Soil Fumigation

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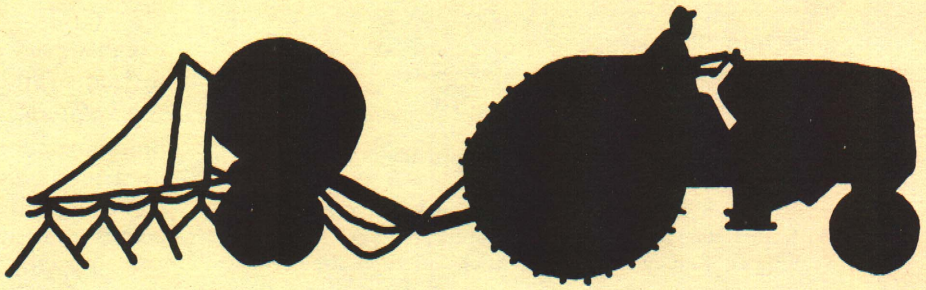
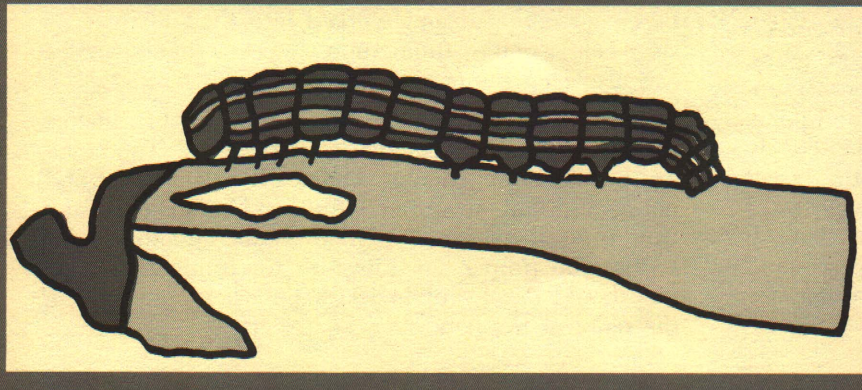


SAFE, EFFECTIVE USE OF PESTICIDES

A MANUAL FOR PRIVATE APPLICATORS



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PREFACE

This manual is intended to assist pesticide applicators to meet the requirements for certification under the Michigan Pesticide Control Act of 1976. The manual was prepared by G. W. Bird, Entomology & Botany - Plant Pathology Dept., and R. F. Ruppel, Entomology Dept., Michigan State University.

A list of self-help questions and instructions for completing the questions are at the end of the manual. If you encounter difficulties in using the manual, please consult your county agricultural extension agent or representative of the Michigan Department of Agriculture for assistance.

Some suggestions on studying the manual are:

1. *Find a place and time for study where you will not be disturbed.*
2. *Read the entire manual through once to understand the scope and form of presentation of the material.*
3. *Then study one section of the manual at a time. You may want to underline important points in the manual or take written notes as you study the section.*
4. *Answer, in writing, the self-help questions at the end of the manual. Instructions on how to use the self-help questions in your study are included with the questions. These questions are intended to aid you in your study and to help you evaluate your knowledge of the subject. As such, they are an important part of your study.*
5. *Reread the entire manual once again when you have finished studying all of its sections. Review with care any sections that you feel you do not fully understand.*

This manual is intended to help you use pesticides effectively and safely when they are needed. We hope that you will review it occasionally to keep the material fresh in your mind.

Introduction

Soil fumigants are pesticides that exert their toxic action as gases. Most are halogenated hydrocarbon compounds. They are formulated and sold as gases, gels, volatile liquids, emulsifiable concentrates or granules. All formulations volatize when applied and penetrate through the soil. They are absorbed or actively taken into the pest, and result in death of the target organism. Soil fumigants can be used for control of nematodes, soil fungi, weeds and soil insects. Not all fumigants are active against all of these pests, and frequently a specific material or rate is required for control of a specific pest or group of pests.

Fumigants, Formulations and Containers

There are five formulations of soil fumigants that are made from the different types of chemicals (Table 1).

1. *Gases* — Gaseous formulations of soil fumigants are sold in 1- or 2-pound seamless cans or pressurized cylinders similar to the acetylene tanks used in welding. Various sizes of cylinders are available ranging from 10 to 2,400 pounds.

2. *Gels* — Gel formulations consist of compressed gas dissolved in a heavy foam. They are sold in pressurized cylinders of various sizes.

3. *Volatile liquids* — Soil fumigants that exist as liquids at normal temperatures are the most commonly used materials. They are sold in 5-, 30- or 55-gallon metal or plastic drums. The liquid volatizes and becomes a gas when injected into the soil.

4. *Emulsifiable concentrates* — Emulsifiable concentrates are volatile liquid soil fumigants that can be used alone or diluted with water. They are most commonly sold in 5-gallon containers. In some areas, they are available in quantities as small as one pint.

5. *Granules* — Granular soil fumigants are available in some regions. The fumigant is absorbed in inert particles that serve as a carrier for ease of application.

Factors Influencing Fumigant Action

For proper pest control, fumigants must be injected into properly prepared soil. Factors such as soil structure, ground trash, soil moisture, soil temperature, soil type, time of application, soil sealing, exposure period and soil aeration influence fumigant action in soil. All of these must be considered before beginning a fumigation operation. Most soil fumigants are toxic to plants and are registered for use only on a preplant basis. DBCP is the only soil fumigant that can be applied at planting or on a postplant basis.

Soil structure — Proper tilth is an important factor in regard to penetration of fumigants through soil. Fumigants will not move well in compacted soil and good pest control will not be achieved. Cultivation prior to soil fumigation is essential. The soil should be free of clods and worked into a good seedbed condition.

Ground trash — Excess debris such as decaying plant material is detrimental to soil fumigation. Soil fumigants are absorbed by organic debris. This prevents the chemical from penetrating the soil and providing good pest control. Existing vegetation should be cut or chopped and worked into the soil three to six weeks prior to fumigation. Excess organic matter can also clog fumigation chisels.

Soil moisture — Soil moisture has a direct influence on the movement of fumigants through soil. Too much soil moisture prevents movement of the fumigant and not enough soil moisture allows the chemical to escape from the soil too rapidly. Good seedbed condition describes the proper soil moisture for fumigation. The soil should barely retain its shape when squeezed in the palm of the hand.

Soil temperature — Soil fumigants should be applied when the temperature at a soil depth of 6 to 8 inches is 50° to 80° F. Some may be applied when the soil temperature is between 40° and 50° F. Pest control, however, may not be as good as with the higher range. Fumigants will not volatize and penetrate uniformly throughout the soil if the soil temperature is below 40°F. Above 80°F., the fumigant will volatize too rapidly and be lost from the soil prior to the optimum exposure time for pest control.

Soil type — For fumigation purposes, Michigan agricultural soils can be divided into mineral and organic (muck) soil. Because of the sorptive properties (absorption and adsorption) of the soil fumigants in relation to organic soils, it is necessary to use higher rates when fumigating muck soils. In most cases, a rate approximately two times the fumigant rate recommended for mineral soils is required for good pest control in organic soils.

Time of application — It is usually best to apply soil fumigants in Michigan in the early fall. They can, however, be applied in the spring. At this time, it is much more difficult to obtain proper soil temperature, moisture and structure. If spring fumigation is followed by a period of cold and wet weather, the waiting period prior to planting must be extended to prevent the possibility of severe phytotoxicity.

Soil sealing — Because of rapid surface volatilization, the first several inches of the soil are the most difficult area for pest control. A temporary soil seal is necessary to maintain a lethal concentration of the fumigant. This can be achieved by cultipacking, rolling, dragging or lightly irrigating the soil immediately after fumigation. With fumigants formulated as gases, such as methyl bromide, it is necessary to cover the treated area with a plastic tarpaulin, either before or immediately after fumigation.

Soil aeration — Fumigated soil should be aerated at the end of the fumigant exposure period, prior to planting the crop. The soil should be tilled to the depth of the fumigant treatment zone.

Exposure period — An exposure period during which the soil is left undisturbed is necessary after fumigant application and sealing with most soil fumigants. The length of the exposure period depends on the fumigant used, rate applied and environmental factors such as soil temperature and moisture. The pesticide label should be used to determine the proper length of the exposure period for each specific soil fumigation operation.

Phytotoxicity — Phytotoxicity potential must always be considered before soil fumigants are applied. Most soil fumigants are phytotoxic and, depending on the dosage, they must be applied several weeks or months before a crop is planted. A few plants are so sensitive to specific soil fumigants that they cannot be planted for several years after treatment. Phytotoxicity is influenced by soil type, temperature, moisture, tilth and type of plant grown. The pesticide label must be used to determine the potential phytotoxicity of a soil fumigant to a specific crop plant. Additional lists of plants that are tolerant and moderately tolerant to DBCP are available from the pesticide manufacturer or your local Cooperative Extension office.

Application Types

Soil fumigants can be used for control of specific nematodes, fungi, weeds and insects in greenhouse and top soil, seedbeds or small areas in fields, individual tree sites and in larger agricultural sites and situations of numerous types. Most soil fumigants must be applied on a preplant basis; however, DBCP can be suitable for at-planting or post-planting applications on some crops and sites.

Greenhouse and top soil — Small quantities of greenhouse soil, top soil or mushroom compost can be fumigated for pest control. This should be done in an open or very well ventilated area. Good ventilation is essential during both fumigant application and soil aeration. In most cases, gaseous fumigants such as methyl bromide and mixtures of methyl bromide and chloropicrin are used for this type of fumigation. The soil must be covered with a polyethylene or plastic-coated nylon tarpaulin before fumigant application, and the edges of the cover sealed tightly with soil, sand bags or other appropriate devices. Specially designed fumigation chambers can be used. Emulsifiable concentrates such as VPM are sometimes used, especially with mushroom compost. All environmental factors must be carefully considered prior to fumigation application. A sign should be posted to warn of the danger and the area locked or sealed off.

Seedbeds and small areas — Seedbeds and other small areas in fields can be treated with gaseous or liquid fumigants. If a gaseous formulation is used, the procedure is similar to that used for fumigating greenhouse soil. A small ditch should be dug around the outside of the area to be treated, and the edges of the polyethylene or plastic-coated nylon tarpaulin used to cover the area should be buried in the ditch. All environmental factors must be considered carefully prior to fumigant application. Gel formulations do not have to be tarped and will very likely play an important role in this area in the future. If a volatile liquid or emulsifiable concentrate fumigant is used, the chemical should be injected to a depth of 6 to 8 inches below the soil surface and the area tightly sealed.

Tree sites — Individual sites to be used for planting orchard or ornamental trees and shrubs can be fumigated with gaseous volatile liquid or emulsifiable concentrate formulations. The center of the site should be marked and the fumigant injected into the soil. The size of the area to be treated depends on the size of the tree to be planted. The injection hole(s) should be sealed and in some cases, an appropriate cover may be needed.

Field treatments — Soil fumigants can be applied to many types of agricultural fields in a number of ways. Volatile liquids and emulsifiable concentrates are most commonly used; however, gaseous and gel formulations are suitable for treatment of fields to be planted with high cash value crops. All environmental factors must be considered prior to fumigant application. The

entire field is covered with polyethylene when a gaseous formulation is used on a *broadcast basis*. Granular formulations of DBCP can be applied on an overall field basis using granular *broadcast* equipment. Emulsifiable concentrate fumigants such as DBCP and VPM can be applied as drenches.

For some agricultural commodities, such as orchard and vineyard crops, it is frequently most economical to use a *strip treatment*. Only the area where the crop is to be planted is fumigated with this type of application. In most Michigan tree fruit orchards, a 7- to 8-foot strip is fumigated and the trees planted in the center of the strip. If the rows in the orchard are 24 feet apart, then only one-third of the area is fumigated. Liquid or emulsifiable concentrate formulations are excellent for soil-borne pest control in nursery operations. Granular formulations are also suitable for row application with some crops.

Agronomic crops such as potatoes and sugarbeets are suitable for *row applications* of soil fumigants. With this method of application, one or possibly two chisels are used to inject the fumigant into the row where the crops will be planted. The technique can be used to reduce the amount of pesticide applied without significantly reducing pest control. The area where the fumigant was applied must be carefully marked with a hiller or bedder to insure that the crop will be planted in the fumigated area. Granular formulations can be suitable for row application.

At-planting fumigation — DBCP can be applied for some crops at planting. This may be done on a small area, site, field or row basis. The chemical is applied as indicated for preplant fumigants. Pest control from soil fumigation at-planting is usually not as satisfactory under Michigan conditions as treatment under preplant conditions. DBCP is phytotoxic to some plants.

Postplant fumigation — DBCP can be applied on a postplant basis in a limited number of agricultural situations. It is injected into the soil next to a planted row, such as in an orchard, used as a drench or applied in irrigation water or for broadcast treatment of established turf (lawns, golf courses and other ornamental and recreational turfgrasses and tolerant ornamentals). The emulsifiable formulation of DBCP can be mixed with water and applied as a drench. The soil should be wet prior to application and a small amount of irrigation water should be applied after the fumigant drench. Drenches are for professional use only and cannot be applied by homeowners. Granular formulations can also be applied on a postplant basis. They should be incorporated or drenched into the soil. Pest control with postplant applications of DBCP is not usually as good under Michigan conditions as preplant soil fumigation.

In some cases, DBCP can be applied in flood and basin irrigation water. A number of excellent commercially available applicators can be used for withdrawing DBCP from its original container and properly metering it into the irrigation pump. All irrigation application recommendations on the label must be followed with care. Emulsifiable concentrate fumigants should be used only in irrigation systems constructed of materials certified as being compatible with the specific fumigant. If not used properly, soil fumigants can be corrosive and result in the destruction of irrigation equipment. Very few soil fumigants are presently applied in this manner in Michigan.

Subsoil fumigation — In some situations it may be necessary to inject fumigants to soil depths greater than that achieved with normal chisel application equipment. Nematode control in vineyards is one example of where it is essential to control dagger nematode populations to as great a depth as possible. Deep applications can be made with subsoil shanks. Fumigant rates must be adjusted because of the greater area treated. This can be done on a broadcast, strip or row basis. Deep applications of soil fumigants are often made when treating individual tree sites.

Fumigation Equipment

Various types of soil fumigant applicators are commercially available. These generally meet fumigation needs; however, in some cases, it is necessary to have equipment custom designed and built for specific purposes. Fumigation equipment is not usually expensive. Many Michigan growers, however, either rent fumigation equipment or obtain it on a loan basis from their fumigant supplier. Regardless of the type of fumigation equipment used, proper care is essential. Appropriate soil sealers or drags should follow or be attached to the fumigant applicator. Most soil fumigants are highly corrosive and if fumigators are not constructed from materials tolerant or resistant to these chemicals, they will be damaged. It is also essential that all application equipment be cleaned and stored with the system at least partially full of lightweight fuel oil.

Gaseous formulations — Several simple devices are commercially available for puncturing 1- or 2-pound seamless cans of gaseous soil fumigants and releasing the chemical through a plastic tube to an evaporation pan placed under the sealed plastic. Always use proper opening dispenser! The fumigant flows under pressure from the can to the soil to be fumigated. Large cylinders of gaseous fumigants require valves and pressure regulators to control the delivery of the gas to the evaporation pan. A separate pressurized cylinder of nitrogen should be used to maintain a constant pressure in the fumigant cylinder and insure application of a uniform rate of the chemical. Equipment used with pressurized cylinders can be complex and one must be certain that all aspects of the system are designed to deliver and withstand the fumigant under pressure.

When gaseous formulations are used for fumigation on a broadcast or strip basis, a manifold is added to assure even distribution of the gas to the chisel or shank injectors. The injectors should be mounted 12 inches apart on a tool bar connected directly to a tarping machine. The most commonly used tarping machine consists of two discs that open small furrows immediately outside the area to be treated. Rolled polyethylene is mounted on the tarp machine and unrolled over the treated area using pressure from small press-wheels that insert the tarp into the open furrows.

The tarp is sealed with soil thrown back into the furrow by closing discs. This type of fumigant applicator is suitable for strip application. The rate of application depends on the speed the rig is driven and the rate of flow of the chemical. To treat a field on a broadcast basis with a gaseous formulation, one strip is applied as described above and then one set of discs removed and replaced with an adhesive dispenser. One side of the second tarp is sealed with the adhesive to the first tarp and the other side of the second tarp is sealed in the furrow made by the remaining discs. This is repeated and the entire field is fumigated and covered with polyethylene.

Augers for site injection of gaseous formulations are available. They can be used with either the one- or two-point seamless cans or with large cylinders of gaseous fumigants. Augers for site injection are attached to a large drill operated electrically or by a hydraulic system.

Liquid and emulsifiable concentrates — Chisel applicators are used to inject volatile liquid fumigants to a soil depth of 6 to 8 inches. The chisels are mounted 10 to 12 inches apart on a tool bar. The fumigant is injected to a soil depth of 6 to 8 inches. This equipment can be used for broadcast and strip applications. The applicator may be either pump or gravity-flow driven. The fumigant passes through a manifold where its rate of flow can be regulated and the proper amount of material metered to each chisel through plastic tubing. Filter screens and metering orifices are usually used in the manifold. Several types and sizes of gravity flow and pump-driven chisel fumigation applicators are commercially available. Broadcast application of soil fumigants can also be made with a fumigant applicator mounted on a bottom plow. These applicators usually work on the gravity flow principle. Gravity flow applicators can be easily mounted on planters for at-planting application of DBCP.

Applicators for row fumigation are similar to those described for broadcast treatment except that fewer chisels are used. The fumigant is only applied where the crop is to be planted and this area must be marked. This is usually done with a small disc or lister hiller. Subsoil-bedders are also excellent for row application of liquid fumigants.

Granules — Broadcast applicators for overall or strip distribution of granular fumigants are commercially available and easy to use. Row applicators for granulars are also commercially available and easily adaptable to most types of farm tillage and planting equipment.

Drenchers — Drenchers consist of an appropriate container for the emulsifiable concentrate and a metering device for depositing the fumigant on the soil. They are not used very often in Michigan and pest control may not be adequate unless the fumigant is worked into the soil.

Irrigation — Application of soil fumigants in irrigation water is not presently a common practice in Michigan. It may hold some promise for future post-plant application of fumigants. Because of the nature of the fumigants in relation to irrigation equipment, a professional fumigation consultant should be used to assist in the design of any system to be used for application of soil fumigants in irrigation water.

Applicator Calibration

All fumigant applicators, except the 1- or 2-pound seamless cans of gaseous fumigants, must be calibrated to deliver the desired rate of pesticide. All commercially constructed applicators are designed so that fumigant rates can be altered. These adjustments to give the proper amount of fumigant are called calibration. Calibration is done by applying the fumigant over a small area (or for a short time), measuring or weighing the amount of fumigant used, computing the amount per acre equivalent to the amount measured or weighed, and adjusting the equipment to more closely approach the desired amount. This may be repeated several times until the equipment delivers the exact amount required per acre.

A useful equation for determining the amount of fumigant that should be delivered in a specified area in order to obtain a desired amount per acre is:

$$A = \frac{W \times D \times R}{43560}$$

. . . where A is the amount that should be delivered, W is the width (in feet) of the test swath, D is the length (in feet) of the test swath, and R is the desired amount (in pounds or gallons) per acre. For example, if you wished to apply 50 pounds of fumigant per acre (R = 50) and are trying the equipment in an area 8 feet wide (W = 8) and 100 feet long (D = 100):

$$A = \frac{8 \times 100 \times 50 \text{ lb.}}{43560} = 0.918 \text{ lb.}$$

Some figures to keep in mind while checking your calibration are:

1 acre = 43560 square feet

1 gallon = 128 fluid ounces = 8 pints = 4 quarts

1 gallon = 3785 milliliters (ml)

1 fluid ounce = 29.57 milliliters (ml)

1 pound = 16 ounces = 453.6 grams (gm)

1 mile per hour = 88 feet per minute = 1.467 feet per second

Gaseous formulations — The number of 1- or 2-pound seamless cans of gaseous fumigant necessary for good pest control depends on the volume of soil to be treated and the previously discussed environmental parameters. When pressurized cylinders are used, calibration is accomplished by weighing the cylinder, releasing a small amount of fumigant for a known period of time, and then reweighing the cylinder. The rate can be calculated after determining the area covered during the period of time. The rate of flow is then adjusted with the pressure regulator valve. Additional test fumigant releases are made if necessary and the cylinder reweighed. This is repeated until the proper rate is obtained.

PROBLEM 1 — Methyl bromide will be used in a fruit nursery operation at a broadcast rate of 350 pounds/acre for control of nematodes, weeds and soil-borne fungi. The grower will apply the chemical with a tarp machine that is 8 feet wide. The tractor and chisel will be operated at 2.0 miles per hour. How many pounds of methyl bromide must be deposited by the fumigant applicator every 30 seconds for proper calibration?

ANSWER TO PROBLEM 1 — The test swath covered is 8 feet wide (W = 8) by 88 feet long (D = 88; 2 mph x 1.467 ft/sec x 30 sec).

$$A = \frac{8 \times 88 \times 350}{43560} = 5.66 \text{ lb.}$$

Volatile liquids and emulsified concentrates — Both ground-driven and tractor-speed-dependent fumigation equipment can be used to apply volatile liquid and emulsified concentrate soil fumigants. Tractor speed does not have to be taken into consideration in the calibration of most ground-driven equipment; however, it must be used in the calibration of gravity flow and tractor-speed-dependent equipment.

PROBLEM 2 — A carrot grower wants to fumigate muck soil on a broadcast basis using a formulation of 1,3-D at 50 gallons per acre. The fumigant applicator is 12 feet wide and uses a ground-driven pump to supply the chemical to the chisels. The applicator is equipped with 12 chisels, each spaced 12 inches apart. How much 1,3-D should be deposited by each chisel during a calibration test over a swath 100 feet in length?

ANSWER TO PROBLEM 2 — During the calibration test each chisel covers 1 foot wide (W = 1) by 100 feet long (D = 100).

$$A = \frac{1 \times 100 \times 50}{43560} = 0.1148 \text{ gallon (14.7 fluid ounces)}$$

PROBLEM 3 — A potato grower wants to apply a mixture of 1,3-D and chloropicrin on an in-row basis at a rate of 6 gallons per acre. The pesticide will be applied with a tractor-speed-dependent gravity flow applicator driven at a ground speed of 2.5 miles per hour. The rows of potatoes will be spaced 3 feet apart. How much soil fumigant should be deposited in a 30-second calibration trial?

ANSWER TO PROBLEM 3 — During the calibration test, the applicator covers a swath 3 feet wide (W = 3) by 110 feet long (D = 110; 2.5 mph x 1.467 ft/sec x 30 sec).

$$A = \frac{3 \times 110 \times 6}{43560} = 0.0455 \text{ gallon (5.82 fluid ounces)}$$

PROBLEM 4 — An apple grower wants to fumigate 100 tree replant sites with DBCP at 3.0 gallons per acre. He or she will use a hand fumigation gun and treat a 9-square-foot area for each tree making nine separate individual injections of DBCP. If the emulsifiable concentrate is diluted so that the mixture applied is 20 percent DBCP and 80 percent water, how many milliliters of the soil fumigant mixture must be applied at each injection site?

ANSWER TO PROBLEM 4 — Since the DBCP will be diluted 1:4 with water, the required amount of the mixture would be 15 gallons per acre (R = 15; 3785 ml/gal x 15 gal = 56775 ml). The area covered at each injection site is one square foot (D = 1, W = 1).

$$A = \frac{1 \times 1 \times 56775}{43560} = 1.303 \text{ ml}$$

Note that 1.303 ml is a very small amount. Measurements of groups of 10 or more injections should be made and their average amount used for calibration.

Techniques for calibration of granule application equipment are the same as those used for calibration of equipment for applying nonfumigant granular nematicides and insecticides. The general principles are the same as those presented for calibration of liquid fumigant applicators. Procedures for calibration of systems designed for application of soil fumigants in irrigation water should be obtained from professional irrigation consultants, irrigation equipment manufacturers, or directly from the fumigant manufacturer.

Safety

Fumigants are penetrating gases that are toxic. They are a very special hazard because of this and must be handled with full precautions. The first element in safety is to READ THE LABEL on the container before you buy the fumigant. Be sure that you read and understand all the instructions, particularly those dealing with the safe storage, handling and application of the fumigant. Always use all of the safety equipment (gloves, respirator or gas mask, and goggles, for example) that is required. Equipment is probably available where you buy the fumigant. Most fumigants are hazardous if inhaled or contacted by the skin. An emergency supply of water should be available at all times. Some fumigants are irritating to the skin or eyes and a few of them are vesicants (cause burns or blisters on the skin). All of the fumigants can cause poisoning by a single large exposure. Some of them can cause poisoning through repeated small exposures. The label will have information on how the specific fumigant is hazardous, symptoms of poisoning, and first aid in case of poisoning. Be sure to read these instructions. Instructions to a physician on treating the poisoning are also given. In case of poisoning, be sure to take the container along with the victim to the doctor.

Storage of fumigants is a hazard. They should be purchased just before use whenever possible to shorten the storage period. Store them on sturdy shelving in an area apart from feed or seed. They are best stored in a separate building that can be well ventilated and securely locked. The storage area should be posted to warn others of the presence of the fumigants. Fumes can escape from faulty valves or from damaged or corroded cans and build up to a dangerous concentration in closed storerooms. Valves and containers should

be checked frequently for possible leaks. The ventilator should be run to clear the air before entering the storage area.

All equipment, including safety equipment, should be thoroughly checked and adjusted before use. Check that pressure-approved components are used and tightly sealed when compressed gases are used. Make sure, too, that all components used will withstand the corrosiveness of the fumigants. Time of your exposure to the fumigant is reduced by getting everything set before the fumigant container is opened. Be especially sure that there is adequate ventilation if you are using fumigants indoors. Apply the fumigants as rapidly as possible following the application instructions exactly. Clothing will retain fumigants; immediately take off any clothing, including shoes, that is accidentally wetted by the fumigant.

The treated area should be sealed off as tightly as possible from access by people, livestock or pets. Inform everyone with access to the area of the danger. You may post the area to warn off people, and keep an eye on it for stray children and pets. Do not allow anyone to re-enter the area for the period specified by the manufacturer. Once again, make sure of full ventilation of an indoor area before you enter it to remove the covers to aerate the soil. Follow the instructions on aerating the soil, and plant only after the period specified after application has elapsed.

A SPECIAL WORD OF WARNING: Fumigants can be especially hazardous under special circumstances. The instructions and precautions for their use are written for "normal" operations and cannot include all unusual combinations. The best rule to follow is: If you are in doubt as to the safety of the fumigation, do not use the fumigant.

SELF-HELP QUESTIONS

Now that you have studied the manual, answer the following questions. Write the answers with pencil without referring back to the text. When you are satisfied with your written answers, see if they are correct by checking them with the text. Erase and write in the correct answer if your first one is wrong. Note that these questions are not necessarily those that are used in the certification examination.

Fumigants, Formulations and Containers

1. *Describe the basic chemical composition of most soil fumigants.*

2. *Name the five ways soil fumigants can be formulated.*

3. *List the four major groups of pests that can be controlled with soil fumigants.*

4. *How does the packaging of gaseous and volatile liquid soil fumigants differ?*

5. *Name three volatile liquid and two gaseous soil fumigants.*

Factors Influencing Fumigant Action

1. *Name the ten factors that influence fumigant action and that must be considered prior to application of a soil fumigant.*

2. *Why are most soil fumigants used only on a preplant basis?*

3. *What is the proper range of soil temperature for optimal soil fumigation?*

4. *Describe the proper soil moisture potential for a good soil fumigation job.*

5. *If 15 gallons per acre of 1,3-D are used for control of the northern root-knot nematode* (Meloidogyne hapla) *in mineral soil, what rate would you recommend for control of this pest in muck soil?*

6. *When should most soil fumigants be applied in Michigan?*

Application Types

1. *Name the common methods of applying soil fumigants for pest control in agricultural production.*

2. *What soil fumigant can be applied at-planting or on a post-planting basis?*

3. *Why do tarps have to be used to cover areas treated with methyl bromide?*

4. *Differentiate between broadcast, strip, row and site soil fumigation treatments.*

5. *True or False? Most soil fumigants can be applied under Michigan conditions between 48 and 72 hours before planting.*

Fumigation Equipment

1. *How can growers obtain suitable fumigation equipment?*
2. *Do all soil fumigation applicators have to apply a tarp?*
3. *Do most commercial soil fumigant applicators inject the soil to a depth of 6 to 8 inches?*
4. *Differentiate between broadcast, strip, row, and site fumigation treatments.*
5. *True or False? Soil fumigants are corrosive chemicals and can ruin farm machinery.*

Safety

1. *Why are fumigants a special hazard?*
2. *Where can you find information on how a specific fumigant is hazardous, symptoms of poisoning, and first aid in case of poisoning?*
3. *What is the best place to store fumigants?*
4. *How can you reduce the time of your exposure to a fumigant?*
5. *How can you warn people about the danger of a treated area?*
6. *Do fumigant instructions and precautions for use include all unusual combinations?*

TABLE 1. Soil Fumigant Compounds, Formulations and Toxicity.

Common Name	*Trade Name*	*Chemical*	*Formulation*	*Toxicity*	
				VA[a]	*OA*[b]
Methyl bromide	Brom-o-gas Dowfume MC-2 Meth-o-gas	Methyl bromide	Gas and gel	200	—
Chloropicrin	Chlor-o-pic	Trichloronitro-methane	Gas	20	—
Methyl bromide	Terr-o-gas	Methyl bromide + trichloronitro-methane	Gas and gel	—	—
1,3-D	D-D Telone II	1,3-dichloropropene	Volatile liquid	500	250
1,3-D + chloropicrin	Telone C-17 Terr-o-cide D	1,3-dichloropropene + trichloronitro-methane	Volatile liquid	—	—
1,3-D + MIC	Vorlex	1,3-dichloropropene + methyl isothiocyanate	Volatile liquid	—	100
EDB	Dowfume W-85 Soilbrom	Ethylene dibromide	Volatile liquid	200	108
EDB + chloropicrin	Terr-o-cide	Ethylene dibromide + trichloronitro-methane	Volatile liquid	—	—
DBCP	Fumazone Nemagon	1,2-dibromo-3 chloropropane	Volatile liquid & emulsifiable concentrate	100	173
VPM	Vapam	Sodium methyldithio-carbamate	Emulsifiable	—	820

[a] *Vapor acute toxicity — the amount, in parts per million, in the air that could be fatal in a single exposure by inhalation.*

[b] *Oral acute toxicity — the amount, in milligrams per kilogram of body weight, that could be fatal in a single exposure by ingestion.*