Department of Pesticide Regulation

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SUBJECT: CHEMICAL-SPECIFIC EXPOSURE MONITORING STUDIES FOR HANDLERS OF CARBARYL PRODUCTS

Residential uses are allowed for carbaryl products formulated as granular/baits, ready-to-use (RTU) liquid products applied by hose-end or trigger sprayers, and one dust product. These products may be applied by professionals such as landscape maintenance workers or structural pest control operators, 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/bait products, and applying liquids using several methods (Beauvais *et al*., 2007), but not for handlers applying RTU liquids through trigger sprayers or for handlers applying pesticide dust by any application method.

This memo reviews chemical-specific exposure monitoring studies for residential handlers applying carbaryl dusts and liquids using a hand pump sprayer, a hose-end sprayer, and RTU trigger sprayers, and recommends exposure estimates for use in the risk assessment prepared by the California Department of Pesticide Regulation (DPR). A study monitoring exposure of agricultural applicators applying carbaryl with airblast sprayers was previously reviewed by Beauvais (2006).

Following a description of the scenarios for which the data are being reviewed, exposure data are reviewed for handlers applying carbaryl dust (Kurtz and Bode, 1985; Merricks, 1997), and handlers applying carbaryl dust and liquid products via hand pump sprayers, RTU hose-end sprayers, and RTU trigger sprayers (Merricks, 1997).

Data from Kurtz and Bode (1985) do not provide reliable exposure estimates for two key reasons: dosimetry was incomplete (inhalation exposure was not monitored), and exposure monitoring results were reported only as mean and standard deviation of all handlers monitored rather than as individual values. The study does provide information about dermal exposure patterns, however. Conversely, Merricks (1997) is a well conducted study that provides useful data for the four residential handler scenarios, and exposure rates based on data from Merricks (1997) are reported in this memo. These rates can also be adapted for occupational handler scenarios as needed, by assuming greater amounts of carbaryl handled.

Exposure Scenarios for Carbaryl Products with Chemical-Specific Exposure Monitoring

Dust

In its most recent Reregistration Eligibility Decision (RED), the U.S. Environmental Protection Agency (U.S. EPA) allowed only non-agricultural uses of carbaryl dust to be reregistered (U.S. EPA, 2008). A single carbaryl dust product is registered in California, GardenTech Sevin-5 Ready-To-Use 5% Dust Bug Killer (EPA Registration Number 432-1209-AA-71004), which states that it is "For Homeowner (Residential) Use Only." As the name suggests, this product contains 5% carbaryl active ingredient (AI) by weight.

The product label (DPR approval date March 7, 2007) contains the following directions for use:

> Do not apply this product through any type of irrigation system…Wearing household or rubber gloves, use a dust applicator such as a shaker can, dust gun, puffer or other bulbous duster, rotary duster or other appropriate duster as available. Dust lightly to cover both upper and lower leaf surfaces with a thin, even film of dust. Apply when air is calm to avoid drift and contact with eyes and skin. Start applying at the farthest corner of the treatment area and work backward to avoid contact with dusted surfaces. Allow dust to settle in treated areas before reentering. For plants above chest height, consider using a liquid carbaryl product. Do not repeat applications more than once a week.

These use directions contain a recommendation ("consider using a liquid carbaryl liquid product") along with several imperative statements. Unlike use directions stated as imperatives (e.g., "do not apply this product through any type of irrigation system"), the recommendation is not considered a legal requirement for use. That is, this product can be used on tall plants such as corn. In fact, use directions are given for applying this product on corn.

RTU Liquid in Trigger Sprayers

Two RTU liquid carbaryl products packaged in bottles with trigger sprayers are registered in California, GardenTech Sevin Ready-To-Use Bug Killer (EPA Registration Number 432-1211-AA-71004) and Bayer Advanced Complete Brand Insect Killer for Gardens (EPA Registration Number 432-1211-AA-72155). Both products contain 0.126% AI, and their product labels state that they are to be used on ornamentals, flowers, fruits, and vegetable gardens (Bayer Advanced also lists shrubs and roses as use sites). Product labels were approved by DPR on October 19, 2005 (Bayer Advanced) and March 7, 2007 (GardenTech Sevin); thus, labels predate the current RED (U.S. EPA, 2008). New labels for both products are in review at DPR.

Both product labels require users to wear long-sleeved shirt, long pants, shoes and socks, and household latex or rubber gloves when applying the products. Users are also required to wear a hat and eye protection when making overhead applications. Use directions on both products state

the following, "Hold sprayer 8 to 12 inches from the area to be treated. Spray until surface is wet."

Application directions for these products do not list maximum application rates. Instead, product labels direct the user to "spray until wet." In its risk assessment for carbaryl, U.S. EPA assumed that one bottle, equal to 0.01 lb AI, would be used per handling event (Dawson, 2003a).

RTU Liquid in Hose-End Sprayers

One RTU liquid carbaryl product packaged in a hose-end sprayer is registered in California, GardenTech Sevin Ready-To-Spray Bug Killer (EPA Registration Number 264-334-ZA-71004). This product contains 22.5% AI, and the packaged solution contains 2 lbs carbaryl per gallon. The product label was approved by DPR on June 18, 2008.

The product label requires users to wear long-sleeved shirt, long pants, shoes and socks, and household latex or rubber gloves when applying the product. Users are also required to wear a hat and eye protection when making overhead applications.

The label states that the product is to be used on vegetables, fruits, and ornamentals. Application rates on the product label range from 1.5 to 7.5 fluid ounces of product per 1,000 ft^2. Rates can be converted to lbs AI/acre, for simplicity and comparison with other products expressing rate in acres treated:

$$(2 \text{ lbs AI/gallon}) \times (1 \text{ gallon}/128 \text{ oz}) \times (1.5 \text{ oz}/1{,}000 \text{ ft}^2) \times (43{,}560 \text{ ft}^2/\text{acre}) = 1 \text{ lb AI/acre}$$

Using this conversion, the maximum allowed application rate to vegetables is 1 lb AI/acre, except asparagus and sweet corn, which is 2 lbs AI/acre (up to 4 lbs AI/acre is allowed on asparagus following harvest). On fruits, the maximum application rate is 3 lbs AI/acre, except on citrus, which is 5 lbs AI/acre. Up to 1 lb AI/acre is allowed on ornamentals. U.S. EPA assumes a default of 1,000 ft^2 treated in an 8-hour day with a hose-end sprayer (Dawson, 2003a). At a rate of 1.5 – 7.5 fluid ounces of product per 1,000 ft^2, this is equivalent to 0.023 – 0.117 lbs AI handled per day.

Liquid Diluted in Water Applied Via Hand Pump Sprayers

The hand-pump sprayer is one type of low-pressure hand wand, an application method that is included in PHED. Seven products can be applied by this method, including two aqueous concentrates, three flowable concentrates, and two suspensions, with carbaryl content of 22.5% – 44.1% AI. Products are mixed with water before application, and this is a mixer/loader/applicator (M/L/A) scenario. Products can be applied to fruits, vegetables, ornamentals, as well as on turf, pastures, rights-of-way, forested areas, and rangeland. The highest application rate is 16 lbs AI/acre to citrus.

Primary Review of Dust Handler Exposure Monitoring in Kurtz and Bode (1985)

The intent of the study was to measure exposures to home gardeners applying pesticides in multiple formulations. Carbaryl was selected as a "model pesticide." The study is briefly reviewed in this memo, as it provides some information about exposure patterns, but incomplete dosimetry and the lack of sufficient detail preclude use of the data for estimating exposure.

Study Design

Twelve applications were made by twelve different individuals to corn plants (1.0 – 1.3 m tall), and twelve applications were made to bean plants (0.2 – 0.3 m tall). Some subjects applied to both beans and corn. Each subject applied carbaryl for 15 minutes; application time was held constant while amount of carbaryl used and row length treated were allowed to vary.

Of the 24 dust applications monitored in this study, 22 were made using a pump-type mechanical duster, and two (one on corn and one on beans) were made with the shaker can that the dust was packaged in. A photo of the pump duster in use is shown in Figure 1 (image on left); the handler in the photo is holding the syringe barrel in one hand, and the plunger handle in the other hand; the tubing extends down to the vegetation being treated. The 22 handlers using the mechanical duster were monitored during loading and applying; no loading was needed for the shaker can. Exposures were reported as group statistics, without differentiating between the two types of applicators used in the study.

Figure 1. Pictures of Dusters. Left: Kurtz and Bode (1985). Right: Merricks (1997).

Dusters used in exposure monitoring were pumped by hand, with dust dispensed through rigid tubing. The applicator tip was pointed at target plants, and the plunger was then pushed to dispense dust.

Dermal exposure was monitored by 10-cm^2 square gauze pads both inside and outside clothing on several body locations (shoulder, upper back, forearm, thigh, pant cuff, and top of foot); hand washes (200 ml ethanol containing 0.03% NaOH); and a dust/pollen face mask worn over the

nose and mouth. Hand washes were done by placing each hand into a plastic bag containing the solution and shaking it 20 times. Inhalation exposure was not measured.

Dosimeter gauze pads were placed outside clothing; pads were also placed under clothing on the arm, inside pants, and inside shoes to allow exposure estimates with various clothing combinations. However, exposures for most clothing combinations assumed that clothing provided 100% protection (that is, zero contribution from covered body parts to total dermal exposure). Calculations were not shown; only resulting means and standard deviation values for each combination were given.

Analytical Methods

All samples were analyzed within 6 hours of collection to minimize degradation of carbaryl. The concern was greatest for hand wash samples; ethanol had been used instead of methanol to minimize toxicity to subjects, yet carbaryl degrades more rapidly in ethanol.

Gauze pads were extracted by dipping each of them five times into a test tube containing 20 ml of methanol with 0.03% NaOH. Excess solvent was then squeezed into the test tube from the pads. Carbaryl in the solvent was quantitated colorimetrically at 580 nm after reaction with p-nitrobenzenediazonium tetrafluoroborate using the method of Chiba (1981). Carbaryl was quantitated directly in the hand wash solutions; Kurtz and Bode (1985) noted that the color reaction is about one-fifth as sensitive in ethanol as it is in methanol.

Quality Assurance

Quality assurance for dosimeter patches consisted of two sets of six gauze pads spiked in the field with 10 µg and 50 µg of carbaryl standard solution. Recoveries from the low and high spike levels were 101% and 98%, respectively. Hand wash solution spikes were made with both carbaryl standard solution and XLR aqueous suspension. Two samples spiked with carbaryl standard solution at 50 µg and 200 µg had recoveries of 144% and 189%, respectively. Conversely, triplicate samples spiked at the same levels had recoveries of 90% and 45% at the low and high spike levels.

Results

In 15-minute monitoring intervals, test subjects applied an average ± standard deviation of 190 ± 98 g dust to corn (range: 41 – 320 g), and 220 ± 210 g to beans (range: 23 – 680 g). This correlates to 9.5 ± 4.9 g AI applied to corn and 11 ± 10.5 g AI to beans. In the 15-minute intervals, subjects treated 140 ± 70 m row length in corn and 180 ± 100 m row length in beans. Beans were more sparsely planted than corn.

Considering only outer dosimeters (the “no clothes” regime), total potential dermal exposure of subjects applying carbaryl dust to corn was reported to be calculated as 9,900 ± 8,100 µg AI. Total potential dermal exposure of subjects applying carbaryl dust to beans was 10,200 ± 8,900

µg AI. Dividing mean total potential dermal exposure by mean amount handled results in estimated potential dermal exposure rates of 1,000 µg/g AI handled (450,000 µg/lb AI handled) for corn and 900 µg/g AI handled (410,000 µg/lb AI handled) for beans.

The highest amount of carbaryl was recovered from pads attached to pant cuffs (i.e., lower legs), 22 ± 35 µg on right leg and 25 ± 32 µg on left leg for subjects applying carbaryl dust to corn, and 36 ± 52 µg and 52 ± 58 µg, respectively, for subjects applying carbaryl dust to beans.

Exposure Appraisal

Exposure monitoring techniques used in this study do not reflect the current state of the science, not surprising for a study published in 1985. Especially problematic are the lack inhalation exposure monitoring and the use of ethanol for a hand wash solution. Total exposure is likely to be underestimated if inhalation exposure is not measured. And although U.S. EPA (1996) recommends 95% ethanol as "satisfactory for the removal of most pesticide residues without undue damage to the skin," it warns against using ethanol for AIs that are not stable in ethanol; carbaryl breaks down readily in ethanol (Kurtz and Bode, 1985).

Kurtz and Bode (1985) noted an issue with the untrained subjects used in their studies. Although the dust formulation was applied the same way on corn and beans, there nevertheless was an extreme variability in application amounts to both crops:

> There is not a clear reason why corn should receive a lower amount unless it is found only in the high variability of the application. In this case the range of application on beans was 23 to 680 g, a 30-fold range! On corn it was better but still very large at 41 to 320 g. This clearly shows how variable an ordinary gardener's estimate is of how much pesticide is needed to do the job. Some people just dust a tiny amount on the leaves while others produce totally white leaves.

This concern could potentially apply to all residential applications.

Additionally, the monitoring intervals were short, only 15 minutes: "It was felt that 15 minutes was a good estimate of the time a person would spend in the garden doing this activity at any given time." DPR does not have data on the range of times spent applying pesticides by residential users. Professional applicators would be anticipated to apply for longer durations. Extrapolating over longer durations is a source of uncertainty for exposure estimates based on these data.

Finally, individual results were not provided. Mean and standard deviation exposure estimates were reported, based on assumed surface area for body regions where patches were placed. Mean and standard deviation patch dosimeter and hand wash results also were reported. However, some of these results were noted to have extreme outliers. Incomplete dosimetry and the lack of

sufficient detail preclude use of this study for estimating exposure. This study provides some information that may be helpful in interpreting exposure estimates from other sources.

Primary Review of Dust Handler Exposure Monitoring in Merricks (1997)

Study Design

Twenty "non-professional male and female volunteers" applied Sevin® 10 Dust, containing 10% AI (Merricks, 1997). Each application was made to one 18-ft row of cucumbers and two 18-ft rows of tomatoes. The study was conducted in Florida, and used volunteers aged 19 – 72. Applications all used The Spritzer™, a garden duster. An application is shown in Figure 1. As the image in Figure 1 does not give a clear picture of the applicator, another one from a vendor's website is shown in Figure 2, along with text describing the applicator's advertised capabilities.

Figure 2. Commercial Picture of The Spritzer™ Sprayer/Duster [a]

Imagine being able to spray the bottom of leaves for aphids without bending over! The angled tip of the Spritzer Garden Duster/Sprayer allows the operator to easily apply materials without kneeling or crawling on the ground to make sure you don't miss anything. The Spritzer will apply dusts or liquids - it's the only product that will do both! The 30" never-clog barrel holds an ample supply of material to keep refilling at a minimum. The easy-lock filling chamber is located on the top for easy access and is water tight. Also works great on the farm for applying fly spray to the bottom of livestock. Now you don't have to buy a separate sprayer and duster - the Spritzer Garden Duster/Sprayer does it all!

[a] Image and text from vendor website: http://www.earthway.com/product/garden-products-3

According to a stepwise procedure given in the Experimental Design section of the study report, the duster is loaded by first removing its top. After dust has been poured into the duster, the top is replaced. The user then "activates the duster valve" by pushing the inner tube into the outer tube. Although the image in Figure 1 shows the narrow (inner) tube on the bottom, in Figure 2 the opening through which material is applied is located on the outer tube. It's possible that the applicator has undergone a design change since the study was conducted.

The study site was a 3-acre field prepared with raised beds using black plastic mulch; beds were each about 1,000 ft long. Two rows of tomatoes were planted adjacent to an irrigation ditch, with a row of cucumbers planted between the tomatoes and a tractor road. Each row was segmented into 18-ft blocks; replicate blocks were marked with 2-ft segments between in which plants had

been cleared: "Therefore, each model garden area was two 18-ft rows of tomatoes and one 18-ft row of cucumbers (total of approximately 200 ft^2) separated by a 2-ft buffer from the next garden area down the row."

Dermal exposure was monitored with both inner and outer whole-body dosimeters, hand washes and face/neck wipes. Outer dosimeters consisted of long-sleeved work shirts and pants, all made of 100% cotton. Inner dosimeters were long underwear, also made of 100% cotton. 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 lower dosimeters from knee to waist; waistbands were discarded as potential sources of analytical interference), lower legs, front torso and back torso. Study personnel sectioning dosimeters wore latex gloves. Separate, solvent-cleaned scissors were used for inner and outer dosimeters; scissors were rinsed with solvent between replicates. Dosimeter sections were placed in Kapak® sample bags and heat sealed, then placed on dry ice in sample coolers.

Hand washes were conducted by slowly pouring a 400-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 60 seconds. The hand wash solution was poured into a glass jar, which was placed in a Kapak® sample bag that was then heat-sealed and stored on dry ice for transport to the laboratory.

Following hand washes, each subject's face and neck exposure was monitored by wiping the skin with two 100% cotton handkerchiefs (15 x 15 inches, or 38 x 38 cm), each wetted with 25 ml of 0.01% Aerosol® OT-75 solution. The two wipes were combined into a single sample for analysis, which was placed in a Kapak® sample bag that was then heat-sealed and stored on dry ice.

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 270 mg and 140 mg XAD-2 resin. Sampler pumps were calibrated at a flow rate of 2.0 liters/minute. At the end of each monitoring interval, the sample tube was capped at both ends and placed in a resealable bag. No explanation was given for placing samples in a resealable bag, rather than a Kapak® sample bag like other samples.

Analytical Methods

Dosimeter sections and face/neck wipes were extracted with acetone. An aliquot of each extract was subjected to Florisil® clean up and then analyzed. Hand wash samples were extracted with dichloromethane, evaporated to dryness, reconstituted in a 50% aqueous acetonitrile solution, and analyzed. For OVS tubes, front and back sections were combined for analysis; the XAD-2

resin was extracted with acetonitrile, subjected to Florisil® clean up, reconstituted in a 50% aqueous acetonitrile solution, and analyzed.

All samples were analyzed using high performance liquid chromatography with post column derivatization and fluorescence detection. The limit of quantitation (LOQ) for each matrix was 1.0 µg carbaryl/section for both inner and outer dosimeter sections, 1.0 µg carbaryl/sample for hand wash and face/neck wipe samples, and 0.01 µg carbaryl/tube for OVS tubes.

Quality Assurance

Quality assurance consisted of field controls, field spikes, laboratory controls, and laboratory spikes. Each set of samples was analyzed along with a laboratory control and newly fortified laboratory spikes. Spikes were all made with technical carbaryl in methanol rather than formulated products, and the same quality assurance samples covered sampling from all dust and liquid application exposure monitoring in the study. Although formulated product is preferred, use of technical active ingredient in quality assurance is accepted.

Field controls consisting of samples of each matrix were taken into the field each day. Controls were set out in an area away from potential contamination for the duration of field spike processing.

Field spikes consisting of five samples of each matrix were spiked at three levels on each of 3 or 4 days (4 days for dosimeters, 3 days for hand wash, face/neck wipes, and OVS tubes). Dosimeter, hand wash, and face/neck wipes were fortified at 5 µg (5 x LOQ), 50 µg, and 500 µg carbaryl. Five OVS tubes were spiked each day at 0.05 µg (5 x LOQ), 0.5 µg, and 5.0 µg carbaryl. Spike solutions of carbaryl dissolved in methanol were made in the laboratory and carried to the study site where samples were spiked. Immediately after spiking, hand wash and face/neck wipe samples were placed in Kapak® sample bags which were heat sealed and put on dry ice. After spiking, dosimeter samples were weathered for 20 minutes (equal to the average monitoring interval in the study), then they were placed in Kapak® sample bags which were heat sealed and put on dry ice. After spiking, OVS tubes were held upright for 5 minutes to allow excess solvent to evaporate, and then each was connected to a sampler pump. After air was drawn through the OVS tube for 20 minutes, it was disconnected from the pump, capped, and placed into a resealable bag which was put on dry ice.

Results

For the twenty replicate applications, the mean monitoring interval was 21 ± 3 minutes, during which subjects handled an average of 7.22 ± 4.77 g of carbaryl (Merricks, 1997). Monitoring included filling the applicator; applications took an average of 7 ± 1 minutes.

Dust applications were monitored each day between May 13 and May 18, 1997. Two to four applications were monitored on each of these days. Dosimeter field spikes were conducted on two of the 6 days: May 13 and May 18 (also on May 23, in conjunction with other types of applications). Table 1 summarizes daily and overall field spike recoveries.

Table 1. Carbaryl Field Spike Recoveries – Spiked with Technical Carbaryl Dissolved in Methanol (Merricks, 1997)

Matrix	Spike Level (µg)	Percent Recovery (Mean ± Standard Deviation) [a]			
		5/13	5/18	5/23	Overall
Inner Dosimeter	5	75.8 ± 6.2	82.7 ± 3.7	90.9 ± 4.6	83.1 ± 7.8
Inner Dosimeter	500	76.4 ± 3.0	84.6 ± 4.7	95.2 ± 6.7	85.4 ± 9.2
Outer Dosimeter	5	62.0 ± 2.8 [b]	70.7 ± 1.3	91.1 ± 5.6	74.6 ± 13.1
Outer Dosimeter	500	73.4 ± 3.3	70.9 ± 5.1	97.8 ± 8.7	80.7 ± 13.8
Face/Neck Wipes	5	82.2 ± 8.8	90.1 ± 6.0	80.0 ± 1.9	84.1 ± 7.3
Face/Neck Wipes	500	90.1 ± 4.6	81.9 ± 5.0	84.5 ± 2.0 [c]	85.6 ± 5.3 [c]
Hand Wash	5	92.9 ± 1.0 [d]	87.0 ± 1.9	89.1 ± 10.5	89.4 ± 6.4 [d]
Hand Wash	500	92.2 ± 7.4	95.4 ± 11.1	87.8 ± 8.7	91.8 ± 9.1
OVS Tubes	0.5	100 ± 2.0	97.5 ± 3.8	95.0 ± 2.9	97.6 ± 3.5
OVS Tubes	5	101 ± 2.7	102 ± 3.0	95.7 ± 3.9	99.3 ± 4.0

[a] Unless otherwise stated, date-specific statistics have five replicates and overall statistics have 15 replicates. Spike recoveries are used to correct exposure monitoring results from all application methods (not just dust).
[b] Field spikes conducted on 5/13/1997 resulted in zero recovery, suggesting samples were not spiked. Results shown are from an extra set of field spikes conducted on 5/14/1997.
[c] One result on 5/23/1997 was 49.2%. This value was excluded, as Merricks (1997) stated it was a spiking error. The number of replicates on that date was four, and the overall mean has 14 replicates.
[d] One result on 5/13/1997 was 135%. This value was excluded, as Merricks (1997) stated it was a spiking error. The number of replicates on that date was four, and the overall mean has 14 replicates.

Merricks (1997) corrected dosimeter and face/neck wipe results for combined high and low spike recoveries (i.e., one value was used for all samples within a matrix). All inner dosimeter section results were corrected for a recovery of 84.3%, outer dosimeter section results were corrected for a recovery of 77.7%, face/neck wipe sample results were corrected for a recovery of 84.8% (Merricks, 1997; page 26). Neither hand wash nor OVS tube sample results were corrected; combined overall recoveries of field spikes in those matrices were 90.7% and 98.4%, respectively.

Table 2 summarizes exposure monitoring results, reported as overall mean carbaryl residues on each exposure matrix.

Table 2. Carbaryl Residues on Exposure Monitoring Matrices Following Applications of a Dust Product [a]

Matrix [b]	Range of Residues (µg) [c]	Mean Residues (µg) [d]	Upper Bound Carbaryl (µg) [e]	Short-Term Exposure Rate (µg/lb AI) [f]	Long-Term Exposure Rate (µg/lb AI) [f]
Hand Washes	255 – 13,300	1,600	13,300	1,160,000	158,000
Face/Neck Wipes	1.22 – 34.7	9.79	34.7	2,960	824
Inner Dosimeter					
Lower Arm	2.19 – 132	36.2	132	30,600	4,160
Upper Arm	< 1.0 – 22.5	4.74	22.5	1,800	437
Front Torso	2.98 – 45.3	11.4	45.3	3,620	969
Rear Torso	< 1.0 – 38.0	8.20	38.0	2,850	653
Lower Leg	2.19 – 22.8	7.83	22.8	4,690	827
Upper Leg	1.86 – 59.0	11.4	59.0	6,880	1,200
Outer Dosimeter					
Lower Arm	94.7 – 1,750	367	1,750	187,000	37,500
Lower Leg	62.3 – 1,230	396	1,230	260,000	43,800
OVS Tubes [h]	< 0.01 – 3.98	1.33	8.11 [g]	8,160	1,140

[a] Data from Merricks (1997). All values corrected for field spike recoveries (when recoveries were less than 90%; see Table 1), and rounded to three significant figures.
[b] Only matrices used to estimate exposure in the carbaryl risk assessment 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 carbaryl/sample for all matrices except OVS tubes, where the LOQ was 0.01 µg carbaryl/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 carbaryl residue were determined by first calculating the 95th percentile of the 20 results, assuming a lognormal distribution (Frank, 2009). This result was compared to the highest corrected measured residue, and the higher 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, carbaryl residues by the amount carbaryl handled, after converting that amount from grams to pounds.
[g] 95th percentile.
[h] Exposure rate estimates adjusted to assume a default inhalation rate of 16.7 liters/minute.

Results were corrected according to DPR practice, which is in general agreement with U.S. EPA policy: samples are corrected for field fortification recoveries below 90% (U.S. EPA, 1992; U.S. EPA, 1998). In this memo, all results, except for those from OVS tubes and hand wash samples, were corrected for mean field spike recoveries. Samples with an uncorrected result of less than or

equal to 252.5 µg carbaryl (midpoint between 5 µg and 500 µg) were corrected for the overall mean recovery of the low level (5 µg) spike for that matrix, and samples with uncorrected recovery above 252.5 µg carbaryl were corrected for the overall mean recovery of the high level (500 µg) spike, as summarized in the last column of Table 1. One hand wash sample contained less than 252.5 µg carbaryl, and was corrected for recovery of the low level spike; all other samples were above 252.5 µg carbaryl, and were not corrected for field spike recovery as the mean overall high level spike recovery was 91.8% (above 90%).

Table 3 summarizes exposure rate estimates for dust applicators wearing clothing required by the product label, 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 Merricks (1997), 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.

If the amount of dust handled is assumed to be one can per day (Dawson, 2003b), or 0.05 lb carbaryl, then an applicator wearing the label-required long pants, long-sleeved shirt, and gloves would have an estimated dermal exposure of 6,800 µg carbaryl/day:

(0.05 lb AI/day) x (136,000 µg/lb AI) = 6,800 µg AI/day.

If body weight is assumed to be 70 kg, then the short-term dermal dose of carbaryl is calculated as follows:

6,800 µg/day ÷ 70 kg = 97.1 µg/kg/day

Similarly, the long-term dermal exposure estimate is (0.05 lb AI/day) x (25,300 µg/lb AI) = 1,260 µg/day, and 1,260 µg/day ÷ 70 kg = 18.0 µg/kg/day. These estimates reflect potential exposure, or the amount of carbaryl reaching the skin; a dermal absorption factor would be applied to estimate absorbed dose.

Table 3. Exposure Rate Estimates of Carbaryl Dust Applicators [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 Total [f]	136,000 144,000	25,300 26,400
Long-sleeved shirt, long pants, no gloves	Dermal Total	1,180,000 1,190,000	168,000 169,000
Short-sleeved shirt, short pants, and gloves [e]	Dermal Total	348,000 356,000	107,000 108,000
Short-sleeved shirt, short pants, no gloves	Dermal Total	1,390,000 1,400,000	249,000 250,000

[a] Exposure rate (µg/lb AI), based on data by Merricks (1997). Dermal exposures sum matrix-specific (dosimeter, hand wash, face/neck wipe, and inhalation) exposure estimates. Dermal totals were corrected by 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] The current product label requires 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 Merricks (1997).

[e] Applicators monitored by Merricks (1997) were not wearing gloves. Gloves were assumed to provide 90% protection (Aprea *et al*., 1994), 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 = 8,100 µg/lb AI handled, and long-term inhalation = 1,140 µg/lb AI handled.

Exposure Appraisal

Exposure monitoring by Merricks (1997) provided the best available data for estimating exposure of handlers loading and applying carbaryl dust. This was a well-conducted study with apparently acceptable replication (20 applications were monitored) and acceptable quality assurance. Monitoring intervals were short, averaging 21 minutes; subjects spent an average of just 7 minutes applying carbaryl dust. 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.

No information is available regarding exposures associated with use of dusters other than the model used in this study. Also, no data are available to estimate exposure associated with use of the shaker can in which the only product currently registered in California is packaged. Additionally, the position of the duster shown in Figure 1 suggests that during monitored applications carbaryl dust was emitted near ground level; applications to taller crops might correlate with greater exposure to the upper body. In the absence of other data, exposure estimates for all carbaryl dust handlers are based on data from this study.

Applicators did not wear gloves, which are required on the label of the dust product 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). 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.

The estimated short-term dermal exposure of applicators wearing the label-required long pants, long-sleeved shirt, and gloves would be 101 µg/kg/day (see calculations in previous section). For this scenario, U.S. EPA estimated a short-term dermal exposure rate of 148,000 µg/lb AI handled, based on the geometric mean of data from Merricks (1997), and assuming workers wore shorts and a t-shirt, but did not wear gloves (i.e., U.S. EPA's calculation does not assume an applicator wears clothing required on the product label). For a 70-kg applicator handling 0.05 lb AI/day, this yields an estimated potential dermal exposure of 106 µg/kg/day (Dawson, 2003b). For this clothing scenario, DPR estimates a potential dermal exposure rate of 1,390,000 µg/lb AI handled, which corresponds to 70,000 µg/day for an applicator handling 0.05 lb AI, and 993 µg/kg/day. Thus, the potential short-term dermal exposure estimated by U.S. EPA was about one-tenth of the short-term potential dermal exposure estimated by DPR. The difference in potential dermal exposure estimates was due to the choice of statistic: DPR used an upper-bound estimate while U.S. EPA used a geometric mean. DPR's addition of foot exposure did not increase the rounded estimate for handlers wearing shorts and short-sleeved shirt.

The inhalation exposure estimated by U.S. EPA was also based on the geometric mean of data from Merricks (1997), which gave an inhalation exposure rate of 870 µg/lb AI handled (Dawson, 2003b). The short-term inhalation exposure rate estimated by DPR was 8,100 µg/lb AI handled. As was true for dermal exposure, U.S. EPA estimated slightly more than one-tenth the potential inhalation exposure than would DPR for this scenario. Again, the difference is due to the selection of an upper bound by DPR and of the geometric mean by U.S. EPA.

For OVS tubes, front and back sections were combined for analysis, precluding any check for breakthrough (i.e., whether quantifiable carbaryl 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 carbaryl was not sufficiently retained by the sorbent under sampling conditions). DPR is aware of proprietary data suggesting that significant OVS tube breakthrough of carbaryl would not occur in tubes containing XAD-2 resin when sampling

at a flow rate of 2 liters/minute for durations of 8 hours. The breakthrough test was conducted during an exposure monitoring study reviewed by Beauvais (2006).

Primary Review of Exposure Monitoring of RTU Trigger Spray Handlers (Merricks, 1997)

Study Details Differing from Exposure Monitoring of Handlers Using Other Methods

Forty applications, using "non-professional male and female volunteers," involved Sevin® Ready-To-Use Spray (0.126% AI). As with other exposure monitoring in this study, each application was to a 200-ft^2 vegetable garden plot as described above (Merricks, 1997). A total of 70 volunteers were used in the entire study; each volunteer completed two applications, using a different product and application method. If a volunteer did one application without gloves, it was always the second of the two applications; similarly, dust applications always followed liquids to minimize contamination between replicates.

Twenty applications were made with applicators wearing "commonly available household-type latex gloves," and 20 applications were made without gloves. Exposure was monitored using whole-body dosimeters, hand washes and face/neck wipes as previously described. Applications were made on the same days as dust and other liquid applications, and relied on the same quality assurance. The product is shown in Figure 3.

Results

For the forty replicate applications, the mean monitoring interval was 18 $\pm$ 3 minutes, during which subjects handled an average of 1.06 $\pm$ 0.10 g of carbaryl (Merricks, 1997). Gloved applicators handled slightly more carbaryl on average than did applicators who were not wearing latex gloves, 1.12 g and 1.00 g, respectively.

Figure 3. Trigger Sprayer.

Monitoring intervals refer to the length of time the air sampling pump was turned on. In addition to application, monitoring intervals for subjects applying carbaryl with trigger sprayers included removal of the container cap, screwing on the sprayer top mechanism, and shaking well before spraying rows of tomatoes and cucumbers. The actual application took an average of 9 $\pm$ 2 minutes.

Table 4 summarizes carbaryl residues recovered from exposure matrices, as well as estimated exposure rates. Residues were corrected for field spike recoveries, and exposure rates were calculated as previously described.

Table 4. Carbaryl Residues on Exposure Monitoring Matrices Following Applications of a Ready-To-Use Trigger Spray Product [a]

Matrix [b]	Number of Samples	Range of Residues (µg) [c]	Mean Residues (µg) [d]	Upper Bound Carbaryl (µg) [e]	Short-Term Exposure Rate (µg/lb AI) [f]	Long-Term Exposure Rate (µg/lb AI) [f]
Hand Washes						
With Gloves	20	< 1.0 [g]	0.5	0.5	235	205
No Gloves	20	3.67 – 654	160	654	282,000	69,900
Face/Neck Wipes	40	< 1.0 – 12.0	0.787	12.0	5,510	348
Inner Dosimeter						
Lower Arm	40	< 1.0 – 5.16	0.901	5.16	2,370	389
Upper Arm	40	< 1.0 – 3.95	0.606	3.95	1,810	265
Front Torso	40	< 1.0 – 16.3	1.13	16.3	7,500	507
Rear Torso	40	< 1.0 – 10.2	0.854	10.2	4,700	378
Lower Leg	40	< 1.0 – 4.48	0.629	4.54 [h]	2,090	275
Upper Leg	40	< 1.0 – 22.4	1.23	22.4	10,300	547
Outer Dosimeter						
Lower Arm	40	< 1.0 – 13.9	4.12	15.9 [h]	7,140	1,810
Lower Leg	40	1.74 – 100	24.6	100	44,300	10,500
OVS Tubes [i]	40	< 0.01 – 0.501	0.118	0.501	202	50.5

[a] Data from Merricks (1997). All values corrected for field spike recoveries and rounded to three significant figures (when recoveries were less than 90%; see Table 1). With the exception of hand washes, results combine residue results from 20 replicates wearing household latex gloves and 20 replicates not wearing household latex gloves.

[b] Only matrices used to estimate exposure in the carbaryl risk assessment 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 carbaryl/sample for all matrices except OVS tubes, where the LOQ was 0.01 µg carbaryl/tube. Non-detects were set at ½ LOQ for calculating statistics.

[d] Arithmetic mean of residues recovered from exposure monitoring matrix.

[e] Upper-bound estimates of carbaryl residue were determined by first calculating the 95th percentile of residue results, assuming a lognormal distribution (Frank, 2009). The 95th percentile was compared to the highest corrected measured residue, and the higher of the two values was 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, carbaryl residues by the amount carbaryl handled, after converting that amount from grams to pounds.

[g] No carbaryl was detected in hand wash samples from gloved applicators.

[h] 95th percentile.

[i] Exposure rate estimates adjusted to assume a default inhalation rate of 16.7 liters/minute.

No carbaryl was detected in hand wash samples of the 20 gloved applicators; results of these samples were set at 0.5 µg (i.e., ½ the LOQ of 1.0 µg) for calculating exposure rates. Carbaryl was above the LOQ in hand wash samples from all subjects not wearing gloves. In addition to hand washes from gloved hands, many other samples did not have quantifiable carbaryl. Of the 40 face/neck wipe samples, 39 had results below the LOQ. Of the 40 samples of each inner dosimeter section, carbaryl was < LOQ on 32 of the lower arm sections, 38 of the upper arm sections, 35 of the front torso, 36 of the rear torso sections, 38 of the lower leg, and 35 of the upper leg sections. Twenty-one OVS tubes did not have quantifiable carbaryl. Some outer dosimeter sections also did not have quantifiable carbaryl; of the 40 samples, carbaryl was < LOQ on 12 of the lower arm sections, 21 of the upper arm sections, 15 of the front torso and 17 of the rear torso sections, and 1 of the upper leg sections. Carbaryl was above the LOQ in all lower leg outer dosimeter sections.

Table 5 summarizes exposure rate estimates for RTU trigger spray applicators wearing clothing required by the product label, as well as applicators not wearing the label-required gloves and clothing. These values were calculated by summing the overall dosimeter, hand wash, face/neck wipe, and inhalation exposure rates for individual replicates; short-term exposures were the highest total exposure, which exceeded the 95th percentile in each case. Long-term exposure is the mean of total exposures. Estimates for hand exposure while wearing gloves were based on the 20 replicates wearing gloves, and estimates for hand exposure of a handler without gloves were based on the 20 replicates not wearing gloves. For all other exposure matrices, results of 40 samples were combined, as use of gloves was not anticipated to affect exposures other than to hands. Estimated foot exposure was included by adding 0.52 times the lower leg exposure, as previously described.

Exposure Appraisal

Exposure monitoring by Merricks (1997) provided the best available data for estimating exposure of handlers applying carbaryl with trigger sprayers. This was a well-conducted study with apparently acceptable replication (40 applications were monitored, 20 with gloves and 20 without) and acceptable quality assurance. No other exposure monitoring data are available for this scenario.

No quantifiable carbaryl was recovered from hand washes of handlers wearing household-type latex gloves (the LOQ was 1.0 µg/sample). In contrast, residues ranging from 3.67 – 654 µg/sample were recovered from hand washes of handlers not wearing gloves. This suggests that gloves provided at least a 3.67- to 654-fold protection against skin contact with carbaryl in a dilute (0.126 % AI) liquid formulation.

Table 5. Exposure Rate Estimates of Carbaryl Ready-To-Use Trigger Spray Applicators [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	Dermal	35,700	3,070
	Total [e]	35,900	3,120
Long-sleeved shirt, long pants, no gloves	Dermal	273,000	72,800
	Total	273,000	72,900
Short-sleeved shirt, short pants, and gloves	Dermal	48,700	15,400
	Total	48,900	15,500
Short-sleeved shirt, short pants, no gloves	Dermal	287,000	85,100
	Total	287,000	85,200

[a] Exposure rate in micrograms per pound active ingredient handled (µg/lb AI), based on data by Merricks (1997). Dermal exposures sum matrix-specific (dosimeter, hand wash, face/neck wipe, and inhalation) exposure estimates of individual replicates; 20 for hands wearing household latex gloves, 20 for hands without gloves, and 40 for all other matrices. Dermal totals were corrected by addition of the 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] Product labels require handlers 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 handlers 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 carbaryl residues, or on the highest measured residue if it exceeds the 95th percentile.

[d] Long-term estimates are based on the arithmetic mean.

[e] Total exposure is the sum of dermal plus inhalation. Short-term inhalation = 202 µg/lb AI handled, and long-term inhalation = 50.5 µg/lb AI handled.

For this scenario, U.S. EPA estimated dermal and inhalation exposure rates to be 54,000 µg/lb AI handled and 67 µg/lb AI handled, respectively (Dawson, 2003a). These estimates are geometric means of data from Merricks (1997), and assume that handlers wear short-sleeved shirts, short pants, and that they are not wearing gloves. Dawson (2003a) estimated slightly higher geometric mean exposure rates than would DPR, by including exposure results only from the 20 replicates not wearing gloves. With the exception of hands, DPR combined exposures from handlers wearing and not wearing gloves (household latex gloves are anticipated to affect only hand exposure, not exposure to other body parts). In this scenario, handlers wearing gloves happened to have lower residues in most exposure matrices, resulting in lower overall estimates when those matrices were combined across all 40 replicates versus the 20 replicates not wearing gloves.

Some issues discussed with respect to dust applicator exposure monitoring also apply to monitoring of handlers using RTU trigger sprayers. Monitoring intervals were short, and time spent actually applying was even shorter; front and back sections of OVS tubes were combined, precluding breakthrough testing; and a single model of trigger spray applicator was tested.

Primary Review of Exposure Monitoring of Hose-End Spray Handlers (Merricks, 1997)

Study Details Differing from Exposure Monitoring of Handlers Using Other Methods

Forty subjects each poured Sevin® Liquid RP-2 Insecticide, containing 22.4% AI, into an Ortho Dial n' Spray Hose End Sprayer (see Figure 4). They set the sprayer dial to "4 tsp." to mix in 4 teaspoons of formulation per gallon of water, attached the filled sprayer to a garden hose, and applied to 200-ft^2 vegetable garden plots as described above. Following each application, the handler turned off the water, disconnected the sprayer jar, poured remaining Sevin® Liquid RP-2 back into its container, and rinsed the sprayer with water from the hose. Twenty applications were made by handlers wearing household-type latex gloves; no gloves were worn during the other 20 applications. Handlers wearing gloves rinsed them after the application, as required by the product label. Exposure was monitored using whole-body dosimeters, hand washes and face/neck wipes as previously described.

Results

For the forty replicate applications, the mean monitoring interval was 18 $\pm$ 3 minutes, during which subjects handled an average of 23.4 $\pm$ 9.51 g of carbaryl (Merricks, 1997). Gloved applicators handled slightly less carbaryl on average than did applicators who were not wearing gloves, 22.1 g and 24.8 g, respectively.

Figure 4. Ortho Dial n' Spray Hose End Sprayer

In addition to application, monitoring intervals for subjects applying carbaryl with trigger sprayers included removal of the container cap, screwing on the sprayer top mechanism, and shaking the filled container well before spraying rows of tomatoes and cucumbers. The actual application took an average of 4 $\pm$ 1 minutes.

Table 6 summarizes carbaryl residues recovered from exposure matrices, as well as estimated exposure rates. Residues were corrected for field spike recoveries, and exposure rates were calculated as previously described.

Table 6. Carbaryl Residues on Exposure Monitoring Matrices Following Applications with a Hose-End Sprayer [a]

Matrix [b]	Number of Samples	Range of Residues (µg) [c]	Mean Residues (µg) [d]	Upper Bound Carbaryl (µg) [e]	Short-Term Exposure Rate (µg/lb AI) [f]	Long-Term Exposure Rate (µg/lb AI) [f]
Hand Washes						
With Gloves	20	< 1.0 – 4.38	0.756	4.38	34.4	16.4
No Gloves	20	70.2 – 4,440	1,410	5,090 [g]	122,000	27,700
Face/Neck Wipes	40	< 1.0 – 58.5	2.37	58.5	1,610	60.2
Inner Dosimeter						
Lower Arm	40	< 1.0 – 82.2	4.73	82.2	1,620	103
Upper Arm	40	< 1.0 [h]	0.05	0.05	45.9	11.9
Front Torso	40	< 1.0 – 183	5.17	183	3,610	105
Rear Torso	40	< 1.0 [h]	0.05	0.05	45.9	11.9
Lower Leg	40	< 1.0 – 5.82	0.667	5.82	160	16.0
Upper Leg	40	< 1.0 – 53.7	0.721	53.7	53.7	15.3
Outer Dosimeter						
Lower Arm	40	< 1.0 – 2,920	111	2,920	57,500	2,410
Lower Leg	40	23.8 – 8,460	1,260	8,460	570,000	36,800
OVS Tubes [i]	40	< 0.01 – 0.146	0.0534	0.146	3.83	1.21

[a] Data from Merricks (1997). All values corrected for field spike recoveries (when recoveries were less than 90%; see Table 1), and rounded to three significant figures. With the exception of hand washes, results combine data from 20 replicates wearing household latex gloves and 20 replicates not wearing household latex gloves.
[b] Only matrices used to estimate exposure in the carbaryl risk assessment 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 carbaryl/sample for all matrices except OVS tubes, where the LOQ was 0.01 µg carbaryl/tube. Non-detects were set at ½ LOQ for calculating statistics.
[d] Arithmetic mean of residues recovered from exposure monitoring matrix.
[e] Upper-bound estimates of carbaryl residue were determined by first calculating the 95th percentile of residue results, assuming a lognormal distribution (Frank, 2009). The 95th percentile was compared to the highest corrected measured residue, and the higher of the two values was 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, carbaryl residues by the amount carbaryl handled, after converting that amount from grams to pounds.
[g] 95th percentile.
[h] No carbaryl was detected in upper arm and rear torso inner dosimeter sections.
[i] Exposure rate estimates adjusted to assume a default inhalation rate of 16.7 liters/minute.

No carbaryl was detected in hand wash samples of 18 of the 20 gloved applicators; results of these samples were set at 0.5 µg (i.e., ½ the LOQ of 1.0 µg) for calculating exposure rates.

Carbaryl was above the LOQ in hand wash samples from all subjects not wearing gloves. In addition to gloved hands, many other samples did not have quantifiable carbaryl. Of the 40 face/neck wipe samples, 38 had results below the LOQ. Of the 40 samples of each inner dosimeter section, carbaryl was < LOQ on 27 of the lower arm sections, all 40 of the upper arm sections, 36 of the front torso, all 40 of the rear torso, 38 of the lower leg, and 34 of the upper leg sections. Thirty-four OVS tubes did not have quantifiable carbaryl. Some outer dosimeter sections also did not have quantifiable carbaryl; of the 40 samples, carbaryl was < LOQ on four of the lower arm sections, 25 of the upper arm sections, 12 of the front torso and 31 of the rear torso sections. Carbaryl was above the LOQ in all upper and lower leg outer dosimeter sections.

Table 7 summarizes exposure rate estimates for hose-end spray applicators wearing clothing required by the product label, as well as applicators not wearing the label-required gloves and clothing. These values were calculated by summing the overall dosimeter, hand wash, face/neck wipe, and inhalation exposure rates for individual replicates; short-term exposures were the highest total exposure, which exceeded the 95th percentile in each case. Long-term exposure is the mean of total exposures. Exposures were calculated as described above for handlers using RTU trigger sprayers.

Exposure Appraisal

Exposure monitoring by Merricks (1997) provided the best available data for estimating exposure of handlers applying carbaryl with hose-end sprayers. This was a well-conducted study with apparently acceptable replication (40 applications were monitored, 20 with gloves and 20 without) and acceptable quality assurance. Handling activities included pouring carbaryl liquid into the hose-end sprayer. One carbaryl product registered for use in California is a ready-to-use hose-end spray, in which the carbaryl solution is sold within a package that is designed to attach to a garden hose. Handlers of that product would not pour solution; their only exposure would occur during spraying.

Some issues discussed with respect to dust applicator exposure monitoring also apply to monitoring of handlers using hose-end sprayers. Monitoring intervals were short, and time spent actually applying was even shorter; front and back sections of OVS tubes were combined, precluding breakthrough testing; and a single model of applicator equipment was tested.

Table 7. Exposure Rate Estimates of Carbaryl Hose-End Sprayer Applicators [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	Dermal	3,720	347
	Total [e]	3,720	348
Long-sleeved shirt, long pants, no gloves	Dermal	126,000	28,000
	Total	126,000	28,000
Short-sleeved shirt, short pants, and gloves	Dermal	578,000	39,500
	Total	578,000	39,500
Short-sleeved shirt, short pants, no gloves	Dermal	700,000	67,200
	Total	700,000	67,200

[a] Exposure rate in micrograms per pound active ingredient handled (µg/lb AI), based on data by Merricks (1997). Dermal exposures sum matrix-specific (dosimeter, hand wash, face/neck wipe, and inhalation) exposure estimates of individual replicates; 20 for hands wearing household latex gloves, 20 for hands without gloves, and 40 for all other matrices. Dermal totals were corrected by 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] Product labels require handlers 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 handlers 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 carbaryl residues, or on the highest measured residue if it exceeds the 95th percentile.

[d] Long-term estimates are based on the arithmetic mean.

[e] Total exposure is the sum of dermal plus inhalation. Short-term inhalation = 3.83 µg/lb AI handled, and long-term inhalation = 1.21 µg/lb AI handled.

One exposure monitoring study, with eight replicates were monitored while applying an unspecified insecticide to turf, is in PHED (Beauvais *et al*., 2007). That study, conducted in 1978 in Washington state, had reported application times of 15 – 25 minutes (PHED, 1995). Dermal exposure was monitored with outer patch dosimeters and hand rinses; PHED does not identify the solution used in the hand rinses. Figure 5 displays the PHED output for this study. Handlers were not wearing gloves, and the hand exposure, as shown in Figure 5, was 48,437.5 µg/lb AI handled, greater than the average of 27,700 µg/lb AI handled estimated from results reported by Merricks (1997). Conversely, at 594.5486 µg/lb AI handled and 1098.8758 µg/lb AI handled respectively, lower arm ("forearm") and lower leg arithmetic means in the PHED study were lower than the respective means of 2,410 µg/lb AI handled and 36,800 µg/lb AI handled from Merricks (1997). Assuming default protection factors of 90% for clothing and gloves, Beauvais *et al.* (2007) estimated the short-term dermal exposure rate to be 25,600 µg/lb AI handled, which is 10-fold greater than the rate estimated using data from Merricks (1997).

Figure 5. Output from the Pesticide Handlers Exposure Database for Hose-End Sprayer [a]

SUMMARY STATISTICS FOR CALCULATED DERMAL EXPOSURES

SCENARIO: No clothing (total deposition)

PATCH LOCATION	DISTRIB. TYPE	MICROGRAMS PER AVERAGE LB AI Median	Mean	Coef of Var	Geo. Mean	Obs.
HEAD (ALL)	Lognormal	413.335	520.6988	82.6901	393.5742	8
NECK.FRONT	Lognormal	54.8475	73.8637	118.0917	44.7307	8
NECK.BACK	Lognormal	25.443	53.1781	122.7107	28.7246	8
UPPER ARMS	Lognormal	882.1665	902.5729	50.5155	800.8678	8
CHEST	Lognormal	1298.0575	1748.1087	118.0916	1058.6268	8
BACK	Lognormal	821.115	1716.2031	122.7107	927.0225	8
FOREARMS	Lognormal	463.2485	594.5486	116.5038	339.8912	8
THIGHS	Lognormal	1444.533	1778.8308	64.8833	1526.4968	8
LOWER LEGS	Lognormal	1163.939	1098.8758	50.0588	965.4128	8
FEET						0
HANDS	Lognormal	25000	48437.5	125.8443	27523.6248	8
TOTAL DERM:	33608.9722	31566.685	56924.3805		33608.9722	
INHALATION:	Lognormal	9.0625	13.3516	113.0823	9.5372	8
COMBINED:	33618.5094	31575.7475	56937.7321		33618.5094	

95% C.I. on Mean: Dermal: [-1280843.651, 1394692.4129]
95% C.I. on Geo. Mean: Inhalation: [2.0575, 44.2077]
Inhalation Rate : 16.7 Liters/Minute Number of Records: 8
Data File: MIXER/LOADER/APPLICATOR Subset Name: TEMP.NAME.MLAP

ADD INHALATION CHANGE HEAD LB AI TO KG AI EXIT

*** Press 'P' to print this report ***

[a] Screen capture of output from PHED (1995).

For this scenario, U.S. EPA estimated dermal and inhalation exposure rates to be 34,000 µg/lb AI handled and 2 µg/lb AI handled, respectively (Dawson, 2003a). These estimates are geometric means of data from Merricks (1997), and assume that handlers wear short-sleeved shirts, short pants, and that they are not wearing gloves.

As with the exposure of handlers using RTU trigger sprayers, examination of Table 6 suggests that household-type latex gloves are effective at mitigating hand exposure of handlers using hose-end sprayers. No quantifiable carbaryl was recovered from hand washes from 18 of the 20 replicates wearing gloves (LOQ was 1.0 µg/sample); in contrast, 70.2 – 4,440 µg carbaryl was recovered from the 20 handlers who were not wearing gloves.

Primary Review of Exposure Monitoring of Handlers Using Hand Pump Sprayers (Merricks, 1997)

Study Details Differing from Exposure Monitoring of Handlers Using Other Methods

Forty "non-professional male and female volunteers" Forty subjects each measured and poured 8 teaspoons (39.4 ml) of Sevin® Liquid RP-2 Insecticide, containing 22.4% AI, into the reservoir of a Better Homes and Gardens Model No. 1992 8H hand held pump sprayer. After closing the sprayer, handlers shook them to mix the solutions, and pumped up sprayer pressure. Each handler then sprayed a 200-ft^2 vegetable garden plot as described above (Merricks, 1997). Twenty applications were made by handlers wearing household latex gloves and 20 by handlers not wearing gloves. Handlers wearing gloves rinsed them after the application, as required by the product label. Exposure was monitored using whole-body dosimeters, hand washes and face/neck wipes as previously described. Applications with hand pump sprayers were made on

the same days as applications with other methods, and relied on the same quality assurance. No images are available of the specific sprayer used in this study.

Results

For the forty replicate applications, the mean monitoring interval was 23 ± 3 minutes, during which subjects handled an average of 7.53 ± 1.26 g of carbaryl (Merricks, 1997). Gloved applicators handled slightly less carbaryl on average than did applicators who were not wearing gloves, 7.17 g and 7.89 g, respectively. Actual applications took an average of 10 ± 3 minutes.

Table 8 summarizes carbaryl residues recovered from exposure matrices, as well as estimated exposure rates. Residues were corrected for field spike recoveries, and exposure rates were calculated as previously described.

No carbaryl was detected in hand wash samples for 15 of the 20 gloved applicators; results of these samples were set at 0.5 µg (i.e., ½ the LOQ of 1.0 µg) for calculating exposure rates. Carbaryl was above the LOQ in hand wash samples from all subjects not wearing gloves. In addition to gloved hands, many other samples did not have quantifiable carbaryl. Of the 40 face/neck wipe samples, 39 had results below the LOQ. Of the 40 samples of each inner dosimeter section, carbaryl was < LOQ on 28 of the lower arm sections, 37 of the upper arm sections, 37 of the front torso, 38 of the rear torso sections, 36 of the lower leg, and 34 of the upper leg sections. Twenty OVS tubes did not have quantifiable carbaryl. Some outer dosimeter sections also did not have quantifiable carbaryl; of the 40 samples, carbaryl was < LOQ on two of the lower arm sections, 26 of the upper arm sections, 14 of the front torso sections, and 26 of the rear torso sections. Carbaryl was above the LOQ in all lower leg and upper leg outer dosimeter sections.

Table 8. Carbaryl Residues on Exposure Monitoring Matrices Following Applications with a Hand-Pump Sprayer [a]

Matrix [b]	Number of Samples	Range of Residues (µg) [c]	Mean Residues (µg) [d]	Upper Bound Carbaryl (µg) [e]	Short-Term Exposure Rate (µg/lb AI) [f]	Long-Term Exposure Rate (µg/lb AI) [f]
Hand Washes						
With Gloves	20	< 1.0 – 21.9	2.14	21.9	1,720	160
No Gloves	20	56.6 – 2,100	396	2,100	127,000	23,300
Face/Neck Wipes	40	< 1.0 – 9.87	0.734	9.87	597	45.3
Inner Dosimeter						
Lower Arm	40	< 1.0 – 13.2	1.77	13.2	691	102
Upper Arm	40	< 1.0 – 4.78	0.692	4.78	289	42.4
Front Torso	40	< 1.0 – 11.7	1.02	11.7	705	63.5
Rear Torso	40	< 1.0 – 3.58	0.649	3.58	234	40.6
Lower Leg	40	< 1.0 – 5.43	0.753	5.43	285	44.9
Upper Leg	40	< 1.0 – 2.70	0.712	2.70	179	44.0
Outer Dosimeter						
Lower Arm	40	< 1.0 – 385	34.6	385	25,200	2,120
Lower Leg	40	23.8 – 3,320	392	3,320	200,700	24,200
OVS Tubes [g]	40	< 0.01 – 0.257	0.0940	0.257	19.7	5.73

[a] Data from Merricks (1997). All values corrected for field spike recoveries (when recoveries were less than 90%; see Table 1), and rounded to three significant figures. With the exception of hand washes, results combine data from 20 replicates wearing household latex gloves and 20 replicates not wearing gloves.

[b] Only matrices used to estimate exposure in the carbaryl risk assessment 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 carbaryl/sample for all matrices except OVS tubes, where the LOQ was 0.01 µg carbaryl/tube. Non-detects were set at ½ LOQ for calculating statistics.

[d] Arithmetic mean of residues recovered from exposure monitoring matrix.

[e] Upper-bound estimates of carbaryl residue were determined by first calculating the 95th percentile of residue results, assuming a lognormal distribution (Frank, 2009). The 95th percentile was compared to the highest corrected measured residue, and the higher of the two values was used for an upper bound. In all cases, the highest measured residue was greater than the 95th percentile.

[f] Short- and long-term exposure rate estimates were calculated by dividing the upper bound and mean, respectively, carbaryl residues by the amount carbaryl handled, after converting that amount from grams to pounds.

[g] Exposure rate estimates were adjusted to assume a default inhalation rate of 16.7 liters/minute.

Table 9 summarizes exposure rate estimates for hose-end spray applicators wearing clothing required by the product label, as well as applicators not wearing the label-required gloves and clothing. These values were calculated by summing the overall dosimeter, hand wash, face/neck wipe, and inhalation exposure rates for individual replicates; short-term exposures were the highest total exposure, which exceeded the 95th percentile in each case. Long-term exposure is the mean of total exposures. Estimates for hand exposure while wearing gloves were based on the 20 replicates wearing gloves, and estimates for hand exposure of a handler without gloves

were based on the 20 replicates not wearing gloves. For all other exposure matrices, results of 40 samples were combined. Estimated foot exposure was included by adding 0.52 times the lower leg exposure, as previously described.

Table 9. Exposure Rate Estimates of Carbaryl Hand-Pump Sprayer Applicators [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	Dermal	4,170	567
	Total [e]	4,190	573
Long-sleeved shirt, long pants, no gloves	Dermal	129,000	23,700
	Total	129,000	23,700
Short-sleeved shirt, short pants, and gloves	Dermal	209,000	26,900
	Total	209,000	26,900
Short-sleeved shirt, short pants, no gloves	Dermal	334,000	50,100
	Total	334,000	50,100

[a] Exposure rate in micrograms per pound active ingredient handled (µg/lb AI), based on data by Merricks (1997). Dermal exposures sum matrix-specific (dosimeter, hand wash, face/neck wipe, and inhalation) exposure estimates of individual replicates; 20 for hands wearing household latex gloves, 20 for hands without gloves, and 40 for all other matrices. Dermal totals were corrected by 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] Product labels require handlers 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 handlers 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 carbaryl residues, or on the highest measured residue if it exceeds the 95th percentile.

[d] Long-term estimates are based on the arithmetic mean.

[e] Total exposure is the sum of dermal plus inhalation. Short-term inhalation = 19.7 µg/lb AI handled, and long-term inhalation = 5.73 µg/lb AI handled.

Exposure Appraisal

Exposure monitoring by Merricks (1997) provided the best available data for estimating exposure of handlers applying carbaryl with hand held pump sprayers. This was a well-conducted study with apparently acceptable replication (40 applications were monitored, 20 with gloves and 20 without) and acceptable quality assurance.

Some issues discussed with respect to dust applicator exposure monitoring also apply to monitoring of handlers using hand held pump sprayers. Monitoring intervals were short, and time spent actually applying was even shorter; front and back sections of OVS tubes were combined, precluding breakthrough testing; and a single model of applicator equipment was tested.

Other data are available for handlers using hand held pump sprayers. PHED incorporates at least three studies in a scenario that Beauvais *et al.* (2007) called "Low Pressure Handwand Mixer/Loader/Applicator, Liquid (Open Pour)." In the three studies, handlers wore long-sleeved shirt, long pants, and gloves (type of glove was not identified). Using data in PHED, Beauvais *et al.* (2007) estimated the short-term dermal exposure rate to be 5,360 µg/lb AI handled, which is 30% greater than the exposure rate of 4,190 µg/lb AI handled that was estimated using data from Merricks (1997).

For this scenario, U.S. EPA estimated dermal and inhalation exposure rates to be 38,000 µg/lb AI handled and 9 µg/lb AI handled, respectively (Dawson, 2003a). These estimates are geometric means of data from Merricks (1997), and assume that handlers wear short-sleeved shirts, short pants, and that they are not wearing gloves.

As with the exposure of handlers using RTU trigger sprayers and hose-end sprayers, examination of Table 8 suggests that household-type latex gloves are effective at mitigating hand exposure of handlers using hand pump sprayers. No quantifiable carbaryl was recovered from hand washes from 15 of the 20 replicates wearing gloves (LOQ was 1.0 µg/sample), and the maximum carbaryl in the other five was 21.9 µg. In contrast, 56.6 – 2,100 µg carbaryl was recovered from the 20 handlers not wearing gloves.

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