

ANNEX A-6:

GUIDELINES FOR USING PHOSPHINE GAS MONITORING & RESPIRATORY PROTECTION EQUIPMENT

When procuring and using gas monitoring equipment, the following information should be reviewed details on the following:

- 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

US EXPOSURE LIMITS

The short-term exposure limit (STEL) for phosphine is 1.0 ppm. Exposure limits for workers over an 8-hour work day is 1.0 ppm phosphine for 15 minutes, not to exceed 4 exposures in a single day (at least 1-hour of fresh air required between exposure periods). 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.

ODOR IS NOT A RELIABLE MEANS OF DETECTION

Pure phosphine is odorless; a garlic or fishy odor arises from the co-presence of diphosphane gas, which is a typical by-product of phosphine generation reactions. At typical diphosphane: phosphine ratios, the odor threshold is typically ~ 2 ppm of phosphine, which is higher than the established (STEL or TLV) safe levels. Odor cannot be used to determine if the atmosphere is safe. Safety levels can only be ascertained by monitoring for phosphine gas. This is HAZARD monitoring. Monitoring is also important to determine if phosphine levels have been maintained within an enclosure to effectively kill insects. This is EFFICACY monitoring.

PHOSPHINE GAS MONITORING EQUIPMENT

There are three basic types of units available in the market place—1) electrochemical, 2) photo-ionization, and 3) 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 a single measurement and must be disposed of afterwards.

ELECTRO-CHEMICAL/PHOTO IONIZATION UNITS

Advantages

- Readings are presented 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 if 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 electro-chemical 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

EFFICACY MONITORING EQUIPMENT

Efficacy monitoring requires “high range” sensor devices capable of reading concentration levels at or above 500 ppm. Efficacy monitoring is done using the monitoring lines placed during the sheeting operation (see Fumigation Management Plan (A-10) and Best Management Practices (A-3)).

See Annex A-3 for Efficacy Monitoring acceptable practices.

HAZARD MONITORING EQUIPMENT

Hazard monitoring requires “low range” sensors that can detect concentrations at and around the TLV limit (0.3ppm in most countries) and the STEL limit (1.0 ppm in many countries.)

Hazard monitoring must be undertaken just outside the limits of the “exclusion zone” if any bystanders/workers/residents are or are likely to be present. It should be undertaken when crews are applying fumigant and working in the warehouse with stacks under fumigation. See Annex A-3 for Hazard Monitoring acceptable practices.

DECISION CRITERIA FOR CHOOSING MONITORING EQUIPMENT

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, PVOs 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	Repeatability of 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 Internal or external sampling pump
Options and accessories	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?

^aUnited 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

RESPIRATORY 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 strongly preferably to 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.
- NOT be expired. (All manufactures print an expiration date on each canister). Canisters, even if new and unused, must be discarded if they are expired.
- ONLY be re-used up to their printed Canisters may be reused UP TO THEIR PRINTED ; and ONLY if they have been sealed and stored away from air contaminants, including phosphine gas.

REGARDLESS of what the expiration date and use log states: if, during normal use, phosphine gas odor is noticed, the canister should be discarded immediately and new one installed.

Personnel involved in fumigation and required to wear respiratory equipment must:

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

RECOMMENDED EQUIPMENT BY PHOSPHINE CONCENTRATION LEVEL

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

Concentration	Acceptable Equipment
3ppm or less	Supplied-air respirator
7.5ppm or less	Supplied-air respirator operated in a continuous-flow mode
15 ppm or less	Self-contained breathing apparatus with a full face piece, or Supplied-air respirator with a full face piece, or Air-purifying, full-face piece respirator (gas masks) with a chin-style front- or back-mounted canister
50 ppm or less	Supplied-air respirator equipped with a full face piece and operated in a pressure-demand mode, or Self-contained breathing apparatus equipped with a full face piece and operated in a pressure-demand mode
Unknown	Self –contained breathing apparatus with a full face piece

Source: NIOSH Pocket Guide to Chemical Hazards. <http://www.cdc.gov/niosh/npg/npgd0505.html>

TYPES OF RESPIRATORY PROTECTION



Air-purifying, full face-piece
respirator Respirator

Air-purifying, full face-piece
without a hose



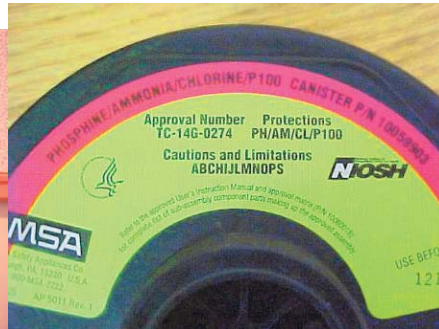
Air-purifying, half mask respirator
mask with canister



Supplied air respirator with full face



Fit Test for Cartridges to Determine
on Tight Fit



Read Information
Cartridges/Canisters

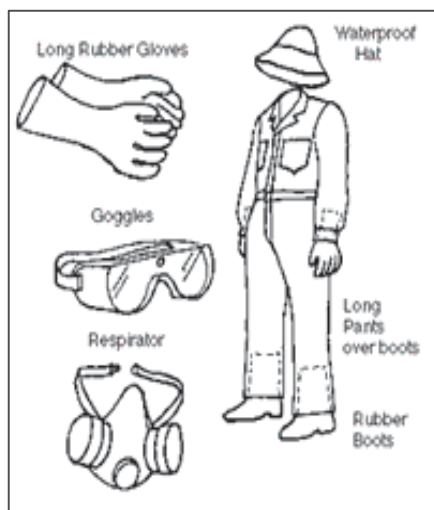


Self-Contained Breathing Apparatus



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/pesticides/d_l.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