Non-Soil Agricultural Fumigation Manual for Private Applicators

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Common chemical and trade names are used in this publication for clarity to the reader. Inclusion of a common chemical or trade name does not imply endorsement of that product or brand of pesticide and exclusion does not imply criticism.

Information and recommendations provided in MSU Extension materials are published for educational purposes only. If any information provided in this document conflicts with or is inconsistent with a product label, follow the product label instructions. Read and follow all product labels carefully and contact the manufacturer with any product specific questions.

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PREFACE

Many fumigants are classified among the most toxic pesticides currently available for use. Accidents are rare but when they do occur, they can result in the fatality of applicators and bystanders. The disparity between fumigants and other pesticides is significant, including personal protective equipment, the use of monitoring devices, determining dosage, etc. This manual was created as an aid in understanding these differences to decrease non-target poisonings, while assisting applicators in delivering a fumigation that maximizes efficacy. This manual is a guide to understanding the product labels of common non-soil fumigants used by farm applicators, however it is an applicators responsibility to read and follow the pesticide product label language which may be updated or differ among products.

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CHAPTER 1 Introduction

Significant economic damage can be caused by invertebrate pests in stored grain (cover photo) and burrowing vertebrate pests in farmland and rangeland. Fumigants, the topic of this manual, can effectively control damage caused by these two different types of pests in Montana.

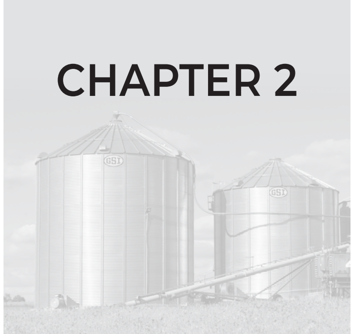
A variety of insects, generally termed 'stored product pests,' can feed on most commercially produced grains after they have been harvested. Stored product pests cause damage by consuming the grain, damaging individual kernels and contaminating the harvest with insect body parts. Partially-eaten kernels or kernels bored or tunneled by insects are termed insect-damaged kernels (IDK). Grain with high levels of IDK or insect filth caused by extreme infestations can result in the grain being condemned for human consumption. Buyers may accept grain with lower levels of IDK but will pay a lower price due to the grain's lower quality and grade.

Burrowing vertebrate animals, primarily rodents, can directly damage crops and rangeland by eating and clipping plants. Their mounds can reduce yield by burying plants and the dirt can contaminate the harvest. Their burrowing activities and tunnel systems can undermine embankments and disrupt irrigation equipment, pose a hazard to livestock and provide a disturbed environment for weedy plants to establish. Both stored product pests and burrowing vertebrates occur in confined spaces, making fumigants an effective control option.

Pest control is guided by the principles of Integrated Pest Management (IPM) utilizing biological, chemical, cultural, and physical tactics in a coordinated plan to reduce damage below economic levels in an environmentally responsible way. Fumigants represent one type of chemical pesticide. Fumigation is a control method where the pesticide disperses as a gas or vapor rather than a liquid or solid, allowing the pesticide to fill spaces and permeate cracks and crevices where pests reside. Unfortunately, the benefits make fumigant application more hazardous to people if misapplied. Soil fumigation is used to kill soil-borne agricultural pests and pathogens, while structural fumigation can be used to control urban and agricultural pests within building structures. Soil fumigation products and techniques are not covered in this publication. For more information please visit the 'EPA Soil Fumigant Toolbox' at https://www.epa.gov/soil-fumigants.

This publication primarily provides guidance on the safe and effective use of phosphine gas fumigants (aluminum phosphide; magnesium phosphide) for the control of invertebrate pests damaging stored agricultural commodities and burrowing vertebrate pests found in Montana's rangeland and farmland. Phosphine gas fumigants represent the most common fumigant treatments for stored product pests in Montana's agricultural sector and are the focus of this manual, although less common alternatives, such as methyl bromide and sulfuryl fluoride are briefly reviewed. Burrowing rodent control with phosphine gas fumigants, as well as non-restricted fumigants, such as ignitable gas cartridges and carbon dioxide pesticides are also discussed.

This publication is NOT a substitute for reading and understanding labeling documents that may accompany the product, including: 1) the product label and 2) the Applicator's Manual. Always read and follow the label as pesticide product labels are updated periodically and differing active ingredients and products may have different requirements.



CHAPTER 2 Aluminum and Magnesium Phosphide Fumigant Overview

Since it is not practical to apply phosphine in its gas state, it is formulated as a stable solid in the form of pellets, tablets, prepacs, prepac ropes, bags, and plates. Tablets and pellets are often most suitable for farm treatments. The combination of aluminum and phosphate atoms, called aluminum phosphide (AlP), forms solid crystals which are stable when dry. Aluminum phosphide is the most common formulation used to generate phosphine gas during fumigation and is sold under trade names such as Phostoxin®, Fumitoxin®, Weevil-cide®, and PH_3 (Figures 2.1 and 2.2). These formulations are activated by moisture in the air, which triggers the formation of phosphine gas and some residue (Figure 2.3). A small amount of residue (aluminum hydroxide, $Al(OH)_3$), is produced by the chemical reaction and inert ingredients in the formulation. This residue remains as a solid after the phosphine gas is produced.

Phosphine can also be formulated with magnesium instead of aluminum to stabilize it. Three atoms of magnesium combine with two atoms of phosphate to form a white crystalline solid (Mg_3P_2). Like aluminum phosphide it reacts with water or humidity in the air to produce phosphine gas.

At high concentrations phosphine gas is extremely flammable. Above its lower flammable limit of 1.8% (18,000 ppm) it will spontaneously ignite. Under moist conditions, including high humidity, phosphine gas can accumulate within the sealed pesticide container. When the container is opened this gas can spontaneously ignite, producing a brief flash (flame) to be emitted from the open container. Always be aware of humidity levels when opening flasks of aluminum phosphide. Invert the container several times prior to opening. Open containers outdoors and hold the flask at arm's length with the lid directed away from your face and perpendicular to the prevailing wind so any escaping gas is carried away.

Knowledge of the effect of temperature on fumigants is important for their effective and safe use since temperature affects the rate of the chemical reaction. The reaction producing phosphine gas starts when aluminum phosphide is exposed to moisture in the air (humidity) but will increase when humidity increases. Chemicals react slower when temperatures are low, compared to a faster reaction when temperatures are high. Warm, humid conditions favor a faster reaction (fast production of phosphine gas) compared to a slower reaction under cool, dry conditions (slow production of phosphine gas).

FIGURE 2.1. Example of aluminum phosphide product. www.feedandgra

FIGURE 2.2. Example of an aluminum phosphide product. Photo by Ruth O'Neill, MSU.

Applications of aluminum phosphide to stored grain are not recommended below 40°F inside the bin. Below this temperature the reaction and production of phosphine gas is not effective.

Grain moisture below 10% will also slow the production of phosphine gas (Ferrell, Mark, 1996).

The type of aluminum phosphide formulation, in tablets or pellets for example, also affects the speed of the reaction and production of phosphine gas. Pellets have more surface area relative to their size and weight compared to larger tablets. A greater surface area to weight ratio exposes more of the aluminum phosphide to surrounding moisture, resulting in a faster reaction and faster production of phosphine gas. The speed at which phosphine gas is produced influences both its effectiveness at killing pest organisms and its safety to the applicator and bystanders.

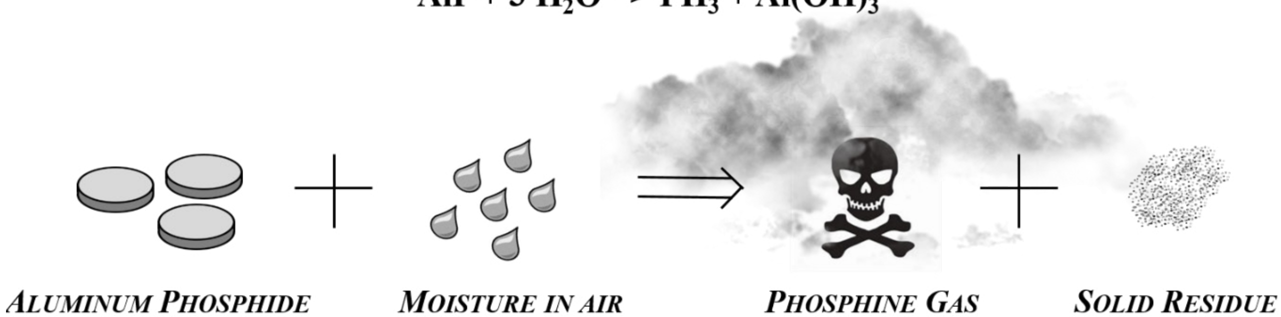
Tablets are five times larger than pellets (Figure 2.4), so for the same weight of product the tablets expose a smaller surface area compared to the pellets, resulting in a slower rate of phosphine gas production and release. Packaging can vary but a single aluminum flask commonly can contain 500 tablets or 2,490 pellets of aluminum phosphide (Degesch America; https://www.degeschamerica.com/products/fumigants/)

The pre-packed forms such as strips, sachets, bags and blister packs contain the residue within the package after the gas has been released, allowing applicators a way to easily dispose of the residue. This type of enclosed packaging is more commonly used to fumigate bagged commodities and processed foods.

FIGURE 2.4. An aluminum phosphide pellet (left) and tablet (right). Photo by Stephen M. Vantassel, Montana Department of Agriculture (MDA).

FIGURE 2.3. Figure describing the reaction of phosphine solids with atmospheric moisture to create phosphine gas. Figure provided by Ruth O'Neill, MSU.

$$AlP + 3\ H_2O \Rightarrow PH_3 + Al(OH)_3$$



CHAPTER 3 Safe Use of Phosphine Gas

Applicators must always read and follow the pesticide label and accompanying Applicator's Manual and the Safety Data Sheet (SDS). They provide specific instructions for the product purchased including information on pests controlled, safety procedures, required equipment, application rates, fumigant management plans (FMPs), etc.

SAFETY AND SITE LOCATION

Prior to using phosphine gas fumigants, safety must be considered when deciding to treat a specific site. When controlling burrowing vertebrate pests, phosphine gas products cannot be used within 100 feet of any building where humans and/or domestic animals do or may reside, on single or multi-family residential properties and nursing homes, schools (except athletic fields), daycare facilities and hospitals. To ensure site safety during an application, applicators must placard all entry points into the treated area (for more details refer to Chapters 6 and 7).

When evaluating a structure for fumigation, an applicator must know phosphine gas products are prohibited by the label and law for use on single and multi-family residential properties, nursing homes, schools, daycare facilities and hospitals. In addition, the structure should be sealable. To ensure site safety during application an applicator must placard all entry points such as structural doors and hatches.

A site assessment must identify any nearby areas that may be at risk for exposure to the fumigant (Chapter 5). If nearby risks are identified (e.g. livestock, pedestrian access such as sidewalks, nearby public spaces such as parks) mitigation strategies need to be described in the fumigant management plan (Chapter 5).

Symptoms of Phosphine Gas Exposure

Phosphine gas is toxic to all mammals including humans, especially by inhalation. If phosphine gas is inhaled, mild exposure may cause: ringing in ears, fatigue, nausea and pressure in the chest. Moderate exposure may cause: weakness, vomiting, pain above the stomach, chest pain, diarrhea and difficulty breathing. Severe poisoning symptoms may appear within a few hours to several days after exposure and cause fluid in the lungs, dizziness, cyanosis (blue or purple skin color), unconsciousness and death. Early symptoms of exposure can be severe but can also be reversible. Overexposure can lead to pulmonary edema and/or coma and death.

Exposure to phosphine gas can be associated with the smell of garlic or fish due to a contaminant in the fumigant formulation. However, some individuals may not be sensitive to this odor and the absence of a foul smell does not guarantee toxic phosphine gas is not present. Do not rely on foul odors as an indicator of exposure risk; phosphine gas levels need to be monitored with specialized testing equipment.

First Aid

Follow the instructions under the First Aid section of the pesticide label for specific details. In summary, your first aid response is guided by the type of exposure. If phosphine gas is:

- **Inhaled:** Remove individual to fresh air. Call 911 or ambulance if not breathing.
- **Ingested:** Have person sip a glass of water if able to swallow. Do not induce vomiting unless told to by a poison control center or doctor. Call poison control center or 911.
- **Skin contact:** Remove contaminated clothing and rinse skin for 15 minutes.
- **Eye contact:** Rinse eyes with fresh water for 15 minutes.

In case of an emergency, have the pesticide product label available for first responders and other medical personnel. In addition, applicators must ensure emergency personnel are aware of the potential for hazardous gas concentrations. Phone numbers for first aid emergencies are available in the First Aid section of the pesticide label including numbers for the manufacturer and poison control.

All placards must contain the signal word DANGER/PELIGRO, skull and crossbones, the words: DO NOT ENTER/NO ENTRE, the name and EPA registration number of the fumigant.

PERSONAL PROTECTIVE EQUIPMENT (PPE)

The pesticide product label will detail the personal protective equipment (PPE) required for fumigation, including the exact type of respirator to buy.

Protective Clothing

PPE legally required for fumigant applications include dry cotton gloves, leather, or similar material that reduces the risk of moisture from sweat, and an approved respirator. Pants and long sleeve shirt, shoes and socks are also recommended by MSU Extension. Keep clothing dry as phosphine gas products are activated by moisture. Do not use chemical-resistant gloves, clothing or shoes; if fumigant becomes trapped inside it will release phosphine gas in response to body moisture and be absorbed by the skin. In addition, chemically-resistant clothing increases sweat production, thereby increasing the risk of exposure to phoshine gas. After completing a fumigant application, air-out clothing in a well-ventilated area before washing.

Gloves must be dry when handling aluminum phosphide pellets or tablets.

TWA and STEL Monitoring

The Occupational Safety and Health Administration (OSHA) has determined permissible exposure limits (PELs) for phosphine gas to ensure safety of the applicator. This is expressed as the Time-Weighted Average (TWA) and the Short-Term Exposure Limit (STEL). Respiratory protection is required when phosphine gas levels exceed PELs as described in the applicator manual and explained in this chapter.

Low exposures to phosphine gas over time are permissible by OSHA and are measured by the TWA. This value is the average of all exposures over an eight-hour work day and cannot exceed 0.3 ppm of phosphine gas. When following the TWA, the applicator must ensure phosphine gas concentrations do not exceed the STEL of 1.0 ppm phosphine gas during any 15-minute period. Applicators may be exposed to a maximum of four STEL periods per eight-hour day, with at least 60 minutes between exposure periods, if the 8-hour TWA is not exceeded.

If concentrations of phosphine gas exceed these limits or are unknown, an approved respirator is required. With specialized monitoring equipment, applicators can monitor real-time cumulative concentrations to ensure they do not exceed the TWA and STEL values set by OSHA, or, manual measurements must be taken throughout the day to calculate those values. See Appendix A for more information on calculating TWA or STEL values.

TWA and STEL values can be difficult to understand and calculate in the field. For this reason, the MSU Extension Pesticide Education Program recommends using a full-face respirator with phosphine gas canister when gas concentrations exceed 0.3 ppm. A self-contained breathing apparatus (SCBA) must be used when phosphine gas concentrations are unknown or exceed 15 ppm. This is a conservative and easy-to-remember recommendation to keep applicators safe while using phosphine gas fumigants.

Respirators are required if time weighted averages (TWA) or short-term time exposure limits (STEL) are exceeded. However, MSU recommends a conservative approach of:

0.3 to 15 ppm phosphine gas: a NIOSH/MSHA approved full-face mask with replaceable phosphine gas canister

Above 15 ppm phosphine gas: a NIOSH/MSHA approved self-contained breathing apparatus (SCBA)

Respiratory Equipment and Corresponding Phosphine Gas Concentrations

A proper respirator is one of the most important pieces of PPE since the risk for inhalation of the toxin is high. Not all respirators on the market are effective for fumigants, and the attached canister filters are specific for different toxic gases. Always follow the requirements on the pesticide label when purchasing and using a respirator. The type of respirator required is determined by knowing the concentration of phosphine gas measured as ppm.

When phosphine gas concentrations range from 0.3 to 15 ppm an air-purifying, full-face piece respirator with a chin-style, front- or back-mounted phosphine gas canister (gas mask) rated with an Assigned Protection Factor 50 (APF50) is required. Technically applicators are not required to wear respirators when phosphine gas levels are below 0.3 ppm TWA and 1.0 ppm STEL (see above description). A full-face mask air-purifying respirator with a phosphine gas canister must be available on-site during all phosphine gas fumigations (Figure 3.1).

FIGURE 3.1. Full-faced gas mask with phosphine gas canister. Photo by MSU Extension.

Phosphine gas canisters are a type of air purifying canister that remove chemical contaminants from the air by an absorption process, before the air enters the breathing zone. These canisters have a limited service life and must be changed periodically. Many factors can influence how long a gas cartridge can be used before it is spent and must be replaced, including: the applicator's breathing rate, the concentration of contaminant in the air, environmental conditions and its capacity. A schedule for changing cartridges needs to be maintained and should be a conservative estimate. Some manufacturers provide service-life recommendations for their products. Canisters should be stored in an airtight container when not being worn as they continue to "work" when exposed to air. Replace canisters when they have been exposed to air, have been used for the full-service life, or are expired.

A full-face mask with phosphine gas canister must be on-site for each applicator during all fumigations.

A self-contained breathing apparatus (SCBA) is required when phosphine gas concentrations are higher than 15 ppm or are unknown. SCBA provides breathable air in a dangerous atmosphere (Figure 3.2). The SCBA has a full-face mask attached to a regulator and a high-pressure oxygen tank. The respirator is termed self-contained because it relies on a canister filled with air and does not depend on clean air being available in the working space. The user's breathing time, however, is limited to the capacity of the canister.

NOTE: Contact your pesticide manufacturer for selecting the proper respirator. Different respirators have variable assigned protection factors (APFs) that may impact duration and efficiency of use. For more information see the NIOSH/MSHA Pocket Guide to Chemical Hazards (https://www.cdc.gov/niosh/docs/2005-149/pdfs/2005-149.pdf),pages 97-140.

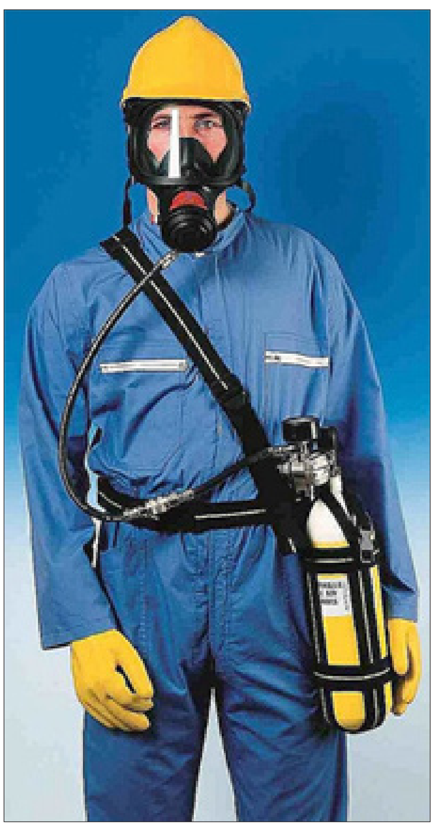


FIGURE 3.2. SCBA respirators supply an applicator with air from an oxygen tank. Photo provided by Oregon OSHA.

WHERE AND WHEN TO MONITOR GAS LEVELS DURING A FUMIGATION

Phosphine gas levels must be monitored periodically during the entire fumigation process to ensure effective pest control and the safety of applicators.

Efficacy Monitoring

During a fumigation, phosphine levels can be monitored within structures to ensure concentrations required for effective pest control have been reached. If adequate phosphine levels are not reached because of a leak or insufficient pesticide rates, an applicator can expect ineffective pest control possibly resulting in costly secondary applications (Chapter 7). Insects can develop resistance to phosphine gas, thus reducing efficacy. Employing alternative practices to reduce reliance on phosphine gas prevents or delays resistance from developing. Refer to the Pest Management for Grain Storage and Fumigation document: http://www.pesticides.montana.edu/documents/manuals/FumSeed.pdf for more details.

Safety Monitoring

Phosphine gas levels must be monitored periodically during the entire fumigation process in areas where applicators and bystanders may be exposed. Testing is essential to identify dangerous phosphine levels and to ensure PEL and STEL safety limits are not exceeded. This monitoring should be performed in workers' breathing zones and within the structure prior to re-entry.

Fumigant gas can penetrate many porous structural materials, and easily vent from non-sealed structures to contaminate adjacent areas. After fumigation, areas surrounding the fumigated structure can be monitored for leaks. Take fumigant readings at regular intervals to monitor the gas levels. After exposure has been adequately characterized by regular monitoring, periodic spot checks are conducted to detect any changes in gas levels. After fumigation is complete and the structure has been aerated, phosphine monitoring ensures safe re-entry. The pesticide label requires an applicator to keep a log showing phosphine gas concentrations are below threshold levels for any vulnerable sites identified in the site-assessment to ensure safety.

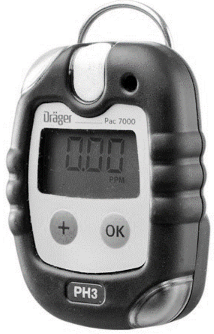
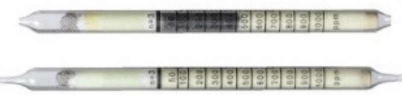


FIGURE 3.3. Digital gas monitoring device.

FIGURE 3.4. Gas detection tubes (left) and pump (right) used to determine phosphine gas concentrations during a fumigation.



Photos provided by Degeschamerica.com

Under most conditions, burrowing rodent applications require safety monitoring only during initiation and midway/conclusion of fumigation, provided each testing is below STEL and TWA.

Concluding Fumigation: Monitoring

Prior to concluding a fumigation, the fumigated structure or burrow must be aerated to allow any remaining phosphine gas to escape. Warning placards can be removed when the concentration of phosphine gas in the treated structure or burrow is below 0.3 ppm. Although the fumigation may be complete for worker safety purposes, aeration may need to continue to meet food/feed tolerances of 0.1 ppm within the grain mass. To guarantee compliance with food and feed tolerances it is necessary to aerate the commodities for a minimum of 48 hours prior to offering to the end consumer.

FUMIGANT GAS MONITORING EQUIPMENT

Phosphine gas monitoring equipment is required by the pesticide label. Gas monitoring equipment allows the user to accurately determine phosphine gas levels for pest control during the fumigation, to select appropriate respiratory PPE during and after the fumigation, and to monitor aeration after the fumigation is complete.

Personal electronic gas monitors are small devices worn on your person to protect yourself from harmful gas concentrations (Figure 3.3). When a threshold of a specific gas has been reached the monitor will sound an alarm indicating the gas concentration has reached unsafe levels. This indicates you either need to leave the vicinity or use proper respiratory equipment as listed on the label (the STEL for phosphine gas for example, 1.0 ppm during any 15 minute period). One benefit of an electronic gas monitor is the device is continuously reading the gas concentrations, so the user is notified immediately if they are being exposed to unsafe concentrations. This device should not be used for reading fumigant concentrations within a structure unless the applicator is wearing required respiratory protection for unknown concentrations of the fumigant (SCBA).

Gas detector tubes consisting of a pump and single-use glass tubes can be used for remote phosphine gas monitoring (Figure 3.4). The ends of each glass tube must be broken prior to insertion into the pump which draws air through the tube. The tube will change colors if phosphine gas is present and will also indicate the concentration of gas in ppm. This type of equipment can be used from a distance (i.e. outside of the grain bin) using hoses to reduce the hazard of fumigant exposure. Gas detector tubes are ideal for monitoring gas within a structure.

Choosing and Purchasing Equipment

Prior to purchasing any equipment, read the pesticide labels of any products you anticipate using to determine what monitoring equipment you need and if there is a specific sensitivity required. Both high and low-range detector tubes are available for the most common fumigants. High-range detector tubes are used during

Steps in the Fumigation Process That Can Result in Exposure to Phosphine Gas.

1. Transport and storage
2. Opening the sealed product
3. During application of the product
4. When resealing and storing leftover fumigant if allowed by the product label
5. When monitoring gas levels within the fumigated structure and its surroundings
6. When venting and aerating the structure or burrow
7. After the fumigation is complete (re-entry or moving the grain) if unspent product remains
8. Disposal of leftover powder

fumigations to ensure proper gas concentrations for pest control are reached (contact your pesticide manufacturer for more information). Low-range detector tubes are used to determine worker safety during and after fumigation, as well as monitoring aeration after a fumigation has occurred. Low-range detector tubes must be accurate to 0.1 ppm for monitoring the TWA PEL of 0.3 ppm. Detector tubes whose range also exceeds 15 ppm, the threshold above which SCBA respirators are required, can be useful for monitoring both thresholds.

Single use glass tubes for monitoring phosphine gas concentrations come in many different measuring ranges.

Examples: 0.05 to 9.8 ppm
0.1 to 25 ppm
2.5 to 1000 ppm
25 to 10,000 ppm

Knowing this information will ensure you purchase the correct equipment. Fumigant labels frequently list suggested manufacturers of gas monitoring equipment. These recommendations will help you narrow down choices of products on the market.

Vertebrate pest applications often need only one type of equipment, however an applicator may wish to consider having both a personal gas monitor and gas detector tubes to monitor fumigant concentrations within the structure and on the individual simultaneously. Applicators may wish to discuss options recommended for the specific fumigant being used with the fumigant manufacturer.

CHAPTER 4 Storage, Disposal and Transport of Phosphine Fumigants

Due to the hazardous nature of phosphine gas fumigants, care needs to be taken when disposing of residual dust or leftover fumigant, when storing or transporting these products and when responding to a spill/leak. Always read and follow the pesticide product label requirements for the product you are using. On the pesticide product label, look for headings such as: Storage Instructions, Transportation Instructions, and Disposal Instructions.

STORAGE

Do not store phosphine gas fumigants in buildings where humans or animals reside. Do not store phosphine gas fumigants near food, water or feed. Store in a dry, well-ventilated area away from heat (never above 130°F). Store sealed flasks in a locked area. When resealing a package (if permitted by the label) do not expose the product to the atmosphere any longer than is necessary and tightly reseal. Some phosphine gas products cannot be resealed, and in this case, excess product needs to be disposed of according to label instructions. The shelf life of phosphine gas fumigants is practically unlimited if the flask or container has not been opened or remains tightly sealed.

The storage area needs to be placarded with a sign indicating it is a pesticide storage area. At minimum, storage areas must be labeled with the following: Danger, Poison (with skull and cross bones), Authorized Personnel Only, and National Fire Protection Association (NFPA) Hazard Identification Symbols for the pesticide (Figure 4.1, explained by Table 4-1).

FIGURE 4.1. Example of a phosphine NFPA Hazard Identification label. Label courtesy of mysmartsign.com.

TRANSPORTATION

Phosphine gas fumigants are classified by the United States Department of Transportation (DOT) as "Dangerous When Wet" and must be transported in accordance with DOT regulations. Montana private applicators using a private vehicle for pest control may transport small amounts of phosphine fumigant (less than 21 kg or 46.3 pounds) without having to placard the vehicle if they possess a transportation exemption. This special permit can be downloaded from manufacturer websites or the manufacturer can be contacted directly. Each manufacturer has a different special permit number for their product.

The special permit must be in the vehicle during transportation and can only be used by a certified pesticide applicator. Never transport phosphine gas fumigants in a space shared with people or animals. The fumigants should be in a well-ventilated and secured area. Other states may have additional restrictions.

DEACTIVATION AND DISPOSAL OF PHOSPHINE GAS PRODUCT

Unreacted or partially spent material must be deactivated prior to disposal. Residual dust with unspent phosphine gas fumigant is green in color and is a hazardous material. Grayish-white dust leftover from a phosphine gas fumigant is non-reactive and no longer has any active ingredient left. This material is non-hazardous.

TABLE 4-1.

Category	Degree of Hazard
Health	4 (severe hazard)
Flammability	4 (severe hazard)
Reactivity	2 (moderate)
Special Notice Key	₩

Residual dust from spent phosphine fumigant in most treated raw commodities is allowable; however, certain commodities may require retrieval of any spent phosphine fumigant from the commodity after fumigation. In those cases, one method of retrieving the residual dust is using the FUMI-SLEEVE Dust Retainer method. This method allows the applicator to place tablets or pellets within sleeves that can easily be retrieved after the application. See additional instructions on the use of this method in the pesticide Applicator's Manual.

Never place unspent residual dust within a closed container because it is flammable. Instead, deactivate unspent dust, pellets or tablets using either the wet or dry deactivation method. The dry deactivation method takes longer and releases relatively lower concentrations of phosphine gas, compared to the wet deactivation method that is quicker at rendering active ingredients inert while delivering higher relative concentrations. Care should be taken regardless of the method used, by constant monitoring of gas concentrations and wearing appropriate PPE and respiratory equipment.

Wet Deactivation

Prepare a deactivation solution of 2% low-sudsing detergent in water using no less than ten gallons for each case of material deactivated. Fill the container to within a few inches of the top. Slowly pour residual material into the solution and stir. Wear respiratory protection during deactivation. Do not cover the deactivation container. The solution may be disposed of at a landfill or held for 36 hours and poured into a storm drain or on the ground.

Dry Deactivation

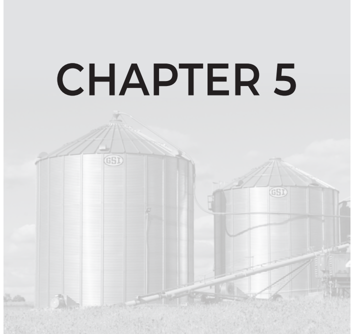
If unspent dust is left in an empty flask, remove the lid and allow the residual dust to fully react prior to disposal. This must be done in a well-ventilated, secure area away from humans and animals. If unspent dust is left in the fumigated structure, extending the fumigation period is the easiest way to dispose of unspent material. However, small amounts of partially spent dust (up to 7 lbs.) may be placed in a one-gallon bucket to allow a complete reaction. Larger amounts of dust (up to 25 lbs.) may be deactivated in cloth bags such as burlap or cotton. This should be done in a secured, outdoor location away from humans and animals.

Disposal of Deactivated Dust

All unreacted product must be deactivated prior to disposal. Deactivated dust may be disposed of by burying small amounts (up to 17 lbs.) or by spreading over the land surface away from human-occupied buildings. Dust may also be disposed of at a landfill as allowed by local regulations.

CONTAINER DISPOSAL

Do not reuse the aluminum flasks. Triple rinse flasks and stoppers with water. Puncture and dispose of at a recycling center or landfill. The rinse water may be disposed of by disposal at a landfill or dumping on the ground.



CHAPTER 5 Fumigant Management Plans of Phosphine Fumigants

A written fumigant management plan (FMP) must be completed prior to every treatment and kept for two years after the fumigation has been completed. An FMP ensures a safe, legal and effective application by organizing all the required steps PRIOR to the actual treatment. An applicator is responsible for working with the owners and/or employees of a treated site to develop and follow an FMP. This chapter will highlight a few commonly misinterpreted sections of the FMP, while providing a general overview. Always consult the Applicator's Manual to ensure your FMP meets all requirements.

An FMP helps an applicator organize their thoughts and materials in advance, identifies risks and hazards before beginning the treatment and provides guidelines in case of an emergency. General safety and efficacy tasks associated with the FMP include items such as:

- **Inspecting the site under consideration to ensure it can be fumigated legally:** This includes reading the entire pesticide label (including the Applicator's Manual) and having a printed copy on site. Ensure both the site to be treated and the pest to be controlled are listed on the label. The FMP includes a statement of the purpose of the fumigation.
- **For burrowing rodent applications:** The use of this product is strictly prohibited within 100 feet of any building where humans and/or domestic animals do or may reside.
- **All applications:** The use of this product is strictly prohibited on single and multi-family residential properties and nursing homes, schools (except athletic fields), daycare facilities and hospitals.
- **Inspecting the site for suitability:** For structures this includes their ability to be sealed and for vertebrate control ensuring there are no non-target and/or endangered species inhabiting the burrow. If mitigation steps are required to improve the suitability of the site, they should be listed in the FMP.
- **Evaluating the site for safety:** A site evaluation includes determining public access points and ensuring all sensitive sites are clearly outlined; with mitigation strategies outlined to prevent poisoning.
- **Placarding:** All entry points requires warning placards, and the type of placard required, should be marked and listed in the FMP including a diagram or map of the site to be fumigated.
- **Safety equipment:** A list of safety equipment including PPE and respirators, which must be on site during the fumigation. This includes phosphine gas monitoring equipment and a description of how and when it will be used for the different stages of the fumigation (i.e. frequency of monitoring; location of monitors; goal of monitoring and corresponding thresholds to determine the type of approved respirator that will be needed).
- **Contacts:** A list of the people, civil agencies and emergency services (including their phone numbers), who need to be informed of the fumigation in case of an emergency. This includes contacting emergency personnel (i.e. fire; ambulance) prior to the fumigation if required by local ordinances or state law.
- **Notification:** Clearly indicate who will participate in the fumigation and that all worker/handlers are trained properly. Record when the training occurred and what subjects were covered (i.e. safety; using monitoring equipment).

Common Headings Found in Fumigant Management Plans.

- Planning and Preparation
- Personnel
- Monitoring
- Notification
- Site Prep and Sealing
- Application and Period of Fumigation
- Post-Application Operations

The required content of an FMP is often organized within descriptive subheadings.

The Applicator's Manual for each product provides a detailed list of tasks to consider within each of the headings. Look for the section called "Required Written Fumigation Management Plan" or similar heading.

FMPs can be complex. To assist the certified applicator, many of the companies that manufacture fumigants provide templates for the FMP as do some government agencies. A template designed to meet FMP requirements for Montana structural applications is available at http://www.pesticides.montana.edu/documents/references/ under "additional resources." This template was designed by the MSU Pesticide Safety program from previous versions published by Degesch America, Inc. A template designed to meet FMP requirements for Montana burrowing rodent applications is available at https://agr.mt.gov/Topics/Vertebrate-Pests. This template was designed by the Montana Department of Agriculture (MDA) and titled "Burrowing Rodent Fumigation Management Plan."

For more information on filling out an FMP, read the instructions within the Applicator's Manual, and/or contact the pesticide manufacturer.

CHAPTER 6

Using Fumigants to Control Burrowing Vertebrate Pests

Fumigants are gaseous pesticides that enter a vertebrate pest's body through their lungs compared to toxic baits that must be consumed. This chapter focuses on the effective use of EPA-regulated and non-regulated fumigants to control vertebrate (i.e. animals with a spine) pests occupying burrows away from structures. Fumigants discussed in this chapter are typically used to control rodents, such as prairie dogs, pocket gophers, and ground squirrels, as well as predators, such as striped skunks, coyotes and red fox.

Fumigants are an important tool for the control of burrowing vertebrate pests and have several advantages over other pesticides such as toxic baits. First, fumigants are easy to use; simply treat active burrows and seal them. No pre-baiting or carcass searches are required. Second, fumigants have several environmental advantages. They lack residual toxicity unlike many rodenticide baits; animals killed by fumigants may be scavenged with minimal risk of pesticide exposure to the scavenger. Likewise, fumigated burrows may be reoccupied without risk of injury to the new occupant after the fumigant has dissipated. Finally, fumigants have a wide application calendar if temperatures are above minimal thresholds for the product being used.

Fumigants also have a few disadvantages. First, a fumigant application is costly. Researchers estimate fumigation applications cost five to 10 times more in labor/product than toxic baits to treat the same amount of ground. Most fumigant work is used to control vertebrate pests on small acreages, sparse populations, or as a cleanup following use of toxic bait. Second, fumigants pose unique risks to applicators. For example, the active ingredients frequently are odorless, so applicators must be sure to heed label safety advice to avoid being exposed to the toxic gas (Chapter 3). Finally, fumigants lack target specificity. Any animal in the burrow will be killed, whether it is a targeted animal or not.

This chapter provides information about the different fumigants used to control burrowing vertebrate animals in Montana. Ultimately the applicator must determine whether fumigants will meet control needs.

PRE-FUMIGATION STEPS

Identifying Non-target Species

Burrow fumigants are highly toxic to non-target wildlife inhabiting burrows. Read and follow label instructions carefully as they contain guidelines designed to reduce the risk of killing nontarget animals including threatened and endangered species. All registered fumigants require applicators to obtain endangered species bulletins for the area where the treatment will occur. Bulletins for your area can be obtained by visiting https://www.epa.gov/endangered-species/bulletins-live-two-view-bulletins and following the instructions on the website. Print out the bulletin for the month and year of your planned application, follow its guidance, and keep it with the fumigation label. If your fumigation is delayed to another month, return the site and obtain an updated bulletin. Some labels will require you contact the U.S. Fish and Wildlife Service (Helena: 406-449-5225 or Kalispell: 406-758-6868) and/or Montana Fish, Wildlife & Parks (406-444-2449 or http://fwp.mt.gov/gis/maps/contactUs/?areaType=nonGameWild) prior to applying the fumigant. The federal or state biologist will let you know if there are any known protected species in your treatment area. There may also be local ordinances or tribal restrictions prohibiting use of fumigants.

Surveying the Site

Your fumigation product may also require you to survey the treatment area for evidence of nontarget animals. Surveys involve purposely monitoring the proposed treatment area to ensure nontarget animals will not be harmed by the fumigation treatment. The extent of the survey

Before using fumigants or any pesticide products, carefully read and follow the pesticide label. When not in use, store pesticides in a dry, cool and secure area. Always keep pesticides in the original labeled container.

FIGURE 6.1. Drawing of a weasel scat by Stephen M. Vantassel, MDA.

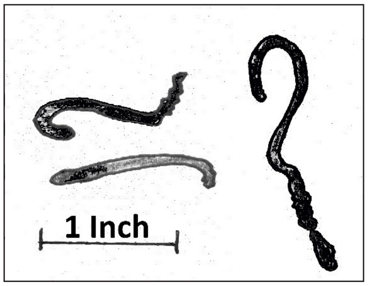


FIGURE 6.2. Scat of a Richardson's ground squirrel illustrating the elongated teardrop form of rodent scat. Photo by Stephen M. Vantassel, MDA.

required varies by label and site. Typically, non-prairie dog treatments will simply require a visual inspection (morning and afternoon) of the treatment area 24-hours prior to fumigation. A good visual inspection involves systematically viewing the field with enough detail to identify burrows/areas that should be avoided such as those occupied by nontarget animals and threatened and endangered species. Some fumigant labels require intensive multi-day surveys when using their fumigant in large prairie dog towns. Contact the U.S. Fish and Wildlife Service for details if your prairie dog town meets the requirements demanded by the label. Though not required by the labels, we recommend applicators write down the date, time, phone number, and name of the government official you contacted on the label of the fumigant you are using. This information can be helpful if you are ever questioned about your treatment of burrowing animals.

ASSESSING THE BURROW

Even if you have surveyed an area, you should always confirm the burrow is appropriate for fumigation prior to applying the fumigant product. Treatment of empty burrows or burrows occupied by nontarget animals is not only illegal, it wastes money and time. Determining whether a burrow is an appropriate candidate for fumigation can often be achieved by evaluating various characteristics, including the appearance of the animal's scat, the size of the burrow entrance, and the burrow's architecture.

Signs of Non-target Burrows

Weasels. Weasels create toilets near den sites. Their scat tends to be long tubes with pointed ends ¼ inch in diameter and up to three inches long (Figure 6.1) which is quite different than the pelleted (tubular) scat of ground squirrels and prairie dogs (Figure 6.2).

Black-Footed Ferret. The black-footed ferret, an endangered species, is known to occupy prairie dog burrows. Look for troughs created by ferrets excavating soil from the burrow (Figure 6.3). Black-footed ferret presence can also be indicated by finding prairie dog burrows backfilled with soil as they attempt to defend against ferret predation. Ferret tracks look similar to mink tracks.

Burrowing Owls. Burrowing owls leave white scat and feathers around the den entrance (Figure 6.4).

Swift Fox. Swift fox burrows are typically six to 10 inches wide and "keyhole" shaped, meaning wider at the top than the bottom (Figure 6.5). Swift foxes will occupy abandoned badger and prairie dog dens. Dens often occur in clusters. Entrances frequently have a J-shaped trench. Soil in front of the den is often soft and marked with tracks. Scats typically are scattered around the entrance. Entrances of dens with young may lack the presence of an excavated soil mound.

Badger. Badger burrows are six to eight inches in diameter and accompanied by a fan-shaped soil plume caused by the badger's excavation.

Signs of Target Burrows

Many rodent pest species are easily seen during daylight hours. Consider the diameter of the burrow opening. If you encounter a burrow that does not match the typical burrow size of the animal you are targeting, avoid it or make sure to investigate carefully before treating it. Below are typical burrow diameters for target species.

- **Ground squirrel:** 2 to 4 inches.
- **Prairie dog:** 4 to 10 inches.
- **Red fox:** 8 to 15 inches.
- **Coyote:** 11 to 18 inches

FIGURE 6.3. Black-footed ferret digging after a prairie dog. Photo by Steve Forrest.

FIGURE 6.4. Note the white specks (bird feces) and feathers. Photo by Stephen M. Vantassel, MDA.

FIGURE 6.5. A swift fox den. Photo by Dr. Donelle Schwalm, University of Maine-Farmington.

Note ground squirrels and prairie dogs defecate outside their dens, as well as foxes and coyotes, but their scat may be accompanied by carcasses of prey as well.

Consider timing of treatment to avoid harming nontarget species. For example, some animals, such as burrowing owls, may migrate from the treatment area as fall approaches. Delaying treatment until the owls have migrated can significantly reduce the likelihood of harming burrowing owls.

Signs of Inactive Burrows

Treat only active burrows containing the target species. Application of pesticides to inactive burrows wastes time and money and puts nontarget animals at unnecessary risk.

Use the following clues to help you identify inactive burrows:

- Burrow is completely or partially collapsed.
- Burrow seems unkempt and lacks evidence of recent digging.
- Burrow area lacks presence of fresh droppings/feces.
- A spider web spans burrow opening (Figure 6.6).

Another way to distinguish active from inactive burrows is by closing holes in affected areas by disking or raking. Be sure to mark burrows of nontarget animals, such as those occupied by burrowing owls, and avoid them during disking or raking operations. Active holes will be reopened in a few days. Treat reopened burrows if evidence of target animals is present.

General Principles for Fumigation of Burrows

Fumigants work best when soil moisture is high, such as in early spring, after soaking rains or irrigation. Moisture helps fill gaps within soil particles, thereby keeping gases contained within the burrow system (Figure 6.7).

Even when using best practices, burrow fumigants seldom achieve 100% control of the animals in treated burrows. Follow up treatment of active burrows is usually required. Fumigants also have no residual effect, allowing neighboring animals to reoccupy treated burrows. To reduce the risk of reinvasion from neighboring areas, control as much ground as is occupied by the target species. Community-based efforts improve long-term success.

EPA-REGISTERED FUMIGANTS FOR VERTEBRATE BURROWS

Currently there are three types of fumigant registered by the EPA and the MDA to be used on burrows: ignitable gas cartridges, carbon dioxide (dry ice) pellets, and aluminum phosphide-based tablets/pellets.

Ignitable Gas Cartridges

Ignitable gas cartridges are a common burrow fumigant because they are effective and do not require a pesticide license to use if using on land you own, rent or lease, not including federal land.

The U.S. Department of Agriculture through the Animal and Plant Health Inspection Service (USDA-APHIS) manufactures two gas cartridges. Both cartridges contain sodium nitrate and charcoal as active ingredients that, when lit, produce toxic carbon monoxide gas.

The smaller gas cartridge is 1½ inches wide by six inches long and weighs about five ounces (Figure 6.8, page 16). It is registered for the control of woodchucks, yellow-bellied marmots, ground squirrels, black-tailed prairie dogs, white-tailed prairie dogs and Gunnison prairie dogs in open fields, non-crop areas, rangelands, reforested areas, lawns and golf courses.

The large gas cartridge is 1½ inches wide by 12 inches long and weighs 10.2 ounces. It is only registered for control of denning coyotes, red foxes, and striped skunks in rangelands, crops, and non-crop areas (Figure 6.9, page 16).

Read and follow the label carefully. These products are restricted for use in outdoor, below-ground burrows

FIGURE 6.6. Inactive prairie dog burrow is identifiable by the spider web and unkempt character. Photo by Stephen M. Vantassel, MDA.

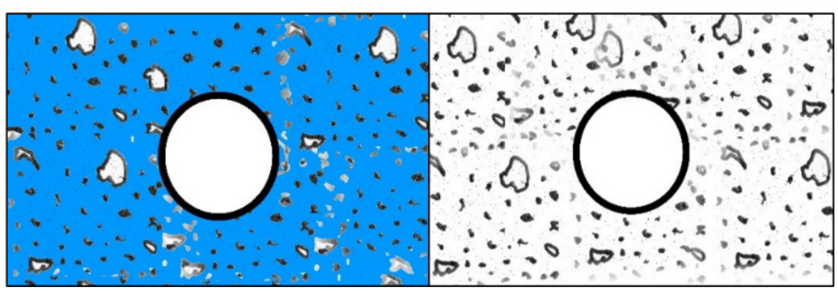


FIGURE 6.7. The left image shows gaps in dry soil that would allow toxic gas to leave the burrow and leak into the surrounding soil. The right image shows how moisture fills those gaps, preventing gas leakage. Image by Stephen M. Vantassel, MDA.

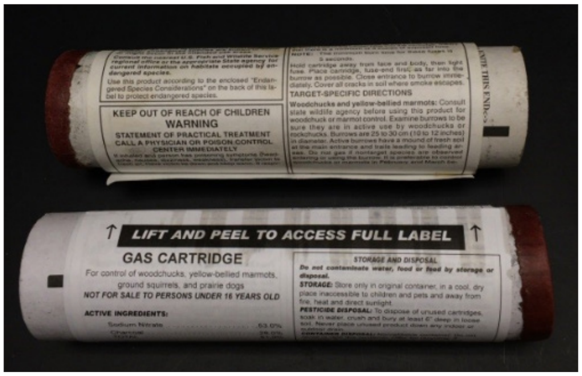


FIGURE 6.8. The small-sized ignitable cartridge manufactured by USDA-APHIS. Photo by Stephen M. Vantassel, MDA.

FIGURE 6.9. The large gas cartridge used to control burrows occupied by coyotes, red foxes, and striped skunks. Photo by John Steuber, USDA-Wildlife Services.

FIGURE 6.10. Sod plugs may also be used to cover a burrow opening. Photo by Stephen M. Vantassel, MDA.

actively used by the target species. Labels contain information on how to identify dens actively used by target species. Some labels require you to contact the Montana Fish, Wildlife & Parks and obtain the contact information for the non-game wildlife biologist designated for your area 406-444-2449 or visit http://fwp.mt.gov/gis/maps/contactUs/?areaType=nonGameWild. Do not treat burrows used by nontarget or protected species.

Example. *If using phosphine fumigants to control prairie dogs, applicators must contact the U.S. Fish and Wildlife Service (Helena: 406-449-5225 or Kalispell: 406-758-6868) and conduct a proper field survey in search of black-footed ferrets prior to application. Officials with the U.S. Fish and Wildlife Service will explain how to perform the survey.*

Effective use of the product requires the cartridges to burn thoroughly and the gases to be contained in the burrow. Neglect of either point will result in lower levels of control.

Whenever possible, identify connecting holes to the burrow(s) you plan to treat. Fill them with soil prior to igniting the cartridge. Have soil available to fill the hole you plan on placing the fumigant cartridge in prior to lighting. The goal is to ensure as much of the toxic gas remains in the burrow as possible.

The procedure for using ignitable gas cartridges is as follows: Puncture the end of the cartridge at the marked locations using a nail at least ⅛-inch in diameter. These holes will allow the gases to escape when the contents burn. If cartridges seem compacted, insert a nail and wiggle it to loosen the contents of the cartridge. This will ensure complete combustion. Insert a fuse in the middle of one end of the cartridge. Ensure at least three inches of the fuse are exposed before lighting. Three inches of exposed wick will burn for about nine seconds.

After lighting the fuse, place the cartridge, fuse end first, into the burrow as far as possible. Begin sealing the hole immediately to ensure the burrow holds as much toxic gas as possible. Do not allow soil to smother the cartridge as this may prevent complete burning. Cover any openings from which smoke escapes (Figure 6.10).

The Atlas Chemical Corporation manufacturers an ignitable gas cartridge called "The Giant Destroyer®" (Figure 6.11). Its active ingredients are sodium nitrate, carbon, and sulfur. When burned, this cartridge produces toxic carbon monoxide as well as sulfur-based oxides. This product is registered to control pocket gophers, moles, woodchucks, Norway rats, skunks and ground squirrels in outdoor burrows located in non-crop areas including residential lawns, parks, golf courses, reforested areas, open fields and rangeland. **Note:** moles do not occur in Montana. Use directions are very similar to those required by USDA fumigants. The minimum fuse length for The Giant Destroyer fuse is only two inches.

Generally, the gases produced from a single cartridge are enough to fill a burrow system. Under normal soil moisture and

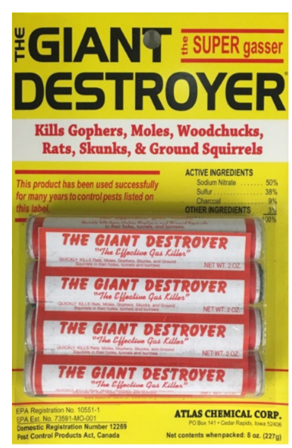


FIGURE 6.11. Photo by Stephen M. Vantassel, MDA

a simple burrow system, one gas cartridge will achieve control efficacy of 75 percent or higher. Fumigant effectiveness can be reduced when used in complex burrow systems, in burrows with several openings and interconnecting tunnels or with turns, dips and rises or when soil is extremely dry and/or cracked.

Cautions with Ignitable Cartridges: Gas cartridges burn with considerable heat and flame. Take great care to prevent accidental fires, especially when used in dry conditions. Do not use ignitable fumigants when soil or vegetation in the area is extremely dry. Fumigating burrows in dry soil is also less effective because gases escape into the porous soil. Moist soil holds gases better because water fills the gaps between soil particles. Whenever possible, plan to fumigate after a soaking rain.

Do not use gas cartridges under or near buildings. Cartridges can cause personal injury. Wear a glove (made of non-petroleum-based materials such as cloth or leather), at minimum, when lighting the cartridge. Stay upwind when possible and avoid breathing the fumes. Store gas cartridges in a secure and dry location.

We do not recommend using ignitable gas cartridges on pocket gophers due to inadequate evidence of efficacy.

Carbon Dioxide Fumigation

Carbon dioxide (CO_2) gas is naturally produced when we breathe. With every breath we exhale CO_2 as a waste product. However, concentrations as low as 30% can be lethal to animals. Research shows rats become unconscious in 25 seconds when exposed to 100% CO_2. Indoor air contains only 0.4 percent CO_2.

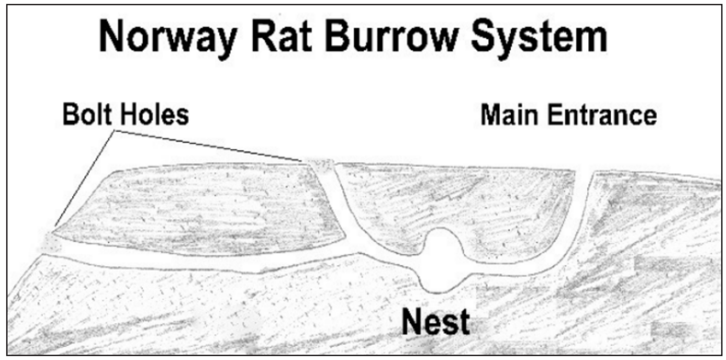
Carbon dioxide offers many benefits as a fumigant. First, the gas is heavier than air, so it naturally sinks into the burrow. Second, it is non-flammable. Finally, it offers a greater margin of safety for the applicator than other fumigant gases, thereby avoiding restricted use designation. Due to this, a pesticide license is not required if using on land you own, rent or lease.

In 2017, the EPA registered carbon dioxide-based fumigants to control burrowing rodents. At the time of this writing, Rat Ice™ (EPA # 12455-148) is the only carbon dioxide-based fumigant registered in Montana.

Rat Ice uses pelleted dry ice to kill Norway, roof, and Polynesian rats in active burrows around industrial, commercial, public and residential areas. (Roof and Polynesian rats do not occur in Montana). It may also be used around homes, lawns, campgrounds, golf courses, public parks and commercial nurseries.

Identify active burrows by occupant sightings, visible runways, burrow holes, and soft soil undermined with tunnels (Figure 6.12). Burrows often are two to four inches in diameter and will have smooth surfaces. The presence of excavated soil and trampled vegetation are also indicators of active burrows. Active burrows may be hidden by debris. All active burrows will have rat hairs present at the opening. Rats shed hundreds of hairs daily, so a close look will reveal the presence of hair if the burrow is active.

FIGURE 6.12. Schematic burrow system of the Norway rat. Image provided by Stephen M. Vantassel, MDA.



Gas fumigant applications may be made only to burrows outside of buildings. Applicators must follow label restrictions when treating burrows near structures. To see if other carbon dioxide-based products are available for use on burrowing rodents in Montana, visit http://npirspublic.ceris.purdue.edu/state/ or call the MDA Vertebrate Pest Specialist.

Aluminum Phosphide-Based Tablets/Pellets

Aluminum phosphide products are restricted use, and better known for use as grain fumigants. Aluminum phosphide-based fumigants may also be applied to control woodchucks (woodchucks do not occur in Montana), yellow-bellied marmots (rock chucks), prairie dogs (except Utah prairie dogs, *Cynomys parvidens*), Norway rats, roof rats (roof rats do not occur in Montana), mice, ground squirrels, voles, pocket gophers, and chipmunks in underground burrow systems located in non-crop areas, crop areas, or orchards.

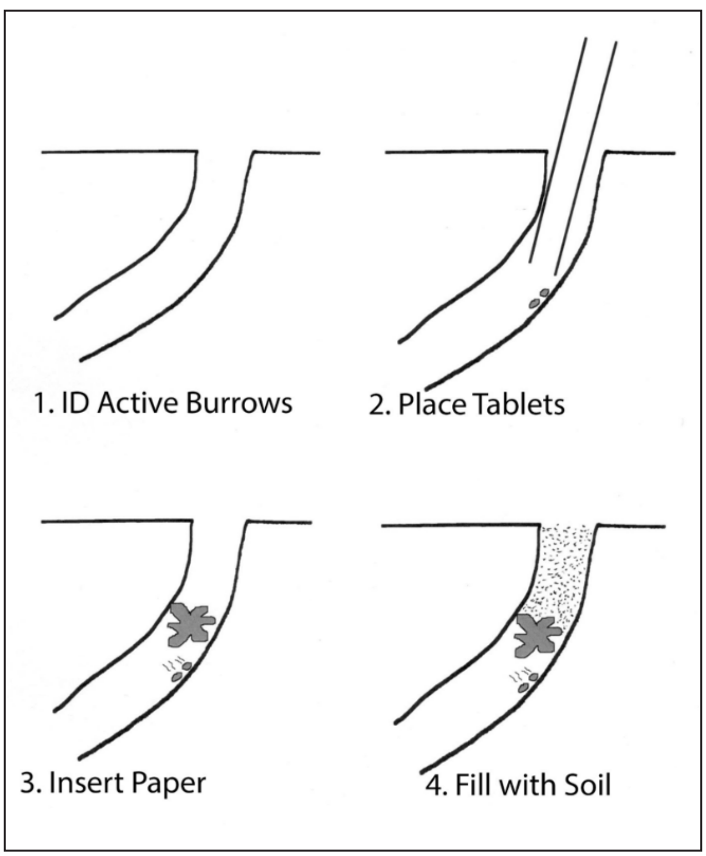
Phosphine gas is highly toxic and capable of killing humans, vertebrate wildlife and insects. Due to its lethality, applicators must follow many safety guidelines to ensure safe and effective use including using gas monitoring equipment, respirators (Chapter 3) and write a detailed Fumigation Management Plan (Chapter 5).

Using aluminum phosphide-based fumigants is strictly prohibited for fumigating rodent burrows on single or multi-family residential properties and nursing homes, schools (except athletic fields), day care facilities and hospitals. There are strict prohibitions against applications to rodent burrow systems within 100 feet of a building that is or may be occupied by humans and/or domestic animals.

FIGURE 6.13. Pellet container with cotton gloves. Photo by Stephen M. Vantassel, MDA.

Prior to applying tablets/pellets, wear cotton, leather, or similar gloves that reduce sweaty hands as phosphine gas readily liberates from the pellets/tablets when they touch moist skin (Figure 6.13). Place two to four tablets or 10 to 20 pellets in each active burrow. Use fewer tablets/pellets in smaller burrows under moist conditions and more tablets/pellets in larger burrows and dry conditions. Never exceed the maximum application amount. Cover the burrow opening with soil after packing the opening with crumpled newspaper to prevent soil from smothering the aluminum phosphide fumigant. A length of plastic pipe (1½-1¾ in. diameter) may be used to help guide the tablets/pellets deep inside the burrow (Figure 6.14). When used correctly and in normal soil conditions, aluminum phosphide will control 80 to 95 percent of the treated prairie dog burrows.

FIGURE 6.14. Steps in the application of aluminum phosphide (tablets/pellets) to a burrow. Image provided by Stephen M. Vantassel, MDA.



NON-REGISTERED ALTERNATIVE FUMIGATION METHODS

Inventors have created devices using carbon monoxide gas (CO) to kill burrowing rodents. The P.E.R.C.® Pressurized Exhaust Rodent Control (Figure 6.15, page 19), the Cheetah (Figure 6.16, page 19) and BurrowRx are three devices marketed to control burrowing rodents.

These devices are not regulated by the EPA, so pesticide licenses are not required for their use on land that you own, rent or lease. If leasing federal or state land, consult with officials to determine if use of fumigants or other pesticides are legal on that ground. Though not regulated, they should be used with care. You are still responsible for avoiding the killing of protected species and nontarget animals. Follow the previous guidance about surveying treatment areas to reduce the risk of harming non-targets.

Carbon monoxide is highly toxic and capable of harming applicators and others exposed to the gas. We recommend working into the wind to reduce the likelihood of being exposed to CO. Do not ignore headaches or tightness in the chest as these may indicate carbon monoxide poisoning.

Likewise avoid fumigating burrows near structures (particularly occupied structures) to prevent poisoning inhabitants. We advise fumigating burrows away from structures at distances no closer than those recommended below; unless the manufacturer's instruction manual suggests a greater distance.

Minimum recommended distances (unless label indicates otherwise) from structures when using fumigants for control of burrowing rodents:

- 150 feet for pocket gophers,
- 100 feet for prairie dogs,
- 20 feet for ground squirrels, and
- 20 feet for rats.

Research on the P.E.R.C. device in California found it achieved 71 to 81 percent control on Belding's ground squirrels and 45 to 61 percent control on pocket gophers. The device has also been used in Colorado to control other burrowing rodents, such as prairie dogs, but efficacy results rely on anecdotal claims and not on controlled studies. As of this writing, we are not aware of any published scientific research on the effectiveness of the Cheetah or BurrowRx.

Carbon monoxide has a weight like normal air, so care should be taken to ensure the gas is entering the burrow. It is advisable to backfill holes after placement of the hose to stop CO from leaking out of the burrow. Burrows that remain open during fumigation may experience lower CO levels as wind can siphon gas out of the burrows. Fumigation injection time is also critical. Follow manufacturer recommended injection times. Use a stop watch to ensure you are not underfilling or overfilling burrows. Evaluate efficacy. You may find injection times may need to be adjusted (up or down) depending on your results and soil conditions.

EVALUATING RESULTS

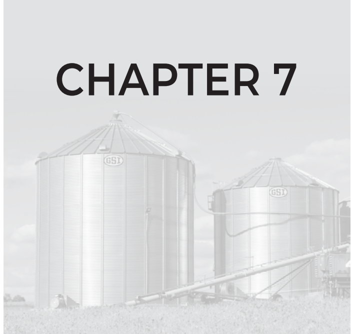
Regardless of your fumigation method, it is important to evaluate the efficacy of treatment. The easiest method is to determine whether a closed and treated burrow has reopened. While it makes sense to think a reopened burrow means the treatment failed, it may not be an accurate assessment of efficacy. You must consider whether the burrow has been opened by rodents from untreated burrows in the same location. Rodents will redistribute themselves in a treated area to take advantage of better living quarters and access to food. Because rodents will redistribute themselves, treat as large an area as possible to reduce the risk of rodents from untreated areas moving to treated areas.

SUMMARY

Fumigation is an important tool in the management of burrowing vertebrate pests in areas away from structures. Careful adherence to the pesticide label will help ensure that the pesticide is used effectively and properly. If you have any questions, call your local Extension agent or the MDA's Vertebrate Pest Specialist.

FIGURE 6.15. P.E.R.C.® device with three hoses being used on a prairie dog town. Photo by Stephen M. Vantassel, MDA.

FIGURE 6.16. The Cheetah being used on a prairie dog town. Photo by Stephen M. Vantassel, MDA.



CHAPTER 7 Fumigating Commodity Pests in Structures using Phosphine Gas

PREPARING STRUCTURES FOR FUMIGATION

When using a fumigant in a structure, applicators must conduct a site assessment, seal the structure properly, post warning signs (placards) and notify workers and emergency personnel.

Site Assessment

Always conduct a site assessment to ensure the structure can be legally fumigated as directed on the pesticide label. Phosphine products are prohibited for use on single and multi-family residential properties, nursing homes, schools, daycare facilities and hospitals. The structure to be fumigated must be sealed properly. If a site assessment reveals the structure cannot be sealed it should not be fumigated. Areas surrounding the fumigation site should be assessed for risk to people and animals by evaluating nearby sidewalks, roads, other inhabited buildings, nearby animals or endangered species for potential exposure to the phosphine gas. A drawing, aerial photograph or map (a mapping website, such as Google Earth™, provides a convenient way to obtain aerial views of locations. Just be sure the site has not undergone significant changes since the date of the satellite image on the mapping site) of the fumigation site can be used to clearly outline sensitive areas. The fumigant management plan, required by the pesticide label, includes a site assessment.

FIGURE 7.1. Examples of products available for sealing a structure prior to fumigation. Photo provided by Degesch America.

Sealing

Creating a sealed area to fumigate is one of the most important steps that will make the difference between a failed attempt and a successful and safe fumigation. Phosphine gas can move through any opening in the treated structure, reducing its concentration within the treated area and exposing a risk to areas surrounding the fumigated structure. The structure must be made as airtight as possible to maintain the gas concentrations needed to control the pest and for safety. Target concentrations for peak efficacy range depending on exposure period, pest species, temperature, and target life stage. Contact the pesticide product manufacturer for more information. Due to this variability it is recommended to always follow the minimum exposure periods recommended in this manual (Table 7-1, page 21).

First, survey the site to determine if the structure can be tightly sealed. Structures not easily sealed, such as wooden bins or buildings, can be covered with tarps to provide a sealed space. If adequate sealing is not possible do not fumigate the structure. Turn off all ventilation and other moving air systems that may negatively affect the treatment. Locate cracks, holes, and openings including windows, doors, vents, chimneys and structural flaws that will need to be sealed to create an airtight space.

There are numerous sealing techniques, but the most commonly used supplies include plastic sheeting, adhesive tape, adhesive sprays, and expandable foam caulking (Figure 7.1). Clean any treated area well so the sealant will adhere. Keep in mind that most of the sealant will need to be removed for venting and for access to the structure. Some cracks and holes may benefit from a more permanent sealing. Cover the grain with a tarp prior to fumigating to reduce the areas to be sealed, such as the roof eaves of the bin.

Placarding

The pesticide label requires placarding of all entrances to the structure to keep unauthorized persons from the fumigated area (Figure 7.2). Placards must be posted prior to the fumigation to keep unauthorized people out of the treated area. Placards cannot be removed until after the concentrations of phosphine gas within the treated area fall below 0.3 ppm (see Aeration, page 23).

FIGURE 7.2. Example of a placard for structural fumigation. Provided by Degeschamerica.com.

Placard signs must contain the following information:

1. The words "DANGER/PELIGRO" and the skull and crossbones symbol in red.
2. The statement, "Structure and/or commodity under fumigation. DO NOT ENTER/NO ENTRE."
3. The statement: "This sign may only be removed by a certified applicator or a person with documented training after the structure and/or commodity is completely aerated (contains 0.3 ppm or less of phosphine gas)."
4. The date the fumigation began.
5. Name & EPA registration number of fumigant used.
6. Name, address and telephone number of the Fumigation Company and/or applicator.
7. A 24-hour emergency response telephone number.

Notification

Prior to every fumigation workers and others with access to the site must be notified of the fumigation. It may be necessary to notify local authorities (police, emergency services, and/or fire) so they can be prepared in the case of an emergency. Always check local codes and regulations to determine if local emergency personnel must be notified prior to the fumigation or if fumigants are prohibited.

EXPOSURE TIME AND TEMPERATURE

For a successful fumigation you will need to determine adequate exposure time to manage the pest. Several factors will affect the concentration of phosphine gas in the structure and your decision on treatment exposure time:

1. Grain temperature
2. Grain moisture
3. Air-tightness/sealing of bin
4. Target pest (different species and life stages may be more difficult to control)
5. Formulation: some products, such as pellets, react faster

Insect pupae and eggs are harder to kill than immature and adult insects. While fumigation can be done at temperatures below 60°F, lower temperatures delay insect mortality by slowing insect metabolism and their intake of phosphine gas. Longer exposure periods listed on the label require a well-sealed bin. Refer to the "exposure conditions" section of the Applicator's Manual for additional guidance on treatment duration. This section will indicate MINIMUM exposure periods for aluminum phosphide at specific temperatures (Table 7-1). Use the Applicator's Manual and/or product label because it provides instructions specific to the product. Exposure periods listed are minimum periods and may not be enough to manage all stored product pests under all conditions. When possible, extending the treatment time in a well-sealed structure can improve the effectiveness of pest control. Worker exposure to unreacted product is a serious hazard; unreacted product must be deactivated following instructions on the pesticide label. When planning your fumigation, begin with the minimum time periods listed in Table 7-1 and add time as necessary for factors such as lower grain moisture, poor sealing and the target pest. Low grain temperature and moisture will necessitate a longer exposure period. Never start a fumigation when conditions are below critical thresholds for aluminum phosphide products, such as temperatures below 40°F, and be aware that grain moisture less than 10% slows the production of phosphine gas.

TABLE 7-1. Minimum exposure times for Phostoxin® based on temperature.

Bin Temperature		Pellets	Tablets
Below 40°F	Below 5°C	Do Not Fumigate	Do Not Fumigate
40 - 53°F	5 - 12°C	8 days (192 hours)	10 days (240 hours)
54 - 59°F	12 - 15°C	4 days (96 hours)	5 days (120 hours)
60 - 68°F	16 - 20°C	3 days (72 hours)	4 days (96 hours)
above 68°F	above 20°C	2 days (48 hours)	3 days (72 hours)

DETERMINING APPLICATION RATE

The pesticide label and Applicator's Manual provide dosage ranges based on either the volume of the space or the bushels of grain to be fumigated (Table 7-2). When fumigating an entire structure, you will use dosages based on the cubic feet (volume) fumigated. It is often helpful to cover grain with a tarp (known as tarping). Tarping is helpful because it reduces the amount of product needed for the fumigation, as upper areas of the structure do not need to be sealed, and it is easier to calculate the dose of fumigant based on bushels of commodity to be treated. Be aware of the specific product you are applying - tablets are much larger than pellets and will release more gas – fewer tablets are required compared to pellets to maintain an effective concentration of phosphine gas.

There is a large range of required dose rates for phosphine gas fumigations. This allows the applicator to choose an appropriate rate for the specific conditions of each fumigation. The severity of insect infestation, temperature in the structure/grain, moisture level in the structure/grain, and how well the structure/grain is sealed are factors to consider when choosing the specific dosage. Higher dosages are usually recommended under cooler, drier conditions, if the bin is not tightly sealed, or if the exposure period is short.

Maximum allowed dosages listed on the pesticide label should not be exceeded – use the rates listed on the label that came with the specific product. Table 7-3 provides an example of the MAXIMUM rates of aluminum phosphide pellets or tablets allowable per 1,000 cubic feet (ft^3) or 1,000 bushels of grain.

TABLE 7-2. Example of dosage ranges for aluminum phosphide products.

DOSAGE RANGE		
Type of Fumigation	Pellets	Tablets
Vertical Storage	200-900 /1,000 bushels	40-189 /1,000 bushels
	150-700/1,000 ft^3	30-140/1,000 ft^3
Farm Bins	450-900 /1000 bushels	90-180 /1000 bushels
	350-725/1,000 ft^3	70-145/1,000 ft^3

TABLE 7-3. An example of MAXIMUM allowable rates of aluminum phosphide fumigant.

Product type	Max quantity per 1,000 ft^3	Max quantity per 1,000 bushels
Pellets	725	900
Tablets	145	180

APPLICATION PROCEDURES

Phosphine gas fumigants may be applied by probing, adding the product as the probe is lifted through the grain, by duct delivery into the structure with select fumigants, or on top of the grain pile. Adding fumigant product to the top of grain piles is the least effective method if conditions are less than ideal, as this approach lacks even distribution.

Probing is the most cost-efficient way of applying phosphine gas fumigants to grain storage in Montana (Figure 7.3). A probe consists of a length of hollow tubing purchased from the fumigant supplier or made from electrical conduit or plastic pipe. When probing, the product should be evenly distributed throughout the grain mass. First, determine the amount of product that a single probe can apply. Then, divide the total amount of fumigant product to be applied by the dose for each probe. This will provide the total number of probes needed to deliver the total dose. The total number of probe applications should be distributed evenly throughout the grain pile.

Insert the probe into the grain pile to the desired depth. Drop in the tablets or pellets. Pull the probe upward in evenly spaced intervals, stopping to drop in more product. Continue until the desired amount of product is used for a single probe. The last tablets or pellets applied through the probe should be about six inches below the surface. Repeat until the total amount of product for the fumigation is applied, distributing the probes evenly throughout the grain pile.

Phosphine tablets and pellets can also be added to the grain stream when loading grain into a bin, by hand or by using an automatic dispenser. The rate of grain flow will determine the interval at which the fumigant is added.

When using phosphine in a structure outfitted with a recirculation system, the product can be added to the system. Ducts connected to blowers circulate the air down through the grain mass, up through the ducting system

Common Causes of Bin Fumigation Failures

1. Too little product
2. Exposure time too short
3. Leaky bin
4. High grain moisture retarding penetration of the fumigant
5. Dusty/broken grain particles retarding penetration of the fumigant

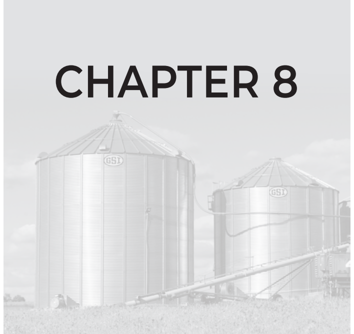
and back into the bin. This allows the gas to penetrate all areas of the structure quickly. Aluminum phosphide manufacturers should be contacted directly for specific instructions related to this method of fumigation.

AERATION

When the scheduled fumigation period has passed, the structure must be aerated until phosphine gas concentrations fall below 0.3 ppm. If the tarp method was used, the tarp must be removed at the end of the scheduled fumigation period. Doors and vents to the grain bin must be opened to release the phosphine gas, while wearing approved respirator and PPE depending on concentrations. The aeration process may take several days, and phosphine gas monitoring equipment is required. A well-sealed structure can retain phosphine gas for long periods of time and continue to pose a hazard to workers. Since stored grain may continue to release phosphine gas, do not immediately close vents when phosphine gas first goes below 0.3 ppm.

The procedures outlined in this chapter are meant as a guide to understanding procedures described in the pesticide product label and Applicator's Manual. This is not a guarantee that discrepancies may not exist due to multiple labels, active ingredients, label changes, etc. Always read and follow the pesticide product label and Applicator's Manual.

FIGURE 7.3. Probing is an effective way of distributing pellets and tablets throughout a grain mass. Photos provided by Degesch America.



CHAPTER 8 Calculating Phosphine Product Dosage for Structures

Fumigants expand and fill an available space at an even concentration under ideal conditions. The applicator must know the volume of space or bushels to be treated to determine the amount of product to add, so the concentration of phosphine gas is above the threshold required to kill pests throughout the space containing the grain.

Applicators can choose from two general approaches when fumigating a stored grain bin with phosphine gas: 1) fumigate the entire bin structure, or 2) use a tarp to cover the grain to create a sealed area. Tarping the stored commodity will reduce the amount of fumigant needed and therefore reduce costs, however, it can be more labor intensive. The pesticide label and Applicator's Manual provide directions for the amount of phosphine gas fumigant to add based on the volume of space to be fumigated or the amount of grain in bushels.

INTRODUCTION TO CALCULATING VOLUME

To determine dosage if not tarping, you must first calculate the volume of the structure you will be fumigating. Commodity storage comes in multiple different shapes and sizes and calculating the volume requires knowledge of a few mathematical terms related to geometry: length (l), width (w), height (h), diameter (d), radius (r) and the number Pi (π), a mathematical constant approximately equal to 3.14. Throughout this chapter we will use 3.14 in place of π.

The diameter (d) of a circular structure like a grain silo is the distance from one side of the structure to the other. If the structure is filled with grain, its diameter can be calculated from its circumference (c), or the distance around the base. Diameter (d) = circumference (c) ÷ 3.14.

The radius (r) is half the diameter (d) or r = ½d.

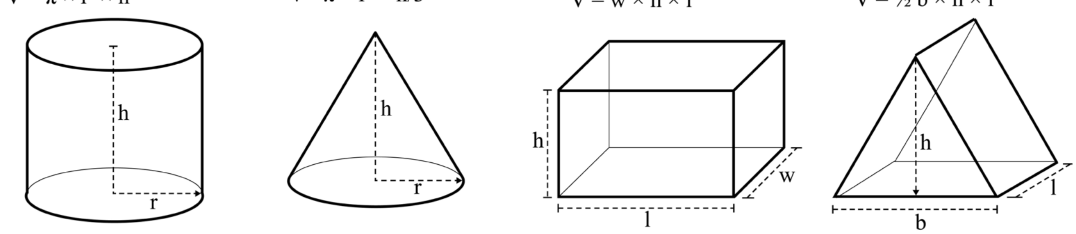
Formulas for calculating the volume of different shapes:

Cylinder
$V = \pi \times r^2 \times h$

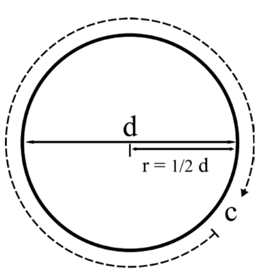
Cone
$V = \pi \times r^2 \times h/3$

Rectangular Prism
$V = w \times h \times l$

Triangular Prism
$V = ½\, b \times h \times l$



v = volume
π = 3.14
r = radius
r^2= radius × radius
h = height
w = width
l = length
b = base



A grain silo might be 30 feet across its widest point; its diameter (d) is 30 feet. The radius (r) is ½ the diameter: r = ½ d, or 15 feet. If the diameter is difficult to measure it can also be calculated from the circumference. The circumference (c) is the distance around the outside of the circle; 94 feet in this example.

The diameter (d) is equal to the circumference divided by 3.14: d = c ÷ 3.14

In this example, c = 94 ft: 94 ÷ 3.14 = 30 ft

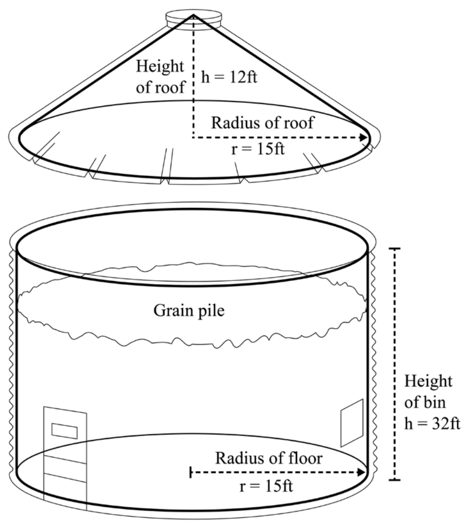
CALCULATING VOLUME

CYLINDRICAL STRUCTURE WITH PEAKED ROOF

This section explains how to calculate the volume for a vertical silo or any cylindrical grain bin (Example A). Use this method if you will be fumigating the entire structure. For tarping grain within a silo or grain bin, see Tarp Fumigations on page 27.

To be effective it is important to accurately calculate the volume of the entire storage structure to be fumigated. This involves dividing the structure into shapes whose dimensions can be measured to calculate their volume. In the case of silos with peaked roofs, the main part of the silo can be considered a cylinder while the roof can be considered a cone. The dimensions of the cylinder portion of the silo are measured, as well as the dimensions of the cone shaped roof. The volume of these two shapes are calculated separately and added together to obtain the total volume of the grain bin.

EXAMPLE A. Calculating the volume of a grain silo.



Calculations for Example A:

1. **Calculate the volume of the silo shaped like a cylinder.**

   The height (h), or distance from the bottom of the silo to the eaves of the roof is 32 feet. The diameter (d) of the silo is 30 feet. Remember the radius (r) is equal to ½ the diameter (r = ½ d). The radius of the bottom of the grain bin is 15 feet. Using the height and radius you can calculate the volume of the cylinder portion of the silo.

   $$V_{cylinder} = 3.14r^2h$$

   The value 3.14 (π) is multiplied by the radius squared (remembering $r^2 = r \times r$) multiplied by the height:

   $$V_{cylinder} = 3.14 \times r \times r \times h$$

   Using example A, above,

   $$V_{cylinder} = 3.14 \times 15\text{ft} \times 15\text{ft} \times 32\text{ft}$$

   $$V_{cylinder} = 22{,}608\text{ft}^3$$

2. **Calculate the volume of the roof shaped like a cone.**

   The volume of the roof needs to be calculated using the formula for the shape of a cone, where the volume of a cone equals the value 3.14 (π) multiplied by the radius squared multiplied by ⅓ the height of the cone:

   $$V_{cone} = (3.14 \times r^2) \times h/3$$

   The radius of the base of the cone is the same as the radius of the base of the silo from step 1. The height of the cone is measured from the base of the roof to its tip, 12 feet in this example. The volume of the roof is:

   $$V_{cone} = (3.14 \times 15\text{ft} \times 15\text{ft}) \times 12\text{ft}/3$$

   $$V_{cone} = 2{,}826\text{ft}^3$$

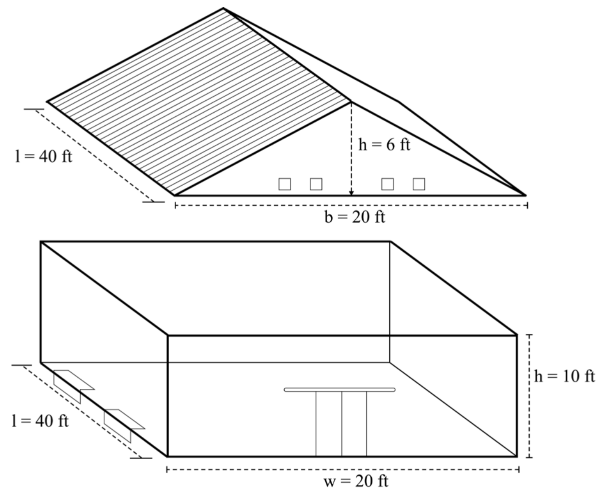
3. **Add the volumes of the cylinder and the cone to determine the total volume of the silo.**

   $$V_{silo} = V_{cylinder} + V_{cone}$$

   $$V_{silo} = 22{,}608\text{ft}^3 + 2{,}826\text{ft}^3$$

   $$V_{silo} = 25{,}434\text{ft}^3$$

EXAMPLE B. Calculating the volume of a rectangular grain bin.



RECTANGULAR STRUCTURE WITH PEAKED ROOF

This section explains how to calculate the volume of a rectangular structure with a peaked roof. The building structure is first divided into different shapes whose volume can be calculated, a rectangular prism (the main building) and a triangular prism (the peaked roof).

The volume of the main structure is calculated by multiplying its length (l), width (w) and height (h) together:

$$V\mathit{building} = w \times h \times l$$

Calculating the volume of the peaked roof, which is the shape of a triangular prism, uses the measurements of its triangular shape. The base (b) of the triangle is the width of the building from the first step, unless there are eaves; the height (h) of the triangle is the distance from the top of the bin walls to the peak of its roof. The length of the triangular prism (l) is equal to the length of the structure from the first step. The volume of the peaked roof can then be calculated using the formula:

$$V\mathit{peaked\ roof} = (b/2) \times h \times l$$

Calculations for Example B:

1. **Calculate the volume of the rectangular structure.**

   For this example, the rectangular shaped grain bin is 40 feet long and 20 feet wide. The longer measurement will be its length (l) while the shorter distance is its width (w). The height (h) is measured from the ground to where the wall connects to the roof, 10 feet in this example. The volume is:

$$V\mathit{building} = w \times h \times l$$

$$V\mathit{building} = 20\text{ft} \times 10\text{ft} \times 40\text{ft}$$

$$V\mathit{building} = 8{,}000\text{ft}^3$$

2. **Calculate the volume of the peaked roof.**

   Next, the volume of the peaked roof in Example B needs to be calculated. When looking at the front of the bin, the face of the roof is the triangle. To calculate the height of the peaked roof you must subtract the height of the bin walls from the highest point of the bin. In this example the peak of the roof is 16 feet. The bin walls are 10 feet, so the height of the peaked roof is 6 feet.

$$\mathit{height\ of\ peaked\ roof} = \mathit{height\ of\ structure} - \mathit{height\ of\ walls}$$

$$\mathit{height\ of\ peaked\ roof} = 16\text{ft} - 10\text{ft}$$

$$\mathit{height\ of\ peaked\ roof} = 6 \text{ feet}$$

   The length (l) of the peaked roof is simply the length of the grain bin (40 feet). The width (w) of the bin (20 feet) from step 1, is the base (b) of the triangle. If there are eaves, they must be added to the length and width measurements. The volume of the roof area can be calculated:

$$V\mathit{peaked\ roof} = (b/2) \times h \times l$$

$$V\mathit{peaked\ roof} = 20\text{ ft}/2 \times 6\text{ft} \times 40\text{ft}$$

$$V\mathit{peaked\ roof} = 2{,}400\text{ft}^3$$

3. **Add the volumes of the building and the peaked roof to determine the total volume of the building.**

$$V\mathit{structure} = V\mathit{building} + V\mathit{peaked\ roof}$$

$$V\mathit{structure} = 8{,}000\text{ft}^3 + 2{,}400\text{ft}^3$$

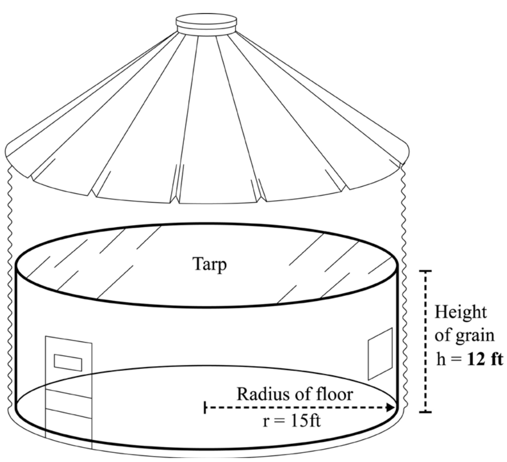
$$V\mathit{structure} = 10{,}400\text{ft}^3$$

TARP FUMIGATIONS

Rather than fumigating an entire structure, another option is to tarp the grain to reduce the volume needing to be fumigated. Covering grain with tarps or plastic sheeting is an easy and effective way to fumigate for pests. Phosphine gas does not penetrate though 2 mm thick polyethylene (poly) tarps very quickly; it forms a reasonably gas-tight enclosure. Poly-sheets can be taped together to form a larger surface and the edges secured with sand bags or other types of weight. Slits can be cut to apply the aluminum phosphide pellets or tablets through the poly, but these slits need to be carefully sealed with tape after the phosphine product is placed into the grain. When treating grain piles covered by a tarp the applicator must know the number of bushels of grain to be treated or the volume it occupies.

If the number of bushels of grain below the tarp is known, no volume calculations are required. The pesticide label provides product rates per 1,000 bushels of grain (Table 7-2, page 22). If the number of bushels is not known, then the formulas to calculate the volume must be used to determine the cubic feet occupied by the grain below the tarp. These calculations are simpler since the volume of the bin roof does not need to be calculated. The phosphine gas only occupies the area underneath the tarp.

EXAMPLE C. Calculating the volume of grain covered by a tarp.



Less fumigant is required if the grain in partially filled bins is covered with a tarp.

If records accurately account for the number of bushels of grain stored in the bin, use the label rate provided per 1,000 bushels (Table 7-2). If the number of bushels in the storage bin is not known, use the volume method:

Calculate the volume of a cylinder. The silo in this example is not full. The grain reaches a height of 12 feet and will be covered with a tarp prior to fumigating. The volume under the tarp is calculated:

$$V\mathit{cylinder} = \pi \times r^2 \times h$$

$$V\mathit{cylinder} = 3.14 \times r \times r \times h$$

$$V\mathit{cylinder} = 3.14 \times 15\text{ft} \times 15\text{ft} \times 12\text{ft}$$

$$V\mathit{cylinder} = 8{,}478\text{ft}^3$$

GRAIN STREAM APPLICATIONS

For grain stream fumigant applications, the total amount of fumigant applied is based on the total number of bushels added to the bin (Table 7-2, dosage per 1,000 bushels) as listed on the pesticide label. For example, if 10,000 bushels of grain is loaded into the bin, a maximum of 9,000 pellets or 1,800 tablets of aluminum phosphide can be added to the grain stream (Table 7-3, page 22). The dosage should be added at intervals that do not exceed 900 pellets or 180 tablets per 1,000 bushels of grain flow (900 pellets per 1,000 bushels x 10 equals 9,000 pellets for the total 10,000 bushels; 180 tablets per 1,000 bushels x 10 equals 1,800 tablets for the total 10,000 bushels).

OTHER RESOURCES

It is not a bad idea for applicators to double-check calculations with other individuals or use volume calculators like PI DAY (https://www.piday.org/calculators/volume-calculator/). For determining the volume of other structures and for alternate methods see the grain storage treatment guide located online: http://www.pesticides.montana.edu/documents/manuals/FumSeed.PDF.

All calculation images in this chapter were created by Tember Dykgreve.

CHAPTER 9 Alternative Structural Fumigants

METHYL BROMIDE

While this publication focuses mainly on phosphine gas fumigants when fumigating structures, methyl bromide is worthy to note. Methyl bromide (CH_3Br), used since the 1930s, was one of the most commonly used fumigant chemicals until it was phased out in accordance with an international agreement called the Montreal Protocol, because of its role in depleting atmospheric ozone. The amount of methyl bromide produced within or imported into the United States was reduced incrementally until it was completely phased out from most uses on January 1, 2005. Certain critical applications of methyl bromide, including quarantine and pre-shipment uses, can be exempted from the Montreal Protocol by the United States Environmental Protection Agency (EPA). The EPA accepts applications every year from methyl bromide users for critical use exemptions. The applications are reviewed, and the EPA seeks authorization for those uses from the Parties to the Montreal Protocol. Examples of exemptions from 2016 include California strawberry fruit growers and dry-cured pork producers. For more information refer to the EPA website on the methyl bromide phase out: https://www.epa.gov/ods-phaseout/methyl-bromide.

If leftover stocks of methyl bromide remain, the MDA Pesticide Waste Disposal can be contacted for information about disposing leftover stocks of methyl bromide (https://agr.mt.gov/Pesticide-Waste-Disposal). However, leftover methyl bromide stocks can legally be used if the product is currently registered for use in Montana. To check on current registrations see the MDA product registration site at https://mtplants.mt.gov/ProductRegFSA/BrandSearch.aspx. Methyl bromide is a restricted use pesticide and applicators must have a pesticide license to apply the fumigant. Methyl bromide is extremely hazardous to humans. Read and follow all instructions on the pesticide label as they may differ from guidelines for other fumigant types described in this manual.

SULFURYL FLUORIDE

Sulfuryl fluoride is a colorless and odorless fumigant gas composed of one sulfur, two oxygen and two iron atoms (SO_2F_2). Sulfuryl fluoride has been registered in the United States as an insecticide and rodenticide since 1959 and is commonly used to control termites, bedbugs, cockroaches, rodents and other pests in closed residential and commercial structures. All sulfuryl fluoride products are restricted use pesticides sold under such trade names as Vikane®, Zythor®, and Master Fume®. In 2004, ProFume® was registered by Dow AgroSciences for fumigating over 50 food commodities, including wheat and barley, and is now manufactured in the United States by Douglas Products. The active ingredient, sulfuryl fluoride, is formulated within gas fumigant cylinders and is labeled to control insects and rodents in most raw and processed commodities stored in structures and during transport and processing. This product is highly toxic and can inhibit normal metabolic functions in high exposure scenarios. "Professional fumigators who use ProFume® gas fumigant must hold the necessary state and federal licensing, and must meet Douglas Products stewardship standards, which include mandatory introductory and recurrent annual training, as well as adherence to the stewardship policy for ProFume®." (Douglas Products; https://profume.com/the-profume-difference).

"ProFume® can only be purchased, transported and applied by those who have completed the training program from Douglas Products or its agents. Once specially trained, state licensed/certified fumigators are authorized to use ProFume®" (Douglas Products; https://profume.com/faq).

Use of sulfuryl fluoride in Montana private agricultural systems is low. This is likely due to mandatory additional trainings, expensive monitoring equipment, and need for specialized equipment for proper delivery when compared to phosphine products. It should be noted this product is highly effective if used properly, and a superior alternative to phosphine products if phosphine-resistant insects are present.

Contact the manufacturer for more information.

APPENDIX A: Time Weighted Average

Without a respirator, concentrations of phosphine gas between 0.3 ppm and 1.0 ppm (the STEL) are permissible for short periods if the TWA does not exceed 0.3 ppm. The TWA accounts for time that different concentrations of phosphine gas are present throughout an eight-hour period. To determine a TWA, an applicator must record the phosphine gas levels several times during an eight-hour period. The TWA is the sum of the portion of each period multiplied by the concentration of phosphine gas during the eight-hour period.

Example: The level of phosphine gas was recorded at the beginning of the day at 7 AM and then every hour for eight hours:

TIME	CONCENTRATION	AMOUNT OF TIME
7 AM	First Measurement	1 hour at 0 ppm
8 AM	0 ppm phosphine gas	1 hour at 0 ppm
9 AM	0.1 ppm phosphine gas	1 hour at 0.1 ppm
10 AM	0.1 ppm phosphine gas	1 hour at 0.1 ppm
11 AM	0.5 ppm phosphine gas	1 hour at 0.5 ppm
12 PM	Missed sample	Assume 1 hour at 0.5 ppm
1 PM	0.2 ppm phosphine gas	1 hour at 0.2 ppm
2 PM	0 ppm phosphine gas	1 hour at 0 ppm
3 PM	0 ppm phosphine gas	

8-hour monitoring period: $3/8$ hours (0.375) at 0 ppm; $2/8$ hours (0.25) at 0.1 ppm; $2/8$ hours (0.25) at 0.5 ppm; and $1/8$ hours (0.125) at 0.2 ppm.

TWA = CxT + CxT + CxT…

C = concentration of phosphine gas in ppm

T = time of phosphine gas concentration as a proportion of the 8 hours

TWA = (0 ppm x 0.375) + (0.1 ppm x 0.25) + (0.5 ppm x 0.25) + (0.2 ppm x 0.125)

TWA = 0 + 0.025 + 0.125 + 0.025 = 0.175 ppm

While the phosphine concentration in this example was above 0.3 ppm for 2 hours (0.5 ppm), the TWA for the 8-hour period was less than 0.3 ppm. In this example a respirator would not be needed.

However, if the phosphine gas concentration was 0.2 ppm for 4 hours and 0.6 ppm for 4 hours the TWA would be exceeded: (0.2 ppm x 0.5) + (0.6 ppm x 0.5) = 0.1 + 0.3 = 0.4 ppm phosphine gas. In this example a respirator would be needed.

APPENDIX B: References

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