Scand J Work Environ Health 1999;25(1):33-38
https://doi.org/10.5271/sjweh.380
Issue date: Feb 1999

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This article in PubMed: www.ncbi.nlm.nih.gov/pubmed/10204668

Print ISSN: 0355-3140 Electronic ISSN: 1795-990X

Scand J Work Environ Health 1999;25(1):33—38

Exposure of farmers to phosmet, a swine insecticide

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Stewart PA, Fears T, Kross B, Ogilvie L, Blair A. Exposure of farmers to phosmet, a swine insecticide. *Scand J Work Environ Health* 1999;25(1):33—38.

Objectives The goal of this study was to measure dermal and inhalation exposures to phosmet during application to animals and to identify what determinants of exposure influence the exposure levels.

Methods Ten farmers were monitored using dermal patches, gloves, and air sampling media during normal activities of applying phosmet to pigs for insect control. Exposures were measured on the clothing (outer), under the clothing (inner), on the hands, and in the air. Possible exposure determinants were identified, and a questionnaire on work practices was administered.

Results The geometric mean of the outer exposure measurements was 79 µg/h, whereas the geometric mean of the inner exposure measurements was 6 µg/h. The geometric mean for hand exposure was 534 µg/h, and the mean air concentration was 0.2 µg/m^3. Glove use was associated with the hand and total dermal exposure levels, but no other determinant was associated with any of the exposure measures. The average penetration through the clothing was 54%, which dropped to 8% when the farmers wearing short sleeves were excluded. The farmers reported an average of 40 hours a year performing insecticide-related tasks.

Conclusions Farmers who applied phosmet to animals had measurable exposures, but the levels were lower than what has been seen in other pesticide applications. Inhalation exposures were insignificant when compared with dermal exposures, which came primarily from the hands. Clothing, particularly gloves, provided substantial protection from exposures. No other exposure determinant was identified.

Key terms exposure assessment, exposure determinants, farmers, pesticides.

Numerous studies have evaluated exposures to herbicides and insecticides during the application of these chemicals to crops, weeds or forests, but few have assessed exposures from insecticides used on farm animals. In a recent paper (1), however, exposure levels from pesticide use on animals were similar to those from pesticide use on crops. One insecticide used in swine production is phosmet (O,O-dimethyl S-phthalimidomethyl phosphorodithioate), an organophosphate. It causes liver tumors in mice (2) and has been associated with neurological dysfunctions in humans (3). Raising hogs has also been associated with excesses of cancer of the rectum and lymphosarcoma and other lymphatic tissue (4), but the specific agents associated with these excesses have not been identified.

In epidemiologic studies of cancer among farmers, exposure measurements are rarely available. Exposure information has usually been obtained with questionnaires that seek information on the workplace and work practices, under the assumption that these data can be used as surrogates for exposure measurements. This report is part of a project designed to evaluate techniques for collecting exposure data in epidemiologic studies on farmers (1, 5—7), and it describes the results of an air and dermal monitoring study on farmers applying phosmet to pigs in order to control insects. It evaluates the

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relationship between exposures and exposure determinants to assess if any of them can be used as predictors of exposure. Because little information has been reported on the pesticide practices of animal farmers, a brief questionnaire was also administered to the subjects.

Methods

Ten farmers in Iowa were monitored during their normal application of phosmet to swine in the open or in confinement pens during August and September of 1991. The farmers were monitored from the transport of the pesticide to the mixing or loading area through the loading, mixing, application, and associated clean-up or maintenance tasks performed on the day of the sampling. The percentage of active ingredient in the liquid concentrate was 11.6% for all the farmers.

Dermal patches

Farmers wore cotton gloves and 2 sets of gauze patches (8), 1 on (outer) and 1 under (inner) the clothing for the monitored period. The patches were 12-ply 58 cm^2 (3×3 inches) and 103 cm^2 (4×4 inches) dermal sponge gauzes backed with a 4-ml sheet of Visqueare plastic, held in a protective aluminized paper envelope with openings of 25.65 and 42.03 cm^2, respectively. Two small patches (1 inner, 1 outer) were attached to the hat (if worn), the lower arm, upper inner thigh, and 2 lower legs. Two large patches (1 inner, 1 outer) were located on the chest, the back, the upper arm and the upper outer thigh. The inner and outer patches did not overlap. The inner patches were held to the body with tight-fitting clothes or elastic bands. The outer patches were attached to the farmers' normal clothing with duct tape and safety pins. When the farmer wore short sleeves (N=6), the hands and lower arms had only 1 set of patches, which were considered to be inner patches. If a farmer usually wore gloves while handling the insecticide (N=5), the gloves supplied by the study investigators were worn underneath the farmer's gloves. In this case, only the inner gloves were analyzed. Nine farmers wore jeans or overalls (1 was not identified).

Because of possible interferences from other chemicals or materials in the glove and patch fabric, all the patches and gloves were desorbed using methanol prior to their being shipped to the field industrial hygienists.

Personal air measurements

Personal air measurements were collected in the farmer's breathing zone on XAD-2 sorbent tubes attached to the farmer's shoulder and to personal air sampling pumps for the length of the task being measured. The sampling rate was 0.5 l/min and the pumps were pre- and postcalibrated in the field using rotameters [unpublished results: Anonymous. Determination of Residues of Rabon and Prolate Adsorbed on XAD-2 Air Sampling Tubes. National Cancer Institute, Frederick Cancer Research and Development Center — Chemical Synthesis and Analysis Laboratory, Frederick Maryland].

Spikes and blanks

Solutions containing 3.4 μg of phosmet were prepared for spiking in the laboratory for both the laboratory and field spikes. For the latter, ampules of liquid spikes were shipped to the field in a cooler and applied to a patch, a glove, and an XAD-2 tube. The ampules were rinsed with acetone to ensure that all the liquid spike was added to the spiked media. The spiked media were allowed to air dry for 15 minutes before each was placed into separate prelabeled storage envelopes. The envelopes were double bagged and kept in a separate cooler until shipment to the analytical laboratory. Blank media taken to the field remained unopened, but they were labeled, bagged and placed in the cooler.

Monitoring

The field technicians obtained an informed consent from each participant and instructed him in the procedures to be followed. The farmers performed normal activities. A time-motion record was completed by the technician that documented the time and location of each task. A questionnaire was administered to each farmer to obtain a profile of his typical work practices associated with insecticide treatment.

After completion of the monitoring, the patches were grouped into 3 types (inner, outer or hand), placed into separate storage bags and then into a larger bag for dry ice transportation to the laboratory. All the samples were collected in a cooler packed with ice, which was then transported to an interim freezer and kept at -20°F (-19.5°C). The samples were then repacked in dry ice and sent overnight to the analytical laboratory.

Phosmet was extracted from the gloves and patches with 400 ml of acetone for 1 hour [unpublished results: Anonymous. Determination of Residues of Rabon and Prolate in Dermal Exposure Dosimeters. National Cancer Institute, Frederick Cancer Research and Development Center — Chemical Synthesis and Analysis Laboratory, Frederick Maryland]. After the acetone was evaporated at 50°C, 1 ml of iso-octane was used to reconstitute the residue. Phosmet was desorbed from the XAD-2 tubes using 1 ml of acetone and 2 ml of toluene with sonication. An additional 2 ml of toluene was added for further extraction. The extracts were combined and dried under nitrogen. The residue was reconstituted in 1 ml of iso-octane with vortexing. The residue from the gloves, patches, and XAD-2 tubes was analyzed using gas chromatography with thermionic-specific detection.

The mass of phosmet measured on all the inner patches constituted the inner patch concentration. The outer patch concentration was similarly calculated using the combined outer patches. The hand concentration was the sum of the phosmet found on the gloves. Total dermal exposure was the sum of the inner patches and the gloves. The mass of each of these was divided by the total time (transport, mixing, application and clean-up) to derive exposure rates.

The mass of phosmet reported for the inner and outer patches, the hands, the air samples, and the total exposure are called exposure measures in this report. The exposure determinants recorded by the technician were the method of application, glove use (none, wore some of the time, wore the entire time), amount of active ingredient used, tank size, number of pigs treated, total mixing time, number of times the tank was filled (mixing cycles), total application time, application cycles, the number of times the insecticide was applied to a group of animals (several batches of animals were treated due to the size of the treatment area), and total time.

Statistical methods

Standard statistics were used to summarize the data (means and standard deviations). To evaluate the association between the different measures of exposure and possible determinants of exposure, the logs of the exposure measures were correlated with the untransformed exposure determinants using the Spearman rank correlation coefficient (r). Possible associations among the determinants were also evaluated using the Spearman coefficient.

One farmer had only 1 arm; he was excluded from the analyses on hands and total exposure, but was included in the inner and outer exposure analyses. Therefore, the analyses of the application method used data from only 1 person using the high pressure spray.

Results

Recovery results

The mean of the 9 field spike recovery rates for the patches was 107 (SD 30)% (N=5), while the mean laboratory spike recovery was 109 (SD 15)% (N=9). For the gloves, the mean field spike recovery was 75 (SD 33)% (N=5), while the mean laboratory spike recovery was 93 (SD 16)% (N=9). The mean recovery for the air field spikes was 44 (SD 8% (N=4), and for the laboratory spikes, it was 71 (SD 14)% (N=7). The mean field percentage recovery was used to adjust the exposure measures.

Exposure determinants

The amount of active ingredient used ranged from about 3 ounces (0.09 l) to 1 gallon (3.78 l). Two farmers used a high pressure sprayer, 4 a low pressure sprayer, 2 a backpack sprayer, and 2 a pour-on method. The number of pigs sprayed averaged 90, ranging from 7 to 214. Mixing took an average of about 2.7 (SD = 1.8) minutes, and most farmers mixed once or twice. The application time averaged 11 (SD 8.9) minutes. Winds were fairly calm (<8 miles/h; <13 km/h).

Overall exposure results

The mean of the phosmet deposited on the outer patches was 230 [geometric mean (GM) 79, geometric standard deviation (GSD) 4.2] µg/h. Phosmet on the inner patches averaged 20 (GM 6, GSD 4.1) µg/h. The average penetration through the clothing of all the farmers was 54%; however, when only farmers who wore long sleeves were evaluated, the penetration rate was 8%. The mean exposure on the hands was 1853 (GM 534, GSD 9.6) µg/h. The amount of phosmet collected in the air was 0.38 (GM 0.2, GSD 4.2) µg/m^3 for the application time. The mean total dermal exposure (inner and hand) was 1700 (GM 586, GSD 8.3) µg/h.

Effect of exposure determinants

The farmers who wore gloves had much lower exposures than those who wore gloves sometimes, and the latter had lower exposures than those who never wore gloves (table 1). There was a significant correlation (r) between glove use and hand exposure (r=0.67, P=<0.05). Hand exposure was highly correlated with total exposure (r=0.98, P<0.01) (not shown). In addition, the ratio of hand exposure to outer exposure increased from 1 (wearing gloves) to 39 (wearing gloves some of the time) to 71 (never wearing gloves).

The low-pressure spray method (N=4) resulted in the highest geometric mean concentrations for outer and

Table 1. Phosmet concentration received, by type of exposure measure and glove use. (SD=standard deviation, GSD=geometric standard deviation)

Type of exposure	Glove use (µg/h)				Some glove use (µg/h)				No glove use (µg/h)[a]			
	Arithmetic mean	SD	Geometric mean	GSD	Arithmetic mean	SD	Geometric mean	GSD	Arithmetic mean	SD	Geometric mean	GSD
Hands	95	73	40	5.8	2386	921	2201	1.8	2904	1504	1073	4.8
Total exposure	106	78	52	4.7	2399	928	2212	1.8	2939	1493	1098	4.8

[a] The differences between glove use were statistically significant (P<0.05).

inner exposures (table 2). This method was also associated with the highest variability for the outer and inner exposures. There was little difference among the 3 other methods measuring outer (GM 23—57 µg/h) or inner (GM 2—8 µg/h) exposure. There was little difference among the backpack, low-pressure spray and pour-on methods for hand exposure (228—823 µg/h) or total exposure (294—872 µg/h). The high pressure spray was associated with the highest value for these exposures, but it was only based on 1 measurement. The pour-on method had the highest variability for the hands and total exposures. The method of application was therefore not a significant determinant for any of the exposure measures. None of the other exposure determinants was associated with any of the exposure measures.

The number of times the spray container was filled was highly correlated with the number of application cycles (r=0.92, P<0.01). The number of pigs was associated with the total amount of phosmet applied (−0.86, P<0.01). Several of the exposure determinants were also moderately correlated with each other (r=0.5—0.7), including mixing time with tank size (P=0.058) and total time with the number of tank fills (P<0.05), and the number of applications (P<0.05).

Table 2. Phosmet concentration received by type of dosimeter and application method.[a] (SD=standard deviation, GSD =geometric standard deviation, HP=high pressure, LP=low pressure)

Exposure measure	Arithmetic mean (µg/h)	SD	Geometric mean (µg/h)	GSD
Outer patches				
Backpack	76	50	57	3.1
HP spray	23	3	23	1.2
LP spray	502	270	226	5.5
Pour-on	47	14	45	1.5
Inner patches				
Backpack	12	9	8	4.0
HP spray	4	2	4	1.9
LP spray	40	31	14	5.4
Pour-on	2	1	2	2.5
Hands				
Backpack	330	90	317	1.5
HP spray	1465	0	1465	0
LP spray	1830	711	823	8.0
Pour-on	3615	3608	228	132.5
Air concentration				
Backpack	36	5.0	36	1.2
HP spray	2	1.9	2	2.6
LP spray	12	9.5	9	2.9
Pour-on	1	0.3	1	1.2
Total exposure				
Backpack	342	81	332	1.4
HP spray	1471	0	1471	0
LP spray	1870	708	872	7.5
Pour-on	3618	3606	294	92.4

[a] The differences among the methods were not statistically significant.

Questionnaire results

One farmer reported that he first started using insecticides in 1955, 2 reported first use in the 1970s, and 3 in the 1980s. Phosmet use began in the 1980s for all the farmers (N=7), except 1 who reported he began in 1976. Once started, they continued phosmet use through 1991. Four indicated they consistently wore protective gloves over the years when applying phosmet. The total number of hours per year the farmers used phosmet varied from 1 to 125 (mean 40, SD 47.6) (N=6)). The number of hours per year they performed animal-insecticide-related tasks from 1986—1991 was 0.7 (SD 0.7)h/year (N=8) for transporting insecticides from the warehouse to the farm or the field, 0.4 (SD 0.4) h/year (N=5) for preparing and maintaining the application equipment, excluding calibration, 0.7 (SD 0.4) h/year (N=4) for calibrating equipment, 1.7 (SD 1.9) h/year (N=6) for loading insecticide into a spray container, 22 (SD 42.5) h/year (N=7) for applying an animal insecticide, <0.6 (SD 0.4) h/year (N=3) for dealing with plugged equipment, 0.1 h/year (N=1) for dealing with spills, and 0.8 (SD 0.4) h/year (N=4) for cleaning equipment after use. Only 1 farmer reported that he washed with soap and water after an application but prior to eating, drinking or smoking. Two farmers indicated that they did not follow the instructions on the insecticide container, and 1 said he smoked, ate or drank in the pesticide application area. The insecticides were stored in storage areas or sheds (N=2), in a garage (N=1), a shop (N=1), or in an animal confinement building (N=4).

Discussion

To our knowledge, this is only the second report on exposure to the application of insecticides to farm animals. Ten farmers were evaluated under their normal work conditions. The total exposure levels were much lower than those of crop applicators (9). The concentrations received varied substantially (GSD 8.3). This variability is somewhat higher than what has been reported for dermal exposures among pesticide applicators (10—12) and other populations (13). It is, however, lower than that reported in the other report on animal insecticide exposures, in which a geometric standard deviation of 45 was found for the dermal exposure measurements for 20 farmers (1). It may be that the application of animal insecticides is more dependent on incidental contact (eg, with wet animals) than other types of application are.

The major contributor to total exposure was the hands, which contributed between 60% and 99% of the total dermal exposure for the 10 farmers in this study. This finding has been observed in other studies of workers mixing and loading pesticides, where hands have contributed 60—99% of the total exposure (14, 15), and applying pesticides, where hands have contributed 35—50% of the total exposure (14—16). As in other studies of applicators (9), the contribution of inhalation exposures was found to be insignificant in comparison with exposures from dermal exposures.

The amount of clothing worn, particularly gloves, was an important determinant of exposure. A comparison of hand exposure when gloves were worn and when they were not indicated that gloves substantially reduced exposures and that the longer they were worn, the more protection they provided. The importance of gloves is similar to what has been found by others (9).

The clothing worn on the rest of the body, however, was also important. The overall penetration rate (outer/inner) was higher than has been reported earlier (54%), but when only farmers wearing long sleeves were included, the penetration rate dropped to 8%. One farmer wearing short sleeves actually experienced a higher inner exposure than outer exposure (132 versus 28 µg/h). The reason for this result could be not identified. The higher penetration rate in this report than in the other animal insecticide study (1) may reflect differences in clothing. The earlier study was conducted in cold weather, and many of the farmers wore multiple layers of clothing. Our study was conducted in August and September and the farmers wore only a single layer of clothing. The differences therefore, were probably due to differences in outside temperatures. None of the farmers in either study was wearing true protective clothing. Still, it is interesting that normal clothing can substantially reduce exposure levels. In spite of this apparent protective effect, normal clothing is not recommended as a means of protection. Appropriate protective clothing should be worn according to the carrier solvent (rather than the insecticide) in use (17). Contaminated clothing should be removed and a shower taken as soon as possible after insecticide use.

In the evaluation to predict the exposure measures from exposure determinants, there were few statistically significant associations. It was surprising to find no other correlation between the measures and the determinants. In the previous study (1), the method of application was also important. The exposures resulting from the different methods of application in this study differ from those in the first study, and the methods ranked differently by exposure level (table 3). It may be that the type of animal being treated affected the exposure levels. In this study, only hogs were treated, whereas in the first study both hogs and cattle were treated. There were too few farmers treating hogs in the first study, however, to make statistical testing meaningful. The differences found for the application method may also be due to differences in the sampling and analytic methods. Clearly more studies are needed before definitive conclusions can be drawn regarding this type of pesticide application.

Table 3. Comparison of 2 studies as to the application of animal insecticides.

Method	Arithmetic mean (µg/h)			Geometric mean (µg/h)		
	Phosmet study		Video study[a]	Phosmet study		Video study
	Air	Dermal	Dermal	Air	Dermal	Dermal
Backpack	36	342	10	36	332	7
HP spray	2	1471	634	2	1471	322
LP spray	11	1870	39125	9	872	7705
Pour-on	1	3618	3003	1	294	2

[a] From Stewart et al, in press.

The number of hours using insecticides over a year, as reported in the questionnaire, varied, ranging from 1 to 125 h/year. Only 4 farmers reported consistent use of gloves, and only 1 washed before eating, smoking, or drinking. In the interviews in this project, 35% of the farmers reported wearing gloves when using animal insecticides, and about half the farmers reported washing before smoking or entering the house (6). Two farmers did not follow the instructions on the container, and 1 reported that he ate, smoke, or drank in the pesticide area. These findings indicate that changes in work practices are necessary, in addition to the use of protective clothing, to fully control exposures.

Our results are based on only 10 measurements and therefore should be considered as preliminary. One must use caution when extrapolating these results to other situations because several of the cells were based only on 2 values. Nonetheless, this study provides guidance for future studies examining exposure from the application of animal insecticides.

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Received for publication: 10 March 1998