3.0 AIR CONCENTRATION MEASUREMENTS

3.1 Introduction and Data Availability

Children are exposed to residential pesticides via the ingestion, dermal, and inhalation routes. Of these routes, inhalation is the best characterized and requires measurements that are simple to collect in field studies. Estimating absorption via inhalation relies on measured airborne chemical concentrations and on relatively few default exposure factor assumptions, such as the inhalation rate and time spent in specific locations. Since indoor pesticide concentrations are typically higher than outdoor concentrations, and since young children spend the majority of their time indoors, indoor concentrations account for the bulk of their inhalation exposure.

Absorption via the inhalation pathway involves the uptake of vapors and particle-bound residues present in the air. It is generally assumed that inhaled vapors will be readily absorbed across the alveolar membrane into the bloodstream (at least for soluble compounds). Particle-bound residue may vary in size and composition, both of which may influence thoracic penetration and affect absorption. Inhaled particle-bound contaminants trapped in upper airway (nasal and upper lung) mucosa may also be subsequently ingested.

The methods for measuring of airborne pesticide concentrations are well-developed and easily implemented indoors and outdoors using stationary or personal samplers. The methods involve collecting gases and/or particle-bound residues onto filters and sorbent media (the two are combined so that no distinction is made between gases and particle-bound residues). Stationary samplers are typically placed adjacent to treated areas and/or in the location where the participant spends the most time. Samplers may be placed at several locations throughout the home to investigate the spatial distribution of pesticides. Stationary samplers are located at specified heights above the floor to represent the assumed breathing area of the study participants. Personal samplers are worn by the study participants near the breathing zone. Either type of sampler may be modified with a size selective inlet to exclude specific particle size fractions. Sampling media vary but often consist of a pre-filter in tandem with a sorbent composed of polyurethane foam (PUF) or polymeric resin beads (*e.g.,* XAD).

The sampling approaches and methods for each study are described in Table 3.1. Since air sampling techniques are fairly standardized, the methods are consistent across studies. In the large observational field studies, air samples were collected over multiple days for reasons that included reducing measurement error due to day-to-day variability, improving detection limits, and reducing costs associated with changing and analyzing filters. The smaller, focused studies typically employed multiple, consecutive 24-hour sampling periods to capture temporal variability. Personal sampling was attempted in only one study, MNCPES, but compliance issues were noted.

3.2 Pesticide Presence

All pesticides included in this report have been used in residential settings. Because of the potentially long persistence of some pesticides in the indoor environment (Gurunathan *et al.,* 1998), they may be detected even in the absence of a recent application. Detection frequencies for indoor and outdoor samples are presented graphically in Figure 3.1. While detection frequency corresponds inversely to the limit of detection (LOD), the LOD for each compound is relatively consistent across the large observational field studies. The exception to this is the NHEXAS-Arizona study, which employed a collection method with a relatively small sample volume, resulting in a higher LOD. The LODs for each pesticide by study are presented in Table 3.2.

- Detection limits (Table 3.2) varied by as much as an order of magnitude across studies. Within studies, detection limits were similar for organophosphate and pyrethroid insecticides. Detection limits are influenced by sample volume (Table 3.1). For example, the much lower detection limits for chlorpyrifos and diazinon in MNCPES compared to NHEXAS-AZ reflects the much larger volume sampled in MNCPES.

- The compounds most frequently detected in indoor air (Figure 3.1) were the organophosphate (OP) insecticides chlorpyrifos, (typically > 90%) and diazinon (typically > 75%), followed by the pyrethroid insecticide permethrin (typically > 50%).

- The insecticides most frequently detected in outdoor air (Figure 3.1) were also chlorpyrifos and diazinon, but the detection frequencies were lower and more variable across studies.

- Chlorpyrifos was detected at a high frequency (Figure 3.1) even in those studies conducted after its indoor residential use was restricted (JAX and CHAMACOS).

- The pesticide degradation products of chlorpyrifos and diazinon, TCPy and IMP, respectively, were frequently detected in air samples collected in CTEPP (Figure 3.1); none of the other studies included these as target analytes.

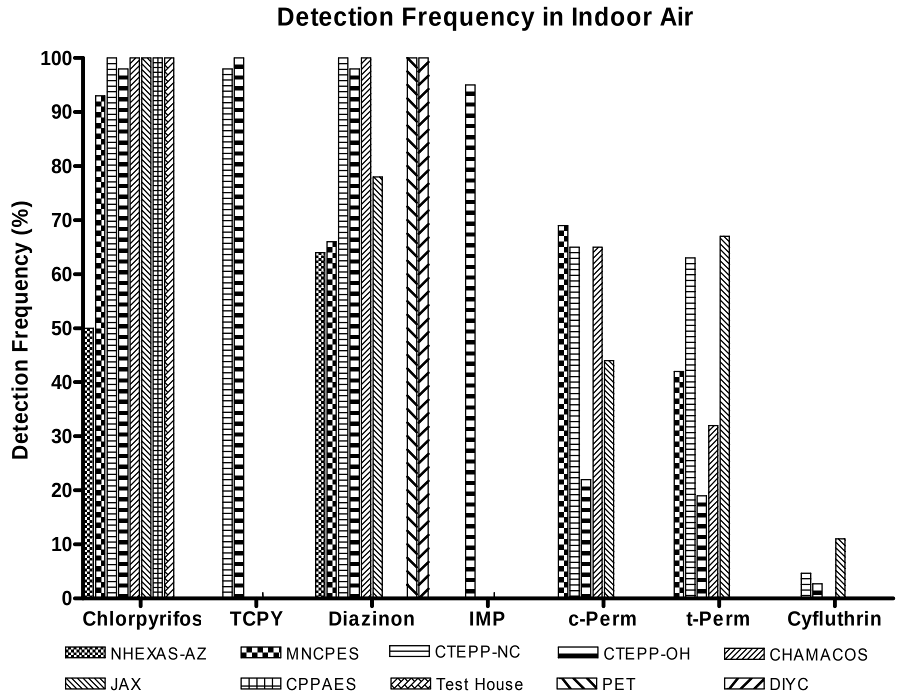
Table 3.1 Summary of air sample collection methods.

Study	Samples Collected	Cohort Size	Sampling Location	Sampling Device	Device Details	Sample Volume	Collection Frequency	Collection After Pesticide Use	Relevant Analytes
NHEXAS-AZ	Indoor	14	Home	Pumps w/ 10 µm inlet, PUF and Teflon-coated glass filters	Intermittent sampling (total of 12 h over 3 d)	Approx 3 m^3 (4 L/min for 12 hr)	Integrated 3-day monitoring period	No	Chlorpyrifos, Diazinon, Malathion
MNCPES	Personal Indoor Outdoor	70 97 52	Home	Pumps w/ XAD cartridge and quartz filter	Backpack carrying case for personal, sound-proof enclosure	Approx 10.8 m^3 (1.25 L/min for 144 hr)	Continuous, Days 1-7, integrated	No	Chlorpyrifos, Diazinon, Malathion, Atrazine
CTEPP	Indoor Outdoor	257	Home and Daycare	Pumps w/ 10 µm inlet, quartz fiber filter and XAD-2 cartridge	Indoor: Styrofoam box w/ cooling fan; Outdoor: plastic dog house. 75 cm height.	Approx 12 m^3 (4 L/min for 48 hr)	One 48-hr sample	No	OPs & Pyrethroids incl. Chlorpyrifos, Diazinon, and Permethrin
JAX 2001	Indoor Outdoor	9	Home	Constant-flow battery powered pump w/ PUF cartridge	Breathing-zone height indoor, 1.5 m height outdoor	Approx 5.5 m^3 (3.8 L/min for 24h)	One 24-hr sample	Yes, indoor	OPs & Pyrethroids incl. Chlorpyrifos, Diazinon, and Permethrin
CHAMACOS	Indoor Outdoor	20	Home	Sampling pump with PUF cartridge	Tamper-resistant box	Approx. 3.6 m^3 (2.5 L/min for 24 hr)	One 24-hr sample	No	OPs & Pyrethroids incl. Chlorpyrifos, Diazinon, and Permethrin
CPPAES	Indoor	10	Home	Harvard Sampler w/ PM_{10} inlet, cotton filter impregnated w/ activated carbon	Placed in room most frequented by child, approx 1 m high.	Approx.14 m^3 (24h) and 29 m^3 (48h)	Four 24-hr samples on days 0-3; four 48-hr samples days 3-11	Yes, indoor	Chlorpyrifos
Test House	Indoor	1	Test House	Low volume pump w/PUF	Multiple rooms	Approx 5 m^3 (3.5 L/min for 24 hr)	Time series over 21 days	Yes	Chlorpyrifos
PET Pilot Study	Indoor	6	Home	Low volume pump w/PUF	Living room and child's bedroom	Approx 5 m^3 (3.5 L/min for 24 hr)	24-hr samples: Pre-application and days 1, 2, 4, & 8 post-application	Yes, lawn application	Diazinon
DIYC	Indoor Outdoor	3	Home	Pump w/XAD	Placed in room most frequented by child,	Approx. 11.5 m^3 (8 L/min for 24 hr)	One pre- and six post-application measurements	Yes, indoor (2 professional, 1 resident)	Diazinon

Table 3.2 Limits of detection (ng/m³) for air samples by compound and study.

Compound	Chlorpyrifos	Diazinon	*cis*-Permethrin	*trans*-Permethrin	Cyfluthrin	TCPy	IMP
NHEXAS-AZ	3.2	2.1	--[a]	--	--	--	--
MNCPES	0.10	0.10	0.09	0.09	--	--	--
CTEPP NC	0.09	0.09	0.09	0.09	0.87	0.09	0.09
CTEPP OH	0.09	0.09	0.39	0.33	0.87	0.09	0.09
JAX	1.0	0.4	1.0	1.0	1.2	--	--
CHAMACOS	0.3	0.3	0.6	0.6	7.0	--	--
CPPAES	2.0	--	--	--	--	--	--
DIYC	--	1.2	--	--	--	--	--
PET	--	1.0	--	--	--	--	--

[a] Blank cells (--) indicate that the pesticide or metabolite was not measured in the study.



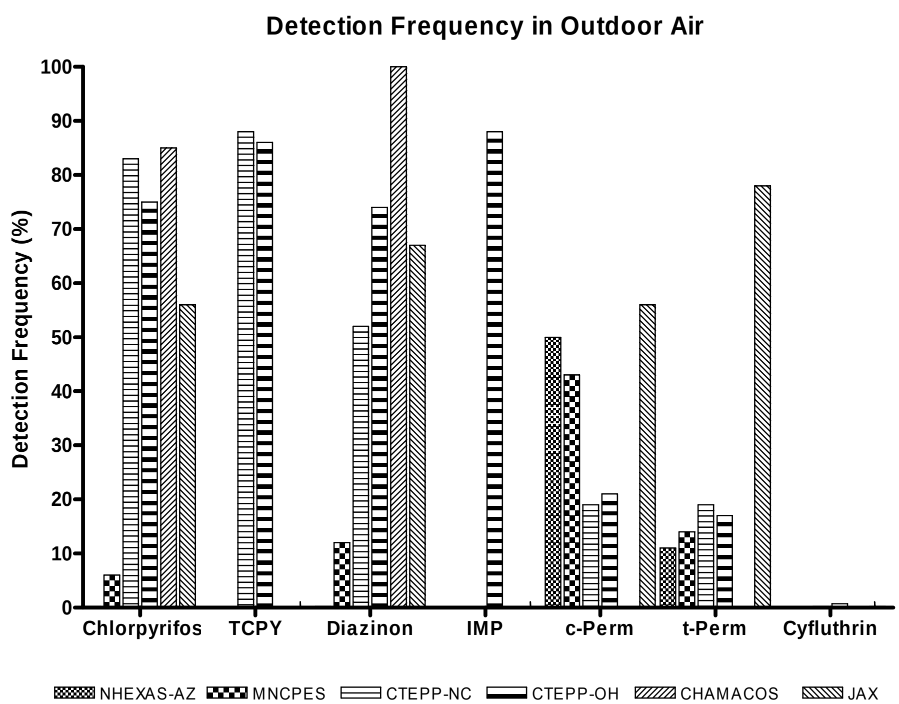


Figure 3.1 Frequency of detection of pesticides measured in indoor and outdoor air in selected studies.

3.3 Comparisons of Air Concentrations

Previous studies have reported post-application concentrations of semi-volatile pesticides in air that may reach levels representing considerable exposure by the inhalation route (Byrne *et al.,* 1998; Fenske *et al.,* 1990; Lewis *et al.,* 2001). Low measurable airborne levels have also been reported even in the absence of a recent application event (Lewis *et al.,* 1994; Whitmore *et al.,* 1994). Lognormal probability plots and box-and-whisker plots graphically depicting the (unweighted) measurements of compounds of interest in our studies are presented in Figures 3.2 through 3.5. The median and 95th percentile concentrations are presented in Table 3.3 (complete summary statistics are presented in Tables A.1 through A.7 in Appendix A).

- For pesticides measured in indoor and outdoor air, the observed concentrations typically approximate lognormal distributions, as demonstrated in the lognormal probability plots in Figures 3.2 and 3.3.

- Despite differences in the lengths of the sample collection periods (1 to 7 days), the indoor chlorpyrifos concentrations observed across the large observational field studies are similar in their variability, as demonstrated by similar slopes in the probability plot (Figure 3.2). Similar variability over varying collection periods suggests that air concentrations are reasonably consistent from day-to-day in the absence of a recent application.

- Comparison of air concentrations across studies in the box-and-whisker plots (Figure 3.4) finds that, as expected, pesticide concentrations in smaller studies, where measurements immediately followed an application, are much higher than in the larger observational field studies; for example, note the high indoor chlorpyrifos levels measured in CPPAES and the Test House.

- Median concentrations are typically an order of magnitude higher indoors than outdoors (Table 3.3). Two notable exceptions are JAX and CHAMACOS. In the JAX samples, collected in a community with high year-round pesticide usage, outdoor diazinon and *cis*- and *trans*-permethrin levels are nearly as high as indoor levels. In the CHAMACOS samples, collected in an agricultural community, median outdoor diazinon levels exceed indoor levels.

- The low pesticide concentrations routinely measured outdoors (notwithstanding the exceptions noted above) together with the relatively short amount of time that young children typically spend outdoors suggest that inhalation of outdoor air is not an important contributor to their aggregate pesticide exposure.

- The median indoor concentrations in the large observational field studies are higher for the organophosphates (OPs) than for the pyrethroids (Figure 3.4). Not only do OPs tend to have higher vapor pressure, but at the time these studies were conducted, OPs still dominated the marketplace. Detectable levels of chlorpyrifos and diazinon are likely to exist for some time after restriction of their indoor uses due continued use of existing home inventories and reemission from indoor surfaces serving as sinks (such as carpet).

- In indoor air measured in CTEPP (Figure 3.6), a relationship is evident between chlorpyrifos and its degradation product TCPy. The same is true for diazinon and its degradation product IMP. The nearly log-log relationship suggests a power relationship, and at the median level the degradate is present at about 25 to 30% of the concentration of its parent. Accordingly, the metabolites/degradates measured in urine may reflect exposure to both the parent pesticide and the degradate, not just to the parent compound as is often assumed.

- Environmental concentrations of the degradation products were not measured in any of the small, pilot-scale studies, thus the degradate-to-parent ratio immediately following application is unknown.

Table 3.3 Median and 95th percentile air concentrations (ng/m³, unweighted) for frequently detected pesticides.

		Chlorpyrifos		Diazinon		*cis*-Permethrin		*trans*-Permethrin	
Study	Location	P50	P95	P50	P95	P50	P95	P50	P95
NHEXAS-AZ	Indoor	3.37	164.7	5.59	219.6	--[a]	--	--	--
	Outdoor	ND[b]	ND	ND	ND	--	--	--	--
MNCPES	Personal	1.52	16.86	0.28	4.66	0.20	2.07	<0.09	1.72
	Indoor	1.85	30.25	0.27	8.59	0.09	1.26	<0.09	1.26
	Outdoor	<0.10	0.19	<0.10	0.22	<0.09	0.15	<0.09	0.48
CTEPP-OH [c]	Indoor	1.75	21.69	0.97	56.87	0.28	1.63	0.23	1.04
	Outdoor	0.20	1.13	0.15	1.49	0.28	0.95	0.23	0.66
CTEPP-NC [c]	Indoor	6.07	62.22	2.03	63.66	0.41	7.79	0.27	7.16
	Outdoor	0.28	3.99	0.09	0.98	0.06	0.47	0.06	0.30
JAX	Indoor	20.37	84.92	4.64	28.04	0.71	92.47	3.06	134.3
	Outdoor	3.77	6.62	3.53	6.76	2.13	2.29	2.50	10.24
CHAMACOS	Indoor	1.90	NA[d]	1.80	NA[d]	0.50	NA[d]	<0.10	NA[d]
	Outdoor	0.90	NA[d]	2.80	NA[d]	0.10	NA[d]	<0.10	NA[d]
CPPAES [e]	Indoor	149.0	815.6	4.55	23.88	--	--	--	--
Test House [e]	Indoor	290.0	1000	--	--	--	--	--	--
PET	Indoor	--	--	45.6	562	--	--	--	--
DIYC	Indoor	--	--	1800	4900	--	--	--	--

[a] Blank cells indicate the pesticide was not measured in the study
[b] ND = not detected
[c] CTEPP samples collected at both homes and daycares
[d] NA = summary statistic not available at time the report was prepared
[e] Day 1 measurements only, multiple rooms

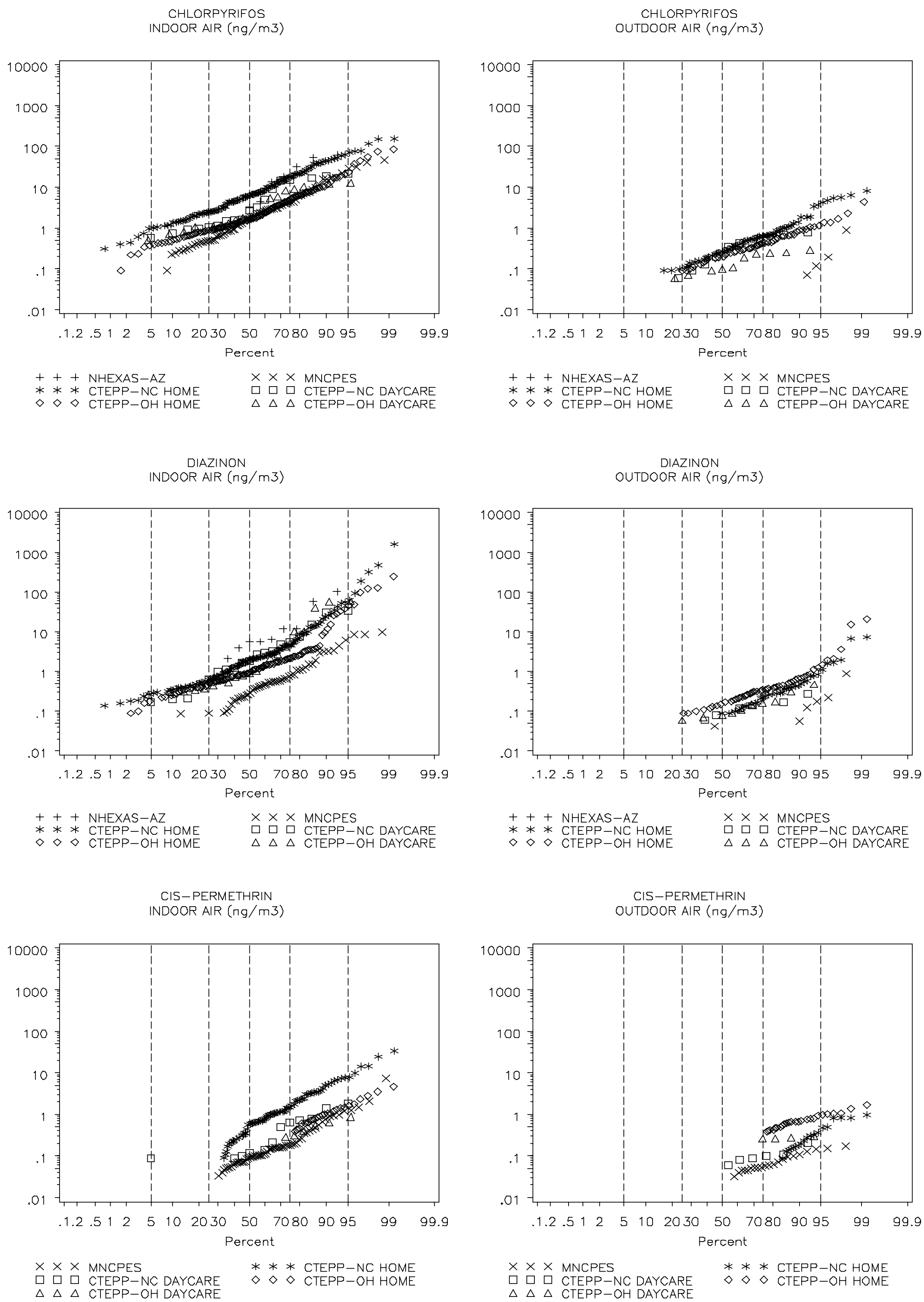


Figure 3.2 Log probability plots for chlorpyrifos, diazinon, and *cis*-permethrin measured in large observational field studies. Only values above the limit of detection are plotted.

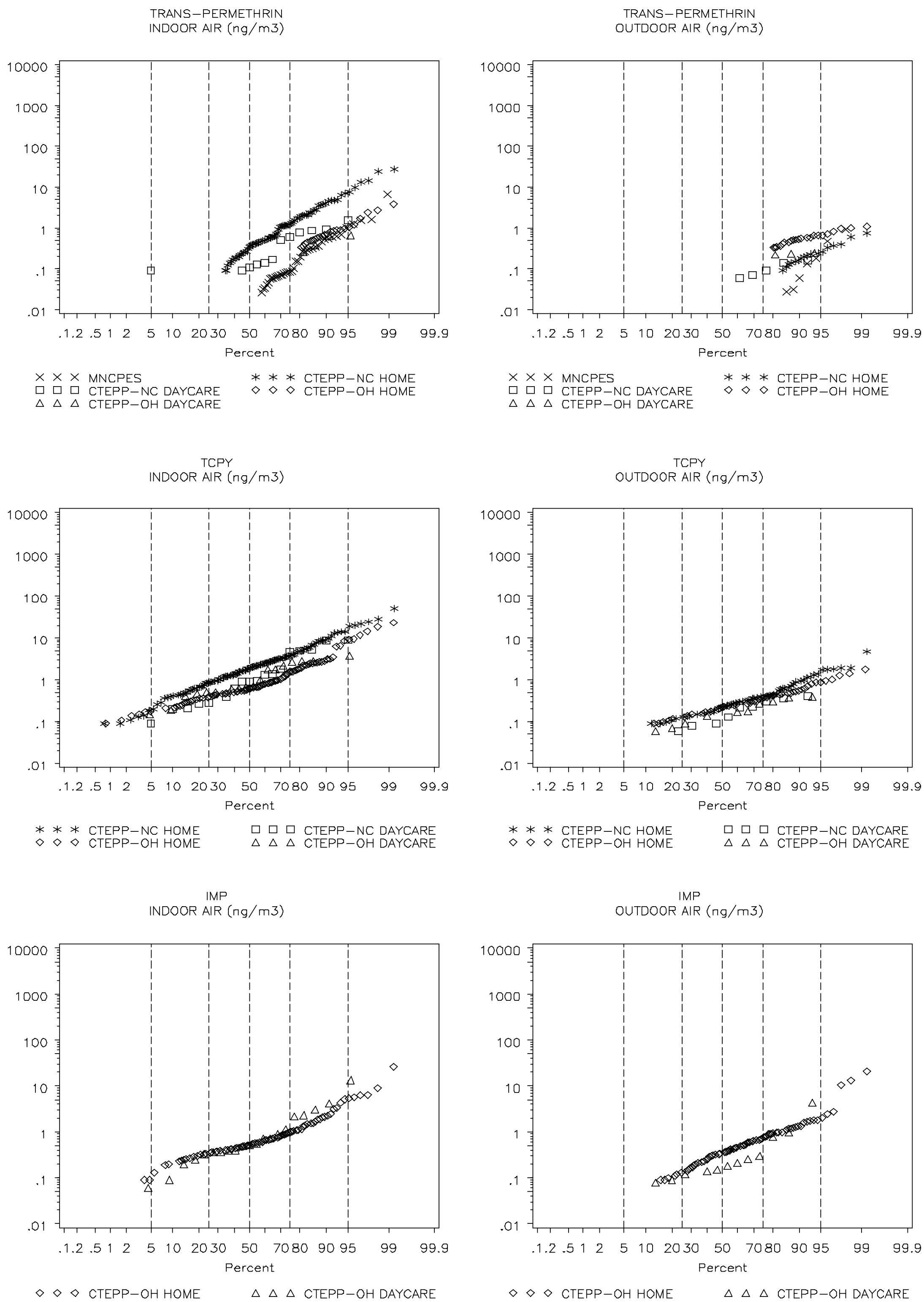


Figure 3.3 Log probability plots for *trans*-permethrin, TCPy, and IMP measured in large observational field studies. Only values above the limit of detection are plotted.

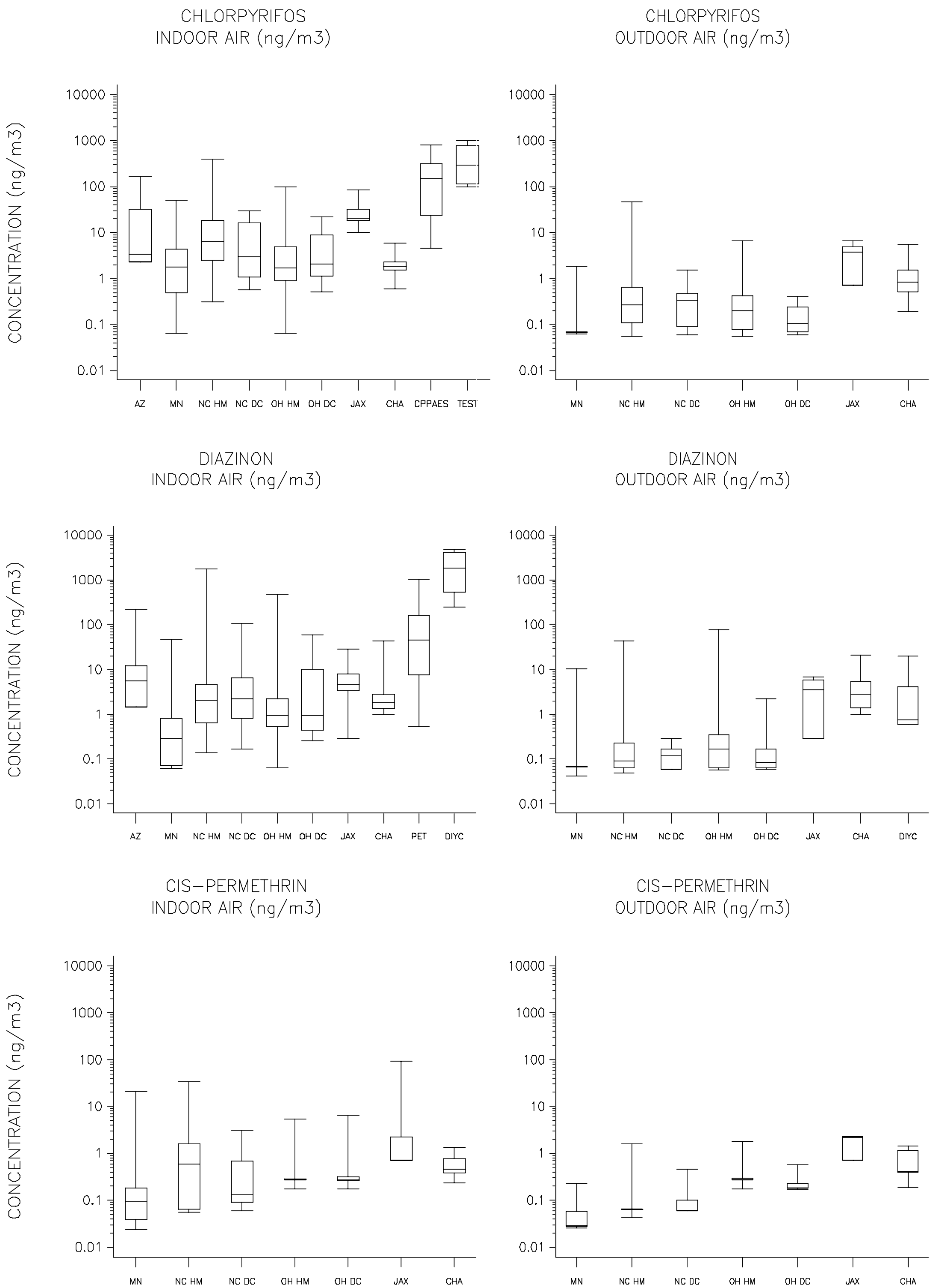


Figure 3.4 Indoor and outdoor air concentrations of chlorpyrifos, diazinon, and *cis*-permethrin measured in selected studies. Legend: AZ = NHEXAS-AZ, MN = MNCPES, NC HM = CTEPP-NC Home, NC DC = CTEPP-NC Daycare, OH HM = CTEPP-OH Home, OH DC = CTEPP-OH Daycare, CHA = CHAMACOS, TEST = Test House.

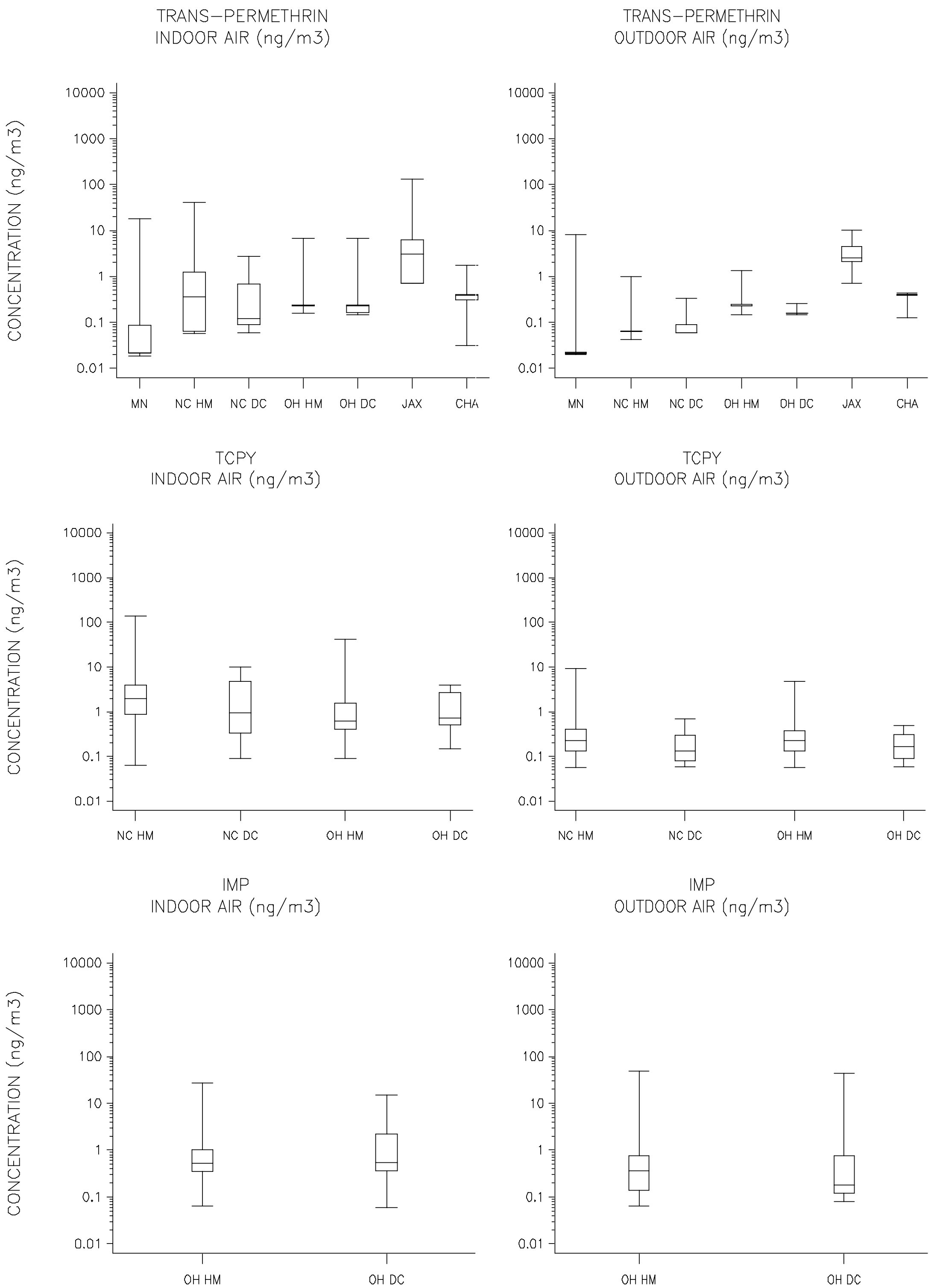


Figure 3.5 Indoor and outdoor air concentrations of *trans*-permethrin and TCPy measured in selected studies. Legend: AZ = NHEXAS-AZ, MN = MNCPES, NC HM = CTEPP-NC Home, NC DC = CTEPP-NC Daycare, OH HM = CTEPP-OH Home, OH DC = CTEPP-OH Daycare, CHA = CHAMACOS, TEST = Test House.

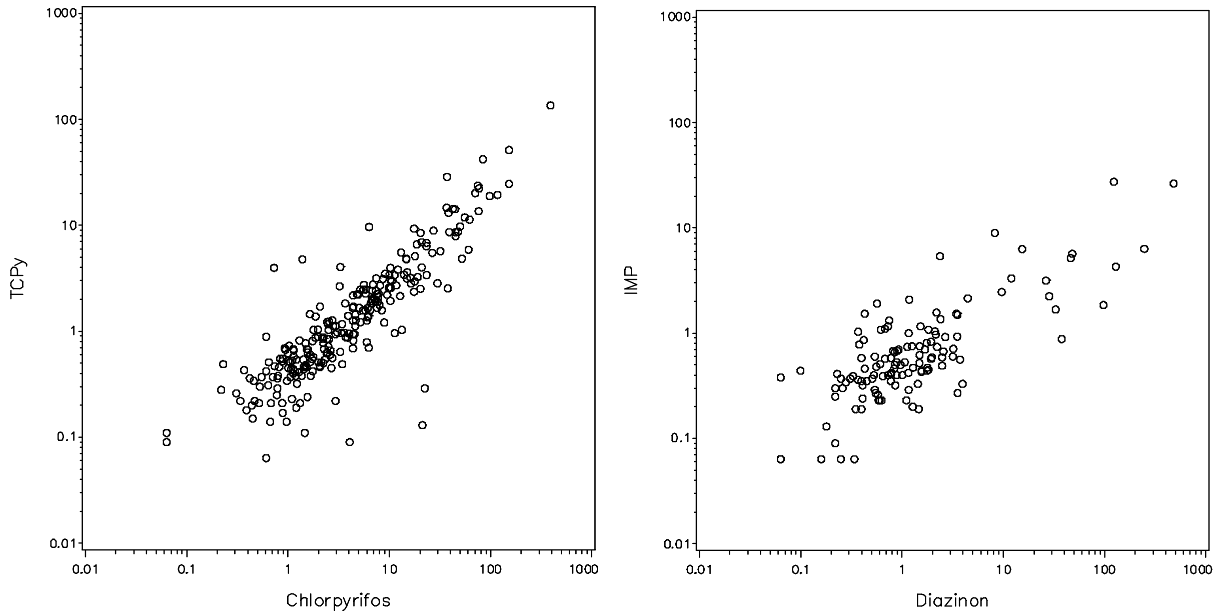


Figure 3.6 Log-scale relationships between levels of parent pesticide (ng/m³) and degradate (ng/m³) measured in CTEPP. Left Panel: Chlorpyrifos with TCPy. Right Panel: Diazinon with IMP.

3.4 Differences Related to Location

This section addresses differences in potential for exposure related to geographic region, population density (urban *vs.* rural), and home *vs.* daycare environment. There is available evidence to support all three of these location-related factors as having a discernable impact on pesticide exposure.

The large observational field studies were conducted in several geographical regions. A difference in climate impacts the type and density of pests found in the region. Residents of areas with mild winter conditions, as exist in the southern United States, may experience significant pest control problems throughout the year and may respond with increased pesticide usage. The landmark EPA Non-Occupational Pesticide Exposure Study (NOPES) conducted during 1986-1988 (Whitmore *et al.,* 1994) reported much higher indoor air concentrations of chlorpyrifos and diazinon in Jacksonville, Florida, than in Springfield and Chicopee, Massachusetts (purposely selected as high-use and low-use regions, respectively).

The residents of rural communities may be exposed to pesticides from residential as well as agricultural applications. Both spray drift and work-to-home transport are potential pathways of exposure to agricultural pesticides, some of which have the same active ingredient as formulations used within the home (Curl *et al.,* 2002). Residents of urban areas, on the other hand, may experience frequent applications to combat persistent pest control problems arising from high population density (Landrigan *et al.,* 1999), may have little control over pesticide applications by building management, and may be exposed to pesticides applied in neighboring residences.

Young children spend nearly 20 hours per day indoors (US EPA, 2002). For pre-school age children, much of this time is spent in residences or in daycare facilities. According to recent estimates, nearly 4 million children under age 6 spend some portion of their day in center-based child care, with many children spending a full work day (8-10 hours) in the child care center (US CPSC, 1999). Pesticide concentrations in daycare facilities are potentially significant (Wilson *et al.,* 2003) and are typically out of the control of the parents.

- Positive and highly significant associations ($p < 0.01$) between personal-air exposures and indoor air concentrations were observed in MNCPES for both chlorpyrifos and diazinon with Spearman correlation coefficients of 0.81 and 0.62, respectively (Table 3.4).

- Comparison of the box-and-whisker plots in Figure 3.4 of indoor air concentrations measured in homes finds median values were somewhat higher in southern states (NHEXAS-AZ and CTEPP-NC) than in northern states (MNCPES and CTEPP-OH). However, considerable overlap in the interquartile ranges is evident. Since these studies focus on compounds that have been used to control a variety of common insect pests both inside and outside of homes (chlorpyrifos was until recently among the most poplar residential insecticides for cockroach, flea, ant and termite control), it is not surprising that the distributions would overlap across geographical locations.

- When daycare measurements are included, a geographical difference is less obvious (results not shown). Despite recent gains in the adoption of integrated pest management policies, many daycare facilities still have regular calendar-based pesticide treatments, irrespective of actual demonstrated need. This may have the effect of minimizing differences in usage in daycares among geographic regions.

- CTEPP data (Figure 3.7) suggest that, within each state, indoor air levels in daycares are similar to those in homes, particularly for diazinon and permethrin. This demonstrates the potential for continued exposure as a child transitions from the home to a daycare. To reduce the uncertainty of risk assessments for children, their exposures must be considered for all indoor and outdoor environments they occupy, including homes, child care centers, and other buildings. Additional information may be required to examine exposure potential from schools, restaurants, and other public and private locations where pesticides are also applied.

- Differences between urban and rural air concentrations of chlorpyrifos were observed in both MNCPES (Table 3.5) and CTEPP-OH (Table 3.6). The differences reached statistical significance only in MNCPES, with higher concentrations in the urban areas. Likewise, the detection frequencies for both chlorpyrifos and diazinon in indoor and personal air were higher in urban locations (Table 3.5).

- Across compounds in MNCPES, median levels were consistently higher in urban areas than in rural areas. A reasonable explanation may be that urban areas require more intensive use of pesticide products to control a range of pests over a wider seasonal span. In addition the application may be of more mass of active ingredients in a smaller area, as is the case with a liquid termiticide application. While it is not entirely clear why the pattern of higher urban levels was not evident in CTEPP-NC, it may be due to a less stringent definition of “urban” in CTEPP.

- Air samples collected in low-income homes generally had higher concentrations of chlorpyrifos and diazinon than samples collected in medium/high income homes (Table 3.6), but the difference was only statistically significant for diazinon in NC.

Table 3.4 Spearman correlations among personal, indoor, and outdoor concentrations of chlorpyrifos and diazinon measured in MNCPES[a].

	Chlorpyrifos		Diazinon	
Type	Indoor	Outdoor	Indoor	Outdoor
Personal	0.81**	0.23	0.62**	0.67**
Indoor	--	-0.01	--	0.28

[a] Excerpted from Clayton *et al.*, 2003
** Statistically significant at the 0.01 level.

Table 3.5 Urban and rural differences in airborne concentrations of chlorpyrifos and diazinon measured in MNCPES. The limit of detection was 0.1 ng/m³.

Sample Type	Chemical	Location	N	Detection Frequency	Median Concentration (ng/m^3)
Personal	Chlorpyrifos*	Urban/Suburban	40	98%	2.2
		Rural	20	90%	1.2
	Diazinon*	Urban/Suburban	30	77%	0.4
		Rural	18	44%	<0.1
Indoor	Chlorpyrifos*	Urban/Suburban	57	96%	2.2
		Rural	25	80%	0.7
	Diazinon	Urban/Suburban	54	74%	0.4
		Rural	21	52%	0.1

* denotes significant ($p < 0.05$) difference in medians using two-sided Wilcoxon test.

Table 3.6 Differences in airborne concentrations measured in CTEPP for urban versus rural, low versus medium income, and home versus daycare expressed as ratios of geometric means. Adapted from Morgan *et al.*, 2004.

State	Chemical	Estimated Ratio of Geometric Means (95% C.I.)		
		Urban/Rural	Low /Mid-High Income	Home/Daycare
North Carolina	Chlorpyrifos	0.94 (0.50, 1.77)	1.36 (0.84, 2.21)	1.78 (0.81, 3.92)
	Diazinon	0.95 (0.43, 2.11)	3.59* (1.95, 6.61)	0.82 (0.30, 2.24)
Ohio	Chlorpyrifos	1.64 (0.80, 3.37)	1.63 (0.97, 2.74)	0.76 (0.38, 1.52)
	Diazinon	1.04 (0.44, 2.49)	1.67 (0.89, 3.12)	0.78 (0.34, 1.80)

* denotes significance, $p < 0.05$.

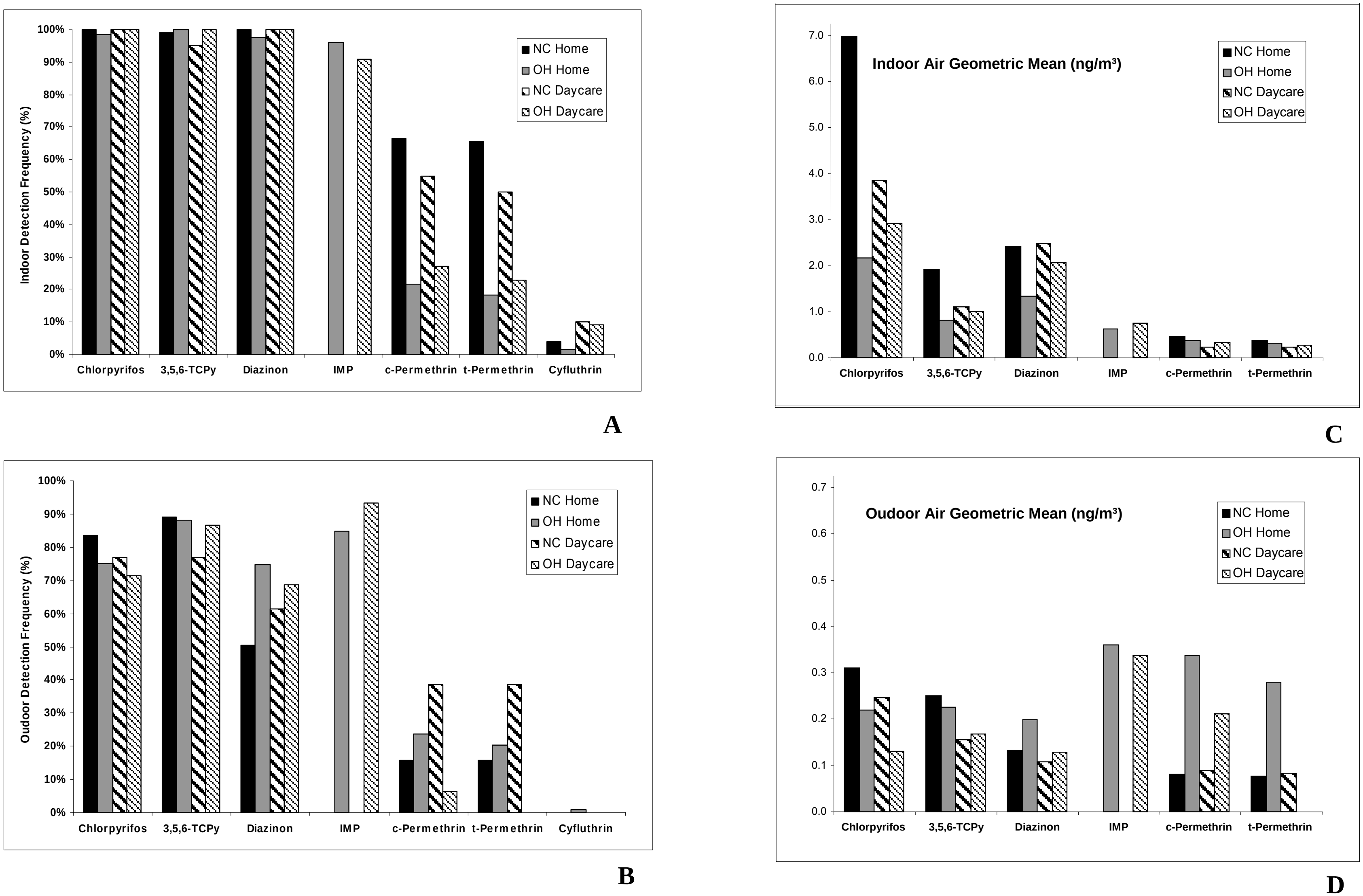


Figure 3.7 The detection frequencies of select pesticides and their metabolites measured from the indoor air (A) and outdoor air (B) of homes and daycares in NC and OH, and the mean concentrations of select pesticides and their degradation products measured from the indoor air (C) and outdoor air (D) of homes and daycares in NC and OH.

3.5 Spatial and Temporal Variability

Few studies have been designed to measure either the spatial variability of airborne pesticide concentrations in a home or the temporal variability following crack-and-crevice pesticide applications (Byrne *et al.,* 1998; Lewis *et al.,* 2001). Recently, the Test House, CPPAES, DIYC, and PET studies have provided data on both spatial and temporal variability, as shown in Figure 3.8.

- Within-home spatial patterns were investigated in the Test House experiments. Following a crack and crevice application of chlorpyrifos (Figure 3.8 and Table 3.7), the pesticide was detected in the application room (kitchen), adjacent den, and the farthest bedroom from the application. Airborne concentrations in the kitchen peaked at 790 ng/m^3, then decreased by approximately 80%, but were still measurable, at 21 days after application. A concentration gradient was observed from the kitchen (application area) to the den (proximal area) to the master bedroom (distal area).

- Between-home spatial variability following a pesticide application was investigated in the CPPAES and DIYC studies. Indoor air concentrations of chlorpyrifos among the 10 homes in the CPPAES spanned more than an order of magnitude one day after application (Figure 3.8).

- The highest measured chlorpyrifos indoor air concentrations following crack and crevice applications among a subset of 5 CPPAES homes were between days 0 and 2 post application (mean = 315 ng/m^3), then decreased throughout the 2-week sampling period (mean = 172 ng/m3), but were still greater than the pre application levels (mean = 18 ng/m^3). The indoor air concentrations for the remaining CPPAES homes were much lower and did not follow the same decay pattern (data not presented, see Hore *et al.,* 2005).

- Air concentrations of diazinon in the homes of the DIYC study were nearly an order of magnitude higher than concentrations of chlorpyrifos in CPPAES, and the decay pattern differed dramatically among the three DIYC homes. The difference in airborne diazinon concentrations among the three homes was most pronounced 4-5 days after application (Figure 3.8), perhaps partially attributable to both the application method employed and the amount of active ingredient applied in each home.

- Following outdoor granular application to lawns in the PET study, indoor air concentrations of diazinon generally reached maximal levels by days 1 and 2 post application and declined over the duration of the study (Figure 3.8).

3.6 Factors that Influence Air Concentrations

Multiple factors influence the concentration of pesticides in air and the potential for inhalation exposure. The physico-chemical characteristics of the chemicals applied, the formulation type and the frequency of application are believed to be some of the most important of these factors. Other factors such as seasonal variation, housing type, pets, occupancy, application location, type of surface to which the applications are made, and the rooms where the samples are collected may also influence the concentrations measured. Some of these factors have been investigated using the data from NERL's pesticide exposure measurement program.

- The impact of air exchange rate (AER) on air concentrations is shown in Figure 3.8 for the CPPAES data. Indoor air concentrations of chlorpyrifos (immediately following application) among the homes spanned more than an order of magnitude. Homes with low air exchange rates had higher initial airborne concentrations and a noticeably slower reduction of airborne levels.

- The amount, or mass, of active ingredient applied also clearly affected the concentrations measured in CPPAES, with low airborne concentrations observed in three homes receiving applications containing only trace amounts of chlorpyrifos (data not presented, please see Hore *et al.,* 2005).

- An empirically derived Application Effective Volume (AEV, applied mass divided by the product of air changes per hour and home volume) was applied to the CPPAES data to demonstrate the relationship between measured air concentrations, air exchange rate, and mass of active ingredient applied. Measured airborne concentration was more consistently correlated with AEV than with any of the constituents of AEV (Pearson product-moment correlations, data not presented). The association of AEV with airborne concentrations measured on the second day after application (Figure 3.9) suggests that AEV may serve as an effective surrogate for air concentrations and that constituent measures including air exchange rate are important determinants of air concentrations.

- The geometric mean concentrations of the organochlorine, organophosphate, and pyrethroid pesticides measured in indoor air in the absence of a recent application appear to be strongly influenced by vapor pressure. Regressing concentrations measured in the CTEPP study upon the logged vapor pressures (Figure 3.10) results in nearly equivalent R^2 values of 0.69 and 0.70 for homes and daycares, respectively. The importance of inhalation as a route of exposure for pesticides is likely to decrease as less volatile pesticides are introduced into the market.

- Results in the US EPA Research Test House comparing total release aerosol to crack and crevice applications confirm that the application method is an important factor influencing the measured airborne concentration of chlorpyrifos (Table 3.7). The application method is also suspected of being a factor responsible for the differences observed among homes in the DIYC study.

- The PET study demonstrates the intrusion of diazinon from an outdoor source. The lawn applications resulted in a source of diazinon that contributed to indoor concentrations in all homes. Indoor concentrations are likely associated with both the physical translocation of particle bound residues and the intrusion of volatilized diazinon from the source. The results suggest that lawn applications increase the potential for occupant exposure both on the treated lawns and indoors.

- While some progress has been made in understanding the multitude of factors that influence the concentration of pesticides in air and the potential for inhalation exposure, additional studies are needed.

3.7 Summary: Air Concentrations

As shown in the bulleted lists of observations from these studies, there are a number of factors that may impact children's exposure to pesticides in homes and child care centers. They include the following:

- The physical and chemical characteristics of the pesticides used indoors will have a significant impact on exposure via the inhalation route. Airborne concentrations will be higher for the more volatile pesticides, such as chlorpyrifos and diazinon (no longer registered for indoor use). Use of less volatile alternatives, such as the pyrethroids, will likely result in lower airborne concentrations of the active ingredients.

- The type and method of pesticide application (see Section 2.4) are factors affecting exposure. As shown in the Test House experiments, the airborne concentrations are higher for foggers than for crack and crevice applications. Past studies have focused on crack and crevice and other spray applications, although newer types of applications, such as use of gels, may further reduce the translocation of pesticides to areas that may be contacted by children.

- The data from these studies highlight the importance of geographic location on airborne concentrations. Frequency of application and total amount of pesticide used may be associated with geographic location.

- The data on spatial variability of pesticide residues within a home are limited. But, data from the Test House and other studies show that pesticides are distributed to other locations within a building from the point of application and are measurable in air samples collected in other rooms.

- The data also clearly show that there are temporal changes in concentrations following an application. These changes are related to air infiltration and air exchange rates in the home. The changes are also likely related to degradation processes, but there are few studies that have addressed the temporal changes in concentration for different pesticides as related specifically to the degradation process.

Table 3.7 Airborne chlorpyrifos residues collected following a crack and crevice type application versus a total release aerosol in the EPA Test House.

Application Type	Room	Indoor Air Concentration (ng/m³)							
		Pre	3 hr	Day 1 [a]	Day 2	Day 3	Day 7	Day 14	Day 21
Crack and Crevice	Kitchen	NC [b]	NC	790	NC	770	320	220	140
	Den	3	NC	250	NC	140	90	60	70
	Bedroom	NC	NC	100	NC	0.07	60	40	30
Total Release Aerosol	Living Room	ND [c]	15	9200	4100	2300	860	450	NC
	Den	ND	17	8300	4000	2100	1100	410	NC
	Bedroom	NC	1.4	4700	NC	NC	370	320	NC

[a] Air sampling was initiated immediately following the application and monitored continuously for 24-h.
[b] NC indicates the sample was not collected.
[c] ND indicates the sample was not detected <0.05 μg/m³

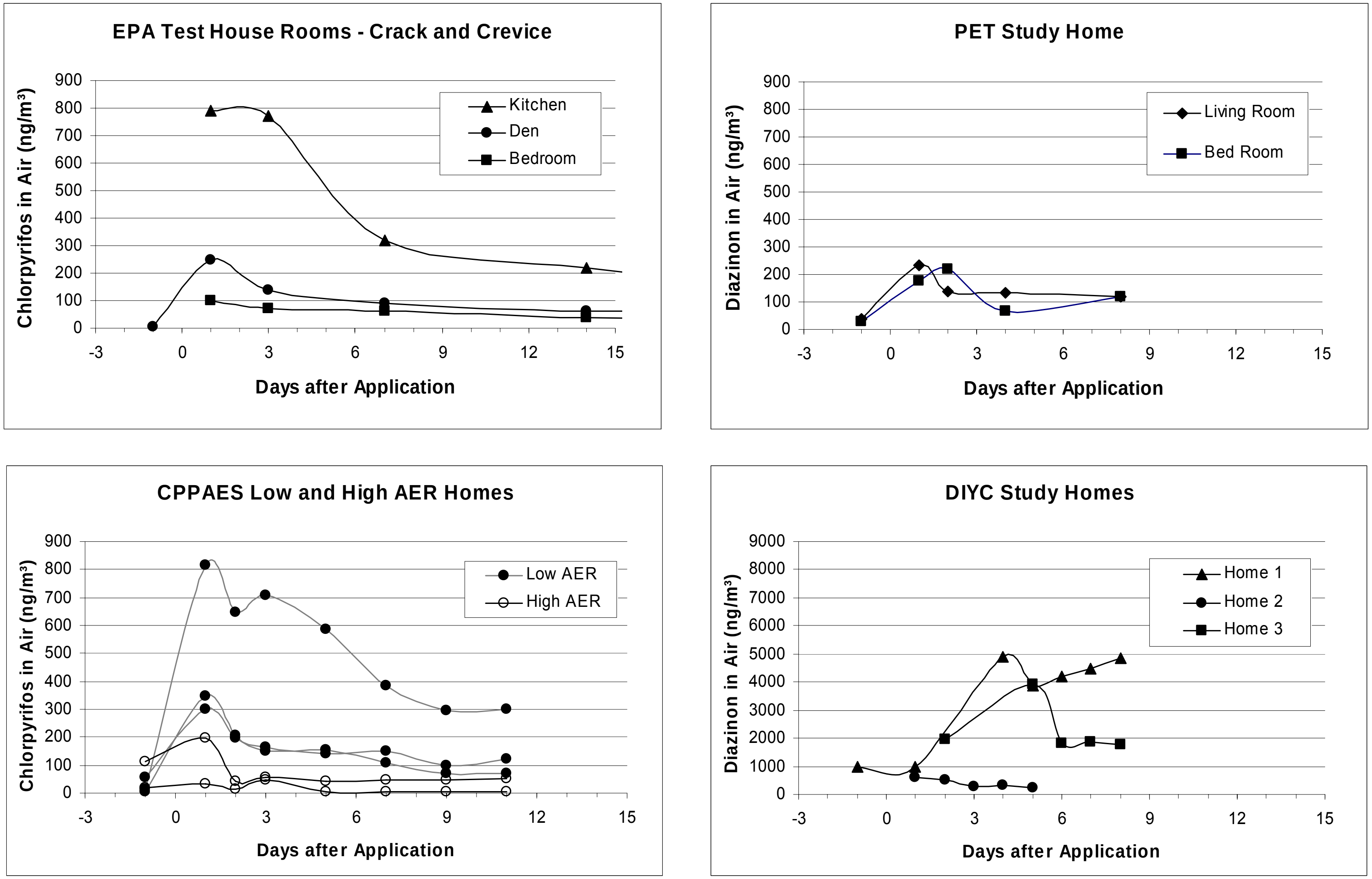


Figure 3.8 Airborne concentrations (ng/m³) of chlorpyrifos or diazinon measured from indoor air over time in the Test House, PET, CPPAES, and DIYC studies.

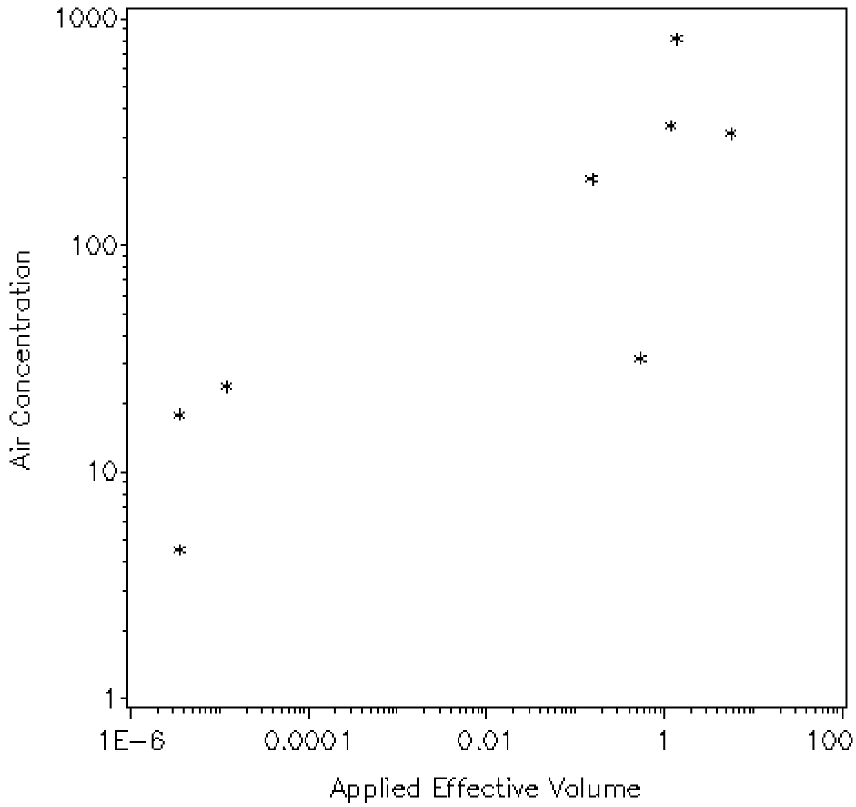


Figure 3.9 Association between measured air concentration (ng/m³) and Applied Effective Volume (ng/m³/h) on the second day after application of chlorpyrifos in CPPAES homes.

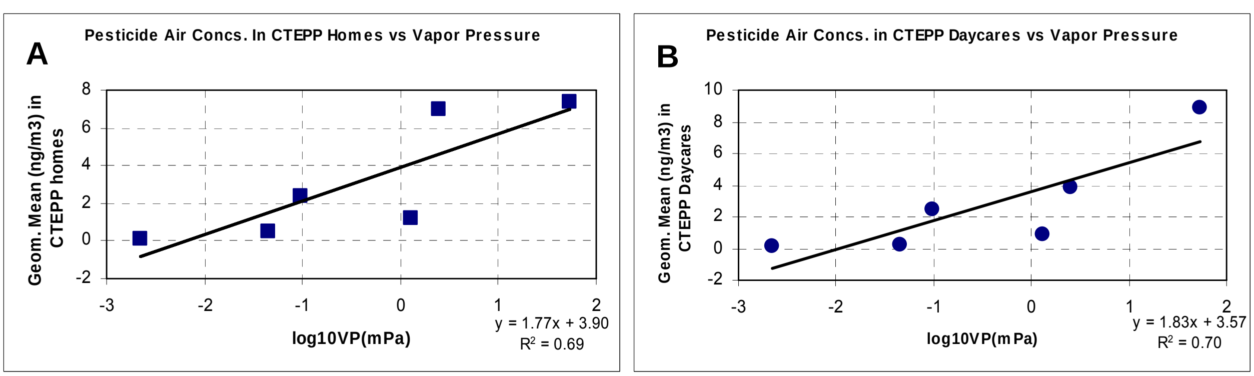


Figure 3.10 Pesticide air concentrations as a function of vapor pressure in CTEPP homes (A) and daycares (B).