EXPOSURE OF PERSONS TO PHOSPHINE GAS FROM ALUMINUM PHOSPHIDE APPLICATION TO RODENT BURROWS

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ABSTRACT: An industrial hygiene study was performed monitoring levels of phosphine gas workers are exposed to when applying aluminum phosphide tablets to rodent burrows. Clothing and gloves were monitored for phosphine gas from residual dust. Air in the breathing zone was monitored with short and long term monitoring equipment. No levels of phosphine exceeding the legal permissible exposure limits (PEL) was detected and although residues were detected on clothing, the levels were usually quite low and dissipated in open air to undetectable levels within 12 to 17 hours in all but a few cases. Hand application was also compared to a mechanical (closed system) type application device which resulted in significantly lower phosphine exposure.

Proc. 15th Vertebrate Pest Conf. (J.E. Borrecco & R. E. Marsh, Editors) Published at University of Calif., Davis. 1992

INTRODUCTION

Aluminum phosphide is a fumigant used for many years to eliminate stored product pests, especially insect pests of grain and cereal products. Over the last decade this fumigant has become well recognized as a very effective rodent control tool when applied to burrow systems (Hayes 1982, Salmon 1982, Baker 1986). The discovery of aluminum phosphide as a rodent control agent was timely, since at least three other fumigants, methyl bromide, carbon disulfide and hydrogen cyanide are no longer registered for use. In addition, several toxic bait chemicals have also been removed from use leaving the industry with few chemical tools for controlling burrowing rodents.

Agricultural producers, pest control operators and governmental agencies have become increasingly reliant on aluminum phosphide for control of burrowing rodents in "urban," "suburban" and "rural" areas, just as the Food Industry has (Anon. 1985). The material has been found to be much more efficient, when proper soil and moisture conditions exist, than many other materials for control of ground squirrels, pocket gophers, Norway rats and under some conditions for moles (Hayes 1982, Shaheen 1981). When used according to the label, the product is safe for the applicator, the general public and the environment (Anon. 1986, Fachmann and Gokhale 1973). However, care must be taken to follow the label since hydrogen phosphide (phosphine) liberated from the tablets in the presence of moisture in the soil and atmosphere, is an acutely toxic gas by inhalation and is classified as a highly toxic Category I pesticide (Anon. 1981). Accidental poisoning in humans has occurred only as a result of improper application or improper handling and no incident could be found in literature review or personal interviews of human poisoning during rodent burrow applications.

Exposure to unsafe gas levels must be avoided by observing proper application precautions, aeration and re-entry procedures when used in structures, according to Pestcon product literature. Many safety precautions are required when handling aluminum phosphide products. Most of the precautions, however, address use for fumigation of stored products in silos, ships, grain mills and other enclosed areas, which is the primary use of the product (Anon. 1985). Use in these situations is much more likely to create hazardous environments for application personnel, than when used outside for rodent burrow application. Required safety precautions are found on product labels, in product literature, in Occupational Safety and Health Standards developed under the U.S. Occupational Health and Safety Act (OSHA) and in National Institute for Occupational Safety and Health (NIOSH/OSHA) Occupational Health Guidelines. In California, Pesticide Worker Safety laws and regulations require additional safety precautions which are enforced by licensed County Agricultural Commissioner personnel under the supervision and direction of the Department of Pesticide Regulation. Some of the requirements in the California Code of Regulations (CCR) regarding worker safety are reported to be causing unsafe conditions and unnecessary expense to governmental agencies and private industry. Persons wearing required goggles and long-sleeved clothing (Sections 6738 & 6736 CCR 1991) complain of fogging of glasses and excessive perspiration, due to this required clothing being worn (Anon. 1991b). The fogged safety glasses or goggles have been cause for numerous reports of falls on slopes and rough terrain. The excessive respiration rate and perspiration may increase the hazards associated with this water reactive material. It is also felt that the cost of daily clean clothing is an unnecessary expense. Gloves are required for all Category I materials and must be new daily or washed inside and out. Additionally, some labels suggest using rubber or cotton gloves, however, they do not last and provide little protection for the rough handling burrow fumigation requires. Leather is the industry choice for long wear and good protection, but cannot be washed as required.

The CCR regulations (Section 6730) also requires persons applying Category I materials to either not work alone or report by phone or radio every two hours. Section 6720(b) exempts persons working with vertebrate pest control baits from the "work clothing and not working alone" requirements and Section 6738 also exempts eye protection and glove requirements for these same baits. Many governmental and private industry leaders feel that solid fumigants—to include aluminum phosphide, magnesium phosphide, and smoke cartridges—should also be exempt when being used for rodent burrow treatment.

ALUMINUM PHOSPHIDE "TECHNICAL INFORMATION"

There are several commercial brands of aluminum phosphide such as Pestcon Systems Fumitoxin®, Degesch Phostoxin®, and Bernardo Chemicals Gastoxin®, but all

are prepared as hard pressed tablets or pellets for rodent control use. These solid products are composed of 55% finely ground aluminum phosphide, ammonium carbamate and may contain a binder or coating of paraffin. These products are classified as "Water Reactive" and "Flammable Solids" and contact with water is to be avoided. The aluminum phosphide liberates hydrogen phosphide (phosphine) gas upon exposure to atmospheric moisture; this gas is spontaneously flammable and piling of the tablets or dust should be avoided. The ammonium carbamate liberates ammonia and carbon dioxide which reduces the fire hazard of the phosphine and the smell of ammonia gas also serves as an initial warning agent since it begins to smell like garlic immediately upon opening the container (Anon. n.d.). Exposure to phosphine must not exceed the 8 hour time weighted average (TWA) or OSHA permissible exposure limit (PEL) of 0.3 ppm (Gibbons 1988) (Anon. 1975). The American Conference of Governmental Industrial Hygienists (ACGIH) has also established a short-term exposure limit (STEL) of 1 ppm for exposure time weighted over any 15 minute period with no more than four exposures per day (Zaebst 1988). These limits were established for use in confined areas such as commodity fumigation, where applicators are using many times the amount of material that is used for rodent burrow application, (2-4 tablets/burrow vs. 25-50/1000 cu. ft.) and where there is little or no fresh air exchange or lapse of gasses. When employees are in areas "exceeding" 0.3 ppm they must wear NIOSH approved respiration protection or self-contained breathing apparatus according to Pestcon product literature and Gibbons 1988. Enclosed areas must be aerated to 0.3 ppm phosphine or less prior to re-entry by unprotected workers. These exposure limits have been developed to avoid short term acute toxicity and low level chronic effects. The odor threshold of the commercial products containing aluminum phosphide and ammonium carbonate is reported to be 0.01 to 0.02 ppm, well below the PEL suggesting the odor is an adequate warning agent (Fluck 1976, Gibbons 1988). There are times however, when the odor may not be adequate to serve as a strong enough warning property (Zaebst 1988).

Figure 1. Pestcon Fumitoxin® flask, cap and tablets.

According to Dr. Jeremiah B. Sullivan, former President of Degesch of America, and literature reviewed, phosphine is either not absorbed percutaneously (through the skin) (Fachmann and Gokhale 1972), or if it is at all, not in any significant amount (Hayes 1982).

The tablets and pellets are packaged in aluminum flasks which are resealable by re-tightening the rubber gasketed screw top (Fig. 1). The rate of decomposition of the material depends on the moisture and temperature with total decomposition of the whole tablets taking from a few days in ideal conditions to 5 days or more under low moisture content and low temperatures (Anon. n.d.). Decomposition of active dust residues takes from one to several hours under optimum conditions, and depending on the amount and type of material contaminated. The fine grey/white powder found after decomposition is composed almost entirely of non-poisonous aluminum hydroxide and is not considered a hazardous waste (Anon. n.d.). However handling and disposal procedures should be closely followed to avoid fire or explosives from improper handling of partially spent dust which may be mixed with spent dust.

GOALS AND OBJECTIVES

Industrial Hygiene monitoring is recommended on product labels so that the amount of phosphine exposure can be documented for each site and type of operation to prevent excessive exposure and to determine where respiratory protection is required (Anon. n.d., Zaebst 1988). This study was performed as an industry sample to help identify and document the level of phosphine to which persons applying tablets to rodent burrows are exposed. Other objectives were to determine when and where exposure occurs, identify improved handling methods, compare traditional hand application with the use of tablet dispensers like the Degesch Tablet Applicator and gain information on how to provide clean clothing and gloves. Additionally data is being gathered to assist County Agricultural Commissioners and Department of Pesticide Regulation personnel in developing, changing or maintaining worker health and safety laws, regulations and policies regarding use of aluminum phosphide.

METHODS AND MATERIALS

Several types of monitoring were involved:

1. The primary and most intensive work dealt with aluminum phosphide dust residues on gloves, pants and long-sleeved shirts. These items were monitored before and after the work day.

2. All contaminated gloves and clothing were aerated over night or longer when necessary to determine if the aluminum phosphide contamination would dissipate without washing.

3. Areas on contaminated clothing were monitored to identify more specifically the areas of contamination.

Figure 2. Kitagawa/Matheson phosphine low level detector tube and hand pump and the Dräeger hand pump and high level detector tube.

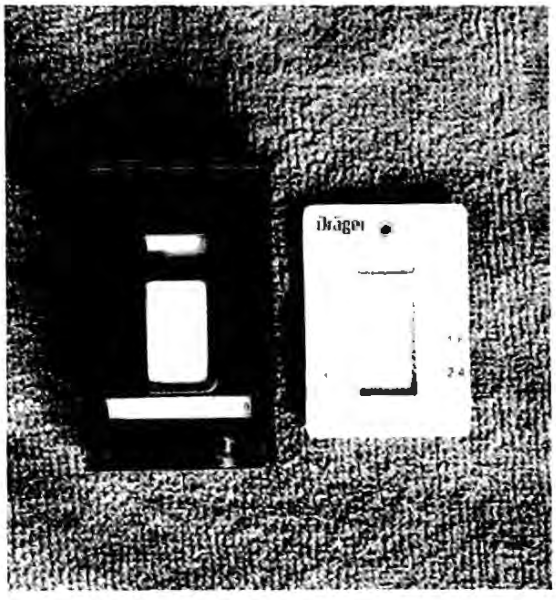

Figure 3. Draeger phosphine badge holder and color indicator badges.

4. Total daily exposure (TWA, PEL) was measured utilizing Draeger Badges throughout the exposure period, from arrival at work until the end of the work day.

5. Work sites were also observed and short-term (STEL) personal exposure readings taken.

Test Groups

Personnel monitored were from both private industry and governmental agencies. Most were certified as Qualified Applicators (QA). Those not certified were supervised by a QA. All but two worst case scenario types (WCS) were well experienced and trained in handling the toxicant. Two test groups were monitored for 3 days each, one group used the traditional hand application methods and the other used a mechanical tablet dispenser. The tests were run several times and varied in number of participants from 2 to 6 per day. At times the three day period was interrupted due to weather conditions, illness or work schedules, or a shortage of monitoring supplies.

Materials

Testing for residues on clothing, gloves and some air sampling was accomplished with Kitagawa Phosphine #121U direct reading detector tubes used in Matheson Toxic Gas Detector, Model 8014-400A hand pumps (Fig. 2) to detect levels from 0.05 to 2.0 ppm (Matheson-Kitagawa Product manual 1989). The Draeger hand pump, also shown in Figure 2, was used to detect levels from 2.0 to 40.0 ppm (Anon. 1991a). A Gas Tech Model SC-7 Toxic Gas Monitor power air flow sampling device was used for much of the air sampling in the field. This device is sensitive from 0.05 to 1 ppm according to the product manual and company employees. Draeger Phosphine Badges, Model 6400171 (Fig. 3), were used to measure long-term exposure to phosphine in the breathing zone. These badges are sensitive from 0.1 to 2.4 ppm and can be used for a duration of 30 minutes to 8 hours according to National Draeger literature and according to tests performed by Draeger and Degesch America (James Fleming, National Draeger Personal Communication 7/91 and 4/92) (Anon. 1991a).

Gloves used for these trials were all smooth surface leather rather than cotton due to the greater protection provided the employee when handling the aluminum phosphide and tools used in application. Cotton gloves were often found to last from less than an hour to several hours before ripping. The decision to use leather gloves aerated nightly rather than cotton also came from previous trials performed by Baker and Sullivan in April and May of 1990 when cotton was found to hold much heavier levels of residue and take longer to aerate. In these trials, 1000 tablets were handled prior to testing. Draeger low level detector tubes were held one inch over the surface of the gloves. While cotton or jersey gloves had up to 1.5 ppm readings, leather had a high of 0.9 ppm. After 4 hours only a trace was found on leather gloves and 0.2 to 0.6 was still coming off the cloth gloves (Fig. 4) (Sullivan 1990, Baker and Sullivan 1990).

The aluminum phosphide mechanical tablet applicator used was made by Degesch America (Fig. 5). The applicator was primarily made of plastic and threaded onto the aluminum Degesch flasks. The device allowed one tablet at a time to drop down a 30 inch tube to the rodent burrow. These applicators were detached and the original top was placed on the flask before being placed in storage at the end of the day. Most applications of aluminum phosphide were Pestcon Fumitoxin® or Degesch Phostoxin® tablets. Other brands tried were found excessively dusty and were returned by the operators.

Methods

Heavy plastic (4 mil) bags were used to contain all items being tested for residue. Each bag held about 1.5 cu. ft. of air and items when sealed. Each participant's gloves and each shirt and pants were placed in individual labeled bags. The first several days readings were taken immediately after being placed in the bags; however this was soon changed to monitoring and recording after 30 minutes, which seemed to

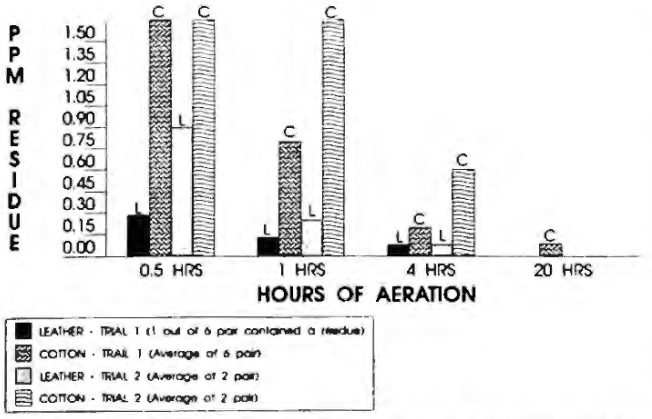

Figure 4. The resulting amount of phosphine gas from residual dust on used gloves as measured at various time intervals.

allow for a good indication of the residue. Longer periods of time (one hour and two hours) were also initially tried but if any detectable residual phosphine was present, the level was consistently detected in 30 minutes. The bagged items being monitored and the monitoring was all performed indoors in temperatures of 70°to 74°F. Information on the number of hours of exposure, and number of tablets used were recorded. Additional comments were also noted when participants had extra exposure due to a spill or handling of zinc phosphide, etc. Weather data was also collected.

Contaminated clothing and gloves were aerated overnight in the warehouse or garage area by laying them on the vehicles or tables. They were placed in a new plastic bag for 30 minutes and re-monitored each morning. Clean clothes were also monitored each day prior to being worn.

Short term personal exposure was monitored in the field and at the warehouse on a random sample basis and to follow up on employees that had higher residue levels. These personal breathing zone readings were taken when personnel first opened poison storage areas, when changing flasks, riding in truck cabs, or making applications. Readings detected with the SK-7 were verified with the Kitagawa tubes.

RESULTS

Residual Dust and Short Term Exposure

The first 3-day hygiene and residue monitoring phase was initiated in October 1990 followed by seven more monitoring phases: two in late October, one each in December, January and April and two in June 1991. The tests were spread over this period of time to allow for monitoring throughout various weather conditions and to allow for testing of personnel from five counties from coastal and warmer inland areas. The employees being monitored, including the two worse case scenarios (WCS) added to the hand application group after observing their poor work habits, were instructed to work according to the normal work practices in order to obtain a good representative sample of exposure to applicators. They were asked not to use zinc phosphide bait to avoid confusion of a second phosphine source, but were allowed to handle other rodenticide baits as needed. Most personnel were chosen because they were scheduled for work that normally calls for use of aluminum phosphide for the three days monitored. Two applicators were monitored for two days and five for four days.

Amounts of aluminum phosphide applied varied from 40 to 970 (3gram) tablets per day, with 227 being the average. Although there was a direct correlation between the amount of material applied and the level of residue on the gloves, shirts and pants, some of the time, there were many samples that gave the opposite results. One notable exception was the highest glove residue level of 12 ppm recorded from one of the WCS employees after only 200 tablets were handled compared to the next day when he handled 560 tablets and had a reading of 2 ppm. All of the higher readings were investigated in an attempt to identify ways to reduce exposure. Most incidents of higher readings were attributed to clean-up of spills, and handling dusty lots of tablets except for the two WCS employees who had the highest readings and had very poor work habits and one who had poor vision.

The residue levels found on shirts as shown in Table 1 were lower than expected, especially when the small size of the test containers is taken into consideration (1.5 cu. ft.). The

Figure 5. The Degesch mechanical aluminum phosphide pellet applicator.

group making hand applications had a mean average of 0.29 ppm phosphine which, although low, was significantly more residue than those using the applicator which averaged 0.07 ppm. Sixteen of 25 (64%) shirts worn by the group using the Degesch applicator and 18 of 31 (58%) shirts of hand applicators had no detectable phosphine. The highest level found on shirts for those using the Degesch applicator was 0.3 ppm while the highest on shirts for hand applicators following label precautions and recommendations was 1.2 ppm; however, one WCS applicator had a level of 4.9 ppm. The residue on the shirts seemed to be near the waist or stomach area. When observed those with higher levels seemed to pour tablets into the cap or glove (not recommended) while standing up, especially on hillsides, thus possibly allowing dust to get on the shirt and top of pants where the greater amounts were most often found. Many of the applicators were observed also carrying the aluminum phosphide canister and/or mechanical applicator resting against the shirt or upper portion of the pants. Some residue was however detected on the leg area of several pairs of pants. Only one shirt of 56 had a detectable level of phosphine (0.1 ppm) after overnight aeration (Table 2).

Residue levels detected on pants (Table 3) indicated that the group not using the mechanical applicator had a mean average of 0.52 ppm phosphine without the WCS employees and 0.875 with the two averaged into the group. These readings were much higher than those using the applicators, which had an average of 0.167 ppm. Out of 25 pairs of mechanical applicator pants, 11 (44%) had no detectable residue while only 6 of 31 (19%) pairs of pants worn by those using hand applications had none. The highest residue reading obtained on the pants of those using the applicator was 1.2 ppm while the highest reading on pants of those making hand applications was 1.8 ppm without the WCS employees. The two highest readings, 7.25 and 12.0 ppm, were taken from the two WCS operators who were observed often holding the phosphide almost over their laps when pouring tablets into their gloves (reportedly due to poor vision). The employer pulled these two applicators for immediate discipline and training resulting in much lower readings the next time.

Only two pairs of pants out of 56 had any detectable level after a night of aeration (Table 2). The levels were 0.03 out of 2.0 and 1.2 out of 7.25 ppm much lower than expected for the very cold weather, 29° to 48°F and a relative humidity of 22-34% during the aeration period.

Residues on gloves are illustrated in Table 4. The group using the hand application had a mean average of 0.39 residue level, somewhat lower than those using the Degesch applicator (0.59), without the WCS employees but had 2.11 ppm with the two added in. Only 6 of 25 (24%) pairs of gloves of the mechancial applicator employees had no detectable residue and 6 of 31 (19%) of the hand applicators had none. The highest reading for those using the mechanical applicator was 6 ppm which was the result of the technician using his gloves to clean up a spill of tablets. The highest reading on gloves of hand applicators was 40 ppm on a WCS employee, almost 7 times the high for the other group. Out of 56 pairs of leather gloves in this trial, all but 6 pairs of gloves had the phosphine completely dissipated and had no residue after 12 to 17 hours of exposure to open air (Table 2). Four of the remaining residue pairs had no detectable residue after an additional airing of 4 to 12 hours. Two other pairs aerated in very dry/freezing weather took from 2 to 4 days for the high 8 and 40 ppm to volatilize to undetectable levels. The low temperatures were 31°, 29°, 24° and 28°F. The highs 53°, 48°, 49° and 52°F, respectively and the humidity averaged 45%, 34%, 22% and 11% respectively.

Short Term Personal Exposure Sampling

Air sampling in the breathing zone, with the SC-7 or the Kitagawa detector tubes rarely indicated detectable levels of phosphine. The only detectable levels occurred with hand application opening the container too close to the body as discussed earlier, or when filling the mechanical applicator if the material was handled without proper precautions. The STEL (1.0) was never detected and the PEL (0.3) was never detected in the breathing zone but one storage box indicated a 1-2 second occurrence when first opened.

Long Term Personal Sampling for PEL & TWA

Draeger phosphine monitoring badges were worn by thirteen applicators for three consecutive days in October 1991 and one in January 1992. The badges were worn on the collar as close to the breathing zone as possible (Fig. 6). One-half of the applicators used the hand method and the others used the mechanical applicator. Out of the 42 readings only four badges showed detectable levels of phosphine (Table 5). All four were from hand application personnel. The levels monitored showed TWAs of 0.01 ppm, 0.05, 0.1 and 0.1. The two TWA 0.1 readings were one third of the allowable level and were thought to be a combination of zinc phosphide dust from rodenticide bait broadcasting and aluminum phosphide. The zinc phosphide was not to have been used during this project but this two-man team broadcast 10 to 30 lbs. Specks of dust on the badge suggested zinc phosphide dust contamination. A badge was exposed to zinc phosphide bait dust for 8 hours and indicated a reading of slightly less than 0.1. One employee with readings on two days was one of the WCS applicators who had the highest levels in the clothing residue trials. The weather for the first October period was warm and

Figure 6. The Draeger badge placed on the collar for PEL monitoring.

Table 1. Phosphine levels found in shirts of each group of workers.

Mechanical Applicator Group

Sample Subject	Day 1		Day 2		Day 3		Day 4		Total/ @ Sub.	Total Tablets Appl.
	ppm	Tab.	ppm	Tab.	ppm	Tab.	ppm	Tab.		
1	0.0	200	0.00	400	0.00	430	—	—	0.00	1030
2	0.0	250	0.00	100	0.00	130	0.00	110	0.00	590
3	0.0	60	0.00	100	0.30	50	0.25	625	0.55	835
4	0.0	100	0.15	110	—	—	—	—	0.15	210
5	0.0	110	0.00	75	0.00	500	—	—	0.00	685
12	0.0	60	0.10	160	0.10	250	—	—	0.20	370
13	0.0	150	0.00	150	0.10	500	—	—	0.10	800
14	0.5	50	0.10	250	0.05	300	—	—	0.65	600
								Total	1.65	
25 Exposure Days								Average Per Day	0.07	

Hand Application Group

Sample Subject	Day 1		Day 2		Day 3		Day 4		Total/ @ Sub.	Total Tablets Appl.
	ppm	Tab.	ppm	Tab.	ppm	Tab.	ppm	Tab.		
6	0.00	140	0.00	190	0.00	360	0.00	120	0.00	810
7	0.00	155	0.00	300	0.00	150	0.00	80	0.00	685
8	0.00	75	0.00	50	—	—	0.00	120	0.00	245
9	0.05	125	0.05	150	—	—	—	—	0.55	275
10	0.00	750	0.10	970	0.00	570	—	—	0.10	1290
11	0.05	750	0.80	970	0.00	570	—	—	0.85	1000
15	1.20	500	0.10	125	0.51	200	—	—	1.81	825
16	0.00	140	0.20	250	0.05	300	—	—	0.25	690
(WCS) 17	0.00	100	4.90	200	0.00	560	—	—	4.90	956
(WCS) 18	0.10	196	0.50	1300	0.00	200	—	—	0.60	1696
								Total	9.06	
31 Exposure Days								Average Per Day	0.29	

Table 2. Number of samples of clothing found with phosphine gas from residual dust after aeration.

	12-17 Hours	24 Hours	48 Hours
Gloves (56 pr.)	6(.03-1.1 ppm)[a]	2 (0.3-0.5 ppm)[a]	2 (.05-0.3 ppm)[a]
Shirts (56)	1 (0.2 ppm)	0	0
Pants (56)	2 (0.3 & 1.2 ppm)[a]	0	0

[a]These levels occurred in near freezing weather.

Table 3. Phosphine levels found in pants of each group of workers.

Mechanical Applicator Group

Sample Subject	Day 1		Day 2		Day 3		Day 4		Total/ @ Sub.	Total Tablets Appl.
	ppm	Tab.	ppm	Tab.	ppm	Tab.	ppm	Tab.		
1	0.09	200	0.70	400	0.40	430	—	—	1.19	1030
2	1.20	250	0.00	100	0.10	130	0.05	110	1.35	590
3	0.00	60	0.05	100	0.60	50	0.20	625	0.85	835
4	0.00	100	0.05	110	—	—	—	—	0.05	210
5	0.00	110	0.00	75	0.15	500	—	—	0.15	685
12	0.00	60	0.00	160	0.00	250	—	—	0.00	370
13	0.00	150	0.05	150	0.45	500	—	—	0.50	800
14	0.00	50	0.10	250	0.00	300	—	—	0.10	600
								Total	4.19	
25 Exposure Days 2								Average Per Day	0.167	

Hand Application Group

Sample Subject	Day 1		Day 2		Day 3		Day 4		Total/ @ Sub.	Total Tablets Appl.
	ppm	Tab.	ppm	Tab.	ppm	Tab.	ppm	Tab.		
6	0.10	140	0.00	190	0.30	360	0.00	120	0.40	810
7	0.25	155	0.10	300	0.10	150	0.10	80	0.55	685
8	0.20	75	0.00	50	—	—	0.10	120	0.30	245
9	0.05	125	0.20	150	—	—	—	—	0.25	275
10	0.10	750	0.10	970	0.20	570	—	—	0.40	1290
11	0.00	750	0.20	970	0.20	570	—	—	0.40	1000
15	1.80	500	0.00	125	0.25	200	—	—	2.05	825
16	0.00	140	0.15	250	0.05	300	—	—	0.20	690
								Total	4.19	
31 Exposure Days								Average Per Day w/o WCS	0.52	
(WCS) 17	0.10	100	12.00	200	2.00	560	—	—	14.10	956
(WCS) 18	1.20	196	7.25	1300	0.03	200	—	—	8.48	1696
								Total	27.13	
31 Exposure Days								Average Per Day w/WCS	0.875	

humid with the high ranging from 82° to 91°F and the average relative humidity ranging from 54-75%. The second three day period was cooler with highs ranging from 68° to 72°F and the average humidity was from 48-63%. The January period high temperatures ranged from 49° to 64°F with average relative humidity of 26-43%. One badge was tested in a plastic bag with contaminated gloves and after an 8-hour period showed 2.0 ppm while the Kitagawa tube indicated a comparable reading of 1.8+ ppm.

DISCUSSION

From an industrial hygiene point of view, the level of exposure to phosphine gas for persons applying aluminum phosphide to rodent burrows did not reach industry exposure limits (TWA, PEL or STEL) when monitored with short or long term equipment. It would seem that industrial hygiene monitoring for this type application is not necessary since the likelihood of protective breathing devices being needed was quite slim.

Table 4. Phosphine levels found in gloves of each group of workers.

Mechanical Applicator Group

Sample Subject	Day 1		Day 2		Day 3		Day 4		Total/ @ Sub.	Total Tablets Appl.
	ppm	Tab.	ppm	Tab.	ppm	Tab.	ppm	Tab.		
1	0.075	200	0.80	400	1.00	430	—	—	1.875	1030
2	2.000	250	0.00	100	0.30	130	0.10	110	2.31	590
3	0.000	60	0.25	100	0.00	50	1.50	625	1.75	835
4	0.200	100	0.10	110	—	—	—	—	0.30	210
5	0.000	110	0.10	75	6.00 [a]	500	—	—	6.10	685
12	0.300	60	0.00	160	0.00	250	—	—	0.30	370
13	0.400	150	0.10	150	1.40	500	—	—	1.90	800
14	0.100	50	0.10	250	0.05	300	—	—	0.25	600
								Total	14.785	
25 Exposure Days								Average Per Day	0.59	

Hand Application Group

Sample Subject	Day 1		Day 2		Day 3		Day 4		Total/ @ Sub.	Total Tablets Appl.
	ppm	Tab.	ppm	Tab.	ppm	Tab.	ppm	Tab.		
6	0.40	140	0.00	190	0.30	360	0.40	120	0.11	810
7	2.00	155	0.05	300	0.00	150	0.00	80	0.05	685
8	0.15	75	0.00	50	—	—	0.10	120	0.16	245
9	0.30	125	0.40	150	—	—	—	—	0.40	275
10	1.00	750	0.90	970	0.20	570	—	—	0.11	1290
11	2.00	750	2.00	970	0.10	570	—	—	4.10	1000
15	3.30	500	0.10	125	0.60	200	—	—	4.00	825
16	0.00	140	0.45	250	0.46	300	—	—	0.91	690
								Total	9.84	
31 Exposure Days								Average Per Day w/o WCS	.39	
(WCS) 17	0.51	100	5.00	200	0.00	560	—	—	5.51	956
(WCS) 18	2.00	196	40.00	1300	8.00	200	—	—	50.00	1696
								Total	65.35	
31 Exposure Days								Average Per Day w/WCS	2.11	

[a]R.C. had a can drop when attaching to applicator causing the spilling of tablets and use of "gloves" to clean up dust and spillage rather than a dust pan as recommended.

Short term personal exposure monitoring supported by clothing residue work identified the greatest chance of hazard to be improperly trained employees who carelessly handled the material by opening the containers and pouring out the material next to and over the waist area with their head right over the open container in the path of the fumes. Another problem was pouring into the glove. Readings taken with the SC-7 and direct reading detector tubes in the breathing zones of application personnel, over 200 individual samplings, never obtained a reading equal to the PEL of 0.3 ppm and far from the STEL of 1 ppm even when the applicator held their head over the flask when open, in violation of safe practices. The highest reading in the breathing zone was 0.21 ppm and that was for a second or two. It must be remembered that these applications used 2 to 4 tablets per application point and were in the open air. Much higher readings would be expected

Table 5. Results of phosphine long term personal monitoring with an eight-hour time-weighted average (TWA).

Hand Application	Day 1			Day 2			Day 3			Total Tablets Appl.
	ppm	Hrs	TWA	ppm	Hrs	TWA	ppm	Hrs	TWA	
1	0.0	7.5	0.0	0.0	8.0	0.0	0.0	7.0	0.0	480
2	0.0	8.0	0.0	0.0	8.0	0.0	0.0	8.0	0.0	390
3	0.0	8.0	0.0	0.8	8.0	0.1	0.0	8.8	0.0	1180
4	0.0	8.0	0.0	0.8	8.0	0.1	0.0	8.0	0.0	46
5	0.0	5.0	0.0	0.0	8.0	0.0	0.0	8.0	0.0	1250
6	0.0	5.0	0.0	0.0	8.0	0.0	0.0	8.0	0.0	835
7	0.0	8.0	0.0	0.4	8.0	0.05	0.1	8.0	0.012	1350

Mechanical Application	Day 1			Day 2			Day 3			Total Tablets Appl.
	ppm	Hrs	TWA	ppm	Hrs	TWA	ppm	Hrs	TWA	
1	0.0	8.0	0.0	0.0	8.0	0.0	0.0	7.5	0.0	410
2	0.0	8.0	0.0	0.0	8.0	0.0	0.0	8.0	0.0	630
3	0.0	9.0	0.0	0.0	8.0	0.0	0.0	8.0	0.0	350
4	0.0	8.0	0.0	0.0	7.5	0.0	0.0	8.0	0.0	730
5	0.0	7.0	0.0	0.0	8.5	0.0	0.0	8.0	0.0	1050
6	0.0	7.5	0.0	0.0	8.5	0.0	0.0	8.0	0.0	1355
7	0.0	8.0	0.0	0.0	8.0	0.0	0.0	8.0	0.0	705

when opening containers inside buildings or when using larger amounts per application.

Improved handling methods was well illustrated by the greatly reduced residue levels on outer clothing with the possible exception of gloves, when the mechanical applicator was compared to hand application. Other similar devices such as fertilizer dispensers could be adapted for application if well sealed and small enough to handle the 200 to 300 tablets at a time. In choosing equipment, care must be taken to avoid excessive air space, entry of moisture and crushing of tablets. Several employees used funnels and even plastic bottles cut off and shaped as funnels, to reduce handling of the product with the gloves. Pouring the product directly from the flask into the burrow or onto the adjacent ground seems to work for some applicators, but accurate measurement of the number of tablets almost necessitates pouring them into the cap or other device prior to placing in the burrow.

Cleaning clothing and gloves was an easy task. Simply hanging them on a peg, or laying them in an open area, preferably a warm area overnight or even for 4 or 5 hours, cleaned all but a few items. The heavier contaminated items were collected in the coldest weather, and some of these items did not clean well overnight although the levels of phosphine were reduced much more than expected for freezing, low humidity weather. The two applicators who were not following the label and spilled material on the clothing washed the clothing after airing out as recommended on the label.

CONCLUSIONS

Gloves should always be worn even when using the mechanical applicators and they should be made of smooth leather. Short sleeved shirts should be allowed since no residue was ever detected on this area and there is very little chance of contamination of arms the way the product is manufactured (tablets) and is handled. This would help avoid excessive body heat and perspiration which may increase the hazards associated with working with this product. Goggles or safety glasses may be needed when transferring tablets from one container to another, but there is little if any hazard at any other time, except from wearing fogged goggles. Employees should be allowed to work alone with this material just as with rodenticide baits. And clothing including gloves should be deemed as being clean when aired over night unless contaminated by a direct spill.

This study supports the need for change in California's worker safety regulations and enforcement policy regarding the issues previous discussed. Labels and Material Safety Data Sheets also need to be amended to recommend leather gloves and less need for protective clothing and safety equipment during rodent control use. Aluminum phosphide is a very effective burrow fumigant for control of burrowing rodents, but it should always be used by trained and certified employees who understand the proper handling methods.

ACKNOWLEDGEMENTS

If it were not for the financial and logistical support of Mr. Dan Fox of Animal Pest Management Services Inc., Chino, California, and Matt Oliver of Agricultural Pest Control Services Inc., San Diego, California, this study would not have been possible. I am also grateful to Pestcon Systems, Inc., Raleigh, North Carolina, who provided the majority of the testing equipment and supplies; Dr. Jerry Sullivan and Donald Shaheen of Degesch America, Wyers Cave, Virginia; and Dr. John Ross of the Department of Pesticide Regulation, California Environmental Protection Agency, for their technical advice. Additional equipment was provided by National Draeger of Pittsburgh, Pennsylvania; and the cooperation of members of the Los Angeles County Agricultural Commissioners office is greatly appreciated. Thanks also to Glenn Fox who assisted in the collection of data and coordination of this project.

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