7.0 DERMAL EXPOSURE MEASUREMENTS

The ability to accurately estimate surface-to-skin transfer of contaminants from intermittent contacts remains a critical and missing link in pesticide exposure and risk assessments. For children's exposures, transfer of chemicals from contaminated surfaces such as floors and furniture is potentially significant. Once on the skin, residues and contaminated particles can be transferred back to the contaminated surface during subsequent contact, lost by dislodgement or washing, or transferred into the body by percutaneous absorption or hand-to-mouth activity. A better understanding of the relevant factors influencing transfers from contaminated surfaces to skin and the resulting dermal loading will reduce uncertainty in exposure assessment. Areas of uncertainty with respect to dermal transfer are related to the important factors that impact transfer, whether or not a steady-state condition is reached, and the conditions that affect removal. Laboratory tests were conducted by NERL using nontoxic fluorescent tracers to evaluate significant transfer parameters. The results of these tests are described in this section (Section 7.1).

Measurements of pesticide residues on children's hands have been performed in a number of studies. Both hand wipe and hand rinse methods have been used. The collection efficiency of different wipe and rinse methods can be expected to differ, with an eight-fold difference reported between hand rinses and hand wipes in one study (Hore, 2003). Furthermore, differences in dermal exposure and dose due to free pesticide residue versus particle- (or dust-) bound pesticides may be important in interpreting the results. Results of wipes and rinses in selected studies are summarized in tables and figures presented below (in Section 7.2).

An alternative approach for estimating dermal exposure is the cotton garment surrogate. Similar to the approach used for measuring occupational exposures to pesticides, cotton garments, which can consist of a bodysuit and/or socks, have been used in three studies that are reported below (Section 7.3).

Important Factors Affecting Transfer

Dermal exposure to surface residues is dependent on human activities that result in contact with surfaces and the physicochemical and mechanical mechanisms of transfer of residues from the surface to the skin. Several factors are commonly believed to affect transfer (Table 7.1). These factors can be grouped as characteristics of the surface (including contaminant loading, type of surface, and temperature), of the contaminant (including formulation, physical state, particle size, vapor pressure, viscosity, water solubility, lipophilicity, and being particle-bound), of the skin (including moistness and contact area), of contact (including duration, force, frequency, motion, and interval), and of protection measures (including clothing and hand washing).

Many of these have previously been investigated, though not necessarily specific to pesticides and skin. Kissel *et al.* (1996) reported *moisture content* and *particle sizes* of soil to be significant factors affecting the process of adherence to skin. Rodes *et al.* (2001) reported that only about 1/3 of the palm contacted surfaces during a press and that dust-to-skin transfer increased with hand dampness, decreased as surface roughness increased, and decreased with consecutive presses (requiring about 100 presses to reach equilibrium). Brouwer *et al.* (1999) reported that whereas only 4-16% of the surface area of the palm of the hand is covered with a fluorescent tracer after one contact with a hard surface, about 40% becomes covered after twelve consecutive contacts. At least three studies have investigated the transfer of pesticides from surfaces to hands (measured using IPA wipes of hands.). Briefly, Lu and Fenske (1999) reported transfer of chlorpyrifos residues to hands to be 0.04 to 0.26% from carpets and 0.69% from furniture. Camann *et al.* (1996) examined transfer from nylon carpet to dry or moistened hands and reported transfers ranging from 0.7–1.3% for chlorpyrifos, 2.9–4.8% for pyrethrin I, and 1.5–2.8% for piperonyl butoxide. Clothier (2000) examined transfer of the same residues from vinyl sheet flooring and reported transfers of 1.5% to dry and 4.4-5.2% to wet skin for chlorpyrifos, 3.6% (dry) and 8.9 – 11.9% (wet) for pyrethrin I, and 1.4% (dry) and 4.1-4.8% (wet) for piperonyl butoxide.

7.1 Laboratory Fluorescent Measurement Studies

Laboratory tests were performed to evaluate transfer efficiencies (TEs) of nontoxic fluorescent tracers (as surrogates for pesticide residues) from common household surfaces to hands (Cohen Hubal *et al.*, 2005). The laboratory studies evaluated parameters affecting surface-to-hand transfer, including surface type, surface loading, contact motion, pressure, duration, and skin condition in two sets of experiments (Table 7.2). The data from the laboratory fluorescent measurement studies are presented in Tables 7.3 to 7.6 and Figures 7.1 and 7.2.

- Tests comparing fluorescent tracers with pesticides (Figure 7.1) showed that the transfer of riboflavin to PUF rollers and C18 disks is similar to that of chlorpyrifos, and that the transfer of Uvitex is similar to that of the pyrethroids permethrin and esfenvalerate.
- Laboratory studies using fluorescent tracers riboflavin and Uvitex OB (Tables 7.3 to 7.6) indicated that *tracer type*, *surface type*, *contact motion*, and *skin condition* were all significant factors. Transfer was greater with laminate (over carpet), smudge (over press), and sticky skin (over moist or dry). *Contact duration* and *pressure* (force) were not important factors.
- Comparison of "first contact" to "repeated contact" results (Table 7.4) suggests that the effect of surface type appears to diminish with repeated contact while the effect of skin condition (moist vs. dry) appears to increase with repeated contact.
- Laboratory surface loadings (0.2 and 2.0 µg/cm²) were much higher than the median values of 0.032 and 0.0014 µg/cm² measured by deposition coupons (Table 4.4) after crack and crevice application of chlorpyrifos in the Test House and CPPAES studies, respectively,
- In the initial tracer experiments with high surface loadings, dermal loadings appear to reach a maximum by the fourth or fifth contact (data not presented), suggesting a saturation effect. In the follow-up experiments with lower surface loadings (Figure 7.2), dermal loadings appear to increase linearly through the seventh contact, suggesting that at lower surface loadings, more contacts may be required to reach steady state.
- In "transfer off" experiments described earlier (Section 6.2), the amount removed from fingers by mouthing was significantly different from zero in only half of the replicates.

Table 7.1 Factors commonly believed to affect dermal transfer.

Category	Parameter	Source
Surface	Level of contamination	Goede *et al.,* 2003; This Report
	Type of surface: roughness, carpet vs. hard surface	Brouwer *et al.,* 1999; Rodes *et al.,* 2001
Contaminant	Formulation	Marquart *et al.,* 2005
	Physical state: solid, liquid	Marquart *et al.,* 2005
	Particle characteristics: particle size distribution, moistness	Kissel *et al.,* 1996
	Liquid characteristics: viscosity and related properties	Marquart *et al.,* 2005
	Physical properties of active ingredient: vapor pressure, water solubility, lipophilicity	This Report
Skin	Moistness	Camann *et al.,* 1996; Clothier, 2000; Rodes *et al.,* 2001; This Report
	Contact area	Brouwer *et al.,* 1999
Contact	Frequency: number of contacts or objects	Brouwer *et al.,* 1999; Rodes *et al.,* 2001; This Report
	Interval between contacts	Camann *et al.,* 1996;
	Motion: press, smudge, drag	Lu and Fenske, 1999;
Protection	Clothing: use, area covered, material	Marquart *et al.,* 2005
	Hand washing: frequency	This Report

Categories and parameters modified from Marquart *et al.,* 2005.

Table 7.2 Study parameters tested in surface-to-skin transfer experiments in the Characterizing Pesticide Residue Transfer Efficiencies study.

Parameter	Initial Experiments	Refined Experiments [a]
Tracer	Riboflavin [a]	Riboflavin [b] or Uvitex [c]
Skin Condition	Dry, Moist, or Sticky	Dry or Moist
Surface Type	Carpet or Laminate	Carpet or Laminate
Surface Loading	2 or 10 $\mu g/cm^2$	0.2 or 2 $\mu g/cm^2$
Contact Motion	Press or Smudge	Press or Smudge
Contact Duration	2 sec or 20 sec	--[d]
Contact Pressure	7 or 70 kg/cm^2	--
Contact Number	Multiple	Multiple

[a] Refined experiments added Uvitex, reduced the loading levels, and reduced the number of parameters tested
[b] Relatively water soluble
[c] Relatively water insoluble
[d] Blank cells indicate that parameter was not investigated in the study

Table 7.3 Skin loadings (mean, standard deviation) measured following surface-to-skin transfer experiments (initial experiments). (Source: Cohen Hubal *et al.*, 2005.)

Contact	Hand condition			Surface type		Surface loading	
	Dry	Moist	Sticky	Carpet	Laminate	High	Low
Skin loading, μg/cm², average (SD) [a]							
1	0.3 (0.6)	0.4 (0.3)	0.7 (0.6)	0.4 (0.5)	0.5 (0.5)	0.6 (0.6)	0.3 (0.3)
2	0.4 (0.4)	0.9 (0.6)	1.2 (0.7)	0.8 (0.7)	0.8 (0.6)	1.0 (0.7)	0.6 (0.5)
3	0.5 (0.5)	1.0 (0.6)	1.5 (0.7)	1.0 (0.8)	1.0 (0.7)	1.2 (0.8)	0.8 (0.6)
4	0.6 (0.5)	1.3 (0.8)	1.6 (0.8)	1.2 (0.9)	1.2 (0.7)	1.4 (0.8)	0.9 (0.7)
5	0.5 (0.3)	1.3 (0.7)	1.8 (0.8)	1.3 (1.0)	1.0 (0.6)	1.4 (0.9)	0.9 (0.7)
Skin loading, μg/cm² (without sticky hand condition), average (SD)							
1	0.3 (0.6)	0.4 (0.3)		0.4 (0.6)	0.3 (0.2)	0.5 (0.6)	0.2 (0.2)
2	0.4 (0.4)	0.9 (0.6)		0.7 (0.7)	0.6 (0.4)	0.8 (0.7)	0.4 (0.3)
3	0.5 (0.5)	1.1 (0.6)		0.8 (0.8)	0.8 (0.5)	1.0 (0.7)	0.5 (0.4)
4	0.6 (0.5)	1.3 (0.8)		1.0 (0.9)	0.9 (0.5)	1.2 (0.8)	0.6 (0.4)
5	0.5 (0.3)	1.3 (0.7)		0.9 (0.9)	0.8 (0.4)	1.1 (0.8)	0.6 (0.4)

[a] Three subjects provided three independent replicates for each experiment

Table 7.4 Statistical analysis results (p-values) from initial surface-to-hand transfer experiments (Riboflavin).

Analysis	Tracer	Surface Type	Surface Loading	Contact Motion	Pressure	Duration	Skin Condition	Contact Number
First contact (ANOVA)								
Transfer efficiency (%)	-------------	p<0.1	**p<0.001** [a]	**p<0.05**	p>0.1	p>0.1	**p<0.001**	-------------
Loading (ug/cm²)	-------------	p>0.1	**p<0.05**	**p<0.05**	p>0.1	p>0.1	**p<0.05**	-------------
First contact, sticky hand excluded (ANOVA)								
Transfer efficiency (%)	-------------	p>0.1	**p<0.001**	p>0.1	p>0.1	p>0.1	**p< 0.001**	-------------
Loading (ug/cm²)	-------------	p>0.1	p<0.1	**p<0.05**	p>0.1	p>0.1	p>0.1	-------------
Repeated contact (Mixed-Effects Model)								
Loading (ug/cm²)	-------------	p>0.1	**p<0.001**	**p<0.001**	p>0.1	p>0.1	**p<0.001**	**p<0.001**
Repeated contact, sticky hand excluded (Mixed-Effects Model)								
Loading (ug/cm²)	-------------	p>0.1	**p<0.001**	**p<0.01**	p>0.1	p<0.1	**p<0.001**	**p<0.001**

[a] **Bold text** indicates the parameter is significant.

Table 7.5 Statistical analysis results (p-values) from refined, follow-up surface-to-hand transfer experiments (Riboflavin and Uvitex).

Analysis	Tracer	Surface Type	Surface Loading	Contact Motion	Pressure [a]	Duration [a]	Skin Condition	Contact Number
First Contact (ANOVA)								
Transfer efficiency (%)	**p<0.05** [b]	**p<0.05**	**p<0.01**	p<0.1	-------------	-------------	p>0.1	-------------
Loading (µg/cm²)	p=0.1	**p<0.05**	**p=0.001**	**p<0.001**	-------------	-------------	p>0.1	-------------
Repeated Contact (Mixed-Effects Model)								
Loading (µg/cm²)	**p<0.01**	p=0.1	**p<0.001**	**p<0.001**	-------------	-------------	**p<0.05**	**p<0.001**

[a] Pressure and duration not included in the follow-up experiments.
[b] **Bold text** indicates the parameter is statistically significant at p<0.05.

Table 7.6 Evidence of importance of factors tested across surface-to-skin transfer experiments.

Parameter	Initial Experiments	Refined Experiments
Tracer	--	●○
Skin Condition	●○	●○
Surface Type	○○	●○
Surface Loading	●○	●●
Contact Motion	●●	●○
Contact Duration	○○	--
Contact Pressure	○○	--
Contact Number	●●	●●

-- not tested
○○ not found to be significant
●○ mixed results or marginally significant at p<0.10
●● significant at p<0.05 in all tests

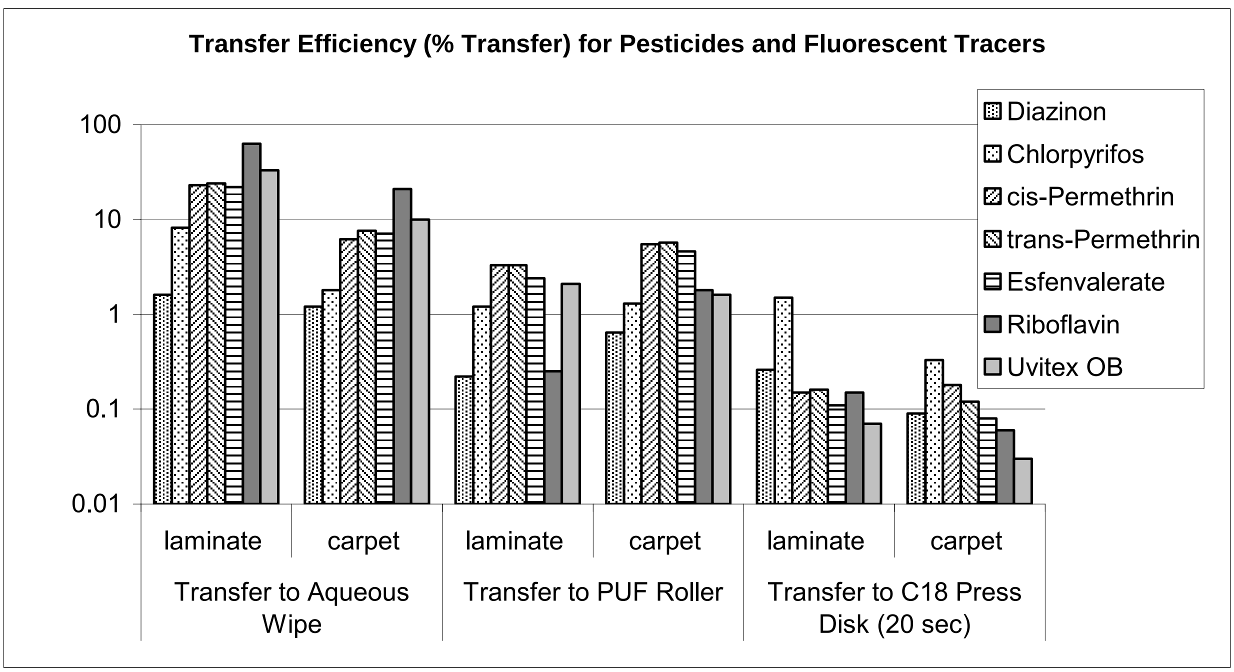

Figure 7.1 Comparison of transfer efficiencies of fluorescent tracers and pesticides from laminate and carpet surfaces to various sampling media.

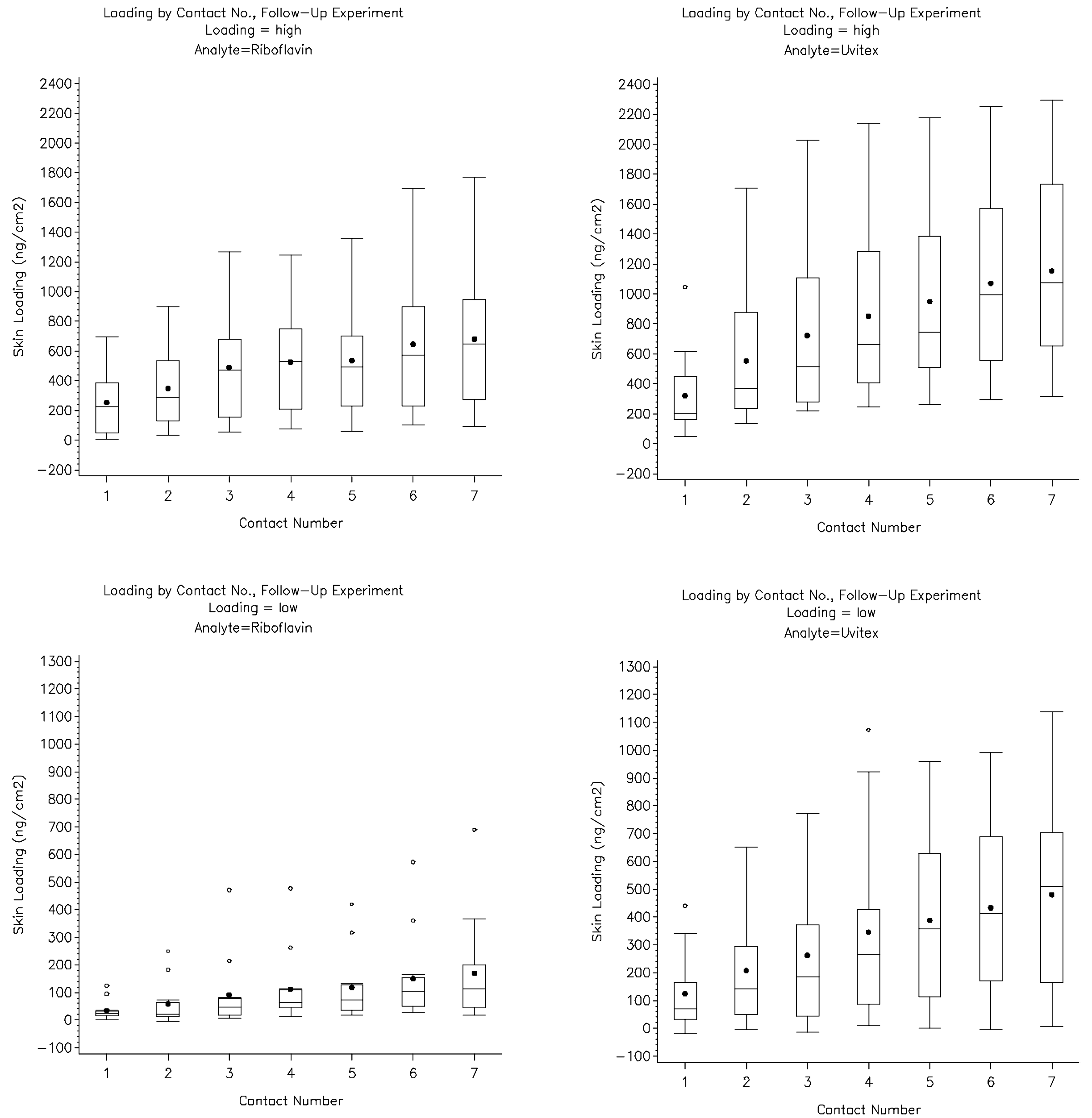

Figure 7.2 Hand loading by contact number, from the refined, follow-up experiments using Riboflavin (left panels) or Uvitex (right panels) with 2 µg/cm² (high) (top panels) or 0.2 µg/cm² (low) (bottom panels) surface loadings. In these particular box-and-whisker plots, means and outliers (below 5th or above 95th percentiles) are represented by dots.

7.2 Measurements of Pesticides on Hands by Wipe and Rinse Methods

Measurements of pesticide residues on children's hands have been performed in the MNCPES, CTEPP, CPPAES, PET, and DIYC studies. Collection efficiencies may vary among studies for a number of reasons. The method of wiping the surfaces of the hand may vary when performed by different researchers or by study participants themselves. Hand rinses may be more effective than hand wipes. Whether the method is a hand wipe or hand rinse, collection efficiency may differ for free pesticide residues versus particle-bound residue. Most of the data presented in this section were collected with hand wipes, except for MNCPES, in which rinses were collected. Both hand wipes and rinses were collected in CPPAES (with mean hand rinse to hand wipe ratios ranging from 4.1 to 7.8 by home). The amount of isopropanol used to collect the hand wipes/ rinses varied by study. A major issue associated with interpreting results of these measurements is the amount of a pesticide on the surface of skin that is never absorbed into the bloodstream. Solvents may extract some of pesticide from top layers of skin, though the extent of extraction will be a function of many factors including pesticide properties.

Methods

In CTEPP, hand wipe samples were collected from 257 preschool children using cotton sponges (SOF-WICK gauze pad; 4" x 4" – 3 ply; Johnson & Johnson) that were pre-cleaned and wetted with 2 mL of 75% isopropanol. The adult caregiver wiped the front and back of both hands of the child. A total of four wipe samples were collected over a 48-hr period (two per day, one before lunch and dinner, before washing hands). Samples were composited (combined) before analysis. The MNCPES hand rinses were collected at home from 102 children on day 1 of the 7-day monitoring period. A technician placed each of the child's hands into a separate zip-closure bag containing 150 mL of isopropanol. Each hand's sample was analyzed separately. The feasibility portion of the PET study collected hand wipes on multiple days from two children after a granular application of diazinon to the lawn by the homeowner. The cotton sponges (SOF-WICK gauze pad; 4" x 4" – 6 ply; Johnson & Johnson) were presoaked with 20 mL of isopropanol. Each child wiped the front and back of each hand. A total of five samples were collected from each child and each was analyzed separately. The CPPAES hand wipe samples were collected from 10 children on multiple days following a professional crack and crevice application of chlorpyrifos. Separate swabs that were wetted with an unreported amount of isopropanol were used to wipe the front and back of each hand. A small number of hand rinse samples were also collected. The DIYC study collected hand wipes on multiple days from three children after a crack and crevice application of diazinon. Each of two gauze pads, pre-wetted with 10 mL of isopropanol, was used to wipe both hands. The two wipes were extracted and analyzed as one sample. In all studies, the surface area of the children's hands was measured.

Results

Table 7.7 summarizes the detection limits for the studies. The median and 95th percentile concentrations are presented in Table 7.8. Individual hand loading measurements are presented in Tables 7.9. Relationships among populations and locations are illustrated in Figures 7.3 to 7.9 and highlighted below.

- In the large observational field studies (Figure 7.3, Table 7.8), the loadings of chlorpyrifos on children's hands measured with rinses in MNCPES were higher than the loadings measured with wipes in the other studies.
- For all compounds, the hand loadings measured with hand wipes in the large observational field studies did not differ substantially (Figure 7.3, Table 7.8).
- Median chlorpyrifos loadings on children's hands (Figure 7.4) were much higher in CPPAES, where homes had recent crack and crevice applications, than in the large observational CTEPP and MNCPES studies.
- Median diazinon loadings on children's hands in the small, pilot-scale PET (lawn application) and DIYC (crack and crevice application) studies were much higher than in the large observational field study CTEPP (Figure 7.4).
- Comparison of hand rinse and hand wipe samples collected from the same participants in CPPAES suggests that hand rinses were more effective at removing residues (Table 7.9).
- Hand rinses may be more efficient than hand wipes at removing chlorpyrifos from the skin, but no information is available on which method better reflects the amount of pesticide that is either absorbed (dermal absorption) or potentially transferred to the mouth (indirect ingestion).
- In the CTEPP study, the median chlorpyrifos hand loadings were higher in NC than OH (at both homes and daycares), suggesting greater chlorpyrifos usage in NC than in OH. Permethrin levels were only slightly higher in NC than in OH (Figure 7.4).
- At residential levels observed in CTEPP, median hand wipe-to-surface loading ratios reach or exceed 1 for the pesticides of interest (Figure 7.5). Please note that floor wipe loadings were measured using an IPA wipe method that was not as efficient as typical wipe methods (Section 4.4).
- A strong relationship is evident in Figure 7.6 between CTEPP hand loadings measured at homes and those measured at daycares for chlorpyrifos (R^2=0.47), diazinon (R^2=0.44), and permethrin (R^2=0.41). The relationship is weak for the degradation product TCPy (R^2=0.03).
- There was a strong relationship between children's hand wipe loadings and adult hand wipe loadings for chlorpyrifos (R^2=0.64; β=0.77), diazinon (R^2=0.77; β=0.81), and permethrin (R^2=0.49; β=0.65) measured in CTEPP (Figure 7.7), despite largely different activity patterns between children and adults.
- Based on regressions of CTEPP hand wipe measurements on either floor dust or floor wipe measurements for chlorpyrifos, diazinon, and permethrin (Figures 7.8 and 7.9), better relationships were observed between hand wipe and floor dust measurements (Figure 7.9) than between hand wipe and floor wipe measurements (Figure 7.8).

Table 7.7 Limits of detection (ng/cm²) for dermal measurements by compound and study.

Study	Sample type	Chlorpyrifos	Diazinon	*c*-Permethrin	*t*-Permethrin
NHEXAS-AZ	Hand wipe	0.004	0.016	-- [a]	--
MNCPES	Hand rinse	0.06	0.08	--	--
CTEPP	Hand wipe	0.003	0.003	0.003	0.003
CPPAES	Hand wipe	NA [b]	--	--	--
CPPAES	Hand rinse	NA [b]	--	--	--
DIYC	Hand wipe	--	0.02	--	--
PET	Hand wipe	--	0.01	--	--

[a] Blank cells indicate that the pesticide was not measured in the study.
[b] Detection limit information unavailable.

Table 7.8 Median and 95[th] percentile values of pesticide hand loadings (ng/cm^2) measured by hand rinse (HR) or hand wipe (HW) in the large observational field studies.

		Chlorpyrifos		Diazinon		*c*-Permethrin		*t*-Permethrin		Cyfluthrin		TCPY		IMP	
Study	Type	P50	P95	P50	P95	P50	P95	P50	P95	P50	P95	P50	P95	P50	P95
NHEXAS-AZ	HW	0.01	0.1	0.015	0.1	-- [a]	--	--	--	--	--	--	--	--	--
MNCPES	HR	0.07	0.3	0.07	0.1	--	--	--	--	--	--	--	--	--	--
CTEPP-NC h [b]	HW	0.02	0.3	0.003	0.1	0.1	1.5	0.1	1.3	0.03	0.4	0.02	0.1	--	--
CTEPP-NC d	HW	0.02	0.1	0.01	0.1	0.1	0.3	0.04	0.3	0.03	0.3	0.01	0.03	--	--
CTEPP-OH h	HW	0.01	0.2	0.003	0.1	0.03	0.8	0.03	0.8	0.03	0.1	0.01	0.03	0.003	0.02
CTEPP-OH d	HW	0.01	0.1	0.003	0.04	0.04	0.6	0.03	0.8	--	--	0.01	0.03	0.003	0.02

[a] Blank cells indicate that the pesticide was not measured in the study.
[b] CTEPP: h = home, d = daycare

Table 7.9 Comparison of chlorpyrifos and diazinon loadings (ng/cm²) on children's hands measured with hand rinse (HR) and hand wipe (HW) methods.

		Pre-Appl [a]		Day 1		Day 3		Day 5		Day 7		Day 9		Day 11		3rd Week	
Study	Participant	HR	HW	HR	HW	HR	HW	HR	HW	HR	HW	HR	HW	HR	HW	HR	HW
CPPAES (chlorpyrifos)	Child 1 (4 yr)	-- [b]	--	--	--	--	--	--	--	0.7	--	--	--	--	--	--	--
	Child 2 (4 yr)	0.53	--	5.2	--	18	--	1.6	--	3.8	--	2.3	--	2.3	--	--	--
	Child 3 (4 yr)	--	--	11	--	2.3	--	--	--	3.8	--	2.6	--	2.6	--	--	--
	Child 4 (2 yr)	0.57	--	--	0.79	--	0.34	--	0.81	1.3	--	--	--	--	0.32	--	21
	Child 5 (4 yr)	0.09	--	--	0.3	--	1.4	--	0.28	--	0.37	1.3	--	--	--	--	0.04
	Child 6 (3 yr)	--	0.57	--	0.36	--	0.67	--	0.35	--	0.68	2.3	--	--	0.08	--	0.5
	Child 7 (3 yr)	2.3	--	--	0.17	--	0.25	--	0.22	--	0.51	--	--	--	0.39	--	0.44
	Child 8 (3 yr)	0.21	--	--	0.1	--	0.01	--	0.02	--	0.02	0.26	--	--	0.02	--	0.02
	Child 9 (4 yr)	--	0.07	--	0.08	--	--	--	0.09	--	--	0.74	--	--	0.05	--	0.09
	Child 10 (4 yr)	--	0.43	--	0.43	--	0.68	--	0.5	--	0.36	1.8	--	--	0.27	--	0.41
PET (diazinon)	Child 1 (6 yr)	--	0.01	--	0.6 [c]	--	0.9	--		--		--	0.2	--	--	--	0.2
	Child 2 (10 yr)	--	0.7	--	0.7 [c]	--	0.6	--		--		--	0.1	--	--	--	0.2
DIYC (diazinon)	Child 1 (2 yr)	--	0.06 [d]	--	--	--	--	--	0.14 [d e] 0.08 [e f]	--	0.13 [g] 0.21 [f g]	--	0.19 [h] 0.20 [h]	--	--	--	--
	Child 2 (3 yr)	--	--	--	--	--	0.03	--	<MDL [f]	--	--	--	--	--	--	--	--
	Child 3 (1 yr)	--	--	--	--	--	0.10 0.10 [b]	--	0.11	--	0.13	--	--	--	--	--	--

[a] Pre-Appl, Pre-application; [b] Blank cells (--) indicate no measurement; [c] Day 0; [d] Collected from only the right hand of the child; [e] Day 4; [f] Two hand wipe samples were collected on that day: one before breakfast and the other one before supper or bedtime; [g] Day 6; [h] Day 8; [f] <MDL, less than method detection limit.

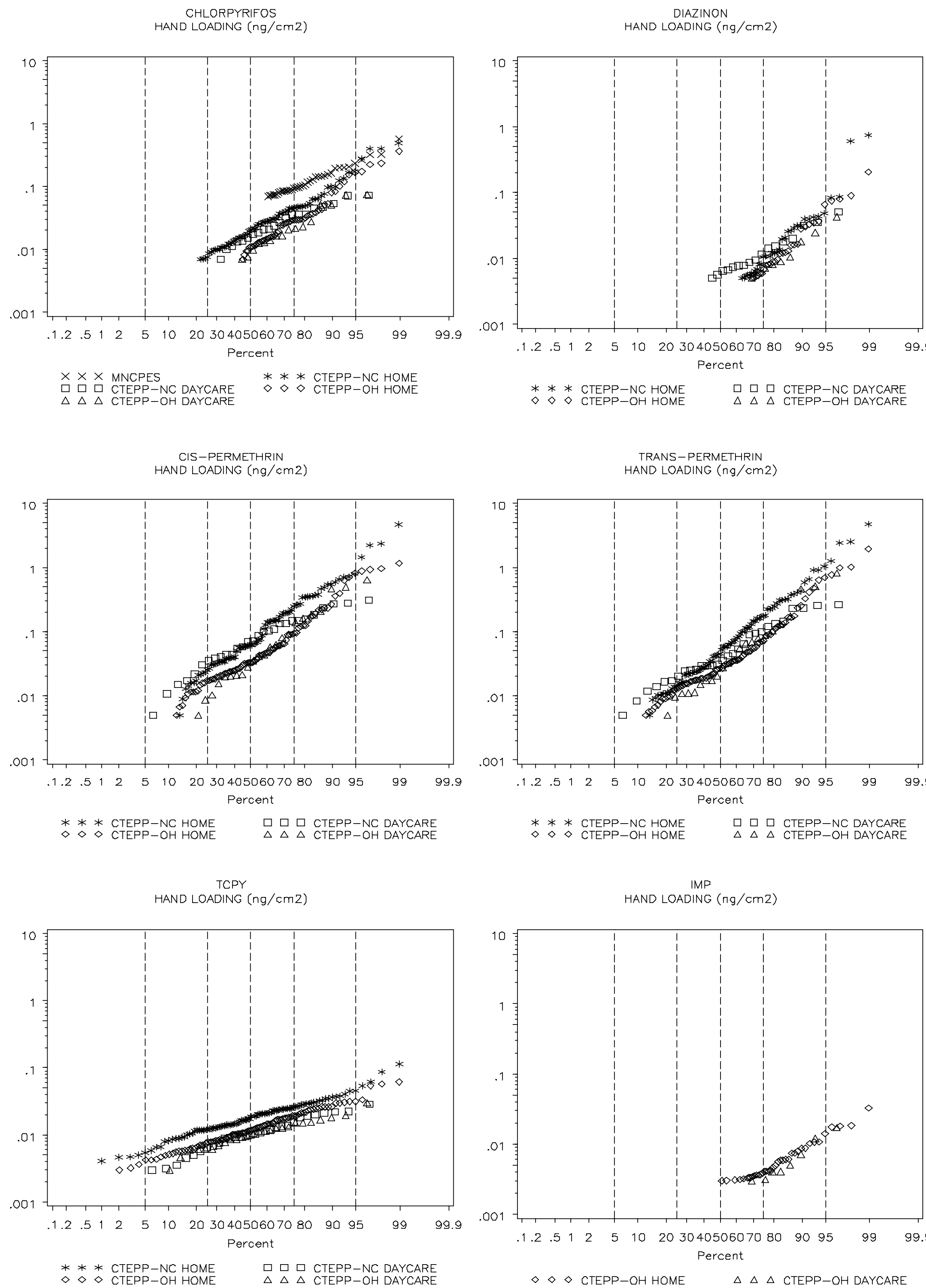

Figure 7.3 Log probability plots of hand loadings (MNCPES data are hand rinses, all others are hand wipes).

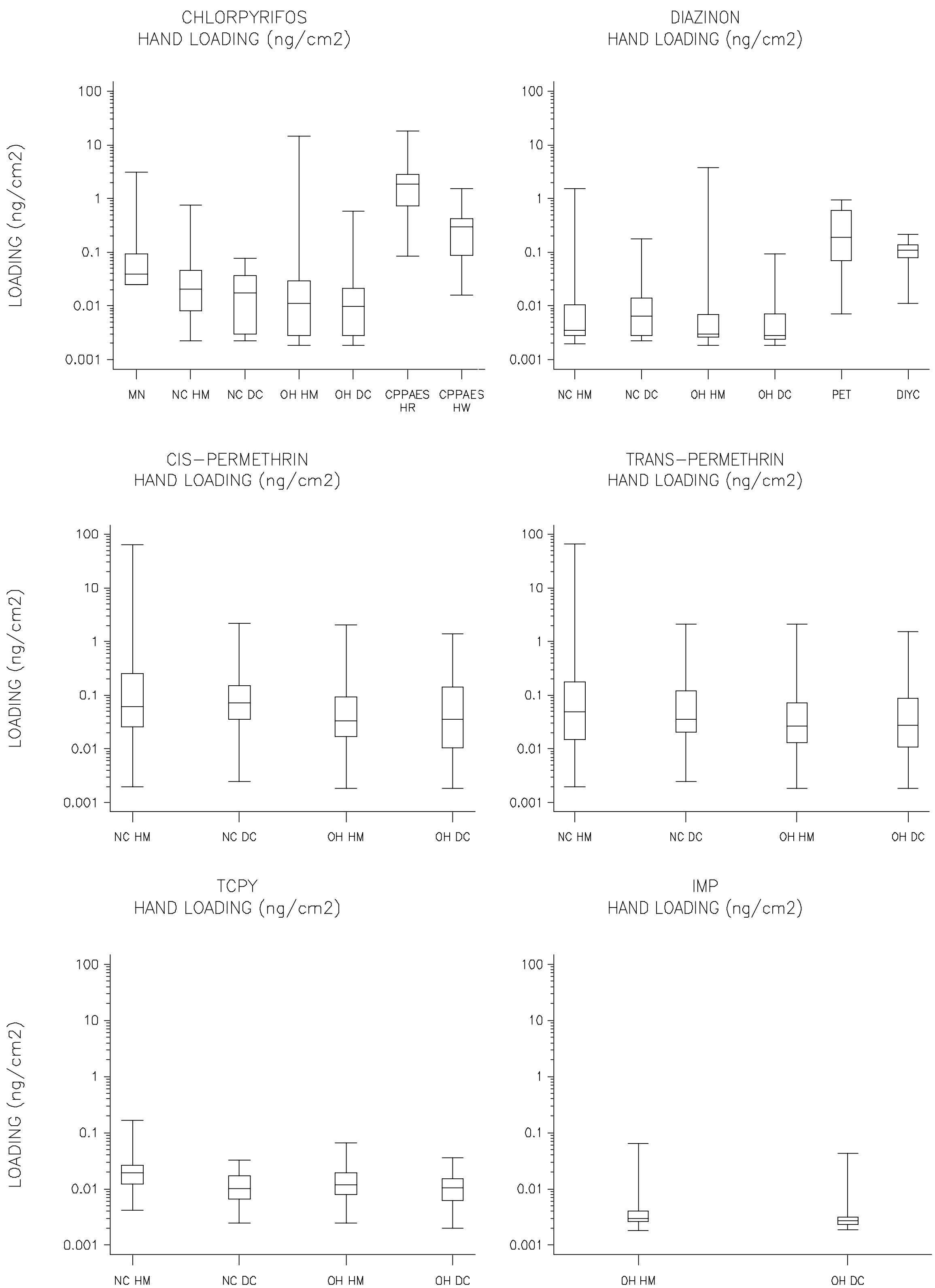

Figure 7.4 Comparison of hand loadings across studies. MNCPES data are hand rinses, CPPAES includes both hand rinses (HR) and hand wipes (HW), all others are hand wipes.

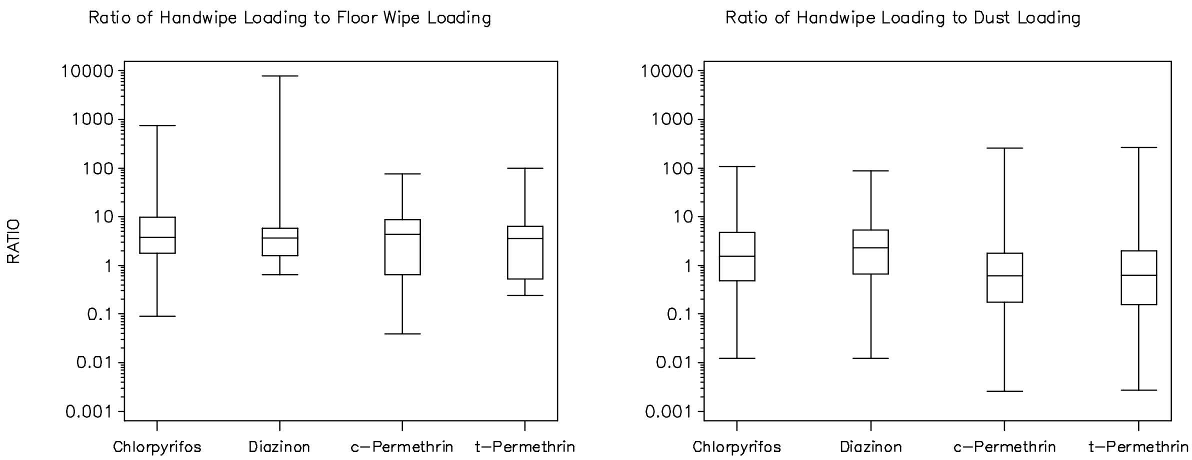

Figure 7.5 Ratios of hand wipe loading to floor wipe loading (left panel) and hand wipe loading to dust loading (right panel) for pesticides in CTEPP.

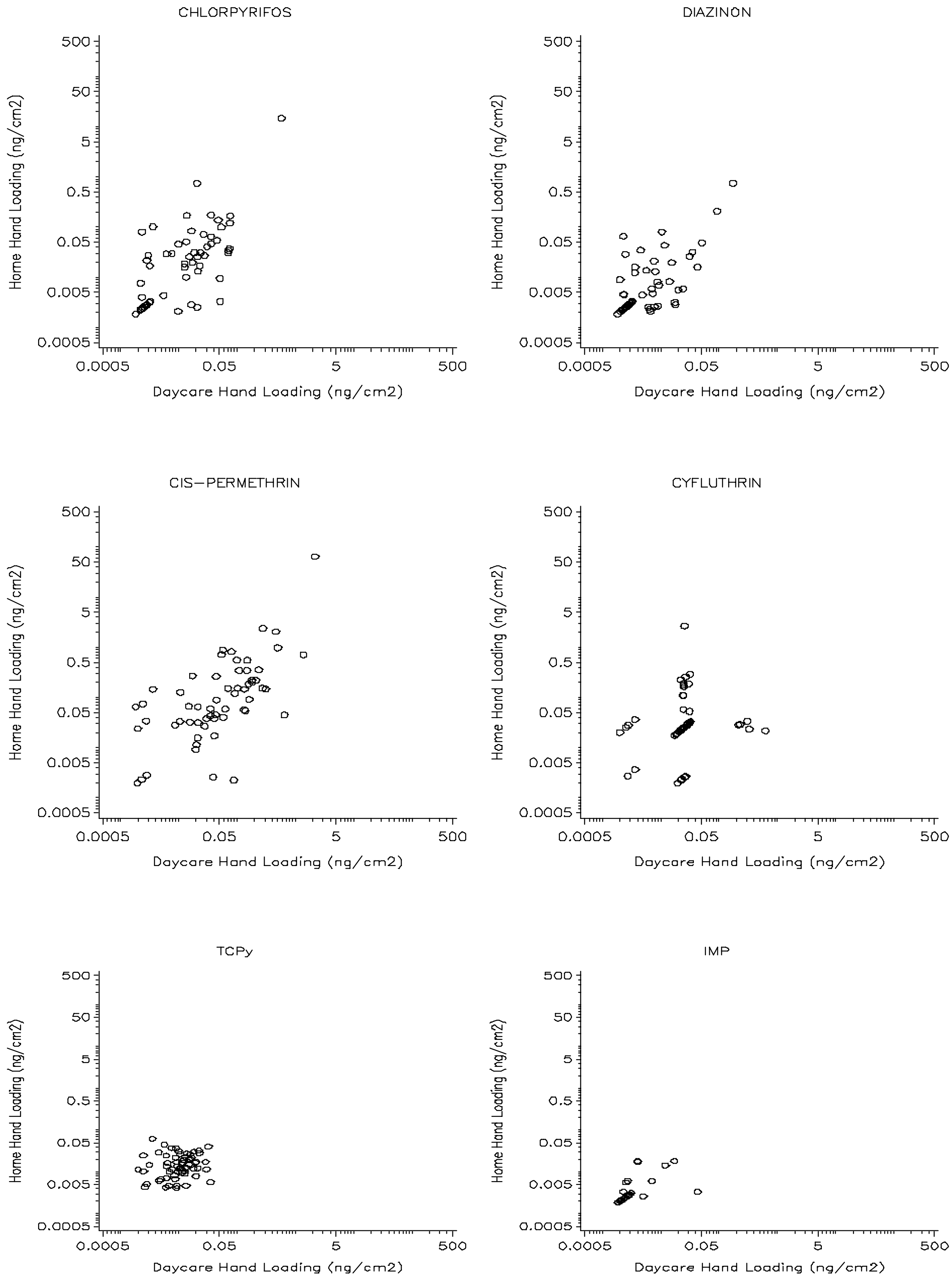

Figure 7.6 Relationship between children's hand loadings measured at CTEPP homes and daycares. Coefficients of determination (R^2) and slopes (β) for log (base 10) values: chlorpyrifos (R^2=0.47; β=0.91), diazinon (R^2=0.44; β=0.81), permethrin (R^2=0.41; β=0.72), cyfluthrin (R^2=0.02; β=0.19), TCPy (R^2=0.03; β=0.54), and IMP (R^2=0.31; β=0.54).

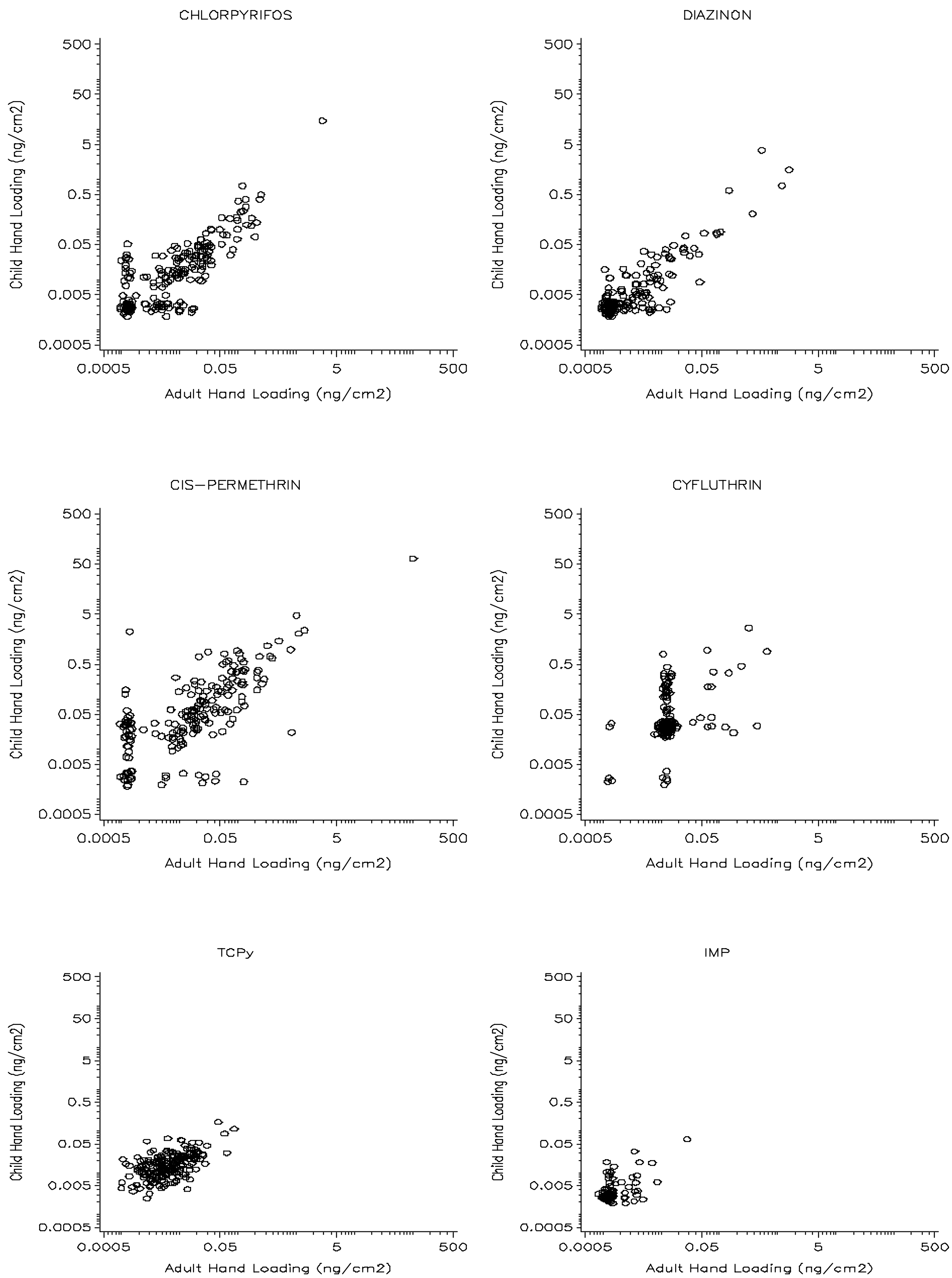

Figure 7.7 Relationship between hand loadings among children and adults in CTEPP. Coefficients of determination (R^2) and slopes (β) for log (base 10) values: chlorpyrifos (R^2=0.64; β=0.77), diazinon (R^2=0.77; β=0.81), permethrin (R^2=0.49; β=0.65), cyfluthrin (R^2=0.20; β=0.61), TCPy (R^2=0.30; β=0.47), and IMP (R^2=0.28; β=0.63).

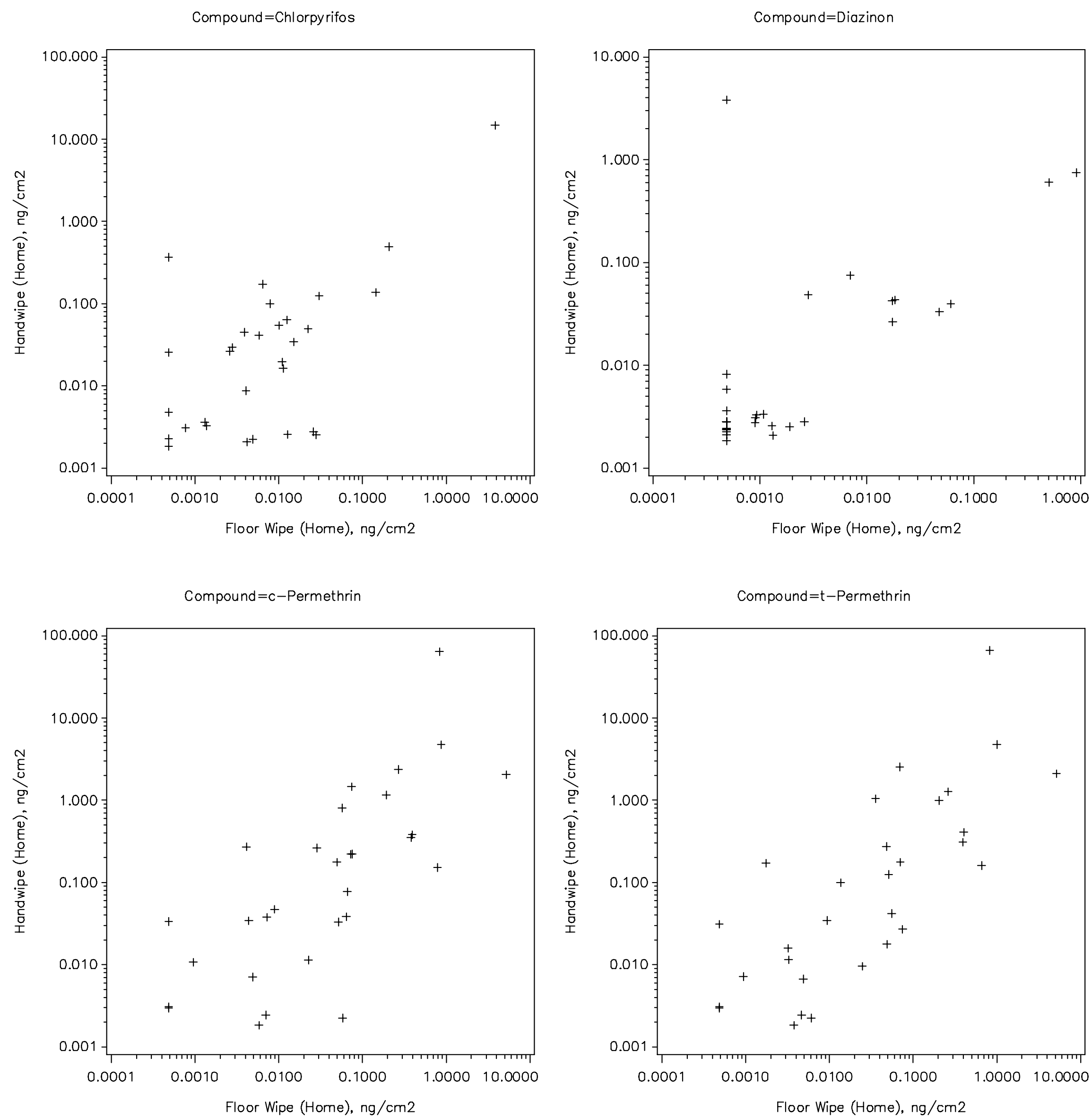

Figure 7.8 Relationship between hand wipe measurements and floor wipe measurements in CTEPP. Coefficients of determination (R^2) and slopes (β) for log (base 10) handwipe loadings regressed on log (base 10) floor wipe loadings are as follows: chlorpyrifos (R^2=0.38; β=0.64), diazinon (R^2=0.46; β=0.64), *cis*-permethrin (R^2=0.54; β=0.78), and *trans*-permethrin (R^2=0.60; β=0.82).

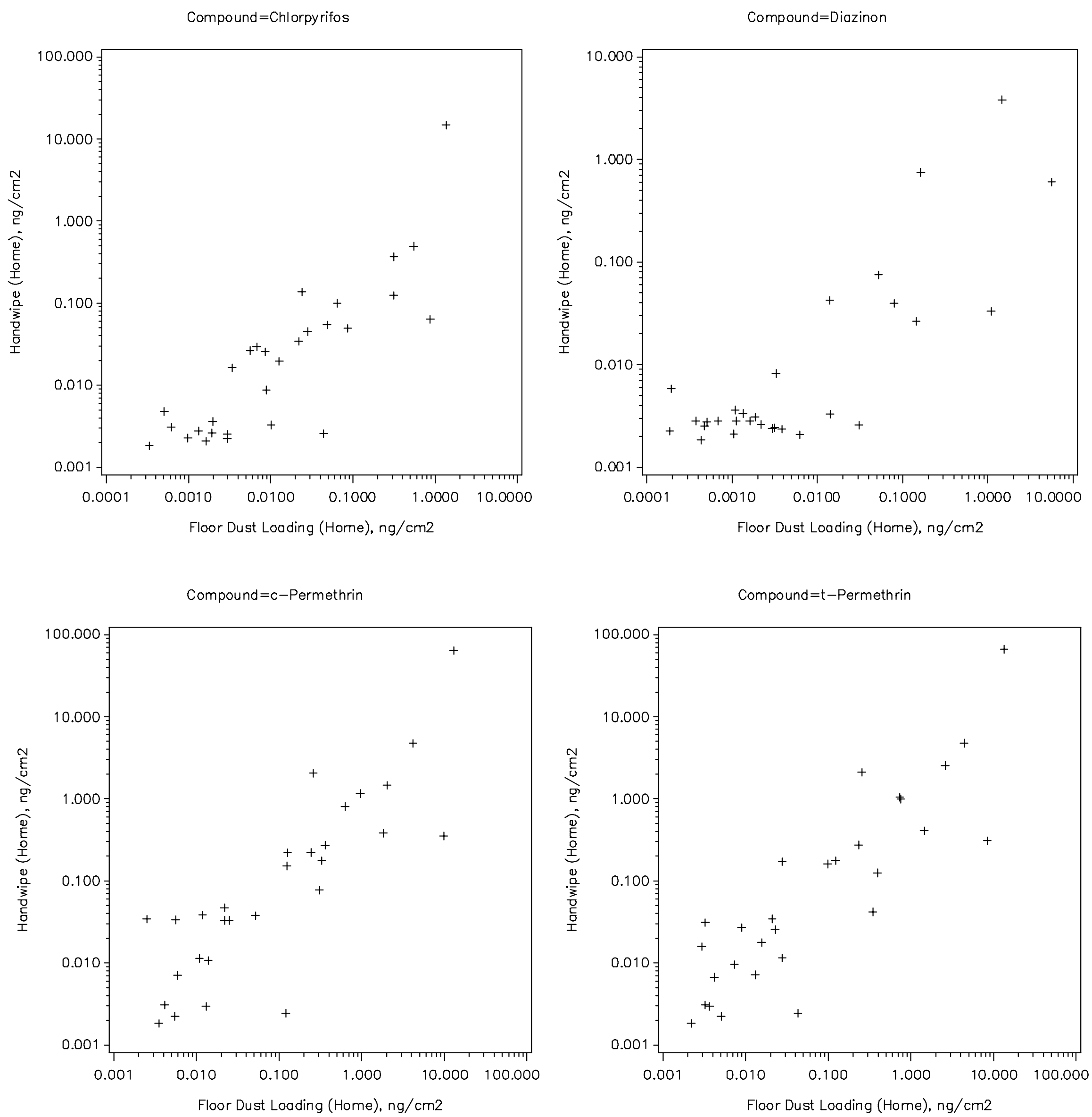

Figure 7.9 Relationship between hand wipe measurements and floor dust measurements in CTEPP. Coefficients of determination (R^2) and slopes (β) for log (base 10) handwipe loadings regressed on log (base 10) floor dust loadings are as follows: chlorpyrifos (R^2=0.71; β=0.78), diazinon (R^2=0.69; β=0.61), *cis*-permethrin (R^2=0.72; β=0.86), and *trans*-permethrin (R^2=0.76; β=0.88).

7.3 Measurements with Cotton Garments

The US EPA Office of Pesticide Programs uses a transfer coefficient approach to assess children's residential exposures to pesticides. The transfer coefficient approach was developed to assess occupational exposure in an agricultural setting, using empirically-derived dermal transfer coefficients to aggregate the mass transfer associated with a series of contacts with a contaminated medium. Dermal exposure sampling using a surrogate-skin technique such as a patch sampler or a whole-body garment sampler is conducted simultaneously with surface sampling for a specific activity, and a dermal transfer coefficient is then calculated. This transfer coefficient can then be used to estimate exposure for a similar activity by collecting only surface samples (Fenske, 1993), assuming that transfer is unidirectional (from surface to skin) and linear with time. Only limited research has been conducted to develop transfer coefficients for children in residential and daycare settings. Data were collected in the Daycare study (Cohen Hubal *et al.*, 2006), JAX, and CPPAES with cotton garments. The data are presented in Tables 7.10 to 7.12 and Figures 7.10 to 7.12.

- Comparison of mean chlorpyrifos loadings on socks in JAX and CPPAES (Table 7.10) with surface loadings (Table 4.4) suggests that higher surface loadings do not necessarily correspond to higher sock loadings across studies. It also suggests that perhaps activity levels influence transfer.
- The median chlorpyrifos loading on socks after a three-hour period in CPPAES was only about twice as high as the median loading after a one-hour period in the same environment (Table 7.10). This suggests that transfer to socks may not be linear with time, and again points towards the importance of activity levels.
- Bodysuit esfenvalerate loadings in the Daycare study were typically higher in the mornings, corresponding to higher group activity levels at that time (Figure 7.10). Depletion of surface loadings by morning activities is unlikely but was not tested.
- Multiple regression analysis of Daycare data suggests that body section (arms, legs, lower torso, and upper torso), relative activity level, and age group are all important predictors of bodysuit loadings (Table 7.11).
- The statistical significance of activity (Table 7.11), even when controlling for age group, suggests that activity level within age groups may be as important as age-related differences.
- The between- and within-person variability (GSD) in dermal exposures in the daycare setting (Table 7.12) is similar to what has been reported in agricultural/industrial settings.
- High within-person variability (compared to between-person variability) in cotton garment loadings (Table 7.12) suggests that factors related to changing environmental conditions and to differences in structured activities may be more important than child-specific characteristics.
- The relative standard deviations (%) of esfenvalerate loadings on cotton garment sections (Figure 7.11) were typically higher among infants during the morning sessions and among preschoolers during the afternoon sessions. This suggests that the structured

activities may have had a stronger influence on the observed variability than surface loadings in the respective rooms.

- Infants had 1.5 times as many hand wipe values (36%) above the MDL as preschool children (24%), consistent with the higher bodysuit loadings, perhaps reflecting greater contact with the floor surface. Figure 7.12 illustrates that among the hand wipes above the MDL, infants typically had higher loadings, with greater variability.
- The association between hand wipe samples above the limit of detection and average body suit loadings was statistically significant (Spearman rho = 0.54, $p < 0.05$, data not presented).

Table 7.10 Pesticide loading (ng/cm²) on cotton garments worn by children in three studies.

Study	Compound	Garment Type/Section	Age	N	% Det	MDL	Mean	SD	P50	P95
Daycare	Esfenvalerate	Arms	9-13 mo	26	92	0.01	0.12	0.18	0.06	0.42
			24-38 mo	28	100	0.01	0.1	0.09	0.07	0.23
		Legs	9-13 mo	26	100	0.01	0.27	0.21	0.22	0.75
			24-38 mo	28	93	0.01	0.2	0.41	0.1	0.46
		Lower Torso	9-13 mo	26	100	0.01	0.28	0.23	0.18	0.73
			24-38 mo	28	100	0.01	0.2	0.18	0.12	0.52
		Upper Torso	9-13 mo	26	96	0.01	0.05	0.05	0.03	0.12
			24-38 mo	28	100	0.01	0.09	0.13	0.05	0.16
CPPAES	Chlorpyrifos	Bottom	2-5 yr	7	100	0.01	0.58	0.37	0.7	1.0
		Knee	2-5 yr	14	100	0.01	0.62	0.4	0.7	1.2
		Leg	2-5 yr	14	100	0.01	0.38	0.27	0.45	0.8
		Sock (1 hr)	2-5 yr	14	100	0.01	8.6	14	3.5	53
		Sock (3 hr)	2-5 yr	14	100	0.01	10.8	13	7.6	30
JAX	Chlorpyrifos	Sock	4-6 yr	9	100	0.4	2.3	1.3	2.2	5.1
	Diazinon	Sock	4-6 yr	9	33	0.08	NC	NC	<0.08	1.8
	Esfenvalerate	Sock	4-6 yr	9	22	0.28	NC	NC	<0.28	2.6
	Cyfluthrin	Sock	4-6 yr	9	0	0.24	NC	NC	<0.24	<0.24
	cis-Permethrin	Sock	4-6 yr	9	44	0.8	NC	NC	<0.8	128
	trans-Permethrin	Sock	4-6 yr	9	100	0.2	23.6	59	1.44	180
CHAMACOS	Chlorpyrifos	Union Suit	6-10 mo	10	100	0.001	0.026	0.025	0.019	0.095
			21-27 mo	10	100	0.001	0.016	0.008	0.015	0.025
		Sock	6-10 mo	9	89	0.05	0.18	0.10	0.17	0.37
			21-27 mo	10	90	0.05	0.28	0.18	0.24	0.64
	Diazinon	Union Suit	6-10 mo	10	100	0.001	0.017	0.012	0.014	0.043
			21-27 mo	10	100	0.001	0.052	0.13	0.009	0.42
		Sock	6-10 mo	9	78	0.02	0.099	0.094	0.070	0.29
			21-27 mo	10	90	0.02	0.50	1.1	0.13	3.5
	Esfenvalerate	Union Suit	6-10 mo	10	10	0.02	NC	NC	<0.02	0.038
			21-27 mo	10	10	0.01	NC	NC	<0.01	0.047
		Sock	6-10 mo	9	11	0.25	NC	NC	<0.25	1.9
			21-27 mo	10	10	0.25	NC	NC	<0.25	2.3
	Cyfluthrin	Union Suit	6-10 mo	10	10	0.07	NC	NC	<0.07	1.1
			21-27 mo	10	0	0.04	NC	NC	<0.04	<0.04
		Sock	6-10 mo	9	0	2.5	NC	NC	<2.5	<2.5
			21-27 mo	10	10	2.5	NC	NC	<2.5	14
	cis-Permethrin	Union Suit	6-10 mo	10	100	0.001	0.19	0.11	0.18	0.41
			21-27 mo	10	100	0.001	0.96	2.4	0.16	7.9
		Sock	6-10 mo	9	100	0.02	2.0	2.8	1.1	8.7
			21-27 mo	10	100	0.02	6.2	13	1.8	43
	trans-Permethrin	Union Suit	6-10 mo	10	100	0.001	0.18	0.35	0.088	1.2
			21-27 mo	10	100	0.001	0.96	2.6	0.059	8.4
		Sock	6-10 mo	9	100	0.02	2.6	2.4	1.9	7.7
			21-27 mo	10	100	0.02	10	22	2.0	71

NC, Not calculated

Table 7.11 Results of multiple linear regression modeling of measured bodysuit pesticide loading (ng/cm²/sec) from data collected in the daycare study.

Effect	Level	Estimate	p-Value
Intercept	intercept	-1.43	<0.0001
Bodysuit Section	arms	0.46	<0.0001
	legs	1.05	
	lower torso	1.35	
	upper torso	0	
Visit	first	0.87	0.0006
	second	0.31	
	third	0	
Session	am	0.44	0.0006
	pm	0	
Activity Level	high	1.36	<0.0001
	middle	0.65	
	low	0	
Classroom	infant	0.38	0.0386
	preschool	0	

Table 7.12 Estimates of between- and within-person variability for loading on individual bodysuit sections.

Statistic	Arms	Upper	Legs	Lower
Between-person variance (logged)	0.26	0.04	0.67	0.37
Within-person variance (logged)	0.76	0.76	1.02	0.59
Intraclass Correlation Coefficient	0.25	0.05	0.40	0.39
GSD, between	1.7	1.2	2.3	1.8
GSD, within	2.4	2.4	2.7	2.2

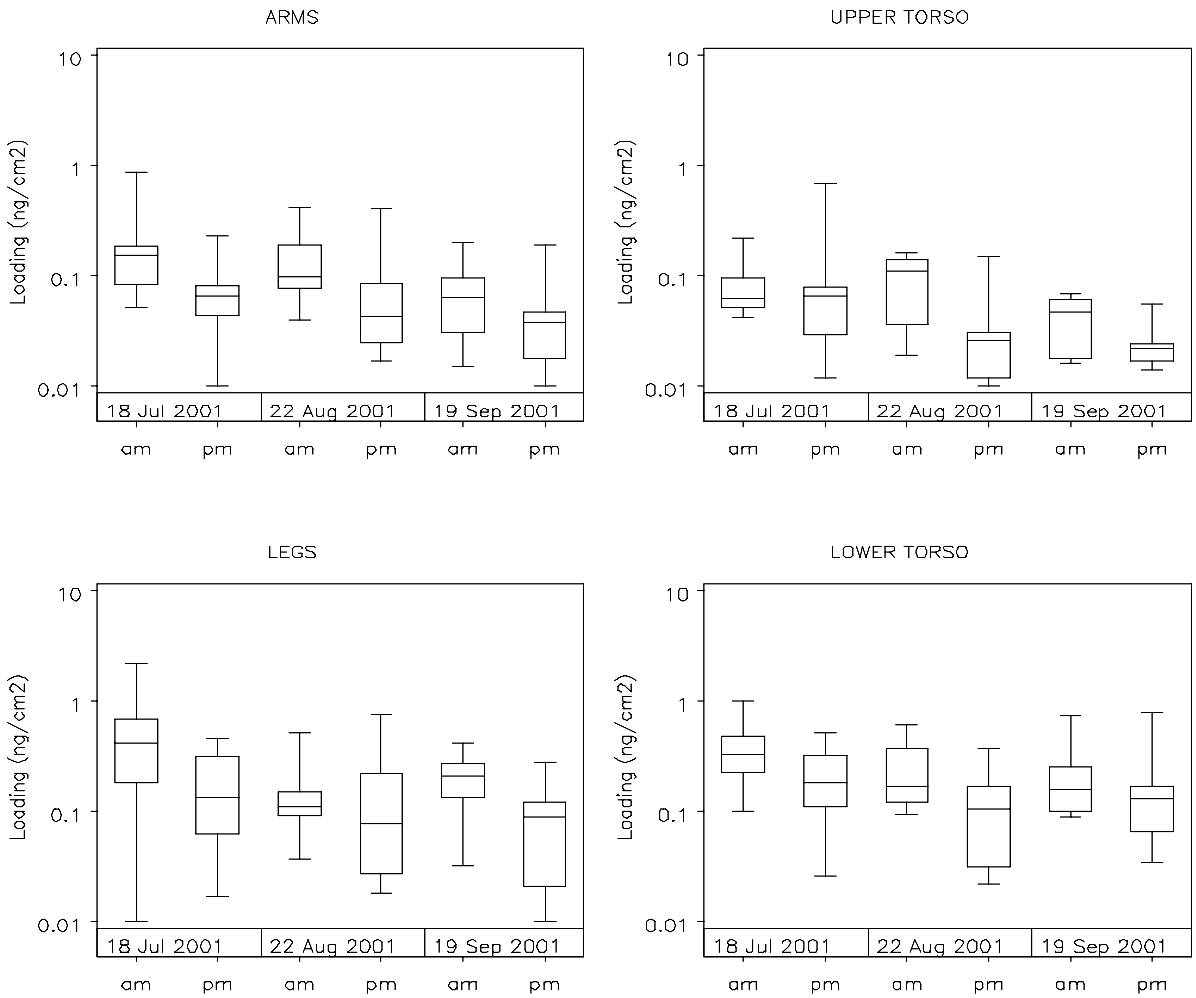

Figure 7.10 Bodysuit section loadings (ng/cm²) by monitoring period from the Daycare study.

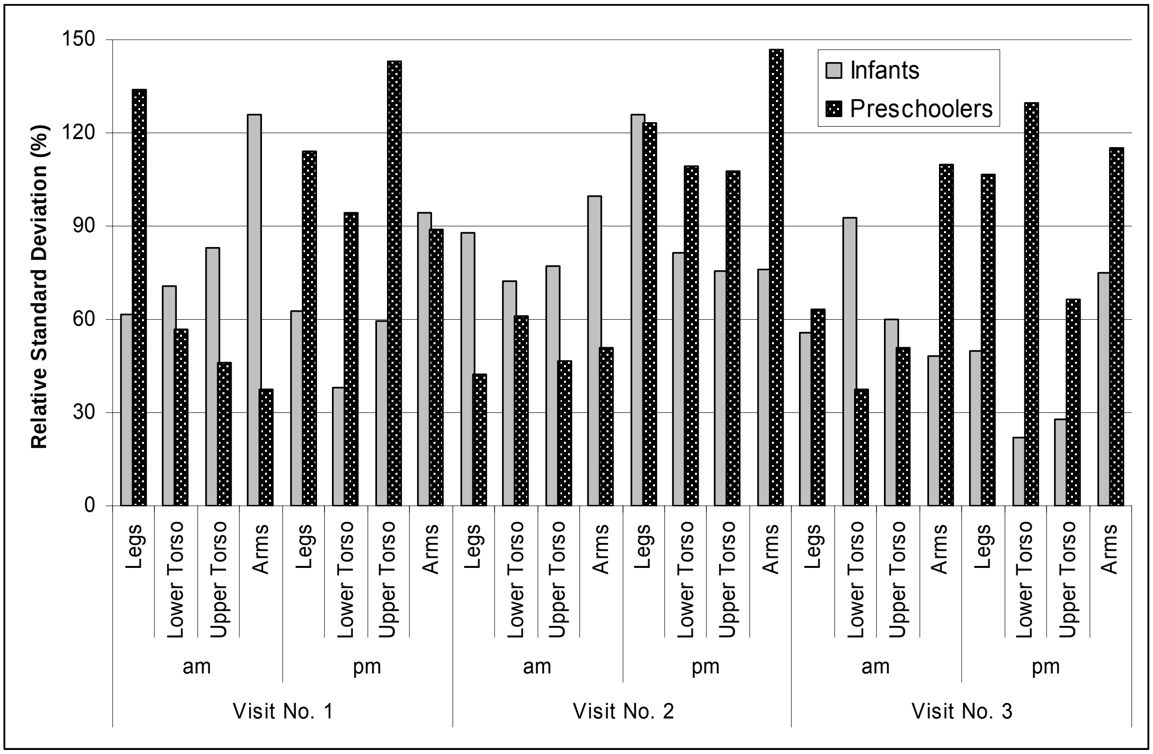

Figure 7.11 Relative standard deviations of esfenvalerate loadings on cotton garment sections among infants and preschoolers in the Daycare study.

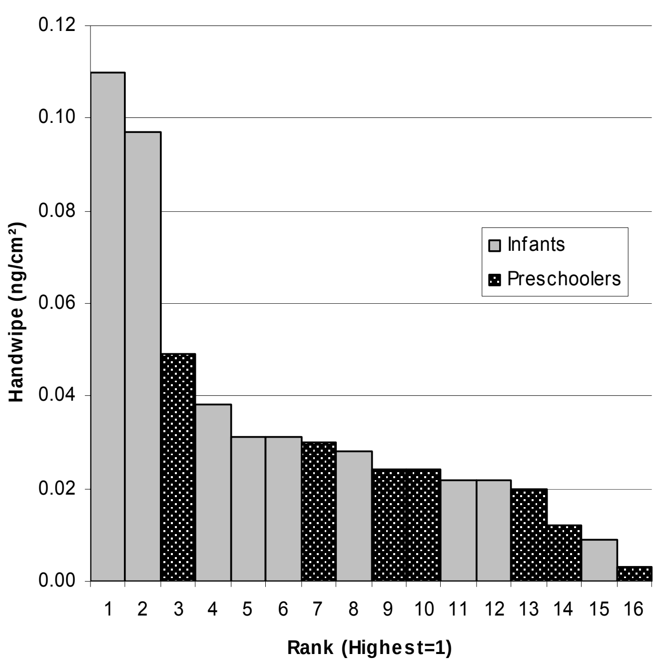

Figure 7.12 Handwipe loadings (ng/cm²) above method detection limit among infants and preschoolers in the Daycare study. Values are sorted in descending order, illustrating that the highest loadings were typically from infants and the lowest typically from preschoolers.