Journal of Toxicology: Clinical Toxicology

ISSN: 0731-3810 (Print) (Online) Journal homepage: http://www.tandfonline.com/loi/ictx19

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To cite this article: Jefferey L. Burgess, Dr. Jefferey Burgess, Barbara Morrissey, Matthew C. Keifer & William O. Robertson (2000) Fumigant-Related Illnesses: Washington State's Five-Year Experience, Journal of Toxicology: Clinical Toxicology, 38:1, 7-14, DOI: 10.1081/CLT-100100909

To link to this article: https://doi.org/10.1081/CLT-100100909

Published online: 23 Feb 2000.

Clinical Toxicology, 38(1), 7–14 (2000)

Fumigant-Related Illnesses: Washington State's Five-Year Experience

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ABSTRACT

Objective: Exposure to fumigants may have severe or persistent health effects. Washington State's fumigant-related illnesses were reviewed to better understand the circumstances surrounding exposure and resultant health effects. Methods: Fumigant-related illnesses reported to and investigated by the Washington State Department of Health were reviewed. Illnesses considered by Department of Health to be definitely, probably, or possibly related to pesticide exposure were then analyzed. Results: From 1992–1996, 39 (3.3%) of 1192 definite, probable, or possible cases of pesticide-related illnesses involved exposures to fumigants. Fumigant exposures during this period were to aluminum phosphide (15), methyl bromide (12), metam-sodium (9), and zinc phosphide (3). Symptoms included respiratory problems and eye and/or skin irritation for the majority of exposures, and no deaths were reported. The nature of exposure for these cases included exposure to applicators (17), reentry into a fumigated structure (9), improper storage or disposal (6), reentry into treated agricultural fields (4), drift from treated fields (2), and other (1). Conclusions: Review of fumigant exposures should be used to prevent future events through continued enforcement of established regulations and training of applicators.

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INTRODUCTION

Fumigants are pesticides with relatively high vapor pressures that allow them to effectively penetrate porous materials. Common uses include structural fumigation for wood-destroying insects; soil fumigation for nematodes and other root damaging organisms; grain, hay, and seed fumigation; and fumigation of shipping containers. In addition, fumigants have other nonpesticide applications, such as in hospital instrument-sterilizing units.

A number of previously available fumigants have been withdrawn from the market due to excessive toxicity, including carbon disulfide, carbon tetrachloride, 1,2-dibromo-3-chloropropane, ethylene dibromide, and ethylene dichloride.[1] However, remaining fumigants are still highly toxic. This study of Washington State fumigant-related illnesses was conducted to raise awareness of these potentially dangerous exposures, and to describe means of preventing future incidents.

METHODS

Fumigant-related illnesses reported to and investigated by the Washington State Department of Health (DOH) from 1992–1996 were reviewed. In Washington, health care providers are required by state law to report incidents of illness associated with pesticide exposure. Reporting can be done directly to DOH or through the Washington Poison Center. DOH also receives notice of pesticide exposures from Washington State Department of Labor and Industries claims administration, Washington State Departments of Agriculture and Ecology, local health departments, and individuals. A case is defined as an exposed individual, and an event is a chemical exposure incident involving one or more cases. Reported cases are investigated by DOH to document pesticide exposure and symptoms.

DOH classifies the relation of symptoms to exposure using the categories definite, probable, possible, unlikely, unrelated, asymptomatic, and unknown. Definite cases require a high correlation between a pesticide exposure and resulting symptoms, and generally physical evidence of exposure and objective medical evidence of effects. Probable cases are similar to definite cases, but lack conclusive objective evidence. In possible cases, correlation with symptoms is evident, but with some uncertainty about exposure or health effects. Symptoms may be nonspecific and other possible etiologies may be present. In unlikely cases, symptoms are not believed to be due to the reported exposure, but pesticide exposure cannot be ruled out. Symptoms may be severe relative to an exposure or may be atypical for the pesticide involved. In unrelated cases, either no pesticide exposure occurred (e.g., product was a fertilizer), or the health effects were determined to have been caused by another agent (e.g., chicken pox). In asymptomatic cases, exposure may or may not have occurred but no symptoms resulted. In unknown cases, insufficient information was available. After classifying each case, the data are entered into a pesticide program database.

For this study, the DOH pesticide-related illness database was searched, selecting for fumigants as a class. Additional searches were done for individual chemicals known to be used as fumigants in the state, regardless of whether they were classified as fumigant exposures. Illnesses considered by DOH to be definitely, probably, or possibly related to pesticide exposure were then analyzed. This review concentrates on commercially used fumigants and does not include flea bombs, mothballs, or other over-the-counter pesticide products with fumigant properties.

RESULTS

Over a 5-year period (1992–1996), 2759 cases of possible pesticide-related illness were reported to DOH and investigated by its pesticide surveillance staff. After investigation, 1192 (43%) of the reported cases were classified as definite, probable, or possible pesticide-related illnesses. Thirty-nine (3.3%) of these cases involved exposures to fumigants, including aluminum phosphide, methyl bromide, metam-sodium, and zinc phosphide (Table 1). There were no reports of illness associated with 1,3-dichloropropene or sulfuryl fluoride, which are also used as fumigants in Washington State. In addition, DOH investigated 31 reports of fumigant cases subsequently classified as unlikely, unrelated, unknown, or asymptomatic.

Symptoms associated with fumigant exposure in definite, probable, and possible cases are listed in Table 2. Aluminum and zinc phosphide were combined into a single phosphine exposure category since both of these substances produce phosphine gas. Respiratory symptoms and eye irritation occurred in the majority of exposures. No fatalities occurred. The nature of exposure for these cases is presented in Table 3. Routes of exposure were as follows: inhalation 21 (54%), dermal/ocular 9 (23%), inhalation/dermal 7 (18%), ingestion 1 (3%), and

Table 1

Fumigant Exposures in Washington State (1992–1996)*

Fumigant	Events	Total Cases	Definite	Probable	Possible
Aluminum phosphide	12	15	3	8	4
Methyl bromide	6	12	1	7	4
Metam-sodium	9	9	2	6	1
Zinc phosphide	3	3		1	2
Total	30	39	6	22	11

* Limited to cases with illnesses classified by DOH as definitely, probably, or possible due to pesticide exposure.

dermal/ingestion 1 (3%). Exposure was most frequent in spring and fall (Figure 1).

Aluminum Phosphide/Zinc Phosphide

Exposures

Seventeen of 18 exposures were by inhalation. The exception was one worker who contaminated his eye while placing aluminum phosphide pellets in rodent burrows. Of the 15 aluminum phosphide exposures, 6 cases were linked with use of aluminum phosphide to fumigate shipping containers, including 3 exposures when containers were opened and 3 in a single incident when spent aluminum phosphide was disposed of improperly at a warehouse. Three cases were linked to use of aluminum phosphide to fumigate grain towers or hay trucks: 2 were applicators and 1 was a handler of recently fumigated seed. Five aluminum phosphide cases and 2 zinc phosphide cases involved exposure to applicators while placing bait in rodent burrows and 1 case for each compound involved exposures by orchard workers to spilled material in storage facilities.

Outcomes

Nine cases (50%) were considered to have a mild medical outcome. These cases frequently presented with eye irritation, headache, shortness of breath, cough, and

Table 2

Fumigant-Related Symptoms Reported in Washington State (1992–1996)*

Symptom	Phosphine	Methyl Bromide	Metam-Sodium
Respiratory symptoms	12	7	4
Eye irritation	6	11	5
Nausea/vomiting	13		3
Headache	8	4	3
Dizziness	8		
Skin irritation	1		6
Weakness	4		
Abdominal pain/cramps	3		1
CNS depression		2	1
Fatigue		2	1

* Limited to cases with illnesses classified by DOH as definitely, probably, or possibly due to pesticide exposure.

Table 3

Nature of Fumigant Exposure in Washington State (1992–1996)*

Exposure†	Container/ Structure	Soil	Orchards (rodents)	Hay/Grain	Total
Direct handler/applicator	2	6	7	2	17
Re-entry	8	4		1	13
Improper disposal/storage	4		2		6
Drift from treated field		2			2
Other		1			1
Total	14	13	9	3	39

* Limited to cases with illnesses classified by DOH as difinitely, probably, or possibly due to pesticide exposure; † Container/structure cases are nonagricultural, while the remaining categories include agricultural cases.

nausea. Symptoms typically resolved in 1–2 days after removal from exposure. Eight cases (44%) were considered to have a moderate medical outcome. Presentation included more severe respiratory irritation and often dizziness. Abdominal pain was reported in 3 cases. Weakness and vomiting were each reported in 2 cases. While most of these symptoms resolved rapidly, 2 cases reported respiratory symptoms persisting at least 2 weeks. One case (6%) had a moderate-to-severe outcome with pulmonary edema and an extended recovery period. All 3 cases with persistent respiratory symptoms had a history of smoking, and 2 were smokers at the time of exposure.

Case Study

A 49-year-old male was 90 feet up on a catwalk in February applying aluminum phosphide pellets to grain tanks. He opened a new can which flamed and singed his cotton glove. He inhaled 2–4 breaths of phosphine gas and almost immediately developed nausea, dizziness, and anxiety. He presented to an emergency department 30 minutes later with dizziness, headache, weakness, and repeated episodes of vomiting. His physical exam was unremarkable. After arrival, his symptoms began to resolve except for a persistent sore throat. He denied any shortness of breath. He was admitted for 24 hours to observe

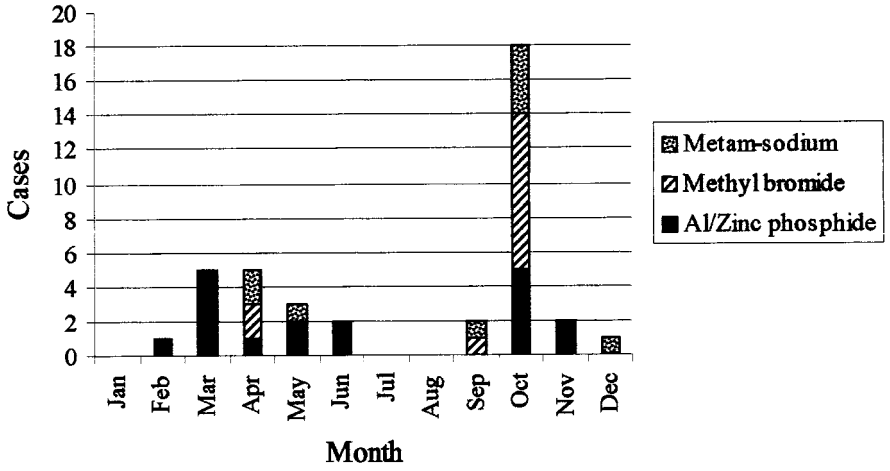

Figure 1. Fumigant exposure by month in Washington State (1992–1996), limited to cases classified by DOH as definitely, probably, or possibly related to exposure.

for delayed pulmonary edema, and a chest radiograph taken the day following admission showed bibasilar interstitial infiltrates and mild peribronchial cuffing. He was discharged with instructions to follow-up if dyspnea developed.

The patient developed dyspnea with exertion upon returning to work. Pulmonary function tests 1 month after exposure revealed pulmonary function deficits [FEV_1 and single breath diffusing capacity for carbon monoxide (DL_{CO})]. The patient's resting oxygen saturation at that time was 91–92%. It was unclear whether the pulmonary deficits were due to phosphine or to his long history of heavy smoking. The patient also reported a history of repeated lesser exposures to phosphine at work. The employer and manufacturer were contacted about the need for better protection and education of aluminum phosphide handlers.

Methyl Bromide

Exposures

In 9 of 12 symptomatic cases of methyl bromide exposure, chloropicrin had been added as a warning agent. The 12 cases included 8 inhalation, 2 dermal or ocular, and 2 combined dermal and inhalation exposures. Three events involving 8 cases resulted from use of methyl bromide in structural fumigation of homes. Three of these cases were exposed while applying product or handling tarps after fumigation. The other 5 cases occurred upon reentry to a fumigated structure. No cases of structural methyl bromide use were reported after 1992. More recent cases (3 events involving 4 cases) involved agricultural use of methyl bromide. Two of these cases were exposed while applying the product. The other 2 cases were exposed to drift from a treated field.

Outcomes

Of the 12 cases, 10 (83%) were classified as having mild medical outcomes and involved brief dermal or inhalation exposures and symptoms which resolved after removal from exposure. These included 5 members of one family who reported eye irritation when they returned to their recently fumigated home, with resolution of symptoms after the home was more thoroughly ventilated. Two cases involved splashes of liquid methyl bromide to the skin and eyes due to failure of application equipment, and irritant symptoms which resolved rapidly after decontamination. Two other cases were exposed to fumes drifting from a treated field and had ocular and respiratory irritation. Two cases (17%) were classified as moderate-to-severe and involved repeated occupational exposure to liquid and gaseous methyl bromide.

Case Study

A 21-year-old white male worked for an exterminator for 7 months, during which time he received minimal training and was never provided personal protective gear. His primary jobs were to tarp houses, guard the houses during methyl bromide/chloropicrin fumigation, and remove tarps after fumigation. He reported frequent eye watering and coughing while removing tarps, and identified 3 separate episodes of significant exposure during the last 2 months of his employment. In one episode, liquid methyl bromide sprayed out of the hose and onto his leg while he was disconnecting hoses from spent methyl bromide cylinders. His legs started burning and he removed his pants. Within 20 minutes he noticed white blisters forming in the exposed area, which resolved in 1 week. Two other times, while pulling roof tarps from chimney areas, he reported immediate eye irritation, shortness of breath, coughing, dizziness, and excessive saliva filling his mouth. One of the times he vomited. Within 2 days of both inhalation exposures, he reported onset of sore throat accompanied by cough and persistent headache.

He sought medical care 3 weeks after his last exposure. He presented to an emergency department with recurrent headache, shortness of breath, blurry vision, drowsiness, and memory problems. Physical examination and laboratory tests were normal. He was given analgesics and told to return if his symptoms worsened. After 3–4 months, his shortness of breath and vision problems resolved but headache, fatigue, and cognitive problems (e.g., short-term memory lapses, confusion, grogginess) persisted. DOH also investigated the case of a co-worker with a similar exposure history and symptoms which resolved within 1 month of exposure. These cases were referred to the Washington State Department of Agriculture, and the extermination company closed its Washington operation in the midst of the subsequent investigation.

Metam-Sodium

Exposure

All 9 cases involved use of metam-sodium to fumigate soil either in orchards (5 cases) or field crops (4 cases). The most common exposure in orchards (4 cases) was

dermal contact with liquid when equipment failed or the fumigant splashed into holes dug for new trees. Three of the 4 exposures in field crops involved inhalation of gas while monitoring a fumigation, checking irrigation lines, or otherwise reentering the field within 1–3 days. The other field crop case was a mechanic who received a dermal exposure while fixing application equipment in the field.

Outcomes

Four cases (44%) were considered to have mild medical outcomes. Eye, skin, and respiratory irritation and nausea were common complaints. Five cases (56%) were considered to have moderate medical outcomes. In 3 of these cases, workers had dermal irritation and edema after direct contact with liquid metam-sodium. These symptoms generally resolved within 1–2 weeks. In the 4th case, immediate decontamination was appropriately performed, but did not prevent second-degree chemical burns from developing.

Case Study

A 60-year-old male used metam-sodium for soil fumigation in an orchard twice during a 2-week period in the month of April. Each application lasted approximately 30 minutes. He wore personal protective equipment including rubber gloves and denied skin contact with the concentrate during mixing. After the first application, he noticed that both hands were red, with subsequent improvement. Shortly after the second application, he noticed burning on his hands, with blisters developing within 6 hours. He presented to an emergency department the next morning with extensive left hand and wrist dermatitis including purplish discoloration and swelling over the dorsal aspect of the hand. The right hand had a papular dermatitis without swelling. The health care provider noted that the patient smelled of chemicals during the examination, and the patient's hands were thoroughly washed. It was determined that the same gloves were used for both applications, and the suspected route of exposure was dermal contact through leaks in the gloves. His condition responded to treatment with topical corticosteriods.

DISCUSSION

From 1992–1996, fumigant-related illnesses comprised 3.3% of all suspected or confirmed pesticide poisonings in Washington State. Although the most frequently reported fumigants were aluminum phosphide, methyl bromide, metam-sodium, and zinc phosphide, we were unable to determine if the incidence of adverse effects reflected the frequency of their use or disproportionate risk of illness. Annual information on number of applications and total volume of fumigants used is not available in Washington State, and therefore rates of illness based on total use could not be determined. Given this lack of denominator information, it is still interesting to note that no illnesses were reported in association with 1,3-dichloropropene or sulfuryl fluoride, both of which are used for fumigation in Washington State.

Aluminum and zinc phosphide combine with water vapor to form phosphine (PH_3), a colorless gas with a fishy or garlic odor, an odor threshold of 0.14 ppm,[2] and a vapor density of 1.17. Aluminum phosphide is most commonly used as a grain fumigant. Zinc phosphide is most often used as a rodenticide. Under proper use conditions, the conversion of phosphide to phosphine is relatively complete, and the residual materials do not present a significant exposure hazard. However, residual phosphide pellets may be capable of producing phosphine if the fumigation is done under excessively cold or dry conditions, since the rate of reaction is dependent on temperature and relative humidity. Application under these conditions would increase the risk of exposure during reentry or handling of partially spent pellets. At sufficient phosphine concentrations, exposure may result in delayed pulmonary and systemic injury without significant initial symptoms.[3] However, acute poisoning at high concentrations often results in rapid onset of symptoms including nausea, dizziness, shortness of breath, and headache.[4,5]

Methyl bromide is used to fumigate structures and shipping containers, and to sterilize soil prior to planting trees. Chloropicrin is commonly added as a warning agent and is probably responsible for complaints of eye irritation in many of the reported cases. Early warning symptoms of methyl bromide exposure include cough, shortness of breath, nausea, headache, and fatigue.[6,7] The most problematic health effect is neurologic injury, which may improve slowly and/or result in permanent impairment.[8] Other effects of acute exposure include dermal, pulmonary, renal, and hepatic injury.[9] Use of methyl bromide is scheduled to be phased out in the US by 2001 under the Clean Air Act.

Metam-sodium decomposes on exposure to water to form methyl isothiocyanate. Methyl isothiocyanate is extremely irritating, and inhalation may cause pulmonary injury and edema. One of the best described large scale exposures to metam-sodium occurred following a 1991 spill into the Sacramento River in California. Out of 197

adults referred to a university occupational/ environmental health clinic or to a private occupational/environmental health practitioner for evaluation of health problems potentially related to the spill, 20 cases of persistent irritant-induced asthma and 10 cases of persistent exacerbation of asthma were identified.[10] An outbreak of dermatitis occurred among county jail inmates who removed dead fish from the Sacramento River after the spill.[11]

The adverse health effects reported in this study are consistent with the known toxicity of each of the fumigants. Common symptoms included respiratory problems, eye and skin irritation, nausea and/or vomiting, headache, and dizziness. Twenty-three (59%) of the cases had mild medical outcomes, with phosphine and metamsodium more likely to result in moderate or severe outcomes. At sufficient concentrations, exposure to fumigants may be fatal. Although there were no fatalities associated with fumigant exposure in Washington State from 1992–1996, fumigant exposures did result in significant morbidity.

Differences in exposure scenarios were noted among the fumigants. The most common phosphine exposures seen in our study were through inhalation, and resulted from reentry into recently fumigated fields, structures, or containers. Dermal exposure to dry pellets did not appear to pose a safety problem. With methyl bromide, both inhalation and dermal exposures were common. No exposures from fumigation of homes were reported after 1992, possibly due to decreased use in this application. With metam-sodium, dermal exposure was most common from use in orchards and inhalation exposure from use in fields.

Despite established regulations and training of pesticide applicators, a common exposure theme was the use of fumigants by personnel with inadequate training and personal protective equipment. There is no specific test or certification for use of fumigants required in Washington State. Several of the cases which involved gross overexposure to metam-sodium and methyl bromide were not licensed applicators but were supposedly working under the direct supervision of a licensed applicator. Because fumigants are restricted use products, applicators must be licensed or working under the direct supervision of a licensed person. Unfortunately, the term ''direct supervision'' can mean simply within phone contact for agricultural applicators. In non-agricultural applications to structures, the supervising licensed person must be on site within eyesight and earshot of applicator. Improved worker education and enforcement of workplace safety regulations would help decrease the frequency of fumigant-related illness.

Use of appropriate personal protective equipment would also help to limit adverse health effects associated with fumigant use. Information on personal protective equipment and proper application techniques is listed on the manufacturer's labels. With methyl bromide, rubber and tight fitting clothing that could trap the gas close to skin should be avoided. Use of liquid metam-sodium requires waterproof (not chemical resistant) gloves. Gas evolves slowly in the soil and should not be a significant skin hazard to the applicator, but may be more of a hazard during reentry.

There is very little published information with which to compare our data. In a study of Iowa and North Carolina licensed pesticide applicators, various application techniques were associated with an increased odds ratio (OR) of health care visits, including pouring fumigants from buckets [OR = 1.63, 95% confidence interval (CI) 1.16–1.79], row fumigation (OR = 1.26, CI 1.06–1.50), and use of a gas canister (OR = 1.22, CI 1.03–1.44).[12] Additional risk factors were identified for exposure-related illness, but not specific to fumigants. In a survey of 1,000 state-licensed pesticide applicators in Minnesota stratified by pesticide class (herbicides, insecticides, fungicides, fumigants), prevalence of chronic lung disease ($p = .027$), as well as combined common chronic diseases ($p = .015$), was significantly increased in fumigant applicators compared with all other pesticide use groups.[13]

In conclusion, aluminum phosphide, methyl bromide, metamsodium, and zinc phosphide were the most common fumigant poisonings in Washington State from 1992–1996, and resulted in moderate or severe medical outcomes in over one third of reported cases. Common exposure themes were identified within each fumigant category. Continued enforcement of existing regulations and provision of focused training are indicated in order to limit future fumigant exposure cases.

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