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HSM-15003

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DATE: June 29, 2015

SUBJECT: PHOSPHINE MITIGATION SCOPING DOCUMENT

Attached is the Phosphine Mitigation Scoping Document that spans a period of five years (2010–2014). Certain data from those years were not yet available when DPR was preparing its 2014 Exposure Assessment and Risk Characterization documents (RCD). The attached scoping document serves to update the phosphine data within those 2014 documents.

The RCD for phosphine concluded that risk estimates potentially were of concern for the following exposure scenarios:

- Occupational handler risks (some short-term, seasonal, and annual risks)
- Occupational bystander risks (most seasonal and annual risks, and some short-term risks)
- Residential bystander risks (all short-term, seasonal, and annual risks)

The updated scoping data show that phosphine and phosphine progenitor (i.e., aluminum phosphide and magnesium phosphide) use patterns, labeling restrictions, and illness report rates have remained similar to previous years that were included in the RCD. Therefore, the updated scoping data remain consistent with the conclusions of the RCD.

Prior to undertaking mitigation activities, it may be useful for DPR to confirm the assumptions that were used when calculating risk estimates in the RCD and address any data gaps that may exist. To the extent that is practical, DPR should confirm assumptions and their appropriateness, and address data gaps using data collected from actual phosphine applications. Appendix 1 describes instances where collecting additional data may be useful to address scenarios for which assumptions do not appropriately reflect California use conditions or to address scenarios for which data are not available.

California Environmental Protection Agency

Department of Pesticide Regulation
Worker Health and Safety Branch

HSM-15003

PHOSPHINE MITIGATION SCOPING DOCUMENT

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PHOSPHINE MITIGATION SCOPING DOCUMENT

I. SUMMARY

The updated scoping data show that phosphine use patterns, labeling restrictions, and illness report rates have remained similar to previous years that were included in DPR's Exposure Assessment Document (EAD; Reeve 2014) and Risk Characterization Document (RCD; Rubin 2014). Therefore, the updated scoping data are consistent with the conclusions of the RCD.

II. PURPOSE

The scoping document spans a period of five years (2010–2014) and identifies new products that were registered after DPR's EAD and RCD for phosphine were completed. The scoping document contains Pesticide Use Reporting (PUR) data and pesticide sales data for 2011 and 2013, and Pesticide Illness Surveillance Program (PISP) data for 2011 and 2012, beyond 2010 data identified in the EAD and RCD. All potential exposure scenarios—occupational handler, occupational bystander, and residential bystander—were identified in the EAD and RCD. The scoping document does not identify additional exposure scenarios.

III. REGULATORY HISTORY/STATUS

Phosphine, also known as hydrogen phosphide, is a rodenticide and insecticide used to fumigate stored agricultural products such as grains, nuts, processed foods, and animal feed; nonfood products such as wood, leather, and clothing; and rodent burrows. Phosphine is marketed as a liquefied pressurized gas and in precursor products. The precursor products include solid aluminum phosphide and magnesium phosphide, both of which generate phosphine gas upon contact with moisture. Zinc phosphide is also a precursor and generates phosphine upon contact with stomach acid. However, zinc phosphide was specifically excluded from this grouping because it reacts with stomach acid rather than water (Rubin 2014) and because its use patterns are significantly different from the fumigation uses of phosphine gas (US EPA 2009b).

Aluminum phosphide and magnesium phosphide were first registered in the U.S. in 1958 and 1979, respectively. Phosphine was registered in 2001 (Rubin 2014). The metal phosphides (aluminum and magnesium phosphide) are stable solids when dry. However, both degrade in the presence of atmospheric moisture to generate phosphine gas, as well as breakdown products aluminum hydroxide and magnesium hydroxide, respectively (Gurusinghe 2014), which are common components in antacids.

Fumigation using either gas or solid product typically lasts a few days to a month, depending on the type of structure and the ambient temperature. At the end of the fumigation period, the remaining phosphine gas is vented out to the ambient air (Gurusinghe 2014) and unreacted product, if present, is deactivated in a detergent-and-water solution and allowed to set for 36 hours. The resulting slurry is disposed at a sanitary landfill (Degesch America, Inc. 2013). Phosphine and phosphine generators, aluminum and magnesium phosphide, have been designated as a toxic air contaminant (TAC) and a hazardous air pollutant (HAP).

Table 1. Federal laws and regulations applicable to aluminum phosphide, magnesium phosphide, and phosphine

Law/Regulation	Aluminum phosphide	Magnesium phosphide	Phosphine
FIFRA Registration Type	Section 3, Regular	Section 3, Regular	Section 3, Regular
FIFRA Reregistration Eligibility Decision (RED)	Issued 1998	Issued 1998	Registered after 1984; not subject to reregistration review
FFDCA Tolerance Reassessment Eligibility Decision (TRED)	Not applicable	Not applicable	Not applicable
FQPA Susceptibility of Children	No increased susceptibility	No increased susceptibility	No increased susceptibility[1]
FQPA Cumulative Risk[2]	Not applicable	Not applicable	Not applicable
Title 40 CFR, Part 170 Worker Protection Standard	Use & safety requirements on label	Use & safety requirements on label	Use & safety requirements on label
Title 40 CFR, Part 180.225 Phosphine Tolerance Levels	Final Rule: September 9, 2009[3] (US EPA 2009)	Final Rule: September 9, 2009[3] (US EPA 2009)	Final Rule: September 9, 2009 (US EPA 2009)
FIFRA: Federal Insecticide, Fungicide, and Rodenticide Act, 1947 [Section 3(c)(5)(D) and Section 2(bb)]; Amended 1988 to require Reregistration of pesticides registered before 11/1/1984 [Section 4(g)(2)(A)]. FFDCA: Federal Food, Drug, and Cosmetic Act, 1938; Amended 1996 to require a safety determination of no harm from aggregate exposures [Section 408(b)(2)(A)(ii)]. FQPA: Food Quality Protection Act, 1996 [Section 408(b)(2)(C)(i) and (ii)]. CFR: Code of Federal Regulations			

[1] Child susceptibility findings identified in the Aluminum and Magnesium Phosphide RED are assumed to apply to phosphine, since both compounds are phosphine generators.

[2] EPA determined that a cumulative risk assessment was unnecessary, as the metal phosphides and phosphine were not identified as members of a cumulative group that shares a common mechanism of toxicity (US EPA 2013).

[3] Tolerances for aluminum phosphide and magnesium phosphide are expressed as phosphine tolerances. EPA consolidated phosphine tolerance expressions to eliminate references to how phosphine gas is generated (i.e., aluminum and magnesium phosphide reaction with moisture to liberate phosphine gas; US EPA 1999a).

Table 2. California regulations applicable to aluminum phosphide, magnesium phosphide, and phosphine

	Restricted Material	Toxic Air Contaminant	Groundwater Protection List	Proposition 65 List
Yes/No	**Yes**	**Yes**	No	No
Law	FAC Div. 7, Ch. 3, Art. 1.5, Sec. 14001	FAC Div. 7, Ch. 3, Art. 1.5, Sec. 14021(b)	FAC Div. 7, Ch. 2, Art. 15, Sec. 13141	HSC Sec. 25249.5
Regulation	3 CCR 6400	3 CCR 6860	3 CCR 6800	27 CCR 25000-27001
FAC: California Food and Agricultural Code HSC: Health and Safety Code CCR: California Code of Regulations				

Risk Characterization Document (RCD), 2014

DPR's comprehensive RCD for phosphine (Rubin 2014) was promulgated on December 29, 2014 (Prichard 2014), making it the most recent regulatory document of note. Key points include:

<u>Hazard Identification and Endpoints evaluated by RCD</u>

Acute inhalational toxicity (assessed via renal tubular necrosis, increased kidney weights and death): The RCD determined that the inhalational acute exposure critical No Observable Effect Levels (NOELs) for phosphine are 5.0 ppm.

Subchronic and chronic inhalational toxicity (assessed via sleeping behavior, respiration and body temperature): Inhalational subchronic exposure critical NOELs are 1.0 ppm; inhalational chronic exposure critical NOELs are 1.0 ppm.

Acute dermal toxicity: No dermal studies were available for analysis.

Reproductive toxicity: No studies were available for analysis.

Developmental toxicity: No developmental effects at the sublethal dose (i.e., study doses up to 4.9 ppm but less than the study's lethal dose of 7 ppm).

Genotoxicity (mutations and chromosomal aberrations): There is potential for genotoxic impacts of phosphine in human populations.

Oncogenicity (induction of tumors): There is no evidence for oncogenicity.

Endocrine effects: There is no evidence to suggest endocrine impacts of phosphine.

Aggregate exposure (simultaneous exposure involving more than one route): There is potential for aggregate exposure by dermal and inhalation routes, because phosphine gas would likely contact both dermal and pulmonary surfaces. Simultaneous exposure by oral and inhalation routes is unlikely outside of intentional ingestion of aluminum and magnesium phosphide.

Cumulative exposure: Exposure to other pesticides with similar mechanisms of toxicity was considered unlikely.

Dietary exposure: A dietary analysis was not conducted because, although there are phosphine residue tolerances for about 50 food crops, residues are unlikely to remain at the time of consumption. EPA established a food tolerance of 0.006 ppm, the highest limit of detection (Rubin 2014). In the absence of a dietary analysis, a tolerance assessment on phosphine was considered unnecessary.

Ambient exposure (exposure to the public that is neither adjacent to, nor associated with, specific applications): Significant ambient exposure was not anticipated.

Target Levels for Acceptable Risk

Non-oncogenic risks: Because the critical NOELs are based on laboratory animal studies, margins of exposure (MOEs) of 100 or higher for acute, seasonal, and annual exposure scenarios are considered sufficient to protect human health. Appendix 2 lists the acute, seasonal, and annual MOEs for the occupational and bystander exposure scenarios identified in the RCD. Since the MOE is calculated as a ratio, the higher the value the lower the risk.

Many acute, seasonal, and annual use scenarios produced MOEs of less than 100, indicating insufficient health protection for workers and bystanders under those scenarios. Moreover, some acute MOEs for occupational bystanders were as low as 17, including those adjacent to farm bins, flat storage facilities, or warehouses during fumigation and aeration. In addition, MOEs were less than 100 for all residential bystander scenarios, except spot fumigation residential bystander. Under most scenarios, MOEs for residential and occupational bystanders were less than 50. Finally, MOEs of less than 20 were common for many seasonal and annual scenarios (Rubin 2014).

Oncogenic risks: There is no evidence for oncogenicity.

Exposure Assessment Document, 2014

DPR's RCD was based on the exposure assessment presented in DPR's comprehensive Exposure Assessment Document for phosphine (Reeve 2014). The EAD evaluated the range of exposure scenarios and hazards that was summarized for the RCD. Appendix 3 details exposure estimate calculations for exposure scenarios in the EAD. Further, the EAD summarized pesticide illness and injury data (page 21) through 2009 and pesticide use data (page 13) through 2010. For other categories of scoping data, such as formulations and label precautions, the EAD does not explicitly state the final year for which data were included.

U.S. EPA Final Work Plan, 2014

EPA's final work plan addresses its intent to review inhalation exposure for applicator and post-application inhalation exposure. A new dietary exposure and risk assessment also may be required during Registration Review to incorporate potential changes to the phosphine toxicological points of departure (PODs). A new occupational handler (mixer, loader, applicator) risk reassessment will incorporate new data, updated PODs, and to the extent that they are available, policies currently under development. Bystander risk (anyone not part of the fumigation) from phosphine emissions from treated commodities and structures will need to be evaluated based on label prescribed use conditions, and if the PODs or uncertainty factors change based on acute toxicological data identified. EPA plans to release the draft risk assessments in fall 2018 and complete a registration review decision by 2020 (U.S. EPA 2014).

Expanded Aluminum and Magnesium Phosphide Use Restrictions, 2010

In response to two exposure-related deaths in Utah, EPA expanded restrictions on aluminum and magnesium phosphide products used to control burrowing rodents. These restrictions prohibited all uses of aluminum and magnesium phosphide products near residential areas and increased buffer zones for treatments near non-residential areas that may be occupied (U.S. EPA 2010).

U.S. EPA Reregistration Eligibility Decision (RED), 1998

U.S. EPA's RED for aluminum phosphide and magnesium phosphide identified the following exposure scenarios: fumigators and helpers; bystanders during and post-fumigation (but before aeration); aerators; and bystanders during and post-aeration. Scenarios involved fumigants applied to concrete upright bins, bulk railcars, railroad boxcars, processing plants, tobacco warehouses, farm bins, flat bins, and in spot fumigation situations. Each site had workers in short term (1 to 7 days) and intermediate term (1 week to several months) exposure situations. Many of the sites had chronic situations (5 days/week for 6 months) as well. Based on the use pattern, the route of exposure of concern is inhalation; significant dermal exposure is not expected. Thus, doses and endpoints were selected only for inhalation exposure risk assessments (U.S. EPA 1998).

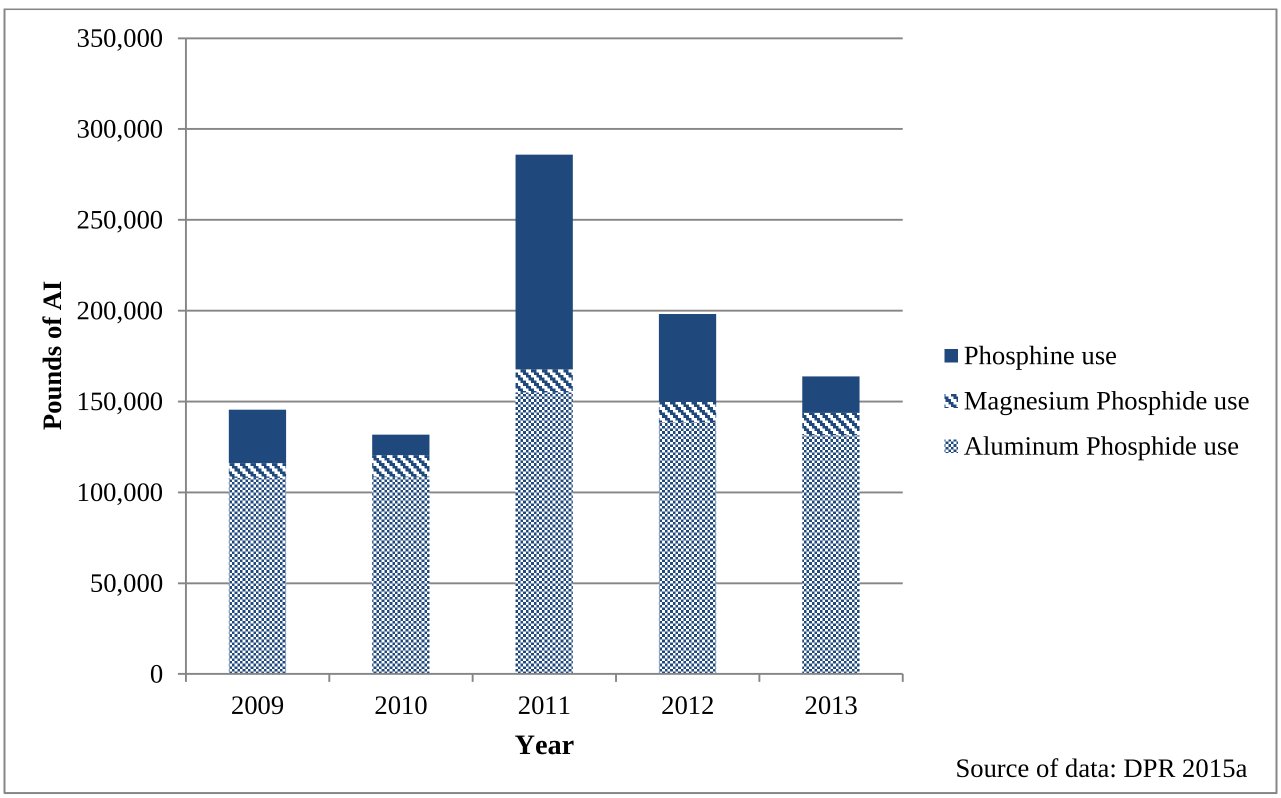
Carcinogenicity was not fully evaluated because the RED was completed before the results of the two-year carcinogenicity study were submitted. However, the study's interim results (at 52 weeks) showed no evidence of carcinogenicity. Further, exposure assessments did not indicate a concern for a potential dietary risk because residues of phosphine were not expected in food. Thus, aluminum and magnesium phosphide were not thought to pose a carcinogenic concern (U.S. EPA 1998).

IV. PESTICIDE USE AND SALES

From 2009 to 2013, aluminum phosphide was used primarily for commodity fumigation, landscape maintenance, and almonds; magnesium phosphine was used for commodity fumigation, other fumigation, and almonds; and phosphine was used for commodity fumigation, regulatory pest control, and almonds (DPR 2015a). The counties with highest use of aluminum phosphide, magnesium phosphine, and phosphine from 2009–2013 were Fresno, Yolo, and Stanislaus, respectively. Appendix 4 lists the top sites and counties using aluminum phosphide, magnesium phosphide, and phosphine, respectively, in terms of pounds of active ingredient (AI) from 2009–2013.

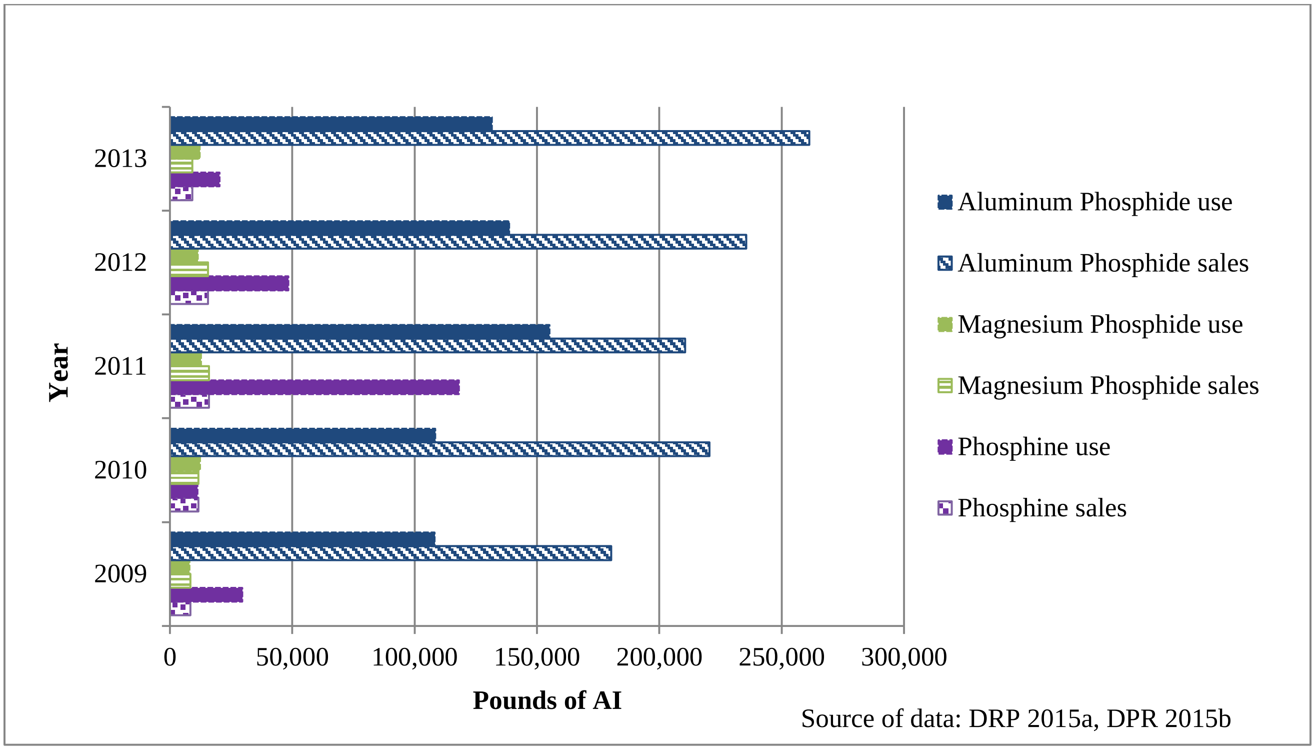
Aluminum phosphide use decreased from 2009 to 2010 and increased again in 2011 when use was at its highest (155,000 pounds AI applied). Magnesium phosphide use has continued to increase since 2009 with highest use in 2011 (12,700 pounds applied). However, magnesium phosphide use compared to aluminum phosphide remains low. Phosphine use also remained relatively low until 2011 when use increase sharply. In 2012 and 2013, there was a sharp decrease in use from 2011. Highest reported use of phosphine was in 2011 (118,000 pounds applied; Figure 1). In 2011, bearing acres and price per pound for tree nuts increased, which may attribute to the significant increase in pounds of phosphine and phosphine generators applied that year (DPR 2011). Use of phosphine and phosphine generators in Stanislaus County was also significantly higher in 2011. Almonds were the top harvested crop and had the highest value (increasing from $3.9 million in 2010 to $6.3 million in 2011), which may partially account for the use increase (Stanislaus County Agricultural Commissioner's Office 2011).

Figure 1. Reported use of aluminum phosphide, magnesium phosphide, and phosphine in California, 2009–2013



From 2009 to 2013, reported aluminum phosphide and magnesium phosphide sales within California have generally increased. Phosphine sales gradually increased from 2009 to 2011, then decreased between 2012 and 2013 (DPR 2015b; Figure 2). Highest reported sales of aluminum phosphide and magnesium phosphide (261,000 pounds and 14,000 pounds, respectively) were in 2013. The highest reported sales of phosphine (16,000 pounds) were in 2011.

Figure 2. Reported use and sales of aluminum phosphide, magnesium phosphide, and phosphine in California, 2009–2013



V. FORMULATIONS

Phosphine is marketed as a pressurized gas, as well as in solid precursor form of aluminum phosphide and magnesium phosphide. The metal phosphides are formulated as impregnated materials, pellets, tablets, and granules (US EPA 2013). As of completion date of the RCD, there were 11 active registrations for products containing aluminum phosphide, five for magnesium phosphide, and two for phosphine (DPR 2015c). Since that time, two additional phosphine products were registered—Eco2Fume Cold and VaporPH3OS Cold. Current formulations are detailed in Appendix 5. All products are state and federal restricted materials and contain signal word “Danger” on the label.

VI. LABEL REQUIREMENTS

According to the current labels, exposure to phosphine must not exceed an 8-hour TWA (time-weighted average) of 0.3 ppm (0.0004 mg/l) for applicators and workers during application.[4] This standard (i.e., 0.3 ppm) was developed as the permissible exposure limit (PEL) by the Occupational Safety and Health Administration (OSHA). The PEL is the amount of hazardous substance to which an average worker may be exposed for eight hours a day, five days a week, for forty years. The regulatory limit assumes that not all workers will be protected by this limit, particularly if they have a preexisting health condition. Therefore, the PEL is not intended to protect bystanders or the public, who may be exposed to an airborne chemical up to 24 hours a day if such a chemical is released into the community (U.S. EPA 1998).

Table 3. Label requirements for products that contain aluminum phosphide, magnesium phosphide, and phosphine

Label requirements	Aluminum phosphide, magnesium phosphide, and phosphine products
PPE	• dry gloves (leather or leather-faced cotton gloves when using phosphine gas) • NIOSH/MSHA approved full-face gas mask-phosphine canister (at phosphine concentrations from 0.3 ppm to 15 ppm) • NIOSH/MSHA approved self-contained breathing apparatus (SCBA) (at phosphine concentrations above 15 ppm or at unknown concentrations)
Signal Word	Danger
Restricted Material	Yes, Federal and California restricted materials
Maximum Application Rate	See Appendix 6
Minimum treatment duration	See Appendix 6
Certified Applicator Presence	• Present during container opening and during application • Present from initial opening of fumigated structure for aeration until aeration process is secure and monitoring indicates aeration can be completed safely
Exposure Limits	Not to exceed 8-hour TWA of 0.3 ppm or 15-minute TWA short-term exposure limit (STEL) of 1.0 ppm
Aeration	Aeration must be conducted at least 48 hours (72 hours for tobacco) before commodities are made available to consumers or, for non-food products, until the phosphine gas concentration is 0.3 ppm or lower. For railcars, containers, and other vehicles, aeration en-route is prohibited.
Fumigant Management Plan	Required to be written prior to all applications

[4] Application is defined as the time period covering the opening of the first container, applying the appropriate first dosage, and closing up the site to be fumigated (US EPA 1998).

VII. POTENTIAL EXPOSURE SCENARIOS

The range of exposure scenarios[5] has not changed since DPR's EAD (Reeve 2014) and RCD (Rubin 2014) were completed. As summarized in the RCD, potential exposures comprise:

- Occupational handlers (applicators, aerators, spent fumigant retrievers, and reentry workers) for all scenarios except spot fumigation;
- Occupational bystanders (nearby and assistant workers during and post-application and post-aeration) for all scenarios except burrowing pest fumigation;
- Residential bystander exposure for all scenarios except ship holds and ship containers,[6] and burrowing pest fumigation [7]

VIII. PESTICIDE ILLNESS REPORTS FOR THE LAST FIVE YEARS

During the last 5 years of data, 2008–2012 (the most recent data available), the Pesticide Illness Surveillance Program (PISP) database reported 26 aluminum phosphide exposure cases, 0 magnesium phosphide cases, and 5 phosphine cases (DPR 2015d). Most cases (80%) were due to agricultural use. Data from 2010 to 2012 were not available when the RCD was written. Thus, cases occurring during these years are summarized by year in Table 4 and by scenario in Table 5. Details of these cases are found in Appendix 7. Details of cases that occurred prior to 2010 are available in the RCD (Rubin 2014).

Table 4. PISP illness cases and incidents for aluminum phosphide, magnesium phosphide, and phosphine exposure by year (2010–2012; DPR 2015d).

Year in which incident occurred	Total cases	Total incidents
Aluminum Phosphide	**24**	**14**
2010	15	5
2011	3	3
2012	6	6
Magnesium Phosphide	**0**	**0**
Phosphine	**2**	**2**
2010	0	0
2011	0	0
2012	2	2
Grand Total	**26**	**16**

[5] Use scenarios examined include commodity fumigations in grain elevators, farm bins, flat storage facilities, warehouses, rail cars (bulk and boxcar), ship holds, and ship containers, as well as spot fumigations and burrowing pest fumigations (Rubin 2014).

[6] Residential bystander exposure estimates were not generated for ship hold or ship container scenarios, as residential bystanders are not anticipated to be near shipyards.

[7] Residential bystander exposure estimates were not generated for burrowing pest fumigation scenarios. EPA prohibited use of aluminum and magnesium phosphide products near residential areas (U.S. EPA 2010) and DPR issued permit conditions prohibiting use of aluminum and magnesium phosphide around all residential areas (DPR 2012). Thus, residential bystander exposure to phosphine due to burrowing pest fumigation is not anticipated.

Table 5. PISP illness data for aluminum phosphide, magnesium phosphide, and phosphine exposure by scenario (2010–2012; DPR 2015d).

Exposure scenario	Number of illness cases
Aluminum Phosphide	**24**
Occupational handler, ag	7
Occupational handler, non-ag	1
Occupational bystander, ag	13
Residential bystander, non-ag	1
Other (intentional ingestion)	2
Magnesium Phosphide	**0**
Phosphine	**2**
Occupational bystander, ag	2
Grand Total	**26**

A literature search identified 16 articles on phosphine gas illness cases from other states and other countries, primarily Iran (Table 6). All exposure cases are due to inhalational or oral exposure to aluminum phosphide (AlP). Aluminum phosphide is widely available and is a major cause of suicidal poisoning in many countries. Hence, many cases are the result of intentional oral exposure.

Table 6. Aluminum phosphide, magnesium phosphide, and phosphine illness cases in other states and other countries (2008–2015)

	Country, City	# of cases (time period)	Age	Route/# of suicides	Reference
1	Iran	3	6-35 yrs	inhalation (AlP)	Shadnia et al., 2008
2	India	1	40 yrs	oral (AlP), intentional	Shah et al., 2009
3	Iran, Tehran	39 (2007-2008)	14-62 yrs	oral (AlP), intentional; 26 suicides	Shadnia et al., 2010
4	U.S., Utah	6	children: 4-9 yrs, 15 mo; adults: not stated	inhalation (AlP)	Lemoine el al., 2011
5	Iran	2	32-46 yrs	oral (AlP), intentional; 2 suicides	Shadnia et al., 2011
6	Iran	1	28 yrs	oral (AlP), intentional; 1 suicide	Soltaninejad et al., 2011
7	Mexico, Jalisco	1	23 yrs	inhalation (AlP)	Trujillo et al., 2011
8	Iran	1	16 yrs	oral (AlP), intentional	Hassanian-Moghaddam and Shahbazi, 2012
9	U.S., Missouri	1	19 yrs	oral (AlP), intentional; 1 suicide	Jadhav et al., 2012
10	Iran	1	35 yrs	oral (AlP), accidental	Abbaspour et al., 2013
11	Denmark	1	31 yrs	oral (AlP), intentional	Moller Eggertsen et al., 2013
12	Greece	1	not stated	inhalation (AlP)	Ntelios et al., 2013
13	Iran, Kerman	1	27 yrs	oral (AlP), intentional	Torabi, 2013
14	Iran	1	24 yrs	oral (AlP), intentional	Mehrpour et al., 2014

15	India, Haryana	7	36.85 (mean age)	oral (AlP), intentional; 3 suicides	Agrawal et al., 2015
16	France	13	34-59 yrs	inhalation (AlP)	Lodde el al., 2015

IX. REFERENCES AND APPENDICES

Abbaspour, A. Nasrabadi, Z. N., Ghorbani, A., Marashi, S. M. 2013. Successful treatment of acute aluminum phosphide poisoning induced heart failure: a case report. *Razi Journal of Medical Sciences*. 2013 May; 20(107):78-83.

Agrawal, V. K., Bansal, A., Singh, R. K., Kumawat, B. L., Mahajan, P. 2015. Aluminum phosphide poisoning: Possible role of supportive measures in the absence of specific antidote. *Indian Journal of Critical Care Medicine*. 2015 Feb; 19(2):109-12.

Degesch America. 1988. Registration Package 51882-015. Registration Resource Center, Division of Registration and Health Evaluation, Department of Pesticide Regulation, California Environmental Protection Agency.

Degesch America, Inc. 2013. Material Safety Data Sheet: Aluminum Phosphide. April 2013. http://www.degeschamerica.com/docs/MSDS/AlP%20MSDS.pdf.

Department of Pesticide Regulation. 2015a. Summary of Pesticide Use Report Data 2004-2012. California Pesticide Information Portal (CalPIP), Pesticide Use Report Database, indexed by Chemical. http://www.cdpr.ca.gov/docs/pur/purmain.htm. Accessed May 15, 2015.

Department of Pesticide Regulation. 2015b. Reports of Pesticides Sold in California 2004-2012. Pesticides Sold in California. http://www.cdpr.ca.gov/docs/mill/nopdsold.htm. Accessed May 15, 2015.

Department of Pesticide Regulation. 2015c. Phosphine, Aluminum Phosphide, and Magnesium Phosphide Pesticide Data. Pesticide Data Index. http://apps.cdpr.ca.gov/ereglib/. Accessed January 6, 2015.

Department of Pesticide Regulation. 2015d. Phosphine, Aluminum Phosphide, and Magnesium Phosphide Pesticide Illness Reports 2008-2012. Pesticide Illness Surveillance Program (PISP), California Pesticide Illness Query (CalPIQ). http://apps.cdpr.ca.gov/calpiq/. Accessed May 4, 2015.

Department of Pesticide Regulation. 2012. Pesticide Use Enforcement Program Standards Compendium: Volume 3, Restricted Materials and Permitting. Department of Pesticide Regulation, California Environmental Protection Agency. http://www.cdpr.ca.gov/docs/enforce/compend/vol_3/rstrct_mat.htm

Department of Pesticide Regulation. 2011. Summary of Pesticide Use Report Data, 2011, indexed by Commodity. Pesticide Use Reporting. http://www.cdpr.ca.gov/docs/pur/pur11rep/comrpt11.pdf.

Gurusinghe, P. 2014. Fumigants: Phosphine and Phosphine-Generating Compounds Risk Characterization Document. Environmental Monitoring Branch, Department of Pesticide Regulation, California Environmental Protection Agency. February 2014. http://www.cdpr.ca.gov/docs/emon/pubs/fatememo/phosphine.pdf.

Hassanian-Moghaddam, H., Shahbazi, A. 2012. Gastric ventilation: a new approach to metal phosphide fumigant ingestion. *Clinical Toxicology (Philadelphia)*. 2012 Jun; 50(5):435-7.

Jadhav, A. P., Nusair, M. B., Ingole, A., Alpert, M. A. 2012. Unresponsive ventricular tachycardia associated with aluminum phosphide poisoning. *American Journal of Emergency Medicine*. 2012 May; 30(4):633 e3-5.

Lemoine, T. J., Schoolman, K., Jackman, G., Vernon, D. D. 2011. Unintentional fatal phosphine gas poisoning of a family. *Pediatric Emergency Care*. 2011 Sept; 27(9):869-71.

Lodde, B., Lucas, D., Letort, J. M., Jegaden, D., Pougnet, R., Dewitte, J. D. 2015. Acute phosphine poisoning on board a bulk carrier: analysis of factors leading to a fatal case. *Journal of Occupational Medical Toxicology*. 2015 Mar 1; 10:10.

Mehrpour, O., Amouzeshi, A. Dadpour, B., Oghabian, Z., Zamani, N., Amini, S., Hoffman, R. S. 2014. Successful treatment of cardiogenic shock with an intraaortic balloon pump following aluminium phosphide poisoning. *Archives of Industrial Hygiene and Toxicology*. 2014 Mar; 65(1):121-127.

Moller Eggertsen, P., Kristensen, A. K., Bredahl, C. 2013. Survival after oral poisoning with insecticide against moles containing aluminium phosphide. *Ugeskrift for Laeger*. 2013 Jun 10; 175(24):1704-5.

Prichard, A. 2014. Notice of Completion of Comprehensive Human Health Risk Assessment for the Active Ingredient Phosphine. California Notice 2014-16. Pesticide Registration Branch, Department of Pesticide Regulation, California Environmental Protection Agency. http://www.cdpr.ca.gov/docs/registration/canot/2014/ca2014-16.pdf.

Reeve, I. 2014. Estimation of Exposure to Persons in California to Phosphine due to Use of Aluminum Phosphide, Magnesium Phosphide, and Cylinderized Phosphine Gas. HS-1888. Sacramento, CA 94271-0001: Worker Health and Safety Branch, Department of Pesticide Regulation, California Environmental Protection Agency. June 12, 2014. http://www.cdpr.ca.gov/docs/risk/rcd/phosphine_ead_final.pdf.

Rubin, A. L. 2014. Phosphine Risk Characterization Document. Medical Toxicology Branch, Department of Pesticide Regulation, California Environmental Protection Agency. June 13, 2014. http://www.cdpr.ca.gov/docs/risk/rcd/phosphine.pdf.

Shadnia, S., Mehrpour, O., Abdollahi, M. 2008. Unintentional poisoning by phosphine released from aluminum phosphide. *Human Experimental Toxicology*. 2008 Jan; 27(1):87-9.

Shadnia, S., Mehrpour, O., Soltaninejad, K. 2010. A simplified acute physiology score in the prediction of acute aluminum phosphide poisoning outcome. *Indian Journal of Medical Science*. 2010 Dec; 64 (12): 532-9.

Shadnia, S., Soltaninejad, K., Hassanian-Moghadam, H., Sadeghi, A., Rahimzadeh, H., Zamani, N., Ghasemi-Toussi, A., Abdollahi, M. 2011. Methemoglobinemia in aluminum phosphide poisoning. *Human Experimental Toxicology*. 2011 Mar; 30(3):250-3.

Soltaninejad, K., Nelson, L. S., Khodakarim, N., Dadvar, Z., Shadnia, S. 2011. Unusual complication of aluminum phosphide poisoning: Development of hemolysis and methemoglobinemia and its successful treatment. *Indian Journal of Critical Care Medicine*. 2011 Apr; 15(2):117-9.

Stanislaus County Agricultural Commissioner's Office. 2011 Annual Crop Report. http://www.stanag.org/ag/croprpts/croppdf/2011-crop-report.pdf.

Torabi, M. 2013. Successful Treatment of Aluminium Phosphide Poisoning: A Case Report. *Iranian Journal of Pharmacology and Therapeutics*. 2013 Jul; 12(2): 77-79.
Trujillo, F. A., Perez, P. M. P., Borrayo, Y. C. 2011. Phosphine poisoning in healthcare workers. *Gaceta Medica de Mexico*. 2011 Jul-Aug; 147(4):350-4.

U.S. Environmental Protection Agency. 2014. Aluminum Phosphide, Magnesium Phosphide, and Phosphine Final Work Plan, Registration Review, Case Numbers 0025, 0645, and 7608. March 2014. http://www.regulations.gov/contentStreamer?documentId=EPA-HQ-OPP-2013-0081-0027&disposition=attachment&contentType=pdf.

U.S. Environmental Protection Agency. 2013. Aluminum Phosphide, Magnesium Phosphide, and Phosphine Preliminary Work Plan, Registration Review: Initial Docket, Case Numbers 0025, 0645, and 7608. September 2013. http://www.regulations.gov/contentStreamer?documentId=EPA-HQ-OPP-2013-0081-0009&disposition=attachment&contentType=pdf.

U.S. Environmental Protection Agency. 2010. Expanding Use Restrictions to Reduce Risks of Aluminum and Magnesium Phosphide. April 2010. http://www.epa.gov/oppsrrd1/reregistration/alphosphide/aluminum-magnsm-phos-fs.html. Accessed May 15, 2015.

U.S. Environmental Protection Agency. 2009. Pesticide Tolerance Nomenclature Changes; Technical Amendment. Federal Register Notice 74, no. 173. September 9, 2009. 46369-46377. http://www.gpo.gov/fdsys/pkg/FR-2009-09-09/pdf/E9-21416.pdf.

U.S. Environmental Protection Agency. 1999a. Phosphine; Pesticide Tolerances. Federal Register Notice 64, no.110. June 9, 1999. 30939-30949. http://www.gpo.gov/fdsys/pkg/FR-1999-06-09/pdf/99-14069.pdf.

U.S. Environmental Protection Agency. 1999b. Phosphine; Pesticide Tolerance. Federal Register Notice 64, no. 249. December 29, 1999. http://www.gpo.gov/fdsys/pkg/FR-1999-12-29/pdf/99-33332.pdf.

U.S. Environmental Protection Agency. 1998. Reregistration Eligibility Decision, Aluminum and Magnesium Phosphide, List A, Cases 0025 & 0645. http://www.epa.gov/opp00001/chem_search/reg_actions/reregistration/red_PC-066501_1-Dec-98.pdf.

Viral Shah, V., Seema Baxi1, S., Tanmay Vyas, T. 2009. Severe myocardial depression in a patient with aluminium phosphide poisoning: A clinical, electrocardiographical and histopathological correlation. *Indian Journal of Critical Care Medicine*. January-March 2009; 13(1):41-3.

Appendix 1. Phosphine Exposure Scenario Data Gaps

On April 17, 2015, DPR staff observed an aluminum phosphide application to tarped bins of raisins set up in a warehouse. Individual stacks containing 200-250 bins were tarped and treated with Fumitoxin pellets (EPA Registration #72959-2). Each stack was approximately 1,000 cubic feet, requiring one flask of 200 Fumitoxin pellets for treatment. Tarped commodity fumigation is common in California. However, DPR's EAD does not contain an appropriate surrogate for this scenario, because such data are not available. The closest potential scenario addressed in the EAD is for spot fumigation (see Appendix 3, Section 11), in which processing equipment within a grain mill complex is treated with magnesium phosphide strips (Degesch 1988, Reeve 2014). However, the spot treatment scenario does not include the use of tarps or treatment of a commodity and, therefore, does not appropriately reflect a tarped commodity fumigation scenario.

Further, because application scenarios in the EAD are based on data from studies carried out in the Midwest, some scenarios are not representative of application methods used in California. For instance, for applicator scenarios in several structure types (e.g., farm bins, flat storage facilities), the applicator added solid fumigant (pellets or tablets) to stored grain using one of four methods: walk-in method,[8] RPC method,[9] probe method,[10] and subsurface hand method[11] (Reeve 2014). Applications using the probe method have been known to occur in California, but the remaining three methods are not known to be used (H. Fong, personal communication).

In both instances, it would be useful to conduct additional air monitoring and collect additional worker and bystander breathing zone data for scenarios that more accurately reflect pesticide use in California in order to refine current phosphine exposure estimates.

[8] Walk-in method: Applicator walks through the grain shaking fumigant from a flask.

[9] RPC method: Applicator submerges a flask below the grain surface; fumigant is shaken into the grain as the flask is withdrawn.

[10] Probe method: Applicator submerges a pipe containing fumigant into the grain; fumigant is deposited into the grain as the pipe is withdrawn.

[11] Subsurface hand method: Applicator submerges a handful of fumigant below the grain surface.

Appendix 2. Margins of Exposure (MOEs) for Phosphine Exposure Scenarios

I. MOE Calculations

The RCD (Rubin 2014) expressed non-oncogenic risks resulting from exposure to phosphine as margins of exposure (MOEs). MOEs are the ratio of the critical No Observable Effect Level (NOEL) and the exposure dose,[12] therefore the higher the value the lower the risk. The RCD determined the NOEL for inhalational acute exposure to phosphine at 5.0 ppm, subchronic (seasonal) NOEL at 1.0 ppm, and chronic (annual) NOEL at 1.0 ppm. NOELs were determined for inhalational exposure only; there were no dermal toxicity studies so NOEL determination was not possible. The absolute air concentration of phosphine, rather than the absorbed dose, is assumed to be the major source of toxicity.

Because the NOELs are based on laboratory animal studies, MOEs of 100 or greater for acute, seasonal, and annual exposure scenarios were considered sufficient to protect human health. Section II (below) lists scenarios with MOEs<100, arranged by exposure (acute, seasonal, annual, or a combination). The MOEs for each scenario were calculated using the following formula:

$$\text{MOE} = \frac{\text{NOEL (ppm)}}{\text{Exposure dose (ppm)}}$$

Sample risk calculation—acute MOE for applicator applying aluminum phosphide in an upright concrete grain elevator bin using an auto-dispenser:

NOEL for acute exposure = 5.0 ppm (ppm)
Exposure dose (ppm) = 0.12 ppm from EAD, Table 12 (Reeve 2014)

MOE = NOEL / Exposure dose = (5.0 ppm) / (0.12 ppm) = 42

Table 1. MOEs for occupational and bystander scenarios resulting from phosphine gas exposure (Rubin 2014).

Exposure Scenario	Margin of Exposure (MOE)[13]		
	Acute	**Seasonal**	**Annual**
Aluminum phosphide fumigation in upright concrete grain elevator bins using auto-dispenser or manual operations			
Applicator (auto-dispenser)	**42**	**50**	100
Applicator (manual)	500	**14**	**20**

[12] Exposure doses are the acute, seasonal, and annual exposure estimates calculated in the EAD (Reeve 2014)
[13] MOEs for exposure scenarios above the level of concern (i.e., MOEs<100) are bolded.

Fumigation in upright concrete grain elevator bins			
Occupational bystander (inside and outside grain-elevator) during application	125	**5**	**8**
Residential bystander	**50**	**10**	**14**
Occupational bystander (inside and outside grain-elevator), post application	250	**7**	**11**
Residential bystander, post application	**50**	**10**	**14**
Occupational bystander (outside grain-elevator), post aeration	500	**14**	**20**
Residential bystander, post aeration	**50**	**10**	**14**
Fumigation in farm bins			
Applicator	**50**	143	200
Aerator	250	**3**	**5**
Occupational bystander (air monitor)	125	100	125
Occupational bystander (adjacent to farm bin during fumigation)	**17**	**3**	**5**
Occupational bystander (adjacent to farm bin during aeration)	**17**	**3**	**5**
Residential bystander (adjacent to farm bin during fumigation and aeration)	**50**	**10**	**14**
Fumigation flat storage facilities			
Applicator	1000	**9**	**14**
Aerator	250	**3**	**5**
Occupational bystander (adjacent to flat storage facility during fumigation)	**17**	**3**	**5**
Occupational bystander (adjacent to flat storage facility during aeration)	**17**	**3**	**5**
Residential bystander	**50**	**10**	**14**
Fumigation in warehouses			
Applicator	125	100	143
Aerator	250	**3**	**5**
Spent fumigant retriever	500	**8**	**13**
Occupational bystander (adjacent to warehouse during fumigation)	**17**	**3**	**5**
Occupational bystander (adjacent to warehouse during aeration)	**17**	**3**	**5**
Residential bystander	**50**	**10**	**14**
Fumigation in bulk rail cars			
Applicator	125	125	200
Occupational bystander (assistant worker)	250	**5**	**8**
Occupational bystander (nearby worker: post-application/pre-aeration)	714	**10**	**14**
Aerator	**63**	**50**	100
Occupational bystander (assistant aerator)	**42**	**8**	**13**
Occupational bystander (nearby worker: post-aeration)	556	**5**	**8**

Occupational bystander (packaging line for consumer products worker)	**63**	**5**	**8**
Residential bystander	**50**	**10**	**14**
Fumigation in box cars			
Applicator	**63**	100	143
Occupational bystander (assistant worker: application)	250	125	200
Occupational bystander (nearby worker: application)	167	**3**	**5**
Occupational bystander(nearby worker: post-application)	100	**3**	**5**
Residential bystander	**50**	**10**	**14**
Aeration in box cars			
Aerator (outdoor)	**83**	**50**	**77**
Aerator (indoor)	**50**	**25**	**33**
Occupational bystander (assistant aerator: outdoor aeration)	500	**6**	**9**
Occupational bystander (nearby worker: indoor post-aeration)	100	**50**	100
Occupational bystander (packaging line for consumer products worker)	**63**	**5**	**8**
Residential bystander	**50**	**10**	**14**
Fumigation in ship holds			
Applicator	1000	**9**	**14**
Aerator	**63**	**50**	100
Occupational bystander (application)	714	**10**	**14**
Occupational bystander (aeration)	556	**5**	**8**
Occupational bystander (in-transit fumigation)	**50**	**10**	**14**
Fumigation in ship containers			
Applicator	**63**	100	143
Aerator	**83**	**50**	**77**
Occupational bystander (application)	167	**3**	**5**
Occupational bystander (aeration)	556	**5**	**8**
Occupational bystander (in-transit fumigation)	**50**	**10**	**14**
Spot fumigation[14]			
Applicator	1250	n/a	n/a
Aerator/retriever/deactivator	250	n/a	n/a
Occupational bystander	**17**	n/a	n/a
Residential bystander	**50**	n/a	n/a

[14] Based on PUR data, minimal amounts of fumigant were used for spot fumigation in California from 2006–2012. Thus, no intermediate-term (seasonal) or long-term (annual) exposure estimates were generated (Reeve 2014).

Burrowing pest fumigation			
Applicator (certified)	**23**	**33**	100
Applicator (non-certified)	**21**	**17**	**33**
Reentry worker[15]	**83**	n/a	n/a
Occupational bystander 100 ft. from treated field[16]	167	n/a	n/a

II. Scenarios with MOEs above the level of concern (MOE<100) by exposure

A. MOE<100 for acute, seasonal, and annual exposures

All residential bystander scenarios, except spot fumigation residential bystander (see section D below)

Occupational bystander adjacent to

- farm bin during fumigation
- farm bin during aeration
- flat storage facility during fumigation
- flat storage facility during aeration
- warehouse during fumigation
- warehouse during aeration

Bulk rail car occupational bystander

- assistant aerator
- packaging line for consumer products worker

Box car

- occupational bystander (packaging line for consumer products worker) during aeration
- aerator (outdoor)
- aerator (indoor)

Ship hold occupational bystander during in-transit fumigation

Ship container

- aerator
- occupational bystander during in-transit fumigation

Burrowing pest fumigation applicator (non-certified)

B. MOEs<100 for acute and seasonal exposures only

Grain elevator applicator (auto-dispenser)
Bulk rail car aerator
Ship hold aerator
Burrowing pest fumigation applicator (certified)

[15] Daily exposure throughout the season is unlikely. Hence, only short-term exposure was estimated (Reeve 2014).
[16] Exposure throughout the season is unlikely. Hence, only short-term exposure was estimated (Reeve 2014).

C. MOEs<100 for seasonal and annual exposures only

Grain elevator applicator (manual)

Grain elevator occupational bystander

- inside and outside of grain-elevator during application
- inside and outside of grain-elevator during post-application
- outside grain-elevator during post aeration

Farm bin aerator

Flat storage facility

- applicator
- aerator

Warehouse

- aerator
- spent fumigant retriever

Bulk rail car occupational bystander

- assistant worker
- nearby worker during post-application/pre-aeration
- nearby worker during post-aeration

Box car occupational bystander

- nearby worker during application
- nearby worker post-application
- assistant aerator for outdoor aeration

Ship hold applicator

Ship hold occupational bystander

- during application
- during aeration

Ship container occupational bystander

- during application
- during aeration

D. MOEs<100 for acute exposure only

Farm bin applicator

Box car applicator

Ship container applicator

Spot fumigation

- occupational bystander
- residential bystander

Burrowing pest fumigation reentry worker

E. MOEs<100 for seasonal exposure only

Box car occupational bystander (nearby worker during indoor post-aeration)

Appendix 3. Phosphine Scenario Exposure Estimates

The EAD (Reeve 2014) presents 12 tables of exposure calculations for a range of exposure scenarios, which were used to tabulate Margins of Exposure (MOEs) in the RCD (Rubin 2014). Sample calculations were provided for short-term, seasonal, and annual exposures that included a respiratory protection factor (See 1.1 below) and for seasonal and annual exposures that did not included a respiratory protection factor (See 2.1 below).

Contents of Appendix 3:

1. Aluminum Phosphide Fumigation in Upright Concrete Grain Elevator Bins

Table 1. Exposure estimates for the applicator using an auto-dispenser or manually adding aluminum phosphide to commodity in concrete upright bins of grain-elevators

Exposure Scenario	Short-Term Exposure (ppm)	Seasonal Exposure (ppm)	Annual Exposure (ppm)
applicator (auto-dispenser)	0.12	0.02	0.01
applicator (manual)	0.01	0.07	0.05

1.1. Applicator (auto-dispenser)

The short-term exposure for the applicator using the auto-dispenser was 5.8 parts per million (ppm), the highest time-weighted average (TWA) breathing-zone air concentration generated for this scenario. Phosphine air concentrations that exceeded the 0.3 ppm 8-hr TWA permissible exposure level (PEL) would require the worker to use a respirator. Thus, the estimate was reduced by the 98% full-face respiratory protection factor (i.e., exposure estimate was reduced from 5.8 ppm to 0.12 ppm).

Based on pesticide use reporting (PUR) data for the years 2006-10, the estimated seasonal use of aluminum phosphide for fumigation for dry flowable commodities (e.g., nut and grains) and space fumigation is 8 months (Reeve 2014). This season was used to estimate seasonal exposure for workers and bystanders for all scenarios except those for spot fumigation and burrowing pest fumigation. Seasonal exposure estimates were generated using the mean air concentration or 0.8 ppm and adjusted for personal protective equipment (PPE) with the 98% protection factor, reducing the exposure estimate from 0.8 ppm to 0.02 ppm. Thus, workers are anticipated to be exposed to a phosphine air concentration of 0.02 ppm each day for 8 months of the year.

Annual exposure estimates were calculated by amortizing the seasonal exposure over the entire year, or 0.5 ppm. Adding the respiratory protection factor (i.e., 0.98) reduces the exposure estimate from 0.5 ppm to 0.01 ppm. Thus, workers are anticipated to be exposed to a phosphine air concentration of 0.02 ppm each day of the year.

Sample calculation for applicator (auto-dispenser) exposures

$$\text{Short-term exposure (ppm)} = \text{highest air concentration (ppm)} \times 98\%$$

$$\text{Short-term exposure (ppm)} = (5.8 \text{ ppm} \times 0.98) - 5.8 \text{ ppm} = 0.12 \text{ ppm}$$

$$\text{Seasonal exposure (ppm)} = \text{mean air concentration (ppm)} \times 98\%$$

$$\text{Seasonal exposure (ppm)} = (0.8 \text{ ppm} \times 0.98) - 0.8 \text{ ppm} = 0.02 \text{ ppm}$$

$$\text{Annual exposure (ppm)} = \left(\frac{\text{mean air concentration (ppm)} \times \text{months in the season}}{\text{months in the year}}\right) \times 98\%$$

$$\text{Annual exposure (ppm)} = \left(\frac{0.8 \text{ ppm} \times 8 \text{ months}}{12 \text{ months}}\right) \times 98\%$$

$$\text{Annual exposure (ppm)} = (0.5 \text{ ppm} \times 0.98) - 0.5 \text{ ppm} = 0.01 \text{ ppm}$$

1.2. Applicator (manual)

Short-term exposure for the manual applicator was 0.6 ppm, the highest TWA breathing-zone air concentration generated for this scenario. The exposure estimate was reduced from 0.6 to 0.01 ppm when adjusted for the use of a respirator such as a NIOSH/MSHA approved, full-face gas mask-phosphine canister combination.

Seasonal exposure estimates were generated using the mean of the air sample replicates, or 0.07 ppm. The exposure was less than 0.3 ppm, so the 98% respiratory protection factor was not added.

Annual exposure estimates were calculated by amortizing the seasonal exposure over 12 months, or 0.05 ppm.

2. Fumigation in Upright Concrete Grain Elevator Bins

Table 2. Occupational and residential bystander exposure to phosphine during fumigant application, post-application, and post-aeration of commodity in concrete upright bins of grain-elevators

Exposure Scenario	Short-Term Exposure (ppm)	Seasonal Exposure (ppm)	Annual Exposure (ppm)
Fumigant Application			
occupational bystander (in and outside grain-elevator)	0.04	0.2	0.13
residential bystander	0.1	0.1	0.07
Post-Application			
occupational bystander (in and outside grain-elevator)	0.02	0.14	0.09
residential bystander	0.1	0.1	0.07
Post-Aeration			
occupational bystander (outside grain-elevator)	0.01	0.07	0.05
residential bystander	0.1	0.1	0.07

2.1. Occupational bystander (inside and outside grain-elevator) during application

The occupational bystander working inside and outside of the grain-elevator had the highest potential exposure level. Therefore, this scenario was used to represent occupational bystander exposure during application and post-application.

Short-term exposure for occupational bystander during application was calculated from the highest measured phosphine air concentration (i.e., 2.0 ppm). The exposure was adjusted for the 98% respiratory protection factor, reducing the exposure estimate from 2.0 ppm to 0.04 ppm.

Seasonal exposure for occupational bystander during application was made equal to the mean of the measured air concentrations (i.e., 0.2 ppm). The exposure was less than 0.3 ppm, so the 98% respiratory protection factor was not added.

For annual exposure, the seasonal exposure air concentration was amortized over 12 months, or 0.13 ppm.

Sample calculations for occupational bystander (in/outside grain-elevator) during application exposures

Short-term exposure (ppm) = highest air concentration (ppm) x 98%

Short-term exposure (ppm) = (2.0 ppm x 0.98) – 2.0 ppm = 0.04 ppm

Seasonal exposure (ppm) = mean air concentration (ppm)

Seasonal exposure (ppm) = 0.2 ppm (less than 0.3 ppm; no respiratory protection factor added)

$$\text{Annual exposure (ppm)} = \frac{\text{mean air concentration (ppm) x months in the season}}{\text{months in the year}}$$

$$\text{Annual exposure (ppm)} = \frac{\text{0.2 ppm x 8 months}}{\text{12 months}} = 0.13 \text{ ppm}$$

2.2. Occupational bystander (inside and outside grain-elevator), post-application

Short-term exposure for the post-application occupational bystander was calculated from the highest measured phosphine air concentration (i.e., 0.99 ppm). The exposure was adjusted for the 98% respiratory protection factor, reducing the exposure estimate from 0.99 ppm to 0.02 ppm.

Seasonal exposure for post-application occupational bystander was made equal to the mean of the measured air concentrations, or 0.14 ppm. The exposure was less than 0.3 ppm, so the 98% respiratory protection factor was not added.

For annual exposure, the seasonal exposure air concentration was amortized over 12 months, or 0.09 ppm.

2.3. Occupational bystander (inside and outside grain-elevator), post-aeration

The occupational bystander working outside of the grain-elevator had the highest potential exposure level. Therefore, this scenario was used to represent occupational bystander exposure post-aeration.

Short-term exposure for the post-aeration occupational bystander was calculated from the highest measured phosphine air concentration (i.e., 0.51 ppm). The exposure was adjusted for the 98% respiratory protection factor, reducing the exposure estimate from 0.51 ppm to 0.01 ppm.

Seasonal exposure for the post-aeration occupational bystander was made equal to the mean of the measured air concentrations, or 0.07 ppm. The exposure was less than 0.3 ppm, so the 98% respiratory protection factor was not added.

For annual exposure, the seasonal exposure air concentration was amortized over 12 months, or 0.05 ppm.

2.4. Residential bystander, during application, post-application, post-aeration

Due to a lack of data for residential bystander, short-term and seasonal exposures were assumed to be 0.1 ppm, the 24-hr equivalent of the 8-hr TWA PEL (i.e., 0.3 ppm). The residential bystander was assumed to not be wearing respiratory protection.

For annual exposure, the seasonal exposure air concentration was amortized over 12 months, or 0.07 ppm.

3. Fumigation in Farm Bins

Application of phosphine using tablets, pellets, and bag belts act as surrogate estimates for other formulations. Farm bin estimate acts as surrogate for "grain storage tank" on product labels.

Table 3. Exposure estimates for the applicator, aerator, occupational bystander, and residential bystander during fumigation and aeration in farm bins

Exposure Scenario	Short-Term Exposure (ppm)	Seasonal Exposure (ppm)	Annual Exposure (ppm)
applicator	0.1	0.007	0.005
aerator	0.02	0.3	0.2
occupational bystander (air monitor)	0.04	0.01	0.008
occupational bystander (adjacent to farm bin during fumigation)	0.3	0.3	0.2
occupational bystander (adjacent to farm bin during aeration)	0.3	0.3	0.2
residential bystander (adjacent to farm bin during fumigation and aeration)	0.1	0.1	0.07

3.1. Applicator

Short-term exposure for the applicator was calculated from the highest measured phosphine air concentration (i.e., 4.8 ppm). The exposure was adjusted for the 98% respiratory protection factor, reducing the exposure estimate from 4.8 ppm to 0.01 ppm.

Seasonal exposure for the applicator was made equal to the mean of the measured air concentrations (i.e., 0.35 ppm[17]). The exposure was adjusted for the 98% respiratory protection factor, reducing the exposure estimate from 0.35 ppm to 0.007 ppm.
For annual exposure, the seasonal exposure air concentration was amortized over 12 months, or 0.23 ppm. Adding the 98% respiratory protection factor reduces the exposure estimate from 0.23 ppm to 0.005 ppm.

3.2. Aerator

Short-term exposure for the aerator was calculated from the highest measured phosphine air concentration (i.e., 1.2 ppm). The exposure was adjusted for the 98% respiratory protection factor, reducing the exposure estimate from 1.2 ppm to 0.02 ppm.

Seasonal exposure for the aerator was made equal to the mean of the measured air concentrations, or 0.3 ppm. Since the exposure was 0.3 ppm, the 98% respiratory protection factor was not added.

For annual exposure, the seasonal exposure air concentration was amortized over 12 months, or 0.2 ppm.

[17] The mean air concentration for farm bin applicator was calculated from the resulting seasonal exposure (i.e., 0.007), as the concentration was not provided in the EAD.

3.3. Occupational bystander (air monitor)

Short-term exposure for the air monitor was calculated from the highest measured phosphine air concentration (i.e., 1.8 ppm). The exposure was adjusted for the 98% respiratory protection factor, reducing the exposure estimate from 1.8 ppm to 0.04 ppm.

Seasonal exposure for the air monitor was made equal to the mean of the measured air concentrations (i.e., 0.6 ppm). The exposure was adjusted for the 98% respiratory protection factor, reducing the exposure estimate from 0.6 ppm to 0.01 ppm.

For annual exposure, the seasonal exposure air concentration was amortized over 12 months, or 0.4 ppm. Adding the 98% respiratory protection factor reduces the exposure estimate from 0.4 ppm to 0.008 ppm.

3.4. Occupational bystander (adjacent to farm bin during fumigation and aeration)

Due to a lack of data for occupational bystander, the 8-hr TWA PEL value of 0.3 ppm was used to estimate the short-term and seasonal exposures.

For annual exposure, the seasonal exposure air concentration was amortized over 12 months, or 0.2 ppm.

3.5. Residential bystander (adjacent to farm bin during fumigation and aeration)

Due to a lack of data for residential bystander, short-term and seasonal exposures were assumed to be 0.1 ppm, the 24-hr equivalent of the 8-hr TWA PEL (i.e., 0.3 ppm). The residential bystander was assumed to not be wearing respiratory protection.
For annual exposure, the seasonal exposure air concentration was amortized over 12 months, or 0.07 ppm.

4. Fumigation in Flat Storage Facilities

Table 4. Exposure estimates for the applicator, aerator, occupational bystander, and residential bystander during fumigation and aeration in flat storage facilities

Exposure Scenario	Short-Term Exposure (ppm)	Seasonal Exposure (ppm)	Annual Exposure (ppm)
applicator	0.005	0.11	0.07
aerator	0.02	0.3	0.2
occupational bystander (adjacent to flat storage facility during fumigation)	0.3	0.3	0.2
occupational bystander (adjacent to flat storage facility during aeration)	0.3	0.3	0.2
residential bystander	0.1	0.1	0.07

4.1. Applicator

Short-term exposure for the applicator was calculated from the highest measured phosphine air concentration (i.e., 45.7 ppm). The air concentration was above 15 ppm, requiring the use of a self-contained breathing apparatus (SCBA) in accordance with the label. Thus, the exposure was adjusted for the 99.99% respiratory protection factor for SCBA, reducing the exposure estimate from 45.7 ppm to 0.005 ppm.

Seasonal exposure for the applicator was made equal to the mean of the measured air concentrations (i.e., 5.4 ppm). The exposure was adjusted for the 98% respiratory protection factor, reducing the exposure estimate from 5.4 ppm to 0.11 ppm.

For annual exposure, the seasonal exposure air concentration was amortized over 12 months, or 3.6 ppm. Adding the 98% respiratory protection factor reduces the exposure estimate from 3.6 ppm to 0.07 ppm.

4.2. Aerator

Short-term exposure for the aerator was calculated from the highest measured phosphine air concentration (i.e., 1.2 ppm). The exposure was adjusted for the 98% respiratory protection factor, reducing the exposure estimate from 1.2 ppm to 0.02 ppm.
Seasonal exposure for the aerator was made equal to the mean of the measured air concentrations, or 0.3 ppm. Since the exposure was 0.3 ppm, the 98% respiratory protection factor was not added.

For annual exposure, the seasonal exposure air concentration was amortized over 12 months, or 0.2 ppm.

4.3. Occupational bystander (adjacent to flat storage facility during fumigation and during aeration)

Due to a lack of data for the occupational bystander, the 8-hr TWA PEL value of 0.3 ppm was used to estimate the short-term and seasonal exposures.
For annual exposure, the seasonal exposure air concentration was amortized over 12 months, or 0.2 ppm.

4.4. Residential bystander (adjacent to flat storage facility during fumigation and during aeration)

Due to a lack of data for residential bystander, short-term and seasonal exposures were assumed to be 0.1 ppm, the 24-hr equivalent of the 8-hr TWA PEL (i.e., 0.3 ppm). The residential bystander was assumed to not be wearing respiratory protection.

For annual exposure, the seasonal exposure air concentration was amortized over 12 months, or 0.07 ppm.

5. Fumigation in Warehouses

Table 5. Exposure estimates for the applicator, aerator, occupational bystander, and residential bystander during fumigation and aeration in warehouses

Exposure Scenario	Short-Term Exposure (ppm)	Seasonal Exposure (ppm)	Annual Exposure (ppm)
applicator	0.04	0.01	0.007
aerator	0.02	0.3	0.2
spent fumigant retriever	0.01	0.12	0.08
occupational bystander (adjacent to warehouse during fumigation)	0.3	0.3	0.2
occupational bystander (adjacent to warehouse during aeration)	0.3	0.3	0.2
residential bystander	0.1	0.1	0.07

5.1. Applicator

Short-term exposure for the applicator was calculated from the highest measured phosphine air concentration (i.e., 2.0 ppm). The exposure was adjusted for the 98% respiratory protection factor, reducing the exposure estimate from 2.0 ppm to 0.04 ppm.

Seasonal exposure for the applicator was made equal to the mean of the measured air concentrations, or 0.6 ppm. The exposure was adjusted for the 98% respiratory protection factor, reducing the exposure estimate from 0.6 ppm to 0.01 ppm.

For annual exposure, the seasonal exposure air concentration was amortized over 12 months, or 0.4 ppm. Adding the 98% respiratory protection factor reduces the exposure estimate from 0.4 ppm to 0.08 ppm.[18]

5.2. Aerator

Short-term exposure for the aerator was calculated from the highest measured phosphine air concentration (i.e., 1.2 ppm). The exposure was adjusted for the 98% respiratory protection factor, reducing the exposure estimate from 1.2 ppm to 0.02 ppm.

Seasonal exposure for the aerator was made equal to the mean of the measured air concentrations, or 0.3 ppm. Since the exposure was 0.3 ppm, the 98% respiratory protection factor was not added.
For annual exposure, the seasonal exposure air concentration was amortized over 12 months, or 0.2 ppm.

[18] The calculation for the warehouse applicator annual exposure estimate was 0.08 ppm. However, the EAD indicates that the exposure estimate was 0.07 ppm. This is a possible rounding or typographical error.

5.3. Spent fumigant retriever

Short-term exposure for the retriever was calculated from the highest measured phosphine air concentration (i.e., 0.5 ppm). The exposure was adjusted for the 98% respiratory protection factor, reducing the exposure estimate from 0.5 ppm to 0.01 ppm.

Seasonal exposure for the retriever was made equal to the mean of the measured air concentrations, or 0.12 ppm. The exposure was less than 0.3 ppm, so the 98% respiratory protection factor was not added.

For annual exposure, the seasonal exposure air concentration was amortized over 12 months, or 0.08 ppm.

5.4. Occupational bystander (adjacent to warehouse during fumigation and aeration)

Due to a lack of data for the occupational bystander, the 8-hr TWA PEL value of 0.3 ppm was used to estimate the short-term and seasonal exposures.

For annual exposure, the seasonal exposure air concentration was amortized over 12 months, or 0.2 ppm.

5.5. Residential bystander (adjacent to warehouse during fumigation and during aeration)

Due to a lack of data for residential bystander, short-term and seasonal exposures were assumed to be 0.1 ppm, the 24-hr equivalent of the 8-hr TWA PEL (i.e., 0.3 ppm). The residential bystander was assumed to not be wearing respiratory protection.

For annual exposure, the seasonal exposure air concentration was amortized over 12 months, or 0.07 ppm.

6. Fumigation in Bulk Rail Cars

Table 6. Exposure estimates for the applicator, aerator, assistant applicator, assistant aerator, occupational bystander, and residential bystander during and after fumigation and aeration in bulk rail cars

Exposure Scenario	Short-Term Exposure (ppm)	Seasonal Exposure (ppm)	Annual Exposure (ppm)
applicator	0.04	0.008	0.005
assistant worker	0.02	0.2	0.13
occupational bystander (nearby worker: post-application/pre-aeration)	0.007	0.1	0.07
aerator	0.08	0.02	0.01
assistant aerator	0.12	0.12	0.08
occupational bystander (nearby worker: post-aeration)	0.009	0.2	0.13
occupational bystander (packaging line for consumer products worker)	0.08	0.2	0.13
residential bystander	0.1	0.1	0.07

6.1. Applicator

Short-term exposure for the applicator was calculated from the highest measured phosphine air concentration (i.e., 2.0 ppm). The exposure was adjusted for the 98% respiratory protection factor, reducing the exposure estimate from 2.0 ppm to 0.04 ppm.

Seasonal exposure for the applicator was made equal to the mean of the measured air concentrations (i.e., 0.4 ppm). The exposure was adjusted for the 98% respiratory protection factor, reducing the exposure estimate from 0.4 ppm to 0.008 ppm.

For annual exposure, the seasonal exposure air concentration was amortized over 12 months, or 0.27 ppm. Adding the 98% respiratory protection factor reduces the exposure estimate from 0.27 ppm to 0.005 ppm.

6.2. Occupational bystander (assistant worker)during application

Short-term exposure for the assistant worker was calculated from the highest measured phosphine air concentration (i.e., 1.0 ppm). The exposure was adjusted for the 98% respiratory protection factor, reducing the exposure estimate from 1.0 ppm to 0.02 ppm.

Seasonal exposure for the assistant worker was made equal to the mean of the measured air concentrations, or 0.2 ppm. The exposure was less than 0.3 ppm, so the 98% respiratory protection factor was not added.

For annual exposure, the seasonal exposure air concentration was amortized over 12 months, or 0.13 ppm.

6.3. Occupational bystander (nearby worker: post-application/pre-aeration)

Short-term exposure for the post-application/pre-aeration nearby worker was calculated from the highest measured phosphine air concentration (i.e., 0.35 ppm). The exposure was adjusted for the 98% respiratory protection factor, reducing exposure estimate from 0.35 ppm to 0.007 ppm.

Seasonal exposure for the post-application/pre-aeration nearby worker was made equal to the mean of the measured air concentrations, or 0.1 ppm. The exposure was less than 0.3 ppm, so the 98% respiratory protection factor was not added.

For annual exposure, the seasonal exposure air concentration was amortized over 12 months, or 0.07 ppm.

6.4. Aerator

Short-term exposure for the aerator was calculated from the highest measured phosphine air concentration (i.e., 4.2 ppm). The exposure was adjusted for the 98% respiratory protection factor, reducing exposure estimate from 4.2 ppm to 0.08 ppm.

Seasonal exposure for aerator was made equal to the mean of the measured air concentrations (i.e., 1.0 ppm). The exposure was adjusted for the 98% respiratory protection factor, reducing the exposure estimate from 1.0 ppm to 0.02 ppm.

For annual exposure, the seasonal exposure air concentration was amortized over 12 months (i.e., 0.7 ppm). Adding the 98% respiratory protection factor reduces the exposure estimate from 0.7 ppm to 0.01 ppm.

6.5. Occupational bystander (assistant aerator)

Only one work shift breathing-zone air concentration was generated for the assistant aerator. Therefore, the short-term and seasonal exposures were derived for the same air concentration (i.e., 5.8 ppm). The short-term and seasonal exposures were adjusted for the 98% respiratory protection factor, reducing the exposure estimates from 5.8 ppm to 0.12 ppm.

For annual exposure, the seasonal exposure air concentration was amortized over 12 months (i.e., 3.9 ppm). Adding the 98% respiratory protection factor reduces the exposure estimate from 3.9 ppm to 0.08 ppm.

6.6. Occupational bystander (nearby worker: post-aeration)

Only one work shift breathing-zone air concentration was generated for the post-aeration nearby worker. Therefore, the short-term and seasonal exposures were derived from the same air concentration.

Short-term exposure: The air concentration was multiplied by the maximum label rate then divided by the application rate used in the registrant study to get 0.43 ppm, which was adjusted for the 98% respiratory protection factor. This reduced the exposure estimate from 0.43 ppm to 0.009 ppm.

Seasonal exposure: The air concentration was multiplied by the estimated seasonal application rate then divided by the application rate used in the registrant study to get 0.2 ppm. The exposure was less than 0.3 ppm, so the 98% respiratory protection factor was not added.

For annual exposure, the seasonal exposure air concentration was amortized over 12 months, or 0.13 ppm.

6.7. Occupational bystander (packaging line for consumer products worker)

Short-term exposure for the packaging line worker was calculated from the highest measured phosphine air concentration (i.e., 3.8 ppm). The exposure was adjusted for the 98% respiratory protection factor, reducing exposure estimate from 3.8 ppm to 0.08 ppm.

Seasonal exposure for the packaging line worker was made equal to the mean of the measured air concentrations, or 0.2 ppm. The exposure was less than 0.3 ppm, so the 98% respiratory protection factor was not added.

For annual exposure, the seasonal exposure air concentration was amortized over 12 months, or 0.13 ppm.

6.8. Residential bystander

Due to a lack of data for residential bystander, short-term and seasonal exposures were assumed to be 0.1 ppm, the 24-hr equivalent of the 8-hr TWA PEL (i.e., 0.3 ppm). The residential bystander was assumed to not be wearing respiratory protection.

For annual exposure, the seasonal exposure air concentration was amortized over 12 months, or 0.07 ppm.

7. Fumigation in Box Cars

Table 7. Exposure estimates for the applicator, assistant applicator, occupational bystander, and residential bystander during and after fumigation in box cars

Exposure Scenario	Short-Term Exposure (ppm)	Seasonal Exposure (ppm)	Annual Exposure (ppm)
applicator	0.08	0.01	0.007
assistant worker	0.02	0.008	0.005
occupational bystander (nearby worker: application)	0.03	0.3	0.2
occupational bystander (nearby worker: post-application)	0.05	0.3	0.2
residential bystander	0.1	0.1	0.07

7.1. Applicator

Short-term exposure for the applicator was calculated from the highest measured phosphine air concentration (i.e., 4.0 ppm). The exposure was adjusted for the 98% respiratory protection factor, reducing exposure estimate from 4.0 ppm to 0.08 ppm.

Seasonal exposure for the applicator was made equal to the mean of the measured air concentrations, or 0.5 ppm. The exposure was adjusted for the 98% respiratory protection factor, reducing the exposure estimate from 0.5 ppm to 0.01 ppm.

For annual exposure, the seasonal exposure air concentration was amortized over 12 months (i.e., 0.33 ppm). Adding the 98% respiratory protection factor reduces the exposure estimate from 0.33 ppm to 0.007 ppm.

7.2. Occupational bystander (assistant worker: application)

Only one work shift breathing-zone air concentration was generated for the assistant worker during application. Therefore, the short-term and seasonal exposures were derived for the nearby worker.

Short-term exposure: The air concentration was multiplied by the maximum label rate then divided by the application rate used in the registrant study to get 1.0 ppm, which was adjusted for the 98% respiratory protection factor. This reduced the exposure estimate from 1.0 ppm to 0.02 ppm.

Seasonal exposure: The air concentration was multiplied by the estimated seasonal application rate then divided by the application rate used in the registrant study to get 0.4 ppm, which was adjusted for the 98% respiratory protection factor. This reduced the exposure estimate from 0.4 ppm to 0.008 ppm.

For annual exposure, the seasonal exposure air concentration was amortized over 12 months, or 0.27 ppm). Adding the 98% respiratory protection factor reduces the exposure estimate from 0.27 ppm to 0.005 ppm.

7.3. Occupational bystander (nearby worker: application)

Short-term exposure for the nearby worker during application was calculated from the highest measured phosphine air concentration (i.e., 1.7 ppm). The exposure was adjusted for the 98% respiratory protection factor, reducing exposure estimate from 1.7 ppm to 0.03 ppm.

Seasonal exposure for the nearby worker during application was made equal to the mean of the measured air concentrations, or 0.3 ppm. Since the exposure was 0.3 ppm, the 98% respiratory protection factor was not added.

For annual exposure, the seasonal exposure air concentration was amortized over 12 months, or 0.2 ppm.

7.4. Occupational bystander (nearby worker: post-application)

Short-term exposure for the post-application nearby worker was calculated from the highest measured phosphine air concentration (i.e., 2.5 ppm). The exposure was adjusted for the 98% respiratory protection factor, reducing exposure estimate from 2.5 ppm to 0.05 ppm.[19]

Seasonal exposure for the post-application nearby worker was made equal to the mean of the measured air concentrations, or 0.3 ppm. Since the exposure was 0.3 ppm, the 98% respiratory protection factor was not added.

For annual exposure, the seasonal exposure air concentration was amortized over 12 months, or 0.2 ppm.

7.5. Residential bystander

Due to a lack of data for residential bystander, short-term and seasonal exposures were assumed to be 0.1 ppm, the 24-hr equivalent of the 8-hr TWA PEL (i.e., 0.3 ppm). The residential bystander was assumed to not be wearing respiratory protection.

[19] The calculation for the box car post-application nearby worker short-term exposure estimate was 0.05 ppm when adjusted for the 98% respiratory protection factor. However, the EAD indicates that the resulting exposure estimate was 0.03 ppm. This is a possible rounding or typographical error.

For annual exposure, the seasonal exposure air concentration was amortized over 12 months, or 0.07 ppm.

8. Aeration in Box Cars

Table 8. Exposure estimates for the aerator, assistant aerator, occupational bystander, and residential bystander during and after aeration in box cars

Exposure Scenario	Short-Term Exposure (ppm)	Seasonal Exposure (ppm)	Annual Exposure (ppm)
aerator (outdoor)	0.06	0.02	0.013
aerator (indoor)	0.1	0.04	0.03
assistant aerator (outdoor aeration)	0.01	0.17	0.11
occupational bystander (nearby worker: indoor post-aeration)	0.05	0.02	0.01
occupational bystander (packaging line for consumer products worker)	0.08	0.2	0.13
residential bystander	0.1	0.1	0.07

8.1. Aerator (outdoor)

Short-term exposure for the outdoor aerator was calculated from the highest measured phosphine air concentration (i.e., 2.8 ppm). The exposure was adjusted for the 98% respiratory protection factor, reducing exposure estimate from 2.8 ppm to 0.06 ppm.

Seasonal exposure for the outdoor aerator was made equal to the mean of the measured air concentrations, or 1.0 ppm. The exposure was adjusted for the 98% respiratory protection factor, reducing the exposure estimate from 1.0 ppm to 0.02 ppm.

For annual exposure, the seasonal exposure air concentration was amortized over 12 months (i.e., 0.67 ppm). Adding the 98% respiratory protection factor reduces the exposure estimate from 0.67 ppm to 0.013 ppm.

8.2. Aerator (indoor)

Short-term exposure for the indoor aerator was calculated from the highest measured phosphine air concentration (i.e., 4.9 ppm). The exposure was adjusted for the 98% respiratory protection factor, reducing exposure estimate from 4.9 ppm to 0.1 ppm.

Seasonal exposure for the indoor aerator was made equal to the mean of the measured air concentrations, or 2.0 ppm. The exposure was adjusted for the 98% respiratory protection factor, reducing the exposure estimate from 2.0 ppm to 0.04 ppm.

For annual exposure, the seasonal exposure air concentration was amortized over 12 months (i.e., 1.33 ppm). Adding the 98% respiratory protection factor reduces the exposure estimate from 1.33 ppm to 0.03 ppm.

8.3. Occupational bystander (assistant aerator: outdoor aeration)

Short-term exposure for the assistant aerator was calculated from the highest measured phosphine air concentration (i.e., 0.5 ppm). The exposure was adjusted for the 98% respiratory protection factor, reducing exposure estimate from 0.5 ppm to 0.01 ppm.

Seasonal exposure for assistant aerator was made equal to the mean of the measured air concentrations, or 0.17 ppm. The exposure was less than 0.3 ppm, so the 98% respiratory protection factor was not added.

For annual exposure, the seasonal exposure air concentration was amortized over 12 months, or 0.11 ppm.

8.4. Occupational bystander (nearby worker: indoor post-aeration)

Short-term exposure for the indoor post-aeration nearby worker was calculated from the highest measured phosphine air concentration (i.e., 2.3 ppm). The exposure was adjusted for the 98% respiratory protection factor, reducing exposure estimate from 2.3 ppm to 0.05 ppm.

Seasonal exposure for the indoor post-aeration nearby worker was made equal to the mean of the measured air concentrations, or 0.9 ppm. The exposure was adjusted for the 98% respiratory protection factor, reducing the exposure estimate from 0.9 ppm to 0.02 ppm.

For annual exposure, the seasonal exposure air concentration was amortized over 12 months (i.e., 0.6 ppm). Adding the 98% respiratory protection factor reduces the exposure estimate from 0.6 ppm to 0.01 ppm.

8.5. Occupational bystander (packaging line for consumer products worker)

Short-term exposure for the packaging line worker was calculated from the highest measured phosphine air concentration (i.e., 3.8 ppm). The exposure was adjusted for the 98% respiratory protection factor, reducing the exposure estimate from 3.8 ppm to 0.08 ppm.

Seasonal exposure for the packaging line worker was made equal to the mean of the measured air concentrations, or 0.2 ppm. The exposure was less than 0.3 ppm, so the 98% respiratory protection factor was not added.

For annual exposure, the seasonal exposure air concentration was amortized over 12 months, or 0.13 ppm.

8.6. Residential bystander

Due to a lack of data for residential bystander, short-term and seasonal exposures were assumed to be 0.1 ppm, the 24-hr equivalent of the 8-hr TWA PEL (i.e., 0.3 ppm). The residential bystander was assumed to not be wearing respiratory protection.

For annual exposure, the seasonal exposure air concentration was amortized over 12 months, or 0.07 ppm.

9. Fumigation in Ship Holds

Table 9. Exposure estimates for the applicator, aerator, and occupational bystander during application and aeration, and during in-transit fumigation in ship holds

Exposure Scenario	Short-Term Exposure (ppm)	Seasonal Exposure (ppm)	Annual Exposure (ppm)
applicator	0.005	0.11	0.07
aerator	0.08	0.02	0.01
occupational bystander (application)	0.007	0.1	0.07
occupational bystander (aeration)	0.009	0.2	0.13
occupational bystander (in-transit fumigation)	0.1	0.1	0.07

9.1. Applicator

No TWA breathing-zone data were available. Thus, the flat storage facility applicator exposure estimates were used as surrogate estimates (i.e., 45.7 ppm).

Short-term exposure for the applicator, adjusted for the 99.99% respiratory protection factor for SCBA, was 0.005 ppm.

Seasonal exposure for the applicator, adjusted for the 98% respiratory protection factor, was 0.11 ppm.

Amortizing the seasonal exposure air concentration over 12 months and adding the 98% respiratory protection factor, the annual exposure for the applicator was 0.07 ppm.

9.2. Aerator

No TWA breathing-zone data were available. Thus, the bulk car aerator exposure estimates were used as surrogate estimates (i.e., 4.2 ppm).

Short-term exposure for the aerator, adjusted for the 98% respiratory protection factor, was 0.08 ppm.

Seasonal exposure for the applicator, adjusted for the 98% respiratory protection factor, was 0.02 ppm.

Amortizing the seasonal exposure air concentration over 12 months and adding the 98% respiratory protection factor, the annual exposure for the aerator was 0.01 ppm.

9.3. Occupational bystander (application)

No TWA breathing-zone data were available. Thus, the bulk car post-application nearby worker exposure estimates were used as surrogate estimates (i.e., 0.35 ppm).

Short-term exposure for the occupational bystander during application, adjusted for the 98% respiratory protection factor, was 0.007 ppm.

Seasonal exposure for the occupational bystander during application was 0.1 ppm. The exposure was less than 0.3 ppm, so the 98% respiratory protection factor was not added.

Amortizing the seasonal exposure air concentration over 12 months, the annual exposure for the occupational bystander during application was 0.07 ppm.

9.4. Occupational bystander (aeration)

No TWA breathing-zone data were available. Thus, the bulk car post-aeration nearby worker exposure estimates were used as surrogate estimates (i.e., 0.43 ppm).

Short-term exposure for the occupational bystander during aeration, adjusted for the 98% respiratory protection factor, was 0.009 ppm.

Seasonal exposure for the occupational bystander during aeration was 0.2 ppm. The exposure was less than 0.3 ppm, so the 98% respiratory protection factor was not added.

Amortizing the seasonal exposure air concentration over 12 months, the annual exposure for the occupational bystander during aeration was 0.13 ppm.

9.5. Occupational bystander (in-transit fumigation)

No TWA breathing-zone data were available. Thus, the short-term and seasonal exposures for the occupational bystander during in-transit fumigation were assumed to be 0.1 ppm, the 24-hr equivalent of the 8-hr TWA PEL (i.e., 0.3 ppm).

Amortizing the seasonal exposure air concentration over 12 months, the annual exposure for the occupational bystander during in-transit fumigation was 0.07 ppm.

10. Fumigation in Ship Containers

Table 10. Exposure estimates for the applicator, aerator, and occupational bystander during application and aeration, and during in-transit fumigation in ship containers

Exposure Scenario	Short-Term Exposure (ppm)	Seasonal Exposure (ppm)	Annual Exposure (ppm)
applicator	0.08	0.01	0.007
aerator	0.06	0.02	0.013
occupational bystander (application)	0.03	0.3	0.2
occupational bystander (aeration)	0.009	0.2	0.13
occupational bystander (in-transit fumigation)	0.1	0.1	0.07

10.1. Applicator

No TWA breathing-zone data were available. Thus, the box car applicator exposure estimates were used as surrogate estimates (i.e., 4.0 ppm).

Short-term exposure for the applicator, adjusted for the 98% respiratory protection factor, was 0.08 ppm.

Seasonal exposure for the applicator, adjusted for the 98% respiratory protection factor, was 0.01 ppm.

Amortizing the seasonal exposure air concentration over 12 months and adding the 98% respiratory protection factor, the annual exposure for the applicator was 0.007 ppm.

10.2. Aerator

No TWA breathing-zone data were available. Thus, the box car outdoor aerator exposure estimates were used as surrogate estimates (i.e., 2.8 ppm).

Short-term exposure for the outdoor aerator, adjusted for the 98% respiratory protection factor, was 0.06 ppm.

Seasonal exposure for the outdoor aerator, adjusted for the 98% respiratory protection factor, was 0.02 ppm.

Amortizing the seasonal exposure air concentration over 12 months and adding the 98% respiratory protection factor, the annual exposure for the aerator was 0.013 ppm.

10.3. Occupational bystander (application)

No TWA breathing-zone data were available. Thus, the box car nearby worker during application exposure estimates were used as surrogate estimates (i.e., 1.7 ppm).

Short-term exposure for the occupational bystander during application, adjusted for the 98% respiratory protection factor, was 0.03 ppm.

Seasonal exposure for the occupational bystander during application was 0.3 ppm. Since the exposure was 0.3 ppm, the 98% respiratory protection factor was not added.

For annual exposure, the seasonal exposure air concentration was amortized over 12 months, or 0.2 ppm.

10.4. Occupational bystander (aeration)

No TWA breathing-zone data were available. Thus, the bulk car post-aeration nearby worker exposure estimates were used as surrogate estimates (i.e., 0.43 ppm).

Short-term exposure for the occupational bystander during aeration, adjusted for the 98% respiratory protection factor, was 0.009 ppm.

Seasonal exposure for the occupational bystander during aeration was 0.2 ppm. The exposure was less than 0.3 ppm, so the 98% respiratory protection factor was not added.

For annual exposure, the seasonal exposure air concentration was amortized over 12 months, or 0.13 ppm.

10.5. Occupational bystander (in-transit fumigation)

No TWA breathing-zone data were available. Thus, the short-term and seasonal exposures for the occupational bystander during in-transit fumigation were assumed to be 0.1 ppm, the 24-hr equivalent of the 8-hr TWA PEL (i.e., 0.3 ppm).

Amortizing the seasonal exposure air concentration over 12 months, the annual exposure for the occupational bystander during in-transit fumigation was 0.07 ppm.

11. Spot Fumigation

Based on Pesticide Use Report data, minimal amounts of fumigant was used for spot fumigation in California from 2006-2010. Thus, no intermediate-term (seasonal and annual) exposure estimates were generated.

Table 11. Exposure estimates for the applicator, aerator/retriever/deactivator, occupational bystander, and residential during spot fumigation

Exposure Scenario	Short-Term Exposure (ppm)	Seasonal Exposure (ppm)	Annual Exposure (ppm)
applicator	0.004	n/a	n/a
aerator/retriever/deactivator	0.02	n/a	n/a
occupational bystander	0.3	n/a	n/a
residential bystander	0.1	n/a	n/a

11.1. Applicator

Short-term exposure for the spot fumigation applicator was calculated from the highest measured phosphine air concentration (i.e., 41.6 ppm). The air concentration was above 15 ppm, requiring the use of SCBA in accordance with the label. Thus, the exposure was adjusted for the 99.99% respiratory protection factor for SCBA, reducing the exposure estimate from 41.6 ppm to 0.004 ppm.

11.2. Aerator/retriever/deactivator

Short-term exposure for the spot fumigation aerator/retriever/deactivator was calculated from the highest measured phosphine air concentration (i.e., 0.8 ppm). The exposure was adjusted for the 98% respiratory protection factor, reducing the exposure estimate from 0.8 ppm to 0.02 ppm.

11.3. Occupational bystander

Due to a lack of data for the occupational bystander, the 8-hr TWA PEL value of 0.3 ppm was used to estimate the short-term exposure.

11.4. Residential bystander

Due to a lack of data for residential bystander, short-term and seasonal exposures were assumed to be 0.1 ppm, the 24-hr equivalent of the 8-hr TWA PEL (i.e., 0.3 ppm).

12. Burrowing Pest Fumigation

Data from a registrant exposure study (Cytec Industries, Inc. [2004] Registration Package Number 51882-0022) was used to estimate exposure. The study investigated exposures to certified and non-certified applicators during application of aluminum phosphide tables to rodent burrows, as well as potential exposures to bystanders in buildings adjacent to the treated area or bystanders entering the treated area (Reeve 2014). Workers were assumed not to be wearing PPE. These estimates acted as surrogates for magnesium phosphide fumigation of rodent burrows.

Table 12. Exposure estimates for the applicator, reentry worker, and occupational bystander during fumigation for burrowing pests

Exposure Scenario	Short-Term Exposure (ppm)	Seasonal Exposure (ppm)	Annual Exposure (ppm)
applicator (certified)	0.22	0.03	0.01
applicator (non-certified)	0.24	0.06	0.03
reentry worker	0.06	n/a	n/a
occupational bystander in structure located 100 feet away from treated field	0.03	n/a	n/a

12.1. Applicator (certified)

Short-term exposure for the certified applicator was made equal to the highest phosphine air concentration generated in the study, or 0.22 ppm.

Based on pesticide use reporting (PUR) data for the years 2006-10, the bulk of burrowing pest fumigations was conducted using aluminum phosphide. The use season for this fumigant during 2006-10 is 6 months (Reeve 2014). This season was used to estimate seasonal exposure for certified and non-certified applicators during the burrowing pest fumigation. Seasonal exposure for the certified applicator was made equal to the mean of the phosphine air concentrations generated in the study, or 0.03 ppm.

For annual exposure, the seasonal exposure air concentration was amortized over 12 months, or 0.01 ppm.

12.2. Applicator (non-certified)

Short-term exposure for the non-certified applicator was made equal to the highest phosphine air concentration generated in the study, or 0.24 ppm.

Seasonal exposure for the non-certified applicator was made equal to the mean of the phosphine air concentrations generated in the study, or 0.06 ppm.

For annual exposure, the seasonal exposure air concentration was amortized over 12 months, or 0.03 ppm.

12.3. Reentry worker

This scenario represents the worker entering the treated field post-application. Daily exposure throughout the season is unlikely. Hence, only short-term exposure was estimated.
Short-term exposure for the reentry worker was made equal to the highest phosphine air concentration generated in the study, or 0.06 ppm.

12.4. Occupational bystander 100 ft. from treated field

Based on DPR’s permit conditions, the occupational bystander is assumed to work in a structure located 100 feet from the edge of the treated field. Due to a lack of data, the 8-hr TWA phosphine air concentration measured 15 feet from the treated field was used as a surrogate exposure estimate for the occupational bystander in a structure located 100 feet from the treated field. Only the short-term exposure estimate was used because exposure throughout the season is unlikely. Thus, short-term exposure for the occupational bystander was made equal to the highest phosphine air concentration 15 feet from the treated field, or 0.03 ppm.

Appendix 4. Top Sites and Counties using Aluminum Phosphide, Magnesium Phosphide, and Phosphine

Table 1. Aluminum phosphide use on top five sites and use in top five counties from 2009-2013

Year	Site	Pounds AI Applied	County	Pounds AI Applied	Total Pounds Applied
2009	Landscape maintenance Pistachios Commodity fumigation Vertebrate pest control Almonds	24,158 12,048 10,531 10,017 9,839	Fresno Kern Santa Barbara San Joaquin Los Angeles	20,242 9,746 8,150 7,180 7,013	108,084
2010	Landscape maintenance Commodity fumigation Vertebrate pest control Almonds Fruits (dried or dehydrated)	24,288 18,231 12,511 12,395 7,674	Fresno Kern Orange Colusa Madera	19,414 19,146 7,491 6,330 5,538	108,406
2011	Commodity fumigation Landscape maintenance Almonds Fumigation, other Vertebrate pest control	61,804 32,339 15,051 9,047 8,155	Stanislaus Fresno Kern San Joaquin Madera	48,757 17,579 8,970 8,624 6,876	155,140
2012	Landscape maintenance Almonds Commodity fumigation Regulatory pest control Rights of way	24,181 20,369 16,326 15,471 15,371	Fresno Stanislaus Butte Yolo Madera	23,699 19,123 16,418 12,324 12,066	138,586
2013	Vertebrate pest control Commodity fumigation Fumigation, other Regulatory pest control Almond	24,523 22,929 12,925 12,912 12,300	Fresno Ventura Kern Butte Madera	19,473 16,023 15,188 14,458 10,371	131,586

Table 2. Magnesium phosphide use on top five sites and use in top five counties from 2009-2013

Year	Site	Pounds AI Applied	County	Pounds AI Applied	Total Pounds Applied
2009	Commodity fumigation Almonds Fumigation, other Walnuts Structural pest control	3,206 2,677 1,060 436 367	Yolo Stanislaus Colusa Butte Glenn	2,532 2,212 926 605 523	8,009
2010	Fumigation, other Commodity fumigation Rice Almonds Walnuts	6,795 3,079 732 440 359	Solano Yolo Colusa Glenn Butte	6,465 2,169 822 513 504	12,233
2011	Commodity fumigation Structural pest control Beans, dried-type Fumigation, other Almonds	3,286 2,439 2,327 1,870 1,314	Stanislaus Yolo Merced Colusa San Joaquin	3,172 3,153 2,774 752 721	12,686
2012	Commodity fumigation Almonds Structural pest control Fumigation, other Rice	4,711 2,547 1,781 1,382 379	Yolo Merced Butte Alameda San Joaquin	4,659 3,002 553 524 516	11,315
2013	Almond Commodity fumigation Fumigation, other Pistachio Structural pest control	3,519 2,949 2,566 1,098 650	Yolo Merced San Joaquin Butte Tulare	2,483 1,915 1,295 1,206 1,106	12,167

Table 3. Phosphine use on top five sites and use in top five counties from 2009-2013

Year	Site	Pounds AI Applied	County	Pounds AI Applied	Total Pounds Applied
2009	Regulatory pest control Almonds Commodity fumigation Pistachios Fruits (dried or dehydrated)	15,950 10,061 1,128 1,079 289	Sacramento Stanislaus Kern Fresno Merced	16,106 8,272 2,082 959 525	29,527
2010	Almonds Commodity fumigation Fumigation, other Pistachios Walnuts	3,026 2,952 2,087 1,952 501	Stanislaus Kern Sacramento Fresno Butte	3,551 3,000 1,037 983 947	11,291
2011	Commodity fumigation Fumigation, other Regulatory pest control Pistachios Almonds	110,775 1,808 1,666 1,243 950	Stanislaus Butte Sacramento Kern Fresno	84,418 25,330 2,004 1,855 1,086	118,089
2012	Regulatory pest control Commodity fumigation Fumigation, other Structural pest control Almonds	30,081 7,705 6,415 1,759 775	Butte Stanislaus Fresno Yolo Kern	32,887 8,928 1,934 1,057 712	48,346
2013	Regulatory pest control Commodity fumigation Fumigation, other Pistachio Almond	9,471 4,159 2,018 1,864 1,312	Butte Kern Fresno Stanislaus Yolo	9,810 2,723 1,351 1,270 1,195	20,234

Appendix 5. Registered Products containing Aluminum Phosphide, Magnesium Phosphide, and Phosphine

Product	Registrant	CA Reg. No.	% AI	Formulation	Evaluated in Reeve 2014	Active as of 5/2015	Inactive date	Most recent DPR label
Aluminum Phosphide								
Gastoxin Fumigation Pellets	Bernardo Chemicals, Inc.	43743-2-AA	57%	pellet	x	x	n/a	01/27/2012
Gastoxin Fumigation Tablets	Bernardo Chemicals, Inc.	43743-1-AA	57%	tablet	x	x	n/a	01/27/2012
Gastoxin Fumigation Sachets	Bernardo Chemicals, Inc.	43743-3-AA	57%	gas-permeable bag	x	x	n/a	01/27/2012
Gastoxin Fumigation Sachet Chain	Bernardo Chemicals, Inc.	43743-3-ZA	57%	gas-permeable bag	x		12/31/2012	06/12/2008
Degesch Phostoxin Tablets	D&D Holdings, Inc.	72959-4-ZB	55%	tablet	x	x	n/a	02/13/2013
Degesch Phostoxin Pellets	D&D Holdings, Inc.	72959-5-AA	55%	pellet	x	x	n/a	02/13/2013
Degesch Phostoxin Tablet Prepac	D&D Holdings, Inc.	72959-9-AA	55%	gas-permeable blister pack of tablets	x	x	n/a	04/24/2014
Degesch Phostoxin Prepac Rope	D&D Holdings, Inc.	72959-8-AA	55%	gas-permeable blister pack of tablets	x	x	n/a	03/15/2013
Weevil-Cide Tablets	United Phosphorous, Inc.	70506-13-AA	60%	tablet	x	x	n/a	11/19/2010
Weevil-Cide Pellets	United Phosphorous, Inc.	70506-14-AA	60%	pellet	x	x	n/a	11/19/2010

Product	Registrant	CA Reg. No.	% AI	Formulation	Evaluated in Reeve 2014	Active as of 5/2015	Inactive date	Most recent DPR label
Weevil-Cide Gas Bags	United Phosphorous, Inc.	70506-15-AA	60%	gas-permeable bag	x	x	n/a	11/19/2010
Fumitoxin Pellets	D&D Holdings, Inc.	72959-2-ZA	55%	pellet	x	x	n/a	02/13/2013
Fumitoxin Tablets	D&D Holdings, Inc.	72959-1-ZA	55%	tablet	x	x	n/a	02/13/2013
PhosFume	Douglas Products and Packaging Co.	70506-13-AA-1015	60%	tablet	x		12/31/2012	04/09/2004
DetiaPhos Tablets	D&D Holdings, Inc.	72959-4-ZA	55%	tablet	x	x	n/a	02/13/2013
DetiaPhos Pellets	D&D Holdings, Inc.	72959-5-ZA	55%	pellet	x	x	n/a	02/13/2013
Detia Fumex	D&D Holdings, Inc.	72959-10-AA	57%	gas-permeable bag	x	x	n/a	04/22/2014
QuickPHlo-R Granules	United Phosphorous, Inc.	70506-69-AA	77.5%	granule	x	x	n/a	12/09/2011
Magnesium Phosphide								
Degesch Magtoxin Granules	D&D Holdings, Inc.	72959-11-AA	94.6%	granule	x	x	n/a	04/24/2014
Degesch Magtoxin Prepac Spot Fumigant	D&D Holdings, Inc.	72959-7-AA	66%	gas-permeable blister pack of pellets	x	x	n/a	03/15/2013
Magnaphos Gas Bags	United Phosphorous, Inc.	70506-17-AA	66%	gas bag	x	x	n/a	11/21/2006

Product	Registrant	CA Reg. No.	% AI	Formulation	Evaluated in Reeve 2014	Active as of 5/2015	Inactive date	Most recent DPR label
Degesch Fumi-Cel	D&D Holdings, Inc.	72959-6-AA	56%	impregnated plate	x	x	n/a	03/25/2015
Degesch Fumi-Strip	D&D Holdings, Inc.	72959-6-ZA	56%	impregnated plate	x	x	n/a	03/25/2015
Phosphine								
Eco_2Fume Fumigant Gas	Cytec Industries, Inc.	68387-7-AA	2%	containerized gas	x	x	n/a	06/26/2013
VaporPH$_3$OS Phosphine Fumigant	Cytec Industries, Inc.	68387-8-AA	99.3%	containerized gas	x	x	n/a	06/19/2013
Eco_2Fume Cold	Cytec Industries, Inc.	68387-7-ZA	2%	containerized gas		x	n/a	10/24/2014
VaporPH$_3$OS Cold	Cytec Industries, Inc.	68387-8-ZA	99.3%	containerized gas		x	n/a	10/24/2014

Appendix 6. Maximum Application Rates and Minimum Durations for Products containing Aluminum Phosphide, Magnesium Phosphide, and Phosphine

Site	Maximum Rate Per Application	Minimum Duration
Aluminum Phosphide		
Tablets (5 products)[20]		
Vertical storages	140 tablets/1,000 cu.ft.	3 days at 68ºF or above
Farm bins	145 tablets/1,000 cu.ft.	
Bulk stored commodities in flat storage, bunkers, and commodities stored on ground covered by tarp	145 tablets/1,000 cu.ft.	
Packaged commodities	90 tablets/1,000 cu.ft.	
Nuts, dates, or dried fruit in bulk or in storage boxes	40 tablets/1,000 cu.ft.	
Railcars, containers, trucks, vans, and other transport vehicles	145 tablets/1,000 cu.ft.	
Space fumigation, such as cereal mills, feed mills, food processing plants, warehouses	60 tablets/1,000 cu.ft.	
Stored tobacco	50 tablets/1,000 cu.ft.	
Non-food products	90 tablets/1,000 cu.ft.	
Stored beehives, supers and other beekeeping equipment for wax moth control and Africanized bees with tracheal mites and foulbrood	45 tablets/1,000 cu.ft.	
Barges	145 tablets/1,000 cu.ft.	
Ship holds	66 tablets/1,000 cu.ft.	
Rodent burrows	4 tablets per burrow	2 days
Pellets (5 products)[21]		
Vertical storages	700 pellets/1,000 cu.ft.	2 days at 68ºF or above
Farm bins	725 pellets/1,000 cu.ft.	
Bulk stored commodities in flat storage, bunkers, and commodities stored on ground covered by tarp	725 pellets/1,000 cu.ft.	
Packaged commodities	450 pellets/1,000 cu.ft.	
Nuts, dates, or dried fruit in bulk or in storage boxes	200 pellets/1,000 cu.ft.	
Railcars, containers, trucks, vans, and other transport vehicles	500 pellets/1,000 cu.ft.	
Space fumigation, such as cereal mills, feed mills, food processing plants, warehouses	300 pellets/1,000 cu.ft.	
Stored tobacco	250 pellets/1,000 cu.ft.	
Non-food products	450 pellets/1,000 cu.ft.	

[20] Gastoxin Fumigation Tablets, Degesch Phostoxin Tablets, Weevil-Cide Tablets, Fumitoxin Tablets, and DetiaPhos Tablets
[21] Gastoxin Fumigation Pellets, Degesch Phostoxin Pellets, Weevil-Cide Pellets, Fumitoxin Pellets, and DetiaPhos Pellets

Stored beehives, supers and other beekeeping equipment for wax moth control and Africanized bees with tracheal mites and foulbrood	225 pellets/1,000 cu.ft.	2 days at 68ºF or above
Barges	725 pellets/1,000 cu.ft.	
Ship holds	330 pellets/1,000 cu.ft.	
Commodity in small containers (Weevil-Cide Pellets only)	2 pellets/10 cu.ft.	
Rodent burrows	20 pellets per burrow	2 days
Gas bags (3 products)[22]		
Mills, food processing plants, warehouses	6 bags/1,000 cu.ft.	3 days at 68ºF or above
Packaged commodities	6 bags/1,000 cu.ft.	
Dried fruits, nuts, and dates	4 bags/1,000 cu.ft.	
Stored tobacco	4 bags/1,000 cu.ft.	
Bulk stored commodities in vertical storage	5 bags/1,000 cu.ft.	
Bulk stored commodities in tanks	6 bags/1,000 cu.ft.	
Flat Storage	13 bags/1,000 cu.ft.	
Farm bins	13 bags/1,000 cu.ft.	
Rail cars	6 bags/1,000 cu.ft.	
Bunkers, tarped ground storage	6 bags/1,000 cu.ft.	
Barges	7 bags/1,000 cu.ft.	
Ship holds	6 bags/1,000 cu.ft.	
Stored beehives, supers and other beekeeping equipment for wax moth control and Africanized bees with tracheal mites and foulbrood (Weevil-Cide Gas Bags and Detia Fumex only)	4 bags/1,000 cu.ft.	
Commodity in small containers (Weevil-Cide Gas Bags only)	1 bag/500 cu.ft.	
Blister pack of tablets (2 products)[23]		
Mills, warehouses, etc.	1,650 cu.ft./tablet prepac 52,800 cu.ft./prepac rope	3 days at 68ºF or above
Bagged commodities	1,100 cu.ft./tablet prepac 35,200 cu.ft./prepac rope	
Dried fruits and nuts	1,650 cu.ft./tablet prepac 52,800 cu.ft./prepac rope	
Stored tobacco	1,650 cu.ft./tablet prepac 52,800 cu.ft./prepac rope	
Vertical storages	1,100 cu.ft./tablet prepac 35,200 cu.ft./prepac rope	
Tanks	1,100 cu.ft./tablet prepac 35,200 cu.ft./prepac rope	
Flat storages	660 cu.ft./tablet prepac 21,120 cu.ft./prepac rope	
Farm bins	470 cu.ft./tablet prepac 15,040 cu.ft./prepac rope	
Bunkers and tarped ground storage	1,100 cu.ft./tablet prepac 35,200 cu.ft./prepac rope	

[22] Gastoxin Fumigation Sachets, Weevil-Cide Gas Bags, and Detia Fumex
[23] Degesch Phostoxin Prepac Rope and Degesch Phostoxin Tablet Prepac

Railcars	1,100 cu.ft./tablet prepac 35,200 cu.ft./prepac rope	3 days at 68ºF or above
Barges	660 cu.ft./tablet prepac 21,120 cu.ft./prepac rope	
Ship holds	1,100 cu.ft./tablet prepac 35,200 cu.ft./prepac rope	
Granules (1 product)[24]		
Vertical storages	132 g/1,000 cu.ft.	2 days at 68ºF or above
Farm bins	319 g/1,000 cu.ft.	
Railcars, containers, trucks, vans, and other transport vehicles	143 g/1,000 cu.ft.	
Space fumigation, such as cereal mills, feed mills, food processing plants, warehouses	132 g/1,000 cu.ft.	
Barges	176 g/1,000 cu.ft.	
Ship holds	143 g/1,000 cu.ft.	
Bulk stored commodities in flat storage and commodities stored on ground covered by tarp	176 g/1,000 cu.ft.	
Bulk stored commodities in bunkers and commodities stored on ground covered by tarp	319 g/1,000 cu.ft.	
Packaged commodities	132 g/1,000 cu.ft.	
Nuts, dates, or dried fruit in storage boxes	88 g/1,000 cu.ft.	
All other commodities	319 g/1,000 cu.ft.	
Stored tobacco	88 g/1,000 cu.ft.	
Magnesium Phosphide		
Granules (1 product)[25]		
Mills, warehouses, etc.	126 g/1,000 cu.ft.	2 days at 68ºF or above
Bagged commodities	126 g/1,000 cu.ft.	
Dried fruits and nuts	84 g/1,000 cu.ft.	
Stored tobacco	84 g/1,000 cu.ft.	
Vertical storages	126 g/1,000 cu.ft.	
Tanks	147 g/1,000 cu.ft.	
Flat storages	304 g/1,000 cu.ft.	
Farm bins	304 g/1,000 cu.ft.	
Bunkers and tarped ground storage	168 g/1,000 cu.ft.	
Railcars (no in-transit fumigation)	136 g/1,000 cu.ft.	
Barges	304 g/1,000 cu.ft.	
Ship holds	136 g/1,000 cu.ft.	
Blister pack of pellets (1 product)[26]		
Empty bins, silos, and holding tanks; grain elevator equipment; food processing equipment; related equipment in mills food/feed processing plants, and breweries	10 prepacs/1,320 cu.ft.	34 hours

[24] QuickPHlo-R Granules
[25] Degesch Magtoxin Granules
[26] Degesch Magtoxin Prepac Spot Fumigant

Gas bags (1 product)[27]		
Vertical storages	6 bags/1,000 cu.ft	3 days at 68ºF or above
Farm bins	6 bags/1,000 cu.ft	
Bulk stored commodities in flat storage, bunkers, and commodities stored on ground covered by tarp	6 bags/1,000 cu.ft	
Packaged commodities	6 bags/1,000 cu.ft	
Nuts, dates, or dried fruit in bulk or in storage boxes	6 bags/1,000 cu.ft	
Railcars, containers, trucks, vans, and other transport vehicles	6 bags/1,000 cu.ft	
Space fumigation, such as cereal mills, feed mills, food processing plants, warehouses	6 bags/1,000 cu.ft	
Stored tobacco	6 bags/1,000 cu.ft	
Non-food products	6 bags/1,000 cu.ft	
Stored beehives, supers and other beekeeping equipment for wax moth control and Africanized bees with tracheal mites and foulbrood	6 bags/1,000 cu.ft	
Barges	6 bags/1,000 cu.ft	
Ship holds	6 bags/1,000 cu.ft	
Commodity in small containers	1 bag/500 cu.ft	
Impregnated plate (2 products)[28]		
Mills, warehouses, etc.	1,650 cu. ft./Fumi-cel 33,000 cu. ft./Fumi-strip	2 days at 68ºF or above
Bagged commodities	1,100 cu. ft./Fumi-cel 22,000 cu. ft./Fumi-strip	
Dried fruits and nuts	1,650 cu. ft./Fumi-cel 33,000 cu. ft./Fumi-strip	
Stored tobacco	1,650 cu. ft./Fumi-cel 33,000 cu. ft./Fumi-strip	
Vertical storages	1,100 cu. ft./Fumi-cel 22,000 cu. ft./Fumi-strip	
Tanks	1,100 cu. ft./Fumi-cel 22,000 cu. ft./Fumi-strip	
Flat storages	660 cu. ft./Fumi-cel 13,200 cu. ft./Fumi-strip	
Farm bins	470 cu. ft./Fumi-cel 9,400 cu. ft./Fumi-strip	
Bunkers and tarped ground storage	1,100 cu. ft./Fumi-cel 22,000 cu. ft./Fumi-strip	
Railcars	1,100 cu. ft./Fumi-cel 22,000 cu. ft./Fumi-strip	
Barges	660 cu. ft./Fumi-cel 13,200 cu. ft./Fumi-strip	

[27] Magnaphos Gas Bags
[28] Degesch Fumi-Cel and Degesch Fumi-Strip

Ship holds	1,100 cu. ft./Fumi-cel 22,000 cu. ft./Fumi-strip	2 days at 68ºF or above
Phosphine		
Cylinderized gas (4 products)[29]		
Eco_2Fume and $VaporPH_3OS$ only		
Fresh commodities	1,000 ppm /1,000 cu.ft.	24 hours at 80ºF or above
Food/feed commodities in bulk storage	3,625ppm/1,000 cu.ft.	
Packaged commodities	2,250 ppm/1,000 cu.ft.	
Stored tobacco	1,250ppm/1,000 cu.ft.	
Non-food products	2,250 ppm/1,000 cu.ft.	
Nuts, dates, or dried fruit in bulk or storage boxes	1,000 ppm /1,000 cu.ft.	
Space fumigation	1,500 ppm /1,000 cu.ft.	
Eco_2Fume Cold and $VaporPH_3OS$ Cold only		
Raw commodities; processed foods and non-food commodities kept refrigerated or in cold storage; fresh flowers; bulbs, tuber, corms, and rhizomes (non-food use)	2,500 ppm/1,000 cu.ft.	24 hours at 43ºF or above

[29] Eco_2Fume Fumigant Gas, $VaporPH_3OS$ Phosphine Fumigant, and Eco_2Fume Cold $VaporPH_3OS$ Cold

Appendix 7. Pesticide Illness Reports

The Pesticide Illness Surveillance Program (PISP) database reported 24 aluminum phosphide exposure cases, 0 magnesium phosphide cases, and 5 phosphine cases from 2010-2012 (DPR 2015d).

Table 1. Illness data for aluminum phosphide, magnesium phosphide, and phosphine exposure by scenario

Exposure scenario	Number of illness cases
Aluminum Phosphide	**24**
Occupational handler, agriculture	7
Occupational handler, non-agriculture	1
Occupational bystander, agriculture	13
Residential bystander, non-agriculture	1
Other (intentional ingestion)	2
Magnesium Phosphide	**0**
Phosphine	**2**
Occupational bystander, agriculture	2
Grand Total	**26**

Aluminum Phosphide Cases

Occupational handler, agriculture:

- A certified applicator left an aluminum phosphide container with an improperly secured lid in his pesticide storage trailer. He developed symptoms soon after inhaling the trapped fumes when he reentered the trailer three days later.
- A vineyard worker developed symptoms after holding his breath as he applied aluminum phosphide to rodent holes.
- A bearded worker wearing a half-face respirator to apply aluminum phosphide pellets (respirator is not required by the label) developed symptoms following the application. Symptoms worsened the next week as he applied herbicides.
- An applicator developed symptoms on the third day of inserting fumigant tabs into the soil in a pistachio orchard.
- A worker developed symptoms after inhaling aluminum phosphide. He stated he was moving a container into storage, not applying it. However, the medical records indicate otherwise.
- A worker wearing improper respiratory protection developed symptoms a day after he fumigated grain and unidentified dust got into his eyes.
- An applicator developed a rash approximately one week after applying aluminum phosphide.

Occupational handler, non-agriculture:

- A worker developed symptoms when he inhaled fumes after opening a can of aluminum phosphide pellets.

Occupational bystander, agriculture:

- Ten cases were due to a single incident during which workers were responding to a fire in tarped bulk bags of fumigated pistachios. Water from a recent rainstorm inundated trays of aluminum phosphide being used to fumigate the pistachios. The aluminum phosphide reacted with the water to created phosphine gas and heat, which started a fire. Ten responding workers developed symptoms after inhaling fumes released during the fire.
- An office worker developed symptoms after smelling an odor, which he attributed to a nearby fumigation. He returned to the site of the fumigation twice to take pictures.
- A man developed symptoms after finding and opening a container of rodenticide pellets leftover from a harvesting business he operated 20 years ago.
- The worker felt ill while conducting a quality inspection at a nut processing facility. It was discovered that nut bins had been treated with phosphine, but fumigant levels had not been monitored.

Residential bystander, non-agriculture:

- A boy developed symptoms during football practice on an athletic field.

Other (intentional ingestion):

- A man committed suicide by ingesting 6 aluminum phosphide tablets.
- A homeless man claimed to have ingested the tablets of a restricted use pesticide (possible exposure to aluminum phosphide) in a gesture of self-harm.

Phosphine Cases

Occupational bystander, agriculture:

- A forklift driver developed symptoms 3 days after standing near treated almond bins as his coworkers were sampling treated nuts.
- A line worker developed symptoms while he was sealing almond bins about 125 feet from a fumigation site.