Department of Pesticide Regulation

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M E M O R A N D U M

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SUBJECT: EXPOSURE MONITORING STUDY FOR RESIDENTIAL HANDLERS APPLYING GRANULAR PESTICIDES VIA PUSH SPREADER

Granular pesticide products may be applied by professionals such as landscape maintenance workers, but they also can be applied by residential users. Exposure estimates are needed for both occupational and residential handlers of these products. Data are available in the Pesticide Handlers Exposure Database (PHED) for handlers applying granular formulations using a push-type rotary spreader (Beauvais *et al*., 2007). However, those data are based on a single study with incomplete dosimetry, for which limited details were provided.

This memorandum reviews an exposure monitoring study sponsored and submitted by the Outdoor Residential Exposure Task Force (ORETF) for residential handlers applying a granular pesticide using a push-type rotary spreader, and recommends exposure estimates for use in risk assessments prepared by the California Department of Pesticide Regulation (DPR).

Klonne and Honeycutt (1999) is a well conducted study that provides useful data for the residential granular handler scenarios. These data can also be adapted for occupational handler scenarios as needed, by assuming greater amounts of active ingredient (AI) handled.

Primary Review of Granular Handler Exposure Monitoring Study (Klonne and Honeycutt, 1999)

The intent of the study reported by Klonne and Honeycutt (1999) was to measure exposures to home gardeners applying granular pesticides using a push-type rotary spreader. Dacthal® granular herbicide, containing 0.9% dimethyl tetrachloroterephthalate (DCPA), was the pesticide used in this study. No granular products containing DCPA are currently registered in California, but the DCPA granular formulation used in this study can be considered a surrogate for other granular pesticides.

Study Design

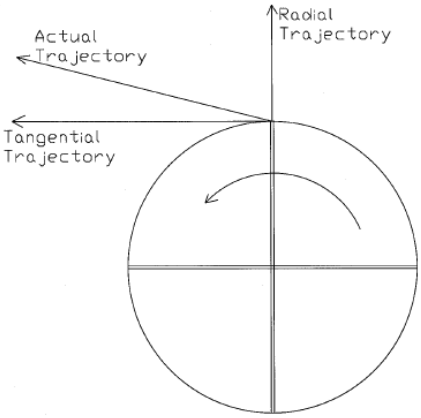
The study site was a sod farm near Maiden, NC, and used previously-established plots of Bermuda and Bluegrass turf. Each plot was 10,000 ft^2, and was divided into two subplots of 5,000 ft^2 each. The study was conducted over 4 days in July 1997.

Applications were made using a Scotts® Model SG-3 SpeedyGreen push rotary spreader (Figure 1). Granules drop through an opening in the bottom of the hopper, and onto a plate with raised fins (an impeller) that rotates as wheels move (arrow). Because rotary spreaders broadcast granules sideways rather than dropping them between the wheels like a drop spreader, rotary spreaders have wider swaths than drop spreaders (Parish, 2001). The typical trajectory taken by granules leaving the impeller is shown in Figure 2. Klonne and Honeycutt (1999) elected to use a rotary spreader in the belief that handler exposure would be greater than with a drop spreader.

Figure 1. Scotts SpeedyGreen Rotary Spreader [a]

[a] Arrow points to the rotating impeller that broadcasts granules when spreader is pushed. Line drawing at right shows impeller and axle linkage from a different model rotary spreader (Lesco, 2002).

Figure 2. Typical Trajectory of a Granule Leaving a Spreader Impeller (Parish, 1999)



The spreader's hopper capacity was 50 lbs. Each replicate sequentially loaded and applied two 25-bags of Dachthal® granules (0.45 lbs AI total). At the beginning of the monitoring interval, one bag was loaded into the hopper of a spreader previously calibrated to apply at a rate of 5 pounds of product per 1,000 ft^2 (equivalent to 2 lbs AI/acre). A subplot of 5,000 ft^2 was treated using the full 25 pounds of product. Once the spreader was empty, the handler loaded and applied a second bag to the second subplot. In total, each replicate treated a 10,000-ft^2 plot with 50 pounds of product.

Thirty replicates were conducted with 30 volunteers (21 male, 9 female) experienced in using rotary spreaders (1 – 45 years experience). The volunteers ranged in age from 21 to 78 years old. Their heights were 62 – 76 inches (157 – 193 cm), and their body weights were 127 – 231 pounds (57.6 – 104.8 kg).

Detailed summaries of exposure monitoring procedures were taken from the Field Report, pages 160 – 179.

Dermal exposure was monitored with inner and outer whole-body dosimeters, hand washes, and face/neck wipes. Outer dosimeters consisted of long-sleeved button shirts and long pants, all made of 100% cotton. Shirts were fully buttoned and tucked into pants. Inner dosimeters were 100%-cotton long underwear. At the end of the monitoring intervals, the dosimeters were removed by test subjects, assisted by study personnel wearing latex gloves. Both inner and outer dosimeters were cut into six portions: upper arms, lower arms, upper legs (including dosimeter pants from knee to waist), lower legs, front torso, and back torso. Study personnel sectioning dosimeters wore latex gloves, which they changed between handling outer and inner dosimeters. Separate, solvent-cleaned scissors were used for inner and outer dosimeters; scissors were rinsed with solvent between replicates. Because of concerns that DCPA might adsorb to the inner surface of a zip-lock style bag, all dosimeter sections were wrapped in foil, then placed in labeled bags and then frozen.

Hand washes were conducted before dosimeter removal. Hand washes consisted of slowly pouring a 250-ml aliquot of a 0.01% aqueous Aerosol® OT-75 (sodium dioctyl sulfosuccinate) detergent solution over hands rubbing together in a stainless steel bowl, then having the test subject rub hands together in the bowl for 30 seconds. The wash was repeated in the same bowl and the aliquots combined into one 500-ml sample. Following each wash, hand wash aliquots were poured into a glass jar, which was capped with a Teflon®-lined lid. The lid was taped and the jar was placed into a plastic bag, and then into a cooler of dry ice.

Face and neck exposure was monitored by wiping the skin with two gauze squares consisting of eight layers of 100% cotton (4 x 4 inches, or 10 x 10 cm). Gauze was wetted with 8 ml of 0.01% Aerosol OT® solution. The two wipes were placed in a glass jar. The process was repeated, and all four wipes were combined into a single sample for analysis, which was frozen for storage. To prevent additional contamination of the face and neck during applications, study personnel used single dry gauze squares to wipe the face and neck of perspiring handlers so that they would not brush potentially contaminated hands and forearms against the face and neck. These gauze wipes were stored separately from the post-application face/neck wipes samples; they were analyzed and results combined with post-application face/neck wipes.

Inhalation exposure was monitored using personal air samplers consisting of OSHA Versatile Sampler (OVS) tubes connected to air pumps with Tygon® tubing. OVS tubes each contained a 13-mm glass fiber filter followed by two sections containing 500 mg and 150 mg Chromasorb® 102 resin, separated by glass wool. Sampler pumps were calibrated at a flow rate of 1.5 liters/minute. At the end of the monitoring intervals, OVS tubes were removed from air samplers, sealed at both ends and placed in zip-lock style bags and into frozen storage.

Analytical Methods

Dosimeter sections and face/neck wipes were extracted with acetone. Foil wrappers were rinsed with 50 ml of acetone, which was added to the extract. An aliquot of each extract was subjected to Florisil® clean up and reconstituted in 2.0 ml of acetone if needed before analysis. Hand wash samples were extracted for 2 minutes in a separatory funnel using 20% w/v sodium chloride solution and petroleum ether as aqueous and organic phases. The organic phase was retained for analysis, and the aqueous phase was extracted a second time with an petroleum ether. A 0.5 ml aliquot was removed from the combined extracts and evaporated to dryness, then dissolved in 5.0 ml acetone for analysis. Front and back sections of OVS tube samples were combined for analysis. The Chromasorb® 102 resin was extracted with toluene. Aliquots of sample extracts were evaporated to dryness under a nitrogen stream in a 45 – 50ºC water bath, and subsequently reconstituted in 2.0 ml of acetone for analysis.

All samples were analyzed using gas chromatography with an electron capture detector. Helium was used as a carrier gas. The limit of quantitation (LOQ) for each matrix was 1.0 µg DCPA/section for both inner and outer dosimeter sections, 1.0 µg DCPA/sample for hand wash and face/neck wipe samples, and 0.01 µg DCPA/tube for OVS tubes.

Quality Assurance

Quality assurance consisted of field controls, travel spikes, field spikes, laboratory controls, and laboratory spikes. Each set of samples was analyzed along with a set of calibration standards, a solvent blank, a laboratory control matrix, and newly fortified laboratory spikes.

Field controls consisting of duplicate samples of each matrix were taken into the field each day. Control hand wash and face/neck wipe samples were placed in glass jars and put on dry ice immediately. Control dosimeter sections were set out in an area away from potential contamination for the duration of a monitoring replicate. Travel spikes consisted of spiking solutions (one bottle of each concentration) that traveled to the study site, were each opened while field spikes were prepared, then closed and returned to the laboratory along with field samples.

Field spikes consisting of three samples of each matrix were spiked at three levels on each monitoring day using DCPA analytical standard in acetonitrile. Outer dosimeter samples were fortified at 5 µg, 50 µg, and 5,000 µg DCPA. Inner dosimeter, hand wash, and face/neck wipe samples were fortified at 5 µg, 50 µg, and 500 µg DCPA. OVS tube samples were spiked with 0.05 µg, 0.5 µg, and 5.0 µg DCPA. Spike solutions of DCPA analytical standard in acetonitrile were made in the laboratory and carried to the study site where samples were spiked. Hand wash and face/neck wipe samples were placed in glass jars immediately after spiking. Jars were capped with Teflon®-lined lids and put into zip-lock style bags and on dry ice. In contrast,

dosimeter samples were weathered after spiking for 29 – 50 minutes (stated to be "typical" monitoring intervals, although the longest weathering interval exceeded actual monitoring), then they were wrapped in foil, placed in zip-lock style plastic bags and put on dry ice. After spiking, OVS tubes were held upright for 5 minutes to allow excess solvent to evaporate, then each was connected to a sampler pump. After air was drawn through the OVS tube for 29 – 50 minutes, it was disconnected from the pump, capped, wrapped in tissue and placed into a bag which was put on dry ice. Honeycutt and Klonne (1999) did not explain why the OVS tubes used for field spikes were wrapped in tissue before placing in bags; sample OVS tubes were placed directly into bags without wrapping, and dosimeter samples were wrapped in foil. Whether or not capped tubes were wrapped in tissue is not anticipated to affect results.

Results

For the 30 replicate applications, the mean monitoring interval was 30 ± 8 minutes (range: 17 – 47 minutes), during which subjects handled 0.45 pounds of DCPA. Monitoring intervals included time spent filling the hopper as well as applications; applications alone took an average of 22 ± 4 minutes (range: 15 – 34 minutes).

Quality assurance was acceptable. No quantifiable DCPA was recovered from any controls. Mean laboratory spike recoveries ranged from 82.5% to 99.0%, and mean field spike recoveries were 83.3% – 97.4%. Table 1 summarizes overall field spike recoveries. Klonne and Honeycutt (1999) corrected all sample results above the LOQ for mean recoveries of the nearest level spikes.

Table 1. Dimethyl Tetrachloroterephthalate (DCPA) Field Spike Recoveries [a]

Matrix	Spike Levels [b] (µg)	Percent Recovery (Mean ± Standard Deviation) [c]		
		Low	Mid	High
Inner Dosimeter	5.0, 50, 500	**90.8** ± 6.3	89.3 ± 4.3	**97.1** ± 4.8
Outer Dosimeter	5.0, 50, 5,000	86.5 ± 10.3	83.4 ± 5.9	**95.7** ± 5.6
Face/Neck Wipes	5.0, 50, 500	**91.0** ± 4.9	**90.3** ± 3.9	**97.4** ± 5.1
Hand Wash	5.0, 50, 500	**90.9** ± 4.0	**95.0** ± 5.0	**91.4** ± 5.4
OVS Tubes	0.05, 0.5, 5.0	**91.0** ± 4.9	**90.3** ± 3.9	**97.4** ± 5.1

[a] Data from Klonne and Honeycutt (1999).
[b] The three levels listed correspond to low, mid, and high level spikes.
[c] Each mean and standard deviation is of 12 replicates. Means at or above 90% are shown in bold; the practice of the California Department of Pesticide Regulation is to correct only for recoveries less than 90%, and samples in the range of spikes ≥ 90% were not corrected for recovery.

Table 2 summarizes exposure monitoring results, reported as overall mean DCPA residues on each exposure matrix. Results were corrected according to DPR practice, which is in general agreement with U.S. EPA policy: samples were corrected for field fortification recoveries below 90% (U.S. EPA, 1992; U.S. EPA, 1998). With the exception of inner dosimeter samples in the

range of the mid level spike, and outer dosimeter samples in the range of the low or mid level spikes, sample results reported in this memorandum were not corrected for mean field spike recoveries.

Table 2. Residues on Exposure Monitoring Matrices Following Applications of a Granular Dimethyl Tetrachloroterephthalate (DCPA) Product and Handler Exposure Rates [a]

Matrix [b]	No. < LOQ [c]	Range of Residues (µg) [c]	Mean Residues (µg) [d]	Upper Bound DCPA (µg) [e]	Short-Term Exposure Rate (µg/lb AI) [f]	Long-Term Exposure Rate (µg/lb AI) [f]
Hand Washes	0	1.1 – 14.7	7.2	14.8 [g]	32.9	16.0
Face/Neck Wipes	23	< 1.0 – 2.9	0.7	2.9	1.8	6.4
Inner Dosimeter						
Lower Arm	14	< 1.0 – 8.4	1.2	8.4	18.7	2.7
Upper Arm	17	< 1.0 – 7.6	0.9	7.6	16.9	2.0
Front Torso	20	< 1.0 – 3.2	0.9	3.2	7.1	2.0
Rear Torso	23	< 1.0 – 2.1	0.7	2.1	4.7	1.6
Lower Leg	1	< 1.0 – 155.4	33.5	155.4	345	74.5
Upper Leg	6	< 1.0 – 56.8	8.1	56.8	126	17.9
Outer Dosimeter						
Lower Arm	1	< 1.0 – 11.0	4.3	11.0	24.4	9.6
Lower Leg	0	< 1.0 – 2,980	417	2,980	6,620	926
OVS Tubes [h]	2	< 0.01 – 0.129	0.043	0.129	3.18	1.10

[a] Data from Klonne and Honeycutt (1999). Results corrected for field spike recoveries according to California Department of Pesticide Regulation practice (see Table 1), and rounded to two or three significant figures depending on the significant figures given in the reported results for each matrix.
[b] Only matrices used to estimate exposure in occupational and residential risk assessments are included. Outer dosimeter residues are used to estimate exposure of handlers wearing shorts and a t-shirt. OVS: OSHA Versatile Sampler air sampler tubes (used to estimate inhalation exposure).
[c] The limit of quantitation (LOQ) was 1.0 µg DCPA/sample for all matrices except OVS tubes, where the LOQ was 0.01 µg DCPA/tube. Non-detects were set at ½ LOQ for calculating statistics.
[d] Arithmetic mean of 20 samples per exposure monitoring matrix.
[e] Upper-bound estimates of DCPA residue were determined by first calculating the 95th percentile of the 30 results, assuming a lognormal distribution (Frank, 2009). This result was compared to the highest corrected measured residue, and the highest of the two values used for an upper bound. In most cases, the highest measured residue was greater than the 95th percentile, and unless otherwise stated, the upper bound value is the highest measured residue.
[f] Short- and long-term exposure rate estimates were calculated by dividing the upper bound and mean, respectively, DCPA residues by the amount DCPA handled in pounds.
[g] 95th percentile.
[h] Results adjusted to default inhalation rate of 16.7 liters/minute.

Table 3 summarizes exposure rate estimates for granular applicators wearing clothing required by most product labels, as well as applicators not wearing the label-required gloves and clothing.

These values were calculated by first summing the individual replicate dosimeter, hand wash, face/neck wipe, and inhalation results and then calculating overall statistics. Foot exposure was not monitored by Klonne and Honeycutt (1999), and was assumed to be equal to lower leg exposure, adjusted for the difference in median surface area: foot surface area is 1,225 cm^2 and lower leg surface area is 2,370 cm^2 (median values combined from data sets for men and women; U.S. EPA, 1997). Thus, 0.52 times the lower leg exposure was added to individual dermal exposure estimates before calculating the short-term and long-term exposure estimates.

Table 3. Exposure Rate Estimates of Handlers Loading and Applying a Granular Dimethyl Tetrachloroterephthalate (DCPA) Product [a]

Clothing Scenario [b]	Exposure Route	Short-Term Exposure (µg/lb AI) [c]	Long-Term Exposure (µg/lb AI) [d]
Long-sleeved shirt, long pants, and gloves [e]	Dermal	627	137
	Dermal + Inhalation [f]	630	138
Long-sleeved shirt, long pants, no gloves	Dermal	648	149
	Dermal + Inhalation	651	150
Short-sleeved shirt, short pants, and gloves [e]	Dermal	6,670	812
	Dermal + Inhalation	6,670	813
Short-sleeved shirt, short pants, no gloves	Dermal	6,680	823
	Dermal + Inhalation	6,680	824

[a] Exposure rate (µg/lb AI), based on data by Klonne and Honeycutt (1999). Dermal exposures sum matrix-specific (dosimeter, hand wash, face/neck wipe, and inhalation) exposure estimates. Dermal totals included addition of estimated foot exposure, calculated by multiplying the value for lower legs by 0.52 (ratio of feet/lower leg surface area; U.S. EPA, 1997). Inhalation exposures assume a default inhalation rate of 16.7 liters/minute. All estimates were rounded to three significant figures.

[b] Most product labels require applicators to wear long-sleeved shirt, long pants, and gloves; dermal exposure rates for these include all inner dosimeter sections, hands, and face/neck. Exposure rates for applicators wearing shorts and short-sleeved shirt included outer dosimeter lower arm and lower leg sections along with all inner dosimeter sections, hands, and face/neck.

[c] Short-term estimates are based on either the 95th percentile, or the highest measured residue if it exceeds the 95th percentile.

[d] Long-term estimates are based on the arithmetic mean of data from Klonne and Honeycutt (1999).

[e] Applicators monitored by Klonne and Honeycutt (1999) were not wearing gloves. Gloves were assumed to provide 90% protection (Aprea *et al*., 1994; Moody and Nadeau, 1994; Stewart *et al*., 1999; Creely and Cherrie, 2001), and exposure of gloved hands was calculated as one tenth the exposure of bare hands.

[f] Total exposure is the sum of dermal plus inhalation. Short-term inhalation = 3.18 µg/lb AI handled, and long-term inhalation = 1.10 µg/lb AI handled.

If the maximum amount of AI handled per day is assumed to be 0.45 lbs, as was used by Klonne and Honeycutt (1999), then an applicator wearing the label-required long pants, long-sleeved shirt, and gloves would have an estimated dermal exposure of 282 µg AI/day:

(0.45 lbs AI/day) x (627 µg/lb AI) = 282 µg AI/day.

The mean body weight in this study was 80 kg, which would give an estimated short-term dermal dose of 3.5 µg/kg/day:

282 µg/day ÷ 80 kg = 3.5 µg/kg/day

Similarly, the long-term dermal exposure estimate would be (0.45 lbs AI/day) x (137 µg/lb AI) = 61.6 µg/day, and 61.6 µg/day ÷ 80 kg = 0.77 µg/kg/day. These estimates reflect potential exposure, or the amount of AI reaching the skin; a dermal absorption factor would be applied to estimate absorbed dose.

Exposure Appraisal

Exposure monitoring by Klonne and Honeycutt (1999) provided the best available data for estimating exposure of handlers loading and applying granular pesticides with a push-type spreader. This was a well-conducted study with apparently acceptable replication (30 applications were monitored) and acceptable quality assurance. Monitoring intervals were short, averaging 30 minutes; subjects spent an average of 22 minutes applying Dacthal®. Short monitoring intervals have been found to yield higher exposures than longer intervals; in a study of peach harvesters exposed to azinphos-methyl, hourly dermal exposure estimates were higher after 2-hour monitoring intervals than after 3- to 7-hour intervals, suggesting that extrapolation of short monitoring intervals to longer workdays can result in overestimating exposure (Spencer *et al.*, 1995). The short monitoring intervals in the present study might reflect typical residential applications, however.

Applicators did not wear gloves, which are required on most labels of granular products currently registered in California. Exposures for applicators wearing gloves were estimated by dividing the overall mean hand exposure by a factor of 10, using DPR's default protection factor of 90% for gloves (Aprea *et al*., 1994; Moody and Nadeau, 1994; Stewart *et al*., 1999; Creely and Cherrie, 2001). This default is currently under review. If the actual protection of gloves is overstated by the default, it would result in hand exposure being underestimated.

For 19 of the 30 replicates, the highest exposure was to lower legs (for the other 11 replicates, the highest exposure was to hands). Data from this study can be used to estimate the protection that clothing provides against dermal exposure to the lower legs. The protection factor (PF) is calculated as follows (Thongsinthusak *et al*., 1991):

PF = 100% – percent penetration, where the percent penetration is
[Dermal exposure]/[Potential dermal exposure] x 100%.

Dermal exposure is taken from the inner dosimeter residue (the amount passing through the outer clothing to reach the skin), and potential dermal exposure is the amount that could potentially reach unclothed skin, estimated as the total of inner and outer dosimeter residues.

The replicate with DCPA below the LOQ on the inner lower leg dosimeter was omitted (the amount of DCPA on the inner dosimeter is unknown), leaving 29 pairs of inner and outer lower leg dosimeter sections for the calculation. Penetration ranged from 0.2% to 46.8%, yielding protection factors of 53.2% – 99.8%. Eighteen of the 29 replicates had calculated protection factors exceeding 90%, and all had estimated protection factors above 50%. The mean protection factor was 86.9%. Thongsinthusak *et al*. (1991) calculated protection factors for work clothing using data from nineteen different studies involving fifteen different pesticides. Calculated protection factors were 53% – 100%, the range estimated for lower leg exposure using data from Klonne and Honeycut (1999).

Face and neck exposure might be over- or underestimated by the practice used in this study of having study personnel wipe perspiration with clean, dry gauze pads. During typical applications in warm weather, some handlers would be anticipated to use their hands or forearms to wipe away sweat, thus transferring pesticide residues to damp skin on the face and neck. This "contamination" that the study intended to avoid is a mode of exposure that can occur during actual applications, and by preventing such transfer the study methodology might have underestimated face/neck exposure. Conversely, wiping perspiration from the face and neck during application with dry sample wipes might capture residues that otherwise would be washed off the face with flowing perspiration. If sweat droplets fall away from the body, entrained residues would not be available for absorption. Another possibility is that sweat droplets might flow down the neck or fall off the face onto the torso.

Data from one other exposure monitoring study, in which fifteen replicates were monitored while applying an unspecified herbicide to turf, are included in PHED (Beauvais *et al*., 2007). That study, conducted in 1993 in North Carolina and Georgia, had reported application times of 30 minutes (PHED, 1995). Dermal exposure was monitored with clothing dosimeters and hand rinses; PHED does not identify the solution used in the hand rinses. Figure 3 displays the dermal PHED subset for this study (Beauvais *et al*., 2007). Handlers were not wearing gloves, and the short-term hand exposure rate was 8,020 µg/lb AI handled, contributing 47% to the total exposure rate for ungloved handlers, which was estimated as 16,900 µg/lb AI handled. Total exposure was calculated by adding a default feet value of 0.52 x (value for lower legs) and a neck value of 0.48 x (value for chest); 0.52 and 0.48 are ratios of feet/lower leg and head/neck surface areas, respectively (U.S. EPA, 1997). Assuming a default protection factor of 90% for chemical-resistant gloves, Beauvais *et al.* (2007) estimated the short-term dermal exposure rate to be 8,930 µg/lb AI handled for gloved applicators. The estimated short-term dermal exposure of applicators handling 0.45 lb/day and wearing the label-required long pants, long-sleeved shirt,

and gloves would be 57.4 µg/kg/day (see calculations in previous section; body weight for PHED data assumed to be 70 kg).

Figure 3. Summary of Results from the PHED Dermal Subset for Scenario 25 [a]

SCENARIO: Long pants, long sleeves

PATCH LOCATION	MICROGRAMS PER AVERAGE LB AI Mean	Coef of Var	Geo. Mean	Obs.
HEAD (ALL)				0
NECK.FRONT				0
NECK.BACK				0
UPPER ARMS	322.4862	141.6077	200.2811	15
CHEST	393.411	141.6077	244.3291	15
BACK	393.411	141.6077	244.3291	15
FOREARMS	134.0922	141.6077	83.2784	15
THIGHS	397.8912	119.3712	198.8172	15
LOWER LEGS	247.9008	119.3712	123.8704	15

[a] Subset criteria included actual and estimated head patches. No head observations in subset. PHED: Pesticide Handlers Exposure Database.

For OVS tubes, front and back sections were combined for analysis, precluding any check for breakthrough (i.e., whether quantifiable DCPA residues would be recovered from back sorbent sections as well as front sections; if amounts recovered from back sections exceed 10% of amount in front sections, it suggests that DCPA was not sufficiently retained by the sorbent under sampling conditions). Breakthrough can result in inhalation exposure being underestimated. However, dermal exposure above the knees, as measured by face/neck wipes, hand washes, and dosimeter sections above the lower leg, was relatively low, suggesting that little DCPA was available in the breathing zone.

Acknowledgments

This memorandum drew in part from a draft study review by former Worker Health and Safety Branch toxicologist Dr. Vivek Mathrani; however, the evaluations, calculations, and conclusions are the responsibility of the author.

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