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Pesticide Exposure of Farmworkers' Children

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1. Introduction

In the United States (US), most manual labor in agriculture is completed by farmworkers. Although the total number of farmworkers in the US is not well characterized, recent estimates range between 2.5-5 million (Villarejo 2003, Hansen and Donohoe 2010, McCauley et al. 2006). They are predominately Spanish-speaking immigrants with a relatively low-level of education, on average about 7 years (Table 1). Their annual family earnings are far below the 2009 US poverty threshold of \$21,756 for a family of four (US Census 2009a) and approximately 83% lack health insurance (Villarejo 2003). Farmworkers are hired by agricultural corporations, contractors, and farmers to plant and tend to crops, weed, pick and pack produce. As these tasks are primarily seasonal, most farmworkers are hired on a temporary basis, and they migrate from region to region depending upon work availability. In addition to many ergonomic challenges, farmworkers face a number of occupational exposures including: dust, sun, noise, and pesticides.

Pesticides in particular present a great hazard to farmworkers because of their widespread use and inherent toxicity. Not only are farmworkers exposed to pesticides while working in

Characteristic	Farmworkers	US Average
Education		
<6 th grade	25-69%	
7 th -12 th grade	21-70%	16% ^a
Completed high school	2-21%	84%
Preferred Language		
English	6%	80%
Spanish	78-96%	12%
Other	1-22%	8%
Family Income		
<\$10,000	19-24%	5%
\$10,000-<\$15,000	22-45%	3%
\$15,000-<\$25,000	23-49%	8%
≥\$25,000	2-11%	84%

Table 1. Characteristics of farmworkers and comparison with US national average (McCauley et al. 2006, US Census 2009b, Thompson et al. 2003, Eskenazi et al. 2004, Coronado et al. 2006, Quandt et al. 2004, Salvatore et al. 2008). ^aLess than high school.

the fields, they and their families may also face increased pesticide exposure due to living in proximity to where the pesticides are applied. Furthermore, children of farmworkers may be exposed to pesticides in their homes that are brought in by the farmworkers on their clothing and shoes (Fenske et al. 2000). Acute health effects of pesticides include: nausea, dizziness, vomiting, headaches, abdominal pain, dermatitis and even death (McCauley et al. 2006). Chronic health effects of pesticides are also numerous and include respiratory and memory disorders, cancer, neurological deficits, Parkinson's disease, autism, infertility, congenital birth defects, and DNA damage (Alavanja et al. 2004, Kirkhorn and Schenker 2002, Eskenazi, Bradman & Castorina 1999, Blair and Zahm 1995, Alavanja, Hoppin & Kamel 2004, Kisby et al. 2009). Babies who are exposed to pesticides prenatally are more likely to have decreased birth weight and length, as well as a smaller head size (Berkowitz et al. 2004, Whyatt et al. 2004), which may predispose them to additional health concerns.

Although farmworkers typically spend more time in active contact with crops and may therefore have greater pesticide exposures than other agricultural workers, it is difficult to study chronic health effects resulting from their pesticide exposure because they are migratory, their work is transient and they may be marginalized due to their immigration status. However, Mills and colleagues (2009), cleverly linked work history records from the main farmworker labor union (United Farmworkers) with California's Cancer Registry and pesticide use database to determine significant increases in particular types of cancer associated with exposure to specific pesticides among farmworkers. Childhood cancers have also been associated with residential and parental occupational exposures to pesticides prenatally as well as pre-conception (Daniels, Olshan & Savitz 1997, Efird et al. 2003, Shim, Mlynarek & Van Wijngaarden 2009, Wigle, Turner & Krewski 2009, Turner, Wigle & Krewski 2010).

In addition to cancer, several studies have also documented associations between pesticide exposure and neurological disorders. Priydarshi and colleagues (2000) conducted a meta-analysis of studies reporting on pesticide exposure and Parkinson's disease. They report a combined odds ratio of Parkinson's disease associated with pesticide exposure of 1.85 (95% confidence interval: 1.31-2.60) for all studies and an odds ratio of 2.16 (95% confidence interval: 1.95-2.39) for studies from the US alone. More recent studies have confirmed these findings (Elbaz and Tranchant 2007, Hancock et al. 2008). Women who live within 500 m of fields where organochlorine applications occurred during pregnancy have an odds ratio of 6.1 (95% confidence interval: 2.4-15.3) that their child will be diagnosed with autism (Roberts et al. 2007). Guilette and colleagues (1998) determined that children who lived in a high pesticide use area had decreased stamina, eye hand coordination, 30 minute memory and the ability to draw a person.

As demonstrated by the previous studies, children may have increased susceptibility to pesticide exposure as their bodies are still developing and they have reduced capabilities of detoxifying pesticides (Eskenazi, Bradman & Castorina 1999, Faustman et al. 2000). Unfortunately, not only do children have a greater susceptibility to adverse consequences of pesticide exposure than adults, they also have increased potential for exposure to pesticides. They eat more food and drink than adults on a per body weight basis. They have increased absorption across their intestines and skin and have a greater surface area to volume ratio (Arcury et al. 2007). Young children spend more time playing on the floor and have a greater frequency of mouthing objects that may have pesticide residues. In addition to being exposed to pesticides in their homes via agricultural spray drift and the take-home pathway, it is not unusual for farmworkers to take their children with them to the fields while they

work and they themselves may be employed as well (Cooper et al. 2001). Compared to other industries in the US, current labor laws allow younger children to be employed in farm work. Children can start working in farm labor at age 12 years, and by 14 years there is no limit to the number of hours they can work. During the summer approximately 25% of farmworkers are children (<18 years of age) (Moses 1989). Farm labor children are more likely to drop out of school compared to other children and they have more injuries and fatalities than adults (Wilk 1993). Furthermore, it is not unusual for farmworkers to continue working in the fields while pregnant (Goldman et al. 2004). Thus, children of farmworkers are likely to be exposed to pesticides prenatally as their mothers continue to work, in their homes via agricultural spray drift and para-occupational exposure, and as field workers themselves.

In 1989, César Chavez described how these conditions lead to an increased potential for pesticide exposures and health effects among farmworkers and their children (Chavez 1989). However, at that time very little research had been completed on these topics. In the early 1990s, it was documented that farmworkers and their children were a high-risk population for pesticide exposure and associated adverse health consequences that had not been studied enough (Moses 1989, Rust 1990). Key data needs identified were: biological and environmental monitoring, longitudinal cohort studies, and additional studies of cancer and neurological development. In the past 20 years, over 50 studies have been completed that examine pesticide exposure in farmworkers' children. A literature review has been conducted to understand if farmworker children face high pesticide exposures, how these exposures occur, if these exposures have adversely affected their health, and if interventions to reduce these exposures have been successful. From this detailed review, directions for future research are identified.

2. Methods

This literature review focuses on pesticide exposure in children of farmworkers. The search terms used for this review included: pesticides, farmworker, farm workers, children, infants, exposure, and farm labor. I used these terms to search PubMed (<http://www.ncbi.nlm.nih.gov/pubmed/>), Google Scholar (<http://scholar.google.com/>), and ISI Web of Knowledge (<http://www.isiknowledge.com/wos>). I concentrated my review on studies that reported primary data collection or analysis. I restricted my review to farmworkers, agricultural workers and individuals engaged in farm labor and their children. I excluded farmers and licensed pesticide applicators. Farmworkers tend to spend more time in the fields in direct contact with pesticides, use less safety precautions and personnel protective equipment, and are more likely to track pesticides into their homes (Mills et al., 2009). I also limited myself only to studies from the United States, as conditions are likely to be very different from other parts of the world. As my focus is on understanding pesticide exposure in the children of farmworkers, I did review articles that discussed measures of farmworker contamination of the home but mostly focused my attention on studies that had direct measures of children's potential exposure.

3. Results and discussion

More than 50 articles were identified covering topics of pesticide exposure, potential health effects and interventions to reduce the exposures in farmworker children. These articles

highlight the complexity in quantifying these children's exposures and relating these exposures to adverse health effects. It is necessary to have a valid understanding of the exposures over time, a report of the diagnosis, symptom or some sort of biological marker, and methods to link the individual exposure with the health effect (McCauley et al. 2006a). In these low income, extremely mobile populations with limited health access it is extremely difficult to link the exposures with the health outcomes.

Not only is keeping track of potential health outcomes complicated, these children are exposed to multiple pesticides via multiple exposure routes and pathways. Measurements with greater specificity of these exposures that have a high degree of temporal and spatial variability are extremely expensive and time intensive, however it is not clear if measurements with less specificity can provide enough power to detect adverse health effects from chronic exposures (Hoppin et al. 2006). It is difficult to compare across studies as different media are sampled with different collection and analytical methods for different pesticides. The studies have different limits of detection, examined children of different ages, use different methods to address samples below the detection limit and report different descriptive statistics in different units. The types of pesticides used vary greatly by geographic region and crop. The amounts of pesticide used can vary greatly throughout the year, depending on the growing cycles, but also there is quite a lot of variability between years depending upon weather and pests of concern. In the US, pesticides are constantly undergoing re-registration and their permitted uses can change dramatically. For example both chlorpyrifos and diazinon were banned for residential use. In spite of all this difficulty in comparing studies and the inherent uncertainties, our knowledge about pesticide exposure in children of farmworkers has greatly increased over the last 20 years through biomonitoring and environmental media studies. Although some interventions have been moderately successful, there are still many considerations for future research.

3.1 Health effects

In spite of the many barriers to studying associations between health effects and pesticide exposures in farmworkers' children (McCauley et al. 2006a), over the last 10 years several adverse health consequences have been associated with exposures in these populations. Our understanding of adverse health effects associated with biomarker levels has come predominately from one cohort in California. In this cohort of mostly farmworker families in the Salinas Valley, increased prenatal organophosphate metabolite levels was associated with a decrease in gestation and abnormal infant reflexes (Eskenazi et al. 2004, Young et al. 2005). Prenatal and postnatal dialkyl organophosphate urinary concentrations were significantly associated with developing pervasive developmental disorder, attention problems, and attention deficit hyperactivity disorder (Eskenazi et al. 2007, Marks et al. 2010) These associations were stronger in boys, which is concerning since they may have higher exposures and biomarker levels to begin with (Arcury et al. 2007, Koch et al. 2002). PON1 enzyme levels are associated with the ability to detoxify organophosphate pesticides. Infants in this cohort had 4-fold lower PON1 levels than their mothers and there was 26-fold range among the infants their levels, indicating a large range in susceptibility due to differences in detoxifying abilities (Furlong et al. 2006). Significant differences were reported by PON1 allele in the association between pervasive disruptive disorder and maternal pesticide metabolite levels (Eskenazi et al. 2010).

Adverse effects of pesticide exposure on agricultural children's neurodevelopment has been demonstrated in other geographic regions and cohorts. Organophosphate pesticide

metabolite levels in urine was associated with deficits in speed of attention, sequencing, mental and conceptual flexibility, visual search, and concept formation among children in a rural agricultural community in Arizona (Sánchez Lizardi, O'Rourke & Morris 2008). Similarly, children of agricultural workers in Oregon and North Carolina performed poorer on measures of response speed and latency compared to the non-agricultural children (Rohlman et al. 2005).

3.2 Biomonitoring

Considering the adverse health consequences identified it is important to determine if farmworker children have high levels of pesticide exposure and what is associated with increased levels. Biomonitoring is considered to be one of the most health relevant measurements of exposure since it is the measurement of environmental contaminants in biological fluids and represents the amount of chemicals that have actually been absorbed into the body and have the potential for adverse health effects. All of the studies that have conducted biomonitoring in farmworker children have evaluated pesticide metabolites in urine. I have summarized the biomonitoring studies in Table 2. The majority of these studies were conducted in populations in Washington, Oregon and North Carolina. As evident from Table 2, these studies report different descriptive statistics from many different pesticide metabolites in different units, making it difficult to compare across studies. Furthermore, these studies mostly report the concentration of non-specific organophosphate pesticide metabolites making it impossible to elucidate which pesticides the child was exposed to or if the child was exposed to the metabolite and not the parent compound (Barr et al. 2006).

Even with all of these complexities, it is clear that farmworkers' children most likely face higher exposures as a result of their parents' employment and proximity to agricultural fields where pesticides are applied (Table 2). Several studies have reported that children of farmworkers have a greater concentration of pesticide metabolites in their urine compared to reference populations (Coronado et al. 2006, Arcury et al. 2007, Mills and Zahm 2001, Lu et al. 2000, Lambert et al. 2005). In Washington State median dimethyl organophosphate pesticide metabolite levels were 4-5 times higher in farmworker children than in reference children from the same community and not significantly different from children of pesticide applicators (Lu et al. 2000). When these metabolite levels were used to estimate dose, researchers determined that 56% of the children of either orchard applicators or field workers exceeded the US EPA chronic dietary reference dose, compared to 44% of other children whose parents did not work in agriculture (Fenske et al. 2000). While most studies have focused on non-specific organophosphate metabolites, Arcury et al. (2007) measured the urine of children 1-6 years of age in North Carolina for 14 specific pesticide metabolites. They report a median of 4 different pesticides detected in the children's urine and a maximum of 7 detects in one child. Although difficult to compare with a national reference population because of differences in age, levels were higher in general in the farmworker children for chlorpyrifos, diazinon and parathion.

There are however, results that indicate that farmworker children may not have increased exposure to all pesticides. For example, although there was a difference in dimethyl organophosphate metabolite levels between agricultural children and a reference population, there was not a significant difference for diethyl organophosphate metabolites in the same Washington populations. (Fenske et al. 2002). Follow up studies have failed to demonstrate increased exposures among farmworker children compared to suburban

Metabolite	Group	Characteristics	Units	n	Mean	Median	Max	Study		
dimethyl	farmworker	California, 5-27 months old	umol/L	20		0.13	4.4	Bradman et al., 2007		
		California, does not report age	ppb	9	21.99			Mills and Zahm, 2001		
		Oregon, Berry Community, 2-6 years old	umol/L	52		0.23		Lambert et al., 2005		
		Oregon, Cherry Community, 2-6 years old	umol/L	52		0.25		Lambert et al., 2005		
		Oregon, Pear Community, 2-6 years old	umol/L	52		0.44		Lambert et al., 2005		
		North Carolina, 1-6 years old	umol/L	60	0.205	0.07	2.01	Arcury et al., 2006		
		Washington, 2-6 years old	umol/L	211		0.08	15.4	Curl et al., 2002		
		Washington, 9 months to 6 years old	ug/mL	13	0.07	0.05	0.2	Lu et al., 2000		
	reference	Washington, Urban, 2-5 years old	umol/L	96	0.19	0.11	0.93	Lu 2001		
		Nationwide, 6-11 years old	umol/L	471		0.050		Barr et al., 2004		
		Washington, 9 months to 6 years old	ug/mL	14	0.06	0.01	0.3	Lu et al., 2000		
		diethyl	farmworker	California, 5-27 months old	umol/L	20		0.001	0.21	Bradman et al., 2007
				California, does not report age	ppb	9	5.73			Mills and Zahm, 2001
North Carolina, 1-6 years old	umol/L			59	0.06	0.04	0.52	Arcury et al., 2006		
Washington, 2-6 years old	umol/L			211		0.06	0.23	Curl et al., 2002		
reference	Washington, Urban, 2-5 years old		umol/L	96	0.05	0.04	0.31	Lu 2001		
	Nationwide, 6-11 years old		umol/L	471		0.014		Barr et al., 2004		

Table 2. Organophosphate pesticide metabolite levels in farmworker and reference children.

children in Seattle (Thompson et al. 2003, Lu et al. 2001, Fenske et al. 2005, Curl et al. 2002). The researchers concluded that dietary exposures may be the primary route for all children regardless of parental occupation. Koch et al. (2002) also fails to report an association with parental occupation and children's pesticide metabolite levels in an agricultural community in Washington, however, they grouped packing shed workers into the same category as truck drivers and sales people. As packing shed workers are also exposed to high levels of pesticides, this could have confounded their analysis (Calvert et al. 2008).

In one cohort in Washington State, children's urinary dialkyl organophosphate metabolite levels were significantly correlated with their parents' metabolite levels (Curl et al. 2002). In this population the geometric mean concentration of dimethyl organophosphate metabolites was 1.5-2.6 fold higher for children who lived in households with a pome (apple or pear) fruit worker than children whose parents did not work in those crops (Coronado et al. 2006). In addition, the children in this study whose parents reported thinning crops had a greater proportion of detectable residues in their urine than children of other farmworker parents (Coronado et al. 2004). However, they did not have statistically higher concentrations (Fenske et al. 2004). As 91% of the thinners worked with pome fruit, after controlling for crop there were no longer any differences between thinners and non-thinners. Similarly in another study, agricultural children from a pear community in Oregon had 1.9 and 1.8 times the dimethylthiophosphate metabolite levels in their urine compared to children from the berry and cherry communities, respectively (Lambert et al. 2005). This indicates that working with pome-fruit may pose a particular hazard to children of farmworkers.

Further analysis of biomonitoring data from this region also indicates potential exposure pathways. Children who lived within 200 ft from an orchard did have higher levels of dimethyl but not diethyl organophosphate metabolites in their urine, than those living farther away indicating that exposure may be related to proximity for certain pesticides (Fenske et al. 2002, Loewenherz et al. 1997). In addition to correlation with proximity to orchards, children's dimethyl organophosphate metabolite levels were also significantly correlated with the concentration of azinphos-methyl pesticides in their house dust in Washington State in two cohorts (Coronado et al. 2006, Lu et al. 2000, Curl et al. 2002). In another study population from California, children's diethyl organophosphate urine metabolite levels were significantly correlated with the concentration of pesticides in house dust and toy wipes (Bradman et al. 2007). The correlations with proximity and house dust concentrations demonstrate the complexity of farmworker children's exposures to pesticides, and that these children probably are exposed both from agricultural spray drift and the take-home pathway from their parents' occupation. Children's incidental ingestion exposure from house dust and mouthing other objects is directly related to their unique activity patterns as well as the pesticide loadings in their home (Beamer et al., 2009), which further complicates the elucidation of these associations. Although not among farmworkers' children, but in a rural agricultural community, loading of pesticides on children's hands was highly correlated with urinary biomarker levels and may be a better predictor than other environmental exposure measures including house dust concentration as it is a measure that integrates the children's unique activities and the pesticide levels in their homes (Shalat et al. 2003).

Additional risk factors for elevated levels of pesticides in the urine of farmworkers' children have been identified. Researchers in North Carolina and Virginia conducted a case comparison analysis. They determined that higher amounts of organophosphate pesticide

metabolites in adults and children living with a farmworker were related to households without a nuclear family structure because the additional residents tended to be additional male farmworkers that were more likely to be exposed to pesticides at work and bring them home on their clothes (Arcury et al. 2005). Also these workers tended to have to wait longer to shower and stayed in their clothes longer after work. Families who rented their home, did not have a vacuum cleaner, had a difficult to clean home, or a high percentage of carpeting flooring also had higher levels of organophosphate pesticides in their urine. Higher levels of metabolites were associated with improper handling of laundry and storage of work clothes (Arcury et al. 2005). In a larger cohort in North Carolina, the same researchers determined that children had a greater number of specific pesticide metabolites detected in their urine only if they lived in rented houses or if their mothers worked part time in farm work (Arcury et al. 2007). However, they found no predictors for non-specific organophosphate metabolite levels (Arcury et al. 2006). Similarly, in Washington State the only factor associated with increased non-specific urinary metabolite concentrations was reported organophosphate pesticide use in the garden (Fenske et al. 2002). This indicates that many of the questions or factors commonly assessed may be not be useful predictors biomarker levels, or appropriate to target in interventions aimed at reducing children's pesticide urinary levels.

As demonstrated already by this review, there are many uncertainties associated with biomonitoring of pesticide metabolites in urine. Additional uncertainties include temporal variation in urine concentration (Barr et al. 2006). Children who live in agricultural communities in Washington had higher DAP metabolites during the spraying season than during the non-spraying season (57-40% difference) (Koch et al. 2002). Season of collection also related to pesticide metabolite concentrations in North Carolina (Arcury et al. 2005). In Oregon, 3 samples were taken from each child over the course of the season and there was substantial intra-individual variability indicating that it is important to obtain multiple samples even if they are combined prior to analysis (Lambert et al. 2005). In addition to concerns about temporal variability over the course of a growing season, there is also concern of temporal variability in urine concentration over the course of a day. Some studies collected a spot (grab) sample, while others collected first morning voids or 24-hour samples and it is not clear which type of samples are most relevant for understanding pesticide exposures. Kissel and colleagues report that first morning void samples may be the best spot collections to obtain (Kissel et al. 2004). Bradman and colleagues (2007) reported that overnight and spot urine samples were significantly correlated in a population of farmworker children from California. Furthermore there may be differences in metabolic and clearance rates between people and due to differences in hydration and dietary intake throughout the day. Some studies normalize their values by the concentration of creatinine measured in the urine sample, however there has also been reported seasonal variation of creatinine levels which may add additional complexities (O'Rourke et al. 2000).

Boys have higher reported metabolite levels than girls in two studies (Arcury et al. 2007, Koch et al. 2002), and no studies report higher metabolite levels in girls. Among applicator children in Washington, younger children had higher concentrations of urine metabolites than their older siblings (Loewenherz et al. 1997). In North Carolina, differences in pesticide metabolite levels as a function of age were observed by organophosphate class. Children 3-4 years of age have higher levels of diethyl but lower levels of dimethyl metabolite levels than children 1-2 years or 5-6 years (Arcury et al. 2007, Arcury et al. 2006). It is not clear if this is

due to differences in activity patterns (Beamer et al. 2008) or physiology as metabolism, clearance and volume of distribution change with age and gender (Beamer 2007).

As demonstrated by this review of biomonitoring studies in farmworker children, it is difficult to compare values across studies even when they were analyzed by the same laboratory and/or using the same procedures. Pesticide metabolite levels will also be affected by the subject's unique activity patterns and physiology. Furthermore pesticide usage is highly variably and is a function of many variables including crop type and pest infestation levels (Fenske et al. 2005). Pesticides are also metabolized relatively rapidly by the body, and urinary metabolite levels may not be the best marker of long-term exposure.

3.3 Environmental media and personal exposure measurements

Environmental media and personal exposure measurements, especially house dust may be more persistent for rapidly metabolized pesticides and helpful in determining risk factors for chronic exposure. It is important to understand if the levels of pesticides in farmworker homes are high compared to other homes and what factors are associated with increased levels in the homes, in order to design more effective intervention strategies. However, like for biomonitoring it is complicated to compare environmental and exposure measurements across studies (Hoppin et al. 2006). Factors that can vary between studies include media sampled such as dust, soil, air, hand and surface wipes. These samples are collected with a variety of collection methods including wipes and vacuum. Different size fractions may have been analyzed for dust, soil and air concentrations. The samples may have been taken from vastly different locations in the home such as child's bedroom or the living room. Different analytical methods have been used, and different quantities of samples have been collected which can result in a wide range of detection limits. Furthermore as in the case of biomarker levels, these measurements will also be affected by site-specific factors including pesticides of interest, geographic region, crops raised, pests of concern and calendar year or season.

Non-dietary ingestion of pesticide residues contributes the most to farmworker children's aggregate organophosphate pesticide exposure (Beamer 2007, Beamer et al. 2009). Primary measures of dust ingestion exposure are house dust concentrations, hand wipes or rinses and surface wipes. Although there are several studies that have quantified pesticide levels in multiple media in farmworker homes (Lu et al. 2000, Bradman et al. 2007), levels in house dust have been reported most frequently. In general, the concentration of agricultural pesticides is higher in farmworker homes (Table 3). During the sample collection period for these studies, chlorpyrifos and diazinon were still allowed for residential purposes and the large variability observed in reference homes most likely indicates indoor applications. Furthermore, concentration of pesticides in dust from farmworker homes was associated with household pesticide use in California and Washington (Fenske et al. 2002, Bradman et al. 1997) but not in Oregon (McCauley et al. 2001, McCauley et al. 2003).

Several studies have demonstrated that proximity to fields where pesticides are applied is related to pesticide levels in house dust (Lu et al. 2000, Fenske et al. 2002, McCauley et al. 2001). In addition to higher levels of pesticides in surface wipes, Quandt et al. (2004) also reports that they detected a greater number of different pesticides in the wipes in relation to proximity. Although Fenske and colleagues (2002) did report that house dust pesticide concentration decreases with distance to field among agricultural families, this did not manifest in differences in urinary metabolite levels. Curl et al. (2002) failed to demonstrate an association between house dust levels and proximity, indicating that geographic location and local wind patterns may be important to consider.

Pesticide	Population	Location	n	Mean	Median	Max	Study
Azinphos methyl	Agricultural	Vehicle, Washington	190		0.85	38.3	Curl et al., 2002
		House, Washington	156		0.53	14.9	Curl et al., 2002
		House, Washington	13	1.47	0.75	5.3	Lu et al., 2000
		House, Washington	22	1.62	0.951	11.3	Simcox et al., 1995
		House, Oregon	26	59	5.3	16	Rothlein et al., 2006
	Reference	House, Washington	14	0.29	0.15	1.1	Lu et al., 2000
		House, Washington	11	0.33	0.283	0.82	Simcox et al., 1995
Chlorpyrifos	Agricultural	House, California	20		0.049	1.2	Bradman et al., 2007
		Vehicle, Washington	190		0.05	2.6	Curl et al., 2002
		House, Washington	156		0.03	2	Curl et al., 2002
		House, Oregon	26	0.2	0.13	1.2	Rothlein et al., 2006
		House, Washington	12	0.27	0.25	0.6	Fenske et al., 2002
		House, Washington	22	0.338	0.172	2.2	Simcox et al., 1995
	Reference	House, Washington	14	0.09	0.07	0.3	Fenske et al., 2002
		House, Massachusetts	119		ND	228	Rudel et al., 2003
		Day Care, North Carolina	4	0.107		0.3	Wison et al., 2003
		House, Maryland	126	2.38	0.355	27	Pang et al., 2002
		House, Washington	11	0.168	0.053	0.5	Simcox et al., 1995
Diazinon	Agricultural	House, California	20		0.021	0.8	Bradman et al., 2007
		Vehicle, Washington	190		0	0.8	Curl et al., 2002
		House, Washington	156		0.01	0.6	Curl et al., 2002
		House, Oregon	26	0.31	0.31	0.7	Rothlein et al., 2006
	Reference	House, Massachusetts	119		ND	51	Rudel et al., 2003
		Day Care, North Carolina	4	0.034		0.1	Wison et al., 2003
Phosmet	Agricultural	House, Washington	13	0.14	0.11	0.3	Lu et al., 2000
		Vehicle, Washington	190		0.02	34.9	Curl et al., 2002
		House, Washington	156		0.02	16.9	Curl et al., 2002
		House, Oregon	26	5.2	4.4	22	Rothlein et al., 2006
		House, Washington	22	2.54	0.519	17.1	Simcox et al., 1995
	Reference	House, Washington	14	0.09	0.09	0.2	Lu et al., 2000
		House, Washington	11	0.227	0.187	0.7	Simcox et al., 1995

Table 3. Concentration of pesticides in house dust ($\mu\text{g/g}$) in farmworker and reference populations.

There is ample evidence for the take-home exposure pathway, given that when sampled together, homes with farmworkers had more pesticides in the dust than homes with no farmworkers (Lu et al. 2000, Bradman et al. 1997, Simcox et al. 1995). In Washington State, the median house dust concentrations of dimethyl organophosphate pesticides was 7 times higher in the homes of agricultural families compared to reference families, and 10 out of 61 agricultural children had detectable pesticides on their hands while no reference children did (Lu et al. 2000). Similarly, in the agricultural households pesticides were detected on 45% of the parents work boots and 11% of the steering wheels of the family car, while no samples from reference families had any detectable levels. In another study in Washington the concentration of azinphos methyl in house dust was highly correlated with the concentration in dust from the household vehicle, indicating that the vehicle is a likely pathway for transporting pesticides from the fields to the home (Curl et al. 2002).

The contribution of the take-home pathway to household contamination may also be dependent on the number of people bringing the pesticides from the fields. In Oregon, the concentration of azinphos methyl in house dust was correlated with the number of farmworkers living in the house (McCauley et al. 2001). The composition of the household may also be a factor. Households with a non-nuclear family structure had higher levels of agricultural but not residential pesticides in wipe samples (Quandt et al. 2004). In this study the non-familial household members tended to be almost entirely additional farm laborers. Due to the number of workers in these households, they also tended to delay showering and changing out of work clothes compared to households with a nuclear family structure. McCauley and colleagues (2003) demonstrated that changing out of work clothes <2 hours from coming home from the fields was associated with significantly lower levels of azinphos methyl and total organophosphate pesticides in house dust.

Factors from the workplace environment may also relate to the potential contribution of the take-home exposure pathway. Farmworkers that reported being involved in pesticide application at work had a greater amount of pesticides in their home (Quandt et al. 2004). In Washington licensed pesticide applicators had higher levels of pesticides in their homes than even farmworkers (Fenske et al., 2005). Farmworkers who reported burning eyes, pain muscles/joints/bones, shortness of breath and blurred vision, indicating that they may be exposed to greater amounts of pesticides at work, were also more likely to have methylparathion, azinphos methyl, malation or phosmet detected in the dust from their vehicles or homes (Strong et al. 2004). Coronado and colleagues (2006) reports that farmworkers who worked in pome fruit had significantly higher levels of azinphos methyl in their vehicles and house dust. These studies indicate that increased exposures at the workplace likely lead to greater contamination of the farmworker homes and potentially greater exposures of their children.

Household characteristics and behaviors may also lead to increased pesticide levels in the homes. Quandt and colleagues (2004) demonstrated that a higher amount of pesticides in farmworker homes was associated with mobile houses and those who rented their home. The same researchers also report the presence of a high amount of pesticides in farmworker homes that were determined to be "difficult to clean." In a pilot study in the Central Valley of California the frequency and method of cleaning was also related to the concentration of pesticides in house dust in farmworker homes as well as the age of the farmworker home (Bradman et al., 1997).

3.4 Pesticide risk perception

Given the importance that individual and household behaviors have on the concentration of pesticides in house dust (Quandt et al., 2004; McCauley et al., 2003), it is important to understand how farmworkers perceive their risk to pesticide exposure and use of safety practices. Several studies have interviewed farmworkers about safety practices at work and in the home. These are summarized in Table 4. Although most farmworkers do launder work clothes separate from family clothes, many do not utilize safety practices that could reduce their own and their family's exposures. Cabrera and Leckie (2009) demonstrated this even in a community of farmworkers in California with a high level of understanding of the risk of pesticide exposure. Interestingly, in a study by Goldman et al. (2004), acculturation was associated with a decrease in self-protective behaviors among pregnant farmworkers. Elmore and colleagues (2001) documented that perceived lack of control and cultural health beliefs were the primary factors that decreased farmworkers' use of safety practices. In another study perceived risk of pesticide exposure had a limited relationship to safety knowledge and was also not related to safety behavior, while perceived control was strongly related to safety knowledge and safety behavior (Arcury, Quandt & Russell 2002). Interviews with mothers in farmworker households document that they experience difficulty incorporating household safety practices and behaviors in their homes because of competing responsibilities, perceived lack of control, community barriers, conflicts with their husbands' intentions and their own cultural health beliefs (Strong et al. 2009). These studies demonstrate that pesticide safety education must address issues of farmworkers' perception of control to be most effective.

Behavior	Frequency (%)
Wears protective clothing	18-67.3
Enters home with work clothing	76-98
Changes clothing when arriving home	40-66.7
Removes shoes before entering home	40-68
Launders clothes separately	56-80

Table 4. Frequency of self-protective behaviors (McCauley et al., 2001; Arcury et al., 2006; Cabrera and Leckie, 2009; McCauley et al., 2003; Thompson et al., 2003; Goldman et al., 2004).

3.5 Interventions

Given the health effects associated with chronic pesticide exposure, effective interventions are needed to reduce farmworkers' and their children's exposure to pesticides. While environmental and occupational health policies and laws are helpful in reducing these exposures, they are only useful to the extent that they can be enforced. This however, presents many challenges. For example, in 2008 there were 81,500 farms operating in the state of California (USDA 2010). During that year the California Occupational Safety and Health Administration conducted 1,113 agricultural inspections (OSHA 2011). They reported that 57% of farms were out of compliance. 251 of these inspections were as a result of an accident. At this rate a farm in California can expect a random inspection once every 95 years (81,500 farms/862 random inspections). Furthermore in 2007, California farms were in full compliance with health and safety laws in 51% of the pesticide poisoning cases indicating that the laws may not be protective enough of the workers.

Arcury and colleagues (1999) interviewed farmworkers to assess how the Environmental Protection Agency's Worker Protection Standard was being implemented. Only a third of the farmworkers reported any pesticide training. Workers with visas were more likely than those without visas to have received training. However, very few workers knew how they could be exposed to pesticides or reported using any method to protect themselves. In a follow up study, Arcury et al. (2001) continues to document that farmers did not adhere to regulations mandating training and basic sanitation facilities. However, similar to the problems in California, there are only 30 staff members to ensure that regulations are upheld at over 10,000 farms in North Carolina. Arcury and colleagues (2001) argue that additional regulations by themselves are not an advantageous starting point, as that creation of additional regulations will probably only make employers feel more alienated and less likely to comply. They conclude that interventions aimed at educating farmers as well as farmworkers, perhaps through cooperative extension agents, may be more effective and help reduce misunderstanding and distrust between the two groups.

Lay community health workers called "promotoras" are known to be very effective at changing health-related behaviors in low-income Latino communities. A few interventions have utilized them in an attempt to reduce pesticide exposures in the farmworker communities. Arcury and colleagues (2009) evaluated a promotora intervention in North Carolina. Promotoras conducted either a nutrition or pesticide curriculum with their clients. Participants in the pesticide curriculum were more likely to recall the promotora visit and the messages, however the only significant difference between the two groups was that they were more likely to know that pesticides may have an effect on their children's health. The intervention was not successful at increasing pesticide safety practices in the home. Researchers in New Mexico developed a comic book for promotoras to use in educating their clients about pesticides (Liebman et al. 2007). The promotoras reviewed the comic book with 273 participants. A post-intervention evaluation documented that participants successfully increased knowledge about exposure routes, children's vulnerability to pesticide exposure, the signs and symptoms of pesticide poisonings and the ways to minimize pesticide exposures in the home. However these researchers did not evaluate if this increased knowledge manifested itself in an increase of safety practices in the home.

Teran and colleagues (2008) targeted an educational intervention at a particularly vulnerable group; teenagers that engage in farm labor. They incorporated a pesticide safety curriculum into "English as a Second Language" classes at high schools in an agricultural community. Almost all of the students reported working with pesticides under the age of 16 years. The teenagers in the intervention group were less likely to report that there was not much they could do to avoid their exposures and they were also less likely to report that it was not worth trying to improve conditions. They were more likely to report that working with pesticides can cause health problems and cite more laws protecting agricultural workers. This manifested in them being more likely to wear a long sleeve shirt and a hat while working in the fields. However, they were not more likely to wash their hands before eating. This is an example of an intervention that has great potential for empowering youth, who may be more vulnerable to the risks of pesticide exposure, and potentially reducing their exposures. In the future this curriculum should be modified to result in more protective behaviors.

There are very few interventions described in the literature that compare measurements of pesticide exposure before and after an intervention. Perhaps the most ambitious and

comprehensive intervention to reduce pesticide exposure in farmworkers' children was a community-wide intervention trial called "Para Niños Saludables" (Thompson et al. 2003). The study was conducted in 24 communities in Eastern Washington, where communities as a whole were randomized into intervention and control groups. A community advisory board designed the intervention. The intervention consisted of activities that were community-wide down to individual interactions. Community wide activities consisted of hosting health fairs, festivals, and block parties, where educational materials were disseminated from booths. Schools, churches, English and citizenship classes, orchards, farms, farmworker clinics and the farmworker union were organizations targeted for intervention opportunities. Promotoras held over 1,100 small home health parties over the 2-year intervention. Additional volunteers went door-to-door or educated workers one-on-one at grocery stores and other community locations. Materials developed and approved by the community advisory board that were distributed for the intervention included educational pamphlets, child coloring books, balloons, sample packets of laundry detergents, clothes sorting bags, bins for storing boots outside, shower kits, and infant bibs with the message "Keep me pesticide free." A puppet show, local media messages, and an annual calendar design competition were used to promote pesticide protection messages. Cross sectional samples of house dust and children's urine were taken across all the communities during years 1 and 4 of the trial and assessed for pesticide levels.

This intervention did result in increased pesticide safety practices in both intervention and comparison communities over time (Strong et al. 2009). Changes were significantly greater in intervention communities for removing work shoes before entering the home and for changing out of work clothes within 1 hour of arriving home. The only specific intervention activity associated with increased precautions was participation in home health parties with promotoras, confirming this as an effective method of reaching the farmworker community. However, there were not any significant differences in pesticide metabolite levels in adults or children, or in the pesticide concentration in house dust or vehicle dust between intervention and control communities (Thompson et al. 2008). There are a number of factors that could explain the lack of ability of this trial to document a reduction in pesticide exposures. Pesticide use patterns varied dramatically between years 1 and 4. There may have been low pesticide use during the baseline year, as demonstrated by pesticide exposure levels being much lower than in other farmworker children populations from Washington State (Fenske, R.A. 2005). Also the use of certain pesticides was restricted over the trial period leading to an increase in the use of different pesticides. The community cross-sectional design of the trial may not have been powerful enough to detect small changes, and it is impossible to determine if the same farmworkers and their homes were sampled in both years. There may have been cross contamination with farmworkers from control communities participating in events at intervention communities or even moving to intervention communities, and thus changing study groups.

McCauley and colleagues (2006b) evaluated the effectiveness of a cleaning intervention in removing pesticides from farmworker homes. Conventional cleaning of linoleum floors was not effective in reducing the total amount of organophosphate pesticides, however this varied among the pesticides. Alternative cleaning products and methods should be evaluated for reducing organophosphate loading on hard floors. Steam cleaning of carpets did reduce the level of pesticides in substantially in homes with higher pesticide levels, but pesticide levels were approximately one third of baseline levels after 12 months. This

indicates that cleaning practices may need to be more intensive and on going to result in an overall decrease of pesticides from carpets.

3.6 Future directions

The review of intervention studies demonstrates that educational interventions primarily through promotoras or English classes can be effective at increasing farmworkers and their families perception of control and utilization of self-protective behaviors (Teran et al 2008, Liebman et al. 2007, Strong et al. 2009). However, to date no single intervention study has documented a decrease in actual pesticide exposures faced by farmworker children. Although the intervention designed for the "Para Niños Saludables" trial is certainly ambitious, comprehensive and admirable, there may have been some issues with the intervention design that could be examined in future studies. The intervention was conducted only over 2 years. Bradman et al. (2007) reports detection of DDT in the majority of multi-media samples taken from farmworker homes 30 years after it was banned for use in California. Arcury et al. (2007) detected pesticides in children's urine that had been banned more than 10 years prior to their birth. The results of these studies may indicate that the residence time of pesticides in farmworker homes is very long, and two years was most likely not an adequate time period to see a reduction of pesticides in house dust nor in children's urine. McCauley et al. (2006b) demonstrated how difficult it is to reduce pesticide levels in farmworker homes following an intensive cleaning operation. In order to determine the effectiveness of a behavioral intervention on reducing pesticide contamination of house dust in a reasonable time span, procedures for decontaminating farmworker homes from pesticides need to be developed, tested and implemented prior to the intervention.

The "Para Niños Saludables" intervention focused on reducing the take-home exposure pathway whereby pesticides are tracked into the homes on clothes and shoes. However, it is possible that pesticides are primarily entering the home via air infiltration of agricultural spray drift and resuspended soil. In another study it was determined that approximately 60% soil contaminants present in house dust are from air infiltration of resuspended soil rather than soil track-in on shoes (Layton and Beamer 2009). In addition to presence of farmworkers in the home, household proximity to fields where pesticides have been applied is also associated with pesticide levels in house dust (Lu et al. 2000, Fenske et al. 2002, McCauley et al. 2001). In their cleaning effectiveness study, McCauley et al. (2006b) report higher loadings of pesticides on the windows than on hard floors. This may demonstrate that the primary source of pesticides in the home in agricultural communities may be from natural ventilation through windows. Future studies should be conducted to determine the relative contributions of air infiltration and soil-track in leading to pesticide levels in house dust, in order to design interventions that are more effective in reducing children's pesticide exposure. If air infiltration is the primary pathway, regulations to reduce drift from pesticide applications will need to be reviewed and families in agricultural communities regardless of occupation will need to be educated about spray drift and how to reduce their exposures.

Most of the current biomonitoring studies of farmworker children have measured non-specific organophosphate metabolites. There is limited data on specific pesticide levels. More studies should be completed like that by Arcury et al. (2007) that will allow us to identify key pesticides that children are exposed to, in order to more effectively target future intervention strategies. As organophosphate pesticide use is decreasing and other pesticides are being used instead, it is also important to develop and use biomonitoring methods for these pesticides. We should consider examining pesticide exposures of children whose

parents are not farmworkers but may face even higher pesticide exposures. For example, in a recent analysis of the 1998-2005 US Acute Pesticide Poisonings, farmers have an incidence rate of 4.8/100,000 full time equivalents compare to 74.8 for farmworkers and 362.6 for processing/packing plant workers (Calvert et al. 2008).

4. Conclusion

In conclusion, children of farmworkers are exposed to pesticides at levels that can result in adverse health effects, particularly affecting neurodevelopment. The children's exposure levels are correlated with adults in their households, and is related to the crops and tasks that their parents engage in. There is evidence that household proximity to pesticide application and the number of household members engaged in farm work relate to pesticide contamination levels in their homes. Interventions have been conducted that are effective for increasing farmworkers self-protective behaviors and perception of control. However, they have not been successful at reducing pesticide exposure levels. Future studies should focus on effective decontamination of farmworker homes, understanding the relative contribution of air infiltration of pesticides, obtaining better exposure measurements of specific pesticides and examining exposures to children of other high-risk agricultural workers.

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6. References

- Alavanja, M.C.R., Hoppin, J.A. & Kamel, F. 2004, "Health Effects of Chronic Pesticide Exposure: Cancer and Neurotoxicity* 3", *Annual Reviews of Public Health*, vol. 25, pp. 155-197.
- Alavanja, M.C.R., Dosemeci, M., Samanic, C., Lubin, J., Lynch, C.F., Knott, C., Barker, J., Hoppin, J.A., Sandler, D.P., Coble, J., Thomas, K. & Blair, A. 2004, "Pesticides and Lung Cancer Risk in the Agricultural Health Study Cohort", *American Journal of Epidemiology*, vol. 160, no. 9, pp. 876-885.
- Arcury, T.A., Grzywacz, J.G., Barr, D.B., Tapia, J., Chen, H. & Quandt, S.A. 2007, "Pesticide urinary metabolite levels of children in Eastern North Carolina farmworker households", *Environmental Health Perspectives*, vol. 115, no. 8, pp. 1254-1260.
- Arcury, T.A., Marin, A., Snively, B.M., Hernandez-Pelletier, M. & Quandt, S.A. 2009, "Reducing farmworker residential pesticide exposure: evaluation of a lay health advisor intervention", *Health Promotion Practice*, vol. 10, no. 3, pp. 447-455.
- Arcury, T.A., Quandt, S.A., Rao, P., Doran, A.M., Snively, B.M., Barr, D.B., Hoppin, J.A. & Davis, S.W. 2005, "Organophosphate Pesticide Exposure in Farmworker Family Members in Western North Carolina and Virginia: Case Comparisons", *Human Organization*, vol. 64, no. 1, pp. 40-51.
- Arcury, T.A., Quandt, S.A., Austin, C.K., Preisser, J. & Cabrera, L.F. 1999, "Implementation of EPA's worker protection standard training for agricultural laborers: An evaluation using North Carolina data", *Public Health Reports*, vol. 114, no. 5, pp. 459-468.

- Arcury, T.A., Quandt, S.A., Cravey, A.J., Elmore, R.C. & Russell, G.B. 2001, "Farmworker reports of pesticide safety and sanitation in the work environment", *American Journal of Industrial Medicine*, vol. 39, no. 5, pp. 487-498.
- Arcury, T.A., Quandt, S.A. & Russell, G.B. 2002, "Pesticide safety among farmworkers: Perceived risk and perceived control as factors reflecting environmental justice", *Environmental Health Perspectives*, vol. 110, no. Supplement 2, pp. 233-240.
- Arcury, T.A., Grzywacz, J.G., Davis, S.W., Barr, D.B. & Quandt, S.A. 2006, "Organophosphorus pesticide urinary metabolite levels of children in farmworker households in eastern North Carolina", *American Journal of Industrial Medicine*, vol. 49, no. 9, pp. 751-760.
- Barr, D.B., Thomas, K., Curwin, B., Landsittel, D., Raymer, J., Lu, C., Donnelly, K.C. & Acquavella, J. 2006, "Biomonitoring of Exposure in Farmworker Studies", *Environmental Health Perspectives*, vol. 114, no. 6, pp. 936-942.
- Beamer, P. 2007, *Development of a Model to Estimate Aggregate and Cumulative Exposure and Dose in Young Children*, Ph.D. Dissertation, Stanford University.
- Beamer, P.I., Canales, R.A., Bradman, A. & Leckie, J.O. 2009, "Farmworker children's residential non-dietary exposure estimates from micro-level activity time series", *Environment International*, vol. 35, no. 8, pp. 1202-1209.
- Beamer, P., Key, M.E., Ferguson, A.C., Canales, R.A., AuYeung, W. & Leckie, J.O. 2008, "Quantified activity pattern data from 6-to-27-month-old farmworker children for use in exposure assessment", *Environmental Research*, vol. 108, no. 2, pp. 239-246.
- Berkowitz, G.S., Wetmur, J.G., Birman-Deych, E., Obel, J., Lapinski, R.H., Godbold, J.H., Holzman, I.R. & Wolff, M.S. 2004, "In utero pesticide exposure, maternal paraoxonase activity, and head circumference", *Environmental Health Perspectives*, vol. 112, no. 3, 388-391.
- Blair, A. & Zahm, S.H. 1995, "Agricultural exposures and cancer", *Environmental Health Perspectives*, vol. 103, no. Suppl 8, pp. 205-208.
- Bradman, A., Whitaker, D., Quiros, L., Castorina, R., Henn, B.C., Nishioka, M., Morgan, J., Barr, D.B., Harnly, M., Brisbin, J.A., Sheldon, L.S., McKone, T.E. & Eskenazi, B. 2007, "Pesticides and their metabolites in the homes and urine of farmworker children living in the Salinas Valley, CA", *Journal of Exposure Science & Environmental Epidemiology*, vol. 17, no. 4, pp. 331-349.
- Bradman, M.A., Harnly, M.E., Draper, W., Seidel, S., Teran, S., Wakeham, D. & Neutra, R. 1997, "Pesticide exposures to children from California's Central Valley: Results of a pilot study", *Journal of Exposure Analysis and Environmental Epidemiology*, vol. 7, no. 2, pp. 217-234.
- Cabrera, N.L. & Leckie, J.O. 2009, "Pesticide Risk Communication, Risk Perception, and Self-Protective Behaviors Among Farmworkers in California's Salinas Valley", *Hispanic Journal of Behavioral Sciences*, vol. 31, no. 2, pp. 258-272.
- Calvert, G.M., Karnik, J., Mehler, L., Beckman, J., Morrissey, B., Sievert, J., Barrett, R., Lackovic, M., Mabee, L. & Schwartz, A. 2008, "Acute pesticide poisoning among agricultural workers in the United States, 1998-2005", *American Journal of Industrial Medicine*, vol. 51, no. 12, pp. 883-898.
- Chávez, C. (1989). We must do justice. Speech given by César Chávez. In *La Voz de Aztlan*, I(2), January 17, 2000.
- Cooper, S.P., Darragh, A.R., Vernon, S.W., Stallones, L., MacNaughton, N., Robison, T., Hanis, C. & Zahm, S.H. 2001, "Ascertainment of pesticide exposures of migrant and

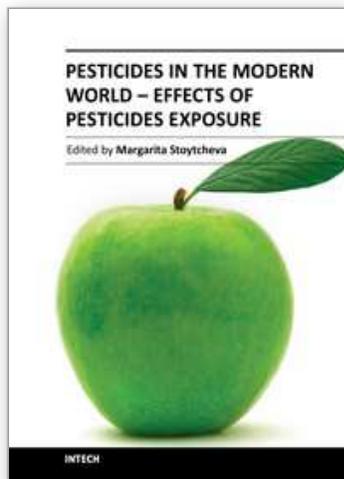
- seasonal farmworker children: findings from focus groups", *American Journal of Industrial Medicine*, vol. 40, no. 5, pp. 531-537.
- Coronado, G.D., Thompson, B., Strong, L., Griffith, W.C. & Islas, I. 2004, "Agricultural task and exposure to organophosphate pesticides among farmworkers", *Environmental Health Perspectives*, vol. 112, no. 2, pp. 142-147.
- Coronado, G.D., Vigoren, E.M., Thompson, B., Griffith, W.C. & Faustman, E.M. 2006, "Organophosphate pesticide exposure and work in pome fruit: evidence for the take-home pesticide pathway", *Environmental Health Perspectives*, vol. 114, no. 7, pp. 999-1006.
- Curl, C.L., Fenske, R.A., Kissel, J.C., Shirai, J.H., Moate, T.F., Griffith, W., Coronado, G. & Thompson, B. 2002, "Evaluation of take-home organophosphorus pesticide exposure among agricultural workers and their children", *Environmental Health Perspectives*, vol. 110, no. 12, pp. A787-A792.
- Daniels, J.L., Olshan, A.F. & Savitz, D.A. 1997, "Pesticides and childhood cancers", *Environmental Health Perspectives*, vol. 105, no. 10, pp. 1068-1077.
- Efird, J.T., Holly, E.A., Preston-Martin, S., Mueller, B.A., Lubin, F., Filippini, G., Peris-Bonet, R., McCredie, M., Cordier, S. & Arslan, A. 2003, "Farm-related exposures and childhood brain tumours in seven countries: results from the SEARCH International Brain Tumour Study", *Paediatric and Perinatal Epidemiology*, vol. 17, no. 2, pp. 201-211.
- Elbaz, A. & Tranchant, C. 2007, "Epidemiologic studies of environmental exposures in Parkinson's disease", *Journal of the Neurological Sciences*, vol. 262, no. 1-2, pp. 37-44.
- Elmore, R.C. & Arcury, T.A. 2001, "Pesticide exposure beliefs among Latino farmworkers in North Carolina's Christmas tree industry", *American Journal of Industrial Medicine*, vol. 40, no. 2, pp. 153-160.
- Eskenazi, B., Harley, K., Bradman, A., Weltzien, E., Jewell, N.P., Barr, D.B., Furlong, C.E. & Holland, N.T. 2004, "Association of in Utero Organophosphate Pesticide Exposure and Fetal Growth and Length of Gestation in an Agricultural Population", *Environmental Health Perspectives*, vol. 112, no. 10, pp. 1116-1124.
- Eskenazi, B., Huen, K., Marks, A., Harley, K.G., Bradman, A., Barr, D.B. & Holland, N. 2010, "PON1 and Neurodevelopment in Children from the CHAMACOS Study Exposed to Organophosphate Pesticides in Utero", *Environmental Health Perspectives*, vol. 118, no. 12, pp. 1775-1781.
- Eskenazi, B., Marks, A.R., Bradman, A., Harley, K., Barr, D.B., Johnson, C., Morga, N. & Jewell, N.P. 2007, "Organophosphate Pesticide Exposure and Neurodevelopment in Young Mexican-American Children", *Environmental Health Perspectives*, vol. 115, no. 5, pp. 792-798.
- Eskenazi, B., Bradman, A. & Castorina, R. 1999, "Exposures of children to organophosphate pesticides and their potential adverse health effects", *Environmental Health Perspectives*, vol. 107, no. Suppl. 3, pp. 409-419.
- Faustman, E.M., Silbernagel, S.M., Fenske, R.A., Burbacher, T.M. & Ponce, R.A. 2000, "Mechanisms underlying children's susceptibility to environmental toxicants.", *Environmental Health Perspectives*, vol. 108, no. Suppl 1, pp. 13-21.
- Fenske, R.A., Kissel, J.C., Shirai, J.H., Curl, C.L. & Galvin, K. 2004, "Agricultural task not predictive of children's exposure to OP pesticides", *Environmental Health Perspectives*, vol. 112, no. 15, pp. A865.

- Fenske, R.A., Lu, C., Curl, C.L., Shirai, J.H. & Kissel, J.C. 2005, "Biologic Monitoring to Characterize Organophosphorus Pesticide Exposure among Children and Workers: An Analysis of Recent Studies in Washington State", *Environmental Health Perspectives*, vol. 113, no. 11, pp. 1651-1657.
- Fenske, R.A., Kissel, J.C., Lu, C.S., Kalman, D.A., Simcox, N.J., Allen, E.H. & Keifer, M.C. 2000, "Biologically based pesticide dose estimates for children in an agricultural community", *Environmental Health Perspectives*, vol. 108, no. 6, pp. 515-520.
- Fenske, R.A., Lu, C.S., Barr, D. & Needham, L. 2002, "Children's exposure to chlorpyrifos and parathion in an agricultural community in Central Washington State", *Environmental Health Perspectives*, vol. 110, no. 5, pp. 549-553.
- Fenske, R.A., Lu, C.S., Simcox, N.J., Loewenherz, C., Touchstone, J., Moate, T.F., Allen, E.H. & Kissel, J.C. 2000, "Strategies for assessing children's organophosphorus pesticide exposures in agricultural communities", *Journal of Exposure Analysis and Environmental Epidemiology*, vol. 10, no. 6, pp. 662-671.
- Furlong, C.E., Holland, N., Richter, R.J., Bradman, A., Ho, A. & Eskenazi, B.C. 2006, "PON1 status of farmworker mothers and children as a predictor of organophosphate sensitivity", *Pharmacogenetics and Genomics*, vol. 16, no. 3, pp. 183-190.
- Goldman, L., Eskenazi, B., Bradman, A. & Jewell, N.P. 2004, "Risk behaviors for pesticide exposure among pregnant women living in farmworker households in Salinas, California", *American Journal of Industrial Medicine*, vol. 45, no. 6, pp. 491-499.
- Guillette, E.A., Meza, M.M., Aquilar, M.G., Soto, A.D. & Garcia, I.E. 1998, "An anthropological approach to the evaluation of preschool children exposed to pesticides in Mexico", *Environmental Health Perspectives*, vol. 106, no. 6, pp. 347.
- Hancock, D.B., Martin, E.R., Mayhew, G.M., Stajich, J.M., Jewett, R., Stacy, M.A., Scott, B.L., Vance, J.M. & Scott, W.K. 2008, "Pesticide exposure and risk of Parkinson's disease: a family-based case-control study", *BMC Neurology*, vol. 8, pp. 6.
- Hansen, E. & Donohoe, M. 2010, "Health issues of migrant and seasonal farmworkers", *Journal of Health Care for the Poor and Underserved*, vol. 14, no. 2, pp. 153-164.
- Hoppin, J.A., Adgate, J.L., Eberhart, M., Nishioka, M. & Ryan, P.B. 2006, "Environmental exposure assessment of pesticides in farmworker homes", *Environmental Health Perspectives*, vol. 114, no. 6, pp. 929-935.
- Kirkhorn, S.R. & Schenker, M.B. 2002, "Current health effects of agricultural work: respiratory disease, cancer, reproductive effects, musculoskeletal injuries, and pesticide-related illnesses", *Journal of Agricultural Safety and Health*, vol. 8, no. 2, pp. 199-214.
- Kisby, G.E., Muniz, J.F., Scherer, J., Lasarev, M.R., Koshy, M., Kow, Y.W., McCauley, L., Conway, G.A., Gordon, J.R. & Kirychuk, S.P. 2009, "Oxidative stress and DNA damage in agricultural workers", *Sixth International Symposium: Public Health and the Agricultural-Rural Ecosystem, Saskatoon, Saskatchewan, Canada, 19-23 October 2008*.
- Kissel, J.C., Curl, C.L., Kedan, G., Lu, C., Griffith, W., Barr, D.B., Needham, L.L. & Fenske, R.A. 2004, "Comparison of organophosphorus pesticide metabolite levels in single and multiple daily urine samples collected from preschool children in Washington State", *Journal of Exposure Science and Environmental Epidemiology*, vol. 15, no. 2, pp. 164-171.
- Koch, D., Lu, C., Fisker-Andersen, J., Jolley, L. & Fenske, R.A. 2002, "Temporal Association of Children's Pesticide Exposure and Agricultural Spraying: Report of a

- Longitudinal Biological Monitoring Study", *Environmental Health Perspectives*, vol. 110, no. 8, pp. 829-833.
- Lambert, W.E., Lasarev, M., Muniz, J., Scherer, J., Rothlein, J., Santana, J. & McCauley, L. 2005, "Variation in Organophosphate Pesticide Metabolites in Urine of Children Living in Agricultural Communities", *Environmental Health Perspectives*, vol. 113, no. 4, pp. 504-508.
- Layton, D.W. & Beamer, P.I. 2009, "Migration of Contaminated Soil and Airborne Particulates to Indoor Dust", *Environmental Science & Technology*, vol. 43, no. 21, pp. 8199-8205.
- Liebman, A.K., Juarez, P.M., Leyva, C. & Corona, A. 2007, "A Pilot Program Using Promotoras de Salud to Educate Farmworker Families About the Risks from Pesticide Exposure", *Journal of Agromedicine*, vol. 12, no. 2, pp. 33-43.
- Loewenherz, C., Fenske, R.A., Simcox, N.J., Bellamy, G. & Kalman, D. 1997, "Biological monitoring of organophosphorus pesticide exposure among children of agricultural workers in Central Washington State", *Environmental Health Perspectives*, vol. 105, no. 12, pp. 1344-1353.
- Lu, C., Fenske, R.A., Simcox, N.J. & Kalman, D. 2000, "Pesticide Exposure of Children in an Agricultural Community: Evidence of Household Proximity to Farmland and Take Home Exposure Pathways* 1", *Environmental Research*, vol. 84, no. 3, pp. 290-302.
- Lu, C.S., Knutson, D.E., Fisker-Andersen, J. & Fenske, R.A. 2001, "Biological monitoring survey of organophosphorus pesticide exposure among preschool children in the Seattle metropolitan area", *Environmental Health Perspectives*, vol. 109, no. 3, pp. 299-303.
- Marks, A.R., Harley, K., Bradman, A., Kogut, K., Barr, D.B., Johnson, C., Calderon, N. & Eskenazi, B. 2010, "Organophosphate pesticide exposure and attention in young Mexican-American children: The CHAMACOS Study", *Environmental Health Perspectives*, vol. 118, no. 12, pp. 1768-1774.
- McCauley, L.A., Anger, W.K., Keifer, M., Langley, R., Robson, M.G. & Rohlman, D. 2006a, "Studying health outcomes in farmworker populations exposed to pesticides", *Environmental Health Perspectives*, vol. 114, no. 6, pp. 953-960.
- McCauley, L.A., Lasarev, M.R., Higgins, G., Rothlein, J., Muniz, J., Ebbert, C. & Phillips, J. 2001, "Work characteristics and pesticide exposures among migrant agricultural families: A community-based research approach", *Environmental Health Perspectives*, vol. 109, no. 5, pp. 533-538.
- McCauley, L.A., Michaels, S., Rothlein, J., Muniz, J., Lasarev, M. & Ebbert, C. 2003, "Pesticide exposure and self reported home hygiene: practices in agricultural families", *AAOHN Journal: Official Journal of the American Association of Occupational Health Nurses*, vol. 51, no. 3, pp. 113-119.
- McCauley, L.A., Travers, R., Lasarev, M., Muniz, J. & Nailon, R. 2006b, "Effectiveness of cleaning practices in removing pesticides from home environments", *Journal of Agromedicine*, vol. 11, no. 2, pp. 81-88.
- Mills, P.K., Dodge, J. & Yang, R. 2009, "Cancer in migrant and seasonal hired farm workers", *Journal of Agromedicine*, vol. 14, no. 2, pp. 185-191.
- Mills, P.K. & Zahm, S.H. 2001, "Organophosphate pesticide residues in urine of farmworkers and their children in Fresno County, California", *American Journal of Industrial Medicine*, vol. 40, no. 5, pp. 571-577.

- Moses, M. 1989, "Pesticide-Related Health Problems and Farmworkers", *AAOHN*, vol. 37, no. 3, pp. 115-30.
- OSHA. 2011, *Enforcement Inspections Database*
<http://www.osha.gov/pls/imis/industry.html>
- O'Rourke, M.K., Lizardi, P.S., Rogan, S.P., Freeman, N.C., Aguirree, A. & Saint, C.G. 2000, "Pesticide exposure and creatinine variation among young children", *Journal of Exposure Analysis and Environmental Epidemiology*, vol. 10, no. 6, pp. 672-681.
- Priyadarshi, A., Khuder, S.A., Schaub, E.A. & Priyadarshi, S.S. 2001, "Environmental Risk Factors and Parkinson's Disease: A Metaanalysis", *Environmental Research*, vol. 86, no. 2, pp. 122-127.
- Quandt, S.A., Arcury, T.A., Rao, P., Snively, B.M., Camann, D.E., Doran, A.M., Yau, A.Y., Hoppin, J.A. & Jackson, D.S. 2004, "Agricultural and residential pesticides in wipe samples from farmworker family residences in North Carolina and Virginia.", *Environmental Health Perspectives*, vol. 112, no. 3, pp. 382-387.
- Roberts, E.M., English, P.B., Grether, J.K., Windham, G.C., Somberg, L. & Wolff, C. 2007, "Maternal residence near agricultural pesticide applications and autism spectrum disorders among children in the California Central Valley", *Environmental Health Perspectives*, vol. 115, no. 10, pp. 1482-1489.
- Rohlman, D.S., Arcury, T.A., Quandt, S.A., Lasarev, M., Rothlein, J., Travers, R., Tamulinas, A., Scherer, J., Early, J. & Marin, A. 2005, "Neurobehavioral performance in preschool children from agricultural and non-agricultural communities in Oregon and North Carolina", *Neurotoxicology*, vol. 26, no. 4, pp. 589-598.
- Rothlein, J., Rohlman, D., Lasarev, M., Phillips, J., Muniz, J. & McCauley, L. 2006, "Organophosphate Pesticide Exposure and Neurobehavioral Performance in Agricultural and Nonagricultural Hispanic Workers", *Environmental Health Perspectives*, vol. 114, no. 5, pp. 691-696.
- Rust, G.S. 1990, "Health status of migrant farmworkers: a literature review and commentary.", *American Journal of Public Health*, vol. 80, no. 10, pp. 1213-1217.
- Salvatore, A.L., Bradman, A., Castorina, R., Camacho, J., López, J., Barr, D.B., Snyder, J., Jewell, N.P. & Eskenazi, B. 2008, "Occupational Behaviors and Farmworkers' Pesticide Exposure: Findings From a Study in Monterey County, California", *American Journal of Industrial Medicine*, vol. 51, no. 10, pp. 782-794.
- Sánchez Lizardi, P., O'Rourke, M.K. & Morris, R.J. 2008, "The effects of organophosphate pesticide exposure on Hispanic children's cognitive and behavioral functioning", *Journal of Pediatric Psychology*, vol. 33, no. 1, pp. 91-101.
- Shalat, S.L., Donnelly, K.C., Freeman, N.C.G., Calvin, J.A., Ramesh, S., Jimenez, M., Black, K., Coutinho, C., Needham, L.L., Barr, D.B. & Ramirez, Y. 2003, "Nondietary ingestion of pesticides by children in an agricultural community on the US/Mexico border: Preliminary results", *Journal of Exposure Analysis and Environmental Epidemiology*, vol. 13, no. 1, pp. 42-50.
- Shim, Y.K., Mlynarek, S.P. & Van Wijngaarden, E. 2009, "Parental exposure to pesticides and childhood brain cancer: US Atlantic coast childhood brain cancer study", *Environmental Health Perspectives*, vol. 117, no. 6, pp. 1002-1006.
- Simcox, N.J., Fenske, R.A., Wolz, S.A., Lee, I.C. & Kalman, D.A. 1995, "Pesticides in household dust and soil: Exposure pathways for children of agricultural families", *Environmental Health Perspectives*, vol. 103, no. 12, pp. 1126-1134.

- Strong, L.L., Thompson, B., Coronado, G.D., Griffith, W.C., Vigoren, E.M. & Islas, I. 2004, "Health symptoms and exposure to organophosphate pesticides in farmworkers", *American Journal of Industrial Medicine*, vol. 46, no. 6, pp. 599-606.
- Strong, L.L., Thompson, B., Koepsell, T.D., Meischke, H. & Coronado, G.D. 2009, "Reducing the Take-Home Pathway of Pesticide Exposure: Behavioral Outcomes From the Para Niños Saludables Study", *Journal of Occupational and Environmental Medicine*, vol. 51, no. 8, pp. 922-933.
- Teran, S., Strohlic, R., Bush, D., Baker, R. & Meyers, J. 2008, "Reaching Teen Farm Workers with Health and Safety Information: An Evaluation of a High School ESL Curriculum", *Journal of Agricultural Safety and Health*, vol. 14, no. 2, pp. 147-162.
- Thompson, B., Coronado, G.D., Vigoren, E.M., Griffith, W.C., Fenske, R.A., Kissel, J.C., Shirai, J.H. & Faustman, E.M. 2008, "Para Niños Saludables: A Community Intervention Trial to Reduce Organophosphate Pesticide Exposure in Children of Farmworkers", *Environmental Health Perspectives*, vol. 116, no. 5, pp. 687-694.
- Thompson, B., Coronado, G.D., Grossman, J.E., Puschel, K., Solomon, C.C., Islas, I., Curl, C.L., Shirai, J.H., Kissel, J.C. & Fenske, R.A. 2003, "Pesticide take-home pathway among children of agricultural workers: Study design, methods, and baseline findings", *Journal of Occupational and Environmental Medicine*, vol. 45, no. 1, pp. 42-53.
- Turner, M.C., Wigle, D.T. & Krewski, D. 2010, "Residential Pesticides and Childhood Leukemia: A Systematic Review and Meta-Analysis", *Environmental Health Perspectives*, vol. 118, no. 1, pp. 33-41.
- US Census. 2009a, *Poverty Thresholds for 2009 by Size of Family and Number of Related Children Under 18 Years*. Available from: <http://www.census.gov/hhes/www/poverty/about/overview/measure.html>.
- US Census. 2009b, *American Community Survey 2005-2009*. Available from: http://factfinder.census.gov/servlet/DatasetMainPageServlet?_lang=en&_ts=318206875334&_ds_name=ACS_2009_5YR_G00_&_program=.
- USDA. 2010, *State Fact Sheets: California*. <http://www.ers.usda.gov/Statefacts/CA.htm>
- Villarejo, D. 2003, "The health of US hired farm workers", *Annual Review of Public Health*, vol. 24, no. 1, pp. 175-193.
- Whyatt, R.M., Rauh, V., Barr, D.B., Camann, D.E., Andrews, H.F., Garfinkel, R., Hoepner, L.A., Diaz, D., Dietrich, J. & Reyes, A. 2004, "Prenatal Insecticide Exposures and Birth Weight and Length among an Urban Minority Cohort", *Environmental Health Perspectives*, vol. 112, no. 10, pp. 1125-1132.
- Wigle, D.T., Turner, M.C. & Krewski, D. 2009, "A Systematic Review and Meta-analysis of Childhood Leukemia and Parental Occupational Pesticide Exposure", *Environmental Health Perspectives*, vol. 117, no. 10, pp. 1505-1513.
- Wilk, V.A. 1993, "Health hazards to children in agriculture", *American Journal of Industrial Medicine*, vol. 24, no. 3, pp. 283-290.
- Young, J.G., Eskenazi, B., Gladstone, E.A., Bradman, A., Pedersen, L., Johnson, C., Barr, D.B., Furlong, C.E. & Holland, N.T. 2005, "Association between in utero organophosphate pesticide exposure and abnormal reflexes in neonates", *Neurotoxicology*, vol. 26, no. 2, pp. 199-209.



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The introduction of the synthetic organochlorine, organophosphate, carbamate and pyrethroid pesticides by 1950s marked the beginning of the modern pesticides era and a new stage in the agriculture development. Evolved from the chemicals designed originally as warfare agents, the synthetic pesticides demonstrated a high effectiveness in preventing, destroying or controlling any pest. Therefore, their application in the agriculture practices made it possible enhancing crops and livestock's yields and obtaining higher-quality products, to satisfy the food demand of the continuously rising world's population. Nevertheless, the increase of the pesticide use estimated to 2.5 million tons annually worldwide since 1950., created a number of public and environment concerns. This book, organized in two sections, addresses the various aspects of the pesticides exposure and the related health effects. It offers a large amount of practical information to the professionals interested in pesticides issues.

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