

NIOSH

ALERT

Preventing Phosphine Poisoning and Explosions during Fumigation



U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES
Public Health Service
Centers for Disease Control and Prevention
National Institute for Occupational Safety and Health



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NIOSH

ALERT

Preventing Phosphine Poisoning and Explosions during Fumigation

WARNING!

Workers may be poisoned, injured, or killed by phosphine gas while working with or near phosphide fumigants.

Workers, do the following if you work near phosphide fumigants:

- Observe warning signs and know which work areas have been fumigated. Do not enter them until they have been aired out and monitored to show that they are safe.
 - Pay careful attention to handling procedures on phosphide fumigant labels.
 - Be aware that phosphide fumigants may explode when they contact air or are mixed with water.
 - Take part in any air monitoring or training programs your employer offers.
 - Do not rely on odor to warn you about toxic amounts of phosphine gas.
 - Use the respiratory protection and protective clothing recommended in this Alert (see back of sheet to order complete Alert).
 - Change into protective clothes before handling fumigants.
- Do not eat, drink, or use tobacco in areas where phosphide fumigants are used.
 - Wash your hands and face before you eat, drink, or smoke.
 - If possible, shower and change into clean clothes before you leave work.



Aluminum and magnesium phosphide containers may flash on opening. Pay careful attention to handling procedures on labels.

*Please tear out and post.
Distribute copies to workers.*

*See back of sheet for employer recommendations
and ordering information.*

Employers, do the following to protect your workers from phosphide fumigants:

- Comply with all applicable OSHA and EPA regulations.
- Inform workers that phosphide fumigants may cause fatal illness or injury.
- Tell workers which materials contain phosphide fumigants or are contaminated with them.
- Make sure that phosphide fumigants are properly disposed of by trained workers.
- Pay special attention to the explosive nature of phosphide fumigants in confined spaces or mixed with water.
- Determine the potential for worker exposure.
- Do not rely on odor to warn workers about toxic amounts of phosphine gas.
- Carefully monitor air concentrations of phosphine gas in the work area and the workers' personal breathing zones.
- Post warning signs to indicate fumigated areas.
- Decide when and where respirators should be used.
- Provide the respiratory protection and personal protective equipment recommended in this Alert (see below to order complete Alert).
- Provide training programs for workers to reduce exposures to fumigants.
- Be aware of the many symptoms associated with phosphine gas exposure.
- Seek immediate medical attention for exposed workers with severe respiratory symptoms.
- Do not permit workers with symptoms such as dizziness and lightheadedness to drive or perform other complex tasks.

For additional information, see ***NIOSH Alert: Preventing Phosphine Poisoning and Explosions during Fumigation*** [DHHS (NIOSH) Publication No. 99-126]. Single copies of the Alert are available free from the following:

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WARNING!

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The National Institute for Occupational Safety and Health (NIOSH) requests help in preventing worker exposures to phosphine gas during the application of phosphide fumigants. These products are often used to fumigate agricultural products and to control rodents.

This Alert describes 205 cases of illness or injury in workers exposed to phosphine gas associated with phosphide fumigants. Information about these exposures is urgently needed by agricultural workers, employers, cooperative extension agents, physicians, and other health care providers. NIOSH therefore requests that editors of trade journals, safety and health officials, labor unions, and agricultural employers bring this Alert to the attention of all workers who handle products that generate phosphine gas.

BACKGROUND

Hazards of Phosphide Fumigants

Phosphide fumigants release toxic phosphine gas (PH_3) when they contact moisture in the

air. When phosphine is inhaled, it can react with moisture in the lungs to form phosphoric acid, which can cause blistering and edema. These effects can be serious or fatal. Exposure to phosphine has also been linked with other effects such as chest tightness, headache, dizziness, and nausea. Also, improper handling of aluminum and magnesium phosphide has caused injuries from flash fires and explosions.



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In 1988, NIOSH published survey results showing that worker exposure to phosphine often substantially exceeded the Occupational Safety and Health Administration (OSHA) permissible exposure limit (PEL) [Zaebst et al. 1988]. The case reports described in this Alert clearly illustrate the hazards to workers who handle or work near phosphide fumigants.

Commonly Used Fumigants

Commonly used fumigants include the following:

- **Aluminum phosphide** (AIP). Aluminum phosphide fumigants include Phostoxin[®] and Fumitoxin[®]. They are used for product fumigation and occasionally for rodent control. Some formulations of aluminum phosphide also contain ammonium carbamate (about 40%), which releases ammonia gas and carbon dioxide [Hayes and Laws 1990]. The carbon dioxide reduces the tendency of the phosphine to oxidize spontaneously and thus prevents explosions and fires.
- **Magnesium phosphide** (Mg₃P₂). Magnesium phosphide fumigants include Magnaphos[®] and Magtoxin[®]. They are used for product fumigation and occasionally for rodent control.
- **Zinc phosphide** (Zn₃P₂). Zinc phosphide fumigants include ZP Rodent Bait[®] and Dexol Gopher Killer[®]. Zinc phosphide is more stable chemically than aluminum phosphide; it forms phosphine gas only when ingested. Thus zinc phosphide is used for rodent control but not for product fumigations.

Odor

Phosphine has been reported to have the odor of decaying fish at concentrations below

the OSHA PEL of 0.3 parts per million (ppm). However, Zaebst et al. [1988] reported that workers noticed no odor when they worked in phosphine concentrations as great as 50 ppm for several minutes with no respiratory protection. This lack of apparent odor may be attributable to olfactory fatigue (inability to detect an odor following exposure).

Others have reported that phosphine has a garlic-like odor, but this may be due to the use of technical grade phosphine fumigants that contain impurities. These impurities can produce substituted phosphines, diphosphines, methane, and most important, arsine (AsH₃). Arsine is a highly toxic gas with a garlic-like odor. In 1979, NIOSH published *Current Intelligence Bulletin 32*, which fully describes the hazards of arsine.

Thus workers should not rely on odor to warn them about the presence of phosphine.

Significant Chemical Reactions

On contact with oxygen, phosphine tends to decompose to more stable forms of phosphorus—ultimately to phosphoric acid. This process may occur explosively at concentrations above 1.8%, especially when trace amounts of diphosphine are present [Cotton and Wilkinson 1972]. Phosphine gas also reacts violently with compounds containing fluorine, chlorine, bromine, and iodine (halides). Furthermore, phosphine gas can react with a variety of metals, including copper, brass, gold, and silver.

Symptoms of Exposure

Phosphine gas irritates mucous membranes—especially those of the deep lungs and upper airways. Because phosphine gas

releases highly acidic forms of phosphorus when it contacts deep lung tissues, it tends to cause pulmonary edema (fluid in the lungs) [Parkes 1982]. Once absorbed into the body, phosphine can damage cell membranes and enzymes important for respiration and metabolism.

Intermittent, low concentrations of phosphine gas (probably 0.08 to 0.3 ppm) have been associated with mild headaches. Higher intermittent concentrations (0.4 to 35 ppm) have been linked to the following symptoms [Jones 1964]:

- Diarrhea, nausea, abdominal pain, and vomiting
- Tightness of the chest, breathlessness, soreness or pain in the chest, and palpitations
- Headache, dizziness, and staggering
- Skin irritation or burns

CURRENT EXPOSURE LIMITS

The OSHA PEL for phosphine is 0.3 ppm as an 8-hour time-weighted average (TWA) [29 CFR^{*} 1910.1000].

The U.S. Environmental Protection Agency (EPA) has established regulations governing the use of phosphide fumigants [40 CFR 152].

The NIOSH recommended exposure limit (REL) for phosphine is 0.3 ppm as a TWA for up to 10 hours per day during a 40-hour

work week, and 1 ppm as a 15-minute short-term exposure limit (STEL) that should not be exceeded at any time during a workday. In addition, NIOSH has established 50 ppm as the immediately dangerous to life and health (IDLH) concentration for phosphine gas. The IDLH is the concentration that could (1) result in death or irreversible health effects, or (2) prevent escape from the contaminated environment within 30 minutes.

The American Conference of Governmental Industrial Hygienists (ACGIH) threshold limit value (TLV) is 0.3 ppm as an 8-hour TWA; the ACGIH STEL is 1 ppm [ACGIH 1998].

CASE REPORTS

Summary of Reports

The case reports described here were reported by the California Pesticide Illness Surveillance Program (PISP). This program has received 29,863 reports of pesticide-related illness or injury for the period 1982–1992. These reports include 205 cases associated with exposure to phosphine gas and solid forms of aluminum, zinc, and magnesium phosphide [Mehler et al. 1992].

Types of Fumigants Involved

Among the 205 cases reported here, the primary fumigant was

- aluminum phosphide in 179 cases,
- zinc phosphide in 3 cases, and
- *not determined* in 23 cases (because the exposure involved more than one pesticide).

^{*} Code of Federal Regulations. See CFR in references.

The 23 *not determined* cases included

- 18 cases involving mixed exposure to zinc phosphide and chlorophacinone (an anticoagulant), and
- 5 cases involving mixed exposure to methyl bromide and aluminum phosphide.

Types of Workers Affected

Fifty-one of the 205 cases (24.9%) involved fumigant applicators (handlers), and 154 (75.1%) involved exposures to nonapplicators (bystanders or workers who did not directly handle fumigants).

Products Involved

Fumigation of the following products were linked to these cases:

	No. Cases	%
Agricultural products (grain, nuts, and fruit)	142	69.3
Rodent control products	52	25.4
Nonagricultural products	6	2.9
Not specified	5	2.4

Sources of Exposure

Applicators—Fumigant applicators were most often exposed during normal handling. The sources of exposure for the 51 applicator cases were as follows:

	No. Cases	%
Normal handling	32	62.7
Handling violations	13	25.5
Fires or disposal problems	4	7.8
Direct exposure	2	3.9

Nonapplicators—Nonapplicators were most often exposed during normal application and aeration. The sources of exposure for the 154 nonapplicator cases were as follows:

	No. Cases	%
Normal application and aeration	70	45.5
Fires or disposal problems	38	24.7
Reentry violations or exposures above 0.3 ppm	14	9.1
Fumigant container handling	6	3.9
Offsite (drift) exposures	4	2.6
In-transit fumigation	3	1.9
Direct exposure	1	0.6
Other	18	11.7

Illnesses

Applicators—Fumigant applicators reported numerous symptoms of illness after exposure to phosphide fumigants. Symptoms included skin irritation, rash, headache, nausea, vomiting, throat irritation, chest tightness, shortness of breath, dizziness, faintness, and incoherence. Two applicators required hospitalization, and four applicators lost work days (5, 7, 11, and 14 days, respectively).

Two applicators involved in phosphide fires and explosions reported chest pains, lightheadedness or dizziness, and difficulty in breathing or talking.

Nonapplicators—Nonapplicators reported nausea, headache, chest tightness, and stomach cramps after exposure to phosphide fumigants. One death also occurred (see Case 7). Reported illnesses in nonapplicators of ten occurred in clusters, accounting for 123 (79.9%) of the 154 reported cases.

Thirty-eight nonapplicators involved in phosphine fires and explosions reported symptoms of illness. Fire fighters were frequent victims. Of these cases, more than 20 were fire fighters who became ill during 6 phosphine exposure incidents. Others included a television reporter, a nearby mechanic, workers, a homeowner, and neighborhood residents.

Injuries

Two applicators were injured when phosphide fumigants spontaneously caught fire or exploded. They reported facial burns, hair loss, a broken leg, cuts, and a perforated eardrum.

Examples of Case Reports (1982–1992)

Case 1—Rodent Control

Six workers reported illness after they applied aluminum phosphide to rodent burrows in a field of tall, wet grass. No air samples were taken, but the employers concluded that application conditions had produced more rapid release of phosphine gas than expected.

Case 2—Rodent Control

A rodent control worker wearing coveralls, rubber gloves, and goggles noticed an onion/garlic odor while applying aluminum phosphide tablets. He soon developed tightness in his chest. Though he was not hospitalized, he missed 11 days of work.

Case 3—Walnut Fumigation

A worker wearing cloth and leather gloves placed Phostoxin[®] tablets into bins of walnuts at a greater rate than recommended on

the label. He then secured a plastic liner on top. One hour later the worker developed dizziness, headache, faintness, incoherence, and shortness of breath. He lost 5 days of work.

Case 4—Disposal

After a fumigation, workers placed unused Phostoxin pellets in a 4-cubic-foot bin and covered it with a tarpaulin. The bin exploded while two workers were checking it to see whether combustion was complete. One worker suffered facial burns, hair loss, a broken left leg, and a perforated eardrum. The other worker received facial cuts and burns.

Case 5—Disposal

At a North Hollywood spaghetti sauce factory, two explosions occurred during attempts to dispose of unused material from 62 trays of aluminum phosphide. First, a small explosion resulted when 20 trays were placed in a barrel with liquid and a detergent. A second explosion occurred when 42 trays were placed in a dry barrel.

Four fire fighters at the scene were hospitalized for 40 hours with nausea. Plant workers were treated and released at a nearby emergency room. And four neighborhood residents were briefly hospitalized.

Case 6—Grain Elevator

Workers at a grain elevator developed headache, nausea, tightness of the chest, and stomach cramps after collecting grain samples and noting a foul odor. A colorimetric tube sample showed a phosphine gas concentration of about 25 ppm.

Case 7—Railcar Fumigation

An unemployed man stowed away in a rice-filled rail car that was being fumigated in transit from Houston, Texas. He was found dead several days later when the train arrived in Colusa, California [CDC 1994].

CONCLUSIONS

Serious illness, injury, and death may result from handling phosphide fumigants in the workplace. These risks are linked to the following:

- Lack of proper handling during fumigant application
- Failure to monitor air concentrations during application
- Failure to use appropriate respiratory equipment
- Improper disposal of unused fumigant products
- Incidental exposure from nearby fumigant application

Fires and explosions due to the mishandling of fumigant products have particularly disastrous consequences.

Workers are often unaware of the risks of working with or near phosphide fumigants. These risks can be greatly minimized by following the recommendations outlined in this Alert.

RECOMMENDATIONS

NIOSH recommends the following measures to reduce exposures to phosphine gas in the workplace.

Summary of Recommendations

Workers

- Observe warning signs and know which work areas have been fumigated. Do not enter them until they have been aired out and monitored to show that they are safe.
- Pay careful attention to handling procedures on phosphide fumigant labels.
- Be aware that phosphide fumigants may explode when they contact air or are mixed with water.
- Take part in any air monitoring or training programs your employer offers.
- Do not rely on odor as a warning of toxic amounts of phosphine gas.
- Use the respiratory protection and protective clothing recommended in this Alert.
- Change into protective clothes before handling fumigants.
- Practice good personal hygiene.

Employers

- Comply with all applicable OSHA and EPA regulations.
- Inform workers that phosphide fumigants may cause fatal illness or injury.
- Tell workers which materials contain phosphide fumigants or are contaminated with them.

- Make sure that phosphide fumigants are properly disposed of by trained workers.
- Pay special attention to the explosive nature of phosphide fumigants when they contact air or are mixed with water.
- Determine the potential for worker exposure.
- Do not rely on odor to warn workers about exposure to toxic amounts of phosphine gas.
- Carefully monitor air concentrations of phosphine gas in the work area and the workers' personal breathing zones.
- Post warning signs to indicate fumigated areas.
- Decide when and where respirators should be used.
- Provide the respiratory protection and personal protective equipment recommended here.
- Provide training programs for workers to reduce exposures to fumigants.
- Be aware of the many symptoms associated with phosphine gas exposure.
- Seek immediate medical attention for exposed workers with severe respiratory symptoms.
- Do not permit workers with symptoms such as dizziness and lightheadedness to drive or perform other complex tasks.

These recommendations are discussed in more detail in the following subsections.

Aeration and Reentry

Take the following steps before permitting workers to reenter the area after fumigation.

- Aerate the area until the airborne concentration of phosphine gas is below the NIOSH REL of 0.3 ppm.
- Monitor the area to make sure that phosphine gas released from the fumigated product does not raise concentrations above 0.3 ppm.
- Allow no one to reenter a treated area without an approved respirator until this monitoring is complete.

Un aerated Products

Do not expose workers to phosphine gas at concentrations greater than 0.3 ppm during the moving, storage, or processing of incompletely aerated products.

Industrial Hygiene Monitoring

- Monitor both the work area and the workers' breathing zones after fumigation to
 - protect workers from phosphine gas exposures that exceed the NIOSH REL of 0.3 ppm, and
 - determine when and where respiratory protection is needed.
- If monitoring shows that airborne concentrations are at or above 0.3 ppm, reduce them by using engineering controls (such as forced-air ventilation) and appropriate work practices.

- For immediate sampling results, use short-term colorimetric indicator tubes, direct-reading lapel badges, and direct-reading phosphine gas and vapor monitors.

Personal Hygiene

- Do not eat, drink, or use tobacco in areas where phosphide fumigants are used.
- Wash hands and face before eating, drinking, or smoking.
- If possible, shower and change into clean clothes before leaving work.

Protective Clothing

- Use safety glasses with solid side shields or goggles to protect eyes if contact with phosphide pellets is likely.
- Wear elastomeric or plastic gloves and shoes to protect hands and feet from contact with phosphide pellets. Clean such clothing with hot water and detergent before the next use.

Respirators

Do not use respirators as the primary means of controlling worker exposures to phosphine gas. Instead, use effective engineering controls and work practices to minimize worker exposures.

Workers may use respirators when engineering controls are being implemented and when intermittent tasks expose them to concentrations that cannot be kept below the NIOSH REL by engineering controls alone.

All respirators should be used in conjunction with a formal respiratory protection program

- as required in the OSHA respiratory protection standard [29 CFR 1910.134], and
- as outlined in the NIOSH Respirator Decision Logic [NIOSH 1987b] and the NIOSH Guide to Industrial Respiratory Protection [NIOSH 1987a].

Important elements of the OSHA respiratory protection standard are as follows:

- An evaluation of the worker's ability to perform the work while wearing a respirator
- Regular training of workers in the proper use of respirators
- Periodic environmental monitoring
- Respirator fit testing
- Maintaining, inspecting, cleaning, and storing respirators
- Selecting proper NIOSH-approved respirators
- Procedures to ensure adequate quality, quantity, and flow of breathing air for atmosphere-supplying respirators

Employers should evaluate the respiratory protection program regularly. Table 1 lists the NIOSH-recommended respiratory protection for workers exposed to phosphine gas.

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We greatly appreciate your assistance in protecting the lives of American workers.



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Table 1. NIOSH-recommended respiratory protection for workers exposed to phosphine gas*

Condition	Minimum respiratory protection†
Phosphine gas concentration (ppm):	
0.3–3	Supplied-air respirator
7.5 or less	Supplied-air respirator operated in a continuous-flow mode
15 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 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

* Only NIOSH/MSHA-approved or NIOSH-approved (effective date July 10, 1995) respiratory equipment should be used.

† Respirators with higher assigned protection factors (APFs) may be substituted for those with lower APFs [NIOSH 1987a].



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