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Potential exposure of children and adults to cypermethrin following use of indoor insecticide foggers

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The magnitude and distribution of cypermethrin from total release, over-the-counter foggers was studied in a test room and in residences to facilitate evaluation of regulatory exposure algorithms and new human exposure assessments based upon urine biomonitoring. Surface residue (SR) was evenly distributed in a small test room (3.6 μg cypermethrin/cm^2) where thorough mixing of the aerosol occurred. In a residence SR was significantly affected by room size and distance from the fogger. Air levels in the residence were as high as 30 μg cypermethrin/cm^3 after 4.5 h. The availability of surface residues was measured with an automated surface cotton cloth wipe and ethyl acetate extraction. Only 5% of the SR was available from nylon carpet. Tile, wood and linoleum resulted in 30, 10, and 10% of SR being available, respectively. These data are used to estimate cypermethrin exposure of children and adults for comparison with existing regulatory reference dosages and exposure assessments based upon biomonitoring.

Keywords: Pyrethroid exposure; children; cypermethrin; indoor; fogger.

Introduction

In the United States, an estimated 80% of households use pesticides at least once a year to mitigate, prevent, or repel pests.[1] Pyrethroids are the most prominent insecticide class for treatment and control of indoor pests.[2] The explosion hazard associated with failure of consumers to heed the flammability warning has resulted in recent regulatory review and even a call for cancellation of fogger registrations. It is important to address this hazard to property and health, but mitigation strategies are likely to require improved packaging and warning labeling. The existing hazard is very unlikely related to use of foggers as directed based upon human insecticide exposure studies with chlorpyrifos and cypermethrin conducted in this laboratory;[3] Krieger, unpublished observations). Total release foggers discharge trace amounts (less than 1 g each) of insecticide with low vapor pressures ranging from 10^{-8} to 10^{-9} mm Hg [4] on indoor target and non-target surfaces. Normal activity will inevitably result in unintentional and unavoidable human contact-transfer and insecticide absorption.[3]

The United States Environmental Protection Agency's (USEPA) Child-Specific Exposure Factors Handbook (2008)[5] catalogs studies of indoor and outdoor children's activities. Children spend 80% or more of their time each day indoors based upon contract research conducted at the national level and in California.[6] Non-dietary pesticide exposures of children to pesticides used in crop protection are of special regulatory importance as a result of the Food Quality Protection Act of 1996 (FQPA). Measurements of indoor exposure of children and adults contribute substantially to estimates of aggregate exposure and therefore they are important for risk assessment, product development and stewardship, and regulatory safety evaluation of pesticides.

Indoor chemical exposures occur via multiple routes including dermal, ingestion, and inhalation. Dermal contact is the primary source of human exposure during the days to weeks that follow insecticide applications. Children's behaviors and lower body weights contribute to higher absorbed dosages than adults.[3,7] Pesticide exposures to children have been estimated following broadcast application of chlorpyrifos[8] and crack-and-crevice application of diazinon and chlorpyrifos.[9,10] Pyrethroid exposure has been measured with a focus on dietary exposure[11] and several studies have estimated pyrethroid exposure in day care centers[12,13] following crack and crevice and total release indoor fogger applications.[14]

This study estimated potential inhalation, dermal, and non-dietary ingestion (including hypothetical hand-to-mouth and object-to-mouth contact-transfer) exposures of children after indoor use of cypermethrin foggers. Surface

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residue (SR) transferability, SR distribution, and air levels following indoor cypermethrin fogger use are included. Environmental levels were used to form children's aggregate exposure estimates using available regulatory default algorithms.[15]

Materials and methods

Materials

Plush nylon carpets (≥24 oz/yd^2, density ≥2600 oz/yd^3, and filament ≥12 denier; Housing and Urban Development, 1993), tile (400 cm^2), linoleum, wood flooring (100 cm^2), and Raid® Deep Reach™ Foggers (EPA Reg. No. 9444-182) were purchased locally.

Aluminum foil spray deposition coupons

Surface residue (SR) was based on the amount of insecticide deposited on aluminum foil coupons (100–200 cm^2) when the foggers were used. Following insecticide application and the restricted entry period, deposition coupons were collected and stored frozen in freezer bags (Ziploc®, S. C. Johnson & Sons, Inc). Coupons were extracted vigorously at room temperature in ethyl acetate on an Eberbach shaker at high speed (two 10 min cycles). A 25 mL aliquot was removed for analysis. SR was insecticide extracted per unit surface area (μg/cm^2).

Transferable surface residue

Transferable surface residues (TSR) were sampled using an Atlas AATCC CM-5 Crockmeter™ (ASW) (Atlas Electric Devices Co., Chicago, IL) (Fig. 1). Flooring coupons (tile, wood, carpet, or linoleum) were attached to the wiping surface. Aluminum foil was fitted to the acrylic sampling (rubbing) finger. Cotton cloth (5 × 5 cm) was attached with a wire over the aluminum foil. Stroke length (7.6 cm), rate (60 rpm), and cycles (10) were controlled. After a sampling cycle, the foil was discarded. The cotton cloth was stored frozen in a glass vial. The vials were brought to room temperature for extraction and analysis. After addition of ethyl acetate (10 mL), the vial was vigorously shaken as above for 30 min. TSR was the amount of pesticide extracted per cm^2 of flooring. Percent transferable residue was [TSR (μg/cm^2)]/[SR (μg/cm^2)] × 100.

Air monitoring

Air sampling (3.5 h to 4.5 h) utilized SKC Model 224-PCXR8 Personal or Area Air Sampling Pumps (SKC).

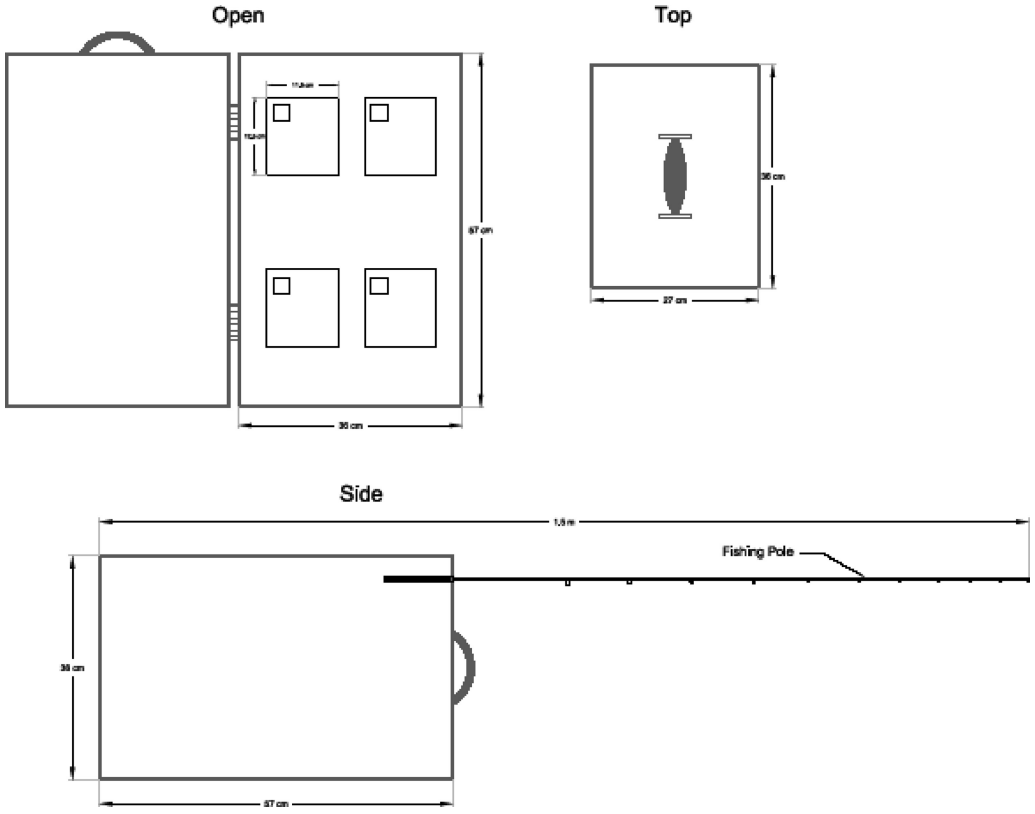

Fig. 1. Four SKC Model 224-PCXR8 Personal or Area Air Sampling Pumps were attached with heavy duty Velcro inside a 60 cm (diagonal length) hard side upright suitcase. Holes were drilled to accommodate sampling in three directions at 45 cm and an extendable fishing pole (Master, Model GC850) was attached to the back of the suitcase to accommodate sampling at 1.5 m.

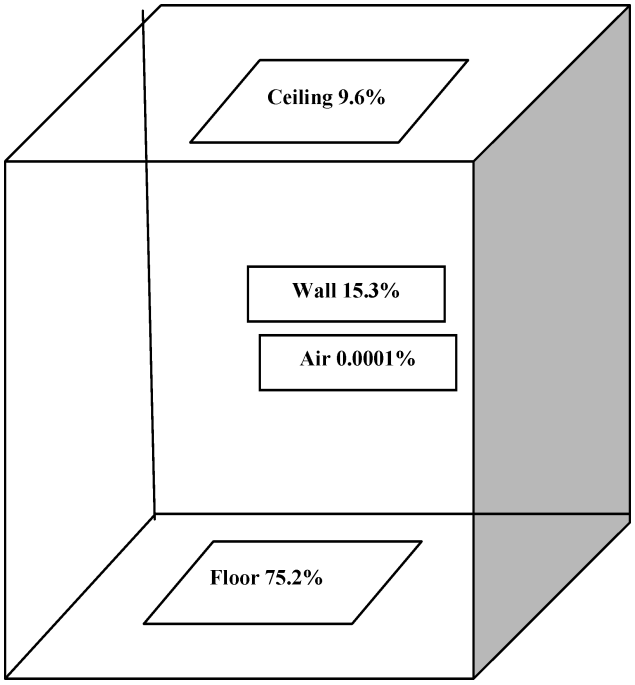

Fig. 2. Cypermethrin was applied using a Raid Deep Reach Fogger in a 3 m × 3 m × 3 m carpeted test room. Surface residue (SR) was measured using foil coupons and 75% of cypermethrin applied was accounted for. Air was monitored using Aircheck Samplers and XAD-2 tubes.

Children (three at a height of 45 cm) and an adult (one at a height of 1.5 m) breathing zone samplers were secured with heavy duty Velcro™ within a custom-made small suitcase (Samsonite®) (Fig. 2).

An Occupational Safety and Health Administration (OSHA) versatile sampler (XAD-2) attached to air pumps (2L/min) by an OSHA Versitile Sampling (OVS) tube holder (SKC) was used. After sampling, XAD-2 tubes were capped and stored frozen in freezer bags. Tubes were brought to room temperature. The 13 mm glass fiber filter and 270 mg sampling section were transferred to an 8 ML glass vial. The first foam plug and 140 mg backup section were transferred to a separate glass vial. The rear foam plug was discarded. Ethyl acetate (3 mL) was added to each vial. Vials were bagged and shaken 30 min as above. The extract was transferred to a 25 mL glass vial and analyzed for cypermethrin.

Analysis

Cypermethrin concentrations were determined from a standard curve using permethrin (Chemservice, West Chester, PA) as an internal standard (LOD = 0.02 μg). Extracts were analyzed on a Hewlett-Packard 5890 GC equipped with a 30 m × 0.32 mm × 0.25 μm film fused silica column. The temperature program was: 100°C for 1 min, then 20°C/min to 230°C, and finally 5°C/min to 300°C where it was held for 1 min. Retention time for cypermethrin was approximately 17 min. Chromatograms were recorded from an electron capture detector and integrated by peak area. Recovery of cypermethrin spikes from foil coupons (50 μg, 500 μg), cotton cloth (5 μg, 30 μg) (ASW), and XAD-2 tubes (1 μg, 2 μg) were 95, 110, and 90 percent, respectively.

Test room experiments 1 and 2

One Raid® Deep Reach™ Fogger was discharged (0 h) according to label instructions in a 3 m × 3 m × 3 m carpeted test room with one window (1 m × 1 m) and one door. The window and door were closed when study personnel left the room. Four hours later, the window was opened, a utility fan was turned on, and the door was opened to the outdoors.

Foil coupons were 0, 0.15, 0.30, 0.60, 1.20, and 1.80 m from the fogger in a "Y" pattern (Fig. 2). Foil coupons were also attached with double-sided tape 0.60, 1.20, and 1.80 m above the floor on three walls of the room. Foil coupons were attached to the ceiling in two rows, 0.60 m from the south and north walls. Foil coupons were collected 4.5 h after the fogger was discharged and 30 minutes after the room was ventilated.

Flooring coupons were placed 1.20 m from the fogger near the door to permit retrieval at early times. Flooring coupons were removed and sampled for TSR at 1, 2, 3, 4, 6, 8, 12, 24, and 72 h. Air samples were obtained at 4.5 h and 8.5 h in experiment 1 and at 4.5, 24, 72, and 144 h in experiment 2.

House experiment

Six Raid® Deep Reach™ Foggers were discharged in a 189 m^2, 3-bedroom and 2-bathroom home. Foggers were placed in the kitchen/dining room (KD), smaller bedrooms (25 m^3; B1 and B2), living room (82 m^3; LR), master bedroom (66 m^3; B3), and study (45 m^3; ST). Each fogger was set on newspaper on a small box above floor level per label instructions. Before discharge of the foggers, the air conditioner was turned off and all doors and windows were closed. Four hours after fogging, the house was reentered, the air conditioning and ceiling fans were turned on, and bathroom windows and outside doors were opened. Normal activities resumed 30 min later.

Two rows (A and B) of foil coupons were placed in unobstructed floor space 0.3, 0.6, 1.2, 2.4, 3.6, 4.8, and 6 m from the fogger in KD, B2, LR, MB, and the ST. Foil coupons were also taped to walls (16 total at a height of 1.2 m) and ceilings (4 total). Foil coupons were collected between 4.5 and 5 h post-fogging. Air was sampled at 4.5 (KD and B3), 24, 72, 144, and 696 h (KD) after fogging.

Eight carpet coupons were placed in KD, 5 in B2, 5 in LR, and 5 in B3. Eight linoleum coupons were placed in

KD and 5 in guest bath (GB). Eight tile coupons were in KD and 5 were in the entryway (ET). Eight wood coupons were in KD and 5 in B3. TSR samples were obtained at 1, 2, 3, 4, 6, 8, 24, and 72 h post-application. Time points 1, 2, and 3 h were only used for KD samples due to limited access to the house during the 4h post-fogging period.

Statistical analysis

All statistical analysis used Statistical Analysis Software JMP® 7 (2007). Differences were determined using Student's t-test. Correlations were determined using nonparametric Spearman's rank correlation. Statistical significance is indicated by p-values of <0.05.

Results and discussion

The overall goal of this study was to evaluate the fate of cypermethrin to clarify the magnitude and determinants of indoor pyrethroid exposure to children following fogger use indoors. This study included extensive multimedia monitoring within a residence and a test room. Study periods were as long as 32 days post-application of Raid® Deep Reach™ Foggers (1.7% cypermethrin). Few studies have examined the time series distribution of OP pesticides in the environment following crack and crevice, broadcast, and fogger application.[8,10,12] Investigators have used indirect and direct measures to estimate potential exposure via inhalation, dermal, and indirect ingestion (hand-to-mouth and object-to-mouth activity) following indoor insecticide applications.[8,10,12,14] No studies to date have comprehensively studied air levels, SR, total carpet pesticide (TCP), and TSR (availability) of pyrethroid pesticides following fogger application.

Total release, over-the-counter insecticide foggers are popular consumer products used indoors to treat and control ants, fleas, roaches, and other domestic insects. Foggers produce an invisible chemical residue on general target and non-target surfaces. This indoor surface residue represents the source of maximum potential exposure from a single application of an over-the-counter product when used as directed. Recent accounts of accidents and illnesses associated with total release foggers document an explosion hazard associated with misuse of foggers.

It is usual to express surface pesticide exposure potential as a measure of mass per unit area. Such a measure may not represent the potential difference in contact transfer potential of nylon carpet and flat surfaces (tile, wood, and linoleum). Cypermethrin deposition was measured on foil coupons (SR) and nylon carpet coupons. Less chemical residue ($p < 0.05$) was retained on foil than on carpet coupons with the same face area. Nylon retained 1.7 times more residue per unit surface area than foil. The difference likely results from greater surface area and porosity of the carpet fibers compared with foil. If foil deposition coupons are used to infer carpet levels, SR is underestimated. On the other hand, SR on foil coupons gives more suitable estimates of SR for surfaces such as tile, wood, and linoleum.

The potentially available percentage of SR used for exposure assessment is the TSR (Table 1). Even though the insecticide is discharged through the air, air levels were insignificant ($\leq 0.06\ \mu g/m^3$) in all test room studies. Cypermethrin air levels in the residence were as high as $30\ \mu g/m^3$ on day one. Air levels declined to $0.06\ \mu g/m^3$ within 24 hours. The magnitude and ephemeral nature of the aerosol minimize the importance of inhalation as a route of exposure relative to dermal contact-transfer.

Table 1. Transferable surface residue following fogger use in a house and a test room.

	Transferability from multiple flooring types ($\mu g/cm^2$)													
	House study average transferability by room													
Room	*Bedroom 2*		*Bedroom 3*	*Entry*	*Guest bath*	*Kitchen/dining room*				*Living room*	*Test room transferability*[b]			
Flooring	*Carpet*	*Wood*	*Carpet*	*Tile*	*Linoleum*	*Carpet*	*Linoleum*	*Tile*	*Wood*	*Carpet*	*Carpet*	*Linoleum*	*Tile*	*Wood*
Hours[a]														
1						0.09	0.11	0.21	0.18		0.34	0.59	1.02	0.50
2						0.06	0.11	0.13	0.13		0.43	0.34	1.04	0.52
3						0.12	0.05	0.21	0.22		0.46	0.28	1.03	0.65
4	0.33	0.33	0.17	0.28	0.08	0.07	0.15	0.38	0.25	0.09	0.58	0.29	1.13	0.58
6	0.25	0.53	0.18	0.27	0.03	0.19	0.04	0.30	0.26	0.11	0.42	0.33	1.25	0.58
8	0.12	0.33	0.11	0.39	0.01	0.15	0.09	0.36	0.19	0.14	0.43	0.35	0.97	0.56
12	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.42	0.31	0.97	0.52
24	0.26	0.15	0.10	0.32	0.02	0.07	0.03	0.33	0.24	0.07	0.25	0.50	0.92	0.62
72	0.20	0.58	0.11	0.21	0.02	0.06	0.02	0.29	0.17	0.09	0.33	0.31	0.99	0.53

[a] Hours after fogger release.
[b] Average of two test room experiments.

Transferability of SR was strongly affected by time and the characteristics of indoor surfaces (Table 1). Availability was studied by measuring the transferability of cypermethrin using two different methods. The California Department of Food and Agriculture (CDFA) roller method[17] was compared with the Automatic Surface Wipe (ASW), a new procedure to sample TSR being developed in this laboratory. The ASW is an instrument of the American Association of Textile Chemists and Colorists for testing the color fastness of textiles (AATCC 2001). Here it facilitated reproducible testing of relatively large numbers of samples. TSR was significantly affected by floor type (Table 1). Plush nylon carpets are the most common indoor floor covering; however, these data clearly show that other floor coverings are associated with greater human exposure potential. This observation has recently been extended to a study of the use of indoor chlorpyrifos foggers (withdrawn from commerce by DowElanco in 1995; Li and Krieger, unpublished observations).

Measurements using the CDFA roller are highly correlated with exposure using whole body dosimeters worn during a structured activity program.[17] The CDFA roller has previously been used as a sampling tool to predict human absorbed dose.[17–20] The roller is a convenient means to estimate transferable residues from surfaces.[16] Transferability measured using the ASW was not significantly different from transferability measured using the CDFA roller. The CDFA roller method requires increased equipment, time, flat space, and is more subject to human influences relative to the ASW. The mechanical ASW can be used to uniformly sample large numbers of a variety of different media. Both procedures represent physical contact-transfer, yield surface chemical residues ($\mu g/cm^2$) and are readily adapted to exposure assessment research.

Transferability of insecticide from carpet is frequently studied[17,20] while relatively less is known about other floor coverings such as linoleum, tile, and wood. Following a cypermethrin fogger application in the test room, 30 percent SR on tile transferred after 3 days. Similarly 10 percent of the total residue was transferred from carpet, wood, and linoleum each after 3 days (Table 1). These findings are similar to current default assumptions for estimating potential exposure.[16] Transferability data was much more variable in the house study, likely due to variability seen in deposition levels (Tables 2 and 3) resulting from the spatial distribution of the foggers and SR foil coupons. The availability of surface residues is expected to be similarly variable in all residences/structures of similar or larger size.

During the hours after a fogger application, a house with tile or linoleum flooring may have more transferable (available) cypermethrin than a house with plush nylon carpeting (Table 1). Houses with predominantly linoleum or wood flooring would be expected to produce intermediate levels of exposure based upon ASW measurements of transferability (Table 1). Cypermethrin residues may persist in unavailable forms for long periods on nylon carpet fibers where they may be protected from hydrolysis, photolysis, and direct contact-transfer. Stabilized residues may be recognized in the extreme by analysis of solvent-assisted wipes or soxhlet extracts. Surface characteristics that could influence transferability and time-availability relationships seem to have received inadequate study to date in indoor insecticide exposure research.

Table 2. Cypermethrin surface residue following fogger use in a test room.

Distance from fogger (m)	*A*	*B*	*C*
	Study 1 by direction ($\mu g/cm^2$)		
0	3.71	3.75	3.72
0.15	3.68	4.22	4.18
0.3	3.07	1.85	3.16
0.6	3.69	4.57	3.57
1.22		3.40	4.24
1.83		3.4	3.17
	Study 2 by direction ($\mu g/cm^2$)		
0	3.01	3.15	18.89
0.15	2.96	3.17	12.61
0.3	3.05	3.26	36.72
0.6	2.55	3.24	11.23
1.22	3.39	3.59	15.24
1.83		2.94	9.52

Test room

The fate of cypermethrin was measured following discharge in a controlled setting following fogger release of a Raid Deep Reach Fogger in a small 27 m^3 carpeted test room (experiments 1 and 2). This room was slightly larger than the smaller bedrooms (B1 and B2) in the house experiment. SR and air monitoring together directly accounted for 75% of the cypermethrin discharged (0.7 g cypermethrin/fogger). Surface residues were distributed as follows: 75% floor, 9.6% ceiling, and 15.3% walls (Fig. 2). Very little cypermethrin was found in the air ($< 0.01\%$, $< 0.1\ \mu g/m^3$). The surface residues create opportunity for contact-transfer and dermal absorption and non-dietary ingestion. Dermal exposure is regarded as the primary exposure route for semivolatile chemicals like cypermethrin indoors.[3,17]

In test room experiment 2 the fogger was displaced, but quickly righted horizontally during the 39 ± 2 sec ($n = 3$) discharge period. SRs for test room experiments 1 and 2 are given (Table 2). The total mass of cypermethrin used in each experiment was identical based upon fogger mass discharged. This incident represents an extreme case of accidental directed discharge. The foil coupons in direction C received a brief direct spray in experiment 2 (Table 2). The incident is reported as a worst-case example since study personnel had used the product many times without any difficulty. This accident produced elevated SRs (up

Table 3. Surface residue of cypermethrin in a residence following fogger use in selected rooms in two directions.

Distance[a] *(m)*	*Bedroom 2 ($\mu g/cm^2$)*		*Kitchen/dining room ($\mu g/cm^2$)*		*Bedroom 3 ($\mu g/cm^2$)*		*Living room ($\mu g/cm^2$)*		*Study ($\mu g/cm^2$)*	
	A	*B*	*A*	*B*	*A*	*B*	*A*	*B*	*A*	*B*
1	1.65	2.23	0.96	1.09	1.46	1.03	0.80	1.16	1.65	1.58
2	1.65	1.92	1.10	1.22	1.29	1.06	0.78	1.53	1.91	N.S.
4	1.40	1.13	0.98	0.94	1.30	0.84	0.75	1.28	1.88	1.30
8			0.77	0.93	1.00	1.05	0.60	0.61	1.94	0.74
12			0.72		1.09	0.95	0.60			
16			0.54							
20			0.55							

N.S.: No sample.
[a]Meters from the fogger.

to 36 $\mu g/cm^2$). This episode would create the possibility of higher exposures for either children or adults. Dosages would remain well below adverse effect levels given the reality of SR distribution, dose, time and toxicity thresholds.

Residence

Air levels, SR, and TSR were studied in a fully furnished occupied 189 m^2 home. Cypermethrin SR decreased with distance from fogger in larger rooms (Table 3). These differences were small but significant ($p < 0.05$). It is likely that distance from the fogger would influence exposure potential in rooms larger than 125 m^3 (the largest room in the house).

Significant negative correlation ($p < 0.05$) was observed between room volume (m^3) and SR. Higher SRs occurred in the smaller rooms (B2, 25 m^3; Table 3). The smaller rooms of the residence ($\sim$ 25 m^3) had SRs about 50% greater than the SR in the largest room (125 m^3; Table 3). Foggers are usually distributed room-by-room. In a residence consisting of multiple small rooms, higher SRs would contribute to higher potential exposures in smaller rooms. The suggested label distribution based upon room volume (or floor area) is commonly ignored (Krieger, personal observation). Room size likely contributes to some of interfamily variability observed in biomonitoring studies.[3,15]

Children often sleep and play in the same room, which is often smaller than other rooms in a home. This creates a special opportunity for exposure if foggers are distributed room-by-room rather than by volume (or floor area) as noted above. SR measurements must be made where contact-transfer occurs. The differences in exposure potential related to contact time and SR are not large, and, correspondingly, the differences in absorbed dose among children and others are less than an order of magnitude (Krieger, unpublished observations). In the case of cypermethrin, companion biomonitoring studies to be published have shown biomarker levels of children to be about 4-fold greater than those of teens and adults living in the same homes.[3,15]

Exposure assessment

Cypermethrin persistence indoors, distribution patterns, transferability, and air levels following fogger use coupled with the nature of human activities will ultimately determine the extent and duration of exposure of adults and children. Crack and crevice, perimeter, and spot sprays will be associated with lower unintentional and unavoidable human exposures than those produced by total release foggers due to characteristically limited distribution of the insecticide. Foggers produce an aerosol that is virtually ubiquitous within the indoor air space relative to other indoor application technologies (Fig. 2). Floor plans and the nature of indoor surfaces will vary and significantly influence exposure potential[15] (Y. Li and R.I. Krieger, unpublished observations).

Aggregate inhalation and dermal exposure

The Food Quality Protection Act (FQPA) of 1996 includes a mandate to assess aggregate exposure. Indoor exposures are particularly important for children given a paucity of validated data for aggregate exposure and cumulative risk assessments. This study focuses on children's exposure via dermal, inhalation, and non-dietary ingestion following fogger use indoors. Air levels and TSR were used to estimate potential dose to a 3-year old child in order to assess the relative contributions from each exposure route (Table 1).

Air levels at reentry were low in the well-mixed air of the small test room, but they were significantly higher in the relatively stable air of the residence. The USEPA default algorithm for inhalation [16] is:

$$\mathrm{PDR} = \mathrm{Ca} \times \mathrm{IR}$$

where dose rate (PDR) is determined by multiplying air concentration (Ca, $\mu g/m^3$) by inhalation rate (IR, m^3/day). Related assumptions include 100% retention and 100% absorption of inhaled dose. Default mean inhalation rates were 8.7 m^3/day for a child (light activity).

The extreme-case scenario is based upon the highest measured air level (34 μg cypermethrin/m^3) measured in the

Table 4. Air levels of cypermethrin following fogger use in a residence and test room.

Residence average air levels by room			*Test room average air levels*	
Hours	*B3*	*KD*	*Study 1*	*Study 2*
4.50	33.85	9.76	0.02	0.07
8.50	NA	NA	0.02	NA
24.00	NA	0.06	NA	0.03
82.00	NA	0.05	NA	0.02
144.00	NA	0.03	NA	0.01
696.00	NA	0.18	NA	NA

residence (Table 4). A 3-year-old (15.7 kg) child could be exposed to 0.02 mg/kg on day one. Air levels decreased significantly after day one and the same child would have an estimated inhalation exposure of 0.0003 mg/kg-day on subsequent days.

Dermal exposure is the primary exposure route of semivolatile chemicals used indoors.[13,15,17] It can be estimated using TSR data which permits sampling under carefully controlled conditions. The USEPA residential exposure assessment algorithm can be used to calculate potential dose rate (PDR) from TSR, a conversion factor (CF1) for μg to mg, an empirical transfer coefficient (TC; 6,000 cm^2/h for children), and exposure time (ET).[16]

$$PDR = TSR^{*}CF1^{*}TC^{*}ET$$

Dermal exposure potential has been indirectly estimated using this algorithm in several studies.[16,18,21,22,23] If the house was assumed to have tile flooring (100%) and a 3-year-old child spent 16 hours at home, the potential child's exposure would be 6.3 mg/kg cypermethrin. This exceedingly high exposure results from the 100% absorption default assumption. If you assume that 1.7 percent absorption of cypermethrin,[24] a more reasonable dosage estimate of 0.11 mg/kg is obtained.

Hand-to-mouth exposure

"Indirect" non-dietary exposure ingestion is a hypothetical route of pesticide exposure of young children. The current default estimates of hand-to-mouth exposure yield very high exposure estimates [25] relative to estimates made by biomonitoring.[15] Variables in the default algorithm include TSR, fingertip surface area (SA), removal efficiency (RE), events/hr, hrs/day, and body weight (BW).

$$TSR \times RE \times SA \times \text{events/hr} \times \text{hrs/day} = PDR$$

EPA Tier One hand-to-mouth assessments use estimates of 20 events/hr for acute and 8.5 events per hour for intermediate and chronic exposures. If the house used in the present study had tile flooring (100%) and a 3-year-old child spent 16 hours at home, the cypermethrin PDR would be 0.42 mg/kg-day. Again the dosage results from the assumptions of 100% removal efficiency and 100% absorption. Our biomonitoring research with cypermethrin was intended, in part, to evaluate the importance of hand-to-mouth exposures. Results to be reported elsewhere give no indication that age-related hand-to-mouth contact is an important determinant of exposure in children.[3,15]

Estimated potential dosages using default algorithms[16] clearly show hand-to-mouth activity of children to be the largest contributor to aggregate exposure of a 3-year-old child. Estimated potential dosages for children in residences with predominantly tile, wood, carpet, and linoleum flooring are 0.54, 0.33, 0.23, and 0.23 mg/kg-day, respectively. These data indicate that flooring type could affect children's exposure to cypermethrin following fogger use indoors, but the default dosages are orders of magnitude greater than those inferred from biomonitoring.[15] Potential dosages estimated using USEPA default algorithms are expected to be high, but experimental evaluation and validation are essential for more refined use. The important insight gained from this aspect of these studies is the influence of surface characteristics on the availability of residues. Use of nylon as a standard is not adequate to represent hard surfaces like tile, wood, and linoleum[15] (Y. Li and R.I. Krieger, unpublished).

Conclusion

This study clarified the magnitude and some of the determinants of indoor pyrethroid exposure to children following fogger use indoors. Pesticide TSR persists at low levels for as long as 14–20 days and SR in preliminary studies was found not to significantly decrease after 30 days. Little to no decrease in SR and TSR indicate the very long lifetime of cypermethrin indoors, much longer than expected. This assessment of cypermethrin persistence should influence pesticide label instructions and registrant evaluation of pesticides due to the possibility for SR accumulation following repeated use. The effects of room size on SR are clear and therefore could affect indoor cypermethrin exposure. Flooring type affects TSR with increased transferability from smoother, harder surfaces. These findings help elucidate determinants of indoor cypermethrin exposure and could be used to evaluate exposure to other semivolatile chemicals used indoors. A clearer understanding of pesticide applications, distribution, transferability, and absorbed dose may contribute toward understanding the significance of children's pesticide exposure resulting from indoor pest management.

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