Fumigation

CATEGORY 6

Pesticide Safety Education Program, Ohio State University Extension

Soil Fumigation Additional Training Requirement

Any applicators who are applying soil fumigants are required to complete U.S. EPA approved training. This training is in addition to requirements for the Ohio Private Pesticide Applicator License.

Below is the front page of the web-based training required for licensed Ohio applicators who are planning ot use the following soil fumigants: methyl bromide, chlorpicrin, chloropicrin, and 1,3-dichloropropene, dazomet, and meta sodium and meta potassium.

The website is *www.fumiganttraining.com*
Information about training for other products is available at:

www.epa.gov/pesticides/reregistration/soil_fumigants

Phosphine Gas: Label, Applicator's Manual and Fumigation Management Plan

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There are only a few materials still on the market that are true fumigants. Of these products, the one that has the greatest potential of being used by an applicator holding a private applicator's license is phosphine gas. Phosphine gas is a Restricted Use Product because of its extreme toxicity primarily by inhalation, but also by absorption. The use of this phosphine gas is strictly prohibited on single and multifamily residential properties and nursing homes, schools (except athletic fields), daycare facilities and hospitals. To purchase and/or use phosphine gas, one must have the new Category 6 on their private applicator's license and acquire re-certification credits for Category 6 to retain that category on their license once every three (3) years. Phosphine gas falls under Category 10c on the commercial pesticide applicator's license.

Typically, phosphine purchased to be used on the farm comes as a solid, Aluminum Phosphide (e.g., Phostoxin, Fumitoxin, and Weevilcide) in the form of a pellet or tablet (5 pellets = 1 tablet). This solid product reacts with moisture (water) to liberate the phosphine gas from the solid. The moisture used to react with the solid primarily comes from the moisture in the air. It is not recommended to bring aluminum phosphide into direct contact with standing water. If this happens, the rate of reaction and the build-up of phosphine gas concentration can result in spontaneous explosion. The moisture in the air is usually more than adequate to move the conversion reaction along at a safe rate and gas concentration. The chemical reaction for this process is aluminum phosphide plus water yields phosphine gas plus aluminum hydroxide powder ($AlP + 3H_2O \rightarrow Al(OH)_3 + PH_3$). The aluminum hydroxide powder or ash is non-toxic.

Beyond the safety issues associated with the use of phosphine gas as a pest management tool is the successful use of phosphine gas to control pest populations. There are several factors that impact the ability of phosphine gas to successfully fumigate a farm bin including: temperature, moisture, condition of the structure to be fumigated, dosage, time, distribution of gas in grain mass, target insect species, life stage of insect, wind, and maybe most significantly, the ability to properly seal the structure to be fumigated. A 39-page Applicator's Manual that is part of the pesticide label for the use of aluminum phosphide, specifically DEGESCH Phostoxin® Tablets and Pellets, can be found on DEGESCH America, Incorporated's website at the following web address: http://www.degeschamerica.com/literature.html.

Sealing of Structure and Aeration

Of critical importance to the success any fumigation is being able to thoroughly seal the structure or area that is to be fumigated to prevent the escape of the gas. After the introduction of the appropriate dosage of the fumigant into the area to be fumigated, one must be able to hold the fumigant in place for the required time at a high enough concentration to satisfactorily kill the majority of the targeted pest. This is one of the greatest reasons why fumigations fail. Many have used phosphine gas in the past without sealing the structure into which the fumigant was introduced. Afterward, it may have superficially appeared that the fumigation was a success. However, the kill of the offending insects may have only been of the most active and exposed stages of the insect (i.e. the adults).

Life stages of primary insect pests (e.g., weevils and grain borers) that are hidden and sealed inside kernels of grain and insects in areas of the grain mass that are not fully exposed to a lethal concentration and/or exposed for too short of a period of time will not be killed. Sealing is a difficult task and requires a lot of time and energy, but without sealing, gas escapes from the area to be fumigated so rapidly, it may never reach a lethal dose.

Why is it a concern if the above occurs?

1. Selecting for Resistance
   It is well documented that exposure of insects to sub-lethal dosages of insecticides leads to the development of resistance to the insecticides. There are already signs of resistance amongst grain infesting insects to phosphine gas.
2. Unsatisfactory Control
   Control may temporarily appear to be successful because of adult knock down, but the infestation may reappear as immature stages complete their development. In the meantime, the grain may have been moved off the farm and into the grain stream. This is simply passing the infestation down the line for someone else to deal with it.
3. Unintended exposure of humans and other animals around the structure being fumigated to an extremely toxic pesticide.

The problem of leakage is exacerbated by structure construction and wind. Some structures are impossible to seal because of construction materials and/or age. Fumigation should never be attempted in these structures. Even small leaks can be problematic out in the country where the wind blows almost constantly.

Ideally, the best set up for fumigation of grain on the farm would be to have a closed-loop recirculation system. This requires retrofitting of older structures or new construction of a system designed to be a closed system.

After the exposure time has passed for a fumigation, then loss of fumigant is desired. Opening a structure to release the fumigant is part of the fumigation process. The gas should be intentionally removed from the material under fumigation to assure that re-entry into the area or structure where the fumigation took place will be safe. A fumigation is not complete until aeration is performed.

Fumigation Management Plans

A relatively new addition to the label and applicator's manual for the use aluminum phosphide is the requirement for the writing of a FUMIGATION MANAGEMENT PLAN (FMP). This document is to be composed prior to any fumigation in which the aluminum phosphide product is used. Each fumigation requires its own FMP. A generic, one-size-fits-all FMP is not permitted. A downloadable, model FMP can be found on the DEGESCH America, Incorporated's website at the following address: http://www.degeschamerica.com/literature.html.

A checklist guide for a Fumigation Management Plan

A. Preliminary Planning & Preparation
B. Personnel
C. Monitoring
D. Notification
E. Sealing Procedures
F. Application Procedures & Fumigation Period
G. Post-Application Operations

Application Procedures

The applicator's manual for the use of aluminum phosphide lays out the entire process for fumigating multiple types of structures and vehicles. The first statements under the section title for application procedures are, "A FMP must be written PRIOR to all applications. A FMP must be devised to cover application, exposure period, aeration and disposal of the fumigant, so as to keep to a minimum any human exposure to phosphine and to help assure adequate control of the insect pests." These statements are immediately followed by the application procedures for fumigating an on-farm, grain-storage bin. This emphasizes the fact that a FMP needs to be produced for all fumigations including the on-farm, grain-storage bin fumigation.

Temperature and Moisture

These two factors should be considered together for one influences the other and both impact the characteristics of the fumigation. Air of different temperatures has varying moisture saturation levels. The relationship between air temperature and moisture holding capacity is a direction relationship where the warmer the air temperature, the greater the amount of moisture it can hold and the colder the air temperature, the lesser the amount of moisture it can hold. Since moisture (water) is required to liberate phosphine gas from the solid aluminum phosphide, the more moisture that is available, the more rapidly the gas can be released from the solid.

One should keep in mind that the temperature of the commodity (grain) to be fumigated can be very different than the ambient surrounding air temperature. Grain is an excellent insulator, thus once grain is chilled, it can hold that temperature for a long period of time even after the ambient air temperature has risen. Since low temperature and moisture result in slow liberation of phosphine from the solid aluminum phosphide, there is a danger that unreacted product could remain within the grain mass for an extended period of time. As a result, unreacted product could begin reacting when the grain rewarms during the spring or when the grain is being moved. This could endanger the lives of those working around the grain in the bin as it is being emptied, in transport vehicles, and/or at the receiving site where the grain is being unloaded.

Once the phosphine gas is liberated from the solid, temperature also influences how rapidly the gas will be distributed throughout the grain mass being fumigated. The relationship once again is a direct relationship where the colder the temperature, the slower the gas will be distributed, and the converse, the warmer the temperature, the faster the distribution.

Temperature also influences insect activity. Insects decrease their activity as temperatures decline. As their activity level declines, they respire less. As they respire less, they will take less fumigant into their systems. Thus, low temperatures will have a negative impact on the success of the fumigation.

Temperature influences several aspects of the fumigation process. Since most things in the fumigation tend to occur more slowly as the temperature declines, the minimum exposure time for a fumigation to occur increases. At the coldest allowable temperature range for fumigating with phosphine gas, a fumigation will minimally require 8 (pellets) to 10 (tablets) days to complete. And a final word on temperature, according to the user's

manual for phosphine gas, fumigations should not be attempted below 40°F. There are too many negative impacts on fumigation success at that temperature and below.

Target Pests and Target Commodities

Phosphine gas is registered for use against numerous species of insects which infest stored commodities and the control of select burrowing mammals. Phosphine gas has been found to be effective against the following insects in all stages of their lives: almond moth, Angoumois grain moth, bean weevil, bees, cadelle, cereal leaf beetle, cigarette beetle, confused flour beetle, dermestid beetle, dried fruit beetle, dried fruit moth, European grain moth, flat grain beetle, fruit flies, granary weevil, greater wax moth, hairy fungus beetle, Hessian fly, Indian meal moth, Khapra beetle, lesser grain borer, maize weevil, pea weevil, Mediterranean flour moth, pink bollworm, raisin moth, red flour beetle, rice weevil, rusty grain beetle, saw-toothed grain beetle, spider beetles, tobacco moth, yellow mealworm, and Africanized bees & honeybees infested with tracheal mites. Unfortunately, there have been some reports of potential development of resistance in a few of the above listed insects. Vertebrate pests for which phosphine gas is registered include: woodchucks, yellowbelly marmots (rockchucks), prairie dogs (except Utah prairie dogs, Cynomys parvidens), Norway rats, roof rats, mice, ground squirrels, moles, voles, pocket gophers, and chipmunks. However, the use of phosphine gas for woodchuck (groundhog) management in Ohio is prohibited.

In the farm grain bin, the primary target for fumigation are the insect pests that attack sound grain and develop in the interior of the grain such as grain borers and weevils. Fumigation in these cases is recommended as a rescue treatment. For many of the other insect pests listed above, other actions are recommended before fumigation such as moving, cleaning and treating the grain with a standard insecticide.

Phosphine gas is registered to treat raw agricultural commodities, animal feed, animal feed ingredients, processed foods, and non-food commodities. Detailed lists of the products that can be treated with phosphine gas are found in the user's manual. On the farm, the primary targets of fumigation are typically wheat, corn and soybeans.

Dosage Rates

The Applicator's Manual lists the maximum allowable dosages for fumigation with aluminum phosphide tablets and pellets. It is important not to exceed these dosages because of the increased hazards associated with too high of concentrations of phosphine gas in confined areas (i.e. potential spontaneous explosions and excessive corrosion of certain metals). The following is directly from Section 8 of the Applicator's Manual:

Max. Allowable Dosages for PHOSTOXIN® Fumigation

Product	per 1000 cu.ft.*	per 1000 bu.*
Pellets	725	900
Tablets	145	180

*NOTE: Maximum Dosage for dates, nuts & dried fruits is 200 pellets/40 tablets/1000 cu.ft. OR 250 pellets/50 tablets per 1000 bu.

- **Maximum allowable dosage rate for Rodent Burrows is 10-20 pellets per burrow OR 2-4 tablets per burrow.**
- **Maximum allowable dosage rate for commodity in small containers – 1-2 pellets per 10 cu.ft.**

As tempting as it may seem, adding higher dosages of aluminum phosphide to a fumigation typically does not significantly shorten necessary exposure times to shorten how long a structure needs to remain sealed and inaccessible. The Applicator's Manual lists multiple dosage ranges for numerous types of fumigations. For on-farm, grain-storage bins, the dosage ranges are as follows:

	Dosage Range	
Fumigation	Pellets	Tablets
Farm Bins	450-900/1000 bu.	90-180/1000 bu.
(Butler Type)	350-725/1000 cu.ft.	70-145/1000 cu.ft.

When fumigating an on-farm, grain-storage bin, one needs to calculate the dosage of tablets or pellets to be applied based on type of structure, volume of the area within the structure in which the fumigant is permitted to circulate, sealing properties of the structure, content type, expected weather conditions, commodity temperature, moisture content of the commodity, and the planned duration of the fumigation. Once the dosage has been calculated, the fumigant may be scattered over the surface or probed into the grain using a rigid PVC pipe about 5-7' in length and having a diameter of 1 1/4". The dosage should be divided such that 20-50 tablets or 100-250 pellets be used per probe and distributed uniformly over the surface. Volume of the structure can be reduced by covering the surface of the grain with a plastic tarpaulin and being certain to seal the edges of the tarpaulin to the walls of the bin. A portion of the dosage should be reserved to place under the bottom of the bin if the bottom of the bin is open to application (i.e. aeration floor or aeration duct). Place no more than 25% of the total dose at the bottom. Before introducing pellets or tablets into aeration

ducts or floors, be sure there is no standing water present. Mixing aluminum phosphide and standing water may result in violent, rapid reaction and fire.

Protective Clothing

Basic worker protection clothing is required for handling phosphine with the addition of dry cotton gloves if the aluminum phosphide product or ash residue is to be touched.

Respiratory Protection

Respiratory protection equipment is required when working with fumigants such as phosphine. Minimal respiratory protection equipment is required under very limited conditions. In most instances, Self-Contained Breathing Apparatus (SCBA) will be necessary. **SCBA respiratory protection is required when concentration levels of phosphine are unknown.**

A NIOSH/MSHA approved full-face gas mask equipped with phosphine canister(s) may be used at levels up to 15 ppm or following manufacturers' use conditions instructions for escape. Above 15 ppm or in situations where the phosphine concentration is unknown, a NIOSH/MSHA approved, SCBA must be worn. Facial hair and/or shape of one's face may prevent proper fit of the respiratory protection and disqualify a person from working with fumigants.

If aluminum phosphide is to be applied from within the structure to be fumigated, an approved full-face gas mask with phosphine canister(s) or SCBA or its equivalent must be available at the site of application in case it is needed. Respiratory protection must also be available for applications from outside the area to be fumigated such as addition of tablets or pellets to automatic dispensing devices, outdoor applications, etc.

Gas Detection Equipment

There are a number of devices on the market for the measurement of phosphine gas at both industrial hygiene and fumigation levels. Glass detection tubes used in conjunction with the appropriate hand-operated air sampling pumps are widely used. These devices are portable, simple to use, do not require extensive training and are relatively rapid, inexpensive and accurate. Electronic devices are also available for both low level and high phosphine gas readings. Such devices must be used in full compliance with manufacturers' recommendations.

Placarding of Fumigated Area

All entrances to the fumigated structure must be placarded. Placards must be made of substantial material that can be expected to withstand adverse weather conditions and must bear the wording as follows:

1. The signal 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). If incompletely aerated commodity is transferred to a new storage structure, the new structure must also be placarded if it contains more than 0.3 ppm. Workers exposure during this transfer must not exceed allowable limits.
4. The date the fumigation begins.
5. Name and 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.

All entrances to a fumigated area must be placarded. Where possible, place placards in advance of the fumigation to keep unauthorized persons away. Do not remove placards until the treated commodity or area is aerated down to 0.3 ppm hydrogen phosphide or less. To determine whether aeration is complete, each fumigated structure must be monitored and shown to contain 0.3 ppm or less phosphine gas in the air space around and, if feasible, in the mass of the commodity.

Once the all clear has been established, placards need to be removed. Leaving old fumigation placards on bins and other structures for long periods of time beyond the fumigation time may lead to persons becoming immune to the alert and not paying attention to the placards in the future. A fumigation is not complete until the placards are removed.

Safety

Working around grain bins is a dangerous job. One should never work alone. The more safety measures that are taken the better off all will be. Bin stairs are ideal. Grain entrapment is also a major concern. Have lock-out equipment so no one can accidentally turn on grain augers while people are inside of bins. Entrapment in flowing grain occurs in a matter of seconds.

References

- Carol Jones, James Hardin, and Edmond Bonjour, Oklahoma Cooperative Extension Service, Design of Closed-loop Fumigation Systems for Grain Storage Structures.
- http://pods.dasnr.okstate.edu/docushare/dsweb/Get/Document-7486/BAE-1111web.pdf

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