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Fumigation for the Commercial/Noncommercial Pesticide Applicator: Revision of the 3rd Edition, 2011

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Nebraska Category 11 Manual

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Introduction & Scope (Section 1)

The primary purpose of this manual is to prepare candidates interested in becoming certified pesticide applicators in Nebraska Category 11, Fumigation. This category includes commercial and non-commercial applicators who use or supervise the use of restricted use pesticides in solid or gaseous formulations within enclosed tight spaces such as tents, vaults, tarped stacks, structures, vehicles or vessels for a wide variety of conditions or commodities, including raw agricultural products.

Candidates for Category 11 may also be interested in pursuing certifications in Category 8, structural and health related pest control, Category 8(a), wood destroying organisms, Category 9, Public health pest control, or Category 9(a) Chlorine products use. Other manuals should be consulted for the broader areas of competency expected in those categories, but this manual will touch on fumigation opportunities.

Not included in the scope of this manual is soil fumigation, Category 1(a).

The greatest demand for fumigation is for commodities, food products and food processing facilities. Target pests are mostly stored product insects and to a lesser extent rodents. There is occasional demand to fumigate wood materials, furniture, art objects, and household goods to control wood borers, stored product insects and perhaps bed bugs. There is also some demand for a new kind of fumigation with sterilizing gases to decontaminate pathogenic microorganisms from food processing, medical and research facilities.

Fumigation is a deadly serious enterprise with highly toxic gases, although most fumigators have long healthy careers following safety precautions and proper protocols. High-profile tragic accidents have occurred in recent years - some involving innocent children, and all involving unqualified applicators and off-label applications. These incidents have focused regulatory attention on fumigation like never before. Label requirements and safety precautions are becoming more stringent.

Fumigation is one of the smallest and more specialized categories of certified applicators. Increasingly fumigation is becoming limited to a professional service. Many fumigators cover regional territories and maintain certifications in multiple states. Achieving certification in Nebraska Category 11 should be viewed as a minimum or mid-level indicator of competency. Experience and increasing levels of responsibility and management are also needed to be fully qualified. There are always new things to learn. Experienced fumigators have the amazing ability to assess how invisible clouds of gas are moving and behaving in a space and often manage those movements to their fumigation advantage.

Stewardship training requirements of fumigant manufacturers

Several fumigant manufacturers impose their own stewardship training requirements over and above state certification for users as conditions of product sale. Stewardship training goes beyond the general education in certification training and addresses many specific hazards, precautions, and procedures associated with a product. Manufacturer stewardship programs often assure availability of specialized safety equipment, and that it is in good repair. Product stewardship helps keep use restricted to qualified applicators and ultimately fewer accidents, longer product life and better customer satisfaction.

Fumigant products all feature package labels with very basic information, as well as much more extensive Applicator Manuals that also have the full legal force of labels. Applicator Manuals contain a wealth of specific product guidance and information on all aspects of product use that far surpasses the general information in this certification manual.

Fundamentals of effective fumigations (Section 2)

Objectives:

- Define a fumigant.
- Distinguish between fumigation and aerosol space treatments.
- Understand three factors that affect the performance of all fumigants.
- Understand meanings and concepts of "CT values", "equilibration", and high concentration fumigant monitoring.

Fumigants are pesticides active in the gaseous state. The gas may come from a solid formulation reacting with humidity in the air, from a compressed gas cylinder, or a generation process brought to the site. Common fumigants are highly toxic by inhalation. In addition to toxic hazards equipment malfunctions can potentially cause injuries ranging from freeze burns, burst hose hazards to eyes, or foot injuries from extremely heavy product cylinders, so a variety of protective equipment is necessary. Damaging reactions or fire hazards can occur if proper precautions and protocols are not followed.

Fumigations are fundamentally space treatments where a dose or concentration of gas is introduced into a space with the expectation that it will disperse evenly *and penetrate* materials and deep harborages to kill pests. The pests can be insects, rodents, or pathogenic microbial organisms. There are parameters for lethal concentrations that must be maintained, exposure time requirements, temperature and sometimes humidity. At the conclusion of a fumigation the fumigant gases are usually released to the atmosphere and dissipate quickly from the fumigated space and materials without leaving any meaningful residue. There is no residual performance from a fumigation aside from dramatic reduction of target pest numbers until their populations can rebound. Fumigation is the only practical way to control certain pests that remain deeply hidden and do their damage within commodities, lumber, and structures.

Fumigation should not be confused with other kinds of space treatments employed in pest management such as aerosol or fogging treatments which are tiny liquid droplets or smoke dispensed into the air. These should NOT be referred to as fumigations, although there is confusion on that point among the general public. These tiny droplets or smokes originate as liquid products applied through mechanical devices, or as pressurized aerosol formulations. They hang in the air briefly to contact exposed insects and may move with air currents to some extent under obstructions. Particles fall out of the air within minutes. Certain ingredients for these space treatments, especially insect growth regulators, have residual performance. No aerosol treatment has the *penetrating* capabilities of a fumigation into packaging, commodities, or deep harborages.

Effective fumigations require certain inter-related parameters of concentration, exposure time, and temperature.

Temperature conditions define how receptive or susceptible target pests are to fumigants, and how fumigant molecules behave in a space. Below about 40 F some fumigants will have difficulty reacting to produce gas. Below about 60 F most insects are not active and respiring enough for good performance. Most fumigations are effective and conducted in temperatures between about 70 and 95 F. Higher temperatures in this range can often allow shorter exposure times and lower dosages.

Fumigant concentration in the fumigated space will be a function of the dose that was applied and the ability of the space to hold the gas. Computing the volume of the space to be fumigated is a key component for determining the dose, along with expectations or allowances for leakage, and pest and temperature information. A certain amount of leakage is inevitable in most fumigations.

There are different ways to manage fumigant leakage and still achieve good results. The best method is to monitor the high concentration fumigant concentration in the fumigated space with remote sampling and gas detection equipment. Supplemental gas can be added to a space in some circumstances to maintain concentrations. High concentration monitoring may also alert a fumigator to an unexpected level of gas loss and a serious leak that needs to be repaired. Another method used with solid phosphine formulations especially is to compensate for anticipated leakage with higher dosages applied at the outset.

Equilibration, or achieving uniform concentrations throughout a fumigated space is another key requirement relating to concentration. Fumigant gases do not penetrate or disperse as evenly as people expect. Fans will be positioned throughout many fumigated structures to move the air and mix the fumigant gas as uniformly as possible. Fumigant movement and penetration through masses of commodities such as grain can be especially challenging, and an unknown factor unless there is good high concentration monitoring. Grain fumigators will try to harness natural convection currents of air rising or sinking through grain, or forced air recirculation systems to move fumigant uniformly through grain.

Exposure time is the time necessary for pests to be exposed to a fumigant concentration for lethal effects. Some fumigants can be effective in as little as several hours if concentrations are sufficiently high. Phosphine tends to have a greater time requirement, or minimum exposure time, than other fumigants. In some situations very long fumigation exposure times are recommended to allow insect pests to advance to more susceptible life stages.

Concentration x Time, or a "CT value" is a target for successful fumigation, or expression of what was achieved. Concentrations are often measured as parts per million (ppm) and time by hours of exposure for an expression of ppm-hours. CT target values for effectiveness are determined by laboratory studies. Gas detection monitoring equipment is necessary to measure concentrations in fumigated spaces periodically during the exposure period. Pest species vary in their susceptibility to different fumigants and depending on their life stage. Insect eggs, for example, do not respire as much as active larvae or adults, so the egg stage is often more difficult to kill. Red flour beetle, for example, is a relatively difficult species to control so is a standard in many efficacy studies.

All fumigant labels address the variables of temperature, concentration, time, and target pests. Sulfuryl fluoride products go beyond traditional paper labels and do the best job of dealing with these variables by utilizing a computer software program that is recognized as having the force of a label. Basic information such as the current temperature, target pest(s) and life stages, volume of the space, and leakage expectations enables the program to prescribe a starting dose. Entering high concentration monitoring data tracks leakage and helps determine the need for correcting leaks or adding supplemental gas. The monitoring data and computer program keeps the fumigator informed about CT value achievements.

Other fumigant labels provide more general guidance for dosing according to the structure type, commodity (penetration characteristics), temperature and time requirements. Fumigants packaged in cylinders, or fumigant gas generated on site – when used in conjunction with high concentration monitoring offer a simple means to quickly add supplemental gas to a space to maintain concentrations necessary to achieve a successful CT value. Solid phosphine formulations take time to react and produce gas. It is not practical to add solid phosphine formulations to a space or commodity after a fumigation is underway. Label dosage advice for these formulations prescribes dosages to compensate for leakage according to some general characteristics of different containment structures.

Aeration is the process at the conclusion of a fumigation exposure period to open the space and allow the fumigant gas to dissipate. A great deal of emphasis is placed on sealing spaces to be fumigated to hold gas, but planning for aeration is equally important! Most fumigants dissipate fairly quickly, but certain commodities or circumstances are slower to aerate, creating lingering safety hazards (See off-gassing, section 3). Low concentration gas detection devices specific for the fumigant gas are used to check spaces and commodities to determine that fumigant gas has dissipated to safe levels for personnel to re-enter without protective equipment. The same low concentration gas monitoring equipment is used to monitor areas for safety where personnel may be working outside, but in the vicinity of a fumigated space, and for monitoring around the perimeter of fumigated spaces for leakage during the exposure period.

Fumigation ***has no residual efficacy*** aside from the reset of pest populations to near zero, and time it will take for population rebound. Re-infestation can occur immediately. Certain fumigation operations will often include residual insecticide applications around perimeters to slow the pace of re-infestations.

Diversity and Methods of Fumigation (Section 3)

Objectives:

- What are some challenges in achieving effective fumigations of grain?
- Why is entry into grain bins a safety hazard?
- What is “off-gassing”?

A wide variety of spaces and methods of gas introduction and containment can be used for fumigation. Fumigations are often characterized by the kind of space, commodity, sealing method or containment being used. Fumigators have developed special skills for safely and efficiently conducting fumigations of different kinds. Following are some of the categories and special hazards and considerations of each.

<u>Bulk Commodity Fumigations</u> usually involve commodities that have been placed in a storage structure like a grain bin, flat storage building or commodity being stored in a bunker under a tarp. Phosphine is most commonly used for commodity fumigations, but sulfuryl fluoride may also be used. Phosphine tablets or pellets may be added to grain streams during storage loading resulting in distribution throughout the grain mass. Storages may feature unknown

conditions throughout a grain mass affecting fumigant penetration. Many grain bins do not hold gas well due to inter-bin vents, lap seams, open eaves and roof vents. Recirculation is best for most reliable penetration and equilibration, however the recirculation system needs to be gas-tight! Monitoring high concentration fumigant gas levels for efficacy is also very difficult unless there is a working recirculation system. See more details on recirculation in Section ___.

A number of grain companies are building bins specifically for fumigation that will be tight with proper recirculation.

Fumigations conducted after a grain mass is in place may involve a variety of application methods:

- Application to grain surfaces or probing tablets or pellets at different depths into a grain mass. Walking on grain for any purpose, especially within grain bins is less frequently done than previously due to grain entrapment and confined space safety hazards. Within a bin or tight vessel the hope with surface application of fumigant would be either adequate passive diffusion into the commodity, or capture of gas in the headspace with a recirculation system to re-direct gas up from the bottom of the grain mass. Probing tablets or pellets into a grain mass dramatically assists in penetration via passive diffusion.
- Split dosing between the top and bottom of a bin may be an attempt to achieve passive penetration from both directions, or it may be done in conjunction with recirculation.
- Grain fumigations with cylinderized phosphine or sulfuryl fluoride products will usually be done with gas introductions into aeration systems, subfloor plenums, or recirculation sytems.

  Off gassing is the slow aeration of certain bulk or packaged commodities that can result in unexpectedly high and dangerous exposures to workers in the vicinity of recently fumigated materials.

- Grain that has been fumigated in an elevator bin may be thought to be aerated, but gas will continually seep out for a period of time. A gallery or tunnel space closed without ventilation can accumulate dangerous concentrations of gas. Workers need to be equipped with safety monitors.
- Flour fumigated in railcars prior to shipment to bakeries will be slow to aerate phosphine gas. Typically the headspace of railcars will be aerated, but the real aeration of the flour will occur with the pneumatic transfer of flour into holding bins, and exhaust of that gas through air handling systems. Work areas near transfer ducts and receiving bins need to be monitored for safety.
- Certain grocery products fumigated in trailers. Trailers will be monitored prior to release for unloading, but phosphine fumigant labels also advise holding grocery products an additional 48 hours before distribution to consumers.
- Certain materials in a food processing plant – pallets of cardboard packaging materials, for example, might have a tendency for slow aeration. Experience will reveal materials to be especially diligent to check with gas detection equipment.

Structural Fumigation might refer to a structure used for food processing and full of equipment, ingredients and finished products, or a warehouse. Products may need to be assessed for their suitability to remain in the space during fumigation, or certain fumigants limited because of reactive metals or other reasons. Food processing structures can be ten stories or more high, and processing areas or warehousing may involve millions of cubic feet of space. Sulfuryl fluoride will be the most common fumigant used for both residential and food processing structural fumigations. Phosphine will be used in certain more limited food processing situations, especially fumigation of bulk raw ingredients and certain bins.

Gas is released from outdoors and introduced through hoses distributed to lots of release points throughout a structural space. Fans are deployed liberally at release points and throughout the structural spaces to mix fumigant gas with air and achieve uniform mixing. Sample hoses for remote monitoring of gas concentration are placed throughout the spaces. The stage is set to monitor concentrations and to add gas when and where needed.

Most food processing structures can be sealed with poly sheeting, poly bags, tape and glue to seal every door, window, ventilation fan and rooftop fixture.

Refrigerated areas can present challenges in food processing plants that need to be addressed during fumigation planning. Fumigant gases derive energy from the temperature in the space they are in that influences how actively they diffuse. If gas molecules are diffusing through a warm space and suddenly come to a much colder zone they will pause and lose their energy in that cold zone. More gas molecules follow and a zone of more concentrated gas develops. When it is time for aeration that sluggish zone of fumigant gas won't have the energy to dissipate so it presents an aeration challenge. The best solution is planning to empty refrigerated areas and bringing them up to ambient temperature before the fumigation. There may also be an option to seal cold areas to prevent fumigant entry. This phenomenon can be an issue with very large cold rooms, or appliance-sized refrigerators.

Aeration Safety Concerns in the Future

Food plants are often located in populated areas with neighborhoods nearby. The prospect of large volume structures containing a high concentration of fumigant gas is an increasingly concern to pesticide regulators. Methyl bromide is hardly relevant any longer but reregistration has gone forward and new labels are in place for buffer zones around fumigations, and protocols during aeration to prevent dangerous drift to neighbors. Often aeration is managed in such a way that gas is exhausted from the roof of structures and high elevations to promote good air dilution to safe levels in the air. Temporary exhaust stacks (perhaps poly duct suspended by a crane) have been prescribed in some places to further elevate fumigant exhaust. Be aware that buffer zones and extraordinary aeration protocols may be a factor in the future, and the greatest impact could be at food processing plants in populated areas.

Residential Structures historically have been tarped and fumigated for pests such as drywood termites in southern parts of the U.S. Qualified pest control operators are finding situations in non-traditional areas of the country where Vikane fumigation is the best option for controlling bed bugs and possible other pests. The concentration x time (CT) value for bed bug efficacy is sufficiently low that tarping is not necessary. There are elevated concerns with fumigation of any residential structure to be sure it is evacuated, secure from re-entry, and absolutely aerated completely before residents can re-enter.

Tarp Fumigation could be a tarp over a complete building – large or small, or a tarp over some quantity of product or equipment to reduce the volume of space necessary to be treated. A tarp could seal something for fumigation indoors or out, or be used to hold gas better than a particular structure.

Trailer Fumigations or shipping containers are simple chambers that are readily available and easily loaded with certain kinds of products or materials for fumigation. Trailers or containers under fumigation are not permitted on public roads. They are normally fumigated in a stationary position for the duration of exposure. Refrigerated trailers are best for this purpose – tighter, metal floors, and the temperature control unit might be used to heat in certain circumstances.

Chamber Fumigations usually refer to specialized rooms or vessels devoted to fumigation. Sometimes these specialized chambers will have equipment to draw a vacuum, permanent plumbing for fumigant introduction, possibly fumigant gas re-capture, and exhaust features.

Ships, Barges, and Railcars have unique advantages of being able to be fumigated in transit. Ships may be variable in their suitability for in-transit fumigation due to crew safety concerns. Export grain is often fumigated at terminal storages before loading rather than on board ships. Several different designs of railcars are commonly fumigated in transit to assure that customers do not receive infested products. Some measure of protection is also desired from pest invasion over the course of long journeys and uncertain conditions at railyard stops along the way. Strict safety rules apply for working on or around ships, barges or railcars.

Quarantine Fumigations refer to the purpose for certain fumigations for products being imported or exported to prevent spread of threatening organisms. These fumigations are often supervised by government authorities. Certificates of fumigation according to specific standards may be needed among shipping papers for exported materials when they reach an import border, or fumigation may be done upon arrival. Fresh fruit and other products are fumigated at ports of entry before produce is released into the U.S. Ships are unloaded onto large areas of warehouse floors marked like parking lots. A vinyl tent suspended from the ceiling is lowered over the produce and the bottom sealed to the floor with weighted tubes. The tent has features built in somewhat similar to a fumigation chamber for automated gas introduction and aeration. Quarantine fumigations may be conducted pre-shipment in a stationary vehicle, shipping container, or facility, or possibly in-transit for rail or ships. Miscellaneous equipment and freight is sometimes crated for shipment, and too late it is discovered that the wood packing materials require certain heat or fumigation treatments for export to a certain country. It would be better to purchase properly certified lumber from a pallet supplier for the crating.

Passenger Vehicles such as aircraft, railroad passenger cars, automobiles, buses, truck cabs with sleepers, and even forklifts have been fumigated on occasion. Bed bugs have been the targets in a number of cases.

Microbial Decontaminations. In 2001 a disgruntled government employee contaminated several government buildings in the Washington, D.C., area with anthrax pathogen. EPA recruited experts in the field and the first large-scale microbial decontamination fumigations were conducted using chlorine dioxide gas. Chlorine dioxide (CD) has a long history in liquid form used for water treatment, process cleaning in place (CIP) operations and a wide variety of sanitizer products. Chlorine dioxide gas is unstable and not suitable for packaging in cylinders; CD has to be generated on site for use. Several methods have been developed to generate CD. Several companies offer decontamination services for large spaces nationwide as well as selling specialized equipment, and supplies for laboratory equipment sterilization. Effectiveness of decontamination treatments is expressed in an unfamiliar way due to huge population numbers for microbes.

Six log reduction is the goal and standard for EPA designation of chemicals as "sterilants", that is 1 survivor out of 1,000,000. Gas sterilization has capabilities far exceeding liquid treatments and flexibility for treating complex equipment that cannot be disassembled and decontaminated any other way. The technology is appealing in medical and veterinary research labs, pharmaceutical facilities, and now food processing. The operational aspects of treatments are very similar to traditional fumigations with the exception of a humidity requirement of about 60% RH. Spaces can be sealed or materials tarped with common sealing or tarping materials. Gas is introduced and monitored to reach a CT of 760 ppm-hours for efficacy. Bioassay methods are available to check treatment quality as well.. Low concentration safety monitors are used for leak detection or aeration. Aeration is to the atmosphere. Food processing facilities have been treated from small rooms and spiral freezers, to nearly a million cubic feet. CD gas decontamination treatments are not intended for food products at this time, and the intention is surface decontamination with the capability to penetrate scratches and equipment assemblies that can harbor pathogens, but not penetrate quite like a traditional insecticidal fumigant. Research is underway on insecticidal potential for CD treatments.

Chlorine dioxide is a noxious chlorine-like gas with definite inhalation hazards to applicators and bystanders.

IPM (Section 3)

Objectives:

- Explain the variety of techniques that are integrated in IPM
- Explain integration of different people and departments in successful IPM programs.
- Explain whether fumigation is reactionary or preventative.

There was a time when people saw a pest and asked, “What should I spray?” Now the question is more likely about identification, if it’s a threat, and what can be done to prevent it. There was a time in the past when certain kinds of food processes fumigated their facilities 3 or 4 times annually. It was more economical to fumigate than clean. Now mills are fumigated much less frequently and some have gone many years without fumigation. Fumigation is very necessary and routine in some facilities but for others it is a fairly drastic last resort.

The “IPM Pyramid” is a graphic presenting the concepts of integrated pest management in the food processing and commodity industries…

(Graphic: “IPM Pyramid” Triangle pyramid with horizontal lines defining zones from bottom to top…)

The base is pest ID and understanding some pest biology. Facilities of similar types tend to have similar challenges so one can plan at the outset for a certain number of key threats. Monitoring and experience will confirm or correct the emphasis. Biological information will contribute to the next step on the pyramid: sanitation.

The function of sanitation is to deprive pests of the things they need, food, water, and harborage, and a cleaning schedule that will break life cycles. Biological information about key threats will identify habitats, key food preferences and other things the sanitation manager might do to make his facility less attractive to pests.

Inspection again draws from biological information to teach staff identification of different life stages, signs, symptoms, type of damage and conducive conditions.

Trapping is a control method for some pests: rodents, flying insects in insect light traps, and stored product pests in pheromone traps. It is not enough to simply trap pests, but identify and count them. The essence of monitoring is analysis of the data. That analysis will point to harborages, exclusion and sanitation deficiencies that can be corrected.

Exclusion and physical controls refers to tasks like tackling the harborage issues, use of heat, cold and other non-chemical tactics.

Pesticides occupy the small but important capstone on the pyramid. Sadly, sometimes sanitation schedules cannot be maintained, and exclusion and harborage issues are not resolved. Pesticides sometimes compensate for shortcomings that cannot be addressed.

Pesticides represent another whole toolbox of ingredients, formulations, methods, and techniques to optimize performance. Fumigation is one kind of tool among many. Fumigation might be the best option, but there might also be very high costs associated with facility down time.

Another lesson to be taken from the pest management pyramid is about communication and teamwork. Each step on the pyramid has a contractor or department with primary responsibility, and a couple might have shared responsibilities. Not only do technical aspects of IPM need to be integrated, but also people need to be led and coordinated. Good communications are essential.

IPM Success story:

A certain cereal plant a dozen years, or so, ago had chronic infestations. They had three fumigations annually, down time for each, and lots of inefficient and ineffective pesticide applications. The situation got turned around with buy-in by all concerned. A good trapping and monitoring effort pointed to harborages and the maintenance department worked on fixing them. Pesticide applications became more preventative than reactionary. Sanitation was maintained at a good level. Infestations were brought under control, fumigations were eliminated for a number of years, and about 10 days annually of run time for the plant was regained.

Fumigation has been the mainstay of stored grain pest control. A little more *management* would be good in the future to foster better quality fumigations and to preserve the fumigation tools we have. The general management scheme for maintaining grain quality is to dry grain to a level that will inhibit most insect and mold growth, and then to cool grain to low temperatures that will also limit biological activity. Air spaces between kernels of grain serve to insulate a grain mass and its temperature can mostly stay cold even into a following summer. However, elevated moisture conditions can get into the grain by different means:

- Weed seeds and debris that did not dry like the grain.
- Structural water leaks or condensation along bin walls.
- Insect activity and moisture created by their bodies and metabolism.

Moisture allows insect and mold growth. Biological activity creates heat. Heat encourages more biological activity and a vicious cycle begins. Grain is often remotely monitored for development of internal hot spots. Grain is not often monitored specifically for insects except when it is moved, bought or sold and subject to grading. Fumigation has been reactionary. Grain storages have not always been in good condition for quality fumigations. High concentration fumigation monitoring has usually been lacking, and penetration characteristics of fumigant through grain masses have been unknown.

Resistance to phosphine by certain key insect pests of stored grain seems to be increasing. When resistance is suspected there is always a question if it is really resistance, or recognition of poor application techniques contributing to control failures. Whichever it is, more recirculation capability, high concentration fumigant monitoring, and a variety of preventative sanitation measures would be positive developments.

Pest ID and Biology (Section 4)

(Existing material is mostly fine.) A few possible additions to the commentary-

Intro to Common pests of stored commodities

Work into intro:

There are several dozen stored product insects that are fairly common, and about ten that are truly serious due to damage or extreme numbers. Many of the insect species found in grain are non-damaging scavengers. Stored product pests are the target of most fumigations.

Internal feeders, add: Internal feeders are the most serious threat to intact kernels in good condition which is fairly immune from most grain insects. Internal feeders provide access and create debris for many other species which can then begin the downward cycle of quality deterioration with metabolic moisture, molds, heat and more insects.

Lesser grain borer, add: LGB can thrive in lower moisture grain than other species. This is one of the reasons it is the worst pest of wheat in storage.

Weevils, add: Weevils prefer grain with higher moisture content so corn will be especially attractive.

Indianmeal moth, add: Silk can accumulate into masses capable of clogging equipment. IMM are considered the worst stored product pest for consumers.

Red and Confused Flour beetle, add: Red flour is considered the worst pest in milling and baking flour systems, and also one of the most difficult to control. RFB is the species used in most bioassays to measure insecticide treatment efficacy.

Add to list: Foreign Grain Beetle: Closely resembles flour beetles but about 2/3 the size. Red/brown color, clubbed antennae. Notice distinctly round eyes separated from the compound eyes, and distinctive bumps like shoulder pads on the forward corners of the thorax. The FGB is a fungus feeder. It can be present in swarming numbers in late summer near grain facilities if grain has spilled and gotten moldy, or if bins have been cleaned out exposing grain that is out of condition.

Some insects primarily feed on mold so they are indicators of moisture conditions:

- Hairy fungus beetle
- Foreign grain beetle
- Mealworm beetles
- Psocids

Conversely, certain food materials are magnets for certain species so you can anticipate certain threats or know where to look to find hot spots of activity. Pet foods, for example, contain higher fat and protein levels than other kinds of grain based products, or certain slaughterhouse waste ingredients. Red legged ham beetles and Dermestid beetles of all kinds, including some that specialize in slaughterhouse wastes will be more prevalent around pet food or their production facilities.

The moisture content of different grains, or locations in storages will tend to have different distributions of insects: Lesser grain borer can tolerate dryer grain such as wheat, especially at dry bin top locations. Weevils would tend to have more affinity for corn or moist tunnel locations of elevators. Indianmeal moth will tend to be most numerous on grain surfaces. Many of the tiny beetle pests of grain get mixed well into the grain mass during the course of grain handling and they can survive throughout the grain mass.

Common Fumigants (Section 6)

Objectives:

- What are some forms of labels that are not necessarily attached to a fumigant package?
- What are some fire hazards associated with fumigants?

As with other types of pesticides fumigants come in a variety of formulations and offer a remarkable variety of application options and uses. Every fumigant has peculiar characteristics and unique hazards. Fumigants normally have very brief package labels to identify the product and provide very basic safety and transportation information. Product specific *Application Manuals* have the full legal force and are the complete label documents.

Hydrogen phosphide, aka PH_3, Phostoxin or phosphine

Phosphine is a colorless gas with a characteristic garlic, carbide, or decaying fish odor at low concentrations. Odor should never be relied upon for gas detection or safety determinations. Odor characteristics may not always be consistent, and dangerously high concentrations can deaden the sense of smell. Nevertheless, some warning odor is a good thing. Phosphine gas is very slightly heavier than air. Phosphine is the commodity fumigant of choice worldwide due to its relatively low cost and convenient handling and application options. A very extensive list of commodities, food ingredients and food products are specifically listed on phosphine labels, as well as another extensive list of non-food materials.

Phosphine gas is corrosive to copper and precious metals, which includes electronic equipment. This limits phosphine fumigations to commodities and fumigation enclosures that will not have sensitive metal exposures. Phosphine gas also has the remarkable attribute of being spontaneously combustible at 17,900 ppm (1.79% by volume) in air. Properly conducted phosphine fumigations should never come close to a combustible gas concentration. One phosphine product is formulated in combination with CO_2 and is non-flammable under all circumstances.

Phostoxin brand aluminum phosphide was introduced in the 1960's, featuring unique solid "pills": pellets with 0.3 grams phosphine gas potential each, and tablets with 1.0 gram gas potential. Phostoxin brand is still viable but the name has taken on a generic meaning for these pills which are mostly from other manufacturers now. Packaged in airtight flasks, this formulation reacts with humidity in the air to produce phosphine gas and an inert aluminum hydroxide waste. These pills can be dropped onto a grain stream as bins are being loaded resulting in distribution throughout the grain mass, or there are methods for applications onto grain surfaces, incorporated into grain at different depths, or dosages divided between tops and bottoms of bins. Formerly in the U.S., and still internationally these formulations are placed on trays, etc. and used to fumigate tarped stacks of bagged products. Spent aluminum hydroxide waste may remain in grain where cleaning operations will eventually remove it.

Magnesium phosphide is similar except it reacts and releases gas much faster than aluminum phosphide. Magnesium phosphide has been favored for certain circumstances where exposure time was limited, or temperature was getting low.

Aluminum and magnesium phosphide products are placed within fumigated spaces.

For fumigations other than grain the spent fumigant material needs to be removed. Conveniently sized packages for dosing have been developed to contain the waste and facilitate easy removal, deactivation and disposal. Improper handling of so-called spent fumigant waste that still had some phosphine reaction potential has caused many small fires and incidents. So-called spent solid fumigant waste packages must always be given air space between packages and never confined in something like a plastic bag or pickup truck cap. Phosphine most often accumulates to spontaneously combustible concentrations in these kinds of inadvertent confinement situations.

Whereas solid phosphine formulations react with humidity to produce gas, there are also hazards if liquid water contacts a solid fumigant. A little liquid water is massive compared to humidity in the air and a very rapid gas reaction can produce combustible concentrations. This is another opportunity for igniting fires, or an unexpected consequence of firefighting with water. Storages for these products need to have appropriate NFPA signs and symbols to alert firefighters NOT to use water.

Phosphine gas packaged as liquefied gas in cylinders was developed and sold in Australia for a number of years before being launched in the U.S. about 2003. Eco2Fume is ready to use 2% phosphine gas and 98% CO_2. It has no flammability potential and no waste to create issues with flammability, recovery and deactivation. Cylinderized phosphine products are dispensed from outside fumigated spaces.

Discharge flow rates of Eco2Fume are regulated to manageable rates with restricted nozzle orifices, so that product can be dispensed by weight. Several years after Eco2Fume, VaporPHos, a 100% phosphine gas cylinder product, was launched. This product is used in conjunction with a specialized machine to safely blend phosphine with air to dispense a non-flammable concentration of phosphine gas. The air blending unit can be set to dispense a desired dose.

Phosphine underwent an extremely lengthy reregistration process that concluded in about 2004 that had label requirements calling for written "Fumigation Management Plans (FMP's). These are comprehensive planning documents that include facility maps, details of all aspects, checklists of safety equipment checks and availability, monitoring plans and records, emergency responder pre-notification, and more. FMP's have now become aspects of virtually all fumigations with any fumigant product. In 2010 a tragic mis-application with phosphine targeting gophers in Utah resulted in the death of 2 children. Burrow gassing with phosphine was quickly prohibited from many kinds of properties. In 2016 another unqualified mis-application in Texas by somebody trying to control rodents under a modular home killed two more children.

In 2013 news publicity mounted about grain insects that were found with levels of resistance to phosphine much higher than what had been found previously. Application methods and attention to details had not been stellar since the introduction of phosphine 50 years earlier so the news was believable. On the other hand, validity of resistance claims was questioned and another explanation for poor performance was poor practices.

Sulfuryl Fluoride

Sulfuyryl fluoride was on the market for many years primarily for structural fumigations targeting drywood termites under the brand name Vikane. Vikane was always used in conjunction with chloropicrin (tear gas) as a warning agent. Vikane remains a fumigant product for dwellings, household goods, furniture and passenger vehicles.

As methyl bromide fumigant gas was being phased out to comply with an international environmental treaty, a new sulfuryl fluoride product, Profume, was developed as a replacement for use in the food industry and commodities. It is now the fumigant of choice for most food processing structures.

Sulfuryl fluoride has excellent characteristics as a fumigant. It is inorganic and not prone to be reactive or binding with any fumigated materials under normal circumstances. It is a better penetrator than others into commodities, and it very readily aerates. Methyl bromide was getting bad publicity as an alleged ozone-depleting chemical, while sulfuryl fluoride was receiving environmental awards. Many fumigators resisted the change, but sulfuryl fluoride and the precision provided by the Fumiguide software program has succeeded.

Sulfuryl fluoride is a colorless and odorless gas 3.52 times heavier than air. It is dispensed from outside fumigated spaces.

<u>Methyl bromide</u>

Methyl bromide was the food processing fumigant of choice for many years. Methyl bromide had an extremely long label list of foods specifically approved for fumigation. Methyl bromide was very effective and versatile. It was also critically important for soil fumigation for certain crops.

Methyl bromide remains registered, but inventories are virtually depleted after all the phase out time. Label revisions have been made despite unavailable product supplies. Those revisions provide a hint to label changes that may be dictated for other fumigants as they progress into reregistration . Buffer zones surrounding fumigated buildings during exposure times, and stringent aeration guidelines may be new requirements for all fumigants.

Methyl bromide remains important as a quarantine fumigant used under government oversight on many kinds of inbound and outbound produce and wood products.

Lesser known fumigants and specialties

<u>Carbon dioxide (CO_2)?</u> often appears in publications suggesting its use as an organic fumigant. The problem is no fumigant or pesticide-registered product exists even though CO_2 is readily available as an industrial gas. At least one industrial gas supplier had fumigant use registrations for its CO_2 years ago, and

some quantities were used in conjunction with methyl bromide. Ownership of that gas company changed and new owners did not care to maintain such a small volume, intermittently sold, and regulated product. Registrations expired. It is awkward to have such plentiful quantities of something useful available while we are bound in our profession to use only registered products.

If CO2 was available as a registered fumigant gas for large spaces it would be very difficult to use successfully. CO2 concentrations are extremely difficult to maintain.

Recently EPA encouraged a rodenticide manufacturer to apply, and granted a registration for "Rat Ice"- dry ice CO2 labeled for rodent burrows. The registrant is challenged to deal with the logistics of such a product so is only offering it in a few Northern cities. Again, it is awkward to have a widely available substance, but not in pesticide-labeled form.

Ethylene oxide is an unstable flammable gas whose use is limited to chamber fumigations. Certain kinds of imported spices and bird seeds are fumigated by specialty companies near ports of entry for spices.

Chlorine dioxide (explained previously. Re-arrange and place that information here?)

Dichlorvos: Fumigant or Aerosol? Dichlorvos, aka DDVP or vapona, is an organophosphate insecticide with a mode of action as a cholinesterase inhibitor and one of the last surviving organophosphates available. Dichlorvos is applied as an aerosol space treatment with mechanical aerosol generators, or an industrial aerosol formulation. Dichlorvos vaporizes fairly readily and the vapors behave much like a gas moving deep into equipment spaces and many harborages, but NOT penetrating packaging, products, and commodities like a true fumigant. Dichlorvos is highly effective against many stored product insects in food processing environments, and it does not require the extensive sealing and down time of a traditional fumigantion. Most people in the industry would consider dichlorvos to be more like an aerosol than a fumigant, but it has often been considered a "weak fumigant"

EPA has muddied the water by proposed classification of dichlorvos as a fumigant, and prescribing safety placarding wording referring to dichlorvos as a fumigant.

Toxicology and Safety (Section 7)

(Iowa Ch. 5 has excellent content.)

Add paragraphs on poisoning symptoms for dichlorvos and chlorine dioxide. Discuss cholinesterase inhibition and availability of blood tests for health monitoring.

First aid for low level fumigant poisoning symptoms is fresh air. Seek medical attention. Beware of cumulative exposure effects and possibility of a surprise trigger into a serious toxic reaction (OP specific?)

Safety Equipment (Iowa Ch. 6 has excellent content)

Fumigation Planning and Protocols (Section 8)

IA Ch. 7 is good.

Make point that FMP's are required by law; Also good business practice to plan supplies and needs thoroughly. Past records provide helpful insight.

Plan ahead for aeration, especially be prepared with ventilation already in place for certain rooms / tanks/ vessels.

Prepare in advance if there are cold rooms and refrigerated areas. Explain sink phenomenon of cool regions with a fumigated space and need to bring those up to ambient temp before fumigation begins. Possible to seal to prevent entry of fumigant but not as satisfactory.

Laws and Regulations (Section 9)

FIFRA brief history, amendments; EPA; Local enforcement delegated to states.

Corresponding state laws, regs, enforcement authorities.

Nebraska 2-2625: preemption of local interference with pesticide law?

Lots of other laws, rules, regulations:

FD&C Act, FSMA etc.

Transportation

OSHA

Community Right to Know

Homeland security

Others?

Specific law and storage qty trigger for phosphine reporting?