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AGRICULTURAL COMMODITY PROTECTION BY PHOSPHINE FUMIGATION

PROGRAMMATIC ENVIRONMENTAL ASSESSMENT SUPPLEMENTAL INFORMATION ANNEX

NOVEMBER 2013

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Cover photos: Phosphine fumigation monitoring equipment (top left), DIMEGSA Pest Control staff in Guatemala (top right), USAID food commodities stored in a warehouse (bottom).

COMMODITY PROTECTION BY PHOSPHINE FUMIGATION IN USAID FOOD AID PROGRAMS

PROGRAMMATIC ENVIRONMENTAL ASSESSMENT SUPPLEMENTAL INFORMATION ANNEX

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ANNEX A. IN-TRANSIT FUMIGATION OF VESSELS WITH ALUMINUM/MAGNESIUM PHOSPHIDE FORMULATIONS

As a precautionary measure to disinfest commodities prior to shipment overseas, food aid is usually fumigated prior to arriving at a US port or once it arrives at the US port. Fumigants may include methyl bromide or sulfuryl fluoride; it is illegal to use them, however, for in-transit fumigation of vessels. In-transit fumigation of vessels is allowed only with aluminum/magnesium phosphide formulations. This treatment may not always guarantee an insect-free commodity when food aid arrives at a port in the receiving country. Since 1975, FGIS, in cooperation with the USDA's ARS and the grain, fumigant, and maritime industries, has been involved in research studies to develop safe, effective, and economical fumigation methods for bulk grain loaded aboard ocean going vessels. Based the data obtained from these studies, ARS has provided FGIS with recommendations for the safe and effective in-transit fumigation of bulk grain aboard several types of vessels. According for bulk grain aboard certain carriers, FGIS has issued policies and procedures for in-transit fumigation with aluminum phosphide formulations.

- Fumigation of bulk grain in land carriers is authorized by section 800.84 (b)(3) of the regulations under the United States Grain Standards Act, as amended.

- The fumigation of bulk rice in land carriers is approved under the provisions of the 1946 Agricultural Marketing Act. Land carriers used for transporting bulk grains and rice (paddy, brown, or milled rice) include box cars, hopper cars with covered tops that can be closed and secured, containers, and trucks with permanently enclosed tops. Grains in these carriers can be fumigated only if the carriers are stationary during the fumigation and aeration period. Box cars are not approved for in-transit fumigation. Hatch and trough type hopper cars, and trucks, trailers, and containers with enclosed tops, sides, and bottoms are approved for in-transit fumigation if they are transported by rail within the US.

- Section 800.86(d)(1) of the regulations under the United States Grain Standards Act, and applicable provisions of the Agricultural Marketing Act of 1946, as amended, govern in-transit fumigation of bulk grain (barley, canola, corn, flaxseed, mixed grain, oats, rye, sorghum, soybeans, sunflower seed, triticale, and wheat) and rice in vessels.

- These Acts stipulate that for in-transit fumigation, only US EPA registered aluminum phosphide formulations may be used and must be applied by certified applicators or under the supervision of certified applicators. A certified applicator is any individual who is certified to use or supervise the use of RUPs covered by the certification (40 CFR 171.2 (h)).

- The certified applicator must inspect the vessel and verify that it is suitable for fumigation, and that no gas will leak into areas occupied by ship personnel.

- The applicator shall provide a written statement on company letterhead to FGIS or the agency requesting the fumigation regarding which tanks or holds are suitable for fumigation; reason for unsuitability must be clearly articulated. Both the certified applicator and the vessel's officer-in-charge sign the statement. The applicator will have a pre-fumigation conference with the vessel's officer-in-charge in the presence of FGIS or agency personnel and provide each party with an EPA-approved aluminum phosphide label.

- Additional signed written statement by the applicator on company's letterhead must include the identification of the tanks or holds to be fumigated; cubic capacity and depth of each hold or tank; date of fumigation; expected time to reach destination; the method of fumigant application; safety

precautions to be followed by the vessel's crew during the voyage; symptoms of exposure to the fumigant, and first-hand aid procedures in case of accidental exposure; determine if appropriate respiratory protection equipment and gas detection equipment are on board the vessel and at least two crew members knowledgeable in their use; a listing of vessel areas judged safe and unsafe areas during the fumigation; a listing of areas to be monitored daily for gas leakage; instructions for aerating the holds or tanks (tanks or holds should not be aerated at sea); and instructions for the retrieval and disposal of fumigant formulation residue and its accompanying packaging such as sachets, bag blankets, sleeves upon arrival at the destination port.

- In accordance with EPA-registered label requirements for aluminum phosphide formulations and US Coast Guard regulations for shipboard fumigation (46 CFR 147A) and any applicable state and local laws, packaged aluminum phosphide formulations or systems to retain residual fumigant dusts should be used after loading of the tank or hold is completed.

- The fumigated tanks or holds must remain closed and sealed for the entire voyage and should not be opened unless there is an emergency such as structural damage or fire.

- Warning placards must be placed on all entrances to the fumigated tanks or holds and on the outside of each manway. Each placard must show the skull and crossbones symbol and include the fumigation date, fumigant formulation used, and that the fumigated holds and tanks should not be aerated until arrival at the destination port. Placards must be in English or in the principal language of the vessel's crew.

- Typical time for vessel fumigation varies with the fumigant application method and commodity depth and may range from 3-18 days. FGIS officials must verify accuracy of information provided by the certified applicator, and attach a copy of all fumigation-related documents to the Inspection Log (form FGIS-921) to have on file.

- Commodities such as bagged rice or grain, bagged commodities, or soybean meal that do not qualify for in-transit fumigation, but are fumigated in land carriers (as mentioned above) require an FGIS observer to witness the fumigation but not its efficacy against insects.

- If bulk grain or rough or brown rice for processing is infested, fumigation in accordance with procedures in the USDA's Fumigation Handbook must be followed. Once fumigated, an FGIS certificate will be issued as if the "infested" designation had never been issued. However, the US Sample Grade designation for milled rice with live or dead insects will remain in place.

- When fumigation is a quarantine requirement, it should be undertaken in accordance with the Fumigation Handbook procedures and the USDA's Animal and Plant Health Inspection Service (APHIS) will issue a phytosanitary certificate denoting that the commodity was fumigated. More information about the APHIS-FGIS Cooperative Agreement can be found in FGIS Directive 9180.35.

ANNEX B. AN ILLUSTRATION OF TITLE II FOOD AID COMMODITY SUPPLY CHAIN FROM EXPORT TO IMPORT COUNTRY

EXPORT COUNTRY (USA)					
STAGES IN THE SUPPLY CHAIN OF FOOD AID	1. PROCUREMENT OF FOOD AID	2. HANDLING	3. STORAGE OF FOOD AID AWAITING SHIPMENT	4. HANDLING	5. SHIPPING
LIKELY ACTIVITIES AT EACH STAGE	▪ Determination of availability and amounts of surplus food commodity ▪ Design and development of emergency food aid programs and multi-year assistance programs specific for target countries needs ▪ Procurement of food aid	▪ Transfer of procured food aid commodity from a transportation carrier to a storage area ▪ Removal of cargo from carriers arriving at the warehouse or silo ▪ Tallying of received food commodity ▪ Segregation of any damaged or suspect units for further treatment ▪ Stacking of all sound units ▪ Inspection of all suspect units ▪ Salvage and reconstitution of	▪ Before stocking food aid commodity in storage facilities, the following have to be ensured: - Storage area is cleaned and dry - Application of contact pesticides ▪ Stored food commodity in grain silos, ware houses or other storage facility have to undergo the following: - Proper staking as required - Fumigated (pre-shipment fumigation) - Stock rotation - Frequent	▪ Transfer (receiving from, stacking and loading into a transport carrier) of sound units of stored food aid commodity to a transportation carrier, in this case, a ship. ▪ Tallying of goods received from the storage facility and that loaded onto a ship for onward delivery, including noting of any unsound/damaged units	▪ Transportation of food aid commodity from export country port to import country port

		any damaged units ▪ Disposal of any commodities certified as unfit for human consumption	inspection of stock		
LIKELY STAKEHOLDERS AND INTERESTED PARTIES AT EACH STAGE	▪ United States (US) department of Agriculture ▪ USAID/DCHR/FFP ▪ USAID country Missions ▪ USAID Cooperating Sponsors with interest in the ò i m p o c ou r t t r ý e.g. WFP	▪ Transportation company ▪ Survey company/firm or commodity brokers (acting on behalf of USAID/ DCHR/FFP, Cooperating Sponsors e.g. WFP) ▪ Silo and ware house managers ▪ Handling company managers and workers	▪ Survey company/firm or commodity brokers (acting on behalf of USAID/DCHR/FFP, Cooperating Sponsors) ▪ Silo and ware house managers ▪ Silo and ware house workers ▪ Fumigation companies (fumigation workers) ▪ Fumigation training and certification companies ▪ USA Federal Grain Inspection Service (FGIS) official ▪ Public housing (near by residents) in close proximity to fumigation sites of food	▪ Survey company/firm or commodity brokers (acting on behalf of USAID/ DCHR/FFP, Cooperating Sponsors e.g. WFP) ▪ Silo and ware house managers ▪ Handling company managers and workers ▪ Long- haul shipping company or vessel representative	▪ Long haul shipping company or vessel representative ▪ Survey company/firm or commodity brokers (acting on behalf of USAID/DCHR/FFP, Cooperating Sponsors e.g. WFP)

IMPORT/RECIPIENT COUNTRY					
STAGES IN THE SUPPLY CHAIN OF FOOD AID	6. RECEIPT OF FOOD AID AT IMPORT COUNTRY PORT	7. HANDLING	8. PRIMARY STORAGE FACILITY	9. HANDLING	10. SECONDARY STORAGE FACILITY OR TRANSFER TO A DISTRIBUTION CENTRE
LIKELY ACTIVITIES AT EACH STAGE	▪ Inspection and clearance of food aid commodity by recipient country customs official(s), or ▪ Transfer of the food aid commodity to a bonded ware house awaiting inspection and clearance by import country customs official(s), government agency or health department representative	▪ Transfer of food aid commodity from a transportation carrier (ship vessel) to a primary storage area ▪ Tallying of goods received ▪ Segregation of any damaged or suspect units for further treatment ▪ Stacking of all sound units ▪ Inspection of all suspect units ▪ Salvage and reconstitution of any damaged units ▪ Disposal of any commodities	▪ Before stocking food aid in storage facilities, the following have to be ensured: - Storage area is cleaned and dry - Application of contact pesticides ▪ Stored food commodity in grain silos, ware houses or other storage facility have to be: - Accounted/documented - Staked as stipulated - Fumigated - Stock rotation - Frequent inspection of stock	▪ Transfer (receiving from, stacking and loading out on to transport) of stored food commodity to a transportation carrier. ▪ Tallying of goods received from the storage facility and that loaded onto a transportation carrier for onward delivery, including noting of any unsound/damaged units	▪ If, a secondary storage facility further inland or at a regional hub at the recipient country, the activities ad stakeholders for this stage are likely similar to that of stage 8. ▪ If, a distribution centre, activities are likely to be: - Tallying of goods received - Segregation of any damaged or suspect units for further treatment - Stacking of all sound units - Inspection of all

		certified as unfit for human			suspect units - Salvage and reconstitution of any damaged units - Disposal of any commodities certified as unfit for human consumption - Distribution of quality food aid to recipients
LIKELY STAKEHOLDERS AND INTERESTED PARTIES AT EACH STAGE	▪ Survey company/firm or commodity brokers (acting on behalf of USAID/ DCHR/FFP, Cooperating Sponsors) ▪ Recipient country customs, government agency or health department representative	▪ Survey company/firm or commodity brokers (acting on behalf of USAID/ DCHR/FFP, Cooperating Sponsors) ▪ Silo and ware house managers ▪ Transportation company ▪ Handling company managers and workers ▪ Recipient country	▪ Survey company/firm or commodity brokers		

Photo no. 7: Spillage of Wheat on Rubber Pallets (WFP, Adama, Ethiopia)

Photo no. 10: Torn Corn Soy Blend Being Rebagged (Catholic Relief Services, Adama, Ethiopia)

Photo no. 8: Bird Fecal Material on Corn Soy Blend (Catholic Relief Services Warehouse, Adama, Ethiopia)

Photo no. 11: Pesticide (includes AlP) Storage Shed with permanently open meshed windows (WFP, Adama, Ethiopia)

Photo no. 9: Tents Used for Food Aid Commodity Storage (Catholic Relief Services, Adama, Ethiopia)

Photo no. 12: Dust Masks Used During Phosphine Fumigation (WFP, Adama, Ethiopia)

Photo no. 13: Sand Snakes Used to Hold Down Fumigation Sheets (WFP, Adama, Ethiopia)

Photo no. 16: Bulk Wheat Being Bagged and Stitched at Djibouti Port

Photo no. 14: Fumigation Sheets in Storage (WFP, Adama, Ethiopia)

Photo no. 17: Bagged Wheat in Temporary Storage at Djibouti Port

Photo no. 15: Grain Being Pneumatically Unloaded From a Ship Hold. Note Birds (circled in red) Inside The Hold (Djibouti Port)

Photo no. 18: Spillage underneath Pallets at a Warehouse in the Free Zone (Djibouti)

Photo no. 19: Corn Soy Blend Spillage with Insect Trails in a Djibouti Warehouse in the Free Zone

Photo no. 21: Nail Sticking Out of a Pallet. Note Spillage of Corn Soy Blend (Warehouse in Free Zone, Djibouti)

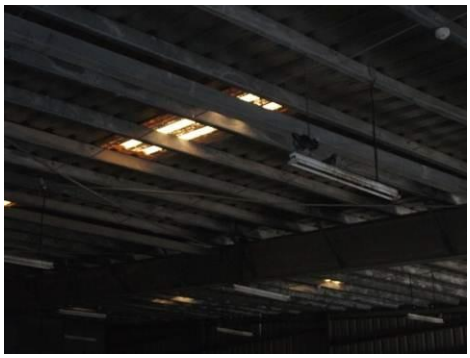


Photo no. 20: Birds Roosting on a Light Fixture Warehouse in the Free Zone in Djibouti

Photo no. 22: Pit Used to Dispose Empty Phosphine Containers (WPF, Adama, Ethiopia)

PEATOOLS

ANNEX T-1. ECONOMICALLY IMPORTANT STORED PRODUCT INSECT SPECIES ASSOCIATED WITH GRAIN AND GRAIN PRODUCTS

Order	Family name	Scientific name	Common name
Major or Primary Insect Pests			
Coleoptera	Bostrichidae	*Prostephanus truncatus* (Horn)	Larger grain borer
		Rhyzopertha dominica (F.)	Lesser grain borer
	Curculionidae	*Sitophilus granarius* (L.)	Granary weevil
		Sitophilus oryzae (L.)	Rice weevil
		Sitophilus zeamais (Mots.)	Maize weevil
	Laemophloeidae	*Cryptolestes ferrugineus* (Stephens)	Rusty grain beetle
		Cryptolestes pusillus (Schönherr)	Flat grain beetle
		Cryptolestes turcicus (Grouvelle)	Turkish grain beetle
	Tenebrionidae	*Tribolium castaneum* (Herbst)	Red flour beetle
		Tribolium confusum (Jacquelin Du Val)	Confused flour beetle
	Bruchidae	*Callosobruchus chinensis* (L.)	Southern cowpea weevil
		Callosobruchus maculatus (F.)	Cowpea weevil
		Acanthoscelides obtectus (Say)	Bean weevil
	Anobiidae	*Lasioderma serricorne* (F.)	Cigarette beetle
	Dermestidae	*Trogoderma granarium* Everts	Khapra beetle
		Trogoderma variabie Ballion	Warehouse beetle
	Silvanidae	*Oryzaephilus surinamensis* (Fauvel)	Sawtoothed grain beetle
		Oryzaephilus mercator (L.)	Merchant grain beetle
Lepidoptera	Pyralidae	*Cadra cautella* (Walker)	Almond moth
		Plodia interpunctella (Hübner)	Indianmeal moth
		Corcyra cephalonica (Stainton)	Rice moth
		Ephestia küehniella (Zeller)	Mediterranean flour moth
	Gelechiidae	*Sitotroga cerealella* (Olivier)	Angoumois grain moth

A brief illustration of the adult stages of the insects is provided below. Generally adults stages are easy to identify.

Prostephanus truncatus (Horn)

Rhyzopertha dominica (F.)

Sitophilus granarius (L.)

Sitophilus oryzae (L.)

Sitophilus zeamais (Motschulsky)

Cryptolestes ferrugineus (Stephens)

Cryptolestes pusillus (Schönerr)

Cryptolestes turcicus (Gourville)

Tribolium castaneum (Herbst)

Tribolium confusum (Jacquelin du Val)

Callosobruchus chinensis (L.)

Callosobruchus maculatus (F.)

Acanthoscelides obtectus (Say)

Lasioderma serricorne (F.)

Trogoderma granarium Everts (Fauvel)

Trogoderma variabile Ballion

Oryzaephilus surinamensis

Oryzaephilus mercator (Fauvel)

Cadra cautella (Walker)

Plodia interpunctella (Hübner)

Corcyra cephalonica (Stainton)

Ephestia kühniella (Zeller)

Sitotroga cerealella (Olivier)

There are several insect species associated with stored products. For a comprehensive list see Hagstrum, D. W., and Bh. Subramanyam (2009) Stored Product Insect Resource. American Association Of Cereal Chemists, St. Paul, Minnesota. Illustrations from: Hagstrum, D. W., T. Klejdysz, Bh. Subramanyam, and J. Nawrot. 2012. Atlas of Stored Product Insects and Mites. American Association of Cereal Chemists, St. Paul, Minnesota (in press).

ANNEX T-2 GUIDE FOR DEVELOPING A FUMIGATION MANAGEMENT PLAN

THESE ADDITIONAL ANNEX PIECES ARE PDF FILES THAT WILL NEED TO BE ADDED TO FINAL DOCUMENT
THIS ANNEX CONTAINS:

1) GUIDANCE FOR DEVELOPING A FUMIGATION MANAGEMENT PLAN
2) TWO FMP TEMPLATES
3) ONE COMPLETED FMP

In the US, all new phosphine labels require anyone fumigating commodities or structures to develop a Fumigation Management Plan (FMP) for each fumigated storage site. Fumigation service providers or Cooperating Sponsors responsible for fumigating food aid commodities with phosphine should develop an FMP as part of fumigation good practice. An FMP is a written documentation that provides specific logistical, performance, and contact information to help "characterize" the fumigation of a commodity storage site. An FMP is written is to ensure the safety of the applicators, the storage facility employees, the surrounding community, and the environment. It is also designed to ensure a legal and effective fumigation.

Prior to writing a FMP, carefully read and review both the label and the Applicator's Manual for the fumigant product to be used. Assemble and organize all of the information needed to develop a FMP. The phosphine Applicator's Manual also lists all items to be considered when developing a FMP. Preparation is the key of any successful fumigation. Once the FMP has been written, a copy of this information must be given to the appropriate company officials (supervisors, foreman, safety officer, etc.) in charge of the site.

The guidance provided here is specific, yet allows flexibility for addressing a wide range of potential fumigation sites. Each item in the list below must be considered. However, each fumigation is different and not all items will be necessary to record for each fumigation site.

Checklist for Developing a FMP

A. Preliminary Planning Facility and Commodity Details
    1. Determine the purpose of the fumigation (elimination of insect infestation, elimination of vertebrate pests, plant pest quarantine).
    2. Determine the type of fumigation (space, vehicle, container, vessel, etc.).
    3. Fully acquaint yourself with the structure and commodity to be fumigated to determine its suitability for fumigation, including:
        a. The general structure layout, construction (materials, design, age, maintenance), fire or combustibility hazards, connecting structures and escape routes above and below ground, and other unique hazards or structural characteristics. Prepare, with the owner/operator/person in charge, a drawing or sketch of structure to be fumigated, delineating features, hazards, and understructural characteristics.

b. The number and identification of persons who routinely enter the area to be fumigated (i.e., employees, visitors, customers, etc.).
c. The specific commodity to be fumigated, its mode of storage, and its condition.
d. The previous treatment history of the commodity, if available.
e. Accessibility of utility service connections.
f. Nearest telephone or other means of communication. Mark the location of these items on the drawing/sketch.
g. Emergency shut-off stations for electricity, water, and gas. Mark the location of these items on the drawing/sketch.
h. Current emergency telephone numbers for local Health, Fire, Police, Hospital, and Physician responders.
i. Name and phone number (both day and night) of appropriate company officials.
j. Check, mark, and prepare the points of fumigant application locations if the job involves entry into the structure for fumigation.
k. Exposure time considerations:
    i. Minimum fumigation period, as defined and described by the label used directions.
    ii. Down time required to be available.
    iii. Aeration requirements.
    iv. Cleanup requirements, including dry or wet deactivation methods, equipment, and personnel needs, if necessary.
    v. Measured and recorded commodity temperature and moisture.
l. Determination of dosage:
    i. Cubic footage or other appropriate space/location calculations.
    ii. Structure sealing capability and methods.
    iii. Label recommendations.
    iv. Past history of fumigation of structure.

B. Personnel Training and Notification
    1. Confirm in writing that all personnel in and around the structure and/or area (bystanders and neighbors) to be fumigated have been notified prior to application of the fumigant. Consider using a checklist that each employee initials indicating they have been notified.
    2. Instruct all fumigation personnel to read the Applicator's Manual concerning the hazards that may be encountered and the selection of personal protection devices, including detection equipment.
    3. Confirm that all personnel are aware of and know how to proceed in case of an emergency situation.
    4. Instruct all personnel on how to report any accident and/or incidents related to fumigant exposure. Provide a telephone number for emergency response reporting.
    5. Establish a meeting area for all personnel in case of an emergency.

C. Notification of Authorities
    1. Confirm the appropriate local authorities (fire departments, police departments, etc.) have been notified as per label instructions, local ordinances, or instructions of the client.
    2. Prepare written procedure ("Emergency Response Plan") which contains explicit instructions, names, and telephone numbers so as to be able to notify local authorities if phosphine levels are exceeded in an area that could be dangerous to bystanders and/or domestic animals.

3. Confirm that the receiver of in transit vehicles under fumigation have been notified and are trained according to the Application Manual.

D. Sealing Procedures
   1. Sealing must be adequate to retain gas for the longest duration (7 days) to control the pests. Care should be taken to insure that sealing materials would remain intact until the fumigation is complete.
   2. If the structure has been fumigated before, review the previous FMP for previous sealing information.
   3. Make sure that construction/remodeling has not changed the building in a manner that will result in loss of the fumigant or affect bystanders.
   4. Warning placards must be placed on every possible entrance (all sides) to the fumigation structure. Confirm the placement of placards.

E. Application Procedures and Fumigation Period
   1. Confirm the required safety equipment is in place and the necessary manpower is available to complete a safe and effective fumigation.
   2. When entering into the area under fumigation, always work with two or more people under the direct supervision of a certified applicator wearing appropriate respirators.
   3. Provide watchmen when the possibility of entry into the fumigation site by unauthorized person cannot otherwise be assured.
   4. When entering structure, always follow safety rules for confined spaces (two people, rope and harnesses).
   5. Turn off any electric lights in the fumigated area of the structure as well as all nonessential electrical motors.

F. Monitoring
   1. Safety
      a. Monitoring of phosphine concentrations must be conducted to confirm that nearby workers and bystanders are not exposed to levels above the allowed limits. Document where monitoring will occur.
      b. Keep a log or manual of monitoring records for each fumigation structure and/or area. This log must at a minimum contain the timing, number of readings taken, and level of concentration found at each location.
      c. When monitoring, document (even if there is no phosphine present above the safe levels).
      d. Monitoring must be conducted during aeration and corrective action must be taken if gas levels exceed the allowed levels in an area where bystanders and/or nearby residents or domestic animals may be exposed.
   2. Efficacy
      a. Phosphine readings should be taken from within the fumigated structure to insure proper gas concentrations for effective insect kills (200 ppm for 5-7 days). If the phosphine concentration have fallen below the targeted level (200 ppm), the fumigators may reenter the structure with proper respiratory equipment, following proper entry procedures, and add additional product.
      b. All phosphine readings should be documented.

G. Post-Application Operations
   1. Provide watchmen when the fumigation structure cannot be secured from entry by unauthorized persons during the aeration process.
   2. Aerate or ventilate in accordance with structural limitations (forced air delivered by fans can be used to facilitate in ventilation).

3. Consider temperature when aerating.
4. Turn on ventilating or aeration fans where appropriate.
5. Use a suitable gas detector before reentry into a fumigated structure to determine fumigant concentration.
6. Keep written records of monitoring to document completion of aeration.
7. Ensure that aeration is complete before moving a treated vehicle onto public roads.
8. Remove warning placards when aeration is complete.
9. Inform business/client that employees/other persons may return to work or otherwise be allowed to reenter the aerated structure.

These factors must be considered in putting a FMP together. Some plans will be more comprehensive than others.

Source: http://www.agr.state.ne.us/pesticide/fmp.html.

ANNEX T-3 PHOSPHINE GAS MONITORING EQUIPMENT, RESPIRATORY PROTECTION, AND FIRST AID

The following information is included in this annex:

- Proper use of the required phosphine gas monitoring equipment;
- Where and when to monitor phosphine gas;
- Types of gas monitoring equipment;
- Proper use of respiratory equipment; and
- First aid in case of phosphine poisoning.

The short-term exposure limit (STEL) for phosphine is one ppm. Workers must not be continuously exposed to one ppm of phosphine for 15 minutes four times a day with at least one hour between such 15-minute exposures. Workers must not be exposed to 0.3 ppm of phosphine (threshold limit value or TLV) for more than eight hours a day or 40 hours a week.

The odor threshold for phosphine (in those who can detect it), is two ppm, which is higher than the established (STEL or TLV) safe levels. Odor should not be used to determine if the atmosphere is safe. Safety levels can only be ascertained by monitoring for phosphine gas. Monitoring is also important to determine if phosphine levels have been maintained within an enclosure to effectively kill insects.

There are three basic types of units available in the marketplace—the electrochemical, photo ionization, and tube types. The electronic monitors use an electrochemical sensor in which the change in current across the sensor is proportional to the phosphine concentration in the atmosphere. The purchase price ranges from about US$800-2,000. The photo ionization detectors directly measure the wavelength of a certain gas. The tube type devices are approximately 10 cm long and 0.5 cm in diameter with a white reactive powder inside the tube which changes color when air containing phosphine is drawn through the tube with the aid of a handheld or mechanical pump. Tubes, with a scale in ppm of phosphine, are available for low and high range of phosphine (0.01 to 10,000 ppm), and the change in color is proportional to the phosphine concentration. Tube type devices cost about US$200. The electrochemical and photo ionization detectors provide continuous measurement of phosphine, whereas the tube type provides non-continuous measurement.

ELECTROCHEMICAL/PHOTOIONIZATION UNITS

Advantages

- Readings are represented on a digital screen.
- Alarms, both audible and visual, alert applicators that they are in an environment that exceeds the TLV for phosphine.
- If used as intended, the cost of operation is the least expensive.
- Multi-gas units can be and should be used in confined spaces; this will preclude the need for multiple monitors to check a variety of atmospheric gases.
- Replacement sensors, as well as calibration gases, are widely available (depending on the brand purchased).
- Power requirements can be as basic as multiple AA batteries.
- Readings are provided in a matter of seconds and are continuous.

Disadvantages

- A separate unit must be used for checking for high range readings in the fumigated area during the exposure period.
- The units must be calibrated every six months; the unit can be tested with a known concentration of the gas or sent back to the manufacturer for calibration.
- If the unit is to be used infrequently (no more than three fumigations/year), the purchase price and use cost may exceed that of colorimetric tubes.
- For servicing, a trained service person must be available.

COLORIMETRIC TUBES

Advantages

- Tubes can be acquired for the intended gas monitoring range (high and low range tubes)
- If only sporadic fumigations are to be done annually, this is an inexpensive alternative to electrochemical units
- Purchase price of the pump and tubes are less than the other option

Disadvantages

- It may take several minutes to adequately characterize a specific area depending on the tube used
- Can only obtain one reading per tube, and the tube should be discarded after use
- The tubes have a defined expiration date printed on each box
- Some discoloration stains in the tube make it difficult to read
- Operators must be able to read to ensure that they are using the correct tube for the intended job

WHERE AND WHEN TO MONITOR

- Reading must be taken frequently while applying gas and when working around the site under fumigation. These reading should be taken in the workers' "breathing zone."
- In areas that are prone to high bystander traffic, monitoring should be done to ensure the safety of those present. Any and all areas that are connected to or are in close proximity to the fumigated site should also be monitored. This helps ensure that there is no gas leakage.
- The fumigated site should be monitored with high range sensing devices during the exposure period. Sensors capable of reading concentration levels at or above 5000 ppm should be used. Monitoring lines must be placed in the fumigated area prior to the release of the fumigant. These lines should be placed or positioned in different areas or depths in the space and/or the commodity being fumigated. A reading should be taken at least every 12 hours in order to verify that the desired amount of phosphine gas is present. This information aids in determining the effectiveness of the seal as well as determining the effectiveness of the fumigation.

The table below should be consulted for determining the appropriate type of phosphine gas monitoring equipment for the particular situation. In addition to the below criteria, CSSs and fumigation service providers should determine whether the manufacturer is able to provide timely maintenance and parts in the host country.

Parameter	Criteria
Simplicity of operation	Ease of set-up and maintenance. If not easy to use, will employees actually use it, or will the unit stay on a shelf? Is calibration required, and if so, can it be easily completed?
Reliability	Ruggedness of unit. Can it withstand impact from a fall and typical field use?
Performance features and maintenance requirements	Will it give repeatable gas readings? Operation temperature range Response time Warranty Sensor life Battery life Approvals and certifications (such as by UL[a]) Auto zero Calibration frequency Calibration gas requirements
Options and accessories	Internal or external sampling pump Computer downloading Calibration and/or alarm check gas Remote sampling hose and/or probe
Support and service	What is the manufacturer's track record in responding to technical questions or repair work? Can training on the unit be provided on-site, or is audio/visual material available?

[a] United Laboratories, St. Charles, Illinois (http://www.unitedlabsinc.com/usa/content/contact_us).asp

Source: Walter, V. 2006. Commodity and Space Fumigation in the Food Industry, pp. 183-198. In Insect Management for Food Storage and Processing, Second Edition, Heaps, J.W. (ed.). American Association of Cereal Chemists International, St. Paul, Minnesota, St. Paul, Minnesota.

TYPES OF GAS MONITORING EQUIPMENT

PortaSens Phosphine Monitor (Photo Ionization Detector)

Dräger Pac III Phosphine Monitor (Electrochemical)

Phosphine Detector Tubes

Handheld Air Pump with Detector Tubes

Gas Monitoring Lines

Gas Monitoring Line Connected to a Detector Tube

RESPIRATORS/EQUIPMENT

Cartridge and canister type respirators or supplied air respirators with self-contained breathing apparatus (SCBA) must be used in situations where workers may be exposed to phosphine. A full face mask must be used with both these types of respirators. Canister type respirators are much more favorable from a safety perspective than cartridge type of respirators, which should be avoided, if possible. Canister gas masks are the least expensive option. The full face mask fit should be verified following manufacturer's instructions.

If a canister is used, it must indicate that it will protect against or can be used to filter out phosphine gas. Most, if not all, manufacturers print an expiration date on each canister. Canisters, even if new and unused, must be discarded if they are expired. Canisters may be reused; however they must be sealed and stored away from air contaminants, including phosphine gas. If, during normal use, phosphine gas odor is noticed, the canister should be discarded immediately and a new one installed.

The following should be considered for personnel who will be involved in fumigation and required to wear respiratory equipment:

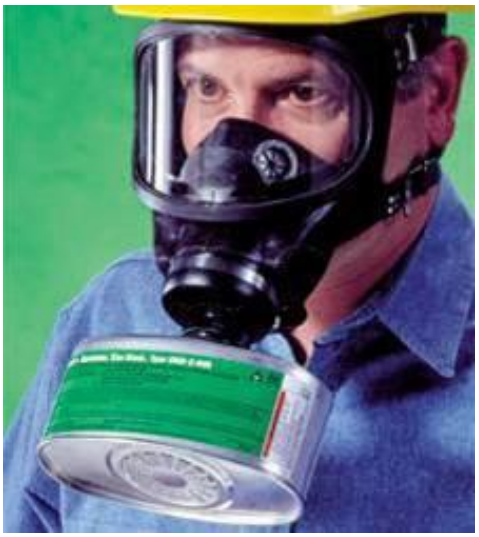
(1) The individual must be adequately trained in the donning and doffing the mask unit.
(2) The individual must be adequately trained in detecting leaks around the face piece.
(3) The individual must not have facial hair that would prohibit an adequate mask seal.
(4) The individual must be able to read and recognize the proper canister to be used as well as identifying the expiration date on the canister.

The US National Institute for Occupational Safety and Health (NIOSH) recommends the following respiratory protection at different phosphine concentrations:

0.3–3 ppm	Supplied air respirator
7.5 ppm or less	Supplied air respirator operated in a continuous flow mode
15 ppm or less	Self-contained breathing apparatus with a full facepiece, or Supplied air respirator with a full facepiece, or Air-purifying, full-facepiece respirator (gas masks) with a chin-style front- or back-mounted canister
50 ppm or less	Supplied air respirator equipped with a full facepiece and operated in a pressure-demand mode, or Self-contained breathing apparatus equipped with a full facepiece and operated in a pressure-demand mode
Oxygen-limited atmospheres	Supplied air respirator equipped with a full facepiece and operated in a pressure-demand or other positive pressure mode, or Self-contained breathing apparatus equipped with a full facepiece and operated in a pressure-demand or other positive pressure mode
Phosphine concentration, Unknown	Self–contained breathing apparatus

TYPES OF RESPIRATORY PROTECTION

Canister Type Respirators With a Full Face Mask

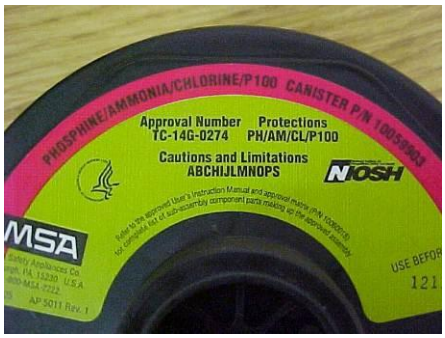


Canister Type Respirator Without a Hose

Cartridge Type Respirator with a Nose Piece

Cartridge Type Respirator with Full Face Mask

Fit Test for Cartridges to Determine Tight Tight Fit



Read Information on Cartridges/Canisters

Self-Contained Breathing Apparatus

Face Mask Connected to SCBA

OTHER PERSONAL PROTECTIVE EQUIPMENT FOR FUMIGATION

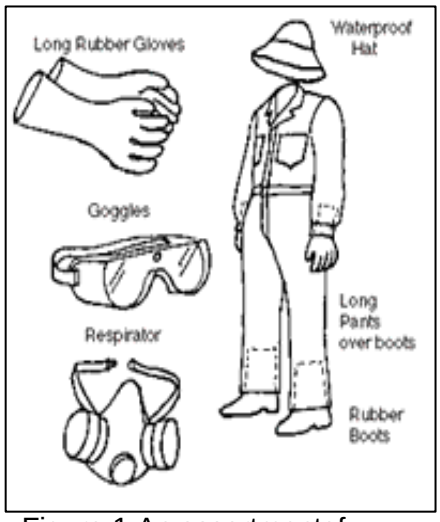


Figure 1: An assortment of personal protective clothing and

Dry cotton (or any other material) gloves should always be worn by fumigant applicants when handling or in contact with aluminum phosphide pellets. Note that the gloves should remain dry during use. Additionally, fumigant applicators should wear rubber boots, eye goggles, and liquid-tight protective coveralls that are long sleeved, over full length pants and long-sleeved shirts. Hands should be washed thoroughly after using aluminum phosphide. The fumigant applicant should also shower with soap as soon as possible and before changing into clean clothes. The gloves and any other protective gear/clothing should be aerated in a well ventilated area before laundering.

Some Useful Sources for PPE Information:

- Ministry of Agriculture, British Columbia http://www.al.gov.bc.ca/pesticid/d_1.htm
- Photos courtesy of Kansas State University, Department of Grain Science and Technology from Lecture 9, Part 2 on Fumigation Safety Considerations by Thadd Bigler, Central States Enterprises, USA
- United Phosphorous, Inc. Rev 4/10. Applicators Manual for Aluminum Phosphide Fumigant Tablets, Pellets and Gas Bags s.n. USA

SYMPTOMS OF POISONING AND RESPONSE

First Aid in Case of Phosphine Poisoning (http://www.fao.org/docrep/x5042e/x5042E0a.htm)

According to the amount of phosphine inhaled, symptoms may occur immediately or several hours after exposure.

Slight or mild poisoning may give a feeling of fatigue, ringing in the ears, nausea, pressure in the chest and uneasiness. Wear Self-Contained Breathing Apparatus and move person to fresh air. Medical attention is important even in mild cases of poisoning.

Greater quantities will quickly lead to general fatigue, nausea, gastrointestinal symptoms vomiting, stomachache, diarrhea, disturbance of equilibrium, strong pains in the chest and dyspnea (difficulty in breathing).

Very high concentrations rapidly result in strong dyspnea, cyanosis (bluish-purple skin color), agitation, ataxia (difficulty in walking or reaching), anoxia (abnormal blood oxygen content), unconciousness and death. Death can be immediate or occur several days later due to edema and collapse of the lungs, paralysis of the respiratory system or edema of the brain. Disturbances of kidney and liver functions (hematuria, proteinuria, uremia jaundice) and cardiac arrhythmia may occur.

There is no specific antidote for phosphine poisoning, and treatment is symptomatic.

Do not administer milk, butter or castor oil, and alcohol to affected person.

If breathing stops or shows signs of failing, resuscitation must commence immediately.

Develop an emergency action plan to know what needs to be in case of poisoning.

ADVICE TO THE PHYSICIAN

The following measures are suggested by the manufacturer for use by the physician.

In its milder forms, symptoms of poisoning may take some time (up to 24 hours) to make their appearance, and the following measures are suggested:

1. Complete rest for one or two days, during which the patient is kept quiet and warm.

2. Should the patient suffer from vomiting or increased blood sugar, appropriate intravenous solutions should be administered. Treatment with oxygen breathing equipment is recommended as is the administration of cardiac and circulatory stimulants.

In cases of severe poisoning intensive care in a hospital is recommended:

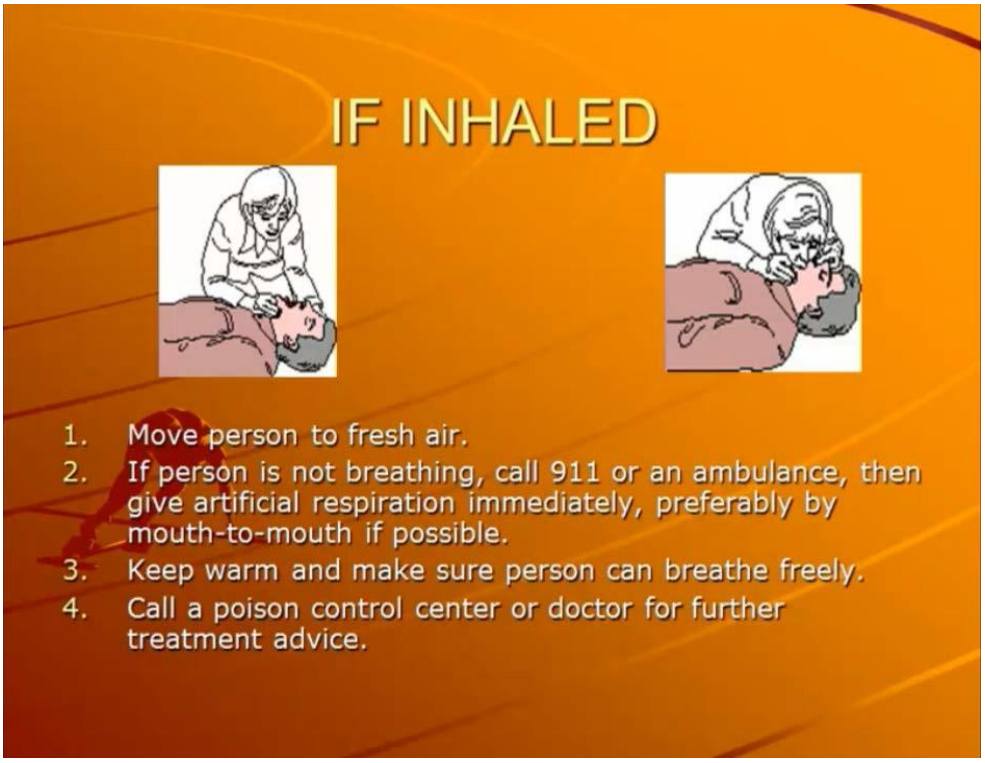
1. Where pulmonary edema is observed, steroid therapy should be considered and close medical supervision is recommended. Blood transfusions may be necessary.

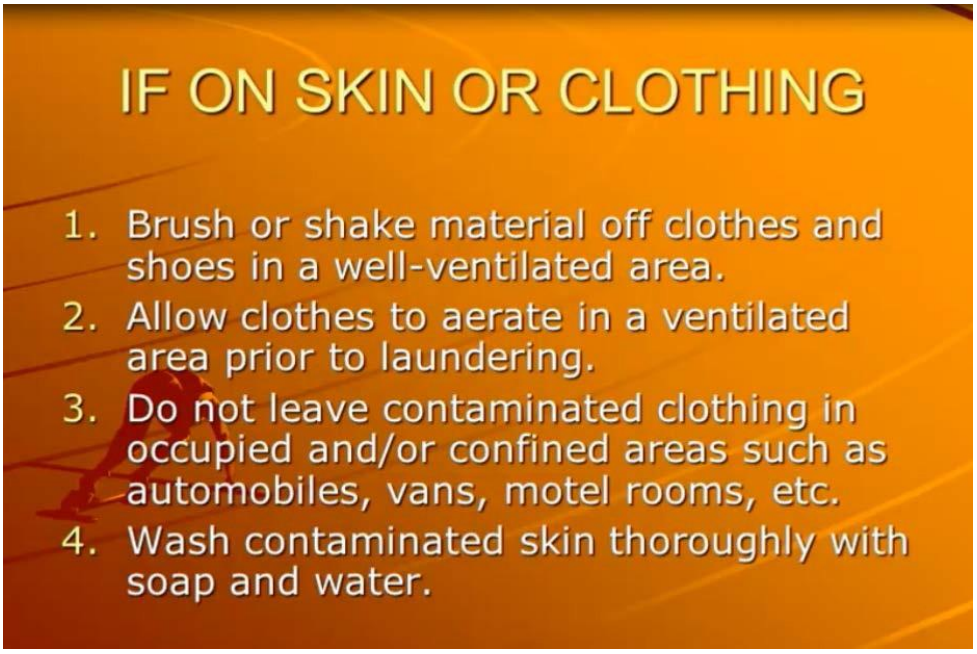
2. In case of manifest pulmonary edema, venesection should be performed under vein pressure control, and intravenous administration of glycosides (in case of hemoconcentration, venesection may result in shock). On progressive edema of the lungs, perform immediate incubation with constant removal of edema fluid and establishment of oxygen positive pressure respiration, as well as any measures required for shock treatment. In Case of kidney failure, extracorporeal hemodialysis is necessary. There is no specific antidote known for this poison.

3. Suicide may be attempted by taking solid phosphides by mouth. In such a case, empty the stomach by inducing vomiting and flush it with a dilute potassium permanganate solution or a solution of magnesium peroxide until the flushing liquid ceases to smell of carbide. Thereafter, administer medicinal charcoal.

4. Scientific research has shown that phosphine poisoning is not chronic; the action of phosphine is reversible and symptoms will disappear by themselves.

EXAMPLES OF DIFFERENT FIRST AID PROCEDURES IN CASE OF ACCIDENTS RESULTING FROM ALUMINUM PHOSPHIDE OR PHOSPHINE GAS



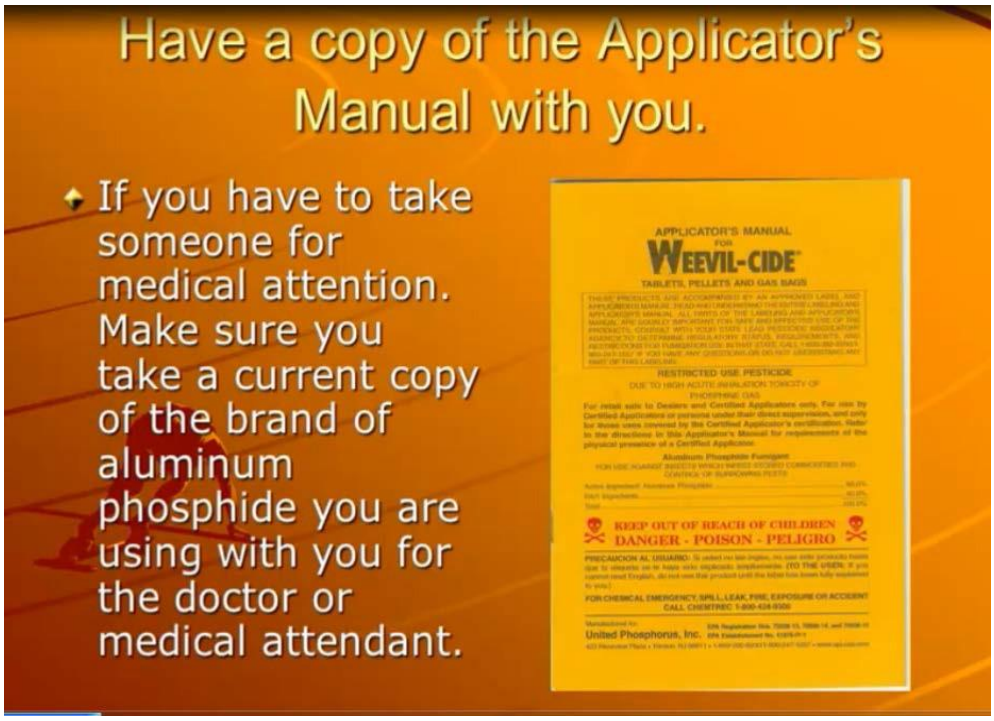


IF SWALLOWED

1. Call a poison control center or doctor immediately for treatment advice.
2. Have person drink one or two glasses of water, Do not induce vomiting unless told by a poison control center or doctor.
3. Do not give anything by mouth to an unconscious person.

IF IN EYES

1. Hold eye open and rinse slowly and gently with water for 15 – 20 minutes.
2. Remove contact lenses, if present, after the first 5 minutes, then continue rinsing eye.
3. Call poison control center or doctor for further treatment advice.



Source:

- Photo and Illustrations courtesy of Kansas State University, Department of Grain Science and Technology from Lecture 9, Part 1 on Fumigation Safety Considerations by Brayn Giroux, Central States Enterprises, USA
- United Phosphorous, Inc. Rev 4/10. Applicators Manual for Aluminum Phosphide Fumigant – Tablets, Pellets and Gas Bags s.n. USA

ANNEX T-4 BEST PRACTICES: FUMIGATION AND SPRAYING CONTACT PESTICIDES

This annex contains the following best practice recommendations, including sets of best practices revised from WFP's Commodity Management Standard Operating Procedure:

- Storage and disposal of pesticide containers (including fumigants)
- Transport of pesticides (including fumigants)
- Determining when to fumigate
- Fumigation of stacks with aluminum phosphide (modified from WFP SOP)
- Specifications and care of fumigation sheets/tarps
- Spraying empty warehouses & surroundings with contact pesticides (modified from WFP SOP)

Besides the below procedures, see Annex T-2, Fumigation Management Plan, for preparing the fumigation procedure, Annex T-3 Respiratory and Monitoring Equipment and First Aid, and Annex T-9 Warehouse Checklist for additional best practices in commodity protection.

PROPER STORAGE OF PESTICIDE CONTAINERS (INCLUDING FUMIGANTS)

Proper storage of pesticides is essential to protect human health and well-being and to protect against environmental contamination. Proper storage will also extend the shelf life of pesticides.

- A separate, isolated building should be dedicated for pesticide storage. The entrance to the storage area should be labeled/placarded as shown below in English and local language(s).

> DANGER
>
> PESTICIDE STORAGE
>
> FIRE WILL CAUSE TOXIC FUMES

- The storage building should be constructed of fire-resistant material and should contain a portable fire extinguisher and a sprinkler system, if feasible.
- Make sure the storage area is not leaky and does not get wet during rain. Vents should be closed in case of rain.
- The storage area should be well ventilated. High temperatures may cause some pesticide drum heads to bulge and leak. High temperatures may also cause emission of toxic fumes.
- All pesticides must be stored in their original, labeled containers. Pesticides must never be stored in food, feed, or beverage containers.
- Keep similar pesticides together, and separate them from other types of pesticides.
- The lids of pesticide containers must be closed when they are not being used.
- Place liquid containers on pallets to avoid corrosion of flooring.
- Protect pesticide dusts from humidity to prevent caking.
- Check containers periodically (at least monthly) for leaks or tears.
- Make an inventory of all pesticides and keep records of use.

- Do not store pesticide solutions in sprayers in the storehouse, use all of the mixed formulation.
- In the case of phosphine, use all the tablets/pellets in a container.
- Do not store food, feed, water or beverages in the pesticide storage area.
- Do not store clothes, respirators, or other protective equipment in the pesticide storage area.
- The storage area should have plenty of water and soap and an eye station in case of an accidental spill on hands or eyes.
- Do not store pesticides for more than one year as they lose their activity.

PESTICIDE CONTAINER DISPOSAL (INCLUDING FUMIGANT PACKAGING)

Human/animal poisonings and environmental contamination may occur if pesticides and pesticide containers are not disposed of properly. In some countries, unused pesticide solutions can be taken to a designated collection place for incineration or disposal. In countries receiving food aid, such a facility may not exist. Therefore, all of the mixed chemical in a sprayer or a duster should be completely used. In the case of phosphine, all tablets/pellets in an opened container should be used for fumigation.

- In the case of liquid pesticides, the empty container should be drained vertically for 30 seconds.
- Triple rinse the container, each time using 1 liter of water for a sprayer of 3.84 L capacity. Allow 30 seconds for draining each time. The rinse water should be collected into a container and disposed of in an area away from any surface or groundwater, following local and state ordinances.
- Crush or break the container and dispose it in an approved manner, and do not reuse the container.
- After all of the phosphine tablets/pellets are used, the empty container should be crushed and disposed as mentioned above.

Modified from: Bohmont, B. L. 1996. The Standard Pesticide User's Guide, Fourth Edition. Prentice Hall, New Jersey.

TRANSPORTING PESTICIDES INCLUDING FUMIGANTS

Transporting Aluminum Phosphide Packages

In the US, the US Department of Transportation (DOT) classifies aluminum phosphide as "Dangerous When Wet" material and it must be transported in accordance with DOT regulations. While these regulations do not apply to Title II programs in USAID host countries, they can provide a framework for implementation of safeguards when transporting aluminum phosphide packages. The US regulations are modified below so they can be applied to Title II situations.

Packaging

No unsealed pouches may be transported. The completed outer packaging containing a combination of canisters and pouches should not exceed 21 kg.

Operational Controls

1. No more than 21 kg of aluminum phosphide may be transported by motor vehicles at any one time.

2. The complete packages must be stowed in metal boxes or compartments on the motor vehicle.
3. Only licensed pest control operators may transport the packages.
4. Each canister or foil pouch and the outré packaging must be labeled POISON and DANGEROUS WHEN WET (see below); vehicles need not display DANGEROUS WHEN WET PLACARDS. Miniature placards (2 cm by 2 cm) are can be used for inner canisters and pouches.

Special Provisions

1. Drivers must have been instructed as to necessary safeguards and proper procedures in the event of unusual delay, fire, or accident.
2. The person performing the transportation tasks must receive training on the requirements and conditions herein.

Reporting Requirements

Notification in writing, of any incident involving a package, shipment, or operation shall be made to the designated contracting authority within 24 hours.

DECISION-MAKING: WHEN TO FUMIGATE WITH PHOSPHINE

In hot, humid climates, fumigation with phosphine is typically the preferred method to eliminate stored product infestations. Fumigation must be undertaken only if trained operators are available, the enclosure in which fumigation is carried out can be sealed adequately, all people can be reliably excluded from the treated area, and the fumigant can be safely ventilated from the enclosure after the fumigation.

The need for fumigation is influenced by three factors:

(1) Acceptability of observed insect pest levels. The acceptable level of insect pests is based on standards established for infested grain. For example, in the US wheat with two or more live insects, on average, is considered infested. The goal for grain managers is to maintain levels below this acceptable level. "On average" is determined by the sampler taking 10 to 30 samples to determine if the average insect density is two live insects or above. If a decision to fumigate will be threshold based, such thresholds must be developed for all food aid commodities. To develop threshold-based approaches for decision making data must be collected from bags over a period of one to two years and analyzed using established statistics (Subramanyam and Hagstrum, 1996, cited in the PEA).

(2) Suitability of the environment for pest multiplication. Stored product insects are cold blooded and develop faster at warmer temperatures. The optimum for rapid development (egg-to-adult, one generation) and reproduction is 28-32°C. Most countries that receive food aid have temperatures close to or greater than this optimum. Temperatures above 50°C are lethal to insects but, depending on the species, insects can do well at temperatures as high as 40°C. Under these conditions insects complete one generation in four to six weeks. Under tropical conditions, stored-product insects multiply 50-fold every six weeks, resulting in a build-up of large populations. Therefore, fumigation on a calendar basis may be the optimum to prevent pest populations from exploding. In this case, depending on site-specific warehouse situations, fumigation may be needed as often as every four to six weeks.

(3) The length of time the commodity is stored before it is shipped to beneficiaries. Commodities stored for longer than four to six weeks can incur damage from multiplying insect populations. Therefore, quick turnover of commodities will provide less opportunity for insects to survive and thrive.

Another consideration is that sampling-based decision-making is useful when only a portion of the total storage structure will be fumigated. If the entire structure is to be fumigated, sampling adds additional costs for storehouse managers; in this case, it is more cost-effective to use a calendar-basis fumigation schedule.

The following guidelines can be used to decide when to fumigate food aid commodities.

(1) Since tropical climates are conducive to year-round infestation by stored product insects, commodities should be fumigated soon after receipt into a primary warehouse.

(2) If instead, the CS prefers to base a fumigation decision on sampling, the best point to sample is at the time of unloading from a container or truck near a primary warehouse or a port warehouse. The warehouse personnel and the CS should decide the best method of sampling.

(3) There are two types of sampling. One, a "destructive" method, requires probes to be inserted into the opened bag or bags, a handful of commodity is sampled from each. Sampling is based on examining seeds/lots for quality factors; insects are not sampled. If this method is used, the bagged commodity must be re-bagged and this will take time away from unloading and loading. Table 1 shows the number of bags to be sampled based on the original number of bags.

(4) Another approach is to conduct a visual inspection for insect infestation, primarily checking the seams of bags and the outside of bags. The number of bags to be sampled should be based on the time it takes to unload a container/truck divided by the time it takes to inspect one bag. This assumes that the inspector is trained in quickly identifying a stored-product insect from a non-stored product insect. If eggs are present inside the commodity, they can never be sampled or detected visually. Bags may be sampled at specified intervals (e.g., every 10th or 20th bag unloaded).

(5) Alternatively bags can be pre-selected at time of unloading and later opened, sampled with probe, or by hand for determining infestation. This type of sampling gives presence or absence type of information and is not threshold based. In other words, if one or more live insects are found in or on many bags, the entire lot should be fumigated upon receipt.

THRESHOLD-BASED DECISION-MAKING

The relationship between the probability of detecting an infestation or the chance of finding an infestation (P), is influenced by the number of samples (bags) observed (n) and the frequency of infestation (f). Frequency of infestation is simply the number of bags out of total unloaded that contained or had one or more live insects, inside it (if is the destructive method of sampling) or outside (if it is a non-destructive type of sampling). For example if 5 bags out of 100 had live insects the frequency of infestation is 5/100 or 0.05. The probability P ranges from 0 to 1 or 0 to 100%. These 3 variables are related as follows:

$$P(x > 0) = 1 - (1 - f)^n \qquad \text{Equation 1}$$

where, P is the probability detecting 1 or more live insects (x).

In bags received recently one can expect that there may be only a few bags with live insects – inside or outside. Therefore, f may be low. In the absence of information one can assume f to be 0.01 (1 bag out of 100 has live insects), 0.05 (5 out of 100 bags has live insects) and so on. Let us assume in this example that we have f = 5% or 0.05, and n = 30. What is our probability of finding that infestation given 2 of the 3 variables. These calculations can be easily done in Microsoft Excel®. At any given frequency one can see the effect of taking samples (n) anywhere from 1 to 300.

$$P = 1 - (1 - 0.05)^{30}$$

$$P = 0.785 \text{ or } 78.5\%.$$

Figure 1 below shows how P changes at different f values. Generally, as the frequency of infestation is greater (more bags have insects), one would need only a few bags to inspect or have greater confidence or probability. Conversely, the graphs can also be used to set a confidence level or probability at 0.95 or 95% and determine how many samples are needed to be sure that you are able to detect insects at a certain f.

The number of samples to be taken is based on time available for the sample and a method highlighted in bold above. Time and resources are always limited so one cannot sample all the bags. Equation 1 above can be rearranged to find n for a given P and f and f for a given P and n. These will be illustrated below.

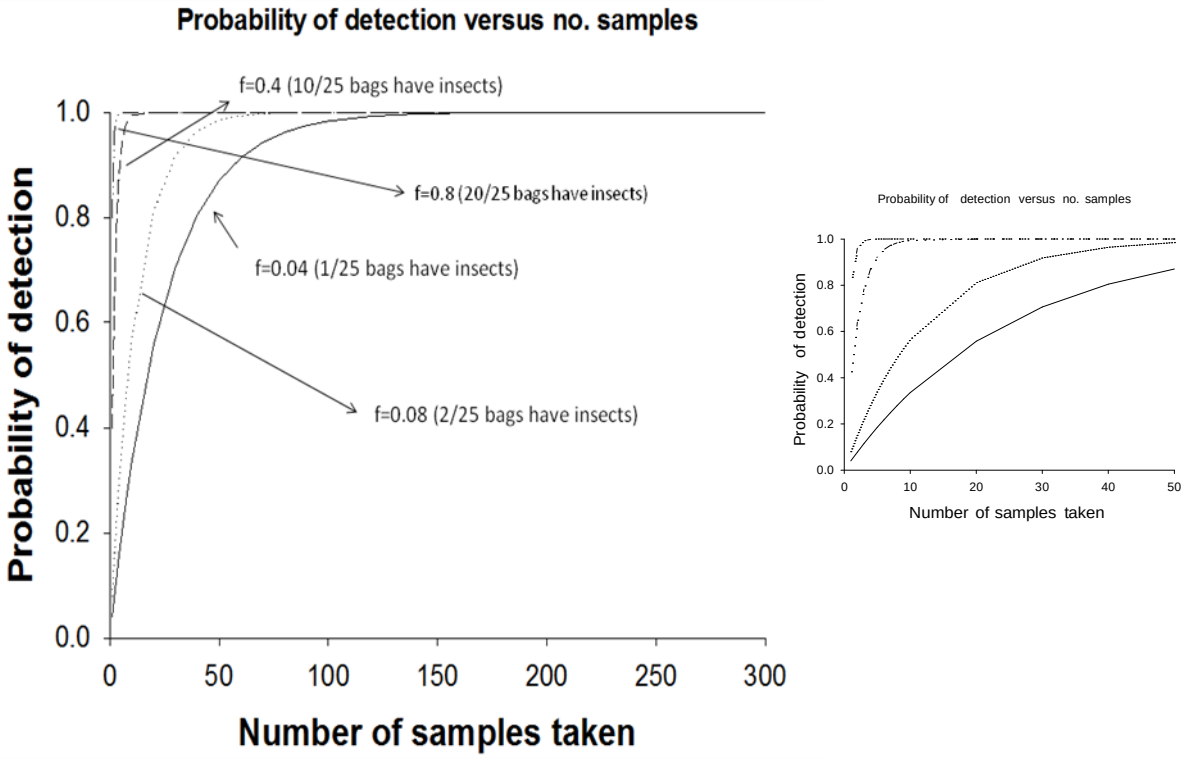


Figure 1 Relationship between Probability of Detection, Number of Samples, and Frequency of Infestation. The Inset Graph Shows the Same Four Lines Over 0 to 50 Samples.

Equation 1 can be rearranged to find how many samples are needed (n) given P and f. Assume that you want to be 95% sure (P = 0.95) that you want to detect an infestation rate of 5% (f = 0.05). How many samples or bags should be inspected?

$n = \ln[1 - P]/\ln[1 - f]$ Equation 2

$n = \ln[1-0.95]/\ln[1-0.05] = 58.4$ or 58 samples/bags

If your warehouse has a policy to inspect only a certain number of bags, we can determine what level of infestation frequency (f) you will be able to find. Let us assume for this exercise that your P = 0.95, and n is 30 bags.

Rearranging Equation 1 then yields, $f = 1 - [1 - P]^{1/n}$ Equation 3

$f = 1 - [1 - 0.95]^{1/30} = 0.095$ or $0.095 \times 100 = 9.5\%$ or approximately 10%. This value is the maximum infestation frequency (f max) I should have in order to be 95% sure that if I take 30 bags will find an infestation. The true frequency may lie anywhere between 0 and 9.5%!

These same calculations can also be used when visually inspecting or sampling bags after the bags are placed in stacks over pallets. However, it is important to realize that only the bags on the exterior and top can be sampled and not those inside or inaccessible. One can also use the same techniques when inspecting various portions of a warehouse. In order to use these equations for warehouse inspections one has to define different zones of the warehouse or divide it into a certain number of equal quadrats or zones. The number of zones with a live insects should then be recorded. Irrespective of whether bags are sampled or floors or underneath pallets are examined, the number of locations out of total examined with a live insects should be recorded to use the above equations.

The frequency of infestation may also vary by month. The tools above provide some quantitative basis to make a decision to fumigate.

Sometimes visual inspections or sampling can be deceptive, because insects may not be active at the time the inspector is sampling. In such situations, the use of devices such as food-baited and pheromone traps for various stored product insects is best. These devices works 24 hours a day, 7 days a week and work on insect behavior.

Insects are attracted to the traps and are captured in the traps. It is also possible for these traps to detect insects that may be attracted from the outside. The food-baited traps are for crawling insects (Figure 2) while traps with pheromones with sticky bottoms (Figure 3) are for flying insects.

Since these traps work on insect behavior, absence of insects does not mean that insects are absent; all it means is that insects failed to come to the tarp and be captured. Fast moving insects are likely to be captured more than slow moving insects. The fact that these devices sample continuous 24 hours a day, 7 days a week helps increase the probability of detecting insects.

How can one use trap data to make a decision to fumigate? The warehouse manager or CS must place 30-40 traps in each warehouse and examine them on a weekly basis. All captured stored product insects should be sorted by species and counted. If a few traps out of the total deployed have insects then it can be assumed that the infestation is not severe.

On the contrary if every trap has an insect then there is a widespread problem. Managers can set an arbitrary threshold to fumigate when 10, 20, or 30 percent of traps have insects. Also, the traps can be used after fumigation to determine the degree and duration of control achieved or the need for the next fumigation.

The trap data should be correlated with visual inspection data. The only limitation of traps is that the food baits and lures should be replaced at monthly intervals.

There is no simple answer to know when to fumigate. It can be done on a calendar basis, every 4-6 weeks as a precautionary measure, or through visual inspections, or sampling using insect traps and some arbitrarily set threshold of one or more live insects or percentage of traps with insects. It is always important to accumulate any visual and trap information for review and refinement of pest management decisions.

Table 1: Recommended Sampling Intensity for Seed in Bags[a]

1 to 6.....*	95 to 104....15	195 to 204....25
7 to 14....6	105 to 114....16	205 to 214....26
15 to 24....7	115 to 124....17	215 to 224....27
25 to 34....8	125 to 134....18	225 to 234....28
35 to 44....9	135 to 144....19	235 to 244....29
45 to 54....10	145 to 154....20	245 to 254....30
55 to 64....11	155 to 164....21	255 or more....30
65 to 74....12	165 to 174....22	
75 to 84....13	175 to 184....23	
85 to 94....14	185 to 194....24	

* For lots of 1 to 6 bags, sample each bag and take a total of at least 5 cores or handfuls.

[a] Source: Knapp, A.D., T. J. Gutormson, and M. K. Misra. 1991. Seed Lot Sampling. North Central Regional Extension Publication 403, July 1991. North Dakota State University, Fargo, North Dakota. http://www.ag.ndsu.edu/pubs/plantsci/smgrains/ncr403w.htm

Figure 2. Food-Baited Traps with Oil and Lures for Three Insect Species for Capturing Crawling Insect Species (Photo: Bh. Subramanyam). These Traps Should be Placed in a Grid Fashion Throughout the Warehouse. They Can Also be Placed Outdoors.

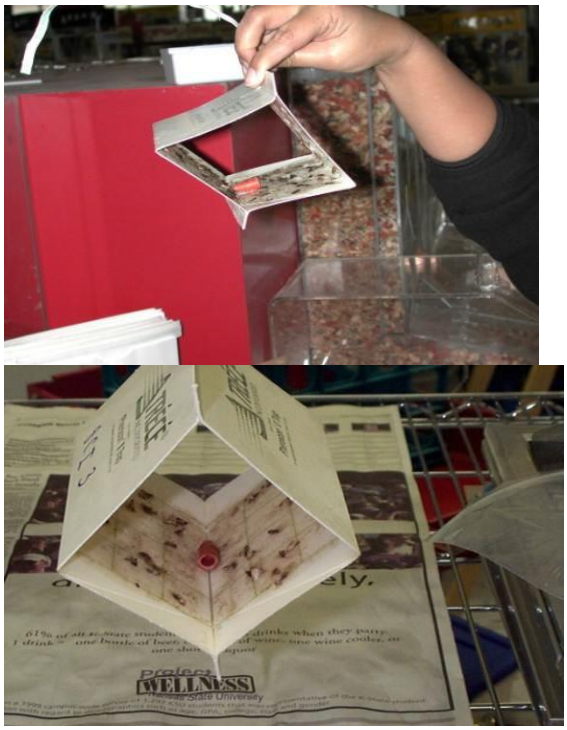


Figure 3. Sticky Traps with a Lure (Red Rubber Septum) for Capturing Flying Insects. These Traps Should be Hung at Eye Level to a Suitable Structure in a Warehouse. They Can Also be Used Outdoors.

FUMIGATION OF STACKS USING ALUMINUM PHOSPHIDE (ALP)

At temperatures of 25°C or above a minimum exposure time of 7 to 10 days is necessary to control phosphine-tolerant insects stages. The fumigations should be planned for a time period that will allow for this length of fumigation. The following steps (modified from WFP's SOPs) should be followed for a proper fumigation.

1. Initial Preparations

- Calculate the amount of food to be fumigated to decide the quantity of fumigant required (general recommendation is dosage rate 3 ALP tablets/metric ton but will vary with commodity and temperature). A dosage of 6 tables/metric ton may be needed for high sorptive commodities, such as paddy rice, brown rice, and pulses.
- Inspect and prepare the safety respiratory equipment, warning signs (placards), and cotton gloves.
- Decide on the number of fumigation sheets needed and check for holes. Repair as necessary. (For information on gas sheets specifications see below.)

- Calculate the number of sand snakes required (two rows should be used) to place around the stack to be fumigated. In the absence of sand snakes, use other bagged commodities.
- Calculate the number of trays for ALP tablets/pellets required and make sure enough trays are available.
- Examine the conditions of the warehouse (the floor for cracks and holes; the stability and form of the stack; the cleanliness of the floor, walls and stack sides; the roof for leakage, etc.). Seal all floor cracks or the gas will be lost through the gaps.
- Identify the time when the fumigation can be performed taking warehouse operations into consideration (need 7 to 10 days).
- Ensure that the contracted service provider or CS fumigation staff are well trained and experienced in the fumigation process; and that they have adequate supplies and protective equipment, especially in case of an emergency.
- Consider the need to spray contact pesticides prior to fumigation, such as spraying the store structure and stack surface (see below).
- In accordance with CS procedures, notify appropriate CS staff, including warehouse managers, workers and other employees about the fumigation and its duration, including safety precautions to be followed; notify neighbors if they are within 100 meters of the fumigated warehouse; and have phone numbers of physicians, police, and fire department in case of an accident or emergency.

2. Sheeting the Stack

- Unfold the sheet towards the stack – always carry the sheet, never drag it over the ground.
- Place the sheet over the stack and position with 1 meter of sheet lying on the ground.
- Unroll the sheet to cover the entire stack.
- Take care when climbing on stacks or up ladders while covering the stacks to avoid falling over the edge.
- Smooth out any wrinkles and folds in the sheets before placing sand snakes on them.
- If more than one sheet is used, join the sheets or clip the joints.
- Place two rows of sand snakes on the sheets along the sides of the stack. Ensure that a good seal is achieved along the whole length and take special care at the corners.
- Place two monitoring lines from the top and one from the bottom of each stack to determine if phosphine concentration of 200-300 ppm is maintained for the duration of exposure. Cut small holes to insert tubes and seal holes in gas sheets with tape.
- Gas monitoring lines should be placed outside of treated area. Place duct tape over the free tube ends, except when measuring gas concentrations with electrochemical or tube type gas monitoring equipment.

3. Apply the Fumigant and Seal the Stack

- Decide on each person's responsibility. Several people may be needed to place trays with ALP under all stacks.
- Lay out the trays for ALP tablets/pellets around the stack. Remove the sand snakes next to the trays that hold down the sheets.
- Place warning signs on the outside of all warehouse doors and on all sides of the warehouse.
- All people who are not going to be involved with the fumigation activity should leave the warehouse.
- Position ALP tablets/pellets in a single layer on each tray. To avoid fire risk, do not pile tablets or pellets. Slide trays under the sheets and replace the sand snakes (two rows). To minimize worker exposure to gas being released, placement of trays should be completed within 15 minutes.
- Leave the warehouse and lock the doors to prevent access to unauthorized people for the whole exposure period (a minimum of 7 to 10 days).

4. Spray Contact Pesticides (optional)

- Consider spraying the empty warehouse (floor, walls, roofs, etc.) and surrounding areas before receipt of food commodities to kill any live insects. The perimeter of the warehouse on the outside should be sprayed, as described below. The aim is to kill insects that might escape the fumigation.

5. Open and Aerate Warehouse

After fumigation (7 to 10 days):

- Check gas readings under the sheets (check the monitoring lines).
- If gas readings are above 0.3 ppm, no one should enter the warehouse without wearing an appropriate respirator, preferably self-contained breathing apparatus or a canister mask.
- Open all doors and ventilators, preferably one half day before starting aeration of the warehouse.
- Remove sand snakes from one or both ends of the stack.
- Pull the corners of the sheet up on to the top of the stack using a rope and leave the warehouse immediately.
- Allow gas to leave the stack and warehouse for approximately one half to one day.
- To further aerate, remove all sheets covering the stacks.
- Check gas readings in the warehouse and within bags. If gas readings are 0.3 ppm or less, it is safe for workers to enter the warehouse.
- Remove warning signs and placards.

6. Dispose of Spent Aluminum Phosphide Residue

The below is from: van Someran Graver, J.E. 2004. Guide to Fumigation Under Gas-Proof Sheets. Food and Agriculture Organization of the United Nations. Produced by the Australian Centre for International Agricultural Research, Canberra, Australia.

All phosphine generating formulations used during fumigation must be collected and disposed of in a safe manner. This is important because "spent residues" still contain 3-5% of unreacted aluminum/magnesium phosphide, which can be a safety hazard. The steps below provide guidance

for safe disposal of the spent residues. Handlers of spent residues should wear respirators with appropriate filters and wear personal protective clothing to avoid contact with the dust.

- Do not breathe the dust of the residue
- Prevent contact with eyes and skin
- Collect the residue in a bucket or drum
- Take the residue outdoors to a safe area
- Mix the residue (ash) slowly with water and detergent
- Slowly stir the water to mix the powder. The mixer must stand upwind to avoid any phosphine exposure that is released during this process.
- After any reaction that may occur has ended, the mixture must be disposed of in a 0.5m deep hole dug in the soil, which is then filled in. The location of the disposal pit should be at least 100 meters away from warehouse structures, where there is no possibility of anyone being exposed to phosphine that may be released.
- Never dispose of unused tablets and pellets using the process above. Always try to use all of the materials in the container, even if the 3 tablets/ton rate has been used. Adding more tablets is allowed by the label.
- Never place unused tablets/pellets in a drum with or without detergent/water as a fire or explosion may occur.

7. Dispose of empty phosphine containers

The following is modified from: Bohmont, B. L. 1996. The Standard Pesticide User's Guide, Fourth Edition. Prentice Hall, New Jersey.

- After all phosphine tablets/pellets are used, the empty containers should be crushed and disposed of in an approved manner (in accordance with CS procedures and host country regulations).
- Do not reuse the container.

8. Notify Appropriate Authorities after the Fumigation is Complete

- After the fumigation, as required by CS procedures, report the type and quantity of commodity treated and the quantity of pesticides used (fumigants and liquid insecticides) to appropriate CS authorities along with any monitoring data.

9. Dispose of Dead Rodents and Birds Following Fumigation

The below is modified from: Proper Disposal of Animal Carcasses in Michigan: An Industry Guide to the Bodies of Dead Animals Act. Michigan Department of Agriculture, Lansing, Michigan. Available at: http://www.michigan.gov/documents/MDA_BODA_80099_7.pdf
Rodent Control: How to Use Rodent Traps and Bait Stations. Public Health Seattle & King County. Environmental Health Services, Seattle, Washington. Available at www.kingcounty.gov/healthservices/ehs/~/.../RatTraps.ashx
Dead Animal Disposal. Indiana State Board of Animal Health. Available at http://www.in.gov/boah/2369.htm

Rodents and birds gain entry into food aid warehouses through structural gaps in the building. Entry is more likely in temporary tent-type structures that store food. Fumigation to kill stored product

insect pests will also kill rodents and birds. After fumigation, the warehouse must be inspected to locate all dead rodents and birds and they must be promptly disposed of (24 hours). The rate of decomposition is faster in tropical and sub-tropical climates than in colder climates. If not promptly disposed of, odor and disease transmission are concerns. In addition, secondary infestations of flesh flies, carrion beetles, blow flies, carpet beetles, and cockroaches could result. Dead animals must be disposed of within 24 hours after fumigation is complete to avoid these issues. The information below provides simple guidelines for carcass disposal.

- With a flashlight (torch) thoroughly inspect all areas of the warehouse, including under the pallets, to locate all dead rodents. Overhead areas may need to be inspected for dead birds.
- Do not touch dead animals with bare hands. Wear disposable gloves, if available, to pick up dead animals. If gloves are unavailable use the inside of a plastic bag or a shovel to pick up the carcasses. Wrap the dead animals in newspaper or preferably in plastic bags before burying in an area and at a depth that will not be disturbed. Dead animals should be buried 0.6 – 1.2m (2- 4 ft) below the surface of the soil, and 61 m (200 ft) from a groundwater well or surface water.
- As an alternative, carcasses can be burned. Burning must be done where it will not cause public nuisance, and in accordance with local laws. The burnt residues must be later buried..
- Wash hands thoroughly with soap and warm water after disposing dead animals.

SPECIFICATIONS FOR FUMIGATIONS (GAS-PROOF) SHEETS OR TARPS AND PROPER CARE OF SHEETS

Sources for fumigation sheets:

Elastec American Marine, Innovative Environmental Products.
http://www.elastec.com/fumigationtarps/
Reef Industries, Inc. http://www.reefindustries.com/prodsite.php?pid=19

Specifications:

- Fumigation sheets are generally made of unsupported polyvinyl chloride (PVC), woven polythene, PVC laminate, PVC nylon or terylene scrim, or multi-layered thin-film laminates.
- Annealed polypropylene sheets and thinly coated and widely woven materials must not be used as fumigation sheets.
- Sheets should be resistant to ultraviolet light. They should be resistant to tearing and impermeable to phosphine (gas loss should be less than 1 mg/day/m^2).
- Sheets must be of 18 x 12 m size, 250 microns thick (1 micron = 1/1000 of a mm), and light weight (200-250 g/m^2).

Care of Sheets:

- To prevent tears, sheets should not be pulled or dragged over rough ground or walked on..

- Sheets should be stored in a place where they will not be damaged by rodents.
- Prior to each use, hang sheets on long supports and inspect against light for any holes. Seal holes or tears with duct tape or PVC solvent glue.

- If two or more sheets are needed to cover a large stack of bags, place one sheet over the other and pull back (fold) the first sheet and place sand snakes to seal the sheets.
- Two rows of sand snakes should be used to seal the sheets to the floor. The use of tape, if the floor is smooth, might be a better option (see picture below).

SPRAYING WAREHOUSE STRUCTURES (EMPTY WAREHOUSE AND SURROUNDING AREAS)

Most fumigations involve spraying a contact pesticide before a fumigation, as mentioned above. Spraying is important prior to fumigating a stack to kill any insects escaping the fumigation. Although CSs must submit a PERSUAP to USAID that requests specific pesticides and delineates safe practices to be implemented, the following steps are provided herein since pre-fumigation spraying is usually an integral part of the fumigation process. The following has been modified from WFP's SOPs.

- Clean empty warehouse of all food grains and debris. This will increase insecticide effectiveness.
- Ensure spray equipment is well maintained and make repairs prior to spraying.
- Give prior notice of the spraying to warehouse staff whose work is likely to be disrupted.
- Calculate the area to be sprayed (recommended rate is two to five liters of water/100 square meters) and provide sufficient insecticide (recommended dosage rate 2% active ingredient in the solution or as recommended by the label). Ensure adequate water and sprayers are available, and that protective clothing and washing water and soap is available.
- Protective clothing, including boots, long-sleeve shirts, pants, disposable gloves, goggles, and coveralls should be worn by applicators. In some cases, cartridge type masks should be worn to protect against inhaling spray droplets. Check label for respiratory protection needed.
- Calibrate sprayer by adjusting volume of water needed to cover a known amount of floor area.
- Provide clear instructions to applicators as to the parts of the warehouse to be treated and an estimate of the area to be covered with one knapsack sprayer of pesticide.
- Give special instructions, for example, about applying heavier than normal dosages of spray to places where insects might be concentrated (i.e., cracks and crevices in walls and floors).

- Notify applicators about hazards such as electrical equipment, dimly lit areas, and slippery floors.
- Mix pesticides in a well-ventilated area using disposable gloves and goggles. If a pest management service provider is used for spraying, pesticides should be mixed off-site before arriving on warehouse grounds. For additional guidance in mixing and handling pesticides, see below.
- Spray empty warehouse (floor, walls, roofs, and the surrounding areas) before receipt of food commodities to kill any live insets. The perimeter of the warehouse on the outside should be sprayed. Do not spray near waterways; spray at least 50 meters away from the edge of a surface water body. An approved contact pesticide must be used.
- Inspect immediately after spraying that all areas have been properly treated. Any surplus spray remaining in the sprayer should be applied to walls to use it up. Diluted water-based sprays should not be retained in the sprayer for longer than one day since the insecticide may deteriorate rapidly.
- Empty the sprayer and wash thoroughly with clean water. Dismantle and clean nozzles. Drain and dry spray tanks, hoses, and lances. Triple rinse sprayer and collect rinse water and dispose safely and securely, preferably in an area designated for this waste, in an area where it will not affect non-target organisms. Empty insecticide containers should be disposed of safely by crushing them and placed in a safe, secure pit/landfill, and covered.
- Applicators should wash hands thoroughly with soap and warm water. Clothes worn during application should be washed with soap and water. Do not reuse gloves. Goggles should be thoroughly washed in soap and water and dried.
- As required by CS procedures, report the area of a warehouse sprayed and the type and quantity of pesticides used.

ADDITIONAL INFORMATION ON PROPER HANDLING AND MIXING OF PESTICIDES

Spills and splashes can occur when mixing pesticides with water in sprayers. The following safety instructions should be observed during the mixing and loading of pesticides:

- After selecting a pesticide for spraying the warehouse, follow label directions for using correct amount of the pesticide and do not exceed label rates.
- Wear protective clothing and respirator as stated by the label, and have first aid equipment available.
- Never work alone when handling highly hazardous pesticides.
- Mix chemicals outside or in a well-ventilated area and not inside the warehouse.
- Do not mix chemicals near surface water. Mixing should occur at least 50 meters away from surface water.
- Always stand upwind when mixing or loading pesticides.
- The measuring containers should be thoroughly cleaned after each use.
- First add water to the spray tank, then add the pesticide and fill the spray tank to the desired level.
- Clean up spilled pesticides immediately. If the pesticide is accidentally spilled on skin, immediately wash it off with soap and water. Notify supervisor to ensure that appropriate procedures are taken to avoid injury.
- If the pesticide is spilled on clothing, change clothing as soon as possible and wash clothes before using them again.
- Protective gloves should be washed before removing them.

- Wear new gloves each time as the pesticide residue can be absorbed into the glove matrix. Discard gloves as above for pesticide containers.
- Persons mixing, handling, or applying pesticides should never smoke, eat, or drink until after they have thoroughly washed their hands with soap and water.
- Never use your mouth to siphon a pesticide from a container.

ANNEX 5. ALUMINUM PHOSPHIDE MSDS & PHOSPHINE FACTSHEET (USEPA)

The Phostoxin applicator manual (expanded label) can be accessed from:
http://www.degeschamerica.com/docs/USA/Phostoxin%20Tablet-Pellet%20manual.pdf

DEGESCH America, Inc.

MATERIAL SAFETY DATA SHEET: ALUMINUM PHOSPHIDE

	U.S. EPA Reg. No.
PHOSTOXIN® TABLETS	72959-4
PHOSTOXIN® PELLETS	72959-5
PHOSTOXIN® TABLET PREPAC	72959-9
PHOSTOXIN® PREPAC ROPES	72959-8
DETIA® FUMEX BAGS, BELTS AND BLANKETS	72959-10
DETIAPHOS TABLETS	72959-4
DETIAPHOS PELLETS	72959-5

PROPER DOT SHIPPING NAME: UN1397 ALUMINUM PHOSPHIDE, 4.3 (6.1) PG-I DANGEROUS WHEN WET, POISON LABELS APPLY

SECTION I - PRODUCT INFORMATION

Manufacturer:

DEGESCH America, Inc.
153 Triangle Dr.
P. O. Box 116
Weyers Cave, VA 24486 USA

Telephone: (540) 234-9281 / 1-800-330-2525
Telefax: (540) 234-8225
Internet Address: www.degeschamerica.com
E-mail: degesch@degeschamerica.com

EMERGENCY TELEPHONE NOS.:

Emergency – Call PROSAR: 1-800-308-4856 for human or animal emergencies
Call Chemtrec: 1-800-424-9300 for all other chemical emergencies
Emergency and Information - DEGESCH America, Inc. (540) 234-9281 / 1-800-330-2525

Phostoxin and DetiaPhos are available as 0.6g pellets and 3.0g tablets. Tabletized Phostoxin is also available in gas permeable packages called Prepacs and Ropes. These products are packed in gas-tight containers. Detia® Fumex is available as 34g bags. Fumex is also packed as bag belts, each equivalent to 4 bags and bag blankets, equivalent to 100 bags.

Date of Revision: April 2011

SECTION II - HAZARDOUS INGREDIENTS INFORMATION

Identity:

Phostoxin, Fumex, DetiaPhos and Aluminum Phosphide (AlP) - react with water to produce phosphine (Hydrogen phosphide, PH_3) as shown in Equation 1. Phostoxin and DetiaPhos is formulated with 55% aluminum phosphide and also contains ammonium carbamate (AC) and inert ingredients. Ammonium carbamate releases ammonia and carbon dioxide as shown in Equation 2. Detia Fumex bags do not contain ammonium carbamate.

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

2) $NH_2COONH_4 \rightleftharpoons 2NH_3 + CO_2$

AlP	CAS No. 20859-73-8
PH_3	CAS No. 7803-51-2
$Al(OH)_3$	CAS No. 21645-51-2

NH_2COONH_4	CAS No. 1111-78-0
NH_3	CAS No. 7664-41-7
CO_2	CAS No. 124-38-9

NFPA Chemical Hazard Ratings:
Flammability Hazard 4
Health Hazard 4
Reactivity Hazard 2
Special Hazard W

SARA Physical and Health Hazards:
Fire
Reactivity
Immediate (Acute)

Inhalation Exposure Limits:

Component	OSHA PEL TWA (ppm)	ACGIH TLV TWA (ppm)	ACGIH TLV STEL (ppm)	NIOSH IDLH (ppm)
Phosphine (Hydrogen Phosphide, PH_3)	0.3	0.3	1.0	50
Ammonia	50	25	35	300
Carbon Dioxide	5,000	5,000	30,000	40,000

SECTION III - PHYSICAL CHARACTERISTICS

Boiling Point:

AlP	>1000°C
PH_3	-87.7°C

Specific Gravity of Vapors (Air = 1):

AlP	N/A
PH_3	1.17

Vapor Pressure:

AlP	0mm Hg
PH_3	40mm Hg @-129.4°C
AC	100mmHg @26.7°C

Solubility in Water:

AlP	Insoluble, reacts
PH_3	26cc in 100 ml water at 17°C
AC	Very soluble, reacts

Appearance and Odor:

The Phostoxin, DetiaPhos and Fumex formulations, and aluminum phosphide have a greenish-gray color and the hydrogen phosphide (phosphine, PH_3