UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
WASHINGTON, D.C. 20460

JUL 24 1992

OFFICE OF
PESTICIDES AND TOXIC SUBSTANCES

MEMORANDUM

SUBJECT: Potential Worker Exposure to Aluminum and Magnesium Phosphine during Fumigation and Reentry Activities

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Please find below, the OREB review of:

DP Barcode:

Pesticide Chemical Code:

EPA Reg. No.:

EPA MRID No.: 40717201

Review Time: 20 days

PHED: NO

I. INTRODUCTION

A. Background:

In 1988, S. Z. Mansdorf and Associates Inc. submitted a phosphine exposure monitoring study for applicators, workers, and bystanders on behalf of Bernardo Chemicals Limited, Inc., Degesch America Inc., Pestcon Systems, Inc., Research Products Company (a division of McShares, Inc.). The study was submitted in response to an October 1986 Guidance for the Reregistration of Pesticide Products Containing Aluminum or Magnesium Phosphide as the Active Ingredient. This phosphine fumigation worker exposure study was evaluated by the Special Review and Reregistration Section/Health Effects Division in February 1989; the study was determined to be acceptable to permit estimation of dermal and inhalation exposure for individuals involved in fumigation activities involving use of metal phosphides.

In September 1989, proposed respiratory protection for metal phosphides were addressed. Research Products Company (RPC) submitted a letter to Registration Division questioning the recommendation of Non-Dietary Exposure Branch (NDEB) that "all individuals actually handling the fumigant during non-automatic dispensing be required to wear respiratory protection." Clarification of conditions for use of respiratory protection requirements were given also; NDEB indicated that respiratory protection was not required for outdoor handlers, and that the exposure data did not support any modification of the recommendation that respiratory protection be required for farm storage, flat storage, and spot fumigation handlers of the fumigant. Research Products was given the option of proposing alternative respiratory protection for rail car and tobacco warehouse handlers; under conditions where phosphine levels remained below the STEL (1 ppm or 1 g/m^3) and TWA (0.3 ppm or 0.4 g/m^3), RPC could propose changes that would permit fumigation without adherence to the blanket respiratory requirement.

In February 1992, American Cyanamid filed an 8E under TSCA. With respect to rat in vivo inhalation studies, for an eight hour postculture study, chromosome aberrations were found after exposure to concentrations between 5 and 25 ppm. These findings are consistent with published reports of humans exposed to phosphide during fumigation activities. Two recent deaths resulting from phosphide fumigation activities in a North Carolina tobacco warehouse has prompted additional concerns about the use and worker exposure to aluminum and magnesium phosphide.

B. Purpose:

Evaluation of potential worker and bystander exposure to aluminum and magnesium phosphide is necessary to evaluate the potential risks associated with fumigation activities. The determination of additional adverse effects of the fumigant has prompted further evaluation.

II. DETAILED CONSIDERATIONS:

The attached study provides an idealistic evaluation of field activities that are grouped by task or work assignment, facility type, and application practice and applicator. Comparisons are possible between various activities, storage sites, and application method and applicator for the amount of exposure. In the attached OREB (formerly NDEB) study, Table 1 provides a breakdown of the facilities, a facility description and number of replicates, and a fumigation job description.

Potential inhalation exposure was calculated by multiplying the measured phosphine concentrations (ug/L) by the duration of exposure and a respiratory rate of 29 L/min was assumed for an adult male performing moderate labor.

The data presented in Table 1 was determined for each fumigation facility, with breakdown by site, formulation type and fumigation method.

FARM BINS:

Fumigation of farm storage bins and tobacco warehouses are of great concern; in many instances, these may be not be large scale facilities, and fumigation practices may not include air monitoring, plus respiratory protective equipment may not be properly worn or used.

Farm Storage Bins	Site	Concentration	N
	popcorn bin	1.32 to 3.15 ppm	5
	commodity bin	0.55 to 2.62 ppm	2
	commodity bin	0.12 to 1.25 ppm	8
	commodity bin	0.17 to 0.87 ppm	4
	Formulation type	Concentration	
	Pellets	1.32 to 3.15 ppm	
	Tablets	0.17 to 2.62 ppm	
	Belted bags	0.12 to 0.90 ppm	
	Fumigation Method	Concentration	
	Subsurface hand	1.32 to 3.15 ppm	
	Probe	0.68 to 2.93 ppm	
	RPC	0.21 to 2.62 ppm	
	Walk-in	0.17 to 1.25 ppm	
	Belted bags	0.12 to 0.90 ppm	

Table 1. Synopsis of Mansdorf and Associates data (1).

Facility Treated	Measured Concentration Range (ppm)[1]	Duration of Activities
Farm style bin		
popcorn	1.32 to 3.15	13 to 26 min
commodity	0.12 to 3.65	6 to 19 min
Flat storage bin	0.60 to 17.93	17 to 24 min
post applic. exposure	0.04 to 0.09	164 to 250 min
Railroad bulk car		
fumigation of 116m^3	0.15 to 0.84	25 to 59 min
fumigation of 74m^3	0.07 to 0.38	8 to 10 min
fumigation of 74m^3	0.03 to 0.61	10 to 20 min
fumigation of 74m^3	0.03 to 0.62	15 to 25 min
post-fum. exposure	0.06 to 1.17	34 to 38 min
post-fum. exposure	0.07	64 min
exp. during aeration	0.15	125 min
Railroad box car		
139-170m^3 car	0.06 to 1.04	8 to 153 min
127-153m^3 car	0.13 to 0.55	8 to 14 min
130-142m^3 car	0.03 to 0.76	12 to 75 min
exp. during aeration	0.09 to 0.64	13 min
Post fumigation exposure near sealed box car	0.31	20 min
Incoming box car aeration (open door)	0.45	4 min
Packaging plant activities-cornmeal or flour packing line	0.003 to 0.85	49 to 232 min
Tobacco warehouse		
spread strips (1)	0.07 to 0.17	219 to 223 min
spread strips (2)	0.19 to 0.27	34 to 40 min
spread strips (3)	0.21 to 0.51	19 to 22 min
aeration	0.03 to 0.21	63 to 210 min
retrieval of strips	0.02 to 0.07	125 to 242 min

phosphine TWA = 0.3 ppm (0.4 mg/m^3 or 400 ug/m^3); STEL = 1 ppm for 15 min interval (5).

[1]Conversion to ug/m^3 = ppm * $\frac{1.393\ mg/m^3}{1\ ppm}$ * 10^3 ug/mg

FLAT STORAGE BINS:

Flat storage bin fumigation represents a broad spectrum of commodity types. In general, fumigation is a function of pest pressure. The Mansdorf study indicated of 80 flat bins (those used in the study) that potentially could have been fumigated in 1987, only 21 received treatment. Exposure calculations are further complicated by the wide variety of commodities that may be stored, and the size of the facility.
Rates of application of phosphine ranged between 45 and 90 g phosphine per 1000 bushels of commodity.

RAILROAD BULK CAR:

Large storage facilities and cereal processing/packaging plants used in the study handled upto 370 bulk cars during a season. Application rates varied from 29 g phosphine per 1000 ft^3 in the storage facility to 43 g phosphine per 1000 ft^3 in the processing and packaging plant. Another processing plant handled 55 cars per year. Overall phosphine levels around individuals handling the fumigant and placing it in the railcars averaged 0.27 ppm with a concentration range from 0.03 to 0.67 ppm.

RAILROAD BOX CAR:

Three sites were utilized to determine worker exposure to phosphine with respect to box car fumigation. All sites used were cereal processing and packaging facilities. Application rates were 32 to 46 g of phosphine per 1000 ft^3 of storage capacity. Typically one applicator did all fumigation using Detia Gas EX-B (bags); one application process required 8 to 12 minutes per boxcar. The number of cars handled ranged between 275 and 315 cars during a 6 month period. Fumigation and aeration processes produced exposures to the highest air concentrations of phosphine; mean air concentration of phosphine was 0.45 ppm across all treatments.

TOBACCO WAREHOUSE:

For the tobacco warehouse, fumigation was accomplished using only Phostoxin pellet Prepac (blister strips). No other formulation type or fumigation methods were used, so no comparisons can be made beyond concentrations measured during the brief exposure period (3 to 5 minute period) while strips were being opened and placed. For this component of the study, professional fumigators were conducting the fumigation within the warehouses. Each warehouse was sealed with plastic prior to fumigation; a fumigation team proceeded from one end of the warehouse, each preplaced blister strips which had been placed on elevated metal tray were opened in a systematic fashion. The team members continued opening strips while moving toward the designated exit; the team members simultaneously completed their opening of all strips, and exited the warehouse through a slit cut in the enclosing plastic covering.

This scenario represents an ideal fumigation conducted by professionals; the data reported represents the "best case" scenario. Values obtained for phosphine concentrations during fumigation of tobacco warehouses are presented below.

Tobacco Warehouse	Site	Mean Concentration		N
	commodity	0.09	0.07 to 0.12 ppm	5
	commodity	0.21	0.16 to 0.27 ppm	4
	commodity	0.33	0.21 to 0.51 ppm	4

Calculation of Potential Inhalation Exposure:

Potential Inhalation Exposure (ug) = Concentration (ppm) *

1393 ug/ppm * 29 L/min * duration,

where 29 L/min is the inhalation rate of an adult worker, and the duration is the length of the activity in minutes. Using measured concentrations from the Mansdorf study, the following potential inhalation exposures were determined for each facility treatment using phosphine (Table 2).

Table 2. Potential Inhalation Exposure for each Facility type.

Facility	Potential Inhalation Exposure (ug)
Farm style bin	
popcorn	693 to 3310
commodity	29 to 2800
Flat storage bin	412 to 17355
post-application exposure	265 to 909
Railroad bulk car	
116m^3 fumigation	150 to 2002
74m^3 fumigation	12 to 626
post-fumigation exposure	82 to 1796
post-fumigation exposure	180
exposure during aeration	47 to 336
Railroad box car	
139-170m^3 car	19 to 6428
127-153m^3 car	42 to 311
130-142m^3 car	14.5 to 2303
exposure during aeration	47 to 336
Post fumigation	
exposure near sealed boxcar	250

Table 2. (continued)

Facility	Potential Inhalation Exposure (ug)
Incoming box car aeration (open door)	72.7
Packaging plant activities on flour/meal packing line	7966
Tobacco warehouse	
spread strips	284 to 1504
aeration	76 to 1782
retrieve strips	101 to 684
aeration	76 to 594
retrieval of strips	101 to 684

DAILY AND ANNUAL EXPOSURE ESTIMATES:

Given potential inhalation exposures for each treatment scenario outlined in the Mansdorf study, it is possible to make estimates of exposure on a per day and annual basis for most scenarios.

Farm Style Bin - popcorn

With respect to popcorn, fumigation is done only when pest pressures are excessive (2). In the Mansdorf study (1), only 21 of 80 storage bins were fumigated during 1987. Since the storage period for popcorn is between 6 and 7 months, an average of 3 fumigations per month may be done on a large storage facility. It is reasonable to assume that these fumigations would be done during the same day. Given these assumptions, and assuming the standard mass of 70 kg for a worker, daily potential inhalation could range between the following values:

693 ug * 3 treatments/day = 2079 ug/day or 0.029 mg/kg/day
3310 ug * 3 treatments/day = 9930 ug/day or 1.42 mg/kg/day.

From information provided by BEAD (2), there are approximately 4200 popcorn growers in the U.S. The Mansdorf study used data from one of the largest popcorn facilities. Using the worst case assumption, and utilizing information provided from the study, it is possible that 80 bins could be fumigated across a 7 month season. Approximately 11 treatments per month is assumed, and annual potential inhalation values could range between:

693 ug * 11 treatments/mo * 7 mo season/yr = 53400 ug/day
or 0.76 mg/kg/yr
3319 ug * 11 treatments/mo * 7 mo season/yr = 255000 ug/day
or 3.64 mg/kg/yr

Commodity bins:

Commodity fumigation is especially difficult to determine potential inhalation exposures, beyond those associated with a single treatment scenario. The need to fumigate varies with commodity, the quantity of commodity, and the necessary storage time. The length of storage time also is a function of commodity type and the types of pest population pressures that may be present. These calculations must be done on a crop specific basis.

Flat bin storage:

Typically storage time for grains loaded in flat bins may range from a few weeks to several months. Within the study, sorghum and wheat storage was examined, and only one fumigation was necessary or done during a season (i.e., year). Within the Mansdorf study, one site possessed 7 storage structures, with storage capacities ranging between 300,000 and 400,000 bushels each (1). Assuming an 8 hour work day, and 24 minutes required per fumigation, the worst case scenario would result in the following range of daily potential inhalation exposure:

412 ug/fumigation * 20 fumigations/day = 8240 ug/day
or 0.12 mg/kg/day
17355 ug/fumigation * 20 fumigations/day = 347100 ug/day
or 4.95 mg/kg/day

Since only one fumigation is conducted per bin within a year, the range of values for annual potential inhalation exposure would be the same, i.e. 0.12 mg/kg/year to 4.95 mg/kg/year.

Railroad bulk car:

Facilities handling railroad bulk cars typically have an 8 month work season per year. Fumigations are done every work day of the season, with an average application time of 20 minutes per car (1). Large facilities handle upto 300 cars per working season. On the average, a facility will fumigate 38 cars per month or approximately 2 cars per work day. Given these assumptions, the daily potential inhalation exposure can be calculated as:

116m^3 car: 150 ug/fumigation * 2 fumigations/day = 300 ug/day
or .0043 mg/kg/day
2002 ug/fumigation * 2 fumigations/day = 4004 ug/day
or 0.057 mg/kg/day

Railroad bulk car (continued)

74m^3 car: 12 ug/fumigation * 2 fumigations/day = 24 ug/day or 0.0003 mg/kg/day
626 ug/fumigation * 2 fumigations/day = 1252 ug/day or 0.018 mg/kg/day

For the 116m^3 car, annual potential inhalation exposure would be 48,000 ug per year to 641,000 ug per year or 0.686 to 9.15 mg/kg/year.

150 ug/car * 2 car/day * 20 workdays/mo * 8 mo/year = 48000 ug/year or 0.686 mg/kg/year

2002 ug/car * 2 car/day * 20 workdays/mo * 8 mo/year = 641000 ug or 9.15 mg/kg/year

For the 74m^3 car, annual potential inhalation exposure would be between 3840 and 200000 ug per year, or 0.548 to 2.86 mg/kg/year.

12 ug/car * 2 car/day * 20 workdays/mo * 8 mo/year = 3840 ug/year or 0.548 mg/kg/year

626 ug/car * 2 car/day * 20 workdays/mo * 8 mo/year = 200000 ug/year or 2.86 mg/kg/year

For postfumigation exposure, daily and annual potential inhalation exposure can be calculated using the same assumption of 2 cars per day.

daily: 180 ug/car * 2 cars/day = 360 ug/day or 0.0051 mg/kg/day

annual: 180 ug/car * 2 cars/day * 20 workdays/mo * 8 mo/year = 57600 ug/year or 0.823 mg/kg/year

With respect to exposure during the aeration process, daily and annual potential inhalation can be calculated as:

daily: 757 ug/car * 2 car/day = 1514 ug/day or 0.022 mg/kg/day

annual: 757 ug/car * 2 car/day * 20 workdays/mo * 8 mo/year = 242000 ug/year or 3.46 mg/kg/year

Railroad box car:

With respect to railroad box cars, there appears to be no significant difference in the measured concentrations of phosphine between different box car sizes. Additionally, wide variation occurred between measurements of phosphine concentrations. With respect to large processing and packaging facilities, the Mansdorf

study utilized a site handling 265 cars/season, with the working season being 6 months long. Approximately 38 cars are fumigated per month, or 2 cars are fumigated per day on the average.

daily: 19 ug/car * 2 car/day = 38 ug/day or 0.0005 mg/kg/day

6428 ug/car * 2 car/day = 6856 ug/day or 0.098 mg/kg/day

annual: 19 ug/car * 2 car/day * 20 workday/mo * 6 mo/year = 4530 ug/year or 0.065 mg/kg/year

6428 ug/car * 2 car/day * 20 workdays/mo * 6 mo/year = 1540000 ug/year or 22.0 mg/kg/year

The range for potential inhalation exposure during box car aeration activities can be calculated on both a daily and annual basis.

daily: 47 ug/car * 2 car/day = 94 ug/day or 0.0013 mg/kg/day

336 ug/car * 2 car/day = 672 ug/day or 0.0096 mg/kg/day

annual: 47 ug/car * 2 car/day * 20 workday/mo * 6 mo/year = 11280 ug/year or 0.161 mg/kg/year

336 ug/car * 2 car/day * 20 workday/mo * 6 mo/year = 80640 ug/year or 1.15 mg/kg/year

With respect to post-fumigation exposure near sealed box cars, utilizing the assumption that 2 cars are fumigated per day, it is possible to calculate the daily and annual potential inhalation exposures.

daily: 250 ug/car * 2 cars/day = 500 ug/day or 0.007 mg/kg/day

annual: 250 ug/car * 2 car/day * 20 workdays/mo * 6 mo/year = 60000 ug/year or 0.86 mg/kg/year

With respect to potential inhalation exposures encountered from aerating incoming box cars, one may assume that a large facility may receive an average of 190 incoming cars (3). With the worst case assumed, i.e. the contents of all cars have been fumigated, and that these cars will be received across a 6 month period, it is possible to calculate the daily and annual exposures. With 190 incoming cars, this would result in 32 cars per month requiring aeration, or an average of 1.6 cars per day requiring aeration.

daily: 72.7 ug/car * 1.6 car/day = 116 ug/day or 0.002 mg/kg/day

annual: 72.7 ug/car * 190 car/year = 13813 ug/year or 0.2 mg/kg/year

Packaging plant activities:

Assuming a worst case scenario, the Mansdorf study indicated that a concentration of 0.85 ppm had been measured during a 49 min activity period. Assuming that this concentration persists at this level for all materials to be packaged and that the activity is sustained, it is possible to estimate both the daily and annual worst case scenario for potential inhalation exposures in a cereal packing plant. The annual work season is assumed to last 6 months.

daily: 7966 ug/49 min * 60 min/hr * 8 hr/day = 78034 ug/day
or 1.11 mg/kg/day

annual: 7966 ug/49 min * 60 min/hr * 8 hr/day * 20 workday/mo * 6 mo/year = 9364000 ug/year or 133.8 mg/kg/year

Tobacco warehouses:

Two sites having 50 warehouses and a third site possessing 30 warehouses were utilized in the Mansdorf study. Only worst case scenarios will be calculated for the three sites; fumigation of warehouses typically span a 6 day period. Warehouses are tarped with plastic, seams are sealed with tape during the first day. Fumigation is done on the second day; on day 6, the warehouse is aerated and strips are collected. Fumigation is typically done once or twice a year; often these treatments are timed during July and/or December (2). The second fumigation is done only if pest pressures are high. For flue-cured tobacco, application of 20 g per 1000 ft^3 of space is used; fumigation is done for 96 hours at temperatures above 68 degrees F, then an aeration period of 72 hours is done. Typically preparation and fumigation is done by a 6 person team, and the team is capable of preparing and fumigating 6 warehouse units per day (2). A three person crew generally does aeration, pickup and disposal activities (2); approximately 12 warehouse units per day can be aerated per day. From available production estimates, it is estimated that approximately 2000 commercial warehouse units are present in the U.S. No information is currently available on the length of the fumigation season or the average number of treatments performed by a commercial applicator; this additional input is required to do daily and annual worker exposure under these conditions. Post-application exposure assessment is further complicated by the presence or absence of mechanical ventilation in warehouses. Phosphine is dissipated from the commodity during aeration and presence of mechanical ventilation aids in rapid phosphine dissipation and reduces post-fumigation exposure (6).

Potential Exposure of Workers Performing Varied Job Tasks during and after Fumigation:

No attempt has been made to calculate worker exposure for those individuals performing varied tasks across an eight hour time period (see Table 1). Additional information concerning duration and frequency of each activity, and proximity to a source of phosphine during the work period is required for the development of these exposure estimates.

IV. REFERENCES

1. S. Z. Mansdorf and Associates. Phosphine Exposure Monitoring for Applicators, Workers, and Nearby Persons. Submitted to EPA, April 15, 1988. MRID No. 40717201.

2. Personal communication with Wilfred Burr, BEAD. From Biological and Economic Assessment of Chemicals.

3. Curt Lunchick, 1989. Phosphine Fumigation Worker Exposure Study (Assessment). Memorandum to J. Kempter, dated February 3, 1989.

4. Curt Lunchick, 1989. Proposed Respiratory Protection for Metal Phosphides (HED Project No. 9-1986). Memorandum to J. Kempter, dated September 6, 1989.

5. NIOSH Pocket Guide to Chemical Hazards. 1990. U.S. Dept. of Health and Human Services, DHHS (NIOSH) Public. No. 90-117.

6. Stanley Gross, 1985. Data Call-in for Aluminum and Magnesium Phosphide Registration Standards. Memorandum sent to Art Costello on October 25, 1985.

cc: Phosphine Work Group
Chemical file
Circulation
J. Smith/OREB