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Evaluation of the relationship between residential orchard density and dimethyl organophosphate pesticide residues in house dust

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Abstract

Reducing residential pesticide exposure requires identification of exposure pathways. mCompared to the agriculture worker ‘take-home’ and residential use pathways, evidence of the ‘drift’ pathway to pesticide exposure has been inconsistent.

Questionnaire data from individuals (n=99) and dust samples (n=418) from households across three growing seasons in 2011 were from the *For Healthy Kids!* study. Summed dimethyl organophosphate pesticide (OP) (Azinphos-Methyl, Phosmet, and Malathion) concentrations were quantified from house dust samples. Spatially-weighted orchard densities surrounding households were calculated based on various distances from homes. Regression models tested associations between orchard density, residential pesticide use, agriculture worker residents, and summed dimethyl OP house dust concentrations.

Estimated relationships between orchard density and dimethyl OP in house dust were mixed: a 5% increase in orchard density resulted in 0.3% and 0.5% decreases in dimethyl OP house dust concentrations when considering land-cover 750m or 1250m away from households, respectively, but null associations with land-cover 60m or 200m away. Dimethyl OP house dust concentrations were 400% higher within homes where at least two residents were agriculture workers.

Despite inconclusive evidence for the drift pathway due to potential for bias, relationships between number of agriculture workers and dimethyl OP house dust concentration underscores the take-home pathway.

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Keywords

pesticide pathways; agriculture community; pesticide drift; spatially-weighted orchard density

INTRODUCTION

Measures of residential exposure to pesticides have been associated with increased risk of Non-Hodgkin lymphoma and leukemia ¹, adverse birth outcomes ², acute respiratory or nervous system illness among children ³, and lower neurobehavioral performance ^{4,5}. Accurate and standardized identification of the pathways through which individuals are exposed to pesticides is critical to motivating interventions that reduce pesticide exposure ^{6,7}. Three important pathways by which individuals become exposed to pesticides at home include: para-occupational (agriculture worker ‘take-home’), residential pesticide use, and off-target pesticide transport (‘drift’) ^{8,9}. Numerous studies have provided evidence for the take-home and residential pesticide use pathways by demonstrating associations between these sources and either elevated pesticide residue concentrations on household surfaces, within household dust samples, or within urinary metabolites of individuals not employed in agriculture ^{10–14}. In contrast, studies of the ‘drift’ pathway have yielded mixed findings.

Although several early studies indicated that ‘drift’ may be an important contributor to residential pesticide exposure ^{11,15–18}, more recent studies failed to replicate previous findings or yielded inconsistent results ^{19–25}. As noted below, Deziel (2015) has highlighted additional important distinctions between studies consistently finding evidence of the drift pathway and those that have not. Due to the inherent difficulty in measuring the relationship between pesticide drift and residential exposure in real-time, many researchers calculate measures of residential proximity to potentially treated agriculture land or actual pesticide application. As expected those studies with access to actual pesticide application data, such as the California Pesticide Use Reporting data, have more consistently found significant inverse associations between distance from pesticides application sites and pesticide exposure within homes ^{26–28}. Short of this high quality data, studies that have estimated drift via residential orchard density have found proportional increases between crop density and herbicide concentrations in house dust ²⁹. The least consistent associations have resulted when the drift pathway has been assessed using straight-line home-to-nearest agriculture land distance (Euclidian distance) ^{19–21,28–31}.

These mixed or null findings might result from the increased potential for measurement error associated with the approximation of drift using home-to-nearest agriculture land distance. The underlying assumption in home-to-nearest agriculture land distance is that the nearest agriculture land is correlated with probability of pesticide exposure due to drift. Consider an example, however, where home ‘A’ is 100m away from cropland that is small in area, and by corollary, amount of pesticides used may be low. Home ‘B’ that is the same distance from a different, much larger field, would be considered an identical estimate of pesticide drift. Using home-to-nearest cropland distance to measure pesticide drift would yield an identical exposure estimate for each home. For this reason, measures that quantify

the *percentage* of area surrounding sampled homes that is cropland where pesticides might be applied may result in lower measurement error of pesticide drift.

Our objective was to test whether the spatially-weighted percentage of land cover considered to be pome (apple and pear) and cherry orchards surrounding homes (hereafter, “orchard density”) was associated with dimethyl organophosphate pesticide (OP) (Azinphos-Methyl, Phosmet, and Malathion) concentrations within house dust samples (DM house dust). Pome and cherry orchards were chosen because they are common crops within the study area that are treated for pest control using mostly OPs. We hypothesized that DM house dust pesticide concentrations would be higher in homes surrounded by a larger percentage of land considered to be pome and cherry orchards.

METHODS

Cohort Formation

Participants were from the *For Healthy Kids!* study; the 2011 Children’s Environmental Health Risk Research Cohort (CHC). Details of CHC and *For Healthy Kids!* recruitment can be found elsewhere^{13,32}. Briefly, the CHC was designed to identify and intervene upon pesticide exposure pathways among residents of the Lower Yakima Valley of Central Washington State. The 100 families of the 2011 CHC were mostly drawn (N=91) from the 2005 CHC with one family from a previous cohort and another eight newly recruited^{13,14}. The 2005 CHC was composed of Latino families who in 2005 had at least one live-in child aged 2–6 years, householder ≥18 years, and intentions to live in the study area for the study’s duration. *Promotores*, study personnel who are residents of Yakima Valley and trained to engage study participants, invited members of the 2005 CHC to participate in the 2011 CHC. Institutional review board approval (Fred Hutchinson Cancer Research Center, File IR #5946) and informed consent were obtained from all participants prior to any data collection.

Questionnaire Data

Interviewer-administered questionnaires and house dust samples were gathered in 2011 during each of three agriculture seasons relevant to pesticide application: pre-thinning (Mar 17–April 30, chlorpyrifos used), thinning (June 15–August 8, several OP pesticides used), and non-spray (November 1–December 12, little to no pesticide application). The head of household provided sociodemographic, acculturation, agriculture work and residential pesticide use information through the questionnaires.

Current age was provided in years. Marital status was analyzed as ‘Married/living with partner’ versus ‘Divorced, widowed, separated, or never married’ due to low numbers within the latter’s separate groups. Pre-tax, annual household income was provided in ranges (< \$5,000, \$5,001 - \$10,000, \$10,000 - \$15,000, \$15,001 - \$25,000, \$25,001 - \$35,000, \$35,001 - \$50,000, >\$50,000), but analyzed by collapsing into <\$15,000, \$15,001 - \$25,000, \$25,001 - \$50,000, and >\$50,000 to limit low category frequencies and maximize variability.

All participants were born in either Mexico (90%) or the U.S. As the majority of participants spoke mostly or only Spanish, language generally spoken was analyzed as ‘All or mostly

Spanish', 'Spanish and English equally', and 'All or mostly English'. In addition to nativity and spoken language, we also assessed acculturation by number of years residing in the study area.

Estimation of Para-occupational and Residential Use Pesticide Pathways

Two questions were asked regarding residential pesticide use: "*In the past 3 days, have you or anyone in your household used any pesticides, such as RAID or Black Flag, in your home*", and "*In the past 3 days, have you or anyone in your household used any pesticides or other bug killers in your garden or yard*". Potential answers to the questions were both 'yes/no'. Questions were analyzed as a dichotomous composite created from those answering affirmatively to either question versus 'no' to both. The number of people currently living in the household who work in agriculture (excluding warehouse or dairy work) was asked (range 0–6) and analyzed by categorizing into '0', '1', and '2'.

Estimation of Pesticide Drift Pathway

Household addresses were geocoded to the point level (i.e., converted to geographic coordinates). Orchard density was spatially linked to geocoded homes following methods described below.

We determined the pome fruit and cherry orchard geographic distribution within the study area using the 2011 CropScape – Cropland Data Layer from the National Agricultural Statistics Service of the United States Department of Agriculture³³. Methods used to generate the CropScape dataset are described elsewhere³⁴. CropScape data are intended to provide spatially and crop-specific area estimates of major agricultural commodities in the U.S. The type of crop present at any given location is estimated using remote sensing classification algorithms and a variety of datasets, the majority of which derive from satellite imagery^{33,34}. The 2011 CropScape dataset has a 30m spatial resolution. Crop survey data are used to validate resulting CropScape data and estimate attribute accuracy. The nationwide 2011 sensitivity and specificity for cherries, apples and pears combined was 0.858 and 0.829, respectively³³. Despite these potentials for exposure misclassification bias³⁵, the CropScape dataset is considered to be an excellent source for obtaining annual estimates of crop land cover measured at a high spatial resolution and consistently over time³⁴.

We used Gaussian Kernel estimation to generate a distance-weighted probability of orchards (i.e., distance-weighted orchard density) around each participant's home by treating the CropScape dataset as a marked point pattern with mark value=1 if the location has cherry, apple or pear orchards, and value=0 if otherwise³⁶. The Gaussian kernel bandwidth is defined as the standard deviation of the bivariate Gaussian function. Although the Gaussian Kernel is a continuous distribution, the kernel bandwidth is used to effectively define the radius between a participant's home and points (i.e., orchards), within which, point values (i.e., presence or absence of orchards) are considered in calculating the distance-weighted probability that an orchard is present. The weights used in calculating the orchard density surrounding each participant's home are inversely proportional to the distance from the home, according to the bivariate Gaussian distribution³⁶. If we assumed a proportional

relationship between orchard density and ambient pesticide concentration, then bandwidth selection is analogous to declaring the radius around a home that pesticides might drift away from orchards. We considered radii of 60m, 200m, 750m, and 1250m, following previous literature^{11,15,20,26–30}. As < 0.01% of potential points would extend beyond $\pm$ four standard deviations from each participant's home, we specified kernel bandwidths for each radius according to $radius \div 8$ (e.g., 60m / 8 = 7.5m). The Spatstat package in R was used for geospatial analyses³⁷.

Pesticide Concentration from House Dust

We gathered house dust samples twice seasonally exactly one week apart. Dust samples were collected using the Metropolitan High-Powered hand-held vacuum (VM500; Metropolitan Vacuum Cleaner Company, Inc, Suffern, NY) from the area where the child played most frequently. We used a 0.5 X 0.5 meter template to identify the area to be vacuumed. The number of templates used was dependent on the floor type, 1 m² for plush carpets (1 inch fiber carpet), 1.5 m² for regular carpet (<1 inch fiber carpet) and 2 m² for hard or smooth floors. Each template vacuumed was traversed vertically and horizontally. Following sample collection the vacuum nozzle was held in the air for 10 seconds to ensure all material had passed into the vacuum bag. Vacuum bags were removed and placed in ziplock bags and stored on ice until arrival at the center where they were frozen at –10C. A separate vacuum cleaner was used for each household. Vacuums were thoroughly cleaned with soap and water and rinsed with methanol between uses.

House dust analysis and pesticide quantification were performed by University of Washington's Environmental Health Laboratory & Trace Organics Analysis Center for OP pesticide concentration quantification^{13,38}. Sample preparation and analytical methods have been previously described^{13,38}. Briefly, dust was removed from the vacuum cleaner bags and sieved for 10 minutes using 150 μ m sieves (VWR, West Chester, PA, USA) in a sieve shaker (Model RX-24; WS Tyler Inc, Mentor, OH, USA). For pesticide analysis, 100mg of sieved dust was required.

Pesticide quantification was conducted via an acetonitrile extraction with liquid-liquid partitioning and quantitative and confirmatory analysis with liquid chromatography-tandem mass spectrometry using electrospray ionization. Levels of detection (LOD) varied by pesticide; 0.0013 nmole/g (Phosmet), 0.0012 nmole/g (Malathion), and 0.032 nmole/g (Azinphos-Methyl). These LODs are based on analyzing 1 g of dust. Samples were accepted if a minimum of 100 mg of dust was available, thus there is some variability around the LODs with smaller sample masses having higher LODs.

Concentrations of OPs in dust were characterized using a multivariate normal distribution model with values below the limit of detection treated as censored values³⁹. With this model, we estimated geometric means of each OP, population geometric standard deviations, correlations between OPs and standard errors of the parameters for farm worker (FW) and non-farm worker (NFW) households in each agricultural season. The model is described by:

$$\log(X_{jk}) \sim \text{MVN}_5(\theta_K, \Sigma)$$

for $j = 1, \dots, n_j$, and $k = 1, \dots, 5$,

where MVN_5 is a five-dimensional multivariate normal distribution of the OPs azinphos-Methyl, phosmet, malathion, diazinon and chlorpyrifos. X_{jk} is the vector of the $k=1, \dots, 5$ measured OP concentrations of the j th household. θ_k is the vector of the estimated mean concentrations in dust of the five OPs and Σ is the estimated variance–covariance matrix (5×5) among the five OPs. The number of households is n_j . Population standard deviations for each organophosphate and correlations between OPs were estimated by the variance-covariance matrix Σ . Separate multivariate Normal distributions, MVN_5 , were estimated for each season, and FW and NFW households. Because of the large number of samples below the LOD, distributions of the model parameters were estimated using Gibbs sampling (e.g., Bayesian Markov chain Monte Carlo simulation)⁴⁰. Censored values (i.e., < LOD) are treated in each simulation as being from the lower tail of a multivariate Normal distribution with an upper cutoff at the limit of detection and the shape of the distribution determined by the parameter values for the simulation. The model was run using the WinBUGS 1.4.3 program⁴¹.

Statistical Analyses

We calculated descriptive statistics of participant household characteristics. Farm worker-, household-, and season-specific, estimated dimethyl OP concentrations were summed in order to test associations with a single pesticide value. Moreover, these pesticides share a common public health endpoint as they all act by inhibiting acetylcholinesterase thereby inducing neurotoxicity⁴². Studies have shown that combined exposure to these pesticides causes more severe neurotoxicity^{43,44}. By examining the total DM OP concentration, we are better able to put our results in the context of neurotoxicity potential and public health. We calculated geometric means of dimethyl pesticide (Azinphos-Methyl, Phosmet, and Malathion) residue concentrations (nmole/g) found in house dust samples by household characteristics and each orchard density estimate. DM house dust and orchard density were log transformed due to highly skewed distributions. Hierarchical linear regression models were built to test the association of orchard density and DM house dust while adjusting for the potential confounding variables. All statistical tests accounted for the nested sampling design through inclusion of random intercepts for repeated questionnaire responses or house dust samples within households and households within seasons. We specified autoregressive covariance structures for modeled random effects. We calculated 95% confidence intervals and p-values of modeled point estimates. In post-hoc outlier analysis we found that one household with one of the highest DM house dust concentrations was driving the overall significance of the 200m radius orchard density association. All analyses were repeated excluding this household ($n=99$ households). As sensitivity analyses we tested the orchard density – DM house dust stratified by: 1) numbers of household members working in agriculture, and 2) each season. SAS v9.4 was used in all statistical analyses (SAS code available upon request)⁴⁵. Tests were two-sided and were not adjusted for multiple comparisons.

RESULTS

Defined as above using the CropScape dataset, the 577 km² study area was covered by 108.8 km² (18.8%) of apple, pear or cherry orchards (results not shown). Regardless of radii, from home, a majority of participants resided in areas where the orchard density was no greater than 5.0% (Table 1). When considering radii of 60m or 200m, 41 and 19 participant's homes, respectively, were not near any orchards.

Socio-demographically, a majority of participants were married, older than 35 years, earned annual household incomes of no more than \$50,000, spoke mostly or only Spanish, were born in Mexico, reported no recent residential pesticide use, and resided in households where at least 1 member worked in agriculture (Table 1).

The percentage of DM OPs < LOD or missing /insufficient dust mass for laboratory testing range from 9.8% (farm workers, thinning season) to 33.3% (non-farm workers, pre-thinning), and 18.8% (non-farm workers, pre-thinning) to 33.3% (non-farm worker, thinning) (Table 2). Geometric means of DM house dust concentrations substantially increased following imputation of samples < LOD (Table 2). Overall, 25.2% of samples had insufficient dust mass for laboratory analysis and only 1.5% were due to true missing (2 households dropped out before the non-spray season samples were taken). There was a greater frequency of insufficient DM house dust samples among those who reported recent residential pesticide use, lower income, Mexican nativity, and estimated lower orchard density ($p < 0.05$, results not shown).

The geometric mean (95% CI) of DM house dust among all participants was 0.16 nmole/g (0.02 – 1.10) (Table 3). DM house dust concentrations statistically significantly varied by spoken language and number of residents working in agriculture. The geometric means of DM house dust concentrations among homes with 0, 1, or at least two residents working in agriculture was 0.07 (0.02 – 0.31), 0.12 (0.03 – 0.56), and 0.35 (0.07 – 1.75), respectively (Table 3). Those who spoke Spanish and English equally had DM house dust concentrations (0.09 nmole/g) that were lower than those who speak mostly or only Spanish (0.18 nmole/g). DM house dust concentrations decreased with increasing orchard density for the 750m and 1250m radii (p -values for linear trend: 0.002 and 0.013, respectively); albeit, with suggestion of non-linearity. DM house dust concentrations did not statistically significantly vary by any other sociodemographic, acculturation, residential pesticide use or orchard density covariate.

After adjustment for other covariates, DM house dust concentrations among homes with at least two agriculture workers was approximately 400% higher than concentrations among homes without any agriculture workers, regardless of orchard density classification (Table 4). None of the orchard density covariates were associated with DM house dust concentration when modeled as a categorical variable. However, two associations between orchard density and DM house dust concentration modeled as a log-linear relationship were statistically significant (750m and 1250m radius); DM house dust concentrations decreased by 0.31% (0.40% - 0.79%, $P = 0.002$) and 0.47% (0.52% - 1.31%, $P = 0.022$) for every 5% increase in orchard density, adjusted for all other covariates (results not shown). Sensitivity

analyses indicated that restriction to number of agriculture workers in the home or agriculture season had negligible effect on the relationships between orchard density and DM house dust concentrations.

DISCUSSION

This study of residential apple, pear and cherry orchard density measured at various distances from participant's homes and dimethyl pesticide concentrations in house dust yielded mostly null findings and some inverse associations. Estimating the association with orchard density as a categorical variable results in null associations. Estimates of the (log) linear relationship between orchard density and DM house dust concentrations resulted in null findings for orchard density estimates using radii of 60m and 200m, and statistically significant inverse associations using orchard density radii of 750m or 1250m. No sociodemographic, acculturation, or residential pesticide use covariates were associated with DM house dust concentrations. The only factor consistently and statistically significantly associated with higher DM house dust concentrations was greater number of household members working in agriculture.

Previous studies of residential orchard proximity and pesticide residues in house dust have reported mixed findings^{11,19–21,26,27,46}. However, statistically significant, proportional relationships with residues in dust have been detected more often in studies that have assessed proximity to orchards using density-based measurements^{26,28,29}, compared to those using nearest distance metrics^{11,15,46}. In an Iowa-based study, a 1.3% increase in crop density within a 750m maximum distance surrounding sampled homes resulted in a 5% increase in agriculture herbicide residue concentrations found in house dust²⁹. A California study combining crop density with pesticide application reported statistically significant increases in various OP pesticide concentrations in house dust with increases in pesticides applied per area of crops within 1250m of sampled homes and one year prior to dust sampling²⁶. Moreover, the relationship between the measurement of drift and OP pesticide concentration in house dust remained statistically significant after adjustment for whether a farmworker lived in the house, providing evidence for the drift pathway²⁶.

Several explanations can be provided for why we failed to detect consistent associations when using density-based measures of residential orchard proximity. First, the DM house dust concentrations in our study were very low (0.17 nmoles/g, 95% CI: 0.02–1.10). Moreover, house dust samples considered missing – due to not being collected (1.5%) or insufficient amount for analysis (25.2%) – ranged from 18.8% to 33% depending on season and householder's work status. In contrast, studies that found significant associations between measures of orchard density and herbicide or pesticide residues found in house dust, report residue concentrations of at least two orders of magnitude higher than the DM house dust concentrations in our study^{26,28,29}. Lower concentrations and a large percent of missing samples could increase the effects that potential biases have on the relationship between orchard density and DM house dust concentration. Under certain conditions, null or even inverse associations between orchard density and DM house dust can result from such biases³⁵. The CropScape dataset was a biased measure of orchard presence or absence which could have led to these null findings, independent of the low DM house dust

concentrations (See Methods above). Our inability to account for potentially important pesticide (e.g., volatility, application history), environmental (e.g., wind direction and speed, temperature) and residential factors (e.g., cleaning practices, air conditioning) could also explain our null findings if these factors are not only associated with DM house dust concentration but also residential orchard density. Lastly, it is possible that fine particulates present in dust and more representative of fugitive dust were not fully captured by our dust collection sampling methods.

Although these results fail to support the ‘drift pathway’ by which residents in close proximity to agriculture areas might become exposed to pesticides, they do reinforce the salience of the ‘take-home’ pathway that has been previously reported^{13,14}. Despite the very low concentrations of pesticide residues found in our house dust samples, more agriculture workers residing in homes was associated with 400% increases in DM house dust concentrations. These results underscore the importance of practices aimed at reducing pesticide exposure via the take-home pathway (e.g., home and personal hygiene, personal protective equipment) especially for high-risk occupations (pesticide mixers) and times of high pesticide use.

Strengths of this study include a moderate sample size and repeated sample design; collection of numerous potential confounders; use of high-resolution, standardized, validated and publicly available satellite data to measure orchard location; and use of distance-weighted orchard density measures of proximity. Our nested sampling design of repeated sampling of homes within seasons enabled us to investigate seasonal effects with improved precision. We also collected and adjusted for multiple potential confounding factors, including acculturation and socioeconomic factors that have been previously shown to correlate with pesticide levels in house dust¹⁹, and may also affect where one chooses to live^{47–49}. To our knowledge, only one recent study of pesticide drift has used the CropScape data⁵⁰. This recent study, however, investigated the association between distance to orchard and OP concentrations within indoor air and was not large enough to estimate the association independent of number of farmworkers within the household⁵⁰.

As detailed above, specific limitations should be considered when interpreting these results, including: potential exposure misclassification bias of the CropScape dataset, bias due to differential missing of house dust samples, and lack of additional information that could influence the exposure pathways studied (e.g., physiochemical properties of the pesticides used, atmospheric conditions, cleaning practices and factors affecting air flow within homes).

We did not find evidence of the ‘drift pathway’ as residential orchard density was not associated with levels of dimethyl pesticide concentrations in house dust among a sample of homes within a Central Washington agricultural community. Future studies should collect pesticide use, hygiene, and environmental factors so that stronger evidence can be used to test the potential relationship between residential proximity to agriculture land and pesticide exposure. Greater numbers of agriculture workers residing in the home, however, was associated with higher pesticide concentrations in house dust, which provides further

evidence of the ‘take-home’ pathway and underscores the importance of preventive measures that reduce this source of inter-person exposure.

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Table 1.

Characteristics of participant households (N=99) of the *For Healthy Kids!* Study¹.

	N		
	Pre-thinning	Thinning	Non-spray
Orchard density surrounding home			
60m radius around home			
0.0%	41	41	41
0.0% - 5.0%	56	56	56
5.1% - 10.0%	0	0	0
10.1% - 49.9%	0	0	0
50.00%	2	2	2
200m radius around home			
0.0%	19	19	19
0.0% - 5.0%	62	62	62
5.1% - 10.0%	3	3	3
10.1% - 49.9%	14	14	14
50.00%	1	1	1
750m radius around home			
0.0%	0	0	0
0.0% - 5.0%	70	70	70
5.1% - 10.0%	13	13	13
10.1% - 49.9%	14	14	14
50.00%	2	2	2
1250m radius around home			
0.0%	0	0	0
0.0% - 5.0%	62	62	62
5.1% - 10.0%	12	12	12
10.1% - 49.9%	23	23	23
50.00%	2	2	2
Agriculture workers in home			
0	28	22	22
1	31	31	29
>1	39	45	45
Recent residential pesticide use			
Yes	10	18	5
Age			
35 y	34	34	34
35–40 y	33	33	33
>40 y	32	32	32

	N		
	Pre-thinning	Thinning	Non-spray
Married			
Yes	85	85	90
Income			
<\$15,001	21	19	17
\$15,001 to \$25,000	22	18	25
\$25,001 to \$50,000	48	53	48
>\$50,000	6	6	5
Don't know/refused	2	2	2
Birthplace			
Mexico	90	90	90
U.S.	8	8	8
Language spoken			
All / mostly Spanish	83	83	83
Spanish / English Equally	13	13	13
All / mostly English	3	3	3
Length of residence in study area			
15 y	36	37	37
15–20 y	37	39	36
>20 y	26	23	27

¹ Subgroups may not total to 99 due to missing values

Table 2.

Percentage of dimethyl (DM) organophosphate pesticides (OP) < limit of detection, missing, and concentrations in house dust by agriculture season and farm worker status

Season	Farm worker Status	% DM OP			
		I		DM Geometric mean	DM Geometric mean
		% DM OPsufficient (nmole/g) (95% CI), < LOD ¹	I	pre-imputation ²	(nmole/g) (95% CI), post-imputation ²
Pre-thinning	Farm worker	22.2	21.7	0.27 (0.20 – 0.36)	0.11 (0.08 – 0.16)
	Non-farm worker	33.3	18.8	0.10 (0.07 – 0.16)	0.05 (0.03 – 0.07)
Thinning	Farm worker	9.8	26.2	0.75 (0.47 – 1.22)	0.57 (0.36 – 0.90)
	Non-farm worker	20.5	33.3	0.36 (0.18 – 0.73)	0.17 (0.10 – 0.31)
Non-Spray	Farm worker	22.8	31.7	0.64 (0.32 – 1.25)	0.23 (0.15 – 0.36)
	Non-farm worker	30.0	28.8	0.20 (0.08 – 0.50)	0.09 (0.05 – 0.16)

¹Percentage is of DM OPs (Azinphos-Methyl, Phosmet, and Malathion) with insufficient (25.2% overall) or missing (1.5% overall) samples on either of the two sample days (n=198 potential samples)

²DM OP geometric mean calculation accounts for house dust samples repeated by day

Table 3.

Geometric mean (nmole/g) of DM house dust concentrations by individual and household level characteristics, the *For Healthy Kids!* Study.¹

	Geometric mean (95% CI)	p-value ²
Overall	0.16 (0.02 – 1.10)	0.055 ³
Orchard density surrounding home		
60m radius around home		0.937 ⁴
0.0%	0.16 (0.03 – 0.91)	
0.0% - 5.0%	0.17 (0.03 – 1.03)	
5.1% - 10.0%	NA	
10.1% - 49.9%	NA	
50.00%	0.15 (0.03 – 0.74)	
200m radius around home		0.062 ⁴
0.0%	0.22 (0.04 – 1.10)	
0.0% - 5.0%	0.16 (0.02 – 1.02)	
5.1% - 10.0%	0.36 (0.08 – 1.69)	
10.1% - 49.9%	0.10 (0.02 – 0.46)	
50.00%	0.42 (0.06 – 3.00)	
750m radius around home		0.002 ⁴
0.0%	NA	
0.0% - 5.0%	0.19 (0.03 – 1.25)	
5.1% - 10.0%	0.13 (0.03 – 0.59)	
10.1% - 49.9%	0.10 (0.02 – 0.49)	
50.00%	0.14 (0.03 – 0.68)	
1250m radius around home		0.013 ⁴
0.0%	NA	
0.0% - 5.0%	0.20 (0.03 – 1.28)	
5.1% - 10.0%	0.12 (0.03 – 0.56)	
10.1% - 49.9%	0.12 (0.02 – 0.62)	
50.00%	0.14 (0.03 – 0.69)	
Agriculture workers in home		<0.001
0	0.07 (0.02 – 0.31)	
1	0.12 (0.03 – 0.56)	
>1	0.35 (0.07 – 1.75)	
Recent residential pesticide use		0.955
No	0.16 (0.02 – 1.10)	
Yes	0.16 (0.04 – 0.69)	

	Geometric mean (95% CI)	p-value ²
Age		0.823
35 y	0.15 (0.03 – 0.84)	
35–40 y	0.17 (0.03 – 0.96)	
>40 y	0.17 (0.03 – 0.90)	
Married		0.325
Yes	0.12 (0.03 – 0.54)	
No	0.17 (0.03 – 1.11)	
Income		0.236
<\$15,001	0.17 (0.03 – 0.84)	
\$15,001 to \$25,000	0.17 (0.03 – 1.00)	
\$25,001 to \$50,000	0.20 (0.04 – 0.99)	
>\$50,000	0.08 (0.02 – 0.32)	
Don't know/refused	0.17 (0.03 – 0.89)	
Birthplace		0.433
Mexico	0.17 (0.03 – 1.10)	
U.S.	0.13 (0.03 – 0.54)	
Language spoken		0.034
All / mostly Spanish	0.18 (0.03 – 1.16)	
Spanish / English Equally	0.09 (0.02 – 0.39)	
All / mostly English	0.13 (0.03 – 0.57)	
Length of residence in study area		0.442
15 y	0.19 (0.03 – 1.09)	
15–20 y	0.15 (0.03 – 0.84)	
>20 y	0.15 (0.03 – 0.79)	

¹ Geometric means account for repeated days within houses within seasons; intra-class correlation coefficient (ICC) season=20.5%; house(season)=64.4%

² P-value is from a global type-III, F-test of model fit improvement

³ P-value is from a t-test of $\beta_0 = 0$ of an intercept-only + random effects model

⁴ P-value is from a t-test of $\beta_0 = 0$ testing linear trend

Table 4.

Model estimated percent changes in DM OP house dust concentrations by orchard density, agriculture workers in the home, and recent residential pesticide use¹, the *For Healthy Kids!* Study.

	% Change DM OP house dust concentration (95% CI)	% Change DM OP house dust concentration (95% CI)	% Change DM OP house dust concentration (95% CI)	% Change DM OP house dust concentration (95% CI)
Orchard density surrounding home				
60m radius around home				
0.0%	Ref			
0.0% - 5.0%	0.86 (-32.73–51.22)			
5.1%- 10.0%	NA			
10.1% - 49.9%	NA			
50.00%	4.88 (-67.77–241.35)			
200m radius around home				
0.0%	Ref			
0.0% - 5.0%	-40.47 (-64.1–1.3) [*]			
5.1%- 10.0%	12.73 (-62.86–242.21)			
10.1% - 49.9%	-52.61 (-75.64–7.78) [*]			
50.00%	9.41 (-81.47–546)			
750m radius around home				
0.0%	NA			
0.0% - 5.0%	Ref			
5.1%- 10.0%	-9.9 (-51.47–67.28)			
10.1% - 49.9%	-20.87 (-54.09–36.38)			
50.00%	-35.49 (-80.72–115.9)			
1250m radius around home				
0.0%				NA
0.0% - 5.0%				Ref
5.1%- 10.0%				13.02 (-36.69–101.77)
10.1% - 49.9%				-21.57 (-51.86–27.77)

	% Change DM OP house dust concentration (95% CI)	% Change DM OP house dust concentration (95% CI)	% Change DM OP house dust concentration (95% CI)	% Change DM OP house dust concentration (95% CI)
50.00%				-35.9 (-80.84–114.44)
Agriculture workers in home				
0	Ref ²	Ref ²	Ref ²	Ref ²
1	77.89 (8.33–192.09) [*]	94.88 (19.51–217.77) ^{**}	83.63 (12.09–200.84) [*]	93.13 (16.17–221.08) [*]
>1	415.8 (213.54–748.53) ^{**}	416.36 (214.28–748.36) ^{**}	408.57 (207–742.48) ^{**}	431.44 (217.77–788.8) ^{**}
Recent residential pesticide use				
No	Ref	Ref	Ref	Ref
Yes	8.69 (-41.35–101.43)	-10.89 (-51.54–63.84)	-10.39 (-51.52–65.63)	-13.37 (-53.28–60.66)
Intra-class correlation (%) season	21.4	21.3	20.2	20.3
Intra-class correlation (%) house(season)	60.1	64.7	65.9	65.7

^{*} $P < 0.05$

^{**} $P < 0.001$ for t-test of $\beta=0$

$P < 0.05$ for F-test of model fit improvement

Adjusted for each other and covariates listed in Table 3