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Organophosphate Pesticide Exposure in Farmworker Family Members in Western North Carolina and Virginia: Case Comparisons

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Farmworkers and their family members are exposed to pesticides in their homes as well as at work. Using a sample of nine farmworker households in western North Carolina and Virginia, this analysis describes the organophosphate (OP) pesticide urinary metabolite levels of adults and children in these households, and compares these farmworker household OP metabolite levels to the national reference data. Data from survey and in-depth interviews are analyzed to find dwelling, household, and work characteristics related to OP metabolite levels. All participants had measurable OP metabolites. Every household had a high level of OP metabolites when compared to national reference data. There were common factors among the households that could cause the high household OP exposure, including farm employment and living adjacent to agricultural fields. Factors associated with household variability in OP exposure included having a non-nuclear family structure, and, therefore, having more adult males who were employed doing farm work, living in rental housing, not owning a vacuum cleaner, residing in a dwelling that is difficult to clean, and the season (spring versus summer) in which urine samples were collected. These results indicate that regulatory changes that improve low income housing, improve industrial hygiene standards, and provide farmworkers information about their pesticide exposure are needed to protect farmworkers and their families.

Key words: migrant and seasonal farmworkers, farmworker families, pesticides, organophosphate pesticide metabolites

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The risk of pesticide exposure among farmworkers is well established. This risk is not limited to those who labor directly in the fields. Those who live with farmworkers—their spouses and children—are exposed to pesticides through a variety of routes (Fenske, Lu, Simcox, Loewenherz, Touchstone, Moate, Allen and Kissel 2000), including drift from applications in nearby fields, entering fields to which pesticides have been applied, residues on workers' skin, clothing, boots and tools, remnants in pesticide containers, and food brought from work. While the dose from each of these exposures may be small, their combined effects can have serious repercussions for every family member's health, particularly that of children (Eskenazi, Bradman and Castronia 1999).

This paper presents evidence of exposure to organophosphate (OP) pesticides by examining the OP metabolite levels measured in urine from the members of nine Latino farmworker families in rural western North Carolina and Virginia. The goal of this analysis is to determine whether the members of farmworker families are exposed to OPs at levels greater than the general US population, and to document factors related to greater exposure. This would document an issue of environmental justice and a possible cause of health disparities. Policy and regulation that can reduce OP exposure based on these results can then be developed.

OP pesticides are among the most widely applied and toxic agricultural pesticides (Reigart and Roberts 1999). They are applied to crops ranging from tobacco and Christmas trees to vegetables and orchard fruit. OPs can be absorbed by inhalation, by ingestion or through the skin. OPs affect the nervous system in reducing the amount of acetycholinesterase (AChE) enzyme at nerve endings. If they do not inactivate AChE, they are quickly metabolized and excreted, with the majority excreted within 24 to 48 hours. Recovery from OP poisoning depends on the generation of new enzyme in affected tissue or the regeneration of OP-inactivated enzyme. The amount needed to cause immediate symptoms or delayed health effects depends on dose. The immediate health effects of OP exposure can include rashes, nausea and vomiting, dizziness and headache, muscle ache, fatigue, loss of consciousness, shock, coma, and death. The delayed health effects can include impotence, birth defects, impaired neurological development and status, and cancer (US-EPA 1999). In addition to their effects on physical health, OPs are suspected to cause depression (Stallones and Beseler 2002).

There are no reliable data on the number of agricultural workers who annually are exposed to OPs, nor are there data on the number whose exposure is sufficiently severe to result in illness. Only a few states have mandated reporting of occupational pesticide exposure (Maizlish, Rudolph and Dervin 1995). Most research on farmworker pesticide exposure focuses on occupational exposure. However, there is growing literature that shows that family members, especially children, of farmworkers are also exposed to pesticides due to: (1) farmworker housing location that exposes them to drift or over-spraying of pesticides; (2) pesticides taken home by farmworkers on skin, clothes, boots, containers, produce, and in vehicles; and (3) direct application of agricultural and residential pesticides to farmworker dwellings to control household pests (Fenske et al. 2000). Several investigators have shown that pesticides can be detected in the dwellings of farmworkers, in the farmworkers themselves, and in those who live with farmworkers (Curl, Fenske, Kissel, Shirai, Moate, Griffith, Coronado and Thompson 2002; Fenske, Lu, Barr and Needham 2002; Lu, Fenske, Simcox and Kalman 2000; Shalat, Donnelly, Freeman, Calvin, Ramesh, Jimenez, Black, Coutinho, Needham, Barr and Ramirez 2003).

There is also growing evidence that there is exposure to agricultural and non-agricultural pesticides in dwellings across the US, including those located in non-agricultural suburban and inner-city locales (Berkowtiz, Obel, Deych Lapinski, Godbold, Lie, Landrigan and Wolff 2003; Curl, Fenske and Elgethun 2003). Therefore, as OPs and other pesticides are used for controlling insects, farmworkers, who often reside in substandard housing in which pest infestation is a problem, may be further exposed to pesticides.

None of the research on pesticide exposure among farmworker family members or in farmworker dwellings has considered farmworker communities in the eastern US, particularly among the newer Latino immigrant farmworker populations in the Southeast. The general Latino immigrant population in this area has grown rapidly since 1990 (Therrien and Ramirez 2001). The official count in North Carolina shows that the Latino population grew by almost 500% between 1990 and 2000, from 76,276 to 378,963. This is probably an undercount. As with the national farmworker population, North Carolina's farmworker population has also become overwhelmingly Latino since 1990 (Mehta, Gabbard, Barrat, Lewis, Carroll and Mines 2000). Estimates of the number of migrant and seasonal farmworkers in North Carolina vary from over 100,000 to almost 250,000.

This analysis expands on studies of agricultural pesticides in farmworker homes. Using the results of urine metabolite analysis for OPs for adults and children who reside in a dwelling with at least one farmworker, it addresses two questions. First, what are the OP metabolite levels in adults and children living in such households? How do these exposure levels compare to national reference data on exposure levels by age group, by gender, and among Latinos? Second, how are these metabolite levels related to social (household), physical (dwelling), work and behavior characteristics of farmworker families?

Methods

The La Familia Study

The data used in this analysis were collected as part of the formative research of the intervention study *¡La Familia! Reducing Farmworker Pesticide Exposure.* The formative research, completed from April 2001, through May 2002, included: (1) in-depth interviews with growers and agricultural extension agents delineating their views of farmworker pesticide exposure (Rao, Arcury, Quandt and Doran 2004); (2) in-depth interviews with adults from 41 farmworker families delineating their beliefs and behaviors related to residential pesticide exposure and safety; (3) pesticide exposure pathway assessment in the dwellings of the 41 farmworker families based on wipe samples and fixed response interviews (Quandt, Arcury, Rao, Mellen, Camann, Doran, Yau, Hoppin and Jackson 2004), and (4) urine samples collected from adults and children from nine of the 41 farmworker families. This case analysis focuses on the OP metabolites found in the urine samples and uses information collected in the exposure pathway assessment fixed response interviews and in-depth interviews with farmworkers to answer the research questions.

The La Familia formative research was completed in five mountain counties in northwest North Carolina and three in southwest Virginia. Like other parts of the Southeast and the nation (Mehta et al. 2000), the majority of farmworkers in these counties are Latino immigrants, and most are from Mexico (Arcury, Quandt and Russell 2002; Quandt, Preisser and Arcury 2002b). The number of farmworkers varies seasonally, with numbers peaking in August through November with the Christmas tree, tobacco and vegetable

harvest. The 2000 census put the total number of Latinos in these counties at 2,975. The estimated total farm laborers in these counties during peak harvest season is 6,900 (North Carolina Employment Security Commission 2003; Virginia Employment Commission 2003).

The agriculture in this region is dominated by the production of Christmas trees, ornamental plants and burley tobacco, with some vegetables and fruits being produced. Christmas trees have become the dominant agricultural commodity, with total annual sales of over $100,000,000. Clippings from the Christmas trees are used to make Christmas wreaths and garlands. Many who make these seasonal ornaments are Latino women.

An array of insecticides, herbicides and fungicides are used in mountain agriculture (Cope, Avery, Storm and Luginbuhl 1998, 1999a,b). The major OP insecticides used include acephate, azinphos methyl, chlorpyrifos, dimethoate, disulfoton, fenamiphos, and phosmet. Current laboratory analysis for six non-specific phosphorus-containing OP metabolites can measure exposure to all of these pesticides except acephate and fenamiphos.

Survey and In-Depth Interview Data

For the larger exposure assessment component of this research, we located, recruited and completed in-depth interviews, survey interviews and wipe sample collection in 41 farmworker households. Inclusion criteria were that the household include at least one adult who had done farm work in the previous 12 months, and at least one child 12 to 84 months of age. Farm work was broadly defined to include planting, cultivating, harvesting or packing and shipping agricultural produce on a farm or nursery, or making Christmas wreaths or garlands. All of the farmworkers included in this sample have "permanent" homes in the study area, and they are employed in agricultural work permanently or seasonally. Other farmworkers who migrate into and out of the area sometimes stay with the study participants.

There is no list of farmworkers who reside in this region. Farmworkers do not live in camps and are scattered throughout the region, except for the short period when Christmas trees are harvested in the fall. Farmworkers with families and children in the restricted age range are even more scattered. Many Latino immigrants in the region do not want to be found, due to a fear of the authorities, even when they have immigration documents. We therefore used a site-based approach (Arcury and Quandt 1999) to locate potential participants, working with local service providers to locate potential families meeting the inclusion criteria. These included local women's groups, English as a Second Language (ESL) classes, and church groups. We expanded the list of potential families using a snowball approach in which recruited participants introduced us to additional potential participants.

The fixed response survey interview was completed with an adult woman in each household. This survey interview had questions on the demographic characteristics of the household members, as well as items on the characteristics of the dwelling. The tape recorded in-depth interview was then completed with the women. In a few instances, the woman respondent's husband also answered some in-depth interview questions. All interviews were conducted in Spanish by a bilingual interviewer. Participants were given a $20 incentive for completing this study. The entire data collection protocol was reviewed and approved by the Institutional Review Boards of Wake Forest University School of Medicine and the Centers for Disease Control and Prevention (CDC).

Survey data were entered into a database for statistical analysis. The in-depth interviews were transcribed verbatim and translated into English by a professional translation service. The transcribed in-depth interviews were entered into *The Ethnograph v5.0*™ (Seidel 1998) for analysis.

Urine Collection and Laboratory Analysis

Our target for the urine sample collection study was to recruit 8 of the 41 environmental exposure assessment study households. The small sample size was dictated by the demands of the urine collection protocol, cost of laboratory analysis and formative nature of the research. Because the population is mobile and we anticipated some loss to follow-up, we asked ten of the 41 households to participate. Only one household did not provide urine samples. The nine households that participated did not differ appreciably from the 41 households that participated in the exposure assessment study (for a description of the 41 households see Quandt et al. 2004.)

Urine collection materials were left with participants. They were asked to contact project staff when an adult farmworker residing in the household was applying pesticides, as we wanted to collect urine samples within one or two days after pesticide application to coincide with maximum metabolite excretion in the urine. Participants were instructed to collect urine samples from two adults and two children in the family on two successive days, and to place urine samples in a closed tray in their refrigerator. Project staff picked up the samples, completed a short questionnaire about current household, dwelling and work characteristics, and gave the participants an incentive of $20.00 for each household member (adult and child) who provided a urine sample.

Frozen samples were shipped to CDC in Atlanta, GA for analysis. Samples were analyzed for six dialkylphosphate (DAP) metabolites of organophosporus pesticides: dimethylphosphate (DMP), dimethylthiophosphate (DMTP), dimethyldithiophosphate (DMDTP), diethylphosphate (DEP), diethylthiophosphate (DETP), and diethyldithiophosphate (DEDTP). Urine samples were analyzed using the method of Bravo, Caltabiano, Weerasekera, Whitehead, Fernandez, Needham, Bradman and Barr (2003).

Measures

Measures considered in each case study included OP pesticide metabolite levels obtained from the urine samples; dwelling, household and work characteristics obtained as part of the survey interview of the participants; and descriptions of pesticide safety behaviors and beliefs obtained as part of participant in-depth interviews.

Pesticide metabolite levels in each individual were based on the two day average concentrations (for those instances in which only one urine sample was collected, un-averaged data for the one day were used). We used all reported data for the urine samples, regardless of whether the reported concentration was below the formal limit of detection reported by the laboratory. For those samples where no metabolite was detected, we assigned a value of 0.

CDC has measured OP metabolites in samples collected as a part of the 1999-2000 cycle of the National Health and Nutrition Examination Survey (NHANES) (CDC 2003; Barr et al. 2004). These data represent the non-institutionalized civilian US population levels of the OP metabolites. This information is reported for each of the six non-specific OP metabolites (DMP, DMTP, DMDTP, DEP, DETP, and DEDTP) in percentiles, with 95% confidence intervals. Results are reported for the total population aged 6 through 59 years, by three age groups (6-11 years, 12-19 years, 20-59 years), by gender, and by ethnicity (Mexican Americans, Non-Hispanic blacks, Non-Hispanic whites). We compared the two day average levels of each of the six OP metabolites for each individual in our sample to the total, age group (excluding children under age 6), gender and ethnic group levels at the 50th and 90th percentiles for each metabolite. The percent of the times household members were above the 50th percentile was calculated: [percent of person-metabolite comparisons above 50th percentile = number of comparisons above 50th percentile / [(total, age, gender, ethnicity) x 6 metabolites x n people age 6 plus] + [(total, gender, ethnicity) x 6 metabolites x n people under age 6)]. We noted whether an individual household member was above the 90th percentile for any reference group. Based on these comparisons, each household was classified into one of three metabolite level groups: (1) low, fewer than 50% of the comparisons were above the NHANES 50th percentile; (2) middle, 50% to 69% of the comparisons were above the NHANES 50th percentile; and (3) high, at least 70% of the comparisons were above the NHANES 50th percentile comparisons, and at least two persons in the household were at or above the NHANES 90th percentile in at least one comparison.

Tenure, which has the values own or rent, is the first *dwelling characteristic*. Length of residence in the dwelling is reported for the male and female householders; it is reported separately if their lengths of residence differed. Building type has the values single family house or mobile home. Pesticides often accumulate in carpeting, and they can be recirculated in a dwelling. We report if a dwelling has carpeting, the rooms with carpet, and the proportion of rooms with carpet. Ease of cleaning is based on the observations of the interviewer and has the values easy or difficult. Ownership of a vacuum cleaner is a dichotomous measure. (For dwellings included in the urine analysis sample, those judged easy to clean always had a vacuum cleaner, while those judged difficult to clean never had a vacuum cleaner. This was not the case for the larger sample of 41 households included in other components of this study.) Adjacency to an agricultural field is a dichotomous measure based on whether the interviewer observed any type of agricultural field next to or across the road from the participant's dwelling. Leave windows open at night is a dichotomous measure indicating whether the participants usually left windows in the dwelling open at night around the time the samples were collected. Season in which the urine sample was collected has the values Spring (April or May, 2002), and Summer (August or September, 2001).

Household characteristics include the numbers of adults, children and total persons in the household; household composition (nuclear or non-nuclear); and length of residence in the US. The number of farmworkers in the household includes all adults who had earned some income doing farm work or making Christmas ornaments in the previous twelve months.

Work characteristics included the farm work in which each farmworker in the household was typically engaged. Pesticide reported is the pesticide that was applied at the time the urine samples were collected. Few participants knew the name of the pesticide.

Pesticide exposure behaviors were determined from the in-depth interviews. In-depth interview transcripts were reviewed for participant discussion about whether they thought their families were exposed to pesticides, how they might be exposed to pesticides, storage and laundering of agricultural work clothes, how long after work those employed in farm work bathed, if materials such as pesticide containers were brought home from work, if they experienced pesticide drift, and if they applied pesticides in their homes. Quotations are used to illustrate behaviors discussed in the interviews; numbers in parentheses refer to lines in the transcript.

Case Analysis and Comparison

There are three components to the case analyses. First, the OP metabolite measures among the household members are described in comparison with NHANES national reference data for OP metabolites (CDC 2003; Barr et al. 2004), with each household categorized into the Low Metabolite Level Group, Middle Metabolite Level Group, and High Metabolite Level Group (Table 1). We then describe the household characteristics, the dwelling characteristics and the work characteristics of each case (Table 2). Finally, we describe pesticide beliefs and behaviors for each case. The household, dwelling, work, and pesticides beliefs and behavior characteristics of cases in the high, middle and low metabolite groups are compared. The goal is to find characteristics that help explain why cases fall into the different metabolite groups.

Results

Case Descriptions

Summaries of each case showing the levels of OP pesticide metabolites measured for each household member, as well as household, dwelling and work characteristics are presented in Tables 1 and 2. All participants had measurable OP urinary metabolites. Only one participant (1 year old female, Case 9) was not above the 50th percentile in comparison with NHANES data for at least one OP metabolite. All households had at least one person at the 90th percentile in comparison to the NHANES data for at least one OP metabolite. Only two households (Case 9, Case 10) did not have at least one child above the 90th percentile.

Case 1 (Low Metabolite Level Group): Forty percent (36 of 90) of comparisons with NHANES data were above the 50th percentile, and one household member was above the 90th percentile. This household includes a nuclear family with two adults and two children; one of the adults was a farmworker. The adults were from Mexico and had been in the United States for two years. They moved into their rented mobile home one month before the urine sample collection. There was no carpeting in the dwelling, which was described as difficult to clean. There were Christmas trees growing within 3 meters of the house. The farmworker (the adult male) typically worked in Christmas trees. The urine samples were collected in the summer, and the farmworker reported that the agricultural chemical he helped apply just prior to the sample collection was an herbicide.

The farmworker changed out of work clothes and showered immediately after work, and wore clean work clothes daily. His wife reported, "He takes off his work clothes and we put them away, and the next day he puts another one on. I keep washing his work clothes" (1259). The soiled work clothes were stored and laundered separately from other family clothing, "Like he keeps the clothes in one place, the ones from work. And he washes in just one place, he washes just what's from work. And the clothes we use, we wash them separate here. And we keep it separate from the girl's and the boy's, like keep it separate, mine and my husband's. And the work clothes separate" (1108). They kept their windows closed to keep bugs out. The adult female washed fruit and vegetables to remove pesticides. She cleaned to get pesticides out of her house, "I don't know what the detergent is called because there's different ones, there's different smells. That you use to mop, so that it gets rid of the smell, the pesticide on the floor so the baby can play" (1344).

Case 2 (Low Metabolite Level Group): Thirty-two percent (29/90) of comparisons with NHANES data were above the 50th percentile, and one household member, a child, was above the 90th percentile. The household included a nuclear family with two adults and three children. Both adults did farm work, were from Mexico, and had been in the United States for six years. They had lived in their mobile home, which they own, for three years. The bedrooms were carpeted and the dwelling was described as easy to clean. There were no nearby agricultural fields. The urine samples were collected in the summer. The male farmworker reported that the pesticide he helped apply just prior to the sample collection was an herbicide.

The mother complained that her son regularly gets rashes. "The boy sometimes gets a rash, or he starts itching, or allergies he gets from the plants" (383). The male farmworker sometimes did not change or shower immediately after work. "Sometimes he sits there a while, and after one hour or two hours he changes and take off his pants and puts on his shorts and then later in the night, like around eight or nine he takes a shower" (1949). They kept their soiled work clothes in a sealed plastic container next to the washer, but did not separate them from the rest of the family's clothing for washing. They used old pesticide containers outside for trash. They did not do anything special to keep pesticides out of the home, "Nothing, nothing at all. Because sometimes not even the window, like it's too hot I can't close the window" (2008). However, they did not use residential pesticides; they used a fly swatter.

Case 5 (Middle Metabolite Level Group): For this household, 51% (37/72) of comparisons with NHANES data were above the 50th percentile. However, two household members, an adult and a child, were above the 90th percentile. This was a nuclear family household with two adults and two children. The adults were Mexican and had been in this country for nine years. They owned the single-family home, and moved into it one month before the samples were collected. There was carpeting in the bedrooms, as well as the living and dining rooms. The dwelling was easy to clean, and it was adjacent to a hay field. The urine samples were collected in Spring. The adult male was a farmworker who typically worked in Christmas trees and vegetables. He reported that he had helped apply the OP disulfoton prior to the urine sample collection.

The farmworker in this household had received pesticide safety training, and wore personal protective equipment (PPE) at work. His wife reported that he usually changed from work clothes and showered immediately upon coming home, and that he did not play with their children until after he showered. "He comes home, takes a shower. He doesn't play with the children because he was very careful about it, like I told you he doesn't want the children to become intoxicated. And the children know, so they don't touch him until he takes a shower and then he plays with them" (672). However, "When he comes from using fertilizers or insecticides he showers right away. When he hasn't, he waits for a while, sometimes he has dinner and then he takes a shower but when he has insecticides he gets into the shower right away" (777). The wife feared pesticide exposure, and knew that her farmworker husband could bring home pesticides on his clothes and body. They laundered work clothes separately (because they were more soiled), but stored them in the laundry room with other family clothing.

Case 6 (Middle Metabolite Level Group): This was a middle metabolite level household with 64% (58/90) of

Table 1. Organophosphate Pesticide Metabolic Levels for Sample Individuals in Each Farmworker Household

Households and Individuals	Organophosphate Pesticide Metabolite Levels in :g/L					
	DEP	DETP	DEDTP	DMP	DMTP	DMDTP
Case 1 / LF07 - Low						
Adult 1 (male, 28, farmworker)	3.04 TAGM	0.83 G	0.00	0.00	0.00	0.00
Adult 2 (female, 30)	1.56 TAGM	0.91 A	0.00	0.99 TAG	1.36	0.00
Child 1 (male, 1)	0.77	0.85 G	0.00	0.91 TG	0.00	0.00
Child 2 (female, 8)	2.58 TAGM	2.13 TAGM	0.00	2.23 TAGM	3.92 TAGM	1.19 TAGM
Case 2 / LF06 - Low						
Adult 1 (male, 43, farmworker)	0.36	0.54 TAG	0.00	2.44 TAGM	1.11	0.00
Adult 2 (female, 41, farmworker)	0.37	0.42 G	0.00	0.99 TAG	0.38	0.50 TAGM
Child 1 (male, 5)	0.00	0.41	0.56 TG	0.16	0.00	0.00
Child 2 (female, 13)	3.16 TAGM	0.56 TAGM	0.37	2.48 TAGM	0.61	0.00
Case 5 / LF21 - Middle						
Adult 1 (male, 40, farmworker)	43.28 TAGM	6.21 TAGM	0.00	2.34 TAGM	0.00	0.00
Adult 2 (female, 33, farmworker)	0.00	0.55 TAG	0.00	0.57	0.00	0.50 TAGM
Child 2 (male, 8)	10.25 TAGM	0.55 TG	0.00	6.26 TAGM	6.88 TAGM	1.35 TAGM
Case 6 / LF10 - Middle						
Adult 1 (male, 31, farmworker)	6.07 TAGM	1.14 TAGM	0.37 TAGM	3.40 TAGM	2.85 TAM	2.09 TAGM
Adult 2 (female, 27)	3.46 TAGM	0.88 TAGM	0.00	5.27 TAGM	1.27	0.00
Child 1 (female, 6)	2.65 TAGM	1.56 TAGM	0.00	5.47 TAGM	11.0 TAGM	0.02 TAGM
Child 2 (female, 1)	0.96	0.42	0.52 TGM	0.00	0.00	0.00
Case 9 / LF08 - Middle						
Adult 1 (male, 30, farmworker)	3.74 TAGM	0.81 TAGM	0.00	11.39 TAGM	18.84 TAGM	2.81 TAGM
Adult 2 (female, 24)	1.23 TAGM	0.72 TAGM	0.00	4.35 TAGM	0.00	0.00
Child 1 (male, 5)	0.86	0.68 TGM	0.00	3.01 TGM	7.72 TGM	0.19 TGM
Child 2 (female, 1)	0.22	0.00	0.00	0.00	0.00	0.00
Case 4 / LF12 - High						
Adult 1 (male, 31, farmworker)	0.00	0.90 TAGM	0.00	8.93 TAGM	4.57 TAGM	2.32 TAGM
Adult 2 (female, 31, farmworker)	0.51	1.29 TAGM	0.00	2.19 TAGM	8.97 TAGM	4.96 TAGM
Child 1 (female, 2)	17.33 TGM	3.87 TGM	0.35	31.19 TGM	97.01 TGM	0.42 TGM
Case 7 / LF11 - High						
Adult 1 (male, 47, farmworker)	25.55 TAGM	9.82 TAGM	0.85 TAGM	2.28 TAGM	5.04 TAGM	0.00
Adult 2 (female, 31)	1.53 TAGM	1.20 TAGM	0.25 TAGM	1.65 TAGM	2.21 AGM	0.00
Child 1 (male, 6)	1.74 TAGM	0.80 TAGM	0.63 TAGM	1.70 TAGM	4.44 TAGM	3.55 TAGM
Child 2 (male, 10)	5.69 TAGM	4.13 TAGM	1.45 TAGM	14.04 TAGM	17.02 TAGM	9.06 TAGM
Case 8 / LF02 - High						
Adult 1 (male,28, farmworker)	11.77 TAGM	1.68 TAGM	0.36 TAGM	4.54 TAGM	5.94 TAGM	0.00
Adult 2 (female, 31)	4.34 TAGM	0.80 TAGM	0.00	2.92 TAGM	4.76 TAGM	0.00
Child 1 (female, 3)	35.54 TGM	4.27 TGM	0.00	28.74 TGM	48.05 TGM	0.00
Child 2 (male, 1)	14.23 TGM	1.77 TGM	0.38 TGM	7.36 TGM	10.52 TGM	0.00
Case 10 / LF19 - High						
Adult 1 (male,21, farmworker)	14.18 TAGM	3.30 TAGM	0.64 TAGM	5.72 TAGM	3.44 TAGM	0.74 TAGM
Adult 2 (female, 19)	3.29 TAGM	1.17 TAGM	0.49 TAGM	3.12 TAGM	2.38 TAGM	0.00
Adult 3 (male, 45, farmworker)	14.04 TAGM	2.29 TAGM	0.40 TAGM	3.18 TAGM	4.33 TAGM	0.00
Child 1 (female, 2)	1.02	0.84 TGM	0.42 TGM	1.97 TGM	0.00	0.00
Child 2 (female, 1)	0.55	0.69 TGM	0.40 TGM	0.00	0.00	0.00

T = at or above the 50th percentile for the total NHANES sample.
A = at or above the 50th percentile for the appropriate age group (6-11 years, 12-19 years, 20-59 years).
G = at or above the 50th percentile for gender.
M = at or above the 50th percentile for Mexican Americans
Shaded = at or above the 90th percentile for at least one of the comparisons.

Table 2. Household, Dwelling, and Work Characteristics for Farmworker Households

Characteristics	Case and Metabolite Level Group								
	Case 1 LF07 Low	Case 2 LF06 Low	Case 5 LF21 Middle	Case 6 LF10 Middle	Case 9 LF08 Middle	Case 4 LF14 High	Case 7LF11 High	Case 8 LF02 High	Case 10 LF19 High
Dwelling									
Tenure	rent	own	own	own	rent	rent	rent	rent	rent
Length of residence	1 mo	3 yrs	1 mo	4 yrs	2 months	2 yrs	6 yrs	adult m, 9mos adult f, 2 yrs	adult m, 6 yrs adult f, 1 yrs adult m, 11 yrs
Building type	mobile home	mobile home	single family	mobile home	mobile home	mobile home	single family	mobile home	single family
Rooms Carpeted	none (0/5)	2 bedrooms (2/5)	4 bedrooms, living rm, dining rm (6/11)	2 bedrooms, living rm, bath (4/5)	2 bedrooms, living rm, dining rm, bath (5/6)	2 bedrooms, living rm, bath, hall (6/6)	3 bedrooms (3/7)	3 bedrooms, living rm (4/8)	none (0/6)
Ease of cleaning	difficult	easy	easy	easy	easy	difficult	difficult	difficult	difficult
Own a vacuum cleaner	no	yes	yes	yes	yes	no	no	no	no
Adjacent to field	yes	no	yes	yes	yes	no	yes	yes	yes
Crop in adjacent field	X-mas trees		hay	X-mas trees, tobacco	X-mas trees		X-mas trees tobacco	X-mas trees	X-mas trees
Leave windows open at night	no	yes	no	yes	yes	yes	no	yes	No
Season collected	Summer	Summer	Spring	Summer	Spring	Summer	Spring	Spring	Spring
Household									
Number persons	4	5	4	4	6	3	7	7	5
Number farmworkers	1	2	1	1	2	2	1	4	2
Number adults	2	2	2	2	4	2	2	5	3
Number children	2	3	2	2	2	1	5	2	2
Household composition	nuclear	nuclear	nuclear	nuclear	non-nuclear	nuclear	nuclear	non-nuclear	non-nuclear
Country of origin	Mexico	Mexico	Mexico	Mexico	Mexico	Mexico	Mexico	Mexico	Mexico
Time in US	2 yrs	6 yrs	9 yrs	8 yrs	6 yrs	2 yrs	6 yrs	2 yrs	adult m, 6 yrs adult f, 1 yrs
Work									
Typical farm work	X-mas trees	Nursery, wreaths	X-mas trees vegetables	X-mas trees	X-mas trees, wreaths	X-mas trees nursery	X-mas trees	X-mas trees	X-mas trees
Pesticide reported	unspecified herbicide	unspecified insecticide	disulfoton insecticide	unspecified herbicide	unspecified insecticide	unspecified herbicide	unspecified insecticide	simazine herbicide	unspecified herbicide

comparisons with NHANES data above the 50th percentile. However, both children were above the 90th percentile for one metabolite. This nuclear family included two adults and two children. The adults were from Mexico, and they had been in the United States for eight years and their current dwelling for four years. Their dwelling was a mobile home, which they owned. There was carpeting in the bedrooms, living room and bath, and it was easy to clean. The dwelling was adjacent to Christmas tree and tobacco fields. The urine samples were collected in Spring. The farmworker typically worked in Christmas trees, and reported applying an unspecified herbicide prior to urine sample collection.

They laundered work clothes separately from other family laundry. The farmworker also took his boots off outside. However, he waited to shower when he came home, "Yes, he changes and back there he puts on comfortable clothes, he spends like fifteen, thirty minutes resting and then he showers. Or if not, he goes to the neighbors' house again when they call him . . . he goes there and when he gets back at like nine at night he takes his shower" (1344). The farmworker applied pesticides at work, and they used residential pesticides at home. He also applied some work pesticides at home; "Yes, he brings it [herbicide] from his job, that's like five miles from here or less. He brings a little at a time then with the pump [backpack sprayer]" (1437). One of their daughters played in the Christmas tree fields around their house, "[Child's name] is the only one that walks around in the Christmas trees for now, running around sometimes when her father is working. And she goes with the dog [to play in the Christmas trees]" (1290).

Case 9 (Middle Metabolite Level Group): This was the only household in which urine tested for one member (a one year old girl) was not above the 50th percentile for at least one OP metabolite. However, 52% (44/84) of comparisons with NHANES data were above the 50th percentile, and one adult was above the 90th percentile. This was a non-nuclear family that included four adults and two children. The adults were from Mexico and had been in the United States for six years. They lived in their rented mobile home for two months before the urine sample collection in the Spring. The dwelling was rated easy to clean with carpeting in most rooms (bedrooms, living room, dining room, bath). The house was near Christmas tree fields. The two farmworkers typically worked in Christmas trees and making wreaths. They reported applying an unspecified insecticide just prior to urine sample collection.

The wife separated soiled work clothes from other family laundry. However, the two farmworkers in the household, her husband and brother-in-law, often wore work boots inside the house. They often sat on the sofa and hugged the children without changing out of work clothes. Sometimes they did not shower for hours after work. The wife described her brother-in-law as a "cochino" (a pig). They used residential pesticides. The woman explained that she did not know about pesticide exposure. She believed you cannot stop pesticides from getting into your home; "I can't stop them because they can enter from anywhere, you don't even know from where they are going to enter" (1589).

Case 4 (High Metabolite Level Group): Seventy-one percent (47/66) of comparisons with NHANES data were above the 50th percentile, and two household members, an adult and a child, were above the 90th percentile. This household included a nuclear family with two adults and one child. Both adults were farmworkers, and typically worked in Christmas trees and a nursery. The adults were from Mexico and had been in the United States for two years, living in the rented mobile home. There was carpeting in the living room, bath, hall and bedrooms. The dwelling was described as difficult to clean. There were Christmas trees growing about 500 meters from the dwelling. The urine samples were collected in the Summer, with the male farmworker reporting that the chemical he helped apply just prior to the sample collection was an herbicide.

The male farmworker changed out of work clothes outside on days they were applying pesticides at work; otherwise he changed in the bathroom. His wife reported, "When they're just pruning he comes and changes in the bathroom. When they use poison or fertilizer and the clothes are wet, the clothes stay outside, and then I just pick them up to put them in the washer" (928). While they laundered work clothes separately, they stored soiled work clothes in a basket in the bathroom. They often left windows open, and used a brand name residential insecticide to kill the biting insects that got into their home.

Case 7 (High Metabolite Level Group): Three of the four family members who gave urine samples were above the 90th percentile for OP metabolites in comparison with NHANES results. One adult was above the 90th percentile for three metabolites; a child was above the 90th percentile for one metabolite; another child was above the 90th percentile for three metabolites. Ninety-one percent (87/96) of comparisons with NHANES data were above the 50th percentile. This nuclear family included two adults and five children. The adults were from Mexico. They had been in the United States for six years, and had lived in the same rented single family dwelling all the time they had been in the US. There was carpeting in the bedrooms. The dwelling was difficult to clean and it was adjacent to Christmas tree and tobacco fields. The urine samples were collected in Spring. The farmworker typically worked in Christmas trees, and he reported applying an unspecified insecticide just prior to urine sample collection.

The farmworker changed from his work clothes in the bathroom, and they laundered these work clothes separately from other family clothes. His wife reported he got sick at work, "My husband sometimes tells me he is nauseous and that he has headache. And he says, 'And I protect myself but still, I don't know, I have a headache,' he says. And that he feels queasy. That's what he says" (1699). They applied residential pesticide in their home, "I buy poison and I spread it underneath the house for rats, mice. I spread it under the house like this or I spread it on the outside of the house, and in the corners, on outside the house in the little corners I spread rat

poison" (1589). She stated that agricultural pesticides were only dangerous when they were being applied and you could breathe them. "Pesticides are only dangerous when they are spreading the poison. After two, three, four days the danger is gone because the strength is gone" (1488); "I would think about protecting myself and not breathe so as not to inhale the pesticides" (1752).

Case 8 (High Metabolite Level Group): One adult in this household was above the 90th percentile for two metabolites; a child was above the 90th percentile for four metabolites; another child was above the 90th percentile for two metabolites. Seventy-five percent (63/84) of comparisons with NHANES data were above the 50th percentile. This was a non-nuclear family household with two children and five adults. In addition to the one woman, her husband, brother-in-law, father-in-law, and "concuño" (mother's sister's husband) lived in the house. All four men worked for the same Christmas tree farmer. The adults were all from Mexico; they had been in the United States for varying periods, with the female respondent having been in the United States for two years. They rented their mobile home in which the female respondent had lived for two years and her husband had lived for nine months. There was carpeting in the bedrooms and living room, and the house was difficult to clean. The house was adjacent to Christmas tree fields. The husband participant reported applying the herbicide simazine just prior to urine sample collection. The samples were collected in the Spring.

The wife in this family was trained in chemical safety when she worked in a chemical plant in Mexico. Her farmworker husband received pesticide safety training at work and was given PPE to wear. She laundered her husband's work clothes separately, and she stated that separating soiled work clothes in the laundry helped to keep pesticides out of the home. She also knew that carpets could harbor pesticides. Her husband told her when they were spraying pesticides at work, and she kept the windows closed. The husband did not bring pesticide containers home from work. Because there were several workers in the house, they had to take turns showering after work. Often, while her husband waited to shower he played with their children. While her husband changed from his work clothes in the bathroom, the other workers changed clothes in their bedroom. These other workers laundered their clothing only once each week at a laundromat; they did not have enough clothes to wear clean work clothes every day. They kept their soiled work clothes in their room.

> It can also be when they change, they change in their room, maybe their clothes or it can remain on the carpet, with pesticides. Or sometimes they use, for example, my husband changes his work clothes daily, but the others don't. I do my husband's laundry. That is why he can change, but the others go to the laundromat every week, so they have to keep their clothes in the same room. So I think that could be a source of pesticide contamination.... They don't have enough clothes and the other thing is that since they go to the laundromat once a week they leave their clothes [in the bedroom]. And there could be some type of pesticide contamination (1233).

Case 10 (High Metabolite Level Group): All five persons in this household provided urine samples. Seventy-three percent (79/108) of the comparisons with NHANES data were at the 50th percentile, and all three of the adults were above the 90th percentile. This was a non-nuclear family with an adult male in addition to the wife, husband and two children. They were all from Mexico, but the husband had been in the US for six years, and the wife for one year. They lived in a rented single family dwelling; each adult had lived there for a different length from one to eleven years. There was no carpeting in the house; rather, the floor was worn down to the sub-flooring and there were holes in the floor. The house was rated difficult to clean. The household was near Christmas tree fields, and the two farmworkers typically worked in Christmas trees. The urine samples were collected in Spring, just after the farmworkers reported applying an unspecified herbicide.

Both of the farmworkers removed their boots outside. The wife laundered the work clothes separately from other family laundry. However, both workers changed out of their work clothes in the bedroom, and they sometimes waited to shower; "Sometime they wait a little bit [to shower], but not usually" (699). They also used residential pesticides; "My husband uses poison for mice. He puts it in a corner of the house. He puts poison. But we don't do anything in particular for ants" (729).

Case Comparison

There are three important commonalities among these nine households. First, everyone who provided a sample was found to have OP metabolites in their urine. Second, with one exception, all participants were above the 50th percentile of the NHANES data for at least one of the six OP metabolites. Third, in every household there was at least one individual above the 90th percentile for at least one of the OP metabolites. Therefore, the comparison of these households is not between those without and with OP metabolites, it is among those with less versus more OP metabolites. Further, while some of the household, dwelling, work and behavior characteristics do not help differentiate among the low, middle and high level metabolite households, when present in the majority of cases, these characteristics may help explain the metabolite levels found in every urine sample.

Some household characteristics are not related to the pattern of OP metabolite levels. For example, all of the adults were from Mexico and had been in the US for diverse lengths of time. However, family structure and household size are related to OP metabolite levels. Two of the four households in the high metabolite level group had a non-nuclear family structure. These two cases had more than two adults, and these extra adults are always males (possibly less careful about cleanliness) and usually farmworkers (more likely to be exposed to pesticides at work and to bring them home). Only one of the three middle metabolite level households and neither of the low metabolite level households had a

non-nuclear structure. The behavioral data emphasized the potential effects of these extra adults on pesticide exposure: multiple problems with farmworkers not showering after work, improperly storing work clothes, and improperly laundering soiled work clothes. Also, the women had little control of behavior of these extra men, even when they acted like "cochinos."

All but two of the dwellings were adjacent to agricultural fields, and most of these fields contained Christmas trees or tobacco. While adjacency to agricultural fields or the types of crops in these fields were not related to the pattern of OP metabolite levels, they probably contributed to the pervasiveness of OPs among the household members (Lu, Fenske, Simcox and Kalman 2000). Other dwelling characteristics were related to the pattern of OP metabolite levels. All four of the high metabolite level households rented their dwellings, compared to one in three of the middle and one in two of the low metabolite level households. Renters have no control over who lives in a house before them or over the owner's (often grower's) use of pesticides. All four of the high metabolite level households had lived in their dwelling for two or more years (2 to 11 years), compared to one in three of the middle and one of two of the low metabolite level households. One of the middle metabolite level households had been in their dwelling for one month and another for two months at time of urine sample collection; one of the low metabolite level households had been in their dwelling for one month. The longer they had lived in a dwelling, the more chance for pesticides brought home from work to accumulate.

There was a great deal of carpeting in three of the four high metabolite level households; in the other high metabolite level household the floors were worn down to the sub-flooring and there were holes. All of the middle level households and one of two of the low metabolite level households had carpeting. For the low metabolite level household with carpeting, it was limited to the bedrooms. All four of the high metabolite level dwellings were rated as difficult to clean and did not have a vacuum cleaner. None of the middle and one of two of the low metabolite level dwellings were rated difficult to clean.

Season when the urine samples were collected is related to OP metabolite level. Samples were collected in the Spring for three of four high metabolite level households, two of the three middle metabolite level households, but none of the low metabolite level households. Spring is the season when the OPs disulfoton and chlorpyrifos are applied.

Not changing out of work clothes and bathing immediately after work is a behavior related to the pervasiveness of OP metabolite levels in these households; in three of four high metabolite level households, all of the middle metabolite level, and one of two low metabolite level households participants indicated that at least at times workers did not change out of work clothes or bathe immediately after work. What differentiates the households is the degree to which this behavior occurs. Among the low and middle level groups the discussion reveals that waiting to change and bathe occurred occasionally; among the high level group, waiting was more common, particularly when there was more than one male farmworker living in the household.

Applying pesticides at home is also related to the pattern of OP metabolites. Farmworkers applied residential pesticides for three of the four high metabolite level households, one of the middle metabolite level, and neither of low metabolite level households. The farmworkers in the middle metabolite level household also applied agricultural pesticides at home. Participants were asked about the exact pesticides that they used in their homes. They were not always clear on this—some mentioned brand name insecticides, while others mentioned specific pests (rat poison, bug spray). We do not know if any of the pesticides they used contained OPs. However, it is possible, as the OP chlorpyrifos was available for residential use until December 2002, and diazinon until August 2003.

The participants discussed a variety of views about pesticide safety. Case 2 (Low) and Case 9 (Middle) expressed the view that they were powerless to keep pesticides out of their house. Case 1 (Low) and Case 8 (High) closed their windows to keep pesticides from getting into their homes. Case 1 (Low) and Case 7 (High) both referred to the smell of the pesticide as the indicator that it is dangerous (Quandt, Arcury, Austin and Saavedra 1998; Rao et al. 2004). Case 5 (Middle) stated a fear of pesticides and acknowledged that they can be brought into the home on clothes and bodies. Case 6 (Middle) acknowledged that her child plays in Christmas tree fields that had been treated with pesticides.

Conclusions

This analysis addresses two questions. The first compares adults and children living in farmworker households to national reference data (CDC 2003; Barr et al. 2003). The exposure to OP pesticides is pervasive among farmworkers in this area. All members of farmworker households have measurable levels of OP metabolites in their urine samples; most levels exceed the 50th and many the 90th percentile.

The second question asks how the OP metabolite levels among these farmworker household residents relate to their social, structural, work and behavioral characteristics. The absolute levels of OP metabolites in the adult and child residents of these households are high; therefore, such common variables as having employment doing farm work and living adjacent to an agricultural field to which pesticides are applied are related to pesticide exposure. Membership in the different OP metabolite level groups among these farmworker households is related to several characteristics. Households that have a non-nuclear family structure, and therefore include more adult males who are employed doing farm work, have higher levels of OP metabolites. Families that rent their dwelling, that do not own a vacuum cleaner or reside in a dwelling that is graded difficult to clean, and have carpeting on a high percentage of their dwellings' floors have higher levels of OP metabolites.

The season in which the urine samples were collected is also related to OP metabolite level group. Spring (April—May) collection is related to higher levels than summer (August—September) collection. Spring is the period when OP insecticides are applied in the study area. OP metabolites are eliminated from the body within two or three days after exposure. Therefore, the participants with summer collection would have had to be exposed to OPs in summer from an agricultural application, from a residential application, from contaminated food sources, or because the places in which farmworkers live and work are contaminated with OP residues. The specific sources need to be determined in future research.

Acephate is an OP insecticide widely used in the region for tobacco (Cope et al. 1998). Acephate metabolites are not included in this analysis, as the laboratory method used in this study does not measure them. It is likely that the measured OP metabolite levels for these farmworker household residents would be greater if acephate could be included.

This analysis documents that most residents of farmworker households (adults and children) in the study area of western North Carolina and Virginia have high levels of OP metabolites in their systems. These high levels are present during the period when agricultural OP pesticides are being applied, as well as at other times. These results provide policy makers with data that have not before been available that document a pesticide exposure problem.

These results indicate policy changes that can be taken to reduce farmworker OP exposure that result in these high OP metabolite levels. It is crucial that occupational hygiene procedures change so that all farmworkers have access to a place to shower and change into clean clothes at work, and receive pesticide safety training. Federal and state Occupational Health and Safety Administration regulations specify that agricultural workers be provided with hand washing and toilet facilities in the fields. These facilities are not always available (Arcury, Quandt, Cravey, Elmore and Russell 2001). The US Environmental Protection Agency Worker Protection Standard (WPS) requires that farmworkers be trained in occupational pesticide safety before accruing five work days in fields to which pesticides have been applied in the past 30 days (Runyan 1993; US Environmental Protection Agency 1992). The content of WPS training provides little information about take-home pesticide contamination. This training is often not provided (US Government Accounting Office 2000). The provision of this training to all farmworkers must be enforced, and its content should be expanded to better address take-home contamination.

It is essential that farmworker families be assisted in reducing their OP exposure through the provision of materials and education. This might include housing with adequate bathing facilities that is located away from agricultural fields to which pesticides are applied, working vacuum cleaners, laundry storage containers and laundry equipment, and sufficient work clothes to wear clean work clothes daily. Agricultural work practices need to change so that when pesticides are applied to fields near homes, the spread of these pesticides into dwellings is curtailed.

Most farmworker families live in substandard housing (Housing Assistance Council 2001). Agricultural pesticides may be applied by farmworkers or growers to reduce infestations of insects or rodents. Providing farmworker families (as well as all Americans) with safe and affordable housing will reduce their exposure to pesticides. This is not an instance of "blaming the victims" for their exposure to pesticides, and attempting to address a systemic health disparity by educating those exposed to pesticides. Rather, it is an effort to build the capacity of farmworkers to defend themselves and to demand safe housing for their children.

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