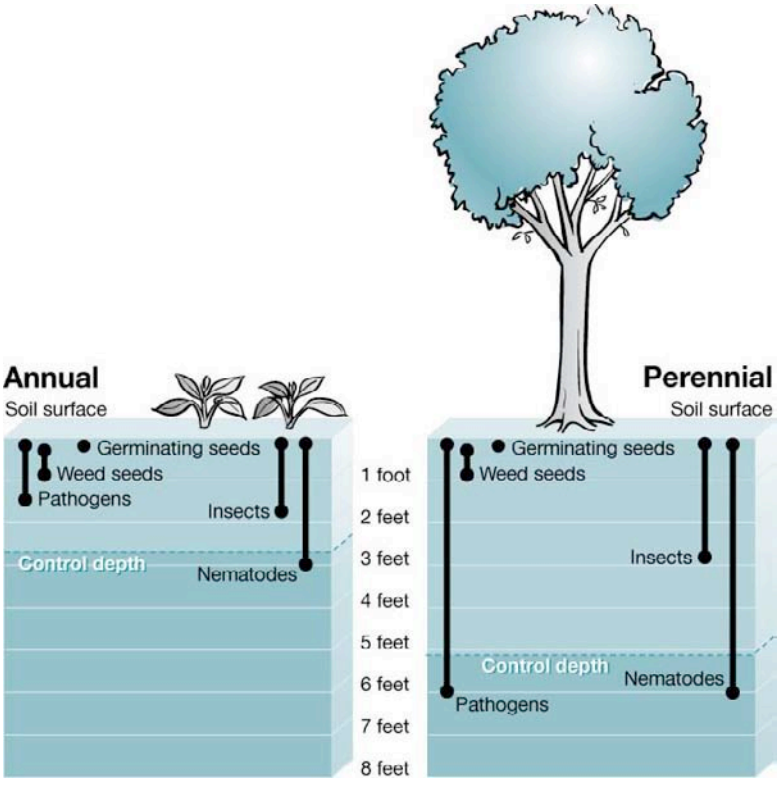


FIGURE 3-3

Different pests are found at different soil depths. Some pest or disease propagules may be found deeper than others even within the same pest group. For instance, nematodes and Armillaria mellea *fungus are likely to be found at much greater depths than many other fungal and bacterial microbes. Whether your crop is an annual or perennial can also influence pest depth, and therefore, fumigant placement.*

TABLE 3-3 (CONTINUED ON NEXT PAGE)

Pests Controlled with Fumigation in California Crops.[1]

	Nematodes	Anthracnose	Armillaria root rot	Bacterial canker[2]	Cavity spot	Corky root rot	Dematophora, Rosellinia root rot	Fairy ring	Fusarium wilt	Leather rot	Monosporascus root rot	Phytophthora	Pink root	Red stele	Root dieback	Southern blight
Almond	●		●	●												
Apple	●		●													
Apricot	●			●												
Asparagus																
Avocado			●				●									
Caneberries			●									●				
Carrot	●				●										●	
Celery	●															
Cherry	●		●	●												
Citrus	●		●									●				
Cole crops	●															
Cucurbits	●										●					
Dry Beans	●															
Fig	●															
Ornamental nurseries									●							●
Garlic, Onion	●												●			
Grape	●		●													
Kiwifruit	●		●													
Lettuce	●															
Nectarine	●		●	●												
Olive	●															
Peach	●		●	●												
Pear			●													
Peppers	●															
Pistachio			●													
Plum, Prune	●		●	●												
Spinach	●															
Strawberry	●	●								●		●		●		
Sugarbeet	●															
Tomato	●					●										
Turfgrass	●							●								
Walnut	●		●													

[1] Fumigants were registered in California for these crops in 2008. Registrations change. Check labels and with the California Department of Pesticide Regulation and county agricultural commissioner for current registration and label information. See the UC IPM Pest Management Guidelines for current UC suggestions.

[2] The key to bacterial canker management is control of nematodes and maintaining healthy, vigorous trees. Fumigation does not directly reduce the pathogen for bacterial canker in orchard crops, but reduces nematode populations that predispose trees to the canker-causing bacteria.

TABLE 3-3 (CONTINUED)

Pests Controlled with Fumigation in California Crops.[1]

	Verticillium wilt	Bulb mites	Root beetles	Seedcorn maggot	Tenlined June beetle	Garden symphylans	Wireworms	Weeds
Almond	●				●			
Apple								
Apricot	●							
Asparagus						●		●
Avocado	●							
Caneberries	●							
Carrot								●
Celery								
Cherry								
Citrus								
Cole crops								
Cucurbits				●			●	
Dry Beans								
Fig								
Ornamental nurseries	●							●
Garlic, Onion		●						●
Grape								
Kiwifruit								●
Lettuce		●						●
Nectarine	●							
Olive								
Peach	●							
Pear								
Peppers								●
Pistachio	●							
Plum, Prune								
Spinach							●	●
Strawberry	●		●					
Sugarbeet								
Tomato								●
Turfgrass								●
Walnut								

[1] Fumigants were registered in California for these crops in 2008. Registrations change. Check labels and with the California Department of Pesticide Regulation and county agricultural commissioner for current registration and label information. See the UC IPM Pest Management Guidelines for current UC suggestions.

Plant Pathogens

Bacteria and fungi, including water molds, are the common soil pathogens treated with fumigants. These pathogens are often microscopic and difficult to identify in the field. Damage symptoms on crops provide clues for identification. However, laboratory analysis may be necessary to confirm pathogen identity.

Typical symptoms of soilborne diseases are wilting plants and rotting roots and crowns. Some pathogens move into the vascular system and affect other plant parts as well.

Armillaria Root Rot (*Armillaria mellea*)

Also known as oak root fungus, Armillaria root rot is a common disease affecting many types of fruit trees and grapevines. Infected roots have white to yellowish fan-shaped mycelial mats, as fungal mycelium grow together just beneath the bark at ground level where available oxygen levels become too high for the fungus to survive (Figure 3-4). Rhizomorphs, thick strands of mycelium that are dark brown to black in color and resemble small roots, can sometimes be seen on the surface of the root (Figure 3-5). Mushrooms may form at the base of diseased trees after rainy weather. Affected trees decline, often suddenly wilting in hot weather, and may eventually die over a period of one to a few years.

FIGURE 3-4

Symptoms of Armillaria root rot include white mycelial mats found at or below the ground.

The fungus can survive for many years on dead roots or fragments of woody plant material as deep in the soil as 10 to 20 feet after diseased trees have been removed. The disease cycle of Armillaria root rot starts with healthy tree roots coming into contact with infected debris or roots of infected living trees (Figure 3-6). The mycelium grows just beneath the bark. Susceptible plants eventually die when the fungus reaches the belowground trunk area. Once there it can spread laterally and grow down adjacent healthy root branches. Armillaria root rot overwinters as a mycellium or rhizomorphs in roots or dead material.

Management options for Armillaria root rot are limited, and fumigation with methyl bromide is standard practice in infested orchards, although complete control is often not achieved. Trees, stumps, and all roots one inch or more in diameter should be removed from infested sites before replanting. Trees with tolerant rootstocks should be planted in infested sites, including fumigated ones, wherever possible. Avoid overwatering which can result in a lack of soil oxygen around tree trunks.

FIGURE 3-5

Dark brown to black rhizomorphs of Armillaria mellea.

Verticillium Wilt (*Verticillium dahliae*)

Verticillium wilt is a common disease of fruit trees, caneberries, strawberries, and ornamental plants. In trees, leaves on one or more branches

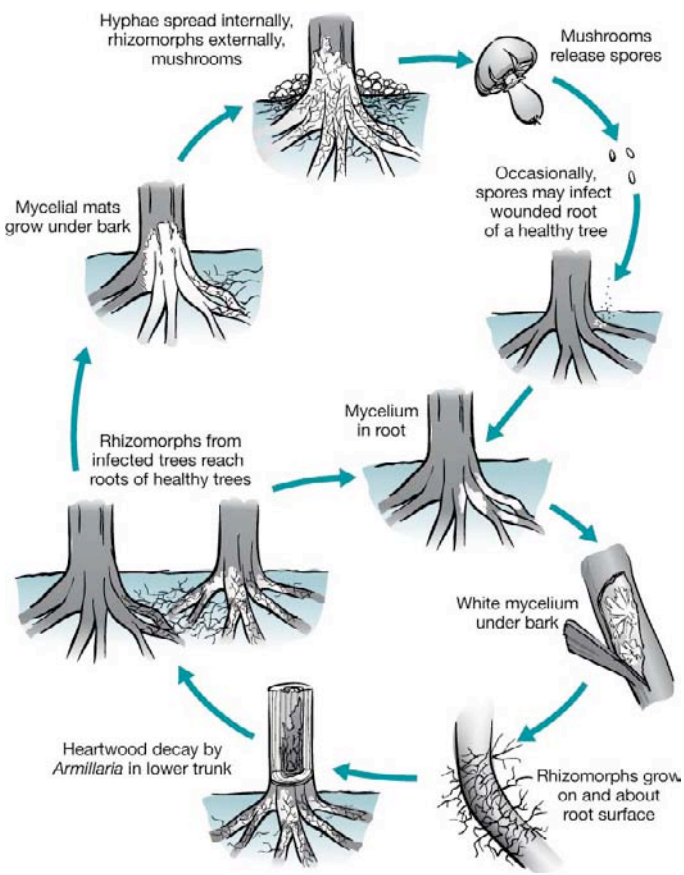


FIGURE 3-6

The disease cycle of Armillaria root rot.

turn yellow and/or wilt early in the growing season, typically on only one side of the tree (Figure 3-7). Leaf yellowing and wilt progress until later in the season when the infected shoots die and dry up. A cross section of shoot, branch, or trunk tissue will display dark discoloration in the vascular ring and heartwood (Figure 3-8). Foliar symptoms usually appear on young trees, while older trees often do not show symptoms. Verticillium wilt can reduce tree yields even when foliar symptoms are not apparent. In strawberry, plants initially show symptoms of stunting and then the outer leaves exhibit marginal and interveinal browning, followed by plant collapse. The inner leaves remain green but are stunted and have brownish black streaks or blotches, distinguishing Verticillium wilt from Phythophthora crown rot (Figure 3-9).

Verticillium wilt infection begins when plant roots come into contact with the actively growing fungus or dormant resting structures (microsclerotia). The *Verticillium* pathogen survives in the soil, debris of previously planted susceptible crops, and probably in roots and the lower trunk of infected trees. The pathogen enters through healthy or wounded roots or root hairs and spreads into the water-conducting tissues (xylem) of the plant. Fungal growth or the plant's own defense system plugs the xylem, leading to wilt and death.

FIGURE 3-7

Symptoms of Verticillium wilt in tree crops include yellowing leaves, typically on one side of the tree, followed by shoot death.

Verticillium wilt can be a difficult disease to manage. Avoid planting in fields or orchards with detectable levels of the pathogen or with a history of susceptible crops (e.g., tomatoes, potatoes, strawberries, cotton, eggplant, pepper, and cucurbits). If the previous crop was susceptible to Verticillium wilt, remove as many roots as possible before replanting. Fields with susceptible weeds (pigweed, nightshade, and lambsquarters) will also contain high levels of the fungus. Specific rootstock varieties vary in susceptibility so plant those that are least susceptible. For caneberries use clean planting stock.

FIGURE 3-8

Discoloration of the vascular tissue is another symptom of Verticillium wilt.

FIGURE 3-9

In strawberry, brownish blotches on stunted inner leaves distinguish Verticillium wilt from Phytophthora crown rot.

In orchards, avoid interplanting with susceptible cover plants such as cotton, tomatoes, melons, etc. Before trees are planted, reduce *Verticillium* levels by flooding the orchard during the summer, growing several seasons of grass cover crops (rye or sudangrass), solarizing the soil, or fumigating. Chloropicrin, alone or with methyl bromide, may also be used depending on the crop.

FIGURE 3-10

Forking and stubbing can occur in carrots with root dieback.

Root Dieback (Forking and Stubbing) (*Pythium ultimum* and *P. irregulare*) in Carrots

Root dieback of carrots kills young tap roots, reducing root length (stubbing) and/or stimulating multiple root formation (forking; Figure 3-10). Only very young tissue (roots less than 2 weeks after germination) is susceptible.

The pathogen overwinters in the soil as an oospore or sporangia. Infection occurs by contact with contaminated water, soil, or infected roots. Disease severity may depend on the levels of the pathogen in the soil. Very wet soil conditions favor the disease.

Management of root dieback in carrots includes avoiding overwatering and providing good soil drainage. Crop rotation with small grains may reduce pathogen levels. Apply preplant fumigants in fields with a history of *Pythium*-related problems. Metam sodium can be applied by sprinkler, drip irrigation, or flood irrigation.

Phytophthora Crown Rot (*Phytophthora cactorum, P. citricola, P. parasitica,* and *P. megasperma*) in Strawberries

Phytophthora crown rot in strawberry causes plant stunting and small leaves, eventually leading to plant collapse. Brown discoloration can be seen in the crown vascular tissue or throughout the crown tissue of infected plants (Figure 3-11). *Phytophthora* infection of the roots causes brown to black root rot. *Phytophthora* also infects many other crops, but for this pest, fumigation is used primarily in strawberries.

Infections occur during cool to moderate temperatures. When the soil becomes saturated with water, zoospores are produced and released. The zoospores swim through the water-filled pores to infect healthy plants. Resilient spores (chlamydospores, oospores) enable the pathogen to survive in the soil for long periods of time without susceptible hosts.

Soil fumigation and good cultural practices provide adequate control of *Phytophthora* in strawberry. Avoid using runoff water for irrigation since *Phytophthora* can be moved in water. Provide good soil drainage during wet weather and don't plant in poorly drained soils. Use certified transplants and tolerant cultivars. Good results have been obtained using drip fumigation with applications of chloropicrin or 1,3-D with chloropicrin, followed 7 days later with metam sodium or metam potassium.

FIGURE 3-11

Discolored crown tissue is a symptom of Phytophthora crown rot.

Anthracnose (*Colletotrichum acutatum*) in Strawberries

Symptoms of anthracnose in recently planted fields are stunting and yellowing. Stem and fruit lesions are the most common symptoms (Figure 3-12). Stem lesions are dark brown or black, lens-shaped, sunken spots found on petioles and runners. Wilting and plant collapse are rarely observed, but occur when the crown tissue is infected and decays. Cutting an anthracnose-infected plant open reveals cinnamon to red-colored crown tissue. In contrast, *Phytophthora*-infected plants have brown discoloration and there are no stem and foliage lesions. Following warm, rainy weather, affected fruit (all stages) may develop small, sunken, oval-to-round brown spots on green fruit or black spots on red fruit that cover most or all of the fruit surface. Salmon or orange-colored spores appear on the stem and fruit lesions when the weather is warm and humid.

FIGURE 3-12

Lesions can be observed in the stem, runners, and fruit of strawberry infected with Anthracnose.

When they become wet, *Colletotrichum* spores are released and infection occurs when the soil containing these spores is splashed by rain or irrigation water onto the plant crowns or stems. Fungal hyphae will penetrate the plant tissue and eventually cause lesions throughout the plant (Figure 3-13). In the soil, the pathogen can survive for at least 9 months without host plants. It may also overseason in weeds, such as chickweed, fiddleneck, and vetch.

Manage anthracnose by using clean nursery stock and removing volunteer strawberry plants. Removing soil using running water can prevent infection of transplants. Dipping transplants in a fungicide solution may also decrease disease incidence and severity. Cultural controls such as drip irrigation, using clean field equipment, crop rotation, and removing weeds are important for the control of this disease. Soil solarization and fumigation are also effective. Good results have been obtained with an application of chloropicrin or 1,3-D with chloropicrin followed 7 days later with metam sodium or metam potassium.

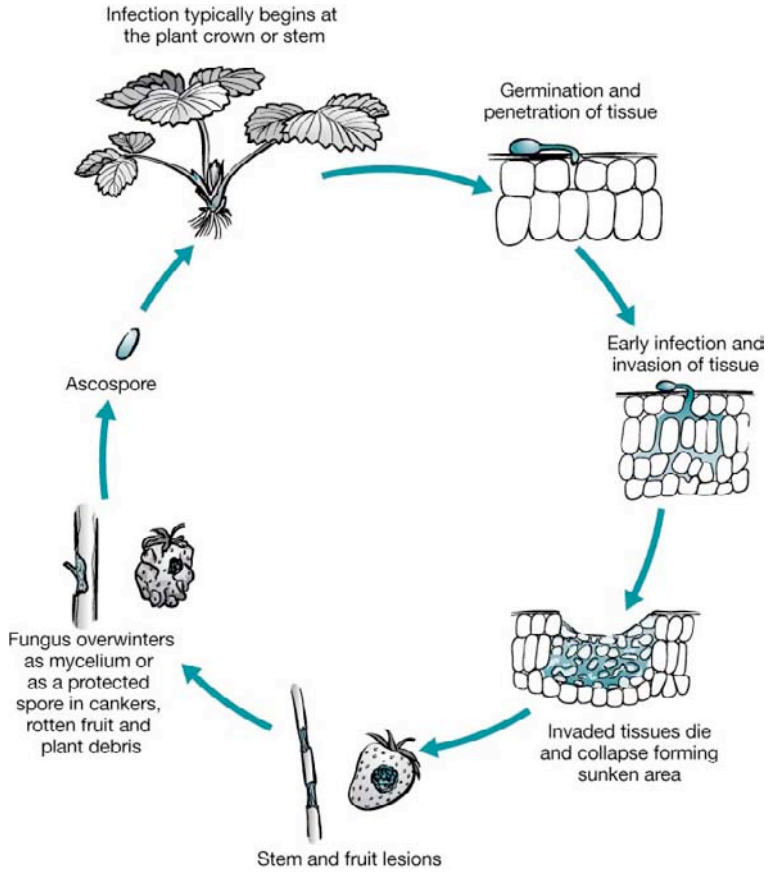


FIGURE 3-13

Anthracnose disease cycle.

Weeds

Weeds compete with crops for water, nutrients, light, and space, and they can also interfere with farming operations. Others release toxins into the soil that inhibit the growth of other plants. Uncontrolled weeds can contaminate harvested crops and harbor insects and pathogens.

Fumigants are not normally applied primarily to control weeds because of the availability of other less expensive management tools, but weed control is one benefit of fumigation. All weed seedlings, most weed seeds, and the reproductive structures of some perennials will be controlled with fumigation. However, several perennial weeds including nutsedge and field bindweed are only suppressed; the seeds of burclover, sweet clover, filaree, and little mallow are also difficult to control with fumigation. Table 3-4 gives an example of fumigants used in strawberries and their effectiveness against specific weeds.

Soil fumigants control weeds by killing both germinating seedlings and ungerminated seeds. Methyl bromide, chloropicrin, 1,3-D plus chloropicrin (Inline, Telone C35), and metam sodium kill weed seedlings and seeds by inhibiting cellular respiration, the cellular process of making energy. However, to kill weed seeds, fumigants must penetrate the seed coat and kill the seed embryo. It is easier to penetrate the seed coat when the seed is moist because the seed tissues swell with water and allow the fumigant to penetrate more thoroughly. Moist seeds also have higher respiration rates and are more susceptible to fumigants than dry seed with low respiration rates. Proper irrigation before fumigation is one of the keys to effective weed control with all fumigants. Soil temperature must be above 55°F (13°C) for effective absorption of water by seeds. Preirrigation allows nondormant weed seeds to germinate, and germinating

weed seedlings are readily killed by fumigation. Tarping improves weed control when using fumigants such as methyl bromide, 1,3-D, and chloropicrin.

TABLE 3-4

Susceptibility of Weeds to Fumigant Control in Strawberry.[1]

	Fumigants[2]				
Weeds	**1,3-D/ PIC**	**PIC**	**MeBr**	**MEP**	**MET**
ANNUALS					
Barley, hare	C	C	C	C	C
Barnyardgrass	C	C	C	C	C
Bluegrass, annual	C	C	C	C	C
Burclovers	N	N	N	N	N
Chickweed, common	C	C	C	C	C
Filarees	N	N	N	P	P
Fleabane, hairy	—	—	C	—	C
Goosefoot, nettleleaf	C	C	C	C	C
Groundsel, common	C	C	C	C	C
Horseweed	—	—	—	—	C
Lambsquarters, common	C	C	C	C	C
Mallow, little (cheeseweed)	P	P	N	P	P
Nettle, burning	C	C	C	C	C
Pigweeds	C	C	C	C	C
Pineapple-weed	C	C	C	C	C
Puncturevine	P	P	P	P	P
Purslane, common	C	C	C	C	C
Ryegrass, Italian	C	C	C	C	C
Sowthistles	C	C	C	C	C
Sweetclovers	N	N	N	P	P
Volunteer grains	C	C	C	C	C
PERENNIALS					
Bermudagrass (regrowth)	T	T	P	T	P
Bermudagrass (seedling)	C	C	C	C	C
Bindweed, field (regrowth)	N	N	P	T	T
Bindweed, field (seedling)	N	N	—	N	N
Nutsedge, yellow	P	P	C	P	P

[1] C = control, P = partial control, N = no control, T = top-kill only, — = no information

[2] 1,3-D/PIC = 1,3-dichloropropene/chloropicrin, MeBr = methyl bromide, PIC = chloropicrin, MEP = metam potassium, MET = metam sodium

Note: Fumigants noted here were registered in California for strawberry in 2008. Not all fumigants can be used on all crops and registrations change. Check labels and with the California Department of Pesticide Regulation and county agricultural commissioner for current registration and label information. See the UC IPM Pest Management Guidelines for current UC suggestions.

Nematodes

Most nematodes are too small to be seen without the aid of a microscope. Nematodes are unsegmented roundworms and can be free-living in the soil or live within the plant roots that they feed on. Immature stages and adult males are long, slender worms. The mature adult females of some species, such as root knot nematode, change to a swollen, pearlike shape, whereas females of other species such as lesion nematode remain slender worms. Soil samples should be taken and sent to a diagnostic laboratory for identification.

In trees, symptoms of nematode feeding are poorly developed root systems, lack of vigor, twig dieback, and decline in growth and yield. Older trees may show symptoms of chlorosis or yellowing of leaves, orange bark, fruit sunburn or sunscald, and small fruit. Heavy nematode infestations on young trees may result in stunting and sometimes death. Orchards with ring nematode may exhibit symptoms of bacterial canker, and trees with root knot nematodes may have galls on roots (Figure 3-14). Damaged trees generally occur in a circular area within the orchard. Nematode infestations may occur without any observable aboveground symptoms. The symptoms described above can also result from other causes as well. In nontree crops, plant yellowing, stunting, wilting, and death are typical symptoms. Lesion nematodes may cause reddish-brown to dark brown lesions on roots.

FIGURE 3-14

Root knot nematode galls on peach roots.

Root Knot Nematodes (*Meloidogyne* spp.)

Heavy infestations of root knot nematodes can cause significant yield reductions in many crops. Root knot nematodes occur in a wide range of soil types, but are most common and cause the greatest damage in coarse-textured sand, loamy sand, and sandy loam soils. Most stages of root knot nematodes are found in root galls. Second stage juveniles invade new sites, typically at the root tips. Nematode invasion causes the root cells to grow into giant cells, which is where the nematodes feed. Continuous feeding results in the plant producing a gall around the infected area (Figure 3-14). In nectarine, root knot nematodes have been reported to increase the incidence of crown gall (*Agribacterium tumefaciens*).

The general life cycle of the root knot nematode starts at the egg (Figure 3-15). The nematode juvenile hatches and remains within the egg until it molts again. It then exits the egg shell and moves through the soil, invading rootlets. Within the plant gall, the nematode molts three more times until it is an adult. Males leave the root and do not feed. Females remain in the root, producing egg masses outside of the plant gall.

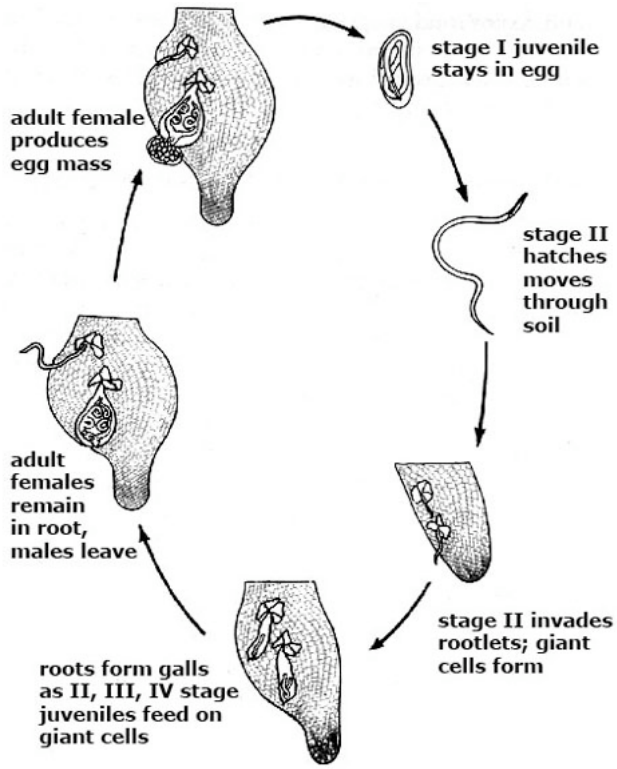


FIGURE 3-15

The life cycle of the root knot nematode.

Root Lesion Nematodes (*Pratylenchus* spp. Including *P. vulnus*)

Found throughout California, root lesion nematodes live in the soil and plant tissue (Figure 3-16). Damage occurs when the nematodes feed and migrate through the cortical tissues. Interaction of the root lesion nematodes with other soilborne organisms such as fungi and bacteria can increase injury to plants.

Similar to the root knot nematode, the life cycle of the root lesion nematode begins with the egg stage, followed by the first stage juvenile remaining within the egg. The second stage emerges from the egg and this stage or third, fourth, or adult stages enter roots to feed. Unlike root knot nematodes, root lesion nematodes leave roots to move to new ones.

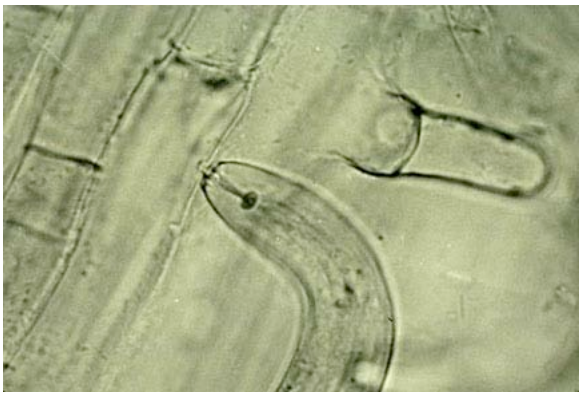


FIGURE 3-16

Adult root lesion nematode feeding inside a root. Photo courtesy of Antoon Ploeg.

FIGURE 3-17

The white body on the left is a living female sugarbeet cyst nematode. On the right is a cyst (brown) containing hundreds of eggs.

Ring Nematode (*Criconemoides* [=*Criconemella, Macroposthonia,* or *Mesocriconema*] *xenoplax*)

Feeding by the ring nematode increases the incidence of trees affected by bacterial canker (*Pseudomonas syringae*). Ring nematodes have life cycles similar to the root lesion nematode, except they feed at the surface of the root, not deep inside.

Cyst Nematodes in Cole Crops (Cabbage Cyst, *Heterodera cruciferae,* and Sugarbeet Cyst, *H. schachtii*)

Cyst nematodes can severely damage cole crops on any soil type, and all cole crops are susceptible. Cyst nematodes are also a problem on sugarbeets. Both nematode species occur frequently in cole crop-growing regions of California, with the sugarbeet cyst nematode being more widespread. Heavy infestations can reduce yields and/or delay crop maturity. Cyst nematodes do not induce gall formation on the roots.

Sugarbeet cyst nematodes are round to lemon-shaped and white in the early stages, and brown in the older stages. The egg-filled females die and remain as cysts within the soil, enabling the eggs to survive for many years (Figure 3-17).

Nematode Management

Depending on the situation, nematodes may be managed using crop rotation, resistant crop varieties or rootstocks, solarization, nonfumigant nematicides, or fumigation. Fumigation reduces nematode populations but does not eradicate them. For annual crops, fumigation may only control nematodes for one season. In tree crops, preplant fumigation may keep nematodes below damaging levels for as long as 6 years to allow trees to grow root systems that are better able to tolerate some nematode activity. Trees planted in infested orchard sites that have been fumigated generally have improved growth and yields

compared to those on nonfumigated sites. Fumigants are most effective when nematodes are outside old roots or in the juvenile stage. Eggs, eggs within cysts, and any stage within the root are the most difficult stages to suppress. Proper soil preparation, as well as correct soil moisture levels and temperature, are essential for good nematode control. Remove old trunks and large roots. Fumigation with true fumigants is effective against those nematodes that reside inside plant tissues that are located below the surface 6 inches of soil.

Arthropods

Arthropoda is a general classification that includes insects, spiders, ticks, and mites. Also included are centipedes, millipedes, scorpions, and sowbugs. Arthropods range in size from very small and microscopic to several inches long.

Because of the availability of less expensive management alternatives, only a few arthropods are targets of soil fumigation applications. These include root beetles in strawberries, wireworms in some vegetable crops, and symphylans.

Root Beetles (*Otiorhynchus* spp., *Nemocetes incomptus, Asynonychus godmani, Pantomorus cervinus, Hoplia dispar, H. callipyge*)

Root beetle adults feed on foliage, notching leaf edges (Figure 3-18). Petiole feeding in apple results in premature fruit drop, water stress, and smaller fruit size and yield. Young trees may be stunted or killed by defoliation and bark feeding. The larval stage feeds on the roots of plants. In caneberries and strawberries, a symptom of larval feeding is plant wilt. Hoplia larvae can severely stunt and eventually kill infested plants.

Except for the hoplia beetle, root beetle adults are flightless and nearly all female (Figure 3-19). Adults emerge in the late spring or early summer. During the day they can be found hiding in cracks in the soil, under clods, or between fruit. They are nocturnal and move from daytime hiding places to feed on the foliage at night. Eggs are laid about 1 month after emergence. Beetle larvae feed on the roots and crowns of plants. The larvae have brown heads, no legs, and are white or pink with curved bodies (Figure 3-19), reaching 0.38 inch (9 mm) long after several molts. The larvae overwinter and continue feeding until they pupate in early spring. Root beetles have one generation a year.

FIGURE 3-18

Adult root beetles feed on the foliage, notching the edges of leaves (below). Larval root beetles feed on the roots.

In strawberries, preplant fumigation for weed and disease control will destroy larvae or pupae in the soil. Root weevils and hoplia beetle do not appear to become problems in fumigated fields. Root weevils

FIGURE 3-19

Larvae and a pupa of a root weevil, left, and a hoplia beetle adult.

can also be managed by using insecticides or employing cultural practices such as destroying infested plants and adjacent healthy plants. In trees and caneberries, sticky barriers prevent movement of adult weevils to uninfested plants or foliage. Crop rotations and the use of annual strawberry plantings reduce the likelihood of high populations building up in fields. Soil solarization may be effective for hoplia beetles or other root weevils in the Central Valley.

Wireworms (*Limonius* spp.)

Wireworms partially or completely devour seeds in the soil, thus reducing plant stands. They injure seedlings by feeding on roots or boring into stems. Damage to older plants is not significant. Damage is more common where soil has a high organic content, such as fields that were previously planted with or are adjacent to alfalfa, pasture, vineyards, uncontrolled weeds, or possibly grains.

Wireworms are the soil-dwelling larvae of click beetles, and it is the larval stage that causes damage to plants (Figure 3-20). Their life cycle is similar to that of root weevils. Eggs hatch into larvae (wireworms). After several molts, the larvae turn into pupae in the soil and eventually emerge as adults (tan to black beetles, about 0.5 inch [12mm] long). Unlike the adult beetles, the larval stage (wireworms) may last several years. Wireworms can be found at all times of the year and in any kind of soil.

Good field sanitation (e.g., minimizing plant residue from previous crops and allowing plant matter to decompose) and measures to ensure rapid seed germination are generally adequate to control this pest. Flooding a field for several weeks also reduces populations. Soil fumigants and other pesticides kill wireworms, but these special controls are seldom needed.

FIGURE 3-20

Wireworms (left) are the larval stage of the click beetle (right).

Garden Symphylans (*Scutigerella immaculata*)

A good indication that garden symphylans are present is circular areas in the field or along edges of the field in which there is little or no crop or weed growth. In asparagus crops, symphylans chew large numbers of small, round holes in storage roots, crowns, and the belowground portions of spears. Pathogens (e.g., *Phytophthora*) enter the wounds caused by symphylan feeding, predisposing plants to disease. Garden symphylans are a particular problem during periods of extended wet weather along the coast or in northern California production areas, primarily the Delta, or on water-saturated soils. They occur mainly in soil with high organic matter and can cause considerable damage in asparagus plantings and other crops such as lettuce and cole crops.

These fast-moving arthropods, closely related to insects, are slender and white (Figure 3-21). They are about 0.33 inch (8 mm long) with 11 to 12 prolegs and distinct antennae. Adult females lay eggs in the soil primarily during the early spring and fall that hatch into immature versions of adult symphylans (immatures look similar to adults but with fewer segments and legs). Adults can live for several years. All stages—eggs, immatures (nymphs), adults—can be found throughout the year.

FIGURE 3-21

Garden symphylans can cause considerable damage in asparagus and several leafy vegetables.

Symphylans are difficult to manage because they can move to deep areas in the soil. Flooding fields during the warmest portion of the summer for 1 to 2 weeks prior to planting asparagus may reduce numbers. For existing asparagus fields, winter flooding for 2 to 3 weeks when plants are dormant may reduce damage. Cultivate the soil to dry out the surface and drive symphylans deeper into the soil and away from the crop. For severe infestations, preplant fumigation with 1,3-D may be necessary. Use carrots or potatoes placed on the soil surface and covered with a pot as baits to assess population levels.

CHAPTER 3: REVIEW QUESTIONS

1. The preapplication section of the label lists
   a. required personal protective equipment
   b. warranty and disclaimer information
   c. optimal soil preparation
   d. posting requirements

2. The optimal time for fumigation is
   a. anytime
   b. dependent on if the crop is an annual or perennial
   c. winter when it is coldest
   d. after rain has saturated the field leaving pools of water on the field surface

3. Clay soil is considered a
   a. coarse-textured soil—water moves fast due to large pore spaces
   b. coarse-textured soil—water moves slowly due to small pore spaces
   c. fine-textured soil—water moves slowly due to small pore spaces
   d. fine-textured soil—water moves fast due to large pore spaces

4. Excessively wet, saturated soil results in

a. reduced fumigant efficacy
b. enhanced movement of the fumigant in soil
c. good soil tilth after working
d. the greatest pest kill

5. Which of the following is NOT a recommended method to estimate soil moisture prior to fumigation

a. the "feel method"
b. soil color
c. a tensiometer
d. quantifying moisture in collected soil

6. Cold soil temperatures

a. decrease volatilization and so increase effectiveness
b. decrease volatilization and so decrease effectiveness
c. increase volatilization and so increase effectiveness
d. increase volatilization and so decrease effectiveness

7. Plant debris in soil will

a. increase phytotoxicity
b. enhance fumigant efficacy
c. reduce soil nitrification
d. form air spaces enabling fumigants to move up and out of the soil

8. The Notice of Intent (NOI)

a. is submitted after fumigation
b. notifies the county agricultural commissioner that a restricted-use pesticide will be applied
c. notifies DPR that a restricted-use pesticide will be applied
d. can always be used up to four days after the date on the NOI

9. Which pests generally occur at the deepest soil depths?

a. weed seeds
b. nematodes
c. insects
d. germinating weed seeds

Chapter 4: Application Methods

Knowledge Expectations

1. Describe following pieces of equipment and how they are used in chemical injection systems:
   a. positive displacement pumps
   b. centrifugal pumps
   c. Venturi injection systems
   d. check valves
   e. chemigation valves
   f. solenoid valves
   g. bypass valves
   h. nondraining valves for nozzles
   i. purge valves
   j. electrical interlock systems
2. Explain how closed systems work.
3. Explain how electronic metering systems can be used during fumigation.
4. Describe the purpose and requirements of a backflow prevention system.
5. Describe how to carry out a liquefied-gas injection application, including calibration and identification of potential problems.
6. Describe how to carry out a chisel-and-plow injection shank application using shanks or spray blades, including identification of potential problems.
7. Describe how to carry out a granular-formulation, soil-incorporation application using power mulch systems.
8. Explain the steps required to carry out the following procedures with chemigation systems:
   a. Inspection of backflow prevention systems
   b. Preinjection irrigation system inspection
9. Identify appropriate types of application equipment for applying the materials listed in Chapter 2.
10. Describe the general procedures for monitoring during the application of a fumigant and where to find the current requirements.

The appropriate application method for any soil fumigation depends on the fumigant chemical and the situation. Label requirements, as well as federal, state, and local regulations, also influence what application methods should be used. Fumigants are either injected into the soil with chisels, shanks, or blades, incorporated into the soil as granules, or applied with irrigation water through sprinklers, drip lines, or flood systems. Table 4-1 lists common application methods for various materials. This chapter describes equipment and methods used for soil fumigation.

Always check current permit conditions, labels and regulatory requirements for allowable methods prior to application. For instance, there are restrictions on application methods that can be used in

nonattainment areas (NAAs) at certain times of the year. These regulations change and, as a result, are not detailed in this book.

TABLE 4-1

Common Application Methods for Various Fumigant Materials.

Fumigant Material[1]	Liquefied Gas Injection	Liquid Shank Injection	Spray Blade Injection	Power Mulch Application	Chemigation (Sprinkler)	Chemigation (Flood or Furrow)	Chemigation (Drip)
Methyl bromide	●						● (hot gas)
Chloropicrin	●	●	●				●
1,3-D (Telone)		●	●				
1,3-D EC (Inline)							●
MITC liquid (metam sodium, metam potassium)		●	●	●	●	●	●
MITC granular (dazomet)				●			
Carbon disulfide (Enzone)						●	●

[1] Sample trade names used only to distinguish very different types of products. Other trade names may be available.

EQUIPMENT

Fumigation application equipment consists of a series of standard parts connected in a way that effectively and safely delivers the fumigant from a tank to the target pest beneath the soil surface. Although the configuration may be different among methods, many of the parts used will be similar in different systems. Application systems generally consist of a fumigant supply tank, a pump, hoses, various valves and devices to safely regulate flow, and an output device such as a shank pulled behind a tractor or sprinkler or drip tape connected to an irrigation system to deliver the material (Figure 4-1). Liquid soil fumigants are brought to the field in pressurized cylinders. In the application system, an inert gas such as nitrogen or compressed dried air is used to maintain constant pressure to the fumigant cylinder and ensure a constant flow of the fumigant through a metering device. Inline valves

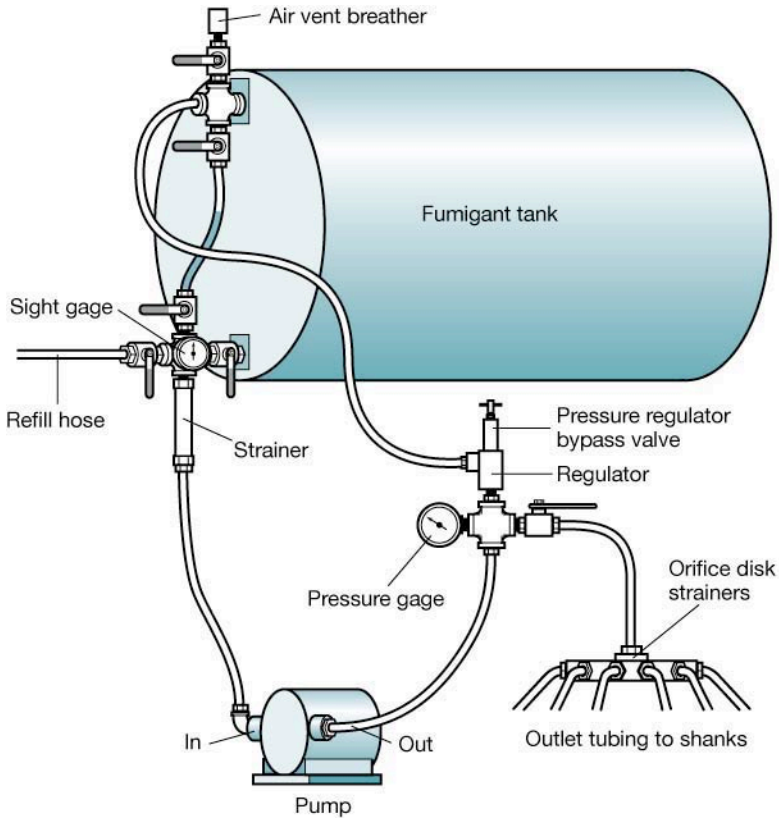


FIGURE 4-1

The basic elements of a fumigation application setup: tank, pump, valves, tubing, regulator or metering device, and injectors (e.g., chisels, shanks, or spray nozzles).

downstream of the cylinder control the delivery rate through the flow meter. Safety devices such as backflow protection valves are also essential components of fumigation systems.

Pumps

Pumps are used to move the fumigant from a tank to the blade, shank, or injection nozzle. There are two main classes of pumps used in agriculture: positive displacement and centrifugal. Centrifugal pumps should not be used for fumigation injections because of their irregular pressure. For some chemigation applications, Venturi injection systems provide a low cost alternative to pumps for injecting fumigants into irrigation lines. Once in irrigation water, the fumigant is moved along to the application site by the irrigation pump.

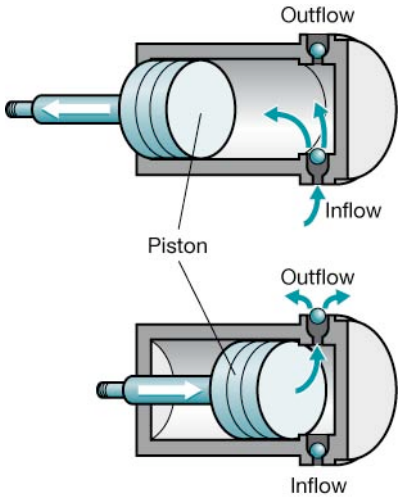


FIGURE 4-2

Example of a positive displacement pump.

Positive Displacement Pumps

Positive displacement pumps (Figure 4-2) are the primary pump type used in soil injection systems. These pumps use a solid object such as a piston or diaphragm to displace and move the liquid forward. Examples of positive displacement pumps are roller pumps, piston pumps, progressive cavity pumps, peristaltic pumps, and diaphragm pumps. These pumps deliver fixed volumes of liquid per stroke or revolution and are easily calibrated by adjusting their rotational speed, strokes per minute, or length of stroke. All positive displacement pumps will attempt to deliver a specified volume regardless of the pressure head against which they are pumping. Thus they also provide an effective metering system. To prevent high-pressure bursting of downstream lines, positive displacement pumps are generally equipped with bypass valves, which return a portion of the pumped liquid back to the intake side of the pump in the case of excessive pressure. High-pressure situations can result if flow is restricted by downstream valves closing or injection nozzles becoming plugged. Positive displacement pumps are reliable and easy to calibrate, making them the best choice for most soil fumigation applications.

Centrifugal Pumps

Centrifugal pumps impart mechanical energy into a hydraulic system by accelerating the liquid through a rotating impellor. Once the mechanical energy has been imparted to the system, that energy is expressed as a combination of velocity and pressure. The flow volume of centrifugally pumped liquid is related to the pressure head of the irrigation system. The greater the discharge head, the lower the volume of liquid pumped. All centrifugal pumps will have a high-pressure point at which the flow will be reduced to zero, referred to as the “shut-off head” of the pump. Because of the potential irregularity of irrigation pressure, centrifugal pumps need calibration while operating to assure proper release rate of fumigant. Centrifugal pumps are commonly used as agricultural irrigation pumps, but *generally are not recommended* for injection of toxic chemicals where flow rates must be precisely controlled. Examples of centrifugal pumps are booster pumps, submersible pumps, and deep-well turbine pumps.

Venturi Injectors

Venturi injectors are not pumps but use the principle of conservation of energy within a closed system to move chemicals into an irrigation line. A Venturi injector reduces the diameter of the hydraulic line, which increases the velocity of the fluid. The increase in velocity will have a corresponding decrease in pressure in the high-velocity section of pipe. If the velocity is high enough to reduce the system pressure

below that of the ambient atmospheric pressure, a small injection port at this point will act in the same way as suction, with the atmosphere pushing air or liquid into the hydraulic system. The advantage of Venturi injectors is that they are relatively inexpensive and lack moving parts. The disadvantage is that they can be energy inefficient, difficult to calibrate, and subject to plugging, rendering them less reliable. If used, they must be carefully monitored and have appropriate safety valves. A quick-closing check valve and a solenoid-operated valve connected to an interlock or hydraulically operated valve on the pesticide supply line is required (Figure 4-3).

Valves

Valves are devices that are opened or closed manually or automatically to control the movement of liquids or gases through the hoses or pipes of the application equipment by opening or closing ports or channels. Valves are especially important to prevent backflow of toxic materials into water systems. A number of different types of valves are used in fumigation application equipment configurations.

Check Valves

Check valves are inline valves that allow the chemical to pass in only one direction. This prevents the fluid from reversing flow direction. An example application of a check valve is on a chemical injector into an irrigation sprinkler system: should the chemical injection pump fail, the irrigation water is prevented from flowing backward through the injection system and over-filling the chemical tank. Another common check-valve application is on pipes between application systems and an agricultural well to prevent potentially contaminated water from flowing back down the well and polluting the groundwater. Check valves are typically spring-loaded wafers or flappers that close against a mechanical seat. Hydraulic diaphragm valves can also be configured to serve as check valves.

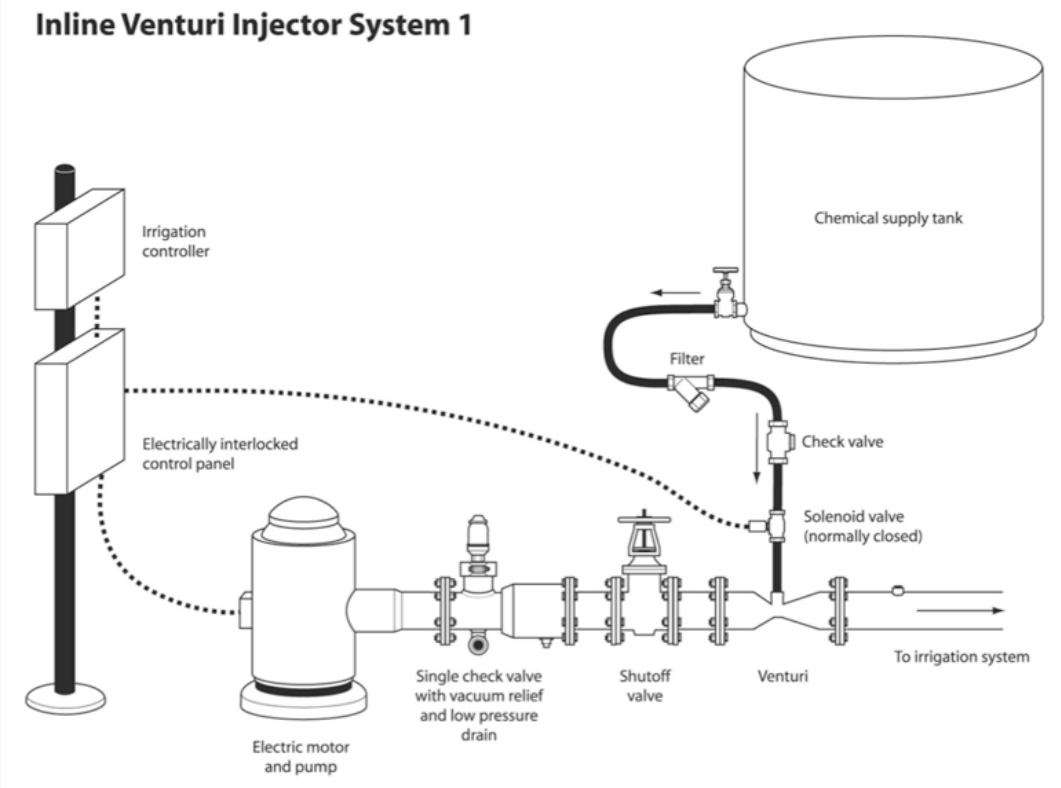


FIGURE 4-3

Venturi injector system for dispersing chemical into an irrigation system. Note that the pesticide supply line includes the required check valve and solenoid valve connected to the interlock control panel. From DPR.

Chemigation Valves

Chemigation valves are specialized check valves designed to add a level of insurance in chemigation systems against contaminated water flowing backward towards a "clean" source of water, such as a well or domestic water supply. As the risk or danger increases, the level of security increases. A simple chemigation valve may be a single flap-check valve with an air vent for vacuum relief. The next step would be two flap-check valves in tandem, with a low-pressure drain and air vent in between them to provide an effective air gap. The most secure chemigation valve would be a reduced-pressure (R-P) device, which is a certified dual check valve and low-pressure drain. R-P devices are generally required when connecting irrigation systems to potable water supplies. Check valves with an air vent and low pressure drain (Figure 4-4) are required for chemigation systems to prevent backflow except where a gooseneck pipe loop is located on the main water line.

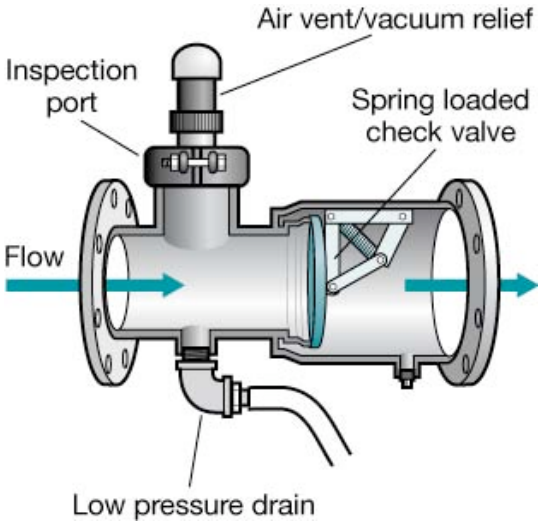


FIGURE 4-4

Cut-away view of a spring-loaded chemigation check valve with air vent and low pressure drain for vacuum relief.

Solenoid Valves

Solenoid valves are electrically actuated inline on/off valves. They are either "normally open" or "normally closed," where the "normal" position is the one without energy being applied to the valve. For example, a normally closed solenoid valve will open when electrical current is applied to it, and close when the current is cut off. A solenoid valve is shown in Figure 4-5.

Hydraulically Activated Valves

Hydraulically activated valves work very similarly to solenoid valves except they are activated when water pressure is applied and close when water pressure is cut off. Solenoid or hydraulically activated valves (Figure 4-5) are required in chemigation systems between the chemical supply tank and the injection pump.

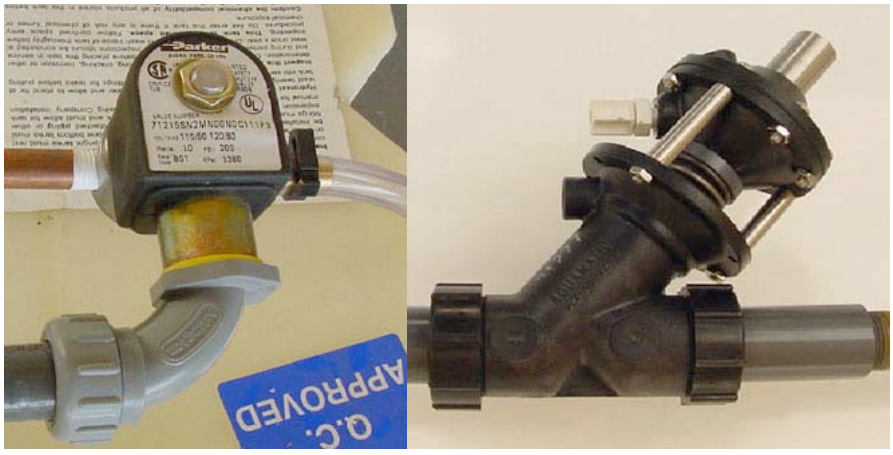


FIGURE 4-5

A solenoid valve (left) and a hydraulically activated valve. From DPR.

Bypass Valves

Bypass valves are three-way, spring-loaded, pressure relief valves used to regulate pressure downstream of a positive displacement pump. They are typically adjustable by increasing or decreasing the spring tension, allowing the operator to set the pressure at which the valve will open. The bypass

valve is plumbed inline, downstream of the pump, with an always-open port feeding the injection system. When the set-pressure is exceeded, the valve begins to open and bleed fluid into a bypass line. This bypass fluid is generally directed back upstream of the pump, either into the fluid supply tank or the intake side of the pump.

Nondraining Valves

Nondraining valves are utilized on injection shanks or chisels and spray rigs to prevent the injection lines from draining when the application rig is temporarily stopped, for example at the end of a row or pass. Draining the lines may cause nonuniformity of the application at the beginning of the next pass and the pesticide draining onto the soil surface may create safety and environmental hazards. A nondraining valve is typically an inline, spring-loaded check valve that requires a minimum pressure (typically ~5 pounds per square inch [psi]) to remain open. While the application rig is operating, the pressure on the injection nozzles may be in the neighborhood of 50 psi. At the end of the pass or turn row and before the chisels are lifted from the application depth, the injection pump is turned off or a solenoid valve is closed to stop the flow of fumigant. When the pressure in the injection line drops to 5 psi, the nondraining valve will close and the injection line will remain full of chemical. The main challenge with nondraining valves on soil injection rigs is that to be effective, the valve needs to be located at the end of the injection line, which is located on the injection blade and subject to tremendous stress as it is dragged through the soil. To prevent the continual repair of these valves on the ends of the injection blades, many operators place the nondrain valves above ground on the tool bar and flush the final section of the injection line with a purge valve.

Purge Valves

A purge valve is basically a tee fitting with check valves installed in two of the ports and the open port leading to the injection orifice. The fumigant is pumped directly through one of the check valves, which also serves as a nondraining valve. At the end of the application pass, the operator stops the fumigant flow and opens a purging system, usually nitrogen gas or compressed air, which enters the injection line through the second check valve. The purging gas is unable to flow backward towards the fumigant pump because of the first check valve, and blows the injection line clear of fumigant liquid to the orifice on the injection shank. Once the injection line is clear, the operator will turn off the purging system, lift the blades out of the soil, and complete the turn to the next pass.

Metering Systems

Flow meters monitor and control the rate of fumigant flow into the system. Accurate metering is essential for even distribution of the fumigant across the application device (e.g., the row of chisels) as well as to assure the correct rate is applied throughout the treated acreage. Meters may be electronic or manual. All pumping systems require reliable meters and control systems to assure proper application. Manual meters such as dial or ball-face meters or pressure gauges must be in view of the operator so shut-off valves or changes in application procedures can be employed as needed.

Electronic Metering Systems

Electronic metering systems use microprocessors to adjust the fumigant injection flow rate “on the fly.” The operator programs the microprocessor by inputting the width of the swath to be treated and the desired application rate of fumigant per area (e.g., gallons per acre). The metering system is connected to a device that determines the ground speed of the application rig, usually a Global Positioning System (GPS) device or a ground-speed radar device, and calculates the injection rate based on the velocity of the rig. The faster the ground speed, the more gallons of chemical is applied per minute. The injection rate is generally controlled by an electrically operated metering valve or controller.

Chisels and Blades

For soil injection applications, knife-like blades called shanks or chisels are mounted vertically on a tool bar behind a tractor and pulled through the soil to deliver the fumigant. A tube carrying the fumigant runs down the back of each chisel. The soil is sealed with a tarp or compacted by a roller or other DPR-approved device immediately afterwards to prevent aboveground fumigant loss. When chisels or injectors are removed from the soil at the end of a row, the fumigant flow must be shut off to prevent dispersal onto the soil surface and into the atmosphere. Nondraining valves are installed for this purpose. At the next row, chisels must be inserted beneath the soil to the proper application depth before product flow resumes. Chisels differ in type and shape depending on the application method.

For broadcast fumigation, chisels (forward or back swept) (Figure 4-6) or Noble plows (Figure 4-7) may be mounted on the tool bar spaced according to the required depth of application. Injection points for chisels are placed about 12 inches apart for shallow (6 to 12-inch-deep) applications. For deep (18–30 inch below the soil surface) applications of methyl bromide, chloropicrin, or Telone, chisels are spaced further apart (up to 66 inches for methyl bromide). For row or band applications, one or more chisels are mounted on the tool bar to treat only the soil where the crop will need pest protection.

Spray blade applications are similar to liquid chisel injections in the delivery system but the injection chisels or shanks have been replaced with horizontally positioned spray blades (Figure 4-8). The spray blades are designed to cut through the soil horizontally, momentarily 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. This application method is particularly useful in treating planting beds for annual crops. A typical spray-blade application may treat a 12-inch-wide bed every 60 inches at a depth of 8 inches. Plows on the tool bar will throw soil on top of the treated bed to seal the soil surface. Prior to planting, the untreated soil will be sliced or smoothed off and thrown back into the furrow, and the crop will be planted into the treated soil of the newly shaped bed.

FIGURE 4-6

Deep shanks or chisels for Telone application. Photo courtesy of Paul Niday.

FIGURE 4-7

Noble plow. Photo courtesy of Paul Niday.

FIGURE 4-8

Spray blades showing fumigant delivery tube in center. Note double valve near bar to allow fumigant shut-off at the end of the row. From DPR.

Safety Systems

Many safety systems or devices are recommended or required when applying fumigants. In California, fumigation application systems (except granular applications) must be closed systems. These systems must also include pressurized nitrogen or air to maintain constant pressure, a vapor recovery system and vacuum relief and pressure relief valves on the tank. Backflow prevention is critical for any system connecting to a water source. Electrical or hydraulic interlock systems add safety to chemigation systems. A liquid level sensor or tape or a sight gauge with a self-closing shut-off valve, and system purge and chisel purge valves are required with some soil application systems.

Closed Systems

Closed systems are chemical application systems that are designed to minimize physical contact with the material being applied. They typically employ dry-lock connectors and containers that must be returned to the manufacturer unrinsed, eliminating the usual hazards associated with the mixing of materials and rinsing of containers. Closed system containers may utilize an internal pump or compressed gas to deliver the material to the injection system. Closed systems are used for all fumigants except granular formulations.

Backflow Prevention

To prevent contamination of the water source, any irrigation system that will be injected with fumigant must include a backflow-prevention system. Backflow-prevention systems must contain a functional check valve, a vacuum relief valve and a low-pressure drain located on the irrigation pipeline to prevent water-source contamination. The pesticide injection line must also contain a functional, normally closed, solenoid-operated valve connected to the system interlock to prevent the fumigant from being withdrawn from the supply tanks when the irrigation system shuts down. In some situations, other types of automatic quick-closing valves (such as hydraulically operated check valves, vacuum relief

valves, or spring-loaded check valves) can be substituted. For details, consult the DPR website (http://www.cdpr.ca.gov/docs/emon/grndwtr/chem/chemdevices.htm) or ask your agricultural commissioner. Figure 4-9 shows required safety devices for a chemigation fumigant application.

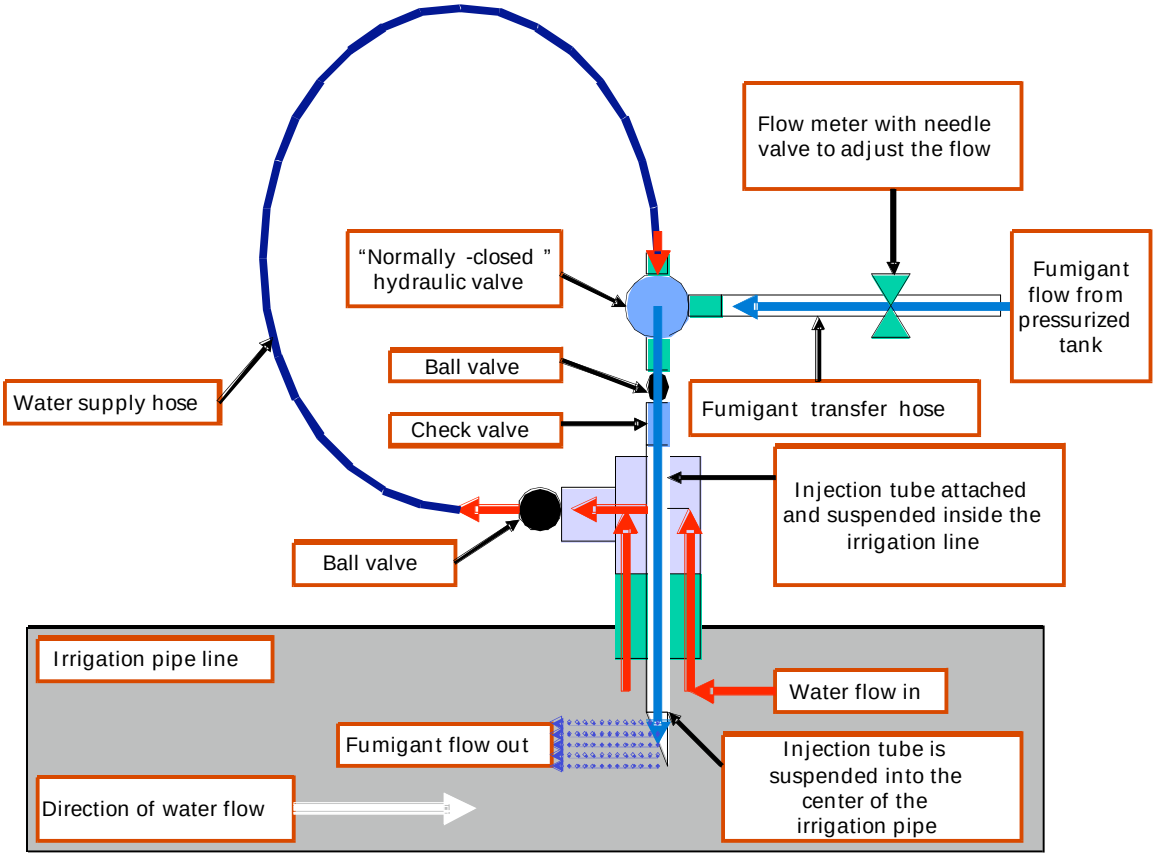


FIGURE 4-9

Required safety devices for a chemigation fumigant application. From Ajwa et al. 2007.

Electrical Interlock System

Electrical interlock systems (Figure 4-10) are required safety devices for use in most chemigation systems. During a typical chemigation application, fumigant is injected into an irrigation pipeline and applied to the field with the irrigation water. There is a potential for the irrigation water pump to shut off and the chemical injection pump to continue pumping fumigant into the irrigation pipeline. The interlock is a system of several electrical interlocks that can insure against this potential problem. In a typical system, the first interlock is a normally closed solenoid valve on the fumigant injection line between the chemical delivery tank and the injection pump. Energy is applied to open the solenoid valve when the irrigation water pump is operating and the power is cut when the water pump is off for any reason. Without power, the solenoid valve closes and the fumigant is prevented from entering the injection system. The second interlock allows the chemical injection pump to operate only when the water pump is operating. The third interlock consists of a pressure sensor on the irrigation mainline that turns off the water pump when the line pressure falls below the level required for adequate chemical distribution. With this system of three electrical interlocks, the fumigant chemical is prevented from entering the irrigation line if the irrigation system loses pressure for whatever reason (pump failure, line break, etc.).

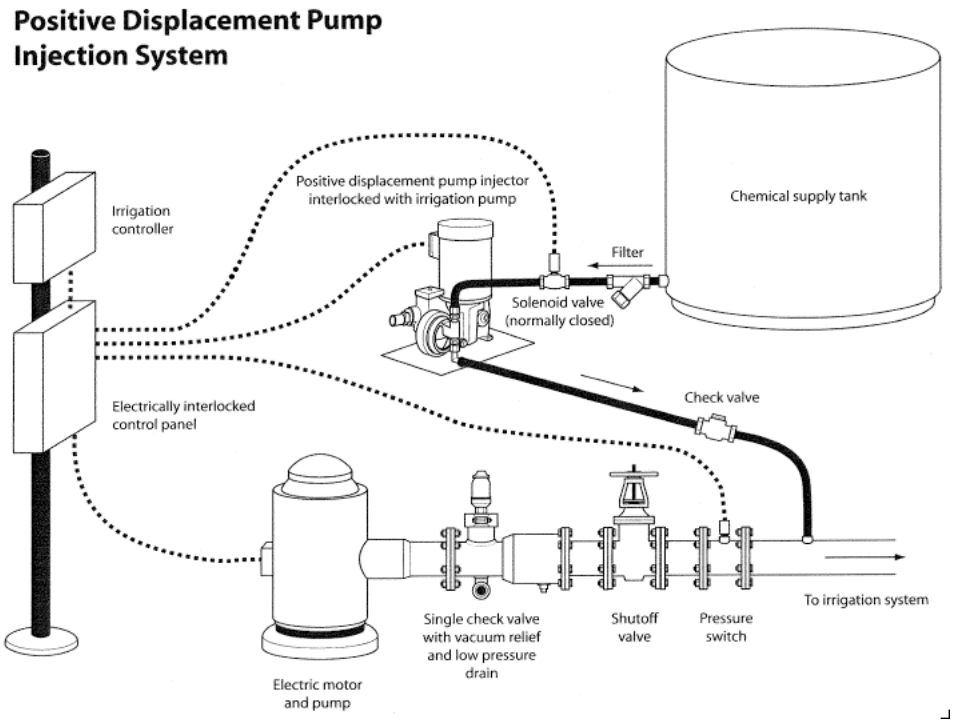
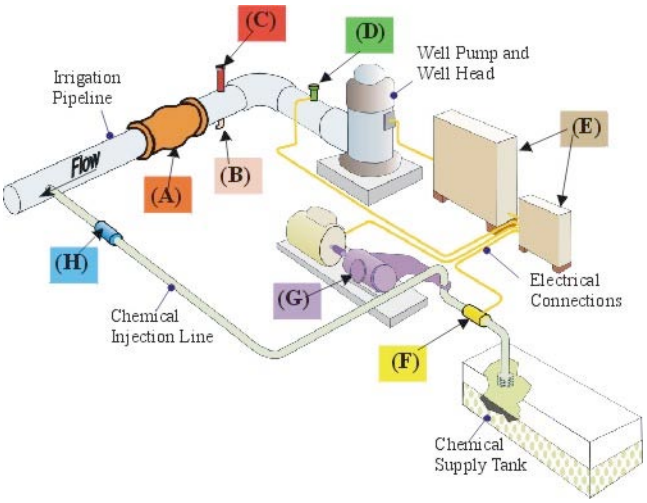


FIGURE 4-10

Dotted lines show electrical interlocks connected to a chemigation system. Interlocks connect the solenoid valve from the pesticide line with the pressure switch from the irrigation line. The injection pump from the pesticide line and the irrigation pump are also interlocked. From DPR.

Hydraulic Interlock System

An hydraulic interlock system (or normally closed hydraulic valve) (Figure 4-11) is an alternative safety device to the electrical interlock systems. The normally closed hydraulic valve opens when the irrigation water pump is operating, and the flow is cut when the water pump is off. Without water pressure, the hydraulic valve closes and the fumigant is prevented from entering the injection system. With this system, the fumigant is prevented from entering the irrigation line if the irrigation system loses pressure.



(A) Mainline Single check Valve
(B) Low-Pressure Drain
(C) Air/Vacuum Relief Valve
(D) Pressure Switch
(E) Interlocking System Controls
(F) Solenoid-Operated Valve
(G) Pesticide Injection Pump
(H) Injection Line Check Valve

FIGURE 4-11

Hydraulic interlock system on a fumigant injection system from a pressurized tank. From DPR.

APPLICATION EXAMPLES

Liquid Gas Injections—High Pressure

Methyl bromide applications are performed as liquid gas injections (Figure 4-12). Methyl bromide has a boiling point of 39°F (4°C) and is a liquid at room temperatures if kept under pressure. It is applied through closed systems, generally delivered with nitrogen gas or pressurized air.

From a high-pressure cylinder mounted on the tractor, methyl bromide liquid is pushed at approximately 80 psi through a glass sight tube visible to the operator and then through an electronic metering system. Should the injection system pressure drop unexpectedly, the liquid methyl bromide in the sight tube will begin to boil, alerting the operator to the low-pressure condition. The electronic metering system consists of an electric throttling valve, flow meter, and ground speed device that are connected to a microprocessor. As the application rig's ground speed increases, the microprocessor opens the throttling valve and confirms the flow increase with the flow meter. Downstream of the flow meter the liquid methyl bromide passes through a purge valve tee and into a flow dividing manifold, which evenly distributes the flow into the separate (typically ~12) chisel-injection lines. At the end of an application pass, the operator stops the tractor and shuts off the flow of methyl bromide. He then pulses two or more shots of compressed purging air through the flow divider and injection lines to clear the tubes of methyl bromide prior to lifting the injection chisels out of the soil. During the application, the liquid methyl bromide passes through the flow divider and into the individual polyethylene (poly) injection tubes leading out of the divider. These flexible poly tubes run from the tool bar to the point of injection or connect to the steel injection tubes that run down the back side of the injection chisel. At the actual injection point the tubes are open, allowing the methyl bromide to drip into the soil as the injection chisel moves through the soil. Vibration in the poly tubing is used as an indicator that the injection system is working properly. If one of the twelve injection tubes is not vibrating, it is an immediate visual indication that methyl bromide is not flowing properly and either the flow divider is plugged or the injection tip is plugged.

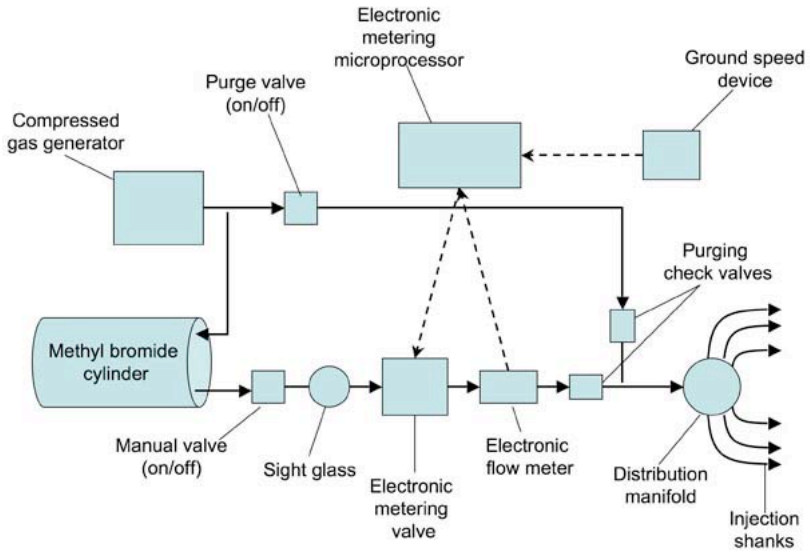


FIGURE 4-12

Schematic of a liquid gas injection application system.

A typical methyl bromide field application in the California coastal regions will be made with injection chisels 12 inches deep and 12 inches apart. The application rig will seal the soil surface behind the chisels with a 1-mil polyethylene tarpaulin. For details on tarpaulin sealing, see Chapter 5. The initial field pass will be 11 feet wide with 12 chisels. This allows 1 foot of the 13-foot-wide tarp to be buried on each side, sealing the edge of the treated area. Each successive pass will be 11 feet wide with 11 chisels. This allows a 1-foot overlap on each edge of the tarp for adhesive sealing and 1 foot to be buried. On the final pass, the terminal edge of the tarpaulin will be buried. The application rate calibration is initially performed by programming the electronic metering system. The operator is able to confirm visually that the methyl bromide calibration is correct in the following manner: The polyethylene tarpaulin is supplied on a 4,000-foot-long roll. With an application width of 11 feet, one roll will cover 44,000 square feet, or 1.01 acres. For a desired application rate of 350 pounds of methyl bromide per acre, each methyl bromide delivery cylinder will need to be filled with about 355 pounds of methyl bromide. (Containers must be filled by registrants when you make your order.) Following these calculations, the roll of tarpaulin and the methyl bromide delivery cylinder should both run out at the same time. Experienced operators should be able to consistently apply methyl bromide to within 5% of the target application rate while staying within the maximum label rate.

Liquid Chisel Injections—Low Pressure

Applications of 1,3-dichloropropene (1,3-D) (Telone II, Telone C35) are typically made as liquid chisel injections. Chloropicrin and metam sodium or metam potassium liquids (Vapam, Sectagon, Sectagon-K, K-Pam) may also be applied in this manner. The application rig will have a storage/delivery tank that is filled from a bulk nurse tank through a closed system (Figure 4-13).

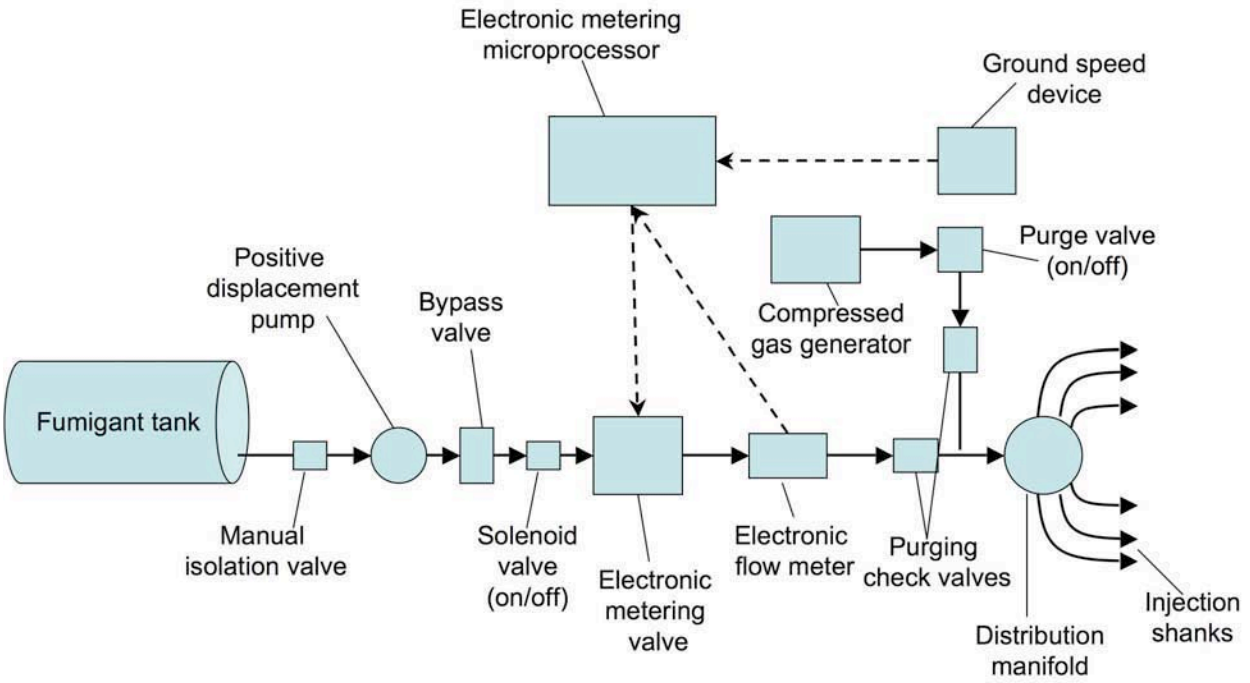


FIGURE 4-13

Schematic of a low-pressure liquid injection application system.

The liquid fumigant is pumped by a positive displacement pump through a bypass valve and an electronic metering control block. The control block regulates the flow volume based on the calibration set point and the application rig's ground speed. Immediately downstream of the control block is an electronic flow meter that sends a signal to the electronic metering system, confirming the regulated flow rate. The tractor's ground speed is generally measured with a ground-radar device or global positioning system (GPS), and this signal is also transmitted to the electronic metering device. This information, along with the width of the treated area, allows the electronic metering device to follow the application rate calibration "on the fly." After the flow meter, the fumigant passes through an operator-activated solenoid valve, which allows the operator to stop the flow of material at the end of a field pass. Downstream of the solenoid valve is a purge valve that the operator activates to flush the fumigant out of the distribution manifold and injection tubes before lifting the tool bar and chisels out of the ground. The purging is generally accomplished with nitrogen or compressed air. Following the purge valve, the material passes through a distribution manifold where it is evenly divided and passes into the individual polyethylene, tygon, or nalgene hoses that lead to the individual injection chisels on the tool bar. The operator will keep an eye on these clear plastic tubes for visual confirmation that fumigant is passing through them. The chisel injection tubes are usually 3/8-inch stainless-steel tubes and are open at the injection point on the rear edge of the injection chisel. A typical 1,3-D application for preplant trees and vines in the lower San Joaquin Valley will inject 18 inches deep with chisels 20 inches apart. The application rig will be immediately followed by a second tractor pulling a disc and ring-roller to seal the chisel traces and field surface.

Power Mulch/Rototiller Applications

Power mulch/rototiller applications can be used when target pests are in the upper soil profile. The fumigant material is applied to the field surface, either as a liquid spray or a granular broadcast, and immediately incorporated to the desired depth with a power mulching device (rototiller). For granular formulation applications, the spreading equipment must be able to adequately handle the small granule size and maintain delivery to the area where the granules will be physically incorporated. Drop spreaders

are generally preferable to broadcast spreaders because of the reduced potential for drift and off-target applications. Once the granular or liquid fumigant has been applied and mechanically incorporated, the soil surface is then sealed with a plastic tarpaulin or a sprinkler irrigation application. Power mulch applications are commonly used as preplant seed-bed fumigations.

Chemigation Applications

Metam sodium (Vapam, Sectagon), and to a lesser degree metam potassium, are two fumigants that have historically been applied through sprinkler, drip, or furrow irrigation equipment, although use of sprinkler systems is now uncommon. Emulsifiable concentrate formulations containing mixtures of 1,3-D and chloropicrin are also commonly applied through drip irrigation systems. Special consideration must be given to field conditions prior to beginning a chemigation (*chemi*cal irri*gation*) application: Air temperature, soil temperature, wind speed and direction, and weather forecast are all factors in keeping the fumigant in the field, while preventing off-site movement of the fumigant and its odors. Specific restrictions are placed on chemigation applications by the fumigant label, including water supply protection (backflow devices) and injection system interlocks. The distribution uniformity (DU) of the fumigant application is dependant upon the DU of the sprinkler, drip, or other output system. Prior to the application, the system must be inspected while operating to ensure appropriate pressure is being delivered to all of the sprinklers or drip tapes and that no leaks are evident. This performance check is generally carried out during the preapplication irrigation, which occurs several days before chemigation to bring the soil moisture to the desirable level for fumigation and moisten weed seeds to increase control.

FIGURE 4-14

Drip fumigant injector with check valve, automatic shut-off valve, and digital flow meter control.

When setting up your drip system for chemigation, it is important to use good quality irrigation components and drip tape. Fumigant loss, odor problems, and emissions can occur if there are leaks in the system. Reconfiguration of drip tape spacing may be necessary to get the best coverage over the soil bed. In strawberries, two drip tapes are generally used. A third drip tape in the center may be needed in beds that are wider than 40 inches or if the soil is sandy. Moderate flow drip tapes (between 0.45 and 0.67 gpm/100 feet) are appropriate for most situations. Low-flow drip tapes are recommended for heavy soils or beds on steep slopes. Pressure in the drip tape must not vary more than 3 psi during application to assure uniform delivery. Safety devices including a fumigant injector equipped with a check valve and an automatic solenoid or hydraulic normally closed valves are required (Figure 4-14).

When using drip tapes, it is essential to flush the lines all the way to the end of the drip tapes after each application. Many fumigants can damage PVC if left in pipelines. The required flush should be approximately three times the volume of the mainline and the laterals. Too much flushing should be avoided because it will dilute the fumigants in the soil around the drip tape.

To calculate the irrigation application rate in inches per hour for sprinkler application, see Sidebar 4-1. Drip fumigation calculations are shown in Sidebar 4-2.

Monitoring the Application

Before beginning a chemigation application, the operator must check to confirm that the irrigation system contains all of the equipment specified on the pesticide label and/or required by DPR and that the equipment is working properly. One way of testing the functionality of the safety equipment is to start the irrigation system and bring it up to pressure. With the chemical feed tank isolated from the injection system, start the injection pump and confirm that the injection system interlocked-solenoid valve is energized. Now, manually turn off the irrigation water pump. The following events should occur if the interlock systems and backflow prevention systems are working properly:

- The irrigation water pump will stop.
- The chemical injection pump will stop.
- The chemical injection solenoid valve will close (de-energize).
- The irrigation system check valve(s) will close.
- Air will be drawn into the irrigation system vacuum-relief valve.
- A small amount of water will be discharged through the low-pressure drain adjacent to the irrigation system check valve(s).

If any of the irrigation equipment specified on the label is not present or is not functioning properly, it would be a violation of federal and state law to proceed with the chemical application.

Once it has been confirmed that the irrigation system is functioning properly and compliant with the label, including the technical information bulletin (TIB), and restricted materials permit conditions, the application can proceed. With the sprinkler system fully pressurized, the chemical injection tank can be connected to the injection system and the injection pump started. The operator should record a log of the application, including the time of day, the system pressure, wind speed and direction, ambient temperature, and any comments regarding observations that may be pertinent, such as odors or passers-by approaching the treated area. The log should be updated frequently during the application. The label, TIB, regulations, and permit may also provide specific monitoring requirements to be followed during any fumigation application. If a circumstance presents itself requiring early termination of the application, it is important to continue operating the irrigation system after the chemical injection has stopped to flush the chemical out of the lines and apply a water seal to the field. Ending an application without applying sufficient irrigation to move the fumigant into the soil and seal the surface can lead to excessive volatilization, health and environmental hazards, and lack of product efficacy can occur. The additional amount of irrigation required to seal the soil may be detailed on the label or technical information bulletin. There may be additional irrigations of specific duration or depth (in inches) called for, as well. Soil treatment is discussed in more detail in the next chapter.

SIDEBAR 4-1

Calculating the Irrigation Application Rate and Injection Rate of a Sprinkler-Applied Fumigant

Step 1. Calculate sprinkler irrigation application rate (AR)

AR (inches per hour) = 96.3 x flow rate (gallons per minute) ÷ area (square feet)

Example 1

Given: The flow meter of a sprinkler system reads 870 gpm for a field with an area of 13.8 acres.

Solution:

AR = 96.3 x 870 gpm ÷ (13.8 ac x 43,560 ft^2)

AR = 83,781 ÷ 601,128

AR = 0.139 inches per hour

To apply one-half inch of irrigation,

0.5 inches ÷ 0.139 inches per hour = 3.6 hours

Example 2

Given: The sprinklers are spaced 30 ft x 45 ft. Each sprinkler has a flow rate of 2.3 gpm.

Solution:

AR = 96.3 x 2.3 gpm ÷ (30 ft x 45 ft)

AR = 221.5 ÷ 1,350 ft^2

AR = 0.164 inches per hour

To apply one-half inch of irrigation:

0.5 inches ÷ 0.164 inches per hour = 3.05 hours

Step 2. Calculate the injection rate of the chemical applied with sprinklers

Given: A 9.8-acre field is to be treated with 40 gallons per acre of liquid fumigant. The fumigant will be applied with a minimum of 0.8 inches of water in a minimum time of 4 hours. The sprinklers are spaced on a 30 ft x 45 ft pattern and each sprinkler has a flow rate of 2.3 gallons per minute.

Solution:

a. Determine the irrigation Application Rate (AR) in inches per hour, as shown in Example 2 above. AR = 0.164 inches per hour. To apply 0.8 inches of water, you need

0.8 inches ÷ 0.164 inches per hour = 4.9 hours

b. Calculate the total amount of chemical to be applied.

40 gallons per acre x 9.8 acres = 392 gallons.

c. Calculate the injection rate in gallons per minute:

392 gallons ÷ (4.9 hours x 60 min per hr) = 392 gal ÷ 294 min = 1.33 gpm

Therefore, you need to inject 1.33 gpm for 4.9 hours to apply 40 gallons per acre on 9.8 acres with a total irrigation of 0.8 inches of water.

SIDEBAR 4-2

Calculating the Rate of Fumigant Applied by a Drip System

Step 1. Determine the actual treated (bed) area.

Step 2. Calculate the total volume of water required to treat the bed area to the required depth with the required concentration of fumigant.

Step 3. Calculate the time required for application based on the flow rate of the drip tape and the soil type.

Example

See table for estimated water amount and time needed to treat two feet of soil depth using two drip tapes when applying 1,3-dichloropropene and/or chloropicrin in strawberries[1]. (From *UC IPM Pest Management Guidelines: Strawberries*)

Soil Type	**Amount of Application Water (inches per acre [gallons])**[2]	**Application Time Using 2 tapes**				Comments
		Drip Tape Flow Rate (gpm/100 ft)—4 Types				
		0.20 gpm	0.34 gpm	0.50 gpm	0.67 gpm	
Fine sand and loamy fine sand	1.6 (27,000)	13.9 hr	8.2 hr	5.5 hr	4.1 hr	Pre-irrigation with one inch water is needed
Sandy loam and fine sandy loam	2.0 (34,000)	17.3 hr	10.2 hr	6.9 hr	4.2 hr	Minimum of 1.5 inches is recommended
Sandy clay loam and loam	2.6 (44,000)	22.5 hr	13.4 hr	9.0 hr	Not recommended	Split application may be required
Clay, clay loam, and silty clay loam	3.2 (54,000)	27.7 hr	16.3 hr	11.1 hr	Not recommended	Soils not common in California strawberry production

[1] Application time and water volume based on 40-inch average bed width (64 inches center to center)

[2] One broadcast acre-inch of water is about 27,000 gallons. One acre-inch of water for a 40-inch wide bed is about 17,000 gallons.

CHAPTER 4: REVIEW QUESTIONS

1. **What types of pumps are recommended for fumigant applications?**
   a. centrifugal
   b. positive displacement
   c. Venturi
   d. solenoid
2. **What type of valve is required between the chemical supply tank and the injection pump when a fumigant is applied with chemigation?**
   a. a purge valve
   b. a check valve
   c. a solenoid or hydraulically activated valve
   d. a closed-system valve

3. Nondraining valves are important because

a. they prevent fumigant leakage when chisels are pulled out of the ground
b. they prevent backflow of fumigant into the water supply
c. they regulate pressure downstream of a positive displacement pump
d. they are required on all chemigation applications

4. Closed systems

a. are required for application of granular fumigants
b. prevent backflow into the water supply
c. minimize physical contact with the material being applied
d. include air dilution fans and are required on tractors applying methyl bromide

5. These systems automatically adjust application rates for changes in application ground rig speed.

a. electronic metering systems
b. global positioning systems (GPS)
c. closed systems
d. electrical interlock systems

6. A backflow prevention system must include

a. an electrical interlock system and a normally closed hydraulic valve
b. an electronic metering device
c. a positive displacement pump and a bypass valve
d. a functional check valve, an air vent/vacuum relief valve and a low-pressure drain

7. If all the injection tubes are vibrating during a liquid-gas chisel application of methyl bromide, this indicates

a. a malfunction in the application system
b. the injection system is working properly
c. the fumigant is not getting into the soil
d. the chisel depth is too shallow

8. For broadcast fumigation, chisels are placed

a. closer together for deep applications
b. further apart for shallow applications
c. horizontally on the tool bar.
d. further apart for deep applications.

9. For applications of granular fumigants, drift can be reduced by using

a. drop spreaders
b. broadcast spreaders
c. rototillers
d. drip systems

10. To assure the safety of your chemigation system

a. ask the agricultural commissioner to inspect and certify it
b. test it out in part of the field with a low rate of fumigant
c. isolate the chemical feed tank, start the injection pump, and then turn off the irrigation water pump and inspect
d. connect the chemical feed tank, turn on the irrigation water pump, start the injection pump and inspect

Chapter 5: Postfumigation Field Surface Treatment Methods

Knowledge Expectations

1. Explain the importance of postfumigation field surface treatments as it applies to product efficacy, public safety, and environmental health (emission reduction).
2. Have a general knowledge in the use of tarps and how to determine if tarps are acceptable for use.
   a. Describe the general range of products available:
      i. thickness and uses
      ii density
      iii permeability
   b. Explain how to seal the tarpaulin or film edges with:
      i. adhesives
      ii. soil
   c. Explain other important tarpaulin characteristics that may be important:
      i. tolerance to ultraviolet (UV) light
      ii. stretching
      iii. color
3. Explain major components of a "Tarpaulin Repair Response Plan."
4. Discuss tarpaulin removal, including how long to wait before removing after cutting.
5. Describe the steps required to create an effective mechanical seal.
6. Describe the steps required to create an effective water treatment using sprinkler irrigation.
7. Describe the general requirements for monitoring after an application of metam sodium or metam potassium and where to go for current information.

Postfumigation field surface treatments involve placing a barrier on the surface of the soil immediately after fumigation to retain toxic gases within the soil profile. The barrier can be a tarpaulin, soil that has been mechanically compacted, or a layer of water. A barrier minimizes the fumigant volatilizing into the environment, which is important for emission reduction and public and worker safety. Field surface treatments also improve pest control by keeping the fumigant within the soil for enough time to allow contact with the pest. If the fumigant requires the soil to be tarped or treated in some manner, initiate such actions immediately after the application, while the fumigation is in progress.

Different soil treatment methods vary widely in their ability to keep fumigant gases in the soil, and emissions vary by fumigant (Table 5-1). California regulations require specific surface treatment methods to be followed depending on fumigant material and application procedure, with significant restrictions in ozone nonattainment areas (NAAs) from May through October. Contact the California Department of Pesticide Regulation (DPR) or local county agricultural commissioner for current regulations related to your area.

This chapter discusses 1) the different field surface treatment methods: tarpaulins, and water and soil treatments, 2) what to consider when removing the tarpaulin, 3) how to develop a Tarpaulin Repair

Response Plan, 4) postapplication monitoring, and 5) where to get current information on field surface treatment requirements.

TABLE 5-1

Example Emission Ratings[1] of 1,3-Dichloropropene and Chloropicrin with Various Application and Soil Treatment Methods.

Method ***All must include compaction of field surface***	**1,3-D emission rating (% volatilizing into air)**	**Chloropicrin emission rating (% volatilizing into air)**
Nontarpaulin/Shallow/Broadcast	65	64
Tarpaulin/Shallow/Broadcast	65	44
Nontarpaulin/Shallow/Broadcast with three water treatments	44	43
Nontarpaulin/Deep/Broadcast	26	64
Tarpaulin/Deep/Broadcast	26	44
Chemigation (Drip with tarpaulin)	19	12

[1]DPR estimates, made in 2008, of percentage of applied fumigant that volatilizes to the air after application.

FIELD SURFACE TREATMENT METHODS

The type of field surface treatment method required depends on the target pest, volatility of the fumigant applied, application method, and applicable regulations. For instance, fumigants that are less volatile or deeply applied can be kept in the soil using a water treatment or soil compaction. At the other end of the spectrum, fumigants that readily volatilize may require tarpaulins that limit vapor escape, especially following shallow applications. Deep applications of fumigants (18–30 inches) may not require tarping or other surface treatments other than soil compaction but this will depend on the target pest you want to control and regulations. Your sources for determining the required method include:

- DPR regulations,
- Restricted material use permit conditions, and
- labels for products registered for use in California.

Tarpaulins

Tarpaulins include a variety of plastic sheeting materials that can be placed over the field surface to restrict volatilization of fumigants. Often called tarps or films, a wide range of tarpaulin products, each differentiated by thickness, density and permeability, is available from various manufacturers. These different tarpaulin types may also differ by tolerance to ultraviolet light, stretching, color, and price. Additional new products are likely to become available every year. DPR requires that tarpaulins used for methyl bromide meet criteria for permeability and has a list of acceptable tarpaulins to be used after methyl bromide fumigation.

TABLE 5-2

Tarp Thickness Depends on Application and Purpose.

Application	**Thickness**
Entire field (solid tarp)	1.0 mil
Strips/raised beds	1.25 mils
By hand	2.0 mils
For potting soil	4.0 mils or greater

Thickness

How the tarp will be applied and for what purpose determines the thickness to use (see Table 5-2). The unit of measurement for tarp thickness is mils (1 mil = 0.001 inch = 0.025 mm). Most acceptable polyethylene tarps or

virtually impermeable films are between 0.75 and 2.0 mil. There is a good relationship between thickness and permeability, regardless of tarp density. For example, an increase in tarp thickness from 1.25 mil to 2.0 mils reduces chloropicrin and 1,3-dichloropropene (1,3-D) fumigant emissions by 35%.

Density

Tarps can be categorized by density. The two main types are high-density polyethylene (HDPE) and low-density polyethylene (LDPE). HDPE tarps are typically used after methyl bromide fumigation. Naming tarps by density is an industry method of describing the way a tarp is made and does not relate to permeability. For example, 1,3-D and chloropicrin pass through HDPE tarps at a faster rate than methyl bromide.

Permeability

Due to the current interest in emission reduction, tarps are also categorized by permeability (Sidebar 5-1). Recent research has begun to distinguish commercially available tarps by permeability but current permeability regulations only apply to methyl bromide. DPR has a permeability requirement for tarpaulins used for methyl bromide soil fumigations. Contact DPR for a list of acceptable tarps.

FIGURE 5-1

Virtually impermeable film used after fumigation provides additional weed control. Photo courtesy of Husein Ajwa.

The newest type of low permeable tarpaulin is the virtually impermeable film (VIF). Composed of an ethylene vinyl alcohol or polyamide (nylon) layer between layers of other polymers, such as low-density polyethylene, VIFs minimize much of the fumigant's emissions. VIFs retain fumigants within the soil for longer periods and are especially good for weed control (Figure 5-1). Due to VIF's low permeability, a longer time before planting or bed ventilation may be required (refer to the pesticide label) than when using standard polyethylene tarpaulins. Standard VIF does not stretch, while embossed VIF has low permeability and stretches similar to polyethylene tarpaulins.

Currently, DPR regulations state that VIFs cannot be used after methyl bromide fumigation in California. Other issues related to VIF use include its higher price, lack of availability, and lack of glue that joins the tarp together so that wind does not cause the tarp to blow away.

Other Important Tarp Factors

Tarps differ in color, stretch, and their ability to withstand the environment. Products change every year. While price is also important, discussed below are other general characteristics that may affect your decision to choose certain tarps.

Tolerance to ultraviolet (UV) light. Tarps used to cover raised beds that remain in the field through the production season should have a UV stabilizer to prevent disintegration from exposure to UV light from the sun. Tolerance to UV light is not important for tarps that will be removed within a few weeks of application.

Stretching and tearing. Stretching properties are important for ease of tarping. Film flexibility is especially important when covering raised beds, but tarps used on flat ground also should be flexible to avoid tearing during application. Use embossed tarps to cover raised beds because it stretches and rarely tears. With bed shank fumigation, thin (< 1 mil) or thick tarps (> 2 mils) tend to tear and are not

recommended. Most polyethylene tarps can stretch without increasing their permeability. However, nylon used in VIF does not stretch as much as polyethylene and stretching may change its permeability (Figure 5-2).

FIGURE 5-2

Stretching in virtually impermeable films may cause these films to lose their low permeability. Photo courtesy of Husein Ajwa.

Color. Tarps are made in a variety of colors, most commonly black, brown, white, and clear. Different tarp colors are used to control soil temperature, suppress weeds, or repel insects. For example, clear and white tarps will heat the soil better than black, but clear standard tarps will not control weeds (clear VIF does provide weed control). Dark standard tarps control weeds as well as dark colored VIF tarps and dark (except blue) standard tarps are commonly used in raised beds. Color has no effect on tarp durability.

Applying Tarpaulins and Sealing Edges

Tarpaulins are applied as part of the fumigant application process. A typical rig will have one or two disc blades that create small furrows on the outside of the fumigation swath. A device for unrolling the tarp is connected to the discs. As the fumigant is applied, the furrows are formed, and the tarp is unrolled. Closing shoes cover the chisel marks from the fumigant application just ahead of a compaction roller. This smoothes the soil surface before the tarp is laid down.

Sealing the edges of the tarp or film is important to prevent escape of the fumigant into the atmosphere. Seal the tarp edges by one of two methods—strip or broadcast—depending on application type. With either method, at the end of the row, bury the ends of the tarp under 4 inches of firmly packed soil.

Strip fumigation. Strip fumigation can be used on fields with beds or flat fields. With strip fumigation, fumigation and sealing occurs on half the field in alternating strips of treated and untreated rows. For flat fields, the tarps are removed at a later time, and the process is repeated for the untreated strips. The fumigation rig covers the edges of the tarp with soil using press wheels that insert the edges of the tarp into open furrows. The furrows are then covered with soil by closing discs, sealing the tarp underneath.

FIGURE 5-3

Plastic tarp application during fumigation.

Broadcast (flat field) fumigation. For broadcast fumigation, the bottom surface of one tarp is glued onto the upper surface of another as the rig passes through the field. In this manner, the entire field can be treated at one time (Figure 5-3). The first pass proceeds similar to a strip treatment with both edges of the film sealed with soil. For the second pass, remove one disc blade and replace with an adhesive dispenser. During the second and subsequent passes, one edge of the film will be glued to the tarp that is already in place there and the other sealed with soil.

Water Treatments

For fumigants that are less volatile, water can be used as a barrier on the field surface rather than tarps. Using water to retain the fumigant in the soil is called a water treatment. Although sometimes referred to as a water seal, this term is not accurate because the seal is not complete. Water treatments can be used after application of MITC generators such as after chemigation with metam sodium or metam potassium, or after dazomet incorporation. Use a water treatment after nontarped shank application of metam sodium or metam potassium if compaction is not possible. Also, water treatments can be used after 1,3-D and chloropicrin fumigation.

Water treatments work by replacing the air-filled pore spaces between soil particles with water, slowing fumigant diffusion at the soil surface, and thus reducing emissions into the air. How long a water treatment remains effective depends on soil texture and fumigant.

The standard water treatment is done immediately after fumigation. As the name suggests, intermittent water treatments apply several small water treatments within 48 hours after the initial standard treatment. Generally, apply water to the field surface after compaction of the top layer of soil with rollers or drags. How much water to apply will depend on the soil texture. For most soils, apply ¼ inch immediately after fumigant application. To learn more about calculating the irrigation application rate, see Sidebar 4-1 in Chapter 4.

SIDEBAR 5-1

Current Research on Tarpaulin Permeability Categories

Commercially available tarpaulins are described as low-density, high-density, semi-impermeable, and virtually impermeable, but these subjective labels do not help the user determine which tarp is more permeable to one specific fumigant compared to another. For instance, a high-density tarp may be more permeable than a semi-permeable tarp for some fumigants.

Current research is categorizing tarps by measuring the mass transfer coefficient (MTC) of tarps for different fumigants at different temperatures. Knowing the permeability of the tarp will allow for better choices of tarps for emission reduction.

The MTC is measured by placing the tarp between two sealed cells. The fumigant is placed in one cell and the amount of fumigant that moves from one cell to the other through the tarp is the MTC. A lower MTC means that a low amount of fumigant moved through the tarp and indicates low permeability. In the near future, tarps could be placed in new categories that best describe their permeability based on the MTC.

In NAAs, post-treatment water applications are currently required for many applications where tarps are not used. To determine the water treatment requirements based on the fumigant being applied and location of the treatment site, you can review DPR regulations, the restricted-material permit conditions, and any California-specific labeling.

Mechanical Soil Treatments

Mechanical soil treatments use mechanical equipment to add a soil barrier or compact the soil surface to reduce the volatilizing of the fumigant into the atmosphere. They are often used in combination with water treatments.

To compact the soil surface, mechanical equipment (e.g., bed shaper, press wheel, roller, or drag) packs the surface of the soil forming a barrier between the fumigant and the air. This is commonly used when making deep chisel applications where there is enough soil above the injection points to provide a thick layer of compacted soil. An important part of this process is eliminating chisel trace. If not covered, this vertical vent in the soil made by the passing injection chisel would provide the fumigant with an easy means of escape.

Mechanical equipment is also used to place untreated soil over treated areas, a practice called capping. After the fumigation period is over, the added soil, including some treated soil, is removed prior to planting. Capping is typically used with strip applications. Untreated soil is pulled from the outside of treated rows, either on flat fields or raised beds, then deposited on the treated rows to add approximately six inches, followed by compaction. A potential problem with capping using untreated soil is the reintroduction of pests into the fumigated beds.

TARPAULIN REPAIR RESPONSE PLAN

The Tarpaulin Repair Response Plan must be included in the Work Site Plan for methyl bromide fumigation. The Work Site Plan is a series of questions to be completed and submitted to the local county agricultural commissioner's office when applying for the restricted materials permit. It covers such items as application (fumigant, rate, and application type), tarp removal, and safety.

The Tarpaulin Repair Response Plan details the procedure to be followed in case tarp damage occurs. While the specific details of a Tarpaulin Repair Response Plan will differ according to the situation, every plan will contain the same major components (Figure 5-4). The purpose of the repair response plan is to be sure that the applicator checks for problems before they can become severe and also is prepared to handle any emergency. Damage to tarps can rapidly create a serious emergency if not handled properly because of the potential leakage of highly toxic chemicals.

TARP REPAIR RESPONSE PLAN

DURING the fumigation injection, the tarp will be repaired by:
- ☑ The pest control business
- ☐ An authorized representative - Name: _____

AFTER the pest control business has finished the application and left the field, the field will be monitored for damage by:
- ☐ The pest control business
- ☑ An authorized representative - Name: Jane Doe

The field will be monitored for problems or damage during the first 24 hours:
- ☐ hourly
- ☐ every two hours
- ☑ every four hours
- ☐ every six hours
- ☐ other _____

Type of testing device: Draeger tube
Type of respiratory protection: SCBA

Tarp repair will be conducted when damage occurs in the following situations:
During the first 24 hours -
1. When the damage exceeds: 6 inches
2. When damage occurs this distance from sensitive sites: 100 feet

After the first 24 hours, report any damage larger than: 6 feet

ANY EVIDENCE OF EXCESSIVE GAS ESCAPING OR ABOUT TO ESCAPE FROM THE TARP, WILL BE IMMEDIATELY EVALUATED AND IMMEDIATELY REPORTED TO BOTH THE PEST CONTROL BUSINESS AND THE COUNTY AGRICULTURAL COMMISSIONER'S OFFICE.

The following criteria will be considered when making decisions on tarp repair:
1. Hazard to public, workers, or residents
2. Proximity to occupied structures
3. Size of damaged areas
4. Timing of damage, feasibility of repair and environmental factors such as wind speed and direction

FIGURE 5-4

Example Tarpaulin Repair Response Plan.

In some cases the tarpaulin cannot be repaired and the local county agricultural commissioner's office should be notified immediately. Call 9-1-1 if anyone experiences symptoms of fumigant exposure, such as watering eyes or coughing. Key information in a Tarpaulin Repair Response Plan includes

- name of person(s) responsible for the repair should damage occur to the tarp
- name and certification number of person(s) testing the ambient air concentrations of the fumigant
- schedule for checking tarps for damage
- minimum distance(s) from sensitive sites that tarps will be repaired
- minimum time following fumigation that the tarp will be repaired
- minimum size of damage that will be repaired
- maximum time following notification of damage that the pest control business or permittee will respond
- other factors—for example, hazard to the people, proximity to occupied structures, feasibility of repair, and environmental factors (e.g., wind speed and direction)

POSTFUMIGATION ACTIVITIES

Monitoring

Postapplication monitoring differs depending on the fumigant. Refer to the fumigant label, restricted materials permit, and DPR regulations for specific monitoring requirements. Generally you must monitor

- tarps for tears, holes, and improperly secured edges. Tarps placed over the surface of drip lines should be monitored for damage and adjustment before chemigation begins.
- the perimeter of the treatment site for any offsite movement of the fumigant, especially downwind. Check for odors and exposure symptoms such as eye, nose, and throat irritation.

Monitoring is especially important after applications of all MITC generators such as metam sodium, metam potassium, and dazomet, as well as methyl bromide with chloropicrin, to minimize off-site vapor movement that can lead to human eye or respiratory irritation. If during the fumigation event or at any time after, odor reaches unacceptable levels, the soil must immediately be sealed. This can be done either by a water treatment (1/4 inch of water or two hours of sprinkler irrigation), capping the treated soil with 3 to 6 inches of untreated soil, or compacting the surface of the treated soil using a bed shaper, roller, press wheel, or other equipment.

When monitoring for MITC, record the air temperature, soil temperature, wind conditions, and the presence of any odors downwind of the fumigation area prior to, during, and when the fumigation event is complete. If the application is within 1500 feet of an occupied structure, monitor air, soil, wind, and odor conditions every 2 to 4 hours for a 12-hour period. The 12-hour period starts with the end of the fumigation event.

Check with the local county agricultural commissioner for more information about postfumigation monitoring when applying MITC generators. Depending on local conditions, the agricultural commissioner may modify monitoring requirements.

Tarpaulin Removal

Cutting and removing tarps is hazardous and workers must be properly trained and fitted with the required personal protective equipment. When the treatment exposure period is complete, adhere to the tarp cutting, ventilation, and removal restrictions found in DPR regulations, restricted materials permit

conditions, and the fumigant label. Generally, the tarp is perforated or cut at least 24 hours before removal to allow escape of any remaining toxic gas. The tarp can then be removed by hand or with a roller machine that spools the used tarp (Figure 5-5).

With broadcast applications of methyl bromide, DPR requires that only mechanical methods be used, such as all-terrain vehicles or tractors with a cutting wheel, and the tarp is to be cut lengthwise. For methyl bromide, the Work Site Plan should include information on tarpaulin removal. The information requested in the plan includes designating the person(s) responsible for removal, equipment and methods used to cut the tarps, and schedule for cutting and removing tarps.

FIGURE 5-5

Handler using a tractor to remove tarp. From DPR.

During removal, measure the fumigant concentration in the air using an accepted device such as the Draeger tube. If the concentration exceeds the safety limits determined by the fumigant label or regulations, or if the presence of the fumigant is readily detected (e.g., from eye or respiratory irritation or strong odor) at any time, discontinue removal of the tarps.

WHERE TO FIND CURRENT INFORMATION

While this manual provides general information about postfumigation field surface treatment methods, you should remain current about changes that may occur with the development of new fumigants, regulations, and sealing materials and techniques. The best place to get current information is to check with the California Department of Pesticide Regulation or with the local county agricultural commissioner's office.

CHAPTER 5: REVIEW QUESTIONS

1. Postfumigation soil treatments

a. are mandatory after all fumigation applications
b. use mechanical equipment to decrease plant debris
c. only include the use of tarpaulins
d. are important for emission reduction

2. What is LEAST LIKELY to be a consideration when determining the type of field surface treatment to be applied after fumigation?

a. target pest
b. regulations
c. irrigation practices
d. application method

3. What is the definition of permeability?

a. the change from a liquid to a gas
b. penetration of gases through a solid
c. type of plastic
d. compounds that are injurious to plants

4. Strip fumigation applies tarpaulins
   a. to the whole field at once
   b. to fields with beds only (not used for flat fields)
   c. using glue to connect the tarps together
   d. in alternating strips of treated and untreated rows

5. How many inches of the tarp edge must be buried at the end of the row?
   a. 4 b. 3 c. 2 d. 1

6. Generally, water treatments _____fumigant diffusion at the soil surface by _____soil pores and preventing fumigant emissions into the air.
   a. increase; opening
   b. increase; blocking
   c. slow; blocking
   d. slow; opening

7. A 5-acre field is to be treated with 1 inch of water. The flow meter on the sprinkler system reads 750 gallons per minute. How long to you irrigate for?
   a. 2 hour
   b. 3 hours
   c. 4 hours
   d. 5 hours

8. Capping after fumigation refers to
   a. tarpaulin placement
   b. placing soil on top of treated soil, which is then removed prior to planting
   c. a specialized water treatment
   d. a monitoring procedure

9. What is the purpose of the Tarpaulin Repair Response Plan?
   a. details tarp removal for each fumigant
   b. discusses irrigation procedures following fumigation
   c. details the plan to follow in case of tarp damage
   d. discusses application methods

10. Tarpaulin removal
   a. is not hazardous
   b. requires proper training and personal protective equipment
   c. can be done at any time after fumigation
   d. is done the same way for all fumigants

11. Field surface treatment monitoring
   a. checks for damage and adjustment before chemigation begins
   b. is important only for MITC generators
   c. has the same requirements for all fumigants
   d. always requires a form from the local agricultural commissioner

12. During tarp removal, the odor of the fumigant is strong. You should
   a. alert the county agricultural commissioner's office
   b. put on your personal protective equipment
   c. continue removing the tarp—odors are always strong during tarp removal
   d. discontinue removal until you know the concentration of fumigant in the air is below safety levels

Chapter 6: Hazards Associated with Field Fumigation

Knowledge Expectations

1. Explain how fumigants move in the environment in air, water, and sediment.
2. Describe the impact of fumigants in California Regional Air Quality Basins in regard to VOC emissions.
3. Explain the impact of fumigants on nontarget organisms.
4. Describe how the various fumigants enter the body.
5. Describe how people get exposed to field fumigants.
6. Describe the health effects of exposure to the various fumigants.

Fumigants present special environmental and health hazards due to their inherent toxicity and volatile nature. All fumigants are general biocides. While very effective for controlling pests, fumigant vapors are extremely hazardous—to the environment, applicators, other people, and wildlife. In air, water, or soil, fumigants may injure nontarget organisms. Fumigant volatile organic compounds (VOCs) pose a threat to air quality. While handlers are most at risk, field workers and others working near the application site, and the public might also be injured from applications. Each fumigant and its application method present different potential hazards. Handlers must know the human health hazards and exposure symptoms, environmental hazards, and methods for preventing problems when applying fumigants.

HOW FUMIGANTS MOVE IN THE ENVIRONMENT

To be effective, a fumigant is placed in the soil and must stay beneath the field surface long enough to kill the target pests. However, during preapplication preparations, application, equipment clean-up, and after the application, fumigants can escape into the air, water, or soil to pose a hazard to people and the surrounding environment. Escaped fumigant can contribute to poor air quality, contaminate water, cause locally dangerous situations that could harm workers and other people nearby, or unintentionally harm animals that weren't meant to be injured. Understanding how fumigants move in air, water, and soil will help you protect human health and the environment (Figure 6-1).

Movement in Air

Volatilization is the most important way fumigants move away from the application site. Fumigants are gaseous pesticides and naturally volatilize into the air unless restricted by tarps, compacted soil, or water.

Soil texture, moisture content, temperature, method of application, and type of surface sealing are all important in determining fumigant movement above ground into the air, along with the characteristics of the specific fumigant chemical. Fumigants vary in the rate of movement into air. For instance, true fumigants such as methyl bromide, chloropicrin, and 1,3-dichloropropene (1,3-D) have a greater potential to escape the field surface rapidly than MITC generators such as metam sodium.

Generally, the least volatilization occurs in cooler weather when fumigants are injected deeply into moist soil. High temperatures and dry, sandy soil increase volatilization rates. Volatilization of some

materials can be minimized when the soil surface is packed, tarped, or treated with water immediately after application.

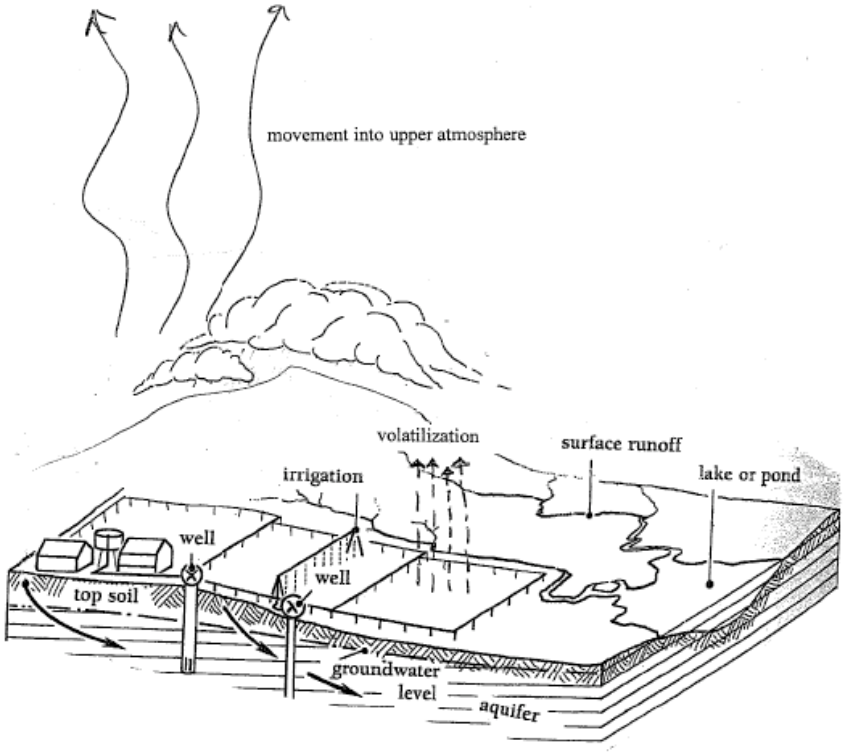


FIGURE 6-1

Fumigants can move through the environment in air, water, and soil to affect nontarget organisms.

The method of application affects emission levels. Efficacy of each method in reducing emissions varies according to fumigant material.For instance, chemigation by drip greatly reduces emissions compared to broadcast applications of MITC materials. On the other hand, when drip is used to deliver 1,3-D or chloropicrin, puddling on the soil surface can increase volatilization if the material is released faster from the emitter than it can be absorbed into the soil. For true fumigants like methyl bromide, deep chisel applications generally result in less fumigant emission into the atmosphere than shallow injections if no tarps are used.

Wind can increase the movement of fumigant off-site. Labels, regulations, or local requirements often have wind speed restrictions for fumigations. A light wind (up to 7 miles per hour) might be useful for protecting workers. However, light winds have been shown to move fumigants to nearby residential areas. Don't apply metam sodium by chemigation when wind speeds are above 7 mph. Excessive winds can lift tarps off treated areas resulting in off-site vapors and reduced effectiveness of the fumigation. Correct tarping and tarp removal methods are key to reducing the impacts of off-site fumigant movement.

Atmospheric inversion layers can increase the adverse effects of off-site movement of fumigants by concentrating toxic vapors instead of allowing them to dissipate in air. Temperature inversions occur when cool air near the ground is trapped by a layer of warmer air above (Figure 6-2). The warm air above the inversion forms a cap that blocks vertical air movement. Since normal air mixing does not take place, fumigants may become trapped in air pockets that may move en masse to locations where they can adversely impact people living nearby and plants and animals. Inversions are a special problem when making sprinkler applications of metam sodium because as much as 60% of the fumigant could be volatilized in a short time.

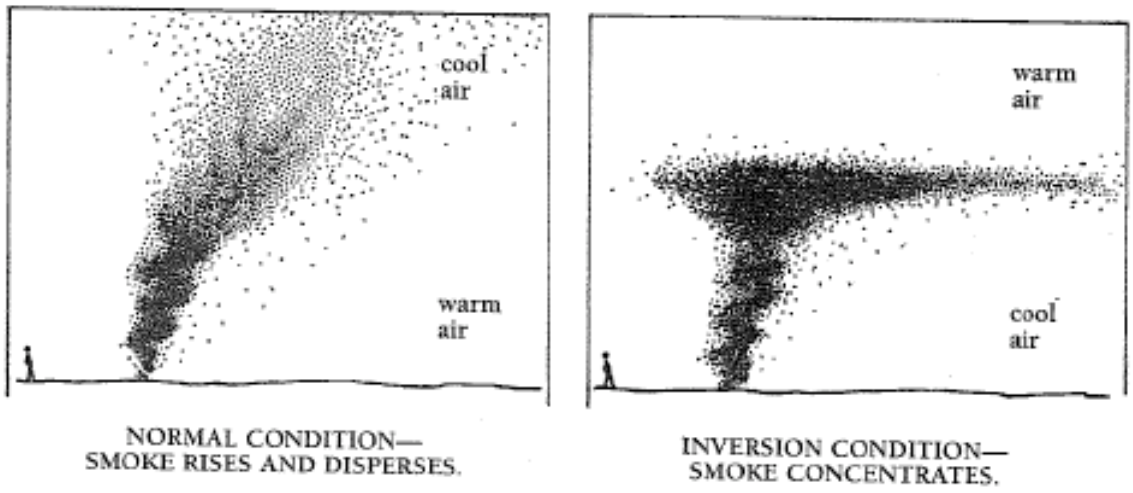


FIGURE 6-2

Normally, warm air cools as it rises and temperatures are higher near the earth's surface. As the air rises and cools, it also mixes and disperses air contaminants (left). In an inversion, cool air near the soil surface is trapped by air above so that there is little vertical movement. Air contaminants concentrate and become trapped (right).

Delay fumigating during inversions or when inversions are expected. Consult with the county agricultural commissioner for more details about your particular area and inversions. There is a high potential for inversion when the following conditions occur simultaneously:

- clear nights
- winds less than 8 mph
- stars are visible (sky is clear)

Movement in Water

Fumigants and other pesticides have the potential to move off-site via groundwater or surface water. Water movement must be addressed when handling fumigants to assure they stay on the targeted application area.

Groundwater

All fumigants are soluble in water. Potential for groundwater contamination is determined by depth to groundwater, soil texture, irrigation practices, and persistence (half-life) of the fumigant chemical. Most of the currently used fumigants break down more rapidly in soil and water than other pesticides known to be present in groundwater. No currently registered fumigants have been identified as contaminants in California groundwater; however, handlers should check DPR's Groundwater Protection Area (GWPA) regulations to determine if any fumigants were added since the publication of this study guide.

The fumigant 1,3-D has been known to reach shallow groundwater in permeable (sandy) soils in other states. Also, 1,3-D products should not be used within 100 feet of wells because of the potential for movement into water supplies. Review 1,3-D labeling to make sure you know how to protect groundwater water sources from movement.

Surface Water

When fumigants are applied in irrigation water (chemigation), there is a significant potential for movement off-site if irrigation water is not contained. Treated water that moves beyond the application

site into another field or area is cause for concern and must be addressed immediately. During chemigation, fumigants can move into water supplies when application equipment stops or water pumps malfunction if the system is not correctly set up. Appropriate backflow devices are essential and required.

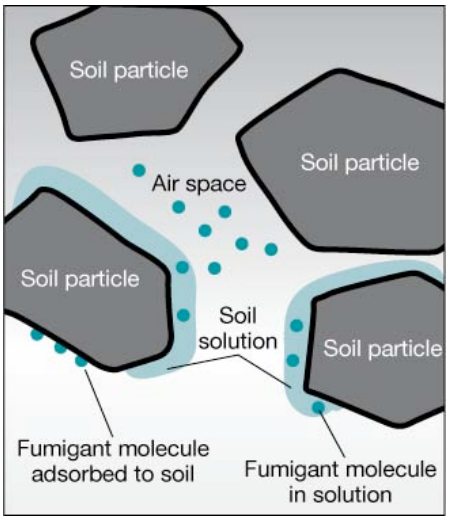


FIGURE 6-3

Soil particles and air spaces showing how fumigants move. Some fumigants move rapidly in air spaces, others move well only in water solution, and some chemicals cling to soil particles and don't move very far.

Movement and Persistence in the Soil

Fumigants vary in their tendency to move through soil and degrade under field conditions (see Tables 2-1, 2-2, and 2-3 in Chapter 2). Soil movement is affected by soil texture, amount of organic matter, water content, and temperature, as well as the presence of a fumigation surface barrier (e.g., tarp). Residues of some fumigants remain in the soil for days or weeks after application. Others break down rapidly. For instance, methyl bromide will persist at toxic levels in well-tarped soil for up to three weeks or more, whereas chloropicrin and carbon disulfide break down within several days unless the soils are cold (< 50°F [10°C]) and wet.

Depending on the product, fumigants may move through the soil in the air spaces, in water films surrounding soil particles, or by adhering to soil particles (Figure 6-3). The fastest movers are very volatile fumigants such as methyl bromide, that travel as vapors through the air spaces. The less volatile fumigants, such as MITC generators like metam sodium, are mostly carried by water through the soil. These materials do not move significantly beyond areas with moist soil except vertically into the atmosphere after generating gas. Some fumigant chemicals re-dissolve in water or adsorb to soil particles, which further slows movement.

IMPACTS OF FUMIGANTS ON AIR QUALITY

Fumigation can affect air quality by contributing to smog and, in the case of methyl bromide, depleting the ozone layer in the upper atmosphere, or stratosphere.

Smog Formation

All of the fumigants are classified as volatile organic compounds (VOCs), which are carbon compounds that readily volatilize into the atmosphere. This is a large class of compounds that includes vehicle exhaust, paint, cleaning supplies, some pesticides, and many other chemicals. Fumigants are among the greatest potential VOC contributors among pesticide chemicals. In the presence of sunlight, VOCs react with nitrogen oxides to produce ozone (Figure 6-4). Accumulations of ozone in the lower atmosphere contribute to smog that we breathe which can injure the lungs and irritate the respiratory system. Ozone at high concentrations can also damage plants.

The U.S. Environmental Protection Agency (U.S. EPA) and the California Air Resources Board (ARB) regulate air quality in California. They have determined that five areas (or air basins) in California, known as nonattainment areas, do not meet air quality standards for ozone (see Chapter 1). Part of the program for improving air quality in the nonattainment areas is to reduce volatilization of fumigants by reducing total fumigant use and employing application methods that limit volatilization.

Ozone Depletion in the Stratosphere

High in earth's atmosphere (stratosphere), ozone forms a protective layer shielding the earth from ultraviolet radiation. A certain percentage of the methyl bromide that makes its way out of the soil and into the atmosphere eventually moves into the stratosphere. There it reacts with the ozone layer, breaking up ozone molecules and causing ozone depletion. Methyl bromide is the only fumigant known to be an ozone depleter. Because of this problem, production of methyl bromide is being phased out worldwide.

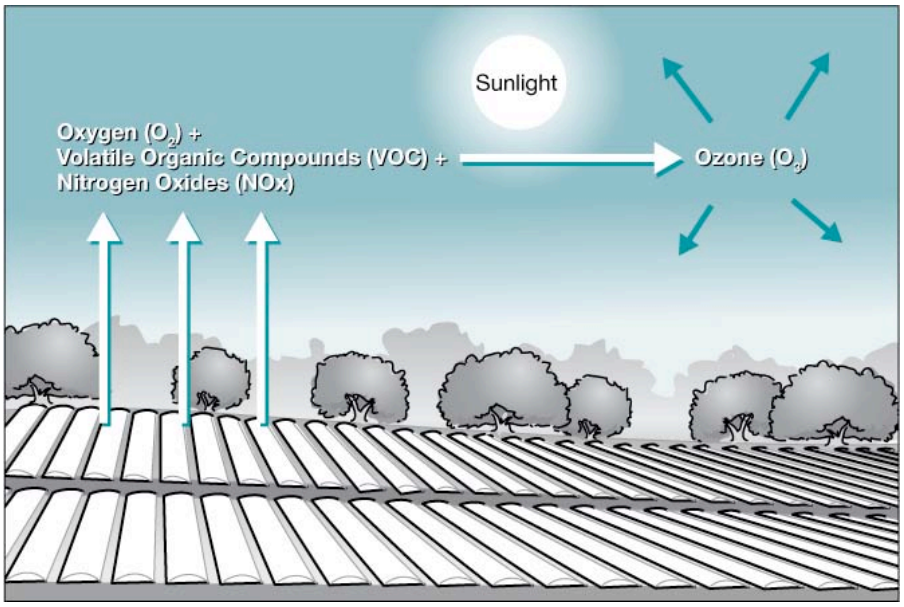


FIGURE 6-4

Ozone is formed when volatile organic compounds move into the lower atmosphere in the presence of sunlight and react with nitrogen oxides.

Ozone depletion in the stratosphere results in an increase in ultraviolet radiation reaching the earth, which has human health impacts such as increasing the incidence or severity of nonmelanoma skin cancers, cataracts, and impairment of the immune system. The increase in ultraviolet radiation also affects the environment and ecosystems by damaging sensitive plants including phytoplankton that are important for maintaining ocean health.

IMPACTS ON NONTARGET ORGANISMS

Fumigants are broad-spectrum biocides that kill a wide range of organisms. They may persist in the soil for days to weeks at levels toxic to plants, microorganisms, and other nontarget organisms. Runoff containing fumigant residues can be highly toxic to fish and other aquatic species.

Most fumigants are toxic to most plants. They can kill or injure desirable plants when they move offsite in air, move in water, or when they are in soils at levels toxic to nontarget plants or animals. A fumigant's toxic residues must dissipate from the soil before crops are planted. Phytotoxicity is a problem in orchards where spot fumigation is used because roots of adjacent trees may be killed or injured if adequate buffering is not provided.

HEALTH EFFECTS OF FUMIGANTS

Fumigants are general biocides. They are toxic to most life forms. People can become seriously injured or killed when exposed to fumigants. This section describes the general ways that bodily exposure can occur as well as the poisoning symptoms of specific fumigants.

Fumigants require special attention and safety practices to prevent body exposure via skin, lungs, eyes, and mouth. Chapter 7 details methods for reducing exposure and assuring safe use of fumigants.

How Fumigants Enter the Body

Fumigants can poison humans by entering the body via multiple routes—skin, eyes, mouth, or lungs (Figure 6-5).

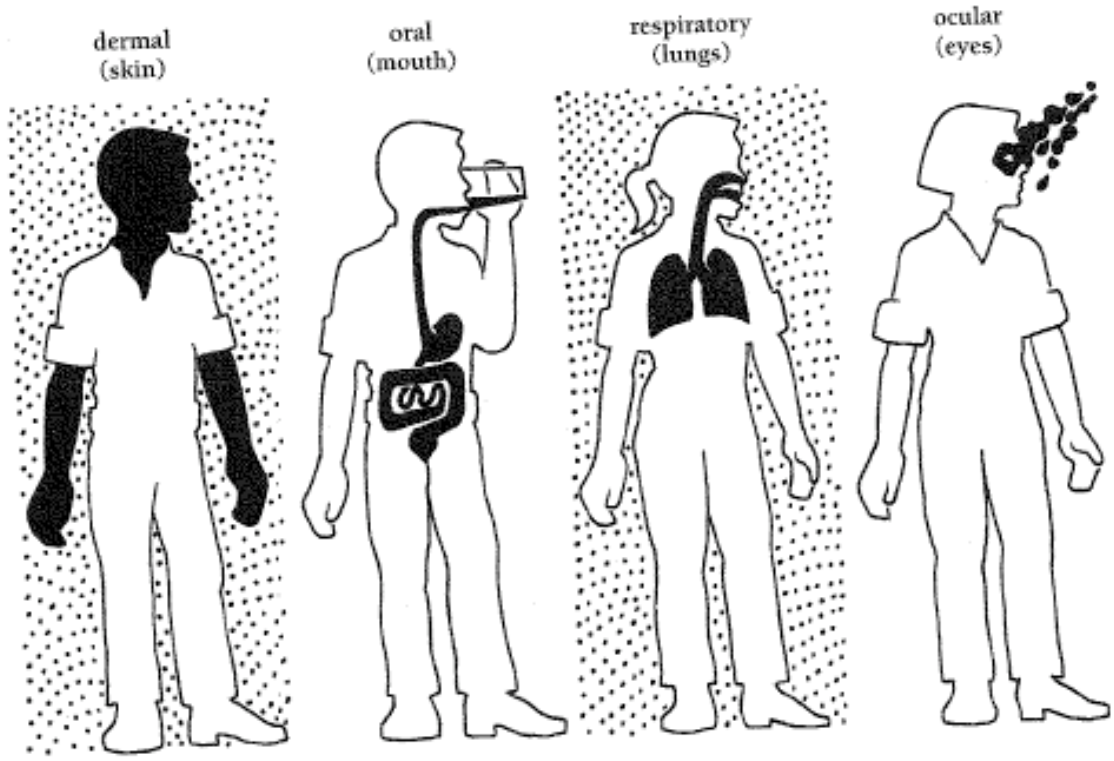


FIGURE 6-5

The most common ways people are exposed to pesticides are through the skin (dermal), mouth (oral), lungs (respiratory), and eyes (ocular).

The most common way to be exposed is through the lungs, by breathing fumigant vapors. Inhalation of fumigants can be minimized by using the specific required respiratory protection and staying upwind of the fumigant.

Skin is also a common entry route. Liquid or gaseous fumigants in contact with skin can cause burning, irritation, and rashes. Fumigants vaporize in air at various rates, but they also can be splashed or spilled onto clothing or skin. The applicator or handler must take quick steps to prevent lengthy skin or clothing exposure. Prolonged exposure can cause damage to internal organs of the body.

Fumigants can enter the mouth directly, such as by splashing, or from airborne particles. Broken or malfunctioning equipment such as pressurized lines or leaking tanks can lead to oral exposure. Another more common exposure scenario can take place when contaminated hands or gloves come in contact with the mouth. A source of exposure is touching the fumigant container or equipment with gloved hands, and then removing personal protective equipment without properly washing the hands with soap and water before eating or using the bathroom.

Know the type of protective equipment to use, wear it, remove it carefully, and wash hands thoroughly afterwards. Know what type of protective equipment and clothing *not* to wear; for example, certain fumigants do not allow use of rubber gloves or goggles because it decreases safety. Also, impermeable gear can trap methyl bromide against the skin.

The eyes are particularly sensitive to pesticides and can be seriously harmed by direct exposure to fumigant liquids, gases, or granules. Generally, handlers are required to wear protective eyewear when handling fumigants. However, some fumigants prohibit the use of goggles for eye protection so it is important to read the label for the protective equipment information for the fumigant being used. Some fumigants can cause irreversible eye damage as a result of exposure.

How People Are Exposed to Fumigants

Fumigants can injure not only handlers, but also others in the area such as field workers, passersby, or local residents.

Handlers

Fumigant handlers include all the people involved in the fumigation; they are the ones most at risk from exposure to fumigants. Handlers include the applicator, the tractor driver, the copilot, shovelers, and others who perform various handling and application tasks during fumigant applications. Handlers can be exposed during all handling activities such as changing cylinders, removing tarps, checking clogged lines, and making turns at the ends of the rows.

Inspect equipment and containers daily and correct any safety defects before use. Recognize mistakes made during application or handling fumigant containers to avoid exposure and injury. Leakage of product can occur if seals on cylinders are defective or broken or if unloading procedures are not properly followed. A broken hose or uncoupled line from a compressed gas can result in immediate exposure. Spills and leaks present particular risks. Spills must be immediately and safely cleaned up, and no one should come near or enter the spill area. When a mistake or accident occurs take corrective action—immediately! See Chapter 8 for information on emergency responses to fumigant accidents.

Handlers must also know the appropriate protective equipment and use it correctly. Failure to use the correct type of protective equipment or working in a rushed situation can result in handler exposure and injury. Fumigant labeling and regulations provide a lot of detail about the required personal protective equipment (PPE) for each handling activity. This information is important for preventing exposure and health risk to applicators and others involved in the application.

Work clothing, foot wear, and PPE can become contaminated while handling fumigant containers or application equipment, loading fumigants, walking in treated areas, or from accidents. Handlers might wear the wrong or ill-fitting PPE, or not dress appropriately for the fumigant being applied. For instance, methyl bromide labeling requires wearing loose fitting clothing and removing watches, rings, and other items that might trap the fumigant close to the skin. Contamination of clothing, particularly when the handler does not know that it has happened, presents a risk of fumigant exposure and more serious health effects. Handlers must watch for defective protective equipment and contaminated clothing and take immediate corrective action.

Placing and removing tarpaulins requires specialized application and removal methods and equipment, as well as PPE. Improper or premature tarp removal can lead to exposure to fumigants, primary through inhalation of off-gassing fumigant. Tarping correctly, taking breaks well away from fumigated fields and application equipment, and immediately leaving fields after applying fumigants can help prevent physical exposure to fumigants.

Common sense is the most basic exposure prevention method. Maintaining a position upwind from the application, assuring tarps are in good repair, and having equipment in good working order are some of the ways that handlers can avoid fumigant exposure. Work-hour limitations, which also provide handler protection, are discussed in Chapter 7.

Field Workers and Other People Working in the Vicinity of Fumigations

All fumigant applications require that people stay out of treated fields for specified time periods. Posted signs and neighbor notification give warnings to stay away (see Chapter 7). People working in fields near fumigation activities or others in the area, particularly those downwind or at lower elevations, can become exposed to the fumigant vapors that off-gas or move off-site. Leave the area if you notice fumigant vapors. Entering treated fields before the required reentry interval has elapsed can result in exposure to dangerous levels of fumigants unless appropriate protective measures are taken. Entering

fields during reentry intervals should be done only if necessary and only with *all* necessary PPE. Read the label to know which field reentry activities are allowed and the required protective equipment.

The Public and Other Bystanders

People not involved in doing fumigations but who are near treated areas could be exposed, particularly via inhalation or eye irritation. Drift and off-gassing of fumigants can cause the public and nearby residents or bystanders to inhale fumigants. Correct application methods are important to prevent drift and off-site odors. Handlers are responsible for assuring that applications are made according to regulations, restricted materials permit conditions, and labeling, and they must use appropriate methods to prevent off-site movement of the fumigant during and after the application. For example, it is important to properly seal tarps or apply other forms of barriers (soil treatments) correctly to minimize the chances of people becoming exposed to fumigant vapors.

Health Effects of Exposure

Fumigants are extremely toxic and people can be killed or seriously injured from a single exposure. Handlers are the most at risk. They must be aware of the general symptoms of pesticide poisoning including dizziness, diarrhea, nausea, headache, and lack of coordination, as well as the impacts of specific fumigants. Handlers must also know the specific exposure symptoms of each fumigant they work with. Handlers must seek immediate professional medical attention whenever there is a possibility of excessive or unsafe exposure to a fumigant. Employers are responsible for ensuring that employees are taken to a physician or other licensed health care professional any time they have symptoms that may have been caused by pesticide exposure.

Recognizing Specific Fumigant Poisoning Symptoms

Knowing the specific dangers and exposure symptoms of the fumigant you handle will help you take effective precautionary measures. The information on specific fumigants (except carbon disulfide liberators) provided here is excerpted from DPR Fumigant Fact Sheets.

Methyl Bromide

Exposure to the gas may cause nausea, vomiting, headache, dizziness, visual disturbances, lethargy, faintness, and eye irritation. Severe exposure can cause convulsions, muscular tremor, pulmonary congestion, cyanosis, delirium, coma, and death. Pulmonary edema is the chief adverse effect of poisoning. Other symptoms include muscle weakness and pain, loss of coordination and gait, an inability to focus, convulsions, hyperthermia, and coma. Accidental overexposure of fumigation workers has produced paralysis of the extremities, delirium, and convulsions. Methyl bromide, especially when trapped by gloves or boots or goggles, is corrosive to the skin and eyes.

Chronic health effects are most likely to occur following acute over-exposure, principally the result of nervous system damage that does not resolve after exposure. Some long-term inhalation studies in animals also demonstrate nervous system damage with maximum tolerated doses. Abdominal wall defects occurred in offspring of female rabbits exposed during pregnancy.

Methyl bromide is commonly applied with chloropicrin as a warning agent, since methyl bromide affects health at low, odorless levels.

Chloropicrin

Chloropicrin has a very strong, irritating odor that causes eyes to water and burn, causes nose, throat, and skin to burn and become irritated, and can lead to shortness of breath, coughing, and vomiting. Exposure to chloropicrin may also cause difficult breathing, wheezing, and aggravation of asthma or existing lung diseases. Exposure to higher amounts of chloropicrin, may lead to worse symptoms such as

pulmonary edema, unconsciousness and even death. There is no evidence that chloropicrin can cause reproductive effects or birth defects.

Mild eye irritation, watery eyes, and coughing are expected to go away rather quickly once exposure stops. Aggravation of asthma or other lung diseases might last longer. Exposure to high amounts of chloropicrin can lead to lung damage.

Metam Sodium, Metam Potassium, and Dazomet (Including Basamid, Vapam, K-Pam, Sectagon, Sectagon-K)

Because metam sodium breaks down so quickly, in normal use there is little chance of exposure to anyone other than persons applying it. Exposure to breakdown products is more likely. All of these products produce methyl isothiocyanate (MITC), a gas that is extremely irritating to the eyes, to the throat and lungs, and to the skin. People with asthma or other respiratory problems may require immediate medical treatment if exposure triggers an attack. These products also liberate sulfur compounds (like hydrogen sulfide) which many people find to have an offensive odor. Other symptoms may include headache, dizziness, diarrhea, or nausea.

Cough or other respiratory symptoms can take time to resolve after a single exposure. People with asthma or other lung problems may be more sensitive to this problem. Metam sodium has been linked to cancer and birth defects in animals. MITC, the major breakdown product, has not been shown to cause cancer in animal tests.

1,3-Dichloropropene (Including Telone II, Telone C-35, and Inline)

Direct exposure from spills or broken hose lines can cause severe irritation of the skin, especially on the lower extremities. Eye irritation is also frequent after direct accidental exposures. Inhalation of vapor may cause nausea, headache, chest pain, dizziness, or loss of consciousness. This may also happen after severe, prolonged skin contact.

Skin sensitization may result from accidental direct contact. After acute irritation subsides, some people may experience allergic dermatitis following minimal subsequent contact. Dichloropropene is classified as a possible carcinogen to humans (by the U.S. EPA) for both the inhalation and oral routes of exposure.

Carbon Disulfide Liberators (Enzone)

Sodium tetrathiocarbonate, which generates carbon disulfide in soil, is a severe skin and eye irritant and is highly toxic if inhaled or ingested. Acute toxicity symptoms include irritation of the eyes, nose, throat, and digestive tract, and exposure may result in nausea, vomiting, dizziness, and fluid in the lungs.

PREVENTING EXPOSURE

Preventing exposure is key to using pesticides safely. Common sense and practical knowledge of the specialized equipment and nature of fumigants are essential to safety for applicators and others in the vicinity of fumigations. Following all regulations, restricted materials permit conditions, and fumigant labeling, along with following safe work practices, will help prevent problems. Chapter 7 discusses protective measures that will help prevent exposure that can lead to injury and illness from fumigation activities.

Chapter 8 describes how to handle emergencies resulting from fumigant exposures.

CHAPTER 6: REVIEW QUESTIONS

1. **The most likely route for fumigants to move off-site and affect environmental quality is**
   a. surface water movement
   b. volatilization
   c. groundwater
   d. through tarp leakage
2. **The use of fumigants in certain California Regional Air Quality Basins (nonattainment areas) has special regulatory requirements**
   a. to improve air quality by reducing VOCs
   b. because fumigants increase ozone in the upper atmosphere
   c. that reduce total use and volatilization
   d. both a and c
3. **Fumigants are**
   a. biocides that kill a wide range of organisms
   b. more toxic to animals than plants
   c. harmless to nontarget organisms within a day after application
   d. unlikely to injure adjacent crops
4. **Fumigants most often affect human health by entering the body through the**
   a. skin
   b. lungs
   c. eyes and mouth
   d. mouth
5. **All of the following would be considered fumigant handlers EXCEPT**
   a. a farmworker in a neighboring field
   b. the copilot
   c. shovelers
   d. the on-site foreman
6. **Symptoms of exposure to fumigants include all of the following EXCEPT**
   a. ozone
   b. burning skin
   c. eye irritation
   d. nausea

Chapter 7: Protecting People and the Environment

Knowledge Expectations

1. Describe where to find information about pesticide hazards and safety, for example, pesticide labels, material safety data sheets (MSDSs), the Pesticide Safety Information Series (PSIS), and technical information bulletins (TIBs).
2. Know how to carry out all safety/precautionary requirements on labels.
3. Know how to select, fit, care for, and use personal protective equipment when handling pesticides.
4. Know how to keep pesticides out of the environment through proper application and disposal practices.
5. Explain how to recognize hazards at the application site that could endanger people or the environment during a fumigation application.
6. Describe requirements for tractor-mounted equipment to protect applicators including air-dilution fans.
7. Know how workers can minimize time of exposure with "work hour limits."
8. Describe how to recognize, treat, and prevent heat illness that is sometimes associated with the use of personal protective equipment.
9. Explain the need to communicate with people who might enter the treated area and understand notification requirements.
10. Describe how buffer zones help reduce problems.
11. Describe the posting requirements for fumigation applications.
12. Describe methods to reduce the environmental impact of fumigant use.
13. Know how environmental conditions, especially wind and inversions, increase hazards (e.g., drift of fumigant or blowing tarp).
14. Explain how to minimize drift of fumigants to nontarget areas.
15. Know where to find information regarding endangered species and where in California they are likely to be encountered.
16. Explain how to properly store, transport, and label pesticides and pesticide service containers.
17. Describe how to safely handle the various fumigants including special requirements for handling cylinders or bulk versus packaged materials.
18. Explain how to safely clean application equipment and dispose of empty containers.

Fumigation applications involve specialized equipment and precautions to assure applicator, bystander, and environmental safety. Applicators need to know about appropriate personal protective equipment, posting and notification requirements, and how to transport and store fumigants properly. This chapter describes some of the methods and resources that help ensure safety.

INFORMATION SOURCES

All pesticides are potentially toxic and can cause problems. Before you handle a product, be sure you learn about its hazards and recommended protective measures. You can learn about hazards and safety by studying the label, technical information bulletins (TIBs), Material Safety Data Sheets (MSDSs), and pesticide safety information series (PSIS) leaflets from the California Department of Pesticide Regulation (DPR). Also, all field fumigants are restricted pesticides, so you will need to be familiar with and follow all restricted materials permit conditions before planning an application.

Pesticide Label and Labeling

The fumigant label and labeling are *the* most important source of information about a pesticide. The pesticide label (Figure 7-1) is there to protect you, the applicator, and others involved in the application or in the area. A label's safety and hazards sections undergo extensive review by scientists and regulators who understand human physiology and the chemistry of the fumigant. The term "labeling" also includes any other document referred to on the label, such as technical information bulletins. Instructions included in all of these documents have the force of law and must be followed exactly.

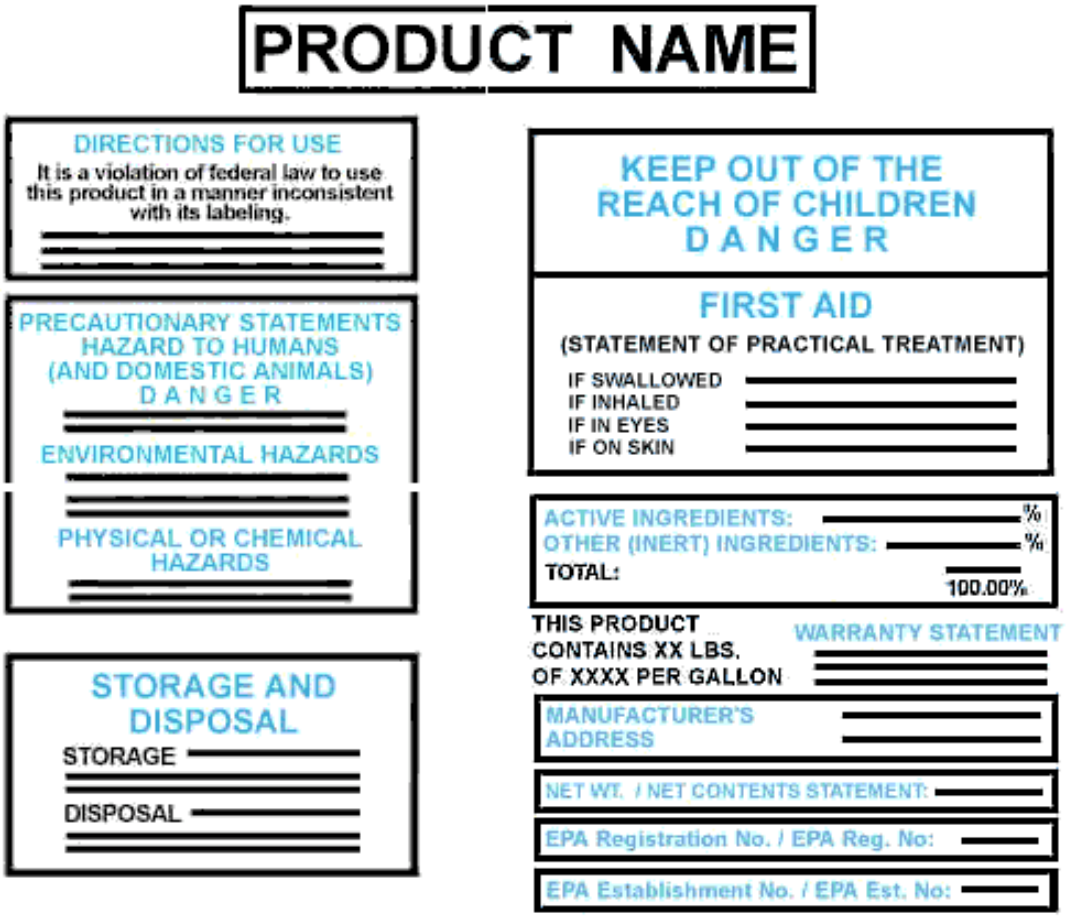


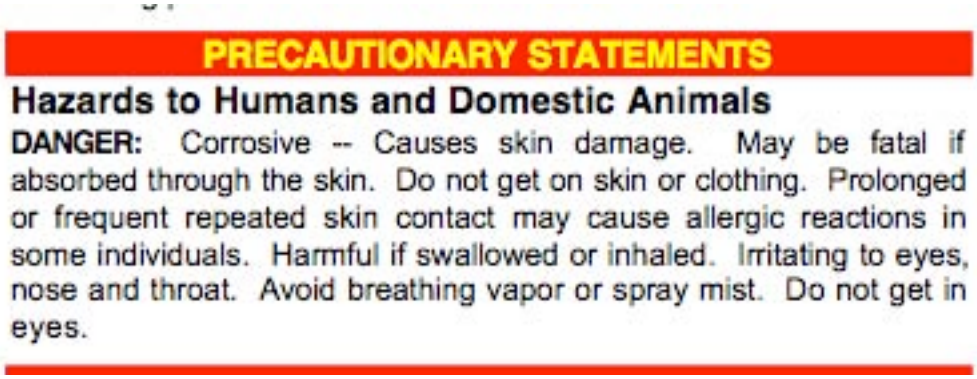
FIGURE 7-1

This is a generic pesticide label format. Fumigant labels contain all of this information. Become familiar with the entire label before handling a fumigant.

Be sure you carefully read, understand, and are able to follow label directions. If you do not understand any part of the label wording, do not attempt to use the material and ask for help from your

supervisor or chemical supplier. Following label instructions will reduce the chances of an accident or exposure that could cause injury or illness.

The PRECAUTIONARY STATEMENTS section of the label contains information on the dangers of exposure and directions on how to prevent and treat exposure. Be very familiar with information in this section of the fumigant label (Figure 7-2).



PRECAUTIONARY STATEMENTS

Hazards to Humans and Domestic Animals

DANGER: Corrosive -- Causes skin damage. May be fatal if absorbed through the skin. Do not get on skin or clothing. Prolonged or frequent repeated skin contact may cause allergic reactions in some individuals. Harmful if swallowed or inhaled. Irritating to eyes, nose and throat. Avoid breathing vapor or spray mist. Do not get in eyes.

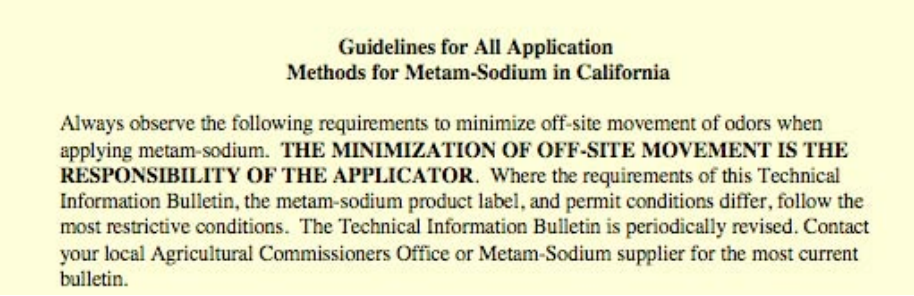
FIGURE 7-2

*All pesticide labels have PRECAUTIONARY STATEMENTS. Be very familiar with the signal word (in this case, "*Danger*") and medical hazards of the particular fumigation product you handle.*

Review the label for any special environmental precautions. Always be sure the label lists the application site you will treat and the method of application you will use. Labels will have information on how to handle empty containers; also consult your supplier and the agricultural commissioner about disposal of empty or partially filled fumigant containers. Cylinders and other containers that have held gas must be returned to the manufacturer.

Technical Information Bulletin (TIB)

A Technical Information Bulletin (TIB) is a tool developed by the manufacturer to ensure the safest and most effective fumigation when using metam sodium and metam potassium. If a fumigant's manufacturer has developed a TIB, it is considered labeling and you need to follow it just as you would the label. For example, the metam sodium TIB (Figure 7-3) helps the user know and follow the best practices to prepare soil for fumigation and prevent odors during or after application.



Guidelines for All Application Methods for Metam-Sodium in California

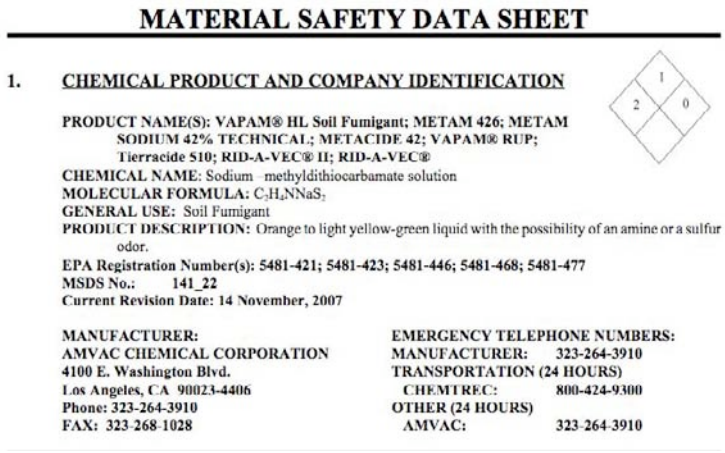
Always observe the following requirements to minimize off-site movement of odors when applying metam-sodium. **THE MINIMIZATION OF OFF-SITE MOVEMENT IS THE RESPONSIBILITY OF THE APPLICATOR**. Where the requirements of this Technical Information Bulletin, the metam-sodium product label, and permit conditions differ, follow the most restrictive conditions. The Technical Information Bulletin is periodically revised. Contact your local Agricultural Commissioners Office or Metam-Sodium supplier for the most current bulletin.

FIGURE 7-3

Technical information bulletins (TIBs) provide very specific and useful information for applicators. Be sure to have the latest update of the TIB and know how to follow all TIB directions.

Material Safety Data Sheet

The Material Safety Data Sheet (MSDS) provides valuable facts about the pesticide's hazards. These informational sheets (Figure 7-4) are prepared by manufacturers for each pesticide product and must be made available (upon request) to every person selling, storing, or handling pesticides. They are not considered labeling.



MATERIAL SAFETY DATA SHEET

1. CHEMICAL PRODUCT AND COMPANY IDENTIFICATION

1 / 2 / 0

PRODUCT NAME(S): VAPAM® HL Soil Fumigant; METAM 426; METAM SODIUM 42% TECHNICAL; METACIDE 42; VAPAM® RUP; Tierracide 510; RID-A-VEC® II; RID-A-VEC®
CHEMICAL NAME: Sodium methyldithiocarbamate solution
MOLECULAR FORMULA: $C_2H_4NNaS_2$
GENERAL USE: Soil Fumigant
PRODUCT DESCRIPTION: Orange to light yellow-green liquid with the possibility of an amine or a sulfur odor.
EPA Registration Number(s): 5481-421; 5481-423; 5481-446; 5481-468; 5481-477
MSDS No.: 141_22
Current Revision Date: 14 November, 2007

MANUFACTURER:
AMVAC CHEMICAL CORPORATION
4100 E. Washington Blvd.
Los Angeles, CA 90023-4406
Phone: 323-264-3910
FAX: 323-268-1028

EMERGENCY TELEPHONE NUMBERS:
MANUFACTURER: 323-264-3910
TRANSPORTATION (24 HOURS)
CHEMTREC: 800-424-9300
OTHER (24 HOURS)
AMVAC: 323-264-3910

FIGURE 7-4

The MSDS provides key health and safety information about the undiluted fumigant. First responders must be provided with the MSDS when there is an emergency or accident.

The MSDS describes the chemical characteristics and hazards of the pesticide ingredients. The MSDS includes information on acute and long-term health effects that could result from exposure to the fumigant. MSDS documents include fire and explosion hazards, health hazards, incompatibility characteristics, and the types of personal protective equipment (PPE) needed for safe handling and emergency response. Storage information and emergency spill or leak cleanup procedures are also described. Toxicological test data from laboratory research is included on the MSDS.

Be sure to have the MSDS for the specific fumigant you are using. If you have an MSDS for a different product with the same active ingredient but not the same formulation, you could accidentally take the wrong emergency action. Also, make sure the MSDS is the most recent version since they may be updated frequently. If the MSDS seems to conflict with the label, you must always follow the label directions.

Keep the MSDS in a safe place at a central location in the workplace, away from pesticide storage areas. Maintain a notebook that contains an MSDS for every pesticide you might use. In case of an emergency give both the MSDS and the label to the fire fighter or other first responders so they have information on chemical emergencies and the correct response procedures for that fumigant material.

Remember that the MSDS information primarily refers to the undiluted material prior to application. Chemical properties change after application to soil or water. For example, exposure to the vapors of an off-gassing field should be treated differently from exposure to a spill of fumigant liquid on an applicator. Pesticide labels are designed to account for these changes and, thus, can be a better source of information for first aid or applicator emergency procedures.

Pesticide Safety Information Series Leaflets

The Pesticide Safety Information Series (PSIS) leaflets (Table 7-1) describe how to properly and safely use pesticides. These leaflets are developed by DPR to provide basic safety information. Employers must post PSIS A-8 for pesticide handlers and PSIS A-9 for farmworkers. PSIS A-5,

Protecting Yourself from Breathing Pesticides on Farms, addresses safety from an inhalation perspective and reviews respiratory protection. Inhalation is one of the main risk factors from fumigant exposure, so all fumigant handlers should be particularly familiar with PSIS A-5. PSIS leaflets in English, Punjabi, and Spanish are available on the Internet at www.cdpr.ca.gov/docs/whs/psisenglish.htm and from the county agricultural commissioner's office.

TABLE 7-1

Pesticide Safety Information Series (PSIS) Leaflets from California Department of Pesticide Regulation.

PSIS Number	PSIS Title, Revision Date, Language, File Size
PSIS A-1	Working Safely with Pesticides on Farms (Rev. 09/03, 828 KB) (En Español, 903 KB) (In Punjabi, 517 KB)
PSIS A-2	Storing, Moving and Disposing of Pesticides on Farms (Rev. 09/03, 701 KB) (En Español, 797 KB) (In Punjabi, 372 KB)
PSIS A-3	Closed Systems, Enclosed Cabs, Water-Soluble Packaging (Rev. 09/03, 716 KB) (En Español, 808 KB) (In Punjabi, 388 KB)
PSIS A-4	First Aid (Rev. 09/03, 717 KB) (En Español, 809 KB) (In Punjabi, 379 KB)
PSIS A-5	Protecting Yourself from Breathing Pesticides on Farms (Rev. 09/03, 700 KB) (En Español, 767 KB) (In Punjabi, 358 KB)
PSIS A-7	Washing Pesticide Work Clothing (Rev. 09/03, 721 KB) (En Español, 793 KB) (In Punjabi, 387 KB)
PSIS A-8	Safety Rules for Pesticide Handlers on Farms (Rev. 09/04, 289 KB) (En Español, 308 KB) (In Punjabi, 642 KB)
PSIS A-9	Pesticide Safety rules for Farmworkers (Rev. 09/04, 245 KB) (En Español, 256 KB) (In Punjabi, 283 KB)
PSIS A-10	Safety Rules for Minimal Exposure Pesticides on Farms (Rev. 09/03, 703 KB) (En Español, 780 KB) (In Punjabi, 354 KB)
PSIS A-11	Rules for Medical Care When Handlers Use Organophosphates and Carbamates (Rev. 09/03, 706 KB) (En Español, 779 KB) (In Punjabi, 354 KB)

Restricted Materials Permit

All field fumigant pesticides require a restricted materials permit from the county agricultural commissioner's office. The permit is also an important source of information related to carrying out your application. Permits list conditions of use (Figure 7-5) which are legal requirements for use of the fumigant at a particular site. Be sure to have a copy of the permit and know how to follow all of the permit conditions before using the fumigant at any particular location. Review the permit conditions and the site so you are familiar with boundaries for the application and any required buffer zones.

Buffer zones	• The buffer zone shall be a minimum of 100 feet measured from the perimeter of the application block to any occupied residences, occupied onsite employee housing, schools, convalescent homes, hospitals, or other similar sites identified by the CAC. • The buffer zone may extend across roads, highways, or similar rights of way or sites approved by the CAC. • If utilizing the label exemption (100 foot permit condition buffer zone) one year, the labeling-required 300 foot buffer zone shall be utilized for the next three years. The 100 foot buffer zone shall not be used again until a minimum of **three (3) complete 365 day periods** (1,095 days) have elapsed.

FIGURE 7-5

Permit conditions, issued by the county agricultural commissioner, are very specific requirements for the use of the fumigant at a particular site. This extract is from 1,3-dichloropropene permit conditions.

USING FUMIGANTS SAFELY

Safe use of fumigants requires safe work practices. Key to learning how to work safely is familiarity with the label, personal protective equipment, and special work requirements, as well as knowing how to recognize hazards, maintain personal hygiene, and prevent heat illness.

Reading and Following Labels—Carrying Out Safety Precautions on Labels

Before using a fumigant, know how to carry out *all* of the safety and precautionary requirements. Before you apply the fumigant, check the label for all of the following:

Signal Word

Look for the signal word (*Danger, Warning,* or *Caution*) on the label. The signal word indicates the acute toxicity of the fumigant mixture. Most fumigants carry the signal word *Danger* which identifies the most dangerous pesticides. Many fumigant labels also have the word "Poison" and the skull and crossbones symbol (☠), indicating very high systemic toxicity. Exposure by swallowing, inhalation, or skin absorption of these fumigants may be fatal. Pesticide labels with the signal word *Danger* but lacking the word "Poison" and the skull and crossbones symbol are highly corrosive to skin or eyes and can cause irreversible eye damage. A few fumigants have the signal word *Warning*.

Special Precautions

Note precautions for use such as specific personal protective equipment (PPE), work clothing (worn under PPE), or special handling methods. Know which materials are incompatible with the hoses that carry the particular fumigant. Be familiar with techniques to blend fumigants safely and specialized application equipment and methods for applying the fumigant.

Active Ingredients and Use Instructions

Know the names of the active ingredients, the rate to be applied, and how to mix with water, if applicable. Understand how to mix with other fumigants; for example, if using chloropicrin with 1,3-dichloropropene (1,3-D), know how to flow them into the tank at the desired ratios.

Personal Protective Equipment (PPE)

Make sure that you have PPE and that it is in good repair. Get new PPE if you have any doubt about its condition. PPE is inexpensive compared to risking your health. When wearing PPE, be sure you know how to use it and that it is well fitted. If you are combining fumigants and you cannot meet *all* of the PPE requirements on each label, the materials cannot be used together.

Environmental Precautions

Review the label for any special environmental precautions. Survey the application site for any environmental concerns.

Site on Label. Be certain that the label lists the intended application site. In California it is legal to use a pesticide on a pest not listed on the label as long as there is no prohibition against using it against that pest; however, the method and site of the pesticide application must be on the label and all other use directions must be followed.

Disposal

Consult the label for information about how to dispose of unwanted pesticide, and also obtain information from your county or regional disposal agencies. The label will have information about handling empty containers; in addition, consult with the supplier about disposal or recycling of empty fumigant containers.

Emergencies

Emergency phone numbers and instructions for emergency medical response to exposures are on the label. First aid information is critical, as you need to know what to do before medical help arrives. Chapter 8 discusses appropriate emergency responses to fumigant incidents.

Basic Safety Information

Labels include information on how the pesticide can enter the body, and signs and symptoms of overexposure. Be familiar with the safety information on the label before handling.

Personal Protective Equipment for the Applicator—How to Select, Fit, Care For, and Use

Everyone who is involved in a fumigation operation must wear personal protective equipment (PPE). Fumigant "handlers" refers to virtually everybody working within the treatment and buffer zones including people shoveling at the ends of tarps, removing tarps, supervising, driving tractor, working with opened fumigant containers, and adjusting equipment. Required PPE varies with the fumigant material and handler's job. Learn how to select, fit, care for, and remove PPE when handling fumigants. PPE is required for all handling activities.

PPE for fumigant applications may include chemical-resistant gloves, protective eyewear, respiratory protective equipment, chemical-resistant boots, coveralls, chemical-resistant apron, and chemical-resistant headgear. Some fumigants may require less PPE for increased safety. Be sure to read the label and use only the PPE required by the label. Become comfortable using and removing all the necessary PPE for the fumigant you are using and know how to clean it after use. Follow the pesticide label for the protective clothing and equipment you must use. You will find directions about PPE in the PRECAUTIONARY STATEMENTS section of the pesticide label.

PPE helps protect your body and clothing from pesticide exposure. Some PPE also protects your eyes or feet. PPE is only effective it if fits correctly and you use it properly. Always keep it clean and well maintained. Clean it at the end of each work period by washing it in soapy water. Allow it to air-dry out of the sun and store it separately from pesticides. When removing PPE after a pesticide application, remove your chemical-resistant gloves last to avoid transferring residues onto your hands. You should wash gloves with soap and water before removing to avoid transferring residues onto your body.

Be sure to use appropriate PPE whenever handling fumigants. It is very important to know which fumigant you are handling because different materials have different PPE requirements. For example, a chloropicrin label states, "Do not wear jewelry, gloves, goggles, tight clothing, rubber protective clothing, or rubber boots when handling." In contrast, a 1,3-D label states, "Handlers performing direct-contact tasks must wear chemical-resistant gloves, chemical-resistant footwear, face-sealing goggles."

PPE requirements for combined fumigants can be complicated. Always ask questions of the supplier, your supervisor, the agricultural commissioner's office, or DPR if mixing fumigants so that you are sure to use the best, safest protective measures and that you correctly follow *all* label safety directions.

Before removing PPE and pesticide application work clothing, stop and think about how you will protect yourself from exposure to pesticide residues on PPE. Take care to prevent skin exposure. You can unwittingly expose skin to pesticides when you remove gloves or your skin comes into contact with pesticide-contaminated clothing or PPE (Sidebar 7-1).

SIDEBAR 7-1

Don't Contaminate Your Body by Removing or Mishandling PPE

Know how to use PPE correctly, and be sure it is clean and in good operating condition. Put on and remove the equipment carefully and do not contact any pesticides that may be on the outside of it. Do not "cheat" on PPE by taking off gloves to adjust equipment or by pulling the respirator away to scratch, wipe off sweat, or take a deep breath while still exposed to the pesticide. Do not wipe gloves on clothing; this will contaminate the clothing and pesticide may move through to the skin.

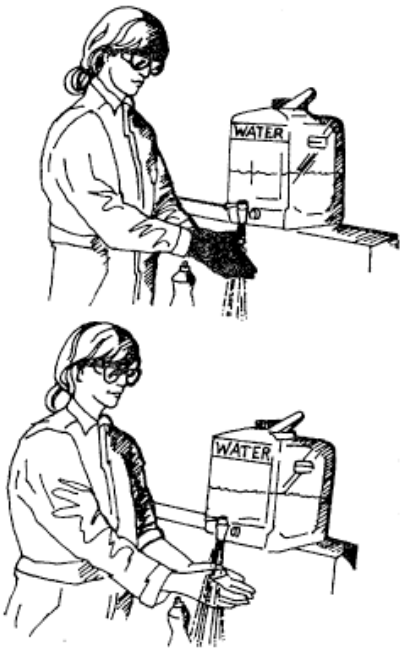
Gloves

Protecting the hands from fumigants is very important. This is done in different ways, depending on which fumigant you are using. *Before choosing gloves, read the label.*

Some fumigant labels require that you *not wear gloves* because they could trap materials against the skin, causing harm. For example, the label of a methyl bromide/chloropicrin fumigant states not to wear gloves when handling. Skin injury and further illness may result if fumigant/skin contact is prolonged.

Gloves protect the hands, the part of the body that usually gets the most exposure to pesticides in a work environment. Hands also have the greatest chance of contaminating other body parts. Before touching any equipment involved in fumigation, make sure you are wearing appropriate hand protection. Wash chemical-resistant gloves before removing them, and then also wash your hands before touching other body parts (Figure 7-6) or using the bathroom, smoking, eating, or performing other personal functions. If you are unsure if a glove is chemical free on the inside, don't use it; get new gloves. Clean, safe gloves are an inexpensive way to protect your health.

Appropriate chemical-resistant gloves are an essential part of your safety equipment for some fumigants. Be sure to follow the fumigant label information for the type of glove material that will provide chemical resistance to that fumigant. Never use leather or fabric gloves (unless specified on the pesticide label) because they absorb water and pesticides. Select a material that offers the best resistance to the fumigant you are using. See the table below (Figure 7-7) and look for a PPE code on the fumigant's label to help make the best glove selection for the fumigant you will be using.



Wash gloves thoroughly *before* taking them off, and wash hands thoroughly and dry them before putting gloves on again.

FIGURE 7-6

Proper glove usage requires washing before and after removal.

dpr Glove Category Selection Key

Label Code	Material Recommended by CDPR
A	1,2,3,4,5,6,7,8
B	1,2
C	1,2,3,4,7,8
D	1,2
E	1,3,4,8
F	1,2,3,8
G	1,8
H	1,8

Material Code
1: Laminate
2: Butyl
3: Nitrile
4: Neoprene
5: Natural
6: Polyethylene
7: PVC
8: Viton

All but Laminate and Polyethylene must be 14 mils or thicker

From Telone II Fumigant Label

Personal Protective Equipment (PPE) Chemical-Resistant Materials: Some materials that are chemical resistant to this product are listed below. If you want more options, follow the instructions for Category H on an EPA chemical resistance category selection chart. PPE constructed of Saranex, neoprene, and chlorinated polyethylene provide short-term contact or splash protection against liquid in this product. Longer-term protection is provided by PPE constructed of Viton, Teflon, and EVAL barrier laminates (for example Responder suits manufactured by Life-guard or Silvershield gloves manufactured by North).

FIGURE 7-7

Gloves are made with different materials that are resistant to specific fumigants. Before using a fumigation material, review the label for glove information and always choose the correct material for that fumigant.

The thickness of the glove material affects the amount of protection. A good fit is very important, so you are able to work safely with your hands. After choosing the glove material, choose the thickest gloves that also allow maneuvering and are made of materials that resist puncturing and abrasion. Gloves must be at least 14 mils thick (exception: polyethylene and laminate) and chemically resistant to the fumigant you are using.

When chemical-resistant gloves are required, wear unlined gloves since fabrics used for linings may absorb pesticides. Glove linings (also known as flocking) can be dangerous if they become contaminated with pesticides, and they are difficult if not impossible to clean. DPR regulations do not allow the use of flocked gloves when handling pesticides. If liners are necessary to insulate your hands from the cold or to absorb perspiration, and it is not prohibited on the label, use removable ones and be sure to discard them after each use or immediately if they become contaminated. Liners cannot extend past the cuff end of the chemical-resistant gloves.

Make sure cuffs of gloves extend to the midforearm. Usually, you will wear the sleeves of your protective clothing outside of your gloves to keep out pesticides, depending on the work activity. Consult the pesticide label for special glove information.

Protective Eyewear

Two types of eyewear are often required for fumigant users: goggles and face shields, but note that some fumigants do not allow goggles. Review the label requirements to determine which type is appropriate for the fumigant you are using. For example, one label states that handlers must wear "full-face shield or safety glasses with brow and temple shields when handling the liquid product (Do NOT wear goggles.)" Be sure that the protective eyewear you use is comfortable to use for a long period. Eyewear must fit well and not be removed during application or handling of fumigants.

Face shields over goggles
In high exposure situations when both face protection and eye protection are needed, a face shield can be worn over goggles.

FIGURE 7-8

Eye protection is very important. Combining a face shield with goggles provides extra protection, but some fumigants prohibit wearing goggles.

Due to the high danger of fumigants, the preferred eye protection is a full-face shield. For added eye protection, wear safety glasses or goggles with the face shield (Figure 7-8). However, be aware of label restrictions on protective eyewear. Some fumigant labels say "do not wear goggles" in the label section on WORKER SAFETY REQUIREMENTS, due to the possibility of the fumigant becoming trapped inside goggles. Other fumigant labels require that goggles be sealed, so that fumigants cannot come into contact with eyes via goggle venting. Use goggles that have anti-fog coatings put on during manufacturing or use anti-fog solutions on the lenses regularly, if needed. Be sure your protective eyewear is compatible with your respiratory protection. Full-face type respirators have built-in eye protection.

Respiratory Protection

Inhalation of fumigants is the most common route of exposure and potentially fatal. You must protect your lungs from inhaling fumigant vapors. Working upwind is one way to minimize breathing fumigant vapors. However, this may not be possible because as the applicator or other handler, you may need to work close to fumigants and application equipment. Some sort of respiratory equipment should be worn by anyone working closely with fumigants.

The respiratory equipment you choose should be based strictly on the requirements listed on the pesticide label. Respirators are highly specialized devices worn by pesticide applicators and others to protect the lungs and other parts of the breathing system of your body from inhalation of harmful chemicals (Figure 7-9). Two types of respirators are available: air-purifying respirators, which reduce the amount of contaminant in the air before it is inhaled, and air-supplying respirators (also referred to as "supplied-air respirators"), which provide a constant source of uncontaminated air. While disposable respiratory protection is available for particulates, these are not appropriate against vapors, which are the major risk with fumigant use. Reusable, full-face, air-purifying respirators with replaceable organic vapor

cartridges and air-supplied respiratory protection provide the best protection when using fumigants. The pesticide label will specify the correct type of air-purifying cartridges to reduce exposure to the fumigant.

FIGURE 7-9

Four types of respiratory protection: (left to right) half-face, full-face air-purifying, air-supplied, and self-contained breathing apparatus (SCBA).

Air-purifying respirators may be powered or nonpowered. The powered types use a blower to move air through a filter and have either tight-fitting face pieces or loose-fitting hoods/helmets. The nonpowered types are either half-face or full-face.

Air-supplying respirators provide clean air from an outside source. Fumigant labels often specify air-supplying or self-contained breathing apparatus (SCBA), also used by emergency responders. SCBA specifications and requirements are beyond the scope of this manual, however many fumigant labels require having a SCBA system in the vicinity of the fumigation. Before you handle a fumigant you must know how to use the respiratory protective system you have, even if it is for emergencies only.

All respirators for use with pesticides are tested and certified by the National Institute for Occupational Safety and Health (NIOSH), and specific approved code numbers are issued for all respirator cartridges. Fumigants generally require air-supplying respirators with NIOSH TC-19C designations or SCBA with NIOSH TC-13F. Fumigant labels will specify the type of respiratory protection to use. You must carefully review the respirator statements on the label to determine if respiratory protection must be worn and the correct type of respirator for that fumigant. Never substitute another type of respirator; always follow the directions on the label regarding the respirator requirements and cartridge type that will offer protection. Do not mix respirator brands or cartridges. Some cartridges come with prefilters to use with the respirator cartridge; if not used, the service life of the cartridge may be reduced.

Discard respirator cartridges daily. The best practice is to crush them after removing them from the respirator so they may not be accidentally reused. Also, discard cartridges or particulate filters if at any time during use you smell vapors within the respirator or breathing becomes labored. If cartridges come in contact with water or other liquids, discard them immediately because wet cartridges will not provide protection.

Use of respiratory protection requires planning ahead, and all employers must put into effect safety programs that encompass all of the legal requirements listed in Sidebar 7-2. Employers must have *written respiratory protection programs* with job-specific procedures. See California Code of Regulations section 6739 or the link on the DPR website (http://www.cdpr.ca.gov/docs/whs/pdf/hs1513.pdf) for assistance on complying with respiratory program requirements. All respirator-wearing employees must have a medical evaluation before using a respirator. No one should use a respirator unless they are deemed medically able. Tight-fitting types of respirators must be fit-tested to the user. Respirators must be cleaned, stored, and inspected regularly. Employees must be trained to recognize situations that are immediately dangerous to life or health (IDLH) and know what to do. Fumigations often require SCBA or air-supplying respirators for inhalation risks above specified air-contamination levels.

Certain fumigants have regulatory guidelines for exposure levels in air. For example, the acceptable air concentration level for methyl bromide is 5 ppm (20 mg/m^3). When this air concentration level in the working area is exceeded *at any time*, specified respiratory protection is required. Refer to the pesticide label for more information on air concentration levels and required respiratory protection.

SIDEBAR 7-2

Elements Required by State and Federal Laws for Respiratory Protection Programs

- Procedures for respirator selection
- Medical evaluation of employees using respirators
- Fit testing procedures for tight-fitting respirators
- Proper use in routine and emergency situations
- Care and maintenance (cleaning, disinfecting, storing, inspecting, repairing, and discarding)
- Breathing air quality and quantity for supplied-air respirators
- Training on hazard recognition, dangers (including Immediately Dangerous to Life or Health [IDLH] atmospheres), proper use and care
- Training on proper use including putting on, removing, use limitations, and maintenance
- Procedures for evaluation of the effectiveness of the respirator program

Air Monitoring

Labels, regulations, or permit conditions may require air monitoring during or following fumigation, and may require taking certain actions or ceasing certain activities if concentrations exceed specified levels. Even if not required, air monitoring can provide additional assurance that the fumigation is proceeding normally and that the appropriate respiratory protection is being used. Colorimetric tubes are most commonly used for this type of monitoring and are available from several manufacturers such as Draeger, Sensidyne, and Matheson-Kitagawa. Colorimetric tubes (approximately 1/4 by 6 inches) produce a color change when fumigant is present. The length of this color change indicates the air concentration. Specific types of tubes must be used for each fumigant. A specific pump must be also used with these tubes; both must be purchased from the same manufacturer. The detection limit of these tubes varies with manufacturer and model.

Colorimetric tube sampling is limited in that its a “grab sample” appropriate only for that moment in time. This method may not pick up transient (i.e., less than 2 minutes in duration) exposures. Colorimetric tube sampling is most suitable for persistant exposures. Carefully read the directions so you know how to recognize cross-reactivity and know that color changes may be difficult to see on methyl bromide super-tubes. Also, be aware that tubes have expiration dates. Select the tube model that best fits your needs.

Air monitoring sampling tests are usually made of the air in the working area where concentrations will be highest. This location will depend on the proximity to the fumigation and wind patterns. If this location is not known or changes over time, several locations need to be tested. Record the test information on a suitable form or report.

Another method for monitoring the air is the use of “real-time monitors.” As of November 2008, however, there are no portable units on the market for methyl bromide, chloropicrin, or MITC.

Chemical-Resistant Boots

Labels of some fumigants require the use of waterproof (chemical-resistant) boots (Figure 7-10). Choose the material of your boots based on its ability to protect you from the fumigant you are applying. Leather boots that have been splashed with pesticide have resulted in worker poisonings. The best overall boot type when dealing with chemicals is an irrigator boot (all rubber, no stitching). However, some labels state "do not wear rubber protective clothing" including boots, due to the danger of the gases becoming trapped inside and causing skin injury. In such cases, leather or canvas boots may be the best selection.

Some pesticides, 1,3-D for example, penetrate most protective waterproof materials. Be sure to use only EVAL barrier laminate or neoprene when handling 1,3-D.

Wear the legs of your protective pants on the outside of the protective footwear. Wear boots inside coveralls. Be sure boots are good for walking and movement so you are able to function safely. Choose a sole design that is slip-proof on wet surfaces and easy to clean.

FIGURE 7-10

Boots are an important part of the personal protective equipment for applicators and other handlers.

Coveralls

Coveralls are another form of personal protective equipment. They are worn over work clothing but under other PPE such as gloves or boots. They are either disposable (e.g., Tyvek) or reusable (e.g., cloth). Both Tyvek and cloth coveralls provide protection. Be sure to wear clean, loose-fitting coveralls at the start of each workday. If pesticide gets on your coveralls, leave the area and immediately decontaminate by removing the coveralls and your clothing, washing your body with soap and water, and putting on clean clothing and coveralls. Decontaminate in a pesticide-free area. Consult the fumigant label for more information on coverall requirements.

Work Clothing. Work clothing is not PPE but the clothing worn under PPE. However, some pesticide labels specify recommended work clothing. Work clothing requires special handling if contaminated with pesticides, including separate laundering. Work clothing provides an extra layer of protection from exposure to fumigants.

Be sure to become familiar with any special work clothing requirements on the fumigant label. Work clothing includes garments such as long- or short-sleeved shirts, long or short pants (as allowed by the pesticide label), shoes, and socks. Even when coveralls are not required, you may choose to wear them over your work clothing for increased safety.

Chemical-Resistant Aprons

Protective aprons extend from the chest to the knees and may be worn over your coveralls when loading pesticides. They are not required when a closed loading system is used. If using an apron, be sure to keep it from catching in machinery. In fact, you might prefer wearing a chemical-resistant suit (pants and jacket) as a safer alternative to an apron. Read the pesticide label to determine when to wear a chemical-resistant apron during fumigant handling.

Chemical-Resistant Headgear

Hats made from fabric absorb liquids and can become seriously contaminated. If you wear a hat, be sure it is chemical-resistant and has a brim for protection. Do *not* wear a cloth baseball cap to protect your head when applying pesticides. If no particular head protection is required, the use of a bump-cap (Figure 7-11) is recommended because they are made of nonabsorbent plastic which is easily decontaminated. Headbands and sweatbands in hats must also be waterproof. An alternative to a bump-hat is a hooded, waterproof jacket (Figure 7-11). Chemical-resistant headgear may be required to protect from overhead exposure; check the label to determine if it is required for your work activity with the fumigant.

FIGURE 7-11

A bump cap or a hooded waterproof jacket provide chemical-resistant head protection.

Other Protective Measures

Air-Dilution Fans on Tractors

Certain types of application systems for methyl bromide require the use of an air-dilution fan system on the tractor. Be aware of the requirements for your particular type of fumigant application. Air-dilution fans direct air downward toward the body of the tractor driver. A functioning air-dilution fan system continually blows the air away from the applicator's face and reduces inhalation risk. Fan intake must be high (10.5 feet) above the ground. Air-dilution fan diverters direct air to the copilot, so that a fresh flow of clean air is aimed to the copilot's nose. Make sure that the fan is not picking up engine exhaust. If it is, reroute the tubing from the exhaust away from the fan intake.

Work Hour Limits—Methyl Bromide

Fumigants are regulated more strictly than other pesticides due to their unique hazards and toxicity. In particular, when workers are handling methyl bromide, regulations limit allowable work hours for each fumigant handling task and rate of application. Work hour limits depend on the type of respiratory protection used. The work hour limit requirements do not allow more than 3 days of handling of fumigants if no respirator is used. If a full-face, SCBA, or a supplied-air respirator is used, then the maximum number of workdays increase. To know which work hour limit rules apply to you, consult with the agricultural commissioner's office.

HEAT ILLNESS

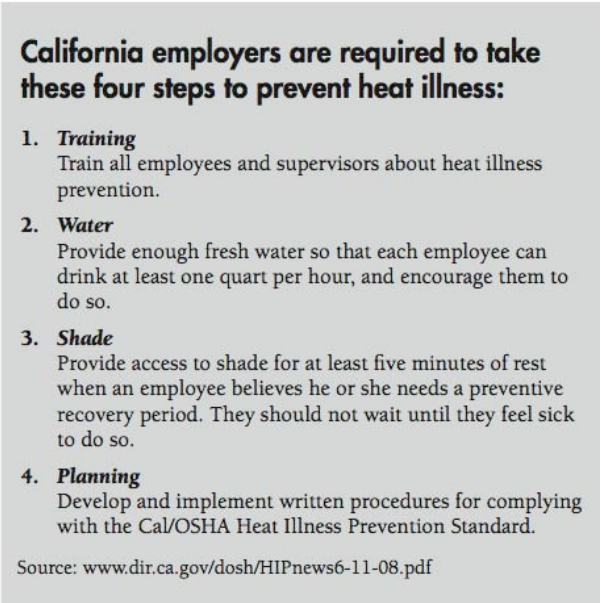
Heat illness is a serious medical condition that occurs when the body builds up more heat than it can shed. Heat illness, even in mild forms, makes people feel ill and impairs their ability to do a good job. The early signs of heat illness include headaches, dizziness, lightheadedness, muscle cramps, and feeling unusually tired and weak. Left untreated, this leads to more serious illness conditions including heat exhaustion and heat stroke. Heat stroke is a serious illness, and unless victims are cooled quickly, they

can die. Symptoms of more serious heat illness include unusual behavior, irritability, mental confusion, nausea or vomiting, rapid pulse, excessive sweating or hot dry skin (lack of sweating), seizures or fits, fainting, and loss of consciousness.

Heat illness is not caused by exposure to pesticides, but it may affect pesticide handlers and others who work in hot conditions. While protecting the handler from pesticides, PPE can increase the risk of heat illness by limiting the body's ability to cool down. On hot days start work early, wear light-colored protective clothing, take frequent breaks, drink water often, and stop work before you begin to experience heat illness. High temperature, high humidity, and direct exposure to sunlight increase the likelihood of heat illness. Air movement from wind or fans may provide cooling. Because hard work causes the body to produce heat, a person is more likely to develop heat illness when working on foot than when driving a vehicle.

DPR regulations address PPE and heat illness. When daytime ambient temperatures are above 80°F (27°C) or nighttime temperatures are above 85°F (29°C), pesticides that require wearing chemical-resistant clothing may not be handled by employees unless they are handled with a closed system or the employees use cooled chemical-resistant suits or another method or procedure such as work/rest cycles, to prevent heat illness. It is dangerous and illegal to apply pesticides while wearing chemical-resistant clothing at or above these temperatures. Applicators wearing chemical-resistant clothing need to be particularly careful about not overheating and take measures to prevent heat illness. California Division of Occupational Safety and Health, better known as Cal/OSHA, also has regulations addressing heat illness and appropriate measures to reduce the possibility of overheating.

Seek immediate medical attention if you experience heat illness symptoms that are not resolved by *immediate* corrective actions. This is an emergency! Before doing any work in the field, learn the signs of heat illness and how to take preventive action (Figure 7-12).



California employers are required to take these four steps to prevent heat illness:

1. ***Training***
   Train all employees and supervisors about heat illness prevention.
2. ***Water***
   Provide enough fresh water so that each employee can drink at least one quart per hour, and encourage them to do so.
3. ***Shade***
   Provide access to shade for at least five minutes of rest when an employee believes he or she needs a preventive recovery period. They should not wait until they feel sick to do so.
4. ***Planning***
   Develop and implement written procedures for complying with the Cal/OSHA Heat Illness Prevention Standard.

Source: www.dir.ca.gov/dosh/HIPnews6-11-08.pdf

FIGURE 7-12

Employers must take these four steps to assure safe working conditions and awareness of the risks and corrective measures for heat illness.

PERSONAL HYGIENE

Follow these basic personal hygiene and work practices when handling pesticides to protect yourself.

- Always wear all required PPE when working with pesticides.

- Clean PPE after use and no less than daily when in use.
- If wearing disposable coveralls, safely discard after each day's use. If wearing reusable coveralls, you must launder them after each day's use (separate from household laundry).
- Remove and handle PPE with care since it might contain pesticide residues that can come in contact with your body.
- If you are contaminated by a pesticide, immediately remove clothing, decontaminate (wash) the affected area of your body with soap and water, and change into clean clothing and coveralls. Decontaminate away from pesticides. Notify your employer.
- Wash your hands with soap and water before you eat, drink, use any tobacco product, or use the bathroom if you have been handling pesticides or working in treated areas.
- Work in pairs. Working alone with fumigants is risky.
- Do not drink alcohol 8 hours before or after handling fumigants.
- Do not wear jewelry when handling fumigants; some fumigants can become trapped underneath it.
- Never eat in areas where pesticides are stored, mixed, or applied. Don't eat lunch adjacent to fumigated fields.
- Stay upwind from fumigation operations and fumigated fields wherever possible.
- Shower thoroughly including washing your hair right after you finish working with fumigants. Put on clean clothing.
- Remove and handle pesticide work clothing with care since pesticide residues can come in contact with your body as you remove it.
- Wash all pesticide work clothing daily, separate from regular laundry. Don't let other people handle your dirty work clothing without notifying them that it is possibly contaminated with pesticide.

PUBLIC AND ENVIRONMENTAL SAFETY

Safety for the public and the environment requires special procedures when fumigants are involved. Be sure to check with the agricultural commissioner's office to know which fumigant materials require notification and field posting since both can vary with fumigants. (For details on field posting, see California Code of Regulations sections 6776 and 6784.) Be aware of nearby endangered species, methods to apply fumigants and prevent drift, and how weather conditions might impact planned fumigations.

Notification and Worksite Plans

Fumigation operations require weeks, if not months, of advance planning. You must give notice to regulators and neighbors near the fumigation site. Be sure to check with the agricultural commissioner before planning a fumigation since some fumigant labels, regulations, or permit conditions require a worksite plan, special notification procedures before fumigating, or other preapplication requirements. Even if you think you know the requirements, verify them since requirements may have changed for that location since the last time you made a fumigation.

The following requirements may apply to the application of a fumigant (verify with the agricultural commissioner in advance):

- Notice of Intent (NOI) 48 hours in advance

- proposed worksite plan 9 days in advance
- notification to property operators within 300 feet of outer buffer zone

Buffer Zones

A buffer zone is an area left untreated to protect nearby workers, homes, or sensitive areas from pesticide exposure. In general, buffer zones are a method to increase safety when applying pesticides. An outer buffer zone is often set for residences and inner buffer zones for worker protection. Buffer zones required for fumigation applications are quite complex and highly regulated.

Methyl bromide regulations and permit requirements specify limitations to application block sizes and also two types of buffer zones, inner and outer. Refer to the California Code of Regulations (section 6447.2) for more information on required buffer zones for methyl bromide applications. Some 1,3-D product labels specify minimum required buffer distances from occupied structures. Permits may also require larger buffer zones when applications are near to schools, hospitals, businesses, or residences.

Due to possible changes and the complexity of buffer zones at any particular site, always refer to the permit conditions and labels for the fumigation that is planned. Be aware of all buffer zones well in advance of starting the fumigation. Before commencing the fumigation, inspect the application site to make sure there are no new hazards or sensitive areas.

Posting

All fumigation applications require posting. Labels, regulations, or permit conditions may require posting of buffer zones in addition to the posting of the treated field. The posting requirement may specify the wording and manner of placement of signs. Be sure that signs remain posted and legible for the required duration. Signs that are not readable due to dirt, fading, or curling in the wind are not legal. Signs must be removed within specific times after the reentry interval expires, and field reentry when signs are posted is strongly regulated. Become familiar, in advance, with all pertinent posting requirements for the particular fumigation site and fumigant to be used. Signs (Figure 7-13) must have the following elements:

- the skull and crossbones symbol
- the following statements:
  - "DANGER/PELIGRO"
  - "Area under fumigation, DO NOT ENTER/NO ENTRE"
  - "[name of fumigant] fumigant in use"
- The date and time of the fumigation
- The name, address, and telephone number of the applicator

FIGURE 7-13

Field posted for fumigation. From Ventura County Agricultural Commissioner.

Chemigation applications also require posting (Figure 7-14). Posting requirements include the following for all signal word *Danger* materials applied via irrigation systems:

- an octagon stop sign symbol at least eight inches in diameter containing the word "STOP" in English

- the phrases “KEEP OUT” and “NO ENTRE” above the symbol and the phrases “PESTICIDES IN IRRIGATION WATER” and “PESTICIDAS EN AGUA de RIEGO” below the symbol
- all letters shall be at least 2-1/2 inches tall
- all letters and the symbol shall be of a color which sharply contrasts with their immediate background

FIGURE 7-14

Field posted for chemigation. Photo courtesy of Husein Ajwa.

Weather Condition Restrictions: Wind and Inversions

Always be aware of the weather just prior to, during, and expected after the application of fumigants. Do not fumigate when it is windy; however, a *gentle* breeze will provide good dispersion of the fumigant. Tarps must be secured to prevent blowing off fields. Do not fumigate during inversions. See Chapter 6 for more information on fumigant hazards related to environmental conditions.

Preventing Drift

Drift is the movement of pesticides in the air to a nontarget area during or soon after application. Labels, regulations, or permit conditions for fumigants usually require specific application equipment and procedures to minimize drift off the target site. These requirements may include placing fumigants under the soil surface or a surface treatment (e.g., tarp, water, or soil). When making turns during fumigant application, be sure that the line is purged and the flow has stopped before lifting the blades. If lines are not empty when blades are lifted, drift and worker injury can occur. Purging lines is a simple way to greatly increase the safety of the fumigation.

Applicators must prevent drift or off-site movement during the application by continually assuring that they are using best practices for the application as described in earlier chapters. Equipment and application methods must be appropriate for continuing the application; if they are not, the job should be stopped.

Endangered Species Protections

Federal and state governments have created laws to protect and prevent the extinction of certain rare or highly vulnerable animals and plants. Severe fines and imprisonment can be imposed on people who break these laws.

Enforcement agencies limit the use of certain pesticides in areas where endangered species exist or in their habitats. Before using a fumigant, check the label for precautions to protect endangered species. Find out if the site you will treat with a fumigant has any endangered species in the vicinity or ask at your local agricultural commissioner’s office. For additional information on endangered species, see the DPR website (http://www.cdpr.ca.gov/docs/endspec/). Protective requirements related to endangered species change so be sure to check regularly for updates.

Precautions: Preventing Environmental Contamination and Protecting Human Health

The use of fumigants requires careful handling to protect people and the environment. When transporting, loading, or storing fumigants or cleaning equipment that has held fumigants, be aware of

their unique physical characteristics. Fumigants are highly toxic and unique materials so always think safety first.

Safe Transport of Fumigants

There is always a risk of an accident when transporting hazardous materials such as fumigants. Spilled materials may cause serious human exposure as well as environmental damage. Chemicals that spill onto roads may wash into ditches, streams, and rivers during rainstorms and create the potential for serious environmental damage, including surface water and groundwater contamination. Pesticide spills may also contaminate the vehicle, its occupants, or other cargo, so use care to solidly secure containers when transporting.

Do not carry pesticides with seeds or fertilizers. Pesticides must not be carried in the driver or passenger section of vehicles. Transporting fumigants has special challenges since many are contained in pressurized cylinders. Tragic accidents have occurred when a cylinder was damaged, turning it into a rocket.

U.S. Department of Transportation (DOT) regulates the transport of many fumigants including placarding requirements. Refer to the U.S. DOT website, www.dot.gov, for information on proper transport of fumigants.

Safe Loading and Transferring

Fumigants are available in different forms. Some are solids, some liquids, and others compressed gases. All are highly toxic. Because of their ability to vaporize, they require special handling and particular care when loading into application rigs.

Be aware of temperature issues and flammability. Some fumigants react with certain metals. For example, methyl bromide attacks aluminum to form a compound which is spontaneously flammable. Prevent fires by assuring that all valves, pipes, tanks, pumps, hoses, and other materials that will come in contact with the fumigant are made of the correct, compatible materials for the fumigant you are using.

When loading or transferring fumigants, be aware of whether you are handling a flammable liquid or explosive gas, and be sure to confine all fumigant vapors within closed systems. Many requirements apply when handling flammable liquids. For example, tanks must have bottom connections for inlet and outlet, emergency relief valves, and fire-resistant valves. Tractor rollover protection systems must be designed so that working vents (other than pressure/vacuum relief) are not knocked off in the case of an accident. Vents must be connected to venting lines that lead back to the source tank (a California requirement). The Telone Guide to Application notes that “sources of ignition must be eliminated”; this means no smoking, minimal use of engines, and having spark arresters on the intake and exhaust of engines in the nearby area.

Tractor tanks to hold fumigants must be made of steel or stainless steel and meet all legal transportation requirements. Hose connectors must be of the dry-disconnect type without using aluminum, magnesium, zinc, cadmium, or alloy containing these metals.

Before starting to load, put on all required PPE and make sure it is comfortable. While loading, have eye-wash water nearby, along with washing water, soap, and towels. Loading and transferring should be done during the day or in a very well-lit area if at night.

Containers: Cylinders, Pigs, Mini Bulk, Tanks, and Nurse Tanks

FIGURE 7-15

Fumigants come in different types and sizes of cylinders. From DPR.

Fumigants are handled in specialized containers, determined by the chemical requirements of the material. Some are transported as solids and others are liquids or compressed gases under pressure. Cylinders may be upright or lie on their sides ("pigs"). Containers have many names and sizes but all require careful handling by an experienced, trained handler (Figure 7-15).

Bulk containers for fumigants are any containers holding more than 110 gallons. Mini bulk cylinders (or totes) contain between 110 and 800 gallons and are transported to application sites. Bulk tanks of fumigants are usually stored at dealers' sites and are subject to many legal requirements for safe storage, handling, and recordkeeping. Bulk tanks are offloaded into nurse tanks for transport to field sites. California's transportation regulations cover transporting compressed gases. Be familiar with all legal requirements before transporting bulk containers (Sidebar 7-3).

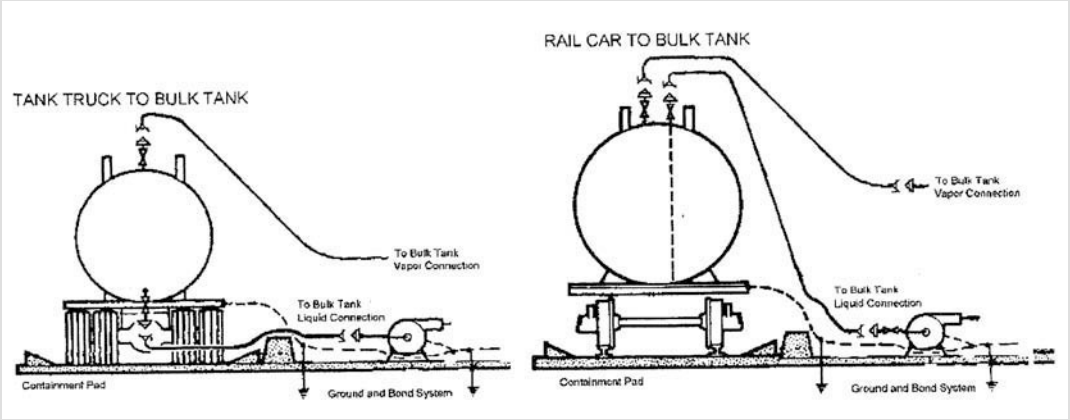
Some fumigant labels prohibit use of hoses, pipes, transfer lines, pumps, valves, or fittings made of certain materials. Be sure to review the TIB and label for each fumigant you will use to avoid the use of incompatible materials. When using 1,3-D products, for example, do not use PVC, urethane, vinyl, buna-N neoprene, or fiberglass as these may disintegrate. Also, do not allow 1,3-D products to come into contact with metals such as aluminum, magnesium, zinc, or alloys. Products that contain 1,3-D may corrode such metals and release hydrogen chloride, a toxic gas.

When applying fumigants, other compressed gases maybe required. For example, nitrogen gas is used to drive methyl bromide and chloropicrin out of the gas cylinder. To reduce the chance of fire, it is very important to use the correct purging gas.

SIDEBAR 7-3

Bulk Containers Hold at Least 110 Gallons

Bulk containers are those with a capacity of 110 gallons or more, including tanker trucks, roll-off bins, and railroad cars (see the definition in California Code of Regulations, title 22, section 66260.10). They are included in the contaminated container regulations, but the requirements are different from smaller containers because they are not normally discarded. If you manage bulk containers, be sure to carefully read the regulations relating to them found in the California Code of Regulations, title 22, section 676261.7(p).



Storing Fumigants

Keep fumigants in locked areas (Figure 7-16) with good ventilation. Keep fumigants off the ground to reduce exposing their containers to moisture, which can lead to rusting. Protect containers from extremes in temperature. Never store fumigants in employee work areas. Secure storage that is outdoors and protected from weather is usually the best approach for gas or liquid fumigants.

Always keep fumigant storage areas posted with warning signs on all four sides. If storing more than threshold amounts, notify the agency responsible for hazardous materials inventories so that fire department staff can be prepared to take correct measures in the case of an emergency. Contact the agricultural commissioner for more information on hazardous materials inventory reporting requirements.

FIGURE 7-16

Always keep fumigants in locked, weather-protected storage areas with warning signs. From DPR.

Cleaning Equipment

Fumigation equipment is usually cleaned with fuel oil, kerosene, diesel fuel, or other similar petroleum solvent. Check the label for guidelines. Fill and then drain the pump system with the cleaning agent. Water is not usually recommended, since it can corrode the equipment; however, some labels mention cleaning with water and immediately ensuring that equipment dries. Even after cleaning, empty containers that have held fumigants may contain residues so always keep them closed and locked.

Even when all of the correct safety procedures are followed, accidents happen. The next chapter discusses what to do when an emergency occurs.

CHAPTER 7: REVIEW QUESTIONS

1. **What is the most likely place to find out what type of PPE would be needed for the application of a particular fumigant?**
   a. manufacturer's representative
   b. MSDS
   c. label
   d. PSIS
2. **The best place to find regulatory information about protecting endangered species from the effects of fumigants is**
   a. The Conservation Organization
   b. manufacturer
   c. DPR's website
   d. Health Department

3. Fumigant drift can be desirable if it is

a. confined to the application site

b. during inversion conditions

c. when no tarp is used

d. never

4. Handlers using any fumigant must wear the following safety equipment

a. gloves

b. SCBA

c. eye protection

d. a and c only

5. Personal protective equipment should be removed and cleaned daily. It is OK to reuse respiratory protective equipment as long as the cartridges are washed daily.

a. true

b. false

6. Fumigant cylinders that have held gas require disposal at

a. the agricultural commissioner's office

b. the landfill

c. the manufacturer's headquarters

d. a recycling facility

7. Fumigants should be stored

a. in locked, weather-protected areas with warning signs

b. in locked, enclosed areas

c. near welding equipment

d. Fumigant storage is not allowed

8. The following would be safe practices EXCEPT

a. purging lines after lifting blades

b. carrying fumigants separately from seeds or fertilizers

c. having fire resistant emergency relief valves

d. 1,3-D tractor tank made of steel

9. Containers that hold fumigants should be kept off the ground because they might

a. explode

b. rust

c. become contaminated by the soil

d. solidify

10. A bulk container is offloaded into a ____ tank for transport to the ____.

a. tote, warehouse

b. pig, fumigation site

c. nurse, field

d. cylinder, railroad car

11. Drift management methods include
a. soil-surface treatment
b. placing fumigants on soil surfaces
c. tarp replacement
d. fumigating in windy conditions

12. Work hour limits apply to use of
a. all fumigants
b. chloropicrin
c. methyl bromide
d. respiratory protection when applying metam sodium

13. Heat illness can be minimized by
a. taking regular breaks
b. recognizing symptoms early
c. drinking lots of water
d. all of the above

14. Before doing a fumigation, the following might be required
a. notification
b. posting
c. establishing buffer zones
d. all of the above

15. Fumigation equipment should be cleaned
a. by soaking in water
b. with petroleum solvents
c. it is not necessary to clean since it will air out
d. only by professional cleaning services

16. Posting fumigation sites requires signs with all of the following information EXCEPT
a. "DANGER"
b. name/address/phone number for the agricultural commissioner
c. fumigant in use
d. date of fumigation

17. Buffer zones protect
a. workers
b. bystanders
c. both a and b
d. applicators

18. Tractor-mounted _____ protect applicators from fumigant vapors.
a. air-dilution fans
b. roll bars
c. valve covers
d. shields

Chapter 8: Pesticide Emergencies

Knowledge Expectations

1. Explain how to recognize and respond to fumigant emergencies.
2. Describe procedures for responding to emergencies, including whom to call.
3. Describe appropriate first responses for human exposures, including first aid procedures.
4. Describe procedures for dealing with fumigant leaks and spills.
5. Describe procedures for dealing with fumigant fires.
6. Describe procedures for properly dealing with fumigant misapplications including how to address errors made during mixing, loading, and application.

An emergency is any unforeseen circumstance that calls for immediate action. Fumigant emergencies may be the result of broken equipment, spills, fires, thefts, misapplication, or lack of care in storage or handling. Fumigants are highly toxic and often-volatile materials so continual awareness while handling them is important. Learn to recognize emergencies and know how to respond to them quickly.

Accidents may occur while you are handling or applying any fumigants, even if you work carefully under the most controlled conditions. Whenever you handle fumigants, be prepared for errors, accidents, and equipment failures. Preparation includes learning about possible emergencies and knowing the correct response. Develop plans and checklists to assist with emergency preparedness and response and train all handlers on how to use them.

This chapter describes how to prepare for emergencies involving fumigations, including:

- having an accident response plan
- recognizing situations that can lead to or cause an emergency
- responding to emergencies
- implementing emergency response procedures including first aid and calling for professional medical help
- properly using personal protective equipment and other safety equipment in emergencies
- properly responding to spills, leaks, or other fumigant releases
- properly responding to a fire involving fumigants

PREPARING FOR EMERGENCIES

Fumigant applications require a great deal of planning because of the dangers they involve and the complexity of fumigation operations. Preparation includes learning about possible fumigant emergencies, knowing and being able to implement the correct response procedures, and having the necessary tools to respond. All persons involved in storing or applying fumigants, or who might be in the area where fumigants are stored or applied, must be trained on emergency recognition and response. Figure 8-1 is a checklist to help you prepare for emergencies. Have necessary personal protective equipment for emergencies and an appropriate communication device so you are able to contact the property operator,

emergency response agencies and others. It is important to have the fumigant label and a functioning two-way radio, walkie-talkie, or telephone on-site (Figure 8-2). Put together a comprehensive accident response plan to be sure you and others are ready for any emergency.

CHECKLIST FOR PREPARING FOR PESTICIDE EMERGENCIES

- ❑ Be prepared for an accident. When accidents happen, the best response is a quick response.
- ❑ Develop an emergency response plan for pesticide exposures and accidents (spills, leaks, and fires).
- ❑ Train all of your handlers how to handle emergencies.
- ❑ Obtain first aid supplies and keep a set in each truck or work place. Keep them updated.
- ❑ Be sure to have adequate clean water for routine washing during the work period, emergency washing of the entire body, and eye flushing.
- ❑ 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.
- ❑ Take training on first aid procedures, including rescue breathing and CPR.
- ❑ Locate and make arrangements for emergency medical care for you and your employee handlers before you need emergency care.
- ❑ Post the name, location, emergency telephone number, and address of the emergency care facility in your vehicle and at your workplace.

FIGURE 8-1

Use a checklist such as this to help prepare for emergencies.

FIGURE 8-2

Be sure to have personal protective equipment and a device to call for assistance and information in case of emergencies.

Accident Response Plan

Regulations require fumigant applicators to have accident response plans at the worksite of each fumigation in anticipation of leaks, spills, fires, or other emergency situations. Knowing how to respond to an emergency will save lives and minimize damage. Establishing a company accident response plan will aid in

- recognizing situations that might lead to an emergency if not corrected
- knowing how to respond when an emergency occurs
- preventing or minimizing human exposure leading to injury, illness, or death
- preventing property and environmental damage

Accident response plans for storage and application scenarios must incorporate elements that are specified on the label and in the restricted materials permit. Read the label and be sure to have the emergency response materials specified. If the restricted materials permit includes a site response plan and tarpaulin repair plan, these can provide pertinent information that also can be used in the plan. Elements of the accident response plan include

- designation of the qualified person responsible for the accident response plan and for coordinating emergency responses
- identification and location of storage and application sites
- identification of surrounding areas that can be affected by a fumigant-related emergency
- evacuation route and procedures
- list of who must be contacted in an emergency including phone numbers
- location of utility shutoffs, emergency equipment and other storage/application site-specific information

The accident response plan must identify the responsible person involved in the fumigation who will notify the authorities of the problem and direct all necessary emergency activities. This person is also responsible for evacuating the site after assessing the situation. The duties of the responsible person are listed in Table 8-1.

TABLE 8-1

Duties of the Responsible Person in an Accident Response Plan.

• Determine type and location of emergency using appropriate personal protective equipment, if needed.
• Immediately shut off the flow of the fumigant (if can be done safely)
• Contact appropriate emergency response agencies and describe emergency.
• Determine wind direction to ensure safety and upwind evacuation route.
• Assess the potential risks and hazards and notify all workers and others in the area of the emergency.
• Coordinate a rapid, orderly evacuation procedure to emergency meeting area.
• Assemble at emergency meeting area, do roll call, and await or give further instructions.
• Contact county agricultural commissioner.
• Contact property operator or person in charge.
• Conduct or arrange for clean up once given approval by responding agencies.

Accident response plans should include information on who must be contacted when there is an emergency including 9-1-1, a medical facility, property owners, and the agricultural commissioner. Fumigant labels may have emergency contact information, including a manufacturer emergency phone number and other emergency phone numbers, all of which should be included in the accident response plan. All emergency contact information must be readily available at all work sites where fumigants are handled. Figure 8-3 provides an example of emergency contact information for a fumigation.

Company Emergency Phone Numbers

	Business #	Home #	Pager #	Mobile #
Company Contacts:				
Emergency Services:				
Fire / Ambulance	911			
County Sheriff	911			
California Highway Patrol	911			
Office of Emergency Services	800-852-7550			
Service Companies:				
Butane / Propane:				
Electric Co.:				
Chemicals:				
Others:				
Doctor:				
Name:				
Address:				
City / Zip				
Hospital:				
Address:				
City / Zip				

Agricultural Commissioner Contact Information:
Office Telephone:
After Hours Emergency Telephone
Manufacturer Contact:

FIGURE 8-3.

Example of emergency contact information to be included in an accident response plan and posted at the work site.

Written accident response plans contain site information such as location of utility shut-offs, sources of power, and other key information that you might need during an emergency including locations of

- water shut-offs
- electrical panel shut-offs
- fire extinguishers
- emergency shower and eye wash facilities
- electrical transformers
- route to emergency meeting area

- emergency exits (gates)

An evacuation plan is an important part of the accident response plan. Develop an evacuation map (Figure 8-4) and review it with all workers before each fumigation. Evacuation maps need to show where emergency shut-offs and safety equipment are located. It is important that everyone involved in the fumigation be aware of the evacuation route and procedures and location of safety equipment prior to the application—not just the designated person. Employees should be trained in advance.

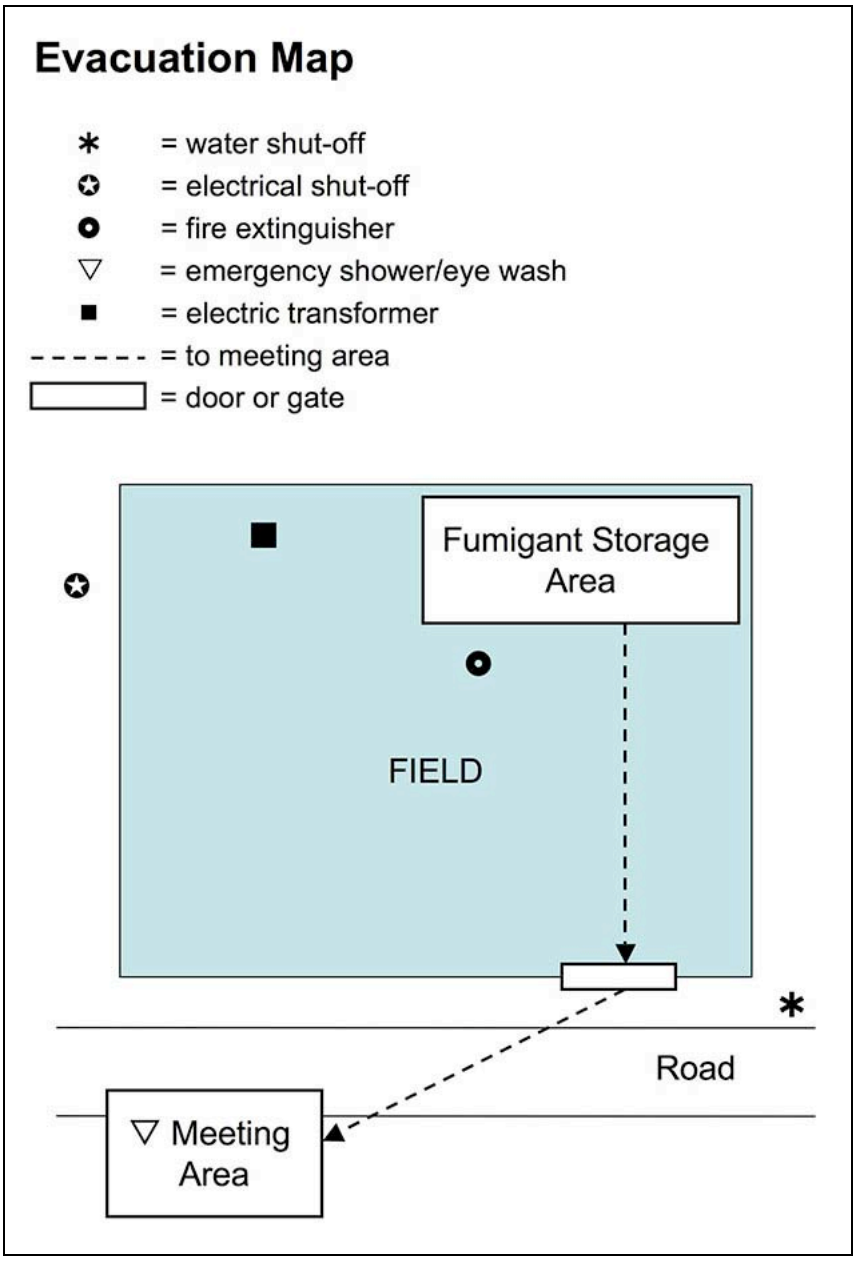
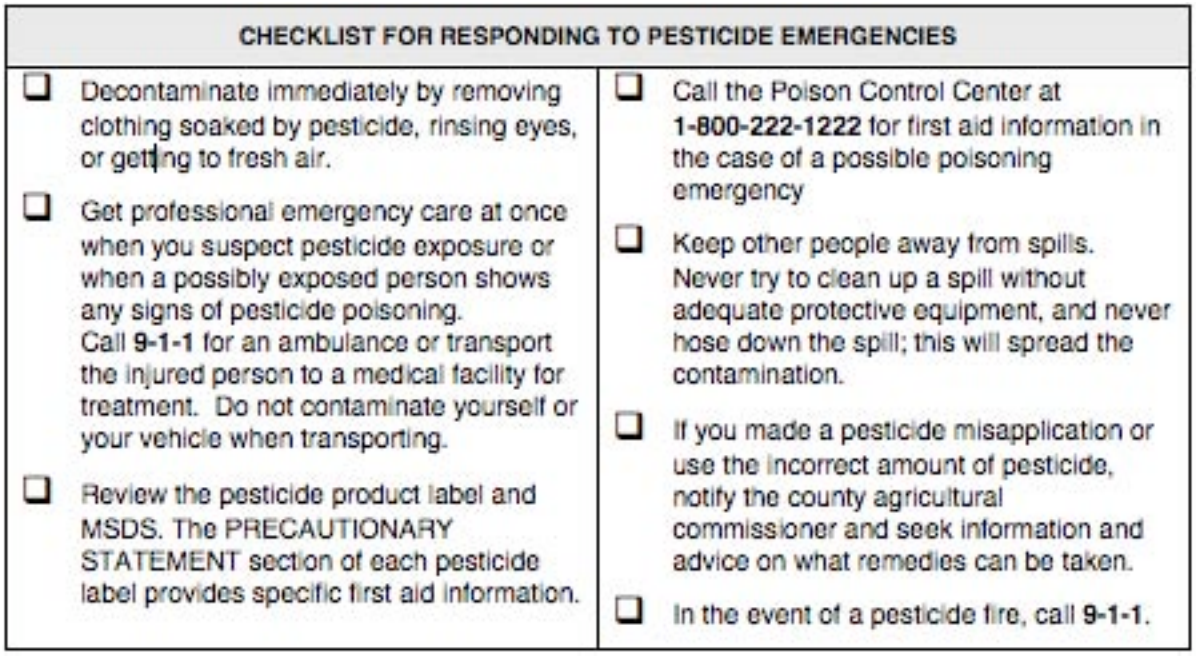


FIGURE 8-4

Evacuation maps need to show key emergency response components including water and electrical shut-offs, emergency shower/eye wash, electric transformers, fire extinguishers, gates, and the route to the emergency meeting area.

HANDLING HUMAN EXPOSURES

Poisoning can occur from fumigant contact with the skin, eyes, or tissues in the mouth or nose. It can be very hazardous to swallow or inhale dusts, fumes, or vapors. The type and length of exposure, and the particular fumigant, will determine the proper first response and what type of first aid and subsequent medical treatment are required. Serious fumigant poisoning can cause respiratory arrest, convulsions, paralysis, skin burns, or blindness. Proper and quick first aid treatment for fumigant exposure may reduce the extent of injury and even save lives. However, it is essential to call for professional medical care as soon as fumigant exposure is suspected. Figure 8-5 provides a checklist of procedures to follow when human exposure is suspected.



CHECKLIST FOR RESPONDING TO PESTICIDE EMERGENCIES

- ❑ Decontaminate immediately by removing clothing soaked by pesticide, rinsing eyes, or getting to fresh air.
- ❑ Get professional emergency care at once when you suspect pesticide exposure or when a possibly exposed person shows any signs of pesticide poisoning. Call **9-1-1** for an ambulance or transport the injured person to a medical facility for treatment. Do not contaminate yourself or your vehicle when transporting.
- ❑ Review the pesticide product label and MSDS. The PRECAUTIONARY STATEMENT section of each pesticide label provides specific first aid information.
- ❑ Call the Poison Control Center at **1-800-222-1222** for first aid information in the case of a possible poisoning emergency
- ❑ Keep other people away from spills. Never try to clean up a spill without adequate protective equipment, and never hose down the spill; this will spread the contamination.
- ❑ If you made a pesticide misapplication or use the incorrect amount of pesticide, notify the county agricultural commissioner and seek information and advice on what remedies can be taken.
- ❑ In the event of a pesticide fire, call **9-1-1**.

FIGURE 8-5

Checklist for responding to a human exposure emergency.

Recognizing Exposure Situations

Learn how to recognize that an exposure is occurring. Notice any fumigant odors and take immediate corrective action. Know the exposure and poisoning symptoms for the fumigant being handled. Poisoning symptoms for each fumigant are described in Chapter 6. Distinctive odors for fumigants are listed in Table 8-2. Take immediate action when symptoms or an odor are noticed. In some cases people will become rapidly accustomed to an odor so that it will no longer be perceived (“odor fatigue”), however, the fumigant may still be present. To prevent further exposure and continued poisoning, protective measures must be taken once an odor is detected even after it appears to have gone away.

Protective measures include terminating the application, removing handlers from the exposure situation, and correcting the cause of exposure. People are living, working, or otherwise in the area of exposure, must also be warned so they can take action to stop the exposure, by staying indoors or leaving the area.

Recognizing when exposure to fumigants has occurred can be challenging (Sidebar 8-1). This is especially true when it involves bystanders or others not involved in the fumigation. They might experience symptoms but not be aware that the cause is a fumigant. For instance, some people may confuse symptoms of exposure to fumigants with allergy symptoms.

SIDEBAR 8-1

Determining that a Fumigant Is Causing Symptoms

One key challenge to first responders is determining that the cause of the symptoms is a fumigant. For example, an incident in 2003 involving the injection of 100% chloropicrin into the soil caused residents living 1/4 mile away to contact first responders because they were experiencing eye itching and burning. Initially, fire fighters were not able to determine the cause. The next day, similar symptoms were experienced, initially by the applicators and then by nearby residents. This time, the first responders were aware of the nearby fumigation. Subsequent problems were prevented when the applicator changed the soil compaction equipment he was using so that vapors did not escape the treated soil.

TABLE 8-2

Odors and Actions to Take if Exposed to Specific Fumigants.

Fumigant	**Odor detection**	**What should I do if I'm exposed?**	**Can I get tested to see if I was exposed?**
1,3-Dichloropropene	Odor is like horseradish, Chinese mustard, or chloroform Detected in 1 to 3 ppm range but faint and odor fatigue occurs rapidly	Leave area if notice irritating odor Gently rinse with clean water if have known exposure or minor eye/skin irritation Get immediate medical attention if additional symptoms	No tests for 1,3-D or its breakdown products in bodily fluids
Metam sodium (MITC)	Odor is like rotten eggs, sewer gas	Leave area if notice odor or experience eye irritation Gently rinse with clean water if have known exposure or minor eye/skin irritation Get immediate medical attention if additional symptoms	No tests for metam sodium or its breakdown products in bodily fluids
Methyl bromide	Odorless at level adverse to health Irritating odor if chloropicrin is used as a warning agent	Leave area if notice irritating odor Gently rinse area with clean water if have known exposure or minor eye/skin irritation Get immediate medical attention if additional symptoms	Bromide levels can be tested in blood but interpretation is complex
Chloropicrin	Odor is irritating, strong	Leave area if notice odor or eye irritation Gently rinse with clean water if have minor eye or skin irritation Call 9-1-1 if having more than minor respiratory or eye irritation	No specific blood test for exposure. Breathing tests sometimes useful in evaluating respiratory problems.
Carbon disulfide liberators (Sodium tetrathiocarbonate)	Odor is strong rotten egg smell The smell disappears rapidly because of odor fatigue. Odor not a reliable indicator of exposure	Leave area if notice odor or eye irritation Gently rinse with clean water if have minor eye or skin irritation Call 9-1-1 if having more than minor respiratory or eye irritation Releases hydrogen sulfide and carbon disulfide when decomposing in stomach	

Calling for Medical Assistance

You must call for professional medical help at once if there is a significant exposure or a person appears ill from the fumigant. Be ready to provide specific accident details including the name of the fumigant to 9-1-1 emergency personnel as shown in Figure 8-6. Medical professionals may either come to the site or request that exposed individuals be transported to the hospital. How fast you obtain medical care can often determine how serious the injury will be. Provide medical personnel with the victims' age and weight along with information about the fumigant suspected of causing the injury and, if possible, show them the label.

Calling 9-1-1 provides quick information and emergency assistance and should be the first call you place. You will need to describe the emergency. The staff at the 9-1-1 call center can contact the appropriate emergency response agency plus provide you with important safety information and procedures to follow.

The Poison Control System in California is another source of information to you or to emergency response personnel about the particular fumigant involved. Poison control experts can be reached by telephone 24 hours a day, 7 days a week. The Poison Control System can be called throughout California by using a single toll-free number, **1-800-222-1222**.

These centers provide lifesaving information on poisoning treatment in many languages.

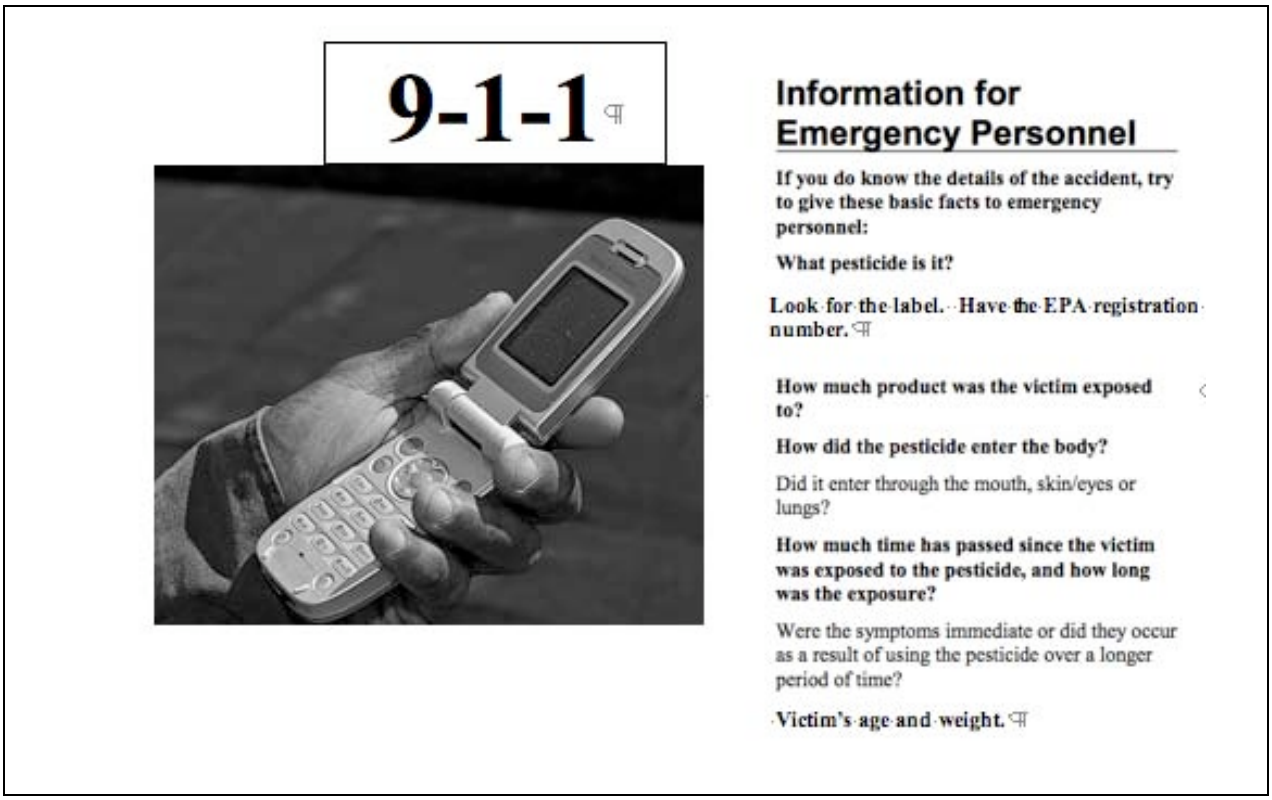


FIGURE 8-6

Be prepared to provide emergency responders with key information about the fumigation and the emergency. Assure that phones function at the fumigation site.

First Aid for Fumigant Emergencies

First aid is the help you are able to give an ill or injured person while you are waiting for professional help to arrive. First aid is not a substitute for professional medical care. The PRECAUTIONARY

STATEMENTS section of the fumigant label provides specific first aid information for each product. Read the label and be sure to stock any recommended materials or equipment. Poison Control Centers can also provide useful specific information in an emergency, so keep the Poison Control telephone number (1-800 222-1222) stored on cell phones and posted at the work site. Also, prepare yourself for emergencies by enrolling in an American Red Cross first aid course and cardiopulmonary resuscitation (CPR) training.

Before rescuing or aiding a person overcome by a fumigant, put on the appropriate protective equipment. If you are not certain whether the air is safe to breathe, put on adequate respiratory protection before entering the area with the fumigant. The fumigant that affected the injured person can also injure you. Avoid getting fumigants onto your skin, and do not inhale vapors. Once you are adequately protected, while waiting for professional help to arrive, decontaminate the exposed parts of the affected person's body as quickly as possible.

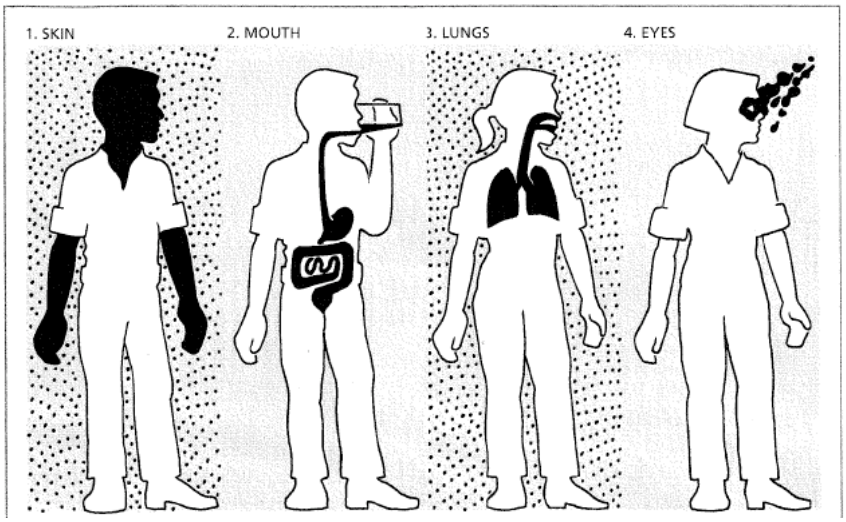


FIGURE 8-7

Four routes of exposure to fumigants.

There are four ways for a person to become exposed to fumigants: skin, eyes, lungs (inhalation), and mouth (swallowing) (Figure 8-7). Decontamination and emergency response are specific to the route of exposure; however, a serious exposure episode might involve more than one route. First aid for each of the exposure routes is detailed below. In general, the steps to take when exposed are

1. Leave the contaminated area.
2. Prevent further (ongoing) exposure.
3. Get medical attention.

Fumigants that get on your skin either directly or via contaminated clothing or personal protective equipment (PPE) can cause serious injury, either in the form of burns or rashes (Figure 8-8), or through skin absorption resulting in possible internal poisoning. Some fumigant labels direct users to not wear tight-fitting clothing or gloves to avoid entrapment of vapors against the skin, causing injury.

Eye tissues absorb fumigants very quickly. The head and groin areas also absorb more readily than other parts of the body (Figure 8-9). Fumigant illness or body organ damage can occur quickly. Some fumigants can cause serious harm to eyes and may result in permanent impairment or temporary blindness. Prompt first aid, followed by professional medical care, is a must and helps reduce the possibility of permanent effects. Recognizing when eyes or other organs have been exposed to fumigants may be complicated by "odor fatigue," which causes people to rapidly become accustomed to some

fumigant odors. Inability to smell the fumigant may cause a person to discount the seriousness of the exposure.

FIGURE 8-8

Skin blistering caused by exposure to pesticide.

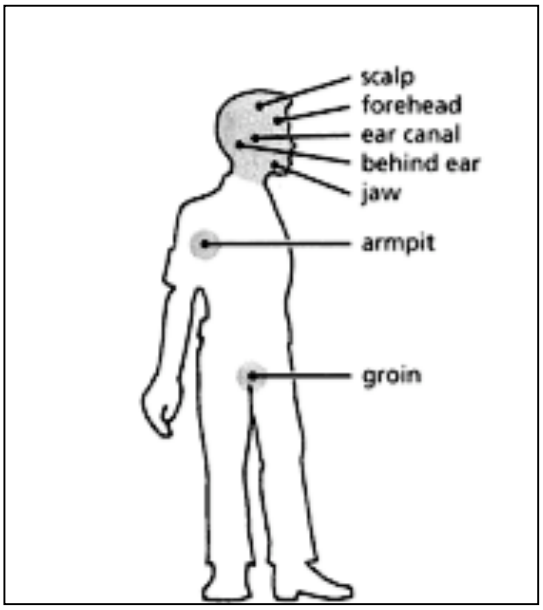


FIGURE 8-9

Many parts of the body can absorb fumigant. Eyes are particularly sensitive because they absorb chemicals faster

Inhaled fumigants, fumigant dusts coming off solid materials, vapors from spilled fumigants, and fumes from burning chemicals can cause serious lung injury and be absorbed into other parts of the body. Bystanders or others not involved with the fumigation may not know to suspect a fumigant as the cause. However, fumigant exposure is a serious problem, so act quickly. If fumigant odor inhalation has lasted for a period of time or if fumigant vapors are highly concentrated, the person may require your help in moving from the area. Protect yourself from exposure while removing possible victims.

If a fumigant enters the mouth, it can then enter the entire body through absorption or swallowing. Exposure through the mouth presents two immediate dangers:

- poisoning effect on a person's nervous system or other internal organs
- physical injury (such as burned tissues) on the linings of the mouth, throat, and lungs.

Corrosive materials (strongly acids, bases or reactive species such as oxidizers) can seriously burn sensitive tissues. Petroleum-based fumigants can cause lung and respiratory system damage, especially during vomiting. Some fumigants, when exposed to air, become very cold which can "burn" tissues of the body. ***NEVER induce vomiting if you suspect that the swallowed fumigant is corrosive, petroleum-based, or might cause chemical burns of body tissues. Emergency response professionals will tell you if inducing vomiting is advised.***

See Sidebars 8-2, 8-3, 8-4, and 8-5 for more information about what to do in case of exposure to skin, eyes, lungs by inhalation, or internally by mouth.

SIDEBAR 8-2

First Aid in Case of Exposure to Skin

Immediately remove liquid-contaminated clothing and wash the affected areas with clean water and soap. Do not reuse contaminated clothing and dispose of it only after consultation with the agricultural commissioner.

Follow these steps for skin exposure to fumigant:

1. **Leave the contaminated area.** Get away (or remove the victim) from the fumes, spilled fumigant, and further contamination. Do this quickly. If assisting another person, do not become exposed to fumigants in the process.
2. **Restore breathing.** If the victim has stopped breathing, begin artificial respiration (rescue breathing) at once and ask someone in the area to call 9-1-1 for help. If there is fumigant on the face or lips, clean this off first, before you begin rescue breathing. Continue until the victim's breathing resumes or until professional medical help arrives. If the person has stopped breathing and has no pulse, begin cardiopulmonary resuscitation (CPR) and continue until professional medical help arrives.
3. **Prevent further (ongoing) exposure.** While wearing gloves, remove the contaminated clothing and thoroughly wash the affected skin and hair, using soap or detergent and large amounts of water. Bag up the contaminated clothing for later disposal. If the exposure has only been to vapor, with no liquid contact, this step may not be necessary. Fumigant vapors do not "stick" to surfaces, including clothing and skin.
4. **Call 9-1-1 for immediate medical care.** Tell the medical provider the name of the fumigant causing the injury. Transport the exposed person in an ambulance (be able to describe the precise location of the injured person) or have someone provide transportation to the nearest medical facility as quickly as possible. Do not contaminate the person providing assistance or vehicle interior while transporting the victim. If possible, dress the exposed person in a clean, disposable coverall to prevent cross-contamination.

SIDEBAR 8-3

First Aid in Case of Exposure to Eyes

To treat eye exposure, you must take these steps immediately.

1. **Leave the contamination area.** Get away (or remove the victim) from the source of eye contamination. Exposure to both fumigant liquids and vapors can cause eye injury or irritation. Fumigant vapors can be absorbed by the fluids in the eye.
2. **Wash the eyes.** *Immediately* wash the affected eyes with a gentle stream of clean, running water. Do not point the hose or water stream directly at the eye; rather, direct the water across the eyes, from the side. Hold eyelids open to assure thorough washing. Continue flushing for at least 15 minutes.
3. When washing the eyes, do not use any chemicals or drugs in the wash water, since this may increase the extent of injury. If running water is not available, slowly pour clean, lukewarm water from a container or water cooler onto the bridge of the affected person's nose, rather than directly into the eyes. Assure that rinse water drains away from the eyes.
4. **Get medical care.** Always get medical attention as soon as possible. Have someone call 9-1-1 to get emergency medical care while the eye flushing gets under way. Tell the medical provider the name of the fumigant causing the injury.

SIDEBAR 8-4

First Aid in Case of Exposure to the Lungs—Inhalation

If any odors are noticed, take immediate corrective actions. If "odor fatigue" has occurred, inhalation injury may be difficult to determine. Bystanders or others not involved with the fumigation may not know to suspect a fumigant as the cause. Fumigant exposure is a serious problem.

Follow these steps when someone is overcome by fumigant vapors:

1. **Leave the contaminated area and remove the exposed person.** Anyone overcome by fumigant vapors must get to fresh air immediately and avoid physical exertion to reduce strain on the heart and lungs.
2. **Protect yourself while removing the exposed person.** Wear a self-contained breathing apparatus (SCBA) or supplied-air respirator appropriate for the specific fumigant when rescuing a person who has been overcome by fumigant gases or vapors. If you do not have SCBA or a supplied-air respirator, call for emergency help. You can be of more assistance to the injured person by seeking proper emergency help than you can be if you are overcome by the fumigant yourself.
3. **Call 9-1-1 for immediate medical care.** Be able to describe the precise location of the injured person and the name of the fumigant that has been inhaled (at least provide the name and concentration of the active ingredients).
4. **Loosen clothing.** Loosening clothing will make breathing easier and also releases fumigant vapors trapped between clothing and the skin. Be careful to avoid exposure to vapors as they are released.
5. **Restore breathing.** If breathing has stopped, or is irregular or labored, begin artificial respiration (rescue breathing). Continue assisting until breathing has improved or until medical help arrives. If the person has stopped breathing and has no pulse, begin CPR and continue until help arrives.
6. **Treat for shock.** Inhalation injury can cause a person to go into shock. Shock is life threatening: not enough blood is delivered to all parts of the body, so that systems and organs begin to fail. The goal of first aid is to give care and minimize shock, while addressing the injury. Keep the injured person calm and lying down. Prevent chilling by wrapping the person in a blanket after removing contaminated clothing. Do not give any liquid if the person is unconscious. If the person has a seizure, protect from hitting his or her head, falling, or other injury. First aid training may also equip you to block the person's mouth to keep him from biting or swallowing his tongue. Keep air passages clear by making sure the head is tilted back.

SIDEBAR 8-5

First Aid in Case of Swallowed Fumigants

If a fumigant has entered the mouth but was not swallowed, and the victim is conscious, rinse the mouth with large quantities of water. Wipe the mouth with a damp cloth and brush teeth thoroughly. Safely wrap the toothbrush and cloth for correct disposal later.

Act quickly when a fumigant may have been swallowed. Follow these guidelines:

1. **Call 9-1-1 for immediate medical care.** Tell the dispatcher that a fumigant has been swallowed. *This is an emergency.* Follow directions from 9-1-1. Know the name of the fumigant that has been swallowed and have the label nearby when you call. Be able to describe the precise location of the injured person.
2. **Dilute the swallowed fumigant.** If the person is conscious and alert, give large amounts (1 quart for an adult or a large glass for a child under age 7) of water or milk. Do not give any liquids to an unconscious or convulsing person.
3. **Induce vomiting ONLY if directed by poison control or 9-1-1.** If you are certain that neither a corrosive nor petroleum-based fumigant pesticide has been swallowed (check the pesticide label) *and* are directed by emergency response professionals, induce vomiting. Make sure the person is kneeling or lying on the right side of the body. If in doubt, do not induce vomiting.

SIDEBAR 8-6

How to Respond to Fumigant Spills or Leaks

1. **Clear the area.** Keep people and animals away from the contaminated area.
2. **Call 9-1-1 for immediate response assistance and medical care.** Tell the dispatcher that a fumigant has been spilled or is leaking. Follow directions from 9-1-1. Know the name of the fumigant and have the label nearby when you call. Be able to describe the precise location of the spill or leak and the surrounding area. Refer to **First Aid information** if necessary.
3. **Do not allow any smoking near a spill.** If the spill occurs in an enclosed area, shut off all electrical appliances and motors that could produce sparks and ignite a fire or explosion. Some fumigants are flammable or are formulated with flammable ingredients.
4. **Before beginning any cleanup, be sure to consult the label and wear appropriate personal protective clothing and equipment.** Depending on the fumigant, PPE might include rubber boots, gloves, waterproof protective clothing, goggles, or respiratory equipment. However, for some materials, certain PPE use can actually lead to injury (entrapped gas). Check the fumigant label and MSDS for additional precautions and information on the appropriate PPE for that fumigant. Wear the maximum protection required by the label.
5. **Contain the leak.** Stop the leak by transferring the fumigant to another container or by patching the leaking container. Use soil, sand, sawdust, or absorbent clay to form containment "dam" around liquid leaks. Cat litter is a good absorbent material for fumigant cleanup. If the wind is blowing fumigant dusts or powders, cover the area with a plastic tarp to prevent off-site movement, place edges of the tarp in a trench and seal with soil.
6. **Clean up the fumigant.** If appropriate, proceed to clean up the spill or leak. (For major spills, professional decontamination companies should be brought in.) Brush the containment dam of absorbent material toward the center of a liquid spill. Add additional absorbent material if necessary. If the spill is on soil, shovel out contaminated soil for disposal. Spilled fumigants and anything (e.g., soil) that was contaminated must be placed into a sealed container such as a 55 gallon drum. Label the drum to indicate it contains hazardous waste and include the name of the fumigant and the signal word (e.g., DANGER or WARNING).
7. **Clean nonporous surfaces and safety equipment.** If the spill occurred on a cleanable surface, such as concrete or asphalt, use a broom to scrub the contaminated surface with strong detergent solution. Consult 9-1-1, CHEMTREC, or the fumigant manufacturer for information on commercial decontamination preparations available for this purpose or to find out if it is appropriate to prepare a solution. Clean up the solution with absorbent material and place it in the container with the contaminated material. Equipment such as brooms, shovels, and dustpans must be properly cleaned with strong detergent or safely disposed of. When you finish, thoroughly clean and air dry your personal protective equipment before storing it.
8. **Dispose of the material.** Local regulations on disposal of hazardous materials may vary. Check with the agricultural commissioner, health department, or Department of Toxic Substance Control for instructions on how to dispose of the hazardous waste container and its contents. Under most circumstances, the residues from a fumigant spill must be transported to a Class 1 disposal facility. If advised by 9-1-1 or CHEMTREC, add up to 10 pounds of soda ash to the drum before sealing it to aid in fumigant detoxification. (Check the fumigant label and MSDS to make sure it is safe to use soda ash.)

LEAKS AND SPILLS

All fumigant leaks or spills should be treated as emergencies. They require correct and quick response to limit human injury and environmental damage. Leaks or spills can occur while transporting, storing, or using fumigants. Fumigants may be spilled indoors, in enclosed areas, or outside.

Cleaning up major fumigant spills requires the help of professionals. It is extremely difficult and costly to remove contaminated soil or clean up water contamination. Applicators may be able to handle some leaks and spills, such as when diluted fumigant leaks from application equipment. However, fumigant leaks and spills can be major incidents with immense danger (e.g., a compressed gas container rupturing). Call CHEMTREC 24-hour emergency response phone service (1-800-262-8200) for expert advice on hazardous materials spills and clean-up information.

When spills occur on public roadways, immediately call 9-1-1. When toxic materials are on public roadways, governmental agencies that respond to the spill will report it to the California Office of Emergency Services. However, all leaks or spills of fumigants applied by custom (commercial) applicators, no matter where they occur, must be reported to the agricultural commissioner as soon as possible. If leaks or spills occur in areas other than public roadways, follow the emergency procedures listed below. Coordinate the clean-up with public agencies.

Know if the fumigant is a flammable or corrosive material. Consult the label or manufacturer for information specific to various fumigant products. Follow the general guidelines in Sidebar 8-6 when handling fumigant spills or leaks. The spill or leak response will vary, depending on the type of fumigant and location. For example, when a spill or leak is from a methyl bromide cylinder, call 9-1-1, evacuate the area, and allow it to evaporate. If a hose or fitting ruptures during methyl bromide application, immediately stop and turn off the tractor and evacuate. People should *not* enter the spill area unless wearing respiratory equipment and other appropriate PPE, and then only if entering is necessary. Approach the equipment from upwind if possible. If chloropicrin is involved, allow it to evaporate or be absorbed into sand or other absorbent material. Contaminated absorbent material must be disposed of as discussed on the fumigant label or MSDS.

FIRES

Fighting fumigant fires requires special care because toxic smoke and gases generated by burning fumigants cannot be contained (Figure 8-10). Areas endangered by these vapors must be evacuated. Toxic vapors hamper fire-fighting efforts and require the use of supplied-air respirators or SCBA and personal protective clothing. First responders must use special materials and extreme caution when fighting fumigant fires. Water can be dangerous with certain fumigants, although it could be useful to cool containers and prevent overheated chemicals from exploding. Only use water if directed by first responders. Do not splash or spread toxic chemicals with high-pressure water.

When a fumigant fire breaks out, take the steps in Sidebar 8-7 immediately.

FIGURE 8-10

Fires are emergencies and require that you call 9-1-1 emergency response experts to handle.

Sidebar 8-7

How to Respond to Fumigant Fires

1. **Immediately call 9-1-1 to contact the nearest fire department.** Inform them that the fire involves a fumigant. Provide them with the names of the fumigants and any other chemicals in the fire, along with the names of other chemicals near the burning area. If possible, provide an MSDS for each chemical to the arriving fire units. Follow directions from 9-1-1. Be able to describe the precise location of the fire and the surrounding area.
2. **Clear the area.** Get people out of the immediate area of the fire; there may be considerable risk of toxic gases and explosion. Do not put out the fire yourself. Fire fighters have specialized knowledge of the correct materials to use to put out chemical fires.
3. **Evacuate people.** Evacuate and isolate the larger area around and downwind of the fire. If you can do it safely, move animals, equipment, and vehicles that could be damaged by the fire or vapors, or that might interfere with fire-fighting efforts. Isolate the burning area and keep bystanders from being exposed to smoke from the fire or runoff from fire fighting. Coordinate with the emergency responders (police or sheriff) to assure they are able to evacuate nearby and downwind residences, schools, and buildings until the danger has passed.

MISAPPLICATIONS AND HANDLING ERRORS

A fumigant misapplication can become an emergency if it is not addressed promptly or if it poses an immediate danger to people, property, or the environment. Misapplication involves the use of a fumigant in a manner inconsistent with label directions, such as making an application to a site not allowed by the label, exceeding the label rate for the soil type or situation, failure to apply to soil with the correct moisture level, or incorrectly calibrating the application rate. Misapplications also include using improper application methods, mixing procedures, or disposing of a fumigant improperly. Using faulty, leaky or malfunctioning equipment also can cause a misapplication. Misapplications may result from lack of attention to fumigant loading or giving the wrong instructions to an employee.

Not only is misapplication illegal, fumigations may not be effective if not done correctly. Take the time to plan and communicate about the fumigation and make sure in advance that equipment is in good working order.

Making an application mistake is a serious problem. Do not compound the damage by failing to take responsible, corrective action once the mistake is discovered. You are responsible for the misapplication and taking appropriate corrective measures. The amount of damage may be reduced by prompt action once the error has been discovered.

Your first concern must be to protect people, animals, and the environment. Take quick action to notify the property owner and the county agricultural commissioner of the problem and seek information and advice on what remedies can be taken. Contact the fumigant manufacturer for help in determining the best corrective measures. Penalties and legal claims accompany many misapplications so be sure you note what went wrong and corrective measures you took to address the situation.

Proper storage is important. Many fumigants are packaged as compressed gases in pressurized containers. Be sure to protect fumigant cylinder valves from mechanical damage. Keep cylinders in upright positions and immobilized, either in pallet cages or strapped to a wall or cylinder dolly (Figure 8-11). An emergency could occur if a cylinder is stored near flammable substances (oil, gasoline, or hazardous waste), electrical connections, or gas flames. Prevent accidents by storing safely and inspecting containers regularly to assure valve covers are in place and safety relief devices appear free from tampering.

Inspect for rust on bottoms of cylinders and assure that containers don't have any of the following defects:

- corrosion
- pitting
- cuts
- gouges
- digs
- bulges
- neck defects
- general distortion

If any of these defects are present, immediately contact the manufacturer or distributor.

FIGURE 8-11

Store cylinders in a pallet cage. From DPR.

Be sure to use safety procedures when handling and working around hazardous products such as fumigants. Good safety practices include storing hazardous materials according to manufacturer's recommendations, mixing fertilizers and chemicals in well-ventilated areas, and performing welding and cutting in areas free of combustibles. Preventing emergencies is good, common sense and will result in better fumigations and increased personal and environmental safety.

CHAPTER 8: REVIEW QUESTIONS

1. **The best way to prepare for fumigant emergencies is to know:**
   a. how to implement the accident response plan
   b. common symptoms of exposure
   c. the name of the fumigant
   d. all of the above
2. **To respond to a fumigant emergency, the first step would be:**
   a. determine the type and location of the emergency
   b. call the agricultural commissioner
   c. arrange for cleanup
   d. plan the evacuation route
3. **Emergency response includes making calls to:**
   a. poison control
   b. 9-1-1
   c. the property operator
   d. all of the above
4. **When a person has been exposed to a fumigant, the first response includes:**
   a. giving the person a drink of water
   b. evacuation of the field
   c. first aid including decontamination of exposed parts of the body
   d. putting on SCBA

5. Cleaning up a major fumigant spill requires:

a. water
b. clearing the area
c. CHEMTREC
d. b and c only

6. A fumigant fire:

a. may be allowed to burn
b. creates toxic smoke and vapors
c. can be put out with high-pressure water
d. a and b only

7. Types of misapplications of fumigants include:

a. applying to a site not on the label
b. incorrectly using a tarp
c. incorrect calibration
d. all of the above

ANSWERS TO ALL REVIEW QUESTIONS

Chapter 1

1. b
2. b
3. a
4. d
5. d
6. b
7. c

Chapter 2

1. d
2. b
3. d
4. a
5. b
6. c
7. a
8. b
9. c

Chapter 3

1. c
2. b
3. c
4. a
5. b
6. b
7. d
8. b
9. b

Chapter 4

1. b
2. c
3. a
4. c
5. a
6. d
7. b
8. d
9. a
10. c

Chapter 5

1. d
2. c
3. b
4. d
5. a
6. c
7. b
8. b
9. c
10. b
11. a
12. d

Chapter 6

1. b
2. d
3. a
4. b
5. a
6. a

Chapter 7

1. c
2. c
3. d
4. c
5. b
6. c
7. a
8. a
9. b
10. c
11. a
12. c
13. d
14. d
15. b
16. b
17. c
18. a

Chapter 8

1. d
2. a
3. d
4. c
5. d
6. d
7. d