Agricultural and Residential Pesticides in Wipe Samples from Farmworker Family Residences in North Carolina and Virginia

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Children of farmworkers can be exposed to pesticides through multiple pathways, including agricultural take-home and drift as well as residential applications. Because farmworker families often live in poor-quality housing, the exposure from residential pesticide use may be substantial. We measured eight locally reported agricultural pesticides and 13 pesticides commonly found in U.S. houses in residences of 41 farmworker families with at least one child < 7 years of age in western North Carolina and Virginia. Wipe samples were taken from floor surfaces, toys, and children's hands. We also collected interview data on possible predictors of pesticide presence, including characteristics of the household residents, cleaning practices, and characteristics of the home. All families were Spanish-speaking, primarily from Mexico. Results indicate that six agricultural and 11 residential pesticides were found in the homes, with agricultural, residential, or both present in 95% of homes sampled. In general, residential pesticides were more commonly found. Presence of both types of pesticides on the floor was positively associated with detection on toys or hands. Agricultural pesticide detection was associated with housing adjacent to agricultural fields. Residential pesticide detection was associated with houses judged difficult to clean. Although the likelihood of agricultural pesticide exposure has been considered high for farmworker families, these results indicate that residential pesticide use and exposure in this population merit further study.
Key words: agriculture, children, exposure, house dust, Latino. *Environ Health Perspect* 112:382–387 (2004). doi:10.1289/ehp.6554 available via *http://dx.doi.org/* [Online 12 November 2003]

The potential health effects of pesticide exposure for children are highlighted in several recent publications (Eskenazi et al. 1999; National Research Council 1993; Zahm and Ward 1998). Pesticides pose a greater health risk for children than for adults because of their small body size and rapid development. Recent research has demonstrated that multiple types of pesticides are present in many dwellings in the United States, particularly in low-income, urban neighborhoods (Berkowitz et al. 2003; Pang et al. 2002; Whyatt et al. 2002).

Children in agricultural communities may be exposed to pesticides in the home because of pathways common to all children (diet, drinking water, residential pest control), as well as parental take-home pesticides and factors related to farm proximity (drift, playing in pesticide-treated fields; Camann et al. 1995; Fenske 1997; Fenske et al. 1999). Pesticides can remain stable indoors for extended periods of time, creating a significant exposure for children, especially those young enough to play on floors or to place toys and household objects in the mouth (Lewis et al. 2001). Simcox et al. (1995) have shown that pesticide concentrations of organophosphate (OP) insecticides in house dust and soil samples were greater for agricultural homes than for nonagricultural homes in the same communities. McCauley et al. (2001) found that OP residues in farmworker housing were associated with distance from fields and with number of farmworkers in the home.

These exposure routes are particularly relevant to children of migrant and seasonal farmworkers. Adults in their households often apply chemicals and perform hand labor in fields treated with pesticides. In addition, these children often live in close proximity to the fields. Farmworker housing is frequently in poor repair and therefore subject to considerable pesticide application for pest control (Harrison 1995; National Advisory Council on Migrant Health 1995).

The research reported here focuses on exposure of farmworker children to a broad range of pesticides. Although previous studies have examined pesticide residues in the homes of such children, they have concentrated on agricultural chemicals and primarily on OPs (e.g., Simcox et al. 1995).

The present study is part of a project designed to develop and evaluate a culturally appropriate pesticide education intervention for farmworker families. During formative research, we used dust wipes to collect samples that were analyzed for a variety of pesticides. We present results of these analyses, describing the types and amounts of pesticides found in farmworker dwellings and their distribution on floor, toy, and hand surfaces in the home. We also examine possible predictors of pesticide presence in these homes to identify the probable pathways of exposure.

Materials and Methods

Recruitment. Data were collected between June and December 2001 from 41 households located in four western North Carolina counties and two southern Virginia counties. To be eligible for the study, the household had to contain a family consisting of at least two related persons, one of whom was a seasonal, migrant, or year-round farmworker employed in agriculture by someone outside of his or her family. At least one adult in the family had to have a child between 12 and 84 months of age residing in the house. The primary interviewee in all households was the mother.

The lack of a census and the dispersed nature of farmworker residences in the mountains precluded the use of a random sample or a block cluster design. Therefore, we developed a strategy to obtain a sample representative of the variability in the local farmworker population. Potential participants were initially identified using a site-based sampling approach (Arcury and Quandt 1999). This approach first identified sites or locations where members of farmworker families were likely to be found. These locations included women's groups sponsored by Cooperative Extension agents and Partnerships for Children, classes for English as a second language and high school equivalency (GED), and social and health services organizations, such as migrant health programs, county health departments, churches, and the Special Supplemental Nutrition Program for Women, Infants, and Children offices. Project research staff visited these sites during the months preceding data collection to introduce themselves and the project, and to determine when and how many eligible families were expected to be in residence during the agricultural season.

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We acknowledge the laboratory assistance of M.M. Zuniga, J.M. Clothier, and B. Walker.

This work was supported by a grant from the National Institute of Environmental Health Sciences (R01 ES08739).

The authors declare they have no competing financial interests.

Received 30 June 2003; accepted 12 November 2003.

The researchers returned to the sites at the appropriate time and were introduced to the group or to individual families by agency staff. Being introduced to the researchers by someone the family member already knew and trusted helped allay concerns about the risks of participating in the study. As the project progressed, observation in the community demonstrated that some families were quite isolated and not accessible in the recruitment sites. Therefore, additional participants were located using snowball sampling from the already enrolled families.

Data collection. Data collection took place in the participant's home. It consisted of an interviewer-administered questionnaire, collection of wipe samples, and observations of the residence and neighborhood. The questionnaires and interviews were conducted in the participant's preferred language, which was Spanish in all cases. Interviewers were bilingual females. Informed consent was obtained in accordance with procedures approved by the Wake Forest University School of Medicine Institutional Review Board.

Wipe samples from three types of surfaces (floors, toys, and children's hands) were collected in each home, following protocols described elsewhere (Geno et al. 1996; Harding et al. 1993). Floor samples were collected from two to four 18-inch-square sections (0.42–0.84 m^2) of uncarpeted flooring in living areas of the house. The number of squares depended upon the amount of suitable floor space available. Most of the homes had a high percentage of carpeted flooring, so most of the samples were taken from uncarpeted kitchens and hallways. The sections were measured and marked using masking tape. Toy samples were taken from two or three suitable toys identified by the mother or child as most frequently handled favorites. Suitable toys were nonplush and made of materials that would not be damaged by the alcohol. Wipe samples were taken from the child's hands by wiping all surfaces of both hands, including between the fingers, with two sponges. Older children wiped their own hands. The child was instructed to pick up and unfold the sponge, and then to wipe all surfaces of both hands. In cases where the child was too young or needed assistance, the mother took the samples while wearing a pair of nitrile gloves.

In 11 households, field blanks were also collected. Two sponges were wetted with 15 mL of isopropanol and placed directly into the jar with tweezers. An additional 50 mL of isopropanol was added, and the jar was sealed with Teflon tape and placed in the cooler. Duplicates of the floor samples were collected in six homes. The area directly adjacent to the original sample was measured and marked, and the sample was collected using the complete floor wipe protocol. The floor dust samples were quite repeatable. Of the 34 pairs of collocated duplicate-floor measurements with detectable loadings, 59% of the pairs had differences < 20%, and 94% had differences < 50%.

In addition to the physical samples and direct interview data, observations were made regarding the general environment of the dwelling. A map was drawn of the yard and immediate neighborhood, including estimated distances to cultivated fields and neighboring houses. These data were used to classify dwellings as adjacent or nonadjacent to agricultural fields. The difficulty of cleaning the house was also rated on a scale of 1 (most difficult to clean) to 10 (easiest to clean), based on age and type of dwelling, general state of repair, and crowding due to number of occupants and amount of furniture and other material possessions.

Laboratory analysis. Samples were analyzed for two groups of pesticides. Eight were pesticides [atrazine, disulfoton (total), esfenvalerate, lindane, metolachlor, oxyfluorfen, pendimethalin, simazine] used frequently in agriculture in the study area and detectable by a single analytic method. Thirteen pesticides [carbaryl, α-chlordane, γ-chlordane, chlorpyrifos, 4,4′-dichlorodiphenyldichloroethylene (DDE), 4,4′-dichlorodiphenyl-trichloroethane (DDT), diazinon, heptachlor, methoxychlor, *cis*-permethrin, *trans*-permethrin, *ortho*-phenylphenol, propoxur] are commonly detected in house dust throughout the United States (Camann et al. 2000). The two groups are labeled "agricultural" and "residential," acknowledging that the composition of the agricultural list reflects local farming practices. Once each month, wipe samples were shipped on dry ice to the laboratory (Southwest Research Institute, San Antonio, TX), where they were stored at –12°C. Within 10 days after arrival, each wipe sample was shake-extracted as previously described (Geno et al. 1996). Each wipe sample was spiked with chlorfenvinphos as an extraction surrogate and then shake-extracted, first with isopropanol, and then twice with 1:1 diethyl ether:hexanes. The combined extract was concentrated with an N-Evap evaporator (Organomation Associates, Berlin, MA) to 5 mL (hand wipe and blank samples) or 20 mL (floor and toy wipes). One milliliter was passed through a carbograph cartridge to remove interferences from coeluting compounds and concentrated to a final volume of 1.0 mL in 10% diethyl ether in hexanes. Amounts of the target pesticides in samples were determined using an Agilent 6890/5973 gas chromatograph/mass spectrometer (Agilent Technologies, Palo Alto, CA) as previously described (Geno et al. 1995). Quantification was performed using a mixture of deuterated polyaromatic hydrocarbons, deuterated pesticides, and ^{13}C-labeled pesticides as internal standards. The nominal analyte detection limit was the analyte level in the lowest standard of the initial five-point calibration curve. Detection limits ranged from 0.05 to 0.3 µg for individual pesticides and 0.8 µg for total disulfoton in hand wipes and from 0.25 to 1.5 µg for individual pesticides and 4 µg for total disulfoton in floor and toy wipes.

No target analytes were detected in the matrix blanks run with each batch of about 10 samples, indicating that there was no laboratory-introduced contamination. Recovery of chlorfenvinphos generally ranged from 75 to 150%, suggesting that each wipe sample was extracted well. A matrix blank wipe was fortified with all target analytes at a low level (1–6 µg), allowed to equilibrate for 30 min, and extracted and analyzed as a regular sample with each batch of samples. All pesticides except carbaryl were extracted efficiently, with the spike recovery mean ± SD ranging from 77 ± 11% for lindane to 137 ± 42% for 4,4′-DDT. Reported wipe amounts are not adjusted for spike recoveries. Carbaryl recovery declined over laboratory batches, suggesting degradation of the laboratory spiking solution or declining extraction efficiency. The use of new spiking solution in the final batch of samples resulted in a 62% recovery from the matrix spike. Although somewhat lower than the other chemicals, this suggests that the low spike recoveries were caused by degrading laboratory spiking solution and that the results presented here are reliable.

Two agricultural pesticide analytes (atrazine and metolachlor) and one residential pesticide analyte (4,4′-DDE) were not detected in any household. One residential pesticide analyte (*ortho*-phenylphenol) was detected in all samples and in field blanks, but not in laboratory blanks, and is excluded from all analyses reported here.

Data analysis. Several measures were created from the questionnaire and observation data collected. A nuclear family household was defined as a respondent (with or without a spouse) and biologic offspring. Nonrelatives in the household were defined as individuals not related to the respondent. Individuals ≥ 18 years of age were defined as adults. Hand surface area was estimated using the child's age, based on results of a simple linear regression model to predict estimated hand surface area from age in seven children with an age range similar to that of the focal children. Houses were rated as adjacent to agricultural fields if they were next to, across the road from, or within a short walk from fields. Those rated as nonadjacent were located in areas with no fields (e.g., in town or across the valley from the nearest agricultural field).

All samples were successfully analyzed for pesticides. Pesticide amounts removed (micrograms) were measured separately on the three surfaces: hand, floor, and toy. Pesticide loadings (micrograms per square meter) were calculated by dividing amounts by corresponding surface areas. Means and SDs of pesticide amounts and loadings were calculated from samples having detected pesticide only. The four primary outcome measures defined *a priori* were the presence of at least one agricultural pesticide detected in wipes from floor, toys, hands, and any surface sampled. Secondary outcome measures were defined after data collection to divide households into groups according to number of residential pesticides detected on surfaces sampled (low, 0–2 pesticides; medium, 3–5 pesticides; high, 6–8 pesticides).

Odds ratios (ORs) and 95% confidence intervals (CIs) were calculated to evaluate associations between categorical variables—for example, the presence of agricultural pesticides on floors and toys. Multiple logistic regression models were used to predict binary outcome measures; proportional odds models were used to predict ordinal outcome measures. Potential predictors were observed sample characteristics and were included in multiple regression models if $p < 0.2$ in corresponding simple regression analyses. If two predictors in a model were highly related, then only the one judged to have greater predictive value was included. No interaction terms were included. ORs and 95% CIs from the multiple regression analyses were used to evaluate associations between outcome measures and potential predictors, adjusting for other predictors in the model. Statistical significance was defined as $p < 0.05$ (two-sided). SAS software (SAS Institute Inc., Cary, NC) was used for all statistical analyses.

Results

Table 1 presents descriptive analysis of the households and their residents. The agricultural and residential pesticides detected in floor, toy, and hand wipes are presented in Table 2. The most commonly detected agricultural pesticides were oxyfluorfen and simazine, and the most commonly detected residential pesticide was *trans*-permethrin. At least one agricultural pesticide was detected in 18 floor samples (44%), 12 toy samples (29%), and nine hand samples (22%). Twenty households (49%) had at least one agricultural pesticide detected in any location. At least one residential pesticide was detected in 39 households (95%), 39 floor samples (95%), 24 toy samples (58%), and 19 hand samples (46%). Eight homes had a low (0–2) number of pesticides detected, 21 a medium (3–5) number, and 12 a high (6–8) number. No home had more than 8 of a possible 13 residential pesticides detected.

When agricultural pesticide detection was compared among sources within households, there was a strong positive association between detecting agricultural pesticides in toy wipes and detecting them in floor wipes (OR = 13; 95% CI, 2.3–74). There was a similar strong positive association between floor wipe and hand detections (OR = 6.7; 95% CI, 1.2–38). This association was even greater between agricultural pesticides found on floors and in toy or hand wipes combined (OR = 17; 95% CI, 2.9–93). In each case, this estimated OR was > 1 ($p < 0.05$), which indicates elevated risk, given presence of agricultural pesticide(s) on the floor.

When household pesticide detection was compared among the three sources within households, there was a strong positive association between detecting > 0 household pesticide in toy wipes and detecting > 3 pesticides in floor wipes (OR = 7.0; 95% CI, 1.7–28). There was a similar strong positive association between > 3 pesticides in floor wipes and ≥ 1 pesticides in hand wipes (OR = 7.7; 95% CI, 1.7–34). The association was even greater between residential pesticides found on floors and in toy or hand wipes combined (OR = 12; CI, 2.5–59). Similarly, in each case, the estimated OR was > 1 ($p < 0.05$), which indicates greater likelihood of pesticides on toys or hands, given presence of > 3 residential pesticides on the floor.

A summary of pesticide loadings is given in Table 2, with values for floors and hands expressed as loadings (micrograms per square meter), and toy wipes expressed as weights (micrograms). There is considerable variability in the loadings or weights of pesticides found on the same surface between different chemicals and within the same chemical.

Among possible predictors of at least one agricultural pesticide detected on any surface sampled (Table 3), two reached statistical significance. An elevated risk of agricultural pesticides was observed given agricultural fields adjacent to the house (unadjusted OR = 18; 95% CI, 3.7–88). The association persisted for location adjacent to agricultural fields, after adjusting for other possible predictors (adjusted OR = 20; 95% CI, 3.2–126.2). No other predictors were statistically significant in the multiple logistic regression model.

Two of the possible predictors of level of residential pesticides detected on any surface

Table 1. Description of 41 farmworker households, North Carolina and Virginia, 2002.

Characteristics	No. (%)	Characteristics	No. (%)
Respondent characteristics		Household characteristics	
Sex		Household structure	
Female	41 (100)	Nuclear family	23 (56)
Male	0 (0)	Nuclear family + other relatives	12 (29)
Age (years)		Nuclear family + others (including relatives)	6 (15)
< 25	11 (27)	Household size (no. of persons)	
25–29	15 (37)	3	4 (10)
30–34	8 (20)	4	12 (29)
≥ 35	7 (17)	5	10 (24)
Work		≥ 6	15 (20)
Agricultural	16 (39)	No. of adults in household ≥ 18 years of age	
Nonemployed/houseworker	21 (51)	2	20 (49)
Other	4 (10)	3	10 (24)
Focal child characteristics		≥ 4	11 (27)
Sex		No. of children in household < 18 years of age	
Female	25 (61)	1	12 (29)
Male	16 (39)	2	16 (39)
Age (months)		3 or 4	13 (32)
12–24	11 (27)	No. of farmworkers in household	
25–48	13 (32)	1	18 (44)
≥ 49	17 (42)	2	14 (34)
Qualifying farmworker characteristics		≥ 3	9 (22)
Sex		Housing characteristics	
Female	5 (12)	Housing type	
Male	36 (88)	Mobile home or trailer	22 (54)
Age (years)		One-family house or other	14 (34)
< 25	7 (17)	Building with ≥ 2 units	5 (12)
25–29	14 (34)	Ease of cleaning	
30–34	7 (17)	Easy	21 (51)
≥ 35	13 (32)	Difficult	20 (49)
Relationship to respondent		Air conditioning	
Self	4 (10)	Does not have	34 (83)
Spouse	32 (78)	Has and uses	4 (10)
Other	5 (12)	Has and does not use	3 (7)
Proportion of year in agricultural work (%)		Owns a vacuum cleaner	
< 50	6 (15)	Yes	28 (68)
50–75	8 (20)	No	13 (32)
≥ 76	27 (66)	Housing adjacent to fields	
		Yes	18 (44)
		No	23 (56)

sampled (Table 4) were statistically significant ($p < 0.05$). Increased odds of a higher number of residential pesticides was associated with houses judged difficult to clean (unadjusted OR = 4.2; 95% CI, 1.2–14.9) and rented housing (unadjusted OR = 4.6; 95% CI, 1.0–21). These two predictors, plus pesticide application work, non-nuclear family, and mobile home were tested in the multiple regression model based on $p < 0.2$ in the simple regression. An increased likelihood of residential pesticides was observed, given that houses were judged difficult to clean (adjusted OR = 5.1; 95% CI, 1.2–22.4).

Discussion

This study of North Carolina and Virginia farmworker residences demonstrates that pesticide residues can be detected in wipe samples for both agricultural chemicals and those commonly found in dwellings. As the first study to screen for a large number of both agricultural and residential pesticides in farmworker dwellings, this extends previous research on exposure of this population. Unlike previous studies that have focused on OP pesticides (e.g., Curl et al. 2002; Fenske et al. 2002; Simcox et al. 1995), this study includes OPs, pyrethroids, organochlorines, carbamate, and herbicides. Our findings indicate that all categories of pesticides examined, not just OPs, are present in farmworker homes with young children in residence.

The presence of common residential pesticides detected in this study is similar to that obtained from house dust samples in seven areas across the United States (Camann et al. 2000). As in the present study, Camann et al. (2000) found that organochlorines, OPs, carbamates, and pyrethroids were present in most homes. The data in the present study suggest that housing quality predicts household pesticide levels. Houses that are harder to clean may provide better habitats for pests (resulting in greater use of pesticides) as well as prevent the removal of pesticide-containing dust. Others have found that pesticides remain embedded in carpets and that carpets have a higher number of pesticides and higher concentrations than indoor air or outdoor soil (Lewis et al. 1994). Because of the wide variety of residential pesticides detected and differences in their concentrations, the composite measure used here of low, medium, and high numbers of pesticides may be too crude to identify the strongest predictors of pesticide presence.

The findings from this study confirm that the floor may be a reservoir of pesticide residues in the home. The greatest number of detections was in floor wipe samples. For only one pesticide was the number of detections on the floor less than that on hands or toys.

Table 3. Analysis of associations between presence of any agricultural pesticide and potential risk factors, using logistic regression modeling, farmworker homes, North Carolina and Virginia, 2002.

Potential risk factor (reference group)	No.	Unadjusted OR (95% CI)	Unadjusted *p*-Value	Adjusted[a] OR (95% CI)	Adjusted[a] *p*-Value
House next to agriculture (not next to)	41	18.0 (3.7–88.0)	< 0.0001	20.0 (3.2–126.2)	0.03
Non-nuclear family (nuclear family)	41	2.4 (0.7–8.6)	0.16	4.9 (0.8–30.6)	0.09
≥ 3 agricultural workers in household (vs. ≤ 2)	41	2.6 (0.5–12.1)	0.23	—	—
October–December interview (vs. June–September)	41	1.1 (0.3–3.7)	0.69	—	—
Pesticide application work (no such work)	41	4.2 (0.9–19.1)	0.05	2.5 (0.4–17.0)	0.34
Multifamily building (single-family home)	19	0.7 (0.1–5.3)	0.70	—	—
Mobile home (single-family home)	36	1.0 (0.3–3.8)	1.0	—	—
House difficult to clean (not difficult)	41	1.6 (0.5–5.6)	0.43	—	—
Rent house (own house)	41	2.3 (0.5–10.7)	0.29	—	—
Windows always closed (sometimes open)	41	1.7 (0.2–11.3)	0.59	—	—
Vacuum < once/week (at least once)	41	1.3 (0.4–4.6)	0.65	—	—
Age of farmworker in units of 10 years	41	0.9 (0.4–2.2)	0.82	—	—
Age of respondent in units of 10 years	41	0.6 (0.2–1.6)	0.28	—	—

—, Other variables were not included in multiple regression model.
[a]Adjusted ORs and corresponding 95% CIs and *p*-values are calculated using a multiple regression model with "house next to agriculture," "non-nuclear family," and "pesticide application work" as independent variables.

Table 2. Measured chemical loadings on floors (μg/m²), toys (μg),[a] and children's hands (μg/m²), 41 farmworker homes, North Carolina and Virginia, 2002.

Pesticide	Category	Floor No. (%)[b]	Floor Mean ± SD	Floor Min–Max	Toys No. (%)[b]	Toys Mean ± SD	Toys Min–Max	Hands No. (%)[b]	Hands Mean ± SD	Hands Min–Max
Agricultural										
Disulfoton	OP	3 (7)	6.5 ± 2.3	4.3–8.9	0	—	—	0	—	—
Esfenvalerate	PY	5 (12)	29.9 ± 37.9	4.8–94.0	2 (5)	3.7 ± 4.0	0.9–6.5	2 (5)	49.8 ± 15.8	38.6–60.9
Lindane	OC	2 (5)	2.2 ± 0.2	2.0–2.3	1 (2)	0.4	—	1 (2)	11.0	—
Oxyfluorfen	HE	10 (24)	15.7 ± 21.7	1.9–71.0	3 (7)	0.6 ± 0.1	0.5–0.7	2 (5)	31.0 ± 39.0	3.4–58.6
Pendimethalin	HE	3 (7)	20.2 ± 34.3	0.4–59.8	2 (5)	1.9 ± 1.0	1.2–2.5	1 (2)	17.9	—
Simazine	HE	9 (22)	20.4 ± 22.5	1.2–70.0	6 (15)	5.9 ± 10.9	0.4–27.9	5 (12)	22.5 ± 34.0	2.7–82.1
Residential										
Carbaryl	CA	8 (20)	6.2 ± 6.1	1.2–18.5	0	—	—	0	—	—
α-Chlordane	OC	14 (34)	1.9 ± 2.4	0.2–8.8	3 (7)	0.5 ± 0.1	0.3–0.6	1 (2)	2.2	—
γ-Chlordane	OC	17 (41)	2.8 ± 3.5	0.3–12.5	6 (15)	0.6 ± 0.4	0.2–1.2	1 (2)	4.4	—
Chlorpyrifos	OP	32 (78)	8.9 ± 18.4	0.2–87.9	11 (27)	2.1 ± 3.9	0.2–13.6	6 (15)	6.1 ± 6.1	1.9–18.0
4,4′-DDT	OC	2 (5)	10.0 ± 0.5	9.6–10.3	1 (2)	0.5	—	0	—	—
Diazinon	OP	14 (34)	2.6 ± 3.1	0.4–9.4	2 (5)	0.5 ± 0.3	0.3–0.7	0	—	—
Heptachlor	OC	4 (10)	2.0 ± 0.8	1.0–2.9	0	—	—	0	—	—
Methoxychlor	OC	1 (2)	19.4	—	0	—	—	2 (5)	8.0 ± 5.3	4.3–11.7
cis-Permethrin	PY	27 (66)	30.6 ± 66.4	1.4–317.4	7 (17)	2.6 ± 1.3	1.5–5.1	4 (10)	13.5 ± 7.5	8.7–24.7
trans-Permethrin	PY	38 (93)	33.5 ± 85.7	0.8–488.1	21 (51)	1.8 ± 1.6	0.3–4.9	16 (39)	10.0 ± 8.3	3.4–33.6
Propoxur	CA	15 (37)	4.0 ± 7.8	0.5–30.5	1 (2)	0.5	—	0	—	—

Abbreviations: CA, carbamate; HE, herbicide; Max, maximum; Min, minimum; OC, organochlorine; PY, pyrethroid. In some cases, there was only one (mean only) or no (—) observation.
[a]Pesticide weights are presented because toy surface area could not be measured. [b]Number of samples above detection limit (percentage of total samples) ($n = 41$).

For both agricultural and residential pesticides, presence of pesticides on the floor predicted pesticides on hands or toys. This is consistent with the ideas that pesticides are frequently tracked into the home on feet and that, once inside the home, they are resuspended into the air and redeposited as they fall on surfaces (Lewis et al. 2001; U.S. EPA 1999).

Relatively fewer homes had detectable agricultural pesticides than residential pesticides, perhaps because specific agricultural pesticides are used on an as-needed basis in most of the common crops (e.g., Christmas trees, ornamental plants, and tobacco). Furthermore, the data collection period spanned 7 months, so exposure peaks may have been missed.

Dwellings adjacent to fields can be contaminated by drift during application and by subsequent wind circulation of dust from fields. Previous studies (Lewis et al. 2001) have demonstrated that pesticides applied outside dwellings are redeposited inside the dwelling within hours. Fenske et al. (2002) showed a gradient in indoor detection of agricultural pesticides based on proximity to orchards where such pesticides are sprayed. Koch et al. (2002) used analysis of biomarkers in children's urine to demonstrate temporal associations of spraying and exposure. This supports the possibility of drift from agricultural fields being a source of agricultural pesticides in the present study. Repeated measurements across the agricultural cycle could better substantiate drift as the mechanism of household contamination.

The presence of agricultural pesticides may be due to safety and hygiene practices of the workers (not measured here). Those applying pesticides can bring residues into dwellings on clothing and skin, as well as track it in on boots. Further investigation is needed of farmworker behaviors such as hand washing before entering the dwelling, storage of soiled work clothes, and showering practices after work. Work environment characteristics such as availability of personal protective equipment and washing facilities should also be investigated. Prior research in eastern North Carolina found that < 40% of workers had access to wash water in the fields (Arcury et al. 2001). A large number reported never having received the pesticide safety training mandated by the U.S. EPA Worker Protection Standard (Arcury et al. 1999). Health beliefs of many migrant workers lead them to delay showering after work (Arcury et al. 2001). Because they believe that their bodies must cool down before washing after work or risk rheumatism or other health effects, they may fail to follow pesticide safety measures that would remove pesticide residues from the skin and decrease transfer to children and household surfaces. Similar practices and training deficiencies have been reported in Oregon (McCauley et al. 2001) and Washington (Thompson et al. 2003). If these same health beliefs and practices characterize the western North Carolina and Virginia study area, they may account for some of the indoor contamination with agricultural pesticides.

Table 4. Analysis of associations between high, medium, and low residential pesticides and potential risk factors using the proportional odds model, farmworker homes, North Carolina and Virginia, 2002.

Potential risk factor (reference group)	No.	Unadjusted OR (95% CI)	Unadjusted *p*-Value	Adjusted[a] OR (95% CI)	Adjusted[a] *p*-Value
House next to agriculture (not next to)	41	0.6 (0.2–2.0)	0.42	—	—
Non-nuclear family (nuclear family)	41	2.5 (0.7–8.3)	0.14	1.4 (0.4–5.6)	0.60
≥ 3 agricultural workers in household (vs. ≤ 2)	41	0.7 (0.2–2.9)	0.63	—	—
October–December interview (vs. June–September)	41	1.1 (0.3–3.5)	0.88	—	—
Pesticide application work (no such work)	41	0.3 (0.1–1.0)	0.06	0.3 (0.1–1.1)	0.07
Multifamily building (single-family home)	19	1.2 (0.2–8.7)	0.84	2.9 (0.3–29.2)	0.38
Mobile home (single-family home)	36	0.3 (0.1–1.3)	0.11	0.4 (0.1–1.6)	0.18
House difficult to clean (not difficult)	41	4.2 (1.2–14.9)	0.03	5.1 (1.2–22.4)	0.03
Rent house (own house)	41	4.6 (1.0–21.0)	0.05	2.3 (0.4–13.6)	0.34
Windows always closed (sometimes open)	41	2.4 (0.4–14.3)	0.35	—	—
Vacuum < once/week (at least once)	41	1.8 (0.6–5.9)	0.32	—	—
Age of farmworker in units of 10 years	41	0.9 (0.4–2.1)	0.85	—	—
Age of respondent in units of 10 years	41	1.0 (0.4–2.4)	0.93	—	—

—, Other variables were not included in multiple regression model.
[a]Adjusted ORs and corresponding CIs and *p*-values are calculated using a multiple regression model with "non-nuclear family," "pesticide application work," "multifamily" and "mobile home," "house difficult to clean," and "rent house" as independent variables.

We presume that hygiene practices that would reduce the introduction of agricultural pesticides into the home are deficient, resulting in agricultural pesticides in households. However, the greater recoveries of residential than agricultural pesticides may indicate that, in fact, work-related hygiene practices are more effective than those related to the use of residential pesticides. Qualitative data collected from worker families at the same time wipe samples were collected (data not reported here) showed a high degree of misinformation about the safety of residential pesticides. Further analyses of these data may reveal the particular practices introducing such pesticides into the home.

It is difficult to interpret the health significance of the amounts of pesticides measured in the wipe samples. The ranges are large, even for floor samples standardized for area. Other studies measuring indoor pesticides have used a variety of different sampling methods—air concentrations, foundation soil samples, and carpet vacuuming, as well as the surface, toy, and hand wipes used here (Gordon et al. 1999; Lewis et al. 2001; Simcox et al. 1995; Whyatt et al. 2002). However, there is no standard for presenting such data, making it impossible to compare one study with another. The wide ranges suggest that examination of behavioral predictors in a larger sample is warranted.

The findings of this study need to be considered in light of several limitations. The sample size is small, particularly given the wide variability of pesticide loadings detected. Because a random sample was not possible, there could be bias introduced by the sampling method. These findings are also limited by the lack of data on several important predictors of concentrations in the home—number of days since last application of residential pesticides and since last application in adjacent fields. Farmworkers rarely have access to such data. They generally reside in rented or grower-supplied housing for which they have no records of pesticide application. They do not have records of when or what pesticides were last applied in adjacent fields. These fields may or may not belong to their employer. North Carolina and Virginia, like many states, have no statewide system for reporting pesticide application.

This study extends previous research that has detected dislodgeable residues of OP pesticides in rural dwellings occupied by migrant and seasonal farmworkers (Lu et al. 2000; Simcox et al. 1995; Thompson et al. 2003). We demonstrate that pesticides used in the home as well as those brought from agricultural settings into the indoor environment contribute to the overall exposure of residents to pesticides. In this study, residents included young children, whose susceptibility to pesticide-related health problems is, in general, greater than that of adults. This study also extends research on farmworker pesticide exposure to the eastern United States. Further investigation of pesticide exposure of farmworkers and their families is needed in other areas to document the extent of the risk experienced by farmworker families and possible health effects of such exposure.

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