DETERMINANTS OF ATRAZINE CONTAMINATION IN IOWA HOMES AND OCCUPATIONAL EXPOSURE IN CENTRAL AMERICA

by

Matthew Joiner Lozier

An Abstract

Of a thesis submitted in partial fulfillment
of the requirements for Doctorate of Philosophy
degree in Occupational and Environmental Health
in the Graduate College of
The University of Iowa

December 2010

Thesis Supervisor: Professor Wayne T. Sanderson

ABSTRACT

Background: Atrazine is an agricultural herbicide used extensively in corn production worldwide. Atrazine is an endocrine disruptor and has been linked to many other deleterious health outcomes. Exposure assessment studies have been carried out in Iowa among farm and non-farm populations. However, commercial pesticide applicators have been left out of those studies. Atrazine is also used in developing countries in grain production. In developing countries there is great concern about acute pesticide poisonings, but chronic exposure to less acutely toxic pesticides has not been studied extensively. This study assessed in-home contamination of atrazine among commercial pesticide applicators in Iowa and compared these results to similar studies. Occupational inhalation exposure to atrazine was also assessed in Honduras.

Methods: Dust samples were taken from 29 commercial pesticide applicator homes in four different locations. Sampling was done during the atrazine application season and again six months later to assess atrazine persistence. Occupational and household characteristics were analyzed for associations with atrazine dust levels. Data from two previous studies that analyzed farm and non-farm household dust samples for atrazine were combined with this data and analysis was performed to identify which population had the greatest risk for take-home atrazine exposure and which determinants were associated with in-home atrazine dust levels. Lastly, corn production practices in Honduras were evaluated and personal air samples were taken from pesticide applicators during atrazine application to assess inhalation exposure.

Results: The first study found that atrazine levels persist into the winter months in the homes of commercial applicators. Atrazine handling (days, pounds, and acres sprayed) were all positively associated with in-home atrazine levels. Commercial applicators that change their shoes inside had higher atrazine levels. The second study identified commercial applicators' homes as the most contaminated compared with farmers who apply atrazine to their own land, farmers who hire out atrazine application, and non-farm homes. Farmers that apply their own atrazine also had significantly higher atrazine levels in their homes. The association between atrazine handling and household atrazine levels was highly significant in this study ($p < 0.001$). In Honduras, atrazine is applied to corn fields with tractor/boom equipment and manual backpack sprayers. Despite applying about one-fifteenth the amount of atrazine, backpack sprayers are exposed to nearly equal amounts of atrazine via inhalation exposure and likely have greater dermal exposure. Among backpack sprayers, which type of spray nozzle used is associated with inhalation exposure. Among tractor/boom applicators, tractor drivers have much lower inhalation exposure than workers who operate and observe the boom.

Conclusions: The amount of atrazine handled is the most important determinant for predicting in-home atrazine levels in Iowa. Ubiquitous atrazine contamination and its distribution within homes and among household type provide strong evidence for the take-home pathway. While some improvements have been made in Honduras regarding pesticide application, poor farm workers and small farmers still use antiquated pesticide application techniques which leads to a higher risk of inhalation and dermal exposure.

Abstract Approved: ______________________________
Thesis Supervisor

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____
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Graduate College
The University of Iowa
Iowa City, Iowa

CERTIFICATE OF APPROVAL

PH.D THESIS

This is to certify that the Ph.D. thesis of

Matthew Joiner Lozier

has been approved by the Examining Committee for the thesis requirement for the Doctor of Philosophy degree in Occupational and Environmental Health at the December 2010 graduation.

Thesis Committee: ______________________________
Wayne T. Sanderson, Thesis Supervisor

____
Thomas M. Cook

____
Laurence J. Fuortes

____
Craig L. Just

____
Kelley J. Donham

____
Anne B. Wallis

To my wife Leda, and my daughter Estela, for their never-ending
support and love that have carried me through my Ph.D. experience.
May there be many adventures ahead of us.

Never doubt that a small group of thoughtful, committed citizens can change the world. Indeed, it is the only thing that ever has.

Margaret Mead

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ABSTRACT

Background: Atrazine is an agricultural herbicide used extensively in corn production worldwide. Atrazine is an endocrine disruptor and has been linked to many other deleterious health outcomes. Exposure assessment studies have been carried out in Iowa among farm and non-farm populations. However, commercial pesticide applicators have been left out of those studies. Atrazine is also used in developing countries in grain production. In developing countries there is great concern about acute pesticide poisonings, but chronic exposure to less acutely toxic pesticides has not been studied extensively. This study assessed the in-home contamination of atrazine among commercial pesticide applicators in Iowa and then quantitatively analyzed these results with results from similar studies. Occupational inhalation exposure to atrazine was also assessed in Honduras.

Methods: Dust samples were taken from 29 commercial pesticide applicator households in four different locations. This sampling was done once during the atrazine application season and again six months later during winter months to assess atrazine persistence. Occupational and household characteristics were analyzed for associations with atrazine dust levels. Data from two previous studies that analyzed farm and non-farm household dust samples for atrazine were combined with data from the commercial applicator's homes. This new and larger dataset was analyzed to identify which population has the greatest risk for take-home atrazine exposure and what determinants were associated with in-home atrazine dust levels. Lastly, corn production practices in Honduras were evaluated and personal air samples were taken from pesticide applicators during atrazine application to assess inhalation exposure.

Results: The first study found that atrazine levels persist into the winter months in the homes of commercial applicators. Atrazine handling (days, pounds, and acres sprayed) were all positively associated with in-home atrazine levels. Commercial applicators that change their shoes inside had higher atrazine levels. More frequent floor cleaning was associated with lower atrazine levels. The second study identified commercial applicators' homes as the most contaminated compared with farmers who apply atrazine to their own land, farmers who hire out atrazine application, and non-farm homes. Farmers that apply their own atrazine also had significantly higher atrazine levels in their homes. The association between atrazine handling and household atrazine levels was highly significant in this study ($p < 0.001$). In Honduras, atrazine is applied to corn fields with tractor/boom equipment and manual backpack sprayers. Despite applying about one-fifteenth the amount of atrazine, backpack sprayers are exposed to nearly equal amounts of atrazine via inhalation exposure and likely have greater exposure via the dermal route. Among backpack sprayers, which type of spray nozzle used is associated with inhalation exposure. Among tractor/boom applicators, tractor drivers have much lower inhalation exposure than workers who operate and observe the boom.

Conclusions: The amount of atrazine handled is the most important determinant for predicting in-home atrazine levels in Iowa. Ubiquitous atrazine contamination and its distribution within homes and among household type provide strong evidence for the take-home pathway. While some improvements have been made in Honduras regarding pesticide application, poor farm workers and small farmers still use antiquated pesticide application techniques which leads to a higher risk of inhalation and dermal exposure.

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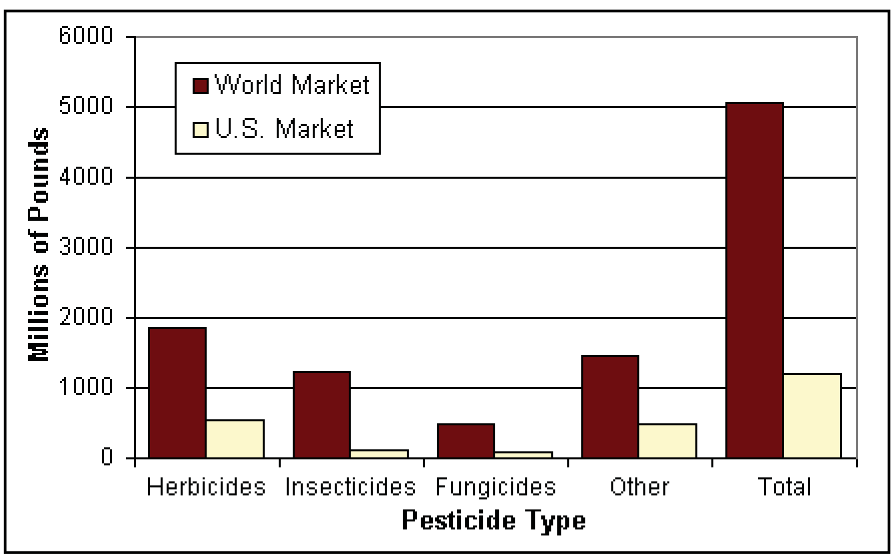
CHAPTER 1

INTRODUCTION

By design, pesticides are meant to kill. Their toxicological properties and mechanisms are meant to attack a specific target. Whether it is an herbicide that works as a photosystem II inhibitor, or an insecticide that is a neurotoxin to insects, pesticides help eliminate pests and plant competition for soil nutrients. This helps increase crop yield.

In 2000 and 2001 the amount of pesticides used worldwide topped 5 billion pounds (EPA, 2004). According to the Centers for Disease Control and Prevention (www.cdc.gov), approximately one-fifth (one billion pounds) of the pesticides worldwide are used in the United States, and there are more than 16,000 pesticides marketed in the U.S. Herbicides makes up the largest portion of pesticides used worldwide (Fig. 1.1).

Figure 1.1 World and U.S. Pesticide Amounts of Active Ingredient at User level (EPA, 2004).



Atrazine

Atrazine, 6-chloro-N-ethyl-N’-(1-methylethyl)-triazine-2,4-diamine, is an herbicide used extensively in grain production. It is used primarily in the agricultural sector but it has other uses in highway and railroad rights-of-way and for evergreen forest re-growth. Atrazine can be used as a pre- or post-emergent herbicide, which means it can be applied to cropland before or after the seed has germinated. In Iowa, atrazine is mostly applied in late spring and early summer around the time that corn is planted.

Atrazine is a Restricted Use Pesticide (RUP), which means that only certified herbicide users can purchase or apply it. Atrazine is a synthetic chemical compound that does not occur naturally in the environment (ATSDR, 2003). Atrazine only works when it is dissolved in water and it enters the plants through absorption in the roots. It is absorbed by all plants but it is not effective in many plants because it is broken down before it has its toxic effects. In grasses and broad-leafed weeds that cannot break down atrazine, the chemical acts as a photosystem II inhibitor (Pfister et al, 1981) and inhibits photosynthesis in the shoots and leaves, thereby killing the plant.

Atrazine is primarily used on corn, sorghum, sugarcane, macadamia nuts, and conifer tree crops. It was applied to 61% of the corn planted in Iowa in 2005 (USDA, 2006). The total annual use of active ingredient of atrazine in the United States is approximately 35 million kilograms. It has been used for over 40 years in agricultural production and currently the allowed application rate is 1.4-2.0 pounds per acre. The EPA estimated that in 1987, 1993, and 1995 between 31-35 million kilograms of active ingredient atrazine were used on agricultural crops (ATSDR, 2003). From 1987 – 2001 atrazine was ranked either 1 or 2 as the most commonly used pesticide in the agricultural sector (Table 1.1).

Table 1.1 Most commonly used conventional pesticide active ingredients, agricultural market sector, 2001, 1999, 1997, and 1987 estimates (EPA, 2004).

Active Ingredient	Type	2001		1999		1997		1987	
		Rank	Range	Rank	Range	Rank	Range	Rank	Range
Glyphosate	H	1	85-90	2	67-73	5	34-38	17	6-8
Atrazine	H	2	74-80	1	74-80	1	75-82	1	71-76
Metam Sodium	Fum	3	57-62	3	60-64	3	53-58	15	5-8
Acetochlor	H	4	30-35	4	30-35	7	31-36	NA	NA
2,4-D	H	5	28-33	6	28-33	8	29-33	5	29-33
Malathion	I	6	20-25	7	28-32	NA	NA	NA	NA
Methyl Bromide	Fum	7	20-25	5	28-33	4	38-45	NA	NA
Dichloropropene	Fum	8	20-25	11	17-20	6	32-37	4	30-35
Metolachlor-s	H	9	20-24	12	16-19	NA	NA	NA	NA
Metolachlor	H	10	15-22	8	26-30	2	63-69	3	45-50
Pendimethalin	H	11	15-19	10	17-22	9	24-28	10	10-13
Trifluralin	H	12	12-16	9	18-23	10	21-25	6	25-30
Chlorothalonil	F	13	8-11	13	9-11	15	7-10	19	5-7
Copper Hydroxide	F	14	8-10	15	8-10	13	10-13	19	5-7
Chlorpyrifos	I	15	8-10	16	8-10	14	9-13	14	6-9
Alachlor	H	16	6-9	17	7-10	12	13-16	2	55-60
Propanil	H	17	6-9	18	7-10	22	6-8	13	7-10
Chloropicrin	Fum	18	5-9	14	8-10	25	5-6	NA	NA
Dimethenamid	H	19	6-8	20	6-8	20	6-9	NA	NA
Mancozeb	F	20	6-8	21	6-8	17	7-10	21	4-6
Ethephon	PGR	21	5-8	24	5-6	NA	NA	NA	NA
EPTC	H	22	5-8	19	7-9	18	7-10	8	17-21
Simazine	H	23	5-7	NA	NA	NA	NA	NA	NA
Dicamba	H	24	5-7	22	6-8	16	7-10	23	4-6
Sulfosate	H	25	3-7	NA	NA	NA	NA	NA	NA

Atrazine is popular among corn producers for many reasons. It is cheap, effective, and safe to handle. Also, when used correctly it will not harm crops, and it persists long enough in the environment to provide a window of weed control. Lastly, atrazine works well in tank mix combinations, so it can be applied at the same time as other pesticides. Despite all its advantages, atrazine does have negative aspects. Due to its persistence, atrazine can be carried into water resources. Atrazine is frequently found in municipal drinking water systems and because of this it receives much attention from the public and in politics.

Human Health Effects of Atrazine

Atrazine has been associated with many diseases and conditions in animal and human studies. In particular, reproductive effects have been associated with atrazine exposure. The Ontario Farm Family Health Study indicated an association between yard atrazine use and an increase in pre-term delivery (Savitz et al. 1997). In the same study, there was no association between using atrazine in crop production or for yard activity with miscarriage. Savitz el al (1997) also demonstrated that sex ratio was not altered and the risk of small for gestational age was not associated with atrazine exposure. A paper resulting from the same study reported that women exposed to atrazine who were age 35 and older had 3 times the risk of spontaneous abortion (OR=2.7, 95% CI=1.1-6.9) compared to unexposed women of the same age (Arbuckle et al, 2001).

Atrazine can act as an endocrine disrupting compound with effects on multiple systems in the body. Cooper et al (2000) found that in rats atrazine effects luteinizing hormone and prolactin secretion through the hypothalamus. Another study showed that atrazine can produce neurotoxicity in dopaminergic systems that are essential to the mediation of movement as well as cognition (Rodriguez et al, 2005). Kniewald (2000) demonstrated that atrazine has a toxic effect on sperm and reduces their motility in rats. Hayes (2003) showed that atrazine retards gonadal development and testicular oogenesis in leopard frogs. A study done in female rats found that atrazine caused an earlier onset and increased incidence of mammary gland tumors in the Sprague-Dawley rat (Wetzel et al., 1994).

Results of studies that analyzed the association between atrazine and cancer have been mixed. McElroy et al. (2007) evaluated the association between the risk of breast cancer among women living in rural Wisconsin and exposure to atrazine from well water. This was a large, population-based study and the results do not suggest an increased risk of breast cancer from adult exposure to atrazine in drinking water. Another study found an association between the risk of breast cancer among California Latinas and the organochlorines methoxychlor and toxaphene, but no significant association with atrazine (Mills & Yang, 2006). A study done by Rusiecki et al (2004) looked at the association between exposure to atrazine among participants of the Agricultural Health Study and lung, bladder, non-Hodgkin lymphoma, and prostate cancer. The results did not find any association between atrazine exposure and the cancers analyzed.

An ecological study carried out in 58 California counties found a correlation between the amount of atrazine used county-wide and several cancers in specific ethnic groups. Brain and testis cancers and leukemia in Hispanic males were correlated, but not significantly, with atrazine use. Non-Hodgkin's lymphoma and leukemia showed similar correlations among Hispanic females. Lastly, the correlation between prostate cancer in black males and atrazine usage was significant (Mills, 1998).

Weisenburger (1990) determined that there was an elevated risk of non-Hodgkin's lymphoma associated with atrazine use and that this risk increased with duration of use. Another case-control study carried out in Iowa and Minnesota concluded that the risk of leukemia for farmers who mixed, applied, or handled triazines or atrazine herbicides was not increased significantly (Brown el al, 1990). A very similar study in Iowa and Minnesota concluded that there was no significant increased risk for non-Hodgkin's lymphoma among farmers who handled triazines or atrazine (Cantor et al. 1992).

An extensive analysis of three studies combined found strong associations between atrazine exposure with non-Hodgkin's lymphoma among farmers in Nebraska, Kansas, Iowa, and Minnesota. One interesting finding was that farmers who used atrazine in their crop production but did not personally handle it, had greater risk of non-Hodgkin's lymphoma than farmers who did personally handle atrazine (Zahm et al, 1993). While some of the odds ratios were significant, many of them decreased when adjusted for other pesticide exposure, and became non-significant. Hoar et al (1985) did not find an association between colon cancer and triazine exposure in a case-control study of Kansas farmers. On the other hand, Donna et al (1989) found strong evidence of an association between triazines and increased risk for ovarian neoplasms among Italian female farmers.

Commercial Pesticide Applicators

In Iowa, people who want to apply restricted-use pesticides must obtain a pesticide application license through the Iowa Department of Agriculture and Land Stewardship. In general, commercial pesticide applicators are those applicators who are employed by agricultural dealerships, pest control companies, or by other businesses that use restricted-use pesticides (Alavanja et al, 1999). In 2008, there were approximately 5,700 commercial pesticide applicators in Iowa certified to apply agricultural weed control products. These commercial pesticide applicators worked for approximately 1,300 different companies that were registered with the state.

Due to the nature of their job, commercial applicators have the potential for more exposure to pesticides than private pesticide applicators. In addition, applicators perform other tasks besides spraying pesticides that could result in pesticide exposure. These tasks include mixing, loading, rinsing herbicide containers, and doing maintenance on spraying equipment. They also carry out a number of non-spray tasks as part of their job such as blending fertilizer, doing paperwork, selling seed, helping customers, scouting fields, delivering chemicals or feed, and running errands (Hines et al, 2001).

The Agricultural Health Study is a prospective study of a large cohort of private and commercial licensed pesticide applicators being conducted in Iowa and North Carolina. Alavanja et al (1999) summarized the demographics and characteristics of pesticide use among pesticide applicators, both private and commercial, in this study. 96.1% of the 4,897 commercial pesticide applicators in Iowa that participated in this study were male, while 3.9 were female. 99.5% were white, 0.1% black, and 0.4% came from other racial backgrounds. The mean number of days annually that pesticides are applied by an Iowa commercial pesticide applicator is 45; compared with 26 days for a private applicator in North Carolina, and 17 days for a private applicator in Iowa. The median number of days pesticides were applied was 43, 12, and 13, respectively. While commercial applicators apply pesticides many more days than private applicators, they have been doing this job for less years (median for Iowa commercial = 7; median for Iowa private = 15; median for North Carolina private = 14). So even though commercial pesticide applicators apply pesticides many more days than private applicators, their lifetime exposure may be less due to fewer years in the business.

23.8% of Iowa commercial applicators, 29.9% of Iowa private applicators, and 14.0% of North Carolina private applicators applied atrazine the year prior to completing the study questionnaire (Alavanja et al, 1999). Atrazine was applied to 58.5% of grain farms, 73.2% of vegetable farms, 53.2% of fruit farms, 34.5% of Christmas tree farms, 56.3% of tobacco farms, 68.6% of cotton farms, and 72% of peanut farms. The relative frequency of specific pesticide use was very similar for Iowa farmers and Iowa commercial applicators ($r^2 = 0.88$).

Commercial pesticide applicators typically apply atrazine using vehicles with an enclosed cab, a tank behind the cab for the mixture of chemicals, and a 15-18 meter spray boom typically mounted on the rear of the tank (Hines et al, 2001). The cabs are often equipped with air conditioning, dust filters and/or charcoal filters. The tank usually contains a mixture of pesticides rather than just one pesticide. Commercial pesticide applicators have varying number of spray jobs each day and it is possible to spray several different tank mixes in the same day (Hines et al, 2001).

Take-Home Exposure Pathway

In 1992 The U. S. Congress acknowledged the issue of take-home exposures when it passed the Workers' Family Protection Act (NIOSH, 1995). Take-home exposures are described as hazardous chemicals unintentionally transported from the workplace of workers to their homes on their person, clothes, and vehicles.

There is concern about the take-home exposure pathway among workers who handle pesticides. Many studies have examined take-home exposure related to pesticides in the agricultural setting. Children living in households with pome-fruit workers were found to have higher concentrations of urinary dimethyl metabolites than children of non-pome-fruit workers (Coronado et al, 2006). Children's urinary concentrations were correlated with house dust levels and with adult urinary concentrations (Coronado et al, 2006). Studies have found that dust samples collected from farm homes where the farmer applied pesticides themselves had significantly higher atrazine levels than dust samples from both non-farm homes, and farm homes that did not self-apply pesticides (Curwin, 2005; Simcox, 1995).

The body of evidence that supports the take-home exposure pathway among farm worker families is convincing. A study analyzing organophosphate pesticide exposure in farm worker households in Washington state, found that house dust and vehicle dust concentrations from the same household were significantly correlated (Curl et al, 2002). The same study also found that dimethyl dialkylphosphate levels in child and adult urine samples from the same household were significantly associated. Quandt et al (2004) found that the presence of agricultural pesticides on floors in homes was positively associated with detection of the same pesticides on toys or hands.

One of the major concerns about take-home exposure to pesticides and other toxic chemicals is children living in the homes of these workers. Children spend a great deal of time near the floor (where pesticide residues can be deposited), they have higher rates of metabolism, and have high hand-to-mouth activity (Strong et al, 2009).

Honduras Agriculture

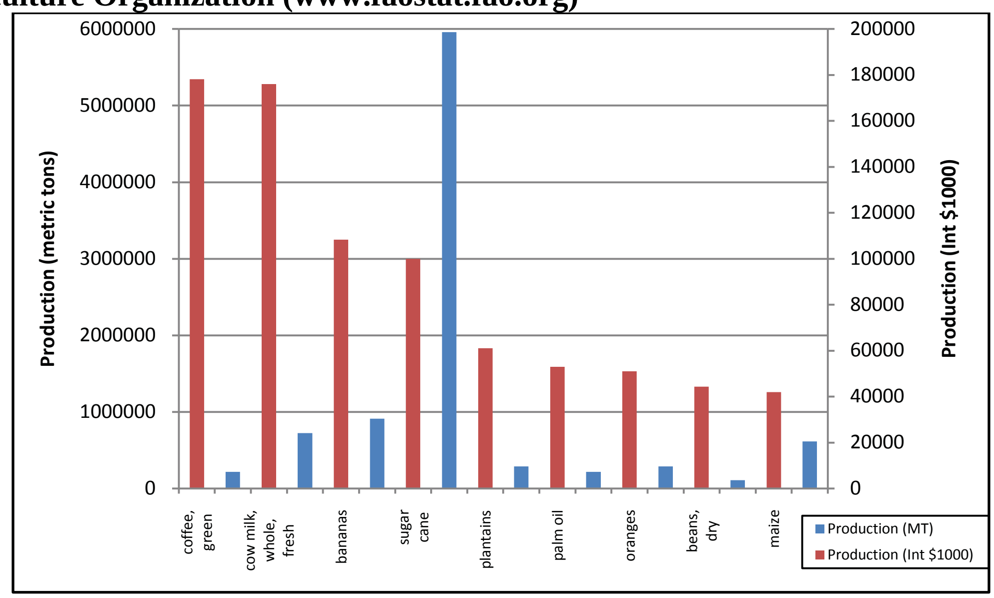
Honduras is the third poorest country in Latin America and the second poorest in Central America, behind Nicaragua. According to the Rural Poverty Portal website (RPP), the root of poverty in Honduras is attributed to, among other things, lack of access to land, fragile social conditions, a vulnerable environment, and low agricultural productivity. Approximately 70% of peasant families have little or no access to land. Those that do have land have small plots, less than 5 hectares, and income for farmers has not increased over the past 30 years. Most of the land suitable for agriculture is dedicated to the production of low-profit crops. Honduras is very mountainous and hilly and these regions, despite treacherous terrain, are sometimes the only land where peasants can produce food. Slash and burn practices have exposed steep hillsides for agricultural production, which makes them extremely vulnerable to erosion, and the quality of the land is degrading rapidly (RPP).

Honduran exports total about $6.95 billion annually, and the major exports are: apparel, auto parts, coffee, shrimp, bananas, palm oil, gold, zinc/lead concentrates, soap, detergents, melons, lobster, pineapple, lumber, sugar, and tobacco (US Dept of State, 2009). Agriculture makes up 18.6% of the Honduran gross domestic product, and major agricultural products include: coffee, bananas, shrimp and lobster, sugar, fruits, basic grains, and livestock (Figure 1.1).

Honduras has approximately 1.7 million hectares of land that is used for agricultural production (Secretary of Agriculture and Livestock [SAG by its Spanish name], 2006). Due to frequent natural disasters in Honduras (mainly hurricanes), only 47,000 of those hectares are irrigated (35% less than in 1993) (SAG, 2006). There are approximately 320,000 farms in Honduras and 72% of them are less than 5 hectares (about 12 acres).

The north coast is where the banana and African palm plantations are concentrated. Extensive shrimp farms in southern Honduras produce shrimp for export. The western region has a cooler climate and is more mountainous, while eastern Honduras has larger valleys and is better suited for grain production. The department of Olancho, in eastern Honduras, is the largest department in Honduras with 24,351 square kilometers, but only has the fourth largest population (Statoids, 2006).

Figure 1.2 Top agricultural products in Honduras in 2007 by USD (Food and Agriculture Organization (www.faostat.fao.org)



According to the Pan American Health organization (PAHO, 2002), from 1994 to 2000 the quantity of pesticides imported into the Central American isthmus increased steadily from 34 to 45 million kilograms. While imports actually decreased for both insecticides and fungicides, herbicide imports increased drastically from 6.3 to 14.6 million kilograms between 1992 and 2000 (PAHO, 2002), an increase of 129% in less than a decade. In 1992 there were very little or no triazine derivates being imported into Central America. However, by 1998, nearly 600,000 kilograms of triazine derivates were being imported into the Central American isthmus annually (Galvao et al, 2002).

In Honduras, corn is produced on a large scale and is primarily used for human consumption (Storz, 2005). Despite their intensive production, Honduras must still import corn because internal production does not satisfy demand (Storz, 2005). Due to this shortfall, and the increasing international market for corn because of ethanol demand, the Honduran federal government established a program in 2007 to increase corn production. This project planned to increase the amount of land in corn production by 300,000 acres with the hope that another 520,000 acres would be planted by independent producers (SAG, 2006). This would more than double the amount of corn production and increase the use of atrazine.

Pesticide application in most developing countries, like Honduras, reflects technical standards of 40 years ago in the United States and results in pesticide waste and environmental damage (Consultative group on international agriculture research, 1997). In Central America farmers typically tend their own land, rarely use tractors, frequently apply pesticides using hand-held sprayers attached to backpack pumps, and use little or no protective measures (Dowling et al, 2005). As a result, farmers and farm-workers are constantly exposed to a wide variety of hazardous pesticides in which exposure levels can be very high (Wesseling et al, 2005).

In many of the poorest countries, agrochemicals are not handled or stored with even minimal hygienic standards (Vaagt, 2002). Many farmers and farm-workers store their pesticides in and around their homes often within reach of children (Cantor & Young-Holt, 2002) and mix or dilute the pesticides in or near their homes (Dowling et al, 2005). It has also been reported that farm families often use empty pesticide containers to store water or food in their homes (Aragón et al, 2001) and have been known to use pesticide-impregnated bags as insulation in their walls (Rodriguez et. Al,. 2006). Lastly, the potential for take home exposure is great because even the simplest personal protective equipment such as gloves is rarely used, women hand wash contaminated clothing, and often workers do not shower immediately after handling pesticides (Dowling el al, 2005). While the farmers and farm-workers are presumably at highest risk for exposure to pesticides, the risks for other family members are not well known. It is common for women and children to help in field work and to handle pesticides directly (Dowling et al, 2005). Due to stature, behavior, surface-to-volume ratio, and metabolism, children have greater exposure to pesticides in their environment than adults (Arcury et al, 2007).

The Secretary of Agriculture and Livestock offers various extension programs to producers throughout Honduras through their regional offices. In the department of Olancho, the department with the highest corn production, SAG has been coordinating two agricultural projects over the last two years. From 2006 to the present, Bono

Tecnológico Productivo (Technological Production Bond), which gives loans to small farmers, has registered approximately 15,000 producers of corn, red beans, and rice. The second project, Plan de Abastecimiento de Maiz (The Corn Supply Plan), present in the region since 2007, has registered about 2,000 corn farmers (personal communication, Aug. 13, 2008).

Conclusion

Atrazine may serve as a surrogate indicator for other insecticides and herbicides. For example, work practice and hygienic factors found to be associated with atrazine contamination in homes and exposure levels during application, are likely to also be associated with other pesticides. Therefore, interventions developed from the results of this study to control risk factors of exposure to atrazine could also control exposure to other pesticides.

Chapter 2 presents the results from a field study that evaluates atrazine dust contamination in the homes of commercial pesticide applicators in Iowa. It also compares the differences in contamination levels by differences in work practices, such as applicator's use of personal protective equipment and hygienic practices, changing clothes and shoes before entering the home, and laundering work clothes separately. Dust sampling is done during the application season and the non-application season to evaluate how long atrazine residuals remain in the home. The results of this study are useful for determining the potential health risks of commercial pesticide applicators and their families.

Chapter 3 combines the data from 3 different studies that have analyzed atrazine dust levels in homes. This combination study compares in-home contamination between different types of households to determine which populations have the greatest risk. The increased sample size obtained by combining these studies allows for more powerful analyses of determinants of exposure.

Chapter 4 travels outside of the United States to assess the use of atrazine in corn production in Honduras. As pesticide use becomes more common worldwide it is important to assess the exposure of workers who use different pesticide application techniques that could result in increased exposure risk. The potential inhalation exposure of farmers applying atrazine in Honduras is evaluated.

Chapter 5 summarizes the findings of all three studies and makes an effort to recommend interventions that could help reduce worker and family exposure to atrazine and other pesticides. Recommendations for future research are also discussed.

Specific Aims

1. To use vacuum dust sampling to measure contamination in the homes of commercial pesticide applicators for the most commonly used herbicide, atrazine;
2. To quantify the variation in pesticide levels in commercial pesticide applicators' homes during planting season and non-planting season;
3. To identify potential behavioral and environmental factors associated with commercial pesticide applicators' long-term pesticide exposures and the take-home exposures of the commercial pesticide applicators' families;

4. To compare the in-home atrazine levels among commercial pesticide applicators, farmers, and a non-farm control group to determine which population has the highest exposure risk.
5. Evaluate the application techniques, storage methods, and variety of pesticides used in a Honduran agriculture focused on corn production.
6. Determine atrazine inhalation exposures of farmers and assess whether or not inhalation is an exposure route of concern.
7. Identify the determinants of exposure associated with Honduran farmers' inhalation and long-term pesticide exposures and the take-home exposures of the farmers' families.

CHAPTER 2

DETERMINANTS OF ATRAZINE CONCENTRATIONS IN THE HOMES OF COMMERCIAL PESTICIDE APPLICATORS ACROSS TIME

Abstract

Twenty-nine commercial pesticide applicator households in eastern Iowa were enrolled to investigate in-home contamination of atrazine, the most commonly used corn herbicide in the Unites States. Four vacuum dust samples were collected during atrazine application season (visit 1) and this was repeated six months later during winter months (visit 2). Samples were taken from similar areas in the home: primary entryway for pesticide applicator, living room, master bedroom, and kitchen. The applicator completed an atrazine handling log and household questionnaire with spouse.

Of the 230 dust samples, only 2 were below the level of detection, 2 ng of atrazine per gram (ng/g) of fine dust (dust particle size 5-150 μm). During application season the entryway (geometric mean [GM]=3268 ng/g) and master bedroom (GM=2457 ng/g) had the highest mean atrazine concentrations. Aggregate concentrations were significantly higher at visit 1 compared to visit 2 when paired by location ($p \leq 0.02$), and all visit 1 concentrations were higher than visit 2. When analyzed on the basis of chemical loading (ng atrazine per cm^2), visit 1 entryway (GM=2.68 ng/cm^2) was the highest, followed by the visit 2 entryway (GM=0.55 ng/cm^2), and visit 1 master bedroom (GM=0.44 ng/cm^2).

ANOVA showed that job (application, mixing/loading, or both) was not associated with in-home atrazine contamination. Linear regression showed a strong positive association between atrazine handling (number of acres applied, number of days

handled, and pounds handled) and aggregate dust concentrations from visit 2 (p=0.02, 0.09, and 0.06, respectively). Frequency of vacuuming was significantly inversely associated with visit 2 concentrations (p=0.02) but not visit 1 (p=0.42). Removing shoes outside the home was associated with lower atrazine concentrations (p=0.02) and applicators changing work clothes in the master bedroom had increased atrazine concentrations in master bedrooms (p=0.08). Changes in hygiene practices for commercial pesticide applicators could significantly reduce atrazine, and likely other pesticide, contaminations in the home.

Introduction

In 1992, the U. S. Congress acknowledged the concern of take-home exposures by passing the Workers' Family Protection Act (U.S. Department of Health and Human Services, 1995). Take-home exposures are described as hazardous chemicals unintentionally transported from the workplace of workers to their homes on their person, clothes, and vehicles. Studies have shown that children of lead-exposed workers have significantly higher blood lead levels than the general population and lead brought through the take-home pathway can cause elevated levels of lead in the home and has even led to severe lead poisoning (Roscoe et al, 1999; Piacitelli et al, 1997; CDC, 2001). Similarly, high concentrations of beryllium in dust found in workers' cars indicates that family members are being exposed to potentially toxic levels of beryllium (Sanderson et al, 1999).

Occupational pesticide exposure has been the subject of research since the 1950s; however, the study of para-occupational exposure to pesticides is a fairly recent field.

Studies on a wide variety of pesticides have demonstrated that workers' family members are being exposed to toxic pesticides through the take-home pathway, which represents a real concern for their health. Curwin et al (2007) estimated pesticide doses using urine samples as biomarkers and showed that the dose of farm children for atrazine, metolachlor, and chlorpyrifos were higher than non-farm children doses. Farm mothers and fathers also had significantly higher levels of atrazine and chlorpyrifos in urine samples when compared with non-farm mothers and fathers (Curwin, 2007a). Adult urinary concentrations had significant correlations with vehicle and house-dust concentrations of azinphos-methyl and with child urinary concentrations in a study of pome fruit workers in Washington State (Coronado et al, 2006). Coronado et al (2004) showed that workers who perform thinning, an agricultural tasks, were more likely to have detectable levels of azinphos-methyl in their house dust and vehicle dust. This means that certain agricultural tasks can lead to increased risk of take-home exposure. McCauley el al (2003) demonstrated that workers who wait more than 2 hours after getting home from work to change their cloths have higher levels of pesticide in the house dust than workers who change within 2 hours of arriving at home after work.

Atrazine was applied to 61 percent of the corn planted in Iowa in 2005, making it the most widely applied corn herbicide in Iowa. There were 8.28 million pounds of atrazine applied to 12.8 million acres of corn planted in Iowa that year (USDA, 2006). The Environmental Protection Agency (EPA) is conducting a comprehensive evaluation of atrazine to determine its effects on humans.

Because of its common usage and potential toxic effects, atrazine was one of the primary pesticides studied by Curwin. Farm homes were about 9 times more likely than non-farm homes to produce a dust sample in which the atrazine levels were higher than the level of detection (Curwin et al, 2005). Atrazine and metolachlor dust concentrations were significantly higher in farm homes that had applied these pesticides in the 7 days before sampling took place than farm homes that did not apply these pesticides, and non-farm homes. Therefore, an important factor determining concentrations of pesticides in farm homes was having applied the pesticide recently. Curwin et al (2005) also found that concentrations of atrazine in the entranceway, laundry room, and the room where the farmer changed clothes tended to be higher than in other rooms in the house. These rooms were areas where dirt was most likely to be tracked in or where the farmer's clothes would contact the floor. This pattern of atrazine contamination provided strong evidence that atrazine was being brought into the home through take-home pathways. This supported the hypothesis that work and personal hygiene practices played an important role in the amount of pesticide that reached the home environment.

Golla (2007) built upon Curwin's study in order to further examine the relationship between atrazine levels in vacuum dust samples from farm family homes and multiple factors such as amount of atrazine applied and family hygienic practices. This study also assessed the persistence of atrazine in farm households by collecting vacuum dust sample during the pesticide application season and also during the off season. In this study, four (4) dust samples were taken from farm homes during the pesticide application season shortly after an atrazine application event. Another round of four (4) samples was taken from each home approximately six (6) months later in the months of November and December. Results showed that atrazine was detectable in all dust samples from both sampling periods (Golla, 2007). From the planting season to the non-planting season, atrazine concentrations reduced by approximately one order of magnitude (Golla, 2007). This study indicated that atrazine is more persistent in the environment than previously thought.

The objective of this study was to measure the levels of the herbicide atrazine in the homes of commercial pesticide applicators. The study focused on atrazine because of concern over its toxic properties and its common usage. There was concern that of all work groups, the families of commercial applicators may have the greatest risk of take-home exposures. Also, by choosing to evaluate atrazine levels the study results could be compared to previous studies of farm families and results from the non-planting season. Many other pesticides are not as widely used, do not have good environmental sampling and analysis methods, and if they are sampled for, often result in non-detectable concentrations (Curwin, 2005; Curwin 2007; Simcox, 1995). Therefore, atrazine served as a marker of potential pesticide contamination of homes and allowed for evaluation of how pesticides might migrate into homes. This study also evaluated the association between pesticide levels and characteristics of the home and family hygiene practices.

To date, studies exploring take-home pesticide exposure have focused primarily on insecticides. Studies on the exclusively agricultural herbicide atrazine have been confined to farm homes and non-farm homes and have not included commercial pesticide applicators. The primary purpose of this paper is to investigate the atrazine contamination of homes of commercial pesticide applicators in Iowa over time. This population and their families are at high risk for exposure because they handle more pesticides than any other agricultural worker (Alavanja, 1999). The results of this study are important in determining how contamination of commercial pesticide applicator homes compares to levels in other peoples' homes.

Materials and Methods

Subject Recruitment

Participants were recruited using the database of all active certified pesticide applicators in Iowa, which is maintained by the Pesticide Bureau of the Iowa Department of Agriculture and Land Stewardship. Initially, applicators in 11 counties in eastern Iowa--Benton, Cedar, Iowa, Johnson, Jones, Keokuk, Linn, Louisa, Muscatine, Scott, and Washington—were eligible for selection. These counties were selected because of their proximity to our laboratory. Exclusion criteria required that the commercial pesticide applicators be actively certified to apply agricultural weed control products, planned to apply the herbicide atrazine in the upcoming planting season, and lived within reasonable driving distance from Iowa City. It was not required that the pesticide applicator have children; however, children in the homes were eligible to participate. According to the Pesticide Bureau of the Iowa Department of Agriculture and Land Stewardship database, there were 652 applicators certified to apply agricultural weed control products in the 11 counties when this study took place.

Because contact information was not provided for individual applicators, the database was sorted by employer. Companies identified through this process were then assigned an index number. This resulted in a list of 205 companies. A random number generator was used to select companies one at a time. When a company was selected, the owner or the manager of the pesticide application company was contacted by telephone.

The manager was told about the study and asked if the study recruiter could visit the company in person to talk with eligible commercial pesticide applicators about participating in the study. If a company manager was not interested in allowing the recruiter to visit, then the recruiter made efforts to talk individually with commercial pesticide applicators and they were asked to participate over the telephone. Once a company had declined to participate, could not be contacted after multiple attempts, or had been visited, another company was selected from the list using the random number generator.

When an owner or manager was willing to allow the recruiter to visit the company, the recruiter gave a short presentation to the eligible workers who were given the opportunity to volunteer to participate in the study. Company owners and managers were not invited to attend the informational session to reduce managerial pressure for workers to either agree or disagree to participate in the study. Likewise, each worker was asked individually if they wanted to participate to reduce pressure from their co-workers.

Frequently a company was contacted that did not apply atrazine. Occasionally these companies would recommend another office of the same company that did apply atrazine. In these cases the recruiter contacted the other office and proceeded to recruit there. This process resulted in company offices outside of the 11-county area being contacted and participants being recruited in an additional 8 counties. There were an additional 369 certified pesticide applicators that applied agricultural weed control products in these 8 counties. However, not all 369 had the same chance of being recruited since their company offices were not on the original recruiting list.

Home Visits and Sample Collection

Each home was visited twice; once during peak atrazine application season (April to June), and the second time approximately 6 months later. During the first visit, three tasks were completed: 1) vacuum dust samples were collected; 2) a questionnaire was completed; and 3) urine samples were collected. During the second visit in the winter months another round of dust samples and urine samples were collected. The dust samples were taken from the same rooms and areas that were sampled during the first visit. Likewise, urine samples at the second visit were collected from the same individuals as the first visit.

The questionnaire was completed with both the spouse and the commercial pesticide applicator to reduce response error. The questionnaire contained items covering demographic information, pesticides used in and around the home, the type of spray equipment used to apply pesticides by the commercial pesticide applicator, personal protective equipment used by the applicator, the laundering practices of work clothes, floor cleaning practices, and general information about the house (Appendix A). Information on how much atrazine the commercial pesticide applicator had handled or applied up to the day of the first visit was also collected. This information was updated at the second visit to collect atrazine handling data that occurred between visits 1 and 2.

Vacuum dust samples were consistently collected from four locations within each home to assess environmental contamination of atrazine. Dust samples were collected from each home at the following locations: 1) where the commercial pesticide applicator usually entered the home (referred to as “entryway”); 2) where the applicator typically changed work clothes (referred to as “master bedroom”); 3) living room; and 4) kitchen.

Dust samples were collected from floors using a high-volume surface sampler (HVS-3, Cascade Stamp Sampling Systems) in accordance with the American Society for Testing Material (ASTM) Standard Practice for Collection of Dust from Carpeted Floors for Chemical Analysis (ASTM D 5438-94, 1994). The vacuum sampler contained a cyclone and a catch bottle. The vacuum head was passed over the floor surface in a straight line back and forth four times. This process was repeated with subsequent adjacent floor strips until the desired area (at least one square meter) had been sampled or a minimum of 1 to 2 grams of dust was collected. Sample area was recorded. A new catch bottle was used for each sample so up to four samples were taken from each house. To prevent cross contamination, the samples were taken in each house in order of presumed increasing contamination: 1) kitchen; 2) living room; 3) master bedroom; and 4) entryway. The vacuum and cyclone were washed with soap and water and cleaned with isopropanol between households to prevent cross contamination.

Sample Analysis

The dust samples were analyzed by Battelle Memorial Institute in Columbus, Ohio. A 0.5 g aliquot of each dust sample dust was spiked with 250 ng of the surrogate recovery standard (SRS) 13C3-atrazine, extracted using sonication in 1:1 hexane:acetone and cleaned using an aminopropyl SPE cartridge (0.5 g; Supelco). Samples were concentrated to 1 mL, spiked with the internal standard dibromobiphenyl, and analyzed using GC/MS in the multiple ion detection mode with a 30 m DB-1701 column and a temperature program from 160-280°C. The atrazine concentrations were reported in nanograms per gram of dust (ng/g). For samples with smaller dust quantities, the entire method was scaled down proportionally to maintain an equivalent method detection limit (2.5 ng/g). Atrazine levels were corrected for recovery efficiency. This is an improvement on previous studies in which dust samples were not corrected for recovery efficiency. Average SRS recovery in samples was 83±13% (n=243); average analyte spike recovery was 88±18% for 5000 ng/g (n=4) and 120±19% for 500 ng/g (n=5). Low-level spike recoveries (50 ng/g) could not be determined because analyte levels in the dust were so high.

Data Analysis

The atrazine concentrations were distributed log-normally, so analyses were based on the natural log of the concentrations and results were presented in geometric mean concentrations. These results were also standardized to ng/cm^2 (calculated by multiplying the atrazine concentration by the total weight of fine dust collected and then dividing by area sampled). This variable represented chemical loading (an estimate of the amount of chemical per square centimeter of carpet).

A new variable was created using the PPE usage data called “PPE rank.” It was calculated by summing the responses to the 11 questions related to PPE for each participant. The values for each response are as follows: always = 3; usually = 2; sometimes = 1; and, never = 0.

Descriptive summary statistics were used to describe the central tendency and variance of each variable measured. Simple linear regression and analysis of variance (ANOVA) were used to determine if atrazine handling and other personal and workplace practices influenced the levels of atrazine found in the homes. Due to a small sample size, Fisher's exact test was used to analyze the relationship between categorical variables and job classification. All statistical analyses were performed using SAS system software, version 9.2 (SAS Institute, Inc., Cary, NC). All significance testing was performed at the 0.05 level.

Results

A total of 32 commercial pesticide applicators were recruited, two of them were lost to follow up. On average, the applicators were 40.5 years old (s.d. = 11.7; range 23-60) and all of them were white males. The applicators' average weight and height was 97.2 kilograms (s.d. = 15.1) and 181.7 centimeters (s.d. = 6.7), respectively. Two of the applicators lived in the same residence and were father and son. For the analysis of personal factors they were considered two different applicators, but for total atrazine handled their amounts were summed for the household. 24 (80%) of the applicators were married. The average weight and height of the spouses was 76.4 kg (s.d. = 31.7) and 167.3 cm (s.d. = 8.1), respectively.

Of the 30 commercial pesticide applicators, 20 had children in the home that participated in the study, for a total of 32 children and an average of 1.6 children per home. The average age of the children was 9.4 years (s.d. = 4.8), 18 were female, and 14 were male.

The commercial pesticide applicators had lived in their homes or apartments for an average of 9.3 years (s.d. = 9.2). The average age of the homes was 43.2 years (s.d. = 36.5) with the oldest house being 137 years old. On average the houses were 600 meters (s.d. = 1188) from the nearest crop fields.

Atrazine Handling

The average number of days that atrazine was handled, either applied or mixed, before the first round of dust sample collection was 9.9 days. This compares to only 3.25 days of atrazine handling on average between visit 1 and visit 2. The mean pounds of atrazine handled by participants before visit 1 was 4743 compared to only an average of 732.74 pounds handled between visit 1 and visit 2. On average, atrazine was applied to only 831.9 acres by study participants between visit 1 and visit 2, while a mean of 3006.6 acres were applied with atrazine before visit 1.

Table 2.1 Atrazine handling before visit 1, between visits, and for entire season.

	Atrazine Handling: mean (sd; n)		
	Before Visit 1	Between Visit 1 and Visit 2	Entire Season
# of Days Atrazine Handled	9.9 (6.41; 20)	3.25 (4.13; 20)*	13.15 (7.61; 20)
Pounds of Atrazine Handled	4743 (3582.2; 27)	732.74 (956.85; 27)*	5475.74 (3474.1; 27)
Acres Applied with Atrazine	3006.6 (1960.0; 20)	831.9 (1116.11; 20)*	3838.50 (2275.2; 20)

*All values for between visit 1 and visit 2 are significantly smaller than the corresponding values for before visit 1 at $\alpha = 0.01$.

There were an average of 189.14 (sd= 24.9; n=29) days between visit 1 and visit 2. The average number of days between the applicator's last day handling atrazine and the day that the first round of dust samples was collected was 4.56 days (sd = 4.23). The mean number of days between the last day handling atrazine until the dust sampling that occurred during visit 2 was 179.52 (sd = 29.36).

Of the 30 participants, 16 (53.3%) worked exclusively as applicators. This means that they were not involved in the mixing and preparation of pesticide batches, but spent many hours driving the tractors that applied pesticides to the fields. Because they only handled atrazine while preparing batches for application and did no application, 8 (26.8%) participants were considered “mixers.” However, they may have traveled to the field to load the pesticide mixtures into the application tanks. The remaining 6 (20%) participants engaged in both application and mixing of the herbicide atrazine. Table 2.2 presents the atrazine handling variables by job category. There was no association between job classification, amount of atrazine handling, and interim days. Therefore, it was justifiable to combine the participants together into one general category of commercial pesticide applicators for univariate analyses.

Table 2.2 ANOVA was used to analyze the differences between the three job categories for the 3 handling variables and for the number of days between atrazine application and visits 1 and 2.

	Atrazine Handling and Interim Days by Job Category: mean (sd)				
Job	Mean number of days atrazine handled for entire season (sd)	Mean pounds of atrazine handled for entire season (sd)	Mean acres applied with atrazine for entire season (sd)	Mean days from last atrazine application to visit 1 (sd)	Mean days from last atrazine application to visit 2 (sd)
Applicator (n=16)	12.7 (8.1)	4794 (3191.8)	3799 (2297.2)	4.6 (4.5)	176.1 (32.6)
Mixer (n=8)	7.5 (6.6)	6743 (4274.3)	–	4.6 (2.7)	173.6 (23.9)
Both (n=6)	15.5 (7.9)	4464 (3083.4)	3932 (2436.4)	4.7 (5.6)	193 (25.5)
Total (n=30)	12.5 (7.9)	5280 (3508)	3838 (2275)	4.6 (4.2)	179 (28.9)
p-value	0.3071	0.3850	0.9084	0.9998	0.4182

* The number of participants in each cell is not always the same as the ‘n’ presented in column one due to various missing data points.

Table 2.3 shows household variables distributed by job category. The age of the home was not statistically significant between job classifications; however, the number of years lived in their home was significantly greater for mixers. There were no other significant differences in household characteristics between applicators, mixers, or mixer-applicators.

Personal Protective Equipment and Hygiene Factors

Only five (17%) of the commercial pesticide applicators washed all of their work clothes every time they used them. The other 25 reported that some of their work clothes were worn multiple times before washing. Of these 25 participants, 20 (80%) reported that they used their jacket or coat multiple days; 9 (36%) did not wash their gloves between each use; 17 (68%) reused their pants or coveralls; 2 (8%) reused work shirts; and 2 (8%) reused undergarments.

Table 2.4 shows personal protective equipment (PPE) and clothing used during both application (by applicators and "both") and mixing and loading (mixers and "both"). During the process of mixing and loading pesticides, long pants, long shirts, rubber gloves, and disposable gloves were the most frequently used PPE. Similarly, during application long pants were always used 90.0% of the time and long shirts were used 86.4% at least sometimes. Eight (36.4%) of 22 applicators wore disposable gloves at least sometimes while 9 (40.9%) used goggles at least sometimes. For both application and mixing/loading, respirators and cloth aprons were never used, chemical protective clothing was rarely used, and rubber aprons were reported as being used "sometimes" by only one applicator but no mixers/loaders.

Table 2.3 Household characteristics of commercial pesticide applicators by job classification.

Household Characteristics	Applicators (n=16)		Mixers (n=8)		Both (n=6)			
	Mean (SD)	**Range**	**Mean (SD)**	**Range**	**Mean (SD)**	**Range**	**Overall Mean (n=30)**	p-value
Age of home	32 (32.4)	1-102	59 (44.6)	13-137	45 (30.4)	9-88	42.2	0.2373
Number of years lived in home †	4.94 (3.89) [b]	1-13	18.13 (10.08) [a]	2-34	9.67 (10.25) [b]	1-23	9.4	0.0013
	No. of homes	**% Homes**	**No. of Homes**	**% Homes**	**No. of Homes**	**% of Homes**	**All (n=30)**	**p-value***
Any pesticide applied inside home within past year	7	43.75	5	62.5	2	33.3	14	0.6978
Lawns treated with any pesticide within past year	8	50	5	62.5	1	16.7	14	0.2658
Garden treated with any pesticide within past year	2	12.5	1	12.5	1	16.7	4	1.00
Carpet vacuumed at least once a week	9	56.25	6	75	6	100	21	0.1730
Presence of doormats	13	81.25	7	87.5	6	100	26	0.7898
Presence of pets	12	75	6	75	6	100	24	0.5813
Distance of the home from crop fields < 0.5 miles	11	68.75	5	62.5	6	100	22	0.3006
Launder worker's clothes separate from rest of the family	13	81.25	6	75	5	83.3	24	1.00
Change work clothes inside the home	16	100	8	100	6	100	30	NA
Change work shoes inside the home	11	68.75	5	62.5	5	83.3	21	0.7649
Spouse or Farmer has another job which involves handling pesticides	3	18.75	3	37.5	3	50	9	0.3276
Spouse or Farmer does farm work	5	31.25	3	37.5	4	66.7	12	0.3752

* A p-value < 0.05 obtained from Fisher's exact test is statistically significant.

† Means with the same letter are not significantly different from each based on p-value < 0.05 obtained from ANOVA test.

Table 2.4 Clothing and Personal Protective Equipment Frequency of Use

Mixing & Loading Pesticides (from "mixers" and "both": n = 14)				
Clothing/Equipment	Always	Usually	Sometimes	Never
Long Pants	12 (85.7%)	1 (7.1%)	1 (7.1%)	0
Long Shirt	1 (7.1%)	2 (14.3%)	9 (64.3%)	2 (14.3%)
Respirator	0	0	0	14 (100%)
Chemical Protective Clothing	1 (7.1%)	0	3 (21.4%)	10 (71.4%)
Rubber Boots	0	0	4 (28.6%)	10 (71.4%)
Rubber Apron	0	0	0	14 (100%)
Cloth Apron	0	0	0	14 (100%)
Goggles	0	0	3 (21.4%)	11 (78.6%)
Disposable Gloves	4 (28.6%)	1 (7.1%)	2 (14.3%)	7 (50%)
Cloth or Leather Gloves	0	0	1 (7.1%)	13 (92.9%)
Rubber Gloves	2 (14.3%)	6 (42.9%)	2 (14.3%)	4 (28.6%)
Applying Pesticides (from "applicators" and "both": n = 22)				
Clothing/Equipment	Always	Usually	Sometimes	Never
Long Pants	20 (90.9%)	2 (9.1%)	0	0
Long Shirt	2 (9.1%)	2 (9.1%)	15 (68.2%)	3 (13.6%)
Respirator	0	0	0	22 (100%)
Chemical Protective Clothing	1 (4.8%)	0	3 (14.3%)	17 (81.0%)
Rubber Boots	1 (4.5%)	1 (4.5%)	6 (27.3%)	14 (63.6%)
Rubber Apron	0	0	1 (4.5%)	21 (95.5%)
Cloth Apron	0	0	0	21 (100%)
Goggles	0	1 (4.5%)	8 (36.4%)	13 (59.1%)
Disposable Gloves	4 (18.2%)	2 (9.1%)	2 (9.1%)	14 (63.6%)
Cloth or Leather Gloves	0	0	1 (4.5%)	21 (95.5%)
Rubber Gloves	2 (9.5%)	4 (19.0%)	1 (4.8%)	14 (66.7%)

The PPE rank for the group of participants with the job classification "both" was tallied for both their PPE during mixing/loading and during application. The PPE rank for participants in the job classification applicators and mixers was tallied only for application and mixing/loading, respectively. This total was then doubled so that it could be compared between all three groups. There was no statistical significance between the PPE rank means for applicators (12.6), mixers (12.9), and both (16.8) ($p=0.35$). There was no significant association of PPE rank with any of the household dust mean concentrations.

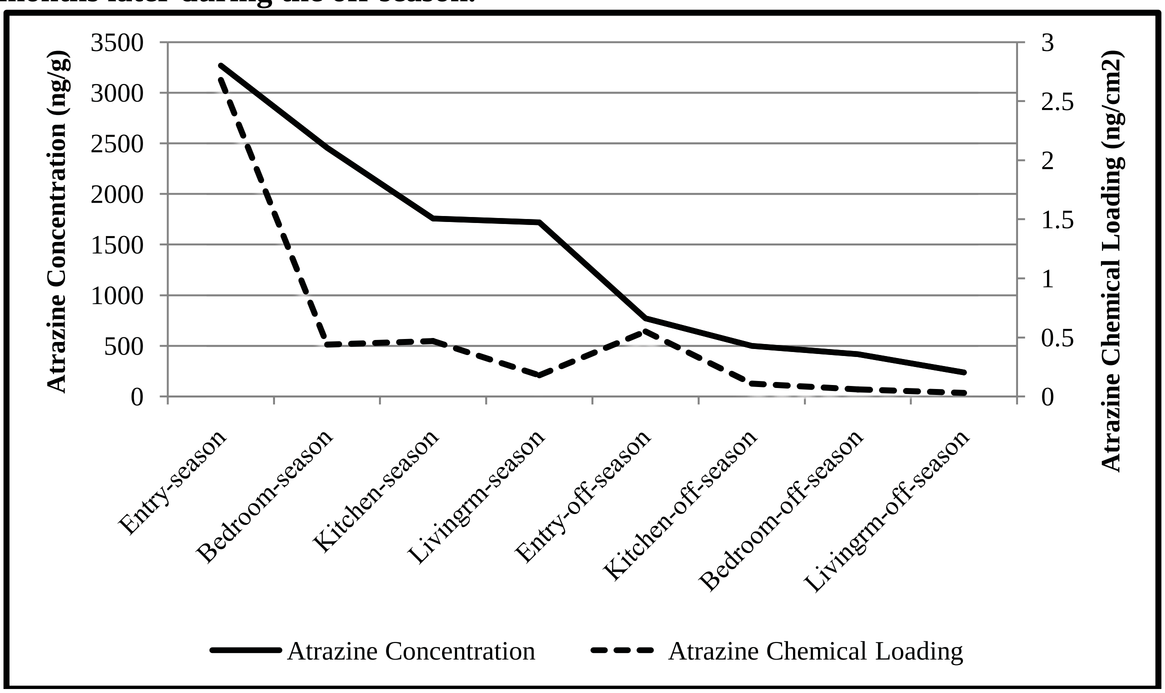
Dust Results

A total of 221 dust samples were taken from 29 homes. These dust samples were taken from similar areas in each house: entryway, living room, master bedroom (or where the pesticide applicator usually changed his clothes inside), and kitchen. A total of 112 samples were taken during visit 1 in the pesticide application season and 109 samples were taken at visit 2 during the winter months. The numbers do not correspond perfectly because two participants were lost to follow up and in some cases area rugs or entryway mats had been removed from the home.

The results of the dust sampling are shown in both atrazine concentration (ng/g) and chemical loading (ng/cm^2) in table 2.5 and figure 2.1. The geometric mean concentration of atrazine among all houses was highest in the entryway during pesticide application season, followed by the master bedroom, kitchen, and living room. The off-season values are all significantly lower than application season levels at $p = 0.05$. During the off-season the atrazine concentration in descending order was; entryway, kitchen, master bedroom, and living room.

When the data is converted to chemical loading (ng/cm^2) there is a drastic rearranging in the rank of atrazine contamination. The entryway sample from pesticide application season is still the highest (2.68 ng/cm^2). However, the second highest atrazine loading is the entryway from the offseason visit with a level of 0.55 ng/cm^2. This is a statistically significant drop but the entryway sample from visit 2 is higher than the remaining three samples from visit 1: kitchen (0.47 ng/cm^2), master bedroom (0.44 ng/cm^2), and the living room (0.18 ng/cm^2). The kitchen (0.11 ng/cm^2), master bedroom (0.06 ng/cm^2), and living room (0.03 ng/cm^2) from visit 2 are the lowest three levels of contamination.

Figure 2.1 Atrazine dust concentration and chemical loading in the homes of commercial pesticide applicators during the application season and approximately 6 months later during the off-season.



The three different job categories, Applicator, Mixer, and Both, had similar household atrazine concentrations and chemical loading at visit 1 and for the visit 1 & 2, overall average. However, the mean concentration and chemical loading for those participants that both applied and mixed atrazine was significantly lower than the Applicator and Mixer group at visit 2 (table 2.6).

Table 2.5 Average dust levels by location and season

	Room in House - GM, ng/g (GSD)			
	Entryway (n)	Living Room (n)	Master Bedroom (n)	Kitchen (n)
Application season	3269 (3.7)[1] n=29	1719 (5.5)[1,2] n=29	2457 (5.6)[1] n=27	1758 (4.5)[1,2] n=27
Winter offseason	771 (3.5)[2,3] n=27	236 (4.9)[4] n=29	416 (4.7)[3,4] n=27	501 (7.3)[3,4] n=26
p-value[1]	0.0001	<0.0001	0.0002	0.0121
	Room in House - GM, ng/cm^2(GSD)			
	Entryway (n)	Living Room (n)	Master Bedroom (n)	Kitchen (n)
Application season	2.68 (7.0)[a] n=29	0.18 (10.2)[b,c] n=29	0.44 (8.0)[b] n=27	0.47 (6.0)[b] n=27
Winter offseason	0.55 (7.5)[b] n=27	0.03 (10.8)[d] n=29	0.06 (12.2)[c,d] n=27	0.11 (12.1)[c] n=26
p-value	0.0043	0.0024	0.0018	0.0164

* The p-values are from a paired t-test between means from the same location and comparing them by season.

Table 2.6 Comparison of household mean atrazine concentration and chemical loading between different job classifications at visit 1, visit 2, and both visits.

JOB (n)	Visit 1 (ng/g)	Visit 2 (ng/g)	Visit 1&2 (ng/g)	Visit 1 (ng/cm^2)	Visit 2 (ng/cm^2)	Visit 1&2 (ng/cm^2)
Applicator (16)	1550 (3)	512[a] (3)	894 (3)	0.500 (5)	0.139[c] (6)	0.265 (5)
Mixer (7)	3389 (3)	733[a] (2)	1576 (2)	0.666 (4)	0.142[c] (3)	0.308 (3)
Both (6)	3939 (6)	168[b] (3)	814 (2)	0.701 (4)	0.021[d] (5)	0.122 (2)
p-value	0.21	0.03	0.31	0.87	0.05	0.42

Univariate Analysis

Table 2.7 presents the analysis of the association between home and atrazine usage variables and average household dust concentration at visit 1, visit 2, and from both visits. Total season atrazine handling (number of days atrazine handled, pounds of atrazine handled, and acres of corn applied with atrazine) have nearly significant and significant positive associations with average household dust concentrations during the winter. A negative association exists between the number of days since the last atrazine handling event and visit 2 mean, indicating that atrazine concentrations do decline over time. There is a counterintuitive positive association between the distance from the home to the nearest crops and household means at visit 2 and both visits. This association could be confounded by atrazine handling. The R^2 values for these variables are all < 0.26 and therefore explain very little of the variability.

Table 2.8 presents the analysis of the same variables using household average chemical loading (ng/cm^2) at visit 1, visit 2, and both visits as outcome variables. Atrazine handling (days handled, pounds applied, and acres applied) continues to be the strongest predictor for in-home atrazine levels. The number of days between the last atrazine handling event and chemical loading at visit 1 are negatively associated.

Table 2.9 displays the analysis of various household characteristics to evaluate their association with atrazine concentration or chemical loading. Vacuuming at least once per week had a negative association with chemical loading and atrazine concentration at visit 2 and for both visits. This association is not present with atrazine levels at visit one, likely due to the limited number of days between atrazine handling and visit 1 sampling for the different vacuuming practices to show their effect. The presence of a pet, and the presence of a pet that spends time both indoors and outdoors, showed no associations with chemical loading, but was associated with lower levels of atrazine concentrations. Households where the commercial pesticide applicator changes his work shoes inside the home had higher levels of atrazine (sometimes significantly higher) in both concentration and chemical loading at all visits. Table 2.10 shows the geometric means for the atrazine dust concentrations (ng/g) of the categorical variables that demonstrated associations with $p \leq 0.10$.

Table 2.7 Regression analyses of continuous variables and household mean concentrations at visit 1, visit 2, and all visits.

		Average household dust concentration at visit 1 (natural log of ng/g)			Average household dust concentration at visit 2 (natural log of ng/g)			Average household dust concentration for both visits (natural log of ng/g)		
Independent Variable (n)	N	β	R^2	p-value	β	R^2	p-value	β	R^2	p-value
Age of the home	29	-0.00036	0.0001	0.96	0.00487	0.0262	0.40	0.00222	0.0084	0.64
Years lived in home	29	0.01078	0.0060	0.69	0.0061	0.0026	0.79	0.00807	0.0071	0.66
# of days between last handling of atrazine and visit 1	27	-0.01223	0.0015	0.85	–	–	–	–	–	–
# of days between last handling of atrazine and visit 2	27	–	–	–	-0.01164	0.1019	0.10	-0.00238	0.0064	0.69
# of days handling atrazine entire season	20	-0.00054	0.0000	0.99	0.06172	0.1557	0.09	0.0283	0.0541	0.32
# of Days handling atrazine before visit 1	20	0.06028	0.0778	0.23	–	–	–	–	–	–
Pounds handled entire season	27	0.000057	0.0226	0.45	0.000112	0.1332	0.06	0.000082	0.1084	0.09
Pounds handled before visit 1	27	0.000093	0.0638	0.20	–	–	–	–	–	–
Acres atrazine applied to entire season	20	0.000002	0.0000	0.99	0.000259	0.2579	0.02	0.000123	0.099	0.17
Acres atrazine applied to before visit 1	20	0.000185	0.0683	0.27	–	–	–	–	–	–
Distance from home to nearest crops	29	0.41802	0.0571	0.21	0.50822	0.1159	0.07	0.469	0.1513	0.04

1. Analysis was not performed for blank cell because in these cases there is no logical relationship between the independent and dependent variables.

Table 2.8 Regression analysis of continuous variables and household mean chemical loading at visit 1, visit 2, and all visits.

Table 2.8		Average household dust concentration at visit 1 (natural log of ng/cm^2)			Average household dust concentration at visit 2 (natural log of ng/cm^2)			Average household dust concentration for both visits (natural log of ng/cm^2)		
Independent Variable (n)	N	β	R^2	p-value	β	R^2	p-value	β	R^2	p-value
Age of the home	29	0.00485	0.0138	0.5	0.0066	0.0199	0.47	0.00574	0.0239	0.42
Years lived in home	29	-0.00064	0.0000	0.98	-0.0011	0.0000	0.98	-0.00113	0.0001	0.97
# of days between last handling of atrazine and visit 1	27	-0.11845	0.1117	0.09	–	–	–	–	–	–
# of days between last handling of atrazine and visit 2	27	–	–	–	-0.0146	0.0648	0.20	–	–	–
# of days handling atrazine entire season	20	0.0808	0.1520	0.09	0.0969	0.1633	0.08	0.08881	0.2285	0.03
# of Days handling atrazine before visit 1	20	0.13533	0.3019	0.01	–	–	–	–	–	–
Pounds handled entire season	27	0.00011	0.0695	0.18	0.000134	0.0761	0.16	0.000123	0.1030	0.10
Pounds handled before visit 1	27	0.000122	0.0850	0.14	–	–	–	–	–	–
Acres atrazine applied to entire season	20	0.000193	0.0798	0.23	0.000327	0.1669	0.07	0.000259	0.1823	0.06
Acres atrazine applied to before visit 1	20	0.000346	0.1895	0.06	–	–	–	–	–	–
Distance from home to nearest crops	29	0.37925	0.0343	0.34	0.59187	0.0648	0.18	0.48445	0.0688	0.17

1. Analysis was not performed for blank cell because in these cases there is no logical relationship between the independent and dependent variables.

Table 2.9 Associations of categorical variables with log transformed household means from visit 1, visit 2, and both visits both in atrazine concentration (ng/g) and chemical loading (ng/cm^2).

		Dependent Variable – p-value					
Independent Variable N=29 for all	N of yes	Visit 1 (ng/g)	Visit 1 (ng/cm^2)	Visit 2 (ng/g)	Visit 2 (ng/cm^2)	Visit 1&2 (ng/g)	Visit 1&2 (ng/cm^2)
Insecticide applied in the home in last year	13	0.80	0.72	0.29	0.51	0.33	0.53
Pesticide applied to lawn in last year	14	0.60	0.44	0.13	0.76	0.29	0.55
Pesticides applied to garden in last year	4	0.22	0.84	0.45	0.26	0.75	0.55
Vacuum home at least once per week	20	0.42	0.30	0.02	0.10	0.03	0.11
At least one doormat at your exterior doors	25	0.93	0.32	0.30	0.06	0.52	0.08
Have either a cat or dog	23	0.09	0.52	0.04	0.38	0.01	0.37
Have a pet that spends time both indoors and outdoors	10	0.03	0.53	0.34	0.67	0.04	0.93
Distance from home to crops < 0.5 miles	21	0.91	0.55	0.52	0.61	0.63	0.99
Worker’s clothes are washed separately	23	0.18	0.09	0.92	0.83	0.33	0.43
Worker changes clothes inside home	29	-	-	-	-	-	-
Worker changes shoes inside home	20	0.08	0.02	0.10	0.15	0.02	0.03
Spouse or worker has other job that involves pesticides	8	0.99	0.35	0.44	0.97	0.63	0.63
Spouse or applicator does farm work	11	0.22	0.88	0.25	0.78	0.08	0.81

Table 2.10 Geometric means of categorical variables that showed strong or statistically significant associations with household atrazine concentrations (ng/g).

Independent Variable	Response	Visit 1 GM (ng/g) (GSD)	Visit 2 GM (ng/g) (GSD)	Both Visits GM (ng/g) (GSD)
Change shoes inside	Yes	2993 (3.5)	556 (3.1)	1290 (2.5)
	No	1228 (3.2)	268 (2.4)	584 (1.8)
	p-value	0.08	0.10	0.02
Own a cat or dog	Yes	1842 (3.4)	358 (2.7)	823 (2.0)
	No	5060 (3.5)	1001 (3.3)	2205 (3.3)
	p-value	0.09	0.04	0.01
Indoor & Outdoor Pet	Yes	1141 (3.0)	338 (3.1)	636 (2.3)
	No	3261 (3.5)	512 (2.9)	1287 (2.3)
	p-value	0.03	0.34	0.04
Vacuum home at least once per week	Yes	1988 (3.4)	324 (2.6)	800 (2.0)
	No	3048 (4.1)	892 (3.1)	1690 (3.0)
	p-value	0.42	0.02	0.03

Commercial pesticide applicators that reported sometimes changing their clothes in their master bedrooms had higher levels of atrazine concentration and chemical loading in their bedrooms at all visits. The associations were strong for visit 2 and for both visits in atrazine concentrations (p=0.13 and 0.08, respectively) and were statistically significant for visit 1, visit 2, and for both visits in chemical loading (p=0.03, 0.05, and 0.01, respectively).

Table 2.11 P-values for difference in household means between commercial applicators who change clothes in master bedroom versus those who do not.

		Master Bedroom Dust Contamination – p-value					
Independent Variable	Yes	Visit 1 (ng/g)	Visit 1 (ng/cm^2)	Visit 2 (ng/g)	Visit 2 (ng/cm^2)	Visit 1&2 (ng/g)	Visit 1&2 (ng/cm^2)
Applicator changes work clothes in the master bedroom (n = 27)	8	0.25	0.03	0.13	0.05	0.08	0.01

Discussion

The participants in this study are demographically similar to commercial applicators from previous studies. Hines et al (2001) studied herbicide exposure among 15 commercial applicators in Ohio; their median age was 40 years (range 23-58). The median age for this study was 41.5 years (range 23-60). All of the commercial applicators in this study were white, compared to 99.5% of Iowa commercial applicators in Alavanja et al (1999).

Similar to Curwin (2005), atrazine levels were the highest in the entryway where the applicator enters the home and the area where the applicator changes out of work clothes. This pattern of contamination indicates that atrazine is being brought into the home on the shoes and clothes of the commercial pesticide applicator. This means that the take-home pathway for atrazine, and possibly other similarly handled pesticides, is prominent among commercial pesticide applicators. The results of this study indicate that the amount of atrazine handled is one of the most important risk factors for atrazine contamination in the home, which also points to the take-home pathway.

Mixers have higher levels of atrazine in their home and this could mean that their job tasks cause them to contaminate their clothes more than applicators. However, higher levels in mixers' homes could be related to the fact that they handled about 2000 more pounds of atrazine than applicators or participants who performed both tasks.

The results of this study raise concern about the persistence of atrazine in commercial pesticide applicators' homes throughout the entire year. Golla's (2007) study showed similar findings in the homes of Iowa farmers. However, in this study, the atrazine levels during the off-season were about one-fifth lower than the levels during application season while they dropped to one-tenth peak season levels in Golla's study. A smaller reduction in atrazine levels between seasons in this study could be attributed to greater loading or longer persistence in commercial pesticide applicator's homes.

This study showed that more frequent vacuuming is associated with reduced pesticide levels in the home over time. The lack of association between vacuuming and atrazine levels at visit 1 may be due to the short time between atrazine handling and visit 1 (4.6 days on average). Since the average time between the last atrazine handling and visit 2 was 179 days, more frequent vacuuming likely led to lower atrazine levels. Educating commercial pesticide applicators and their spouses about the impact that house cleaning can have on contamination levels could be an effective way to reduce in-home pesticide levels.

Golla reported a household atrazine geometric mean of 858 ng/g among farm homes during the pesticide application season. The household average among commercial pesticide applicators was 2224 ng/g during the same time period; nearly three times higher. During the non-planting season commercial pesticide applicators had household atrazine concentrations of 435 ng/g, compared to 49 ng/g for farmers; almost an order of magnitude higher. It appears that commercial pesticide applicators have much higher in-home atrazine contamination levels compared to farmers during both the pesticide application season and the winter months.

Curwin et al (2005) reported that non-farm homes had very low levels of atrazine concentration (geometric mean 2.3 ng/g), farm homes that did not spray atrazine within the last seven days had slightly higher levels (GM 16 ng/g), and farm homes that had sprayed within seven days had the highest levels (GM 170 ng/g). All of these levels are much lower than the homes of commercial pesticide applicators in this study.

The most likely explanation for these differences is the amount of atrazine handled. The quantity of atrazine handled was positively associated with atrazine dust concentrations in the Golla study and this study. However, commercial pesticide applicators handled more pounds of atrazine than farm homes (5475 vs. 830), handled atrazine on more days than farm homes (13 vs. 5), and sprayed more acres than farm homes (3838 vs. 318). It appears that atrazine handling is an important determinant for in-home contamination.

There were notable differences between atrazine concentration (ng/g) and chemical loading (ng/cm^2) in the univariate analysis of exposure determinants. The results reported in ng/g represent how much atrazine was present in each gram of fine dust collected. This variable does not indicate how much fine dust is present in a particular home overall. Houses with low atrazine concentrations could still have high risk for exposure than houses with higher atrazine concentrations if there is more dust present. Similarly, households with high atrazine concentrations may have low exposure risk if there is a relatively small amount of dust.

Chemical loading factors in the cleanliness of a home by using the area sampled in calculating its value. The resulting variable is an indication of how much atrazine is present per square centimeter. This seems to be a better indication of how much atrazine is actually present in the home and the potential for exposure.

One of the strengths of this study is that it builds on previous studies and focused on a population that had not been studied previously. Pounds of atrazine handled was calculated using the amount of active ingredient in each formulation by collecting the EPA registration numbers and pesticide brand names from participants, which provided a much more accurate number than previous studies. The laboratory dust analysis method has been used in previous studies and has a very low limit of detection. In this study the amount of atrazine in each sample was corrected by recovery analysis, providing a more accurate result for the amount of atrazine present in participant homes.

One weakness of this study was that there were missing data points for atrazine handling. One piece of information that was not gathered from participants was the length of time that they had worked as commercial pesticide applicators. This information would have been valuable for this study. The small sample size of the study limited the potential for complicated analysis and true associations may not have been significant. Lastly, this study took place in 2008 when there was extensive flooding throughout Iowa. Some farms had to replant corn and spray atrazine again due to flooding and this may have caused atrazine usage to be higher than other years.

Conclusion

This study adds to the understanding of take-home exposure pathways and the pesticide exposure risks of families of commercial pesticide applicators. Results show that occupational handling of atrazine is the most important determinant of in-home atrazine dust levels. The location that commercial pesticide applicators change out of work clothes and shoes may be determinants of in-home atrazine concentrations. Therefore, interventions to interrupt the take-home pathway should be developed. These interventions should use multiple strategies to address the pesticide take-home pathway. They should focus on preventing workers from taking their clothing and shoes inside their homes and educating families that floor cleaning could reduce in-home levels. The interventions could require the companies to provide a place where pesticide applicators can change in and out of work clothes and shoes at the beginning and end of the work day. Interventions should be evaluated using in-home dust samples, urine samples, atrazine handling and other variables to see if they are effective in reducing in-home pesticide levels.

Results from intervention studies could lead to state regulations that require companies to provide an area where their workers can change in and out of their work clothes. The companies could provide an area for workers to change and also safely store their work clothes. This would allow workers to travel to and from work in street clothes and leave their contaminated clothes at work. There could even be a washer and dryer at work so that work clothes can be washed at the work place.

CHAPTER 3

DETERMINANTS OF ATRAZINE CONTAMINATION IN THE HOMES OF AGRICULTURAL WORKERS IN IOWA

Abstract

Three relatively small in-home pesticide studies have been carried out in Iowa among farmers and commercial pesticide applicators. These studies measured in-home atrazine levels during pesticide application season and two of them also sampled approximately six months later during the winter months. This study analyzed the data of these three similar studies in order to more comprehensively analyze in-home atrazine levels.

Data from two previous studies that measure atrazine in farm and non-farm household dust samples were combined with data presented in Chapter 2. This larger dataset allowed for more powerful analyses of the risk factors for take-home atrazine concentrations. This study contained 100 homes from the following work groups: commercial pesticide applicators, farmers who apply their own atrazine, farmers who hire out atrazine application, and a non-farm control population.

A total of 359 dust samples were collected during the atrazine application season. Commercial applicators had higher average household atrazine levels (GM=2270ng/g) than farmers who applied their own atrazine (GM = 787ng/g), and significantly higher levels than farmers who hired out atrazine application (GM = 107ng/g) and non-farm households (GM = 2ng/g). Amount of atrazine handled was the strongest and most

consistent determinant associated with household atrazine levels. Other determinants showed associations with atrazine levels but were confounded by work group.

Family members of commercial applicators were at the highest risk for exposure to atrazine dust, and presumably other pesticides, in their home. Farmers that applied their own atrazine were also at an increased risk compared to farmers who hired out their atrazine application. It appears that having someone else apply atrazine to fields reduces potential exposure to family members in the home. Policy interventions focused on interrupting the take-home pathway could be most effective among commercial applicators.

Introduction

Over the last decade there have been extensive studies on the human health effects of the widely used corn herbicide atrazine. There is concern about the chronic exposure of populations to this herbicide because it is ubiquitous in many environments. It is found extensively in surface waters, municipal water supply systems, and even homes.

Curwin et al (2005) found that farmers who self-applied atrazine had higher urine metabolite levels than non-farmers or farmers who did not apply the pesticide themselves (Curwin et al, 2005). Curwin et al (2007) also found that children whose father self-applied atrazine had higher levels of atrazine metabolites in their urine than children from non-farm, rural families.

Atrazine has been linked to various deleterious reproductive outcomes such as pre-term birth, miscarriage, and various birth defects while epidemiological studies have shown an association between atrazine and several cancers (ATSDR, 2008). In animals it has been shown to be an endocrine disruptor (ATSDR, 2008).

Meta-analysis is a technique used in statistics to combine the results of several studies that have focused on related research hypotheses. A meta-analysis helps synthesize multiple studies to interpret what a larger body of evidence means; thereby helping policy makers and the general public better interpret research findings. This type of study is useful because smaller studies have lower power which reduces the ability to observe associations (Checkoway, Pearce, & Kriebel, 2004). Making type II errors, failure to reject the null hypothesis when in fact an association does exist, is another weakness of small studies. Small studies can be inconclusive and inconsistent, and provide no clear answers for policy-makers.

Exposure assessment studies have assessed take-home exposure to atrazine among the households of farmers, commercial pesticide applicators, and a non-farm rural population. However, these studies were small and may not have had sufficient sample size to evaluate the differences between the risk factors for in-home exposure to atrazine among groups. This paper combined data from three exposure assessment studies carried out in Iowa using the same sampling protocol and very similar questionnaires. This process synthesizes data from three separate studies that used the same research methods, thereby creating a larger sample size for more intricate statistical analysis.

Materials and Methods

Study Populations

Curwin recruited 25 farm and 25 non-farm households in eastern Iowa in 2001 for a field study that assessed household contamination of multiple pesticides. Not all of the dust samples from all of the homes were analyzed for atrazine, the target pesticide for this study, so some households were removed from analysis; overall, 20 farm homes and 19 non-farm rural households met the criteria that household dust samples had been analyzed for atrazine.

In 2005, Golla recruited 32 farm families from three counties in eastern Iowa for a study that focused exclusively on the herbicide atrazine. The participants were recruited through the Iowa Agricultural Census and had to be designated as farming at least 100 acres of tillable cropland. It was required that these farm families use atrazine on their crops to be eligible to participate in the study.

As an extension of Golla's study, Lozier recruited 29 certified commercial pesticide applicators in east-central and southeast Iowa in 2008. The subjects were recruited through their companies and it was required that they plan to apply or handle atrazine during the 2008 planting season.

Dust Sample Collection

In Curwin's study, samples were taken from up to seven locations in the homes: 1) primary entryway; 2) area where farmer or head of household changes work clothes; 3) child play area; 4) child bedroom one; 5) child bedroom two; 6) child bedroom three; or 7) laundry room. Lozier's and Golla's sampling protocol was slightly different from

Curwin's. In their studies, four samples were taken from each home: 1) primary entryway for pesticide applicator; 2) living room/play area; 3) master bedroom/where worker changes work clothes; and 4) kitchen. The first three correlate well with Curwin's sampling areas. However, kitchen in Lozier's and Golla's study, and the samples from children's bedrooms in Curwin's study, do not have correlating samples.

Dust samples were collected from floors using a high-volume surface sampler (HVS-3, Cascade Stamp Sampling Systems) in accordance with the American Society for Testing Material (ASTM) Standard Practice for Collection of Dust from Carpeted Floors for Chemical Analysis (ASTM D 5438-94, 1994). The vacuum sampler contained a cyclone and a catch bottle. The vacuum head was passed over the floor surface in a straight line back and forth 4 times. This process was repeated with subsequent adjacent floor strips until the desired area had been sampled or a minimum of 1 to 2 grams of dust was collected. Sample area was recorded to standardize the results. A new catch bottle was used for each sample.

Data Preparation and Analysis

Many of the variables between these three studies correlated directly. However, the questionnaires varied slightly between the studies and some of the variables had to be modified to match. For example, in Lozier's study, participants were asked if they wore disposable gloves, cloth or leather gloves, or rubber gloves while handling atrazine. For each type of glove they could answer: 1) always; 2) usually; 3) sometimes; or 4) never. However, in Curwin's and Golla's study, the participants were asked if they used gloves (type was not specified) when they handled atrazine and could answer dichotomously; 1) yes; or 2) no. Therefore, the answers from Lozier's study were transformed into a dichotomous variable. The response to the disposable gloves question in Lozier's study was dichotomized in this way: an answer of always or usually = yes, they used gloves; an answer of sometimes or never = no, they did not use gloves. The same rubric was used to transform the use of the following personal protective equipment: long pants, long shirt, respirator, chemical protective clothing, rubber boots, and goggles.

For comparison of atrazine contamination by location, all atrazine dust results from all three studies were used. For analysis of determinants of exposure, a household mean was created for each home. For Lozier's and Golla's studies, all four samples were used to create the household mean. Two different household averages were calculated for the homes from Curwin's study. The first was based on four sample locations (mean4): laundry room; entryway; area where work clothes changed; and child play area. These four locations are common areas and are more similar to locations from Golla's and Lozier's study. The second household average included these four locations plus any results from the children's bedrooms for a total of up to seven locations (mean7). A paired t-test was performed to compare these two household means. Mean4 was significantly higher ($p=0.02$) than mean7 when looking at atrazine loading (ng of atrazine/cm^2) but there was no significant difference in atrazine concentration (ng of atrazine/g of fine dust collected). Pesticide applicators are likely to spend more time in common areas of the home and their own bedroom than in their children's bedrooms. To avoid artificially reducing the household means in Curwin's study, the atrazine results from the children's bedrooms were not used when calculating household mean because they do not have direct matches and are not common areas of the home.

One of the major goals of this paper is to analyze the household atrazine concentration and chemical loading between different types of households to determine which workers, and their families, are at greatest risk for exposure to atrazine in their home. Among commercial applicators there were two different tasks (applying atrazine and mixing atrazine) resulting in three job categories (applicator, mixer, and both). Data presented in Chapter 2 showed that there was no statistical difference in the amount of atrazine handled or in the atrazine dust concentrations in the home. Therefore, all commercial applicators will be treated as one group for this analysis. The participants from all three studies were classified into the following household categories:

1. Commercial applicator: One of the residents worked as a commercial pesticide applicator.
2. Farm – self apply: This is the home of a farmer who handled atrazine directly through applying it to his/her farm.
3. Farm – other application: This is a farm home where someone other than members of the household applied atrazine to crops on the farm (i.e. commercial applicators, neighbor, or family member living outside the home).
4. Farm – no atrazine: This is a farm household that participated in one of the studies, but at the time of dust sampling had not applied atrazine.
5. Non-farm control: These households were located on land that was not used for farming and had no person in the home working in agriculture or commercial pesticide application.

A variable that existed in each study, but was difficult to standardize between all three studies, was the number of pounds of atrazine applied before the dust samples were collected. Lozier used the number of pounds and the product reported to calculate the pounds of active ingredient that were applied. Curwin reported the number of ounces of dry product that was used. However, the percent of active ingredient in atrazine products varies between 11-90%. Not all of the EPA registration numbers for these products were available so calculating the actual pounds of atrazine used was not possible. Golla estimated the number of pounds of atrazine by using the number of acres sprayed and a standard application rate. This variable was included in the analysis but misclassification is likely.

Results

Household Characteristics

A total of 100 households from the three studies qualified for this analysis. Eleven of the participants from Curwin's study were removed because dust samples from their homes were not analyzed for atrazine. The 100 participants were distributed in the following categories: 29 commercial applicators; 19 farm – self apply; 30 farm – other application; 3 farm – no atrazine; and 19 non-farm.

Commercial applicators had lived in their homes or apartments significantly less time than farm – other application and farm – no atrazine (Table 3.1). It was also lower than farm – self apply, and non-farm households, but not significantly. Non-farm and commercial applicator houses were about 40 years old, while farm homes were much older (Table 3.1).

Table 3.1 Applicator and household age compared by household type.

	Commercial Applicator (n=29)	Farm – Other Application (n=30)	Farm – No Atrazine (n=3)	Farm – Self Apply (n=19)	Non-Farm (n=19)	p-value
Applicator Age[1] (yrs)	41(11.3)[a]	63(9.5)[c]	-	53(11.3)[b]	-	<0.0001
Age of home (yrs)	43	67	69	58	40	0.12
Years living in home	9.3[ef]	23.7[d]	25.3[d]	19.5[ed]	6.8[f]	<0.0001

1. The age of the pesticide applicator or primary farmer was not available for Curwin's study so 'n' for this variable is: commercial applicator (29), farm – other applicator (21), and farm – self apply (10).

Roughly half of the commercial applicators (48%) and the non-farm population (53%) maintained gardens, while 81% of farmer participants had gardens. Fisher's exact test indicates that there was a statistically significant relationship between type of household and having a garden (p = 0.03). It appears that farmers and commercial applicators were more likely to have dogs than non-farmers (Table 3.2). However, non-farmers and commercial applicators were more likely to have a dog that spends time indoors and outdoors. There is an association between applying a pesticide inside the home in the last year and household type, as well as the pesticide applicator changing work clothes inside and the household type. Lastly, there is an association between the number of times that floors are cleaned per month and household type. In general, farm households cleaned there floors more frequently than non-farm homes (not significant) and commercial applicator homes (significant).

Pesticide Application Characteristics

Commercial applicators handled atrazine more days, handled more pounds of atrazine, and applied atrazine to more acres than farm – self apply and farm – other

Table 3.2 Associations between household characteristics and household type. Values are given as percentage of homes with the household characteristic.

Household Characteristics	Commercial Applicator (n=29)	Farm – Other Application (n=30)	Farm – No Atrazine (n=3)	Farm – Self Apply (n=19)	Non-Farm (n=19)	p-value
Number of times floors cleaned per month	2.9	4.6	4.5	4.3	3.8	<0.001
Garden	48	80	100	79	53	0.03
Presence of Dog	72	60	67	84	37	0.03
Presence of a dog that spends time both indoors and outdoors	48	18	0	28	71	0.03
Any pesticide applied inside home within past year	45	23	67	63	32	0.04
Lawns treated with any pesticide within past year	48	37	67	32	32	0.57
Garden treated with any pesticide within past year	14	47	33	26	16	0.04
Carpet vacuumed at least once a week	69	87	67	84	68	0.32
Presence of pet (cat or dog)	79	77	100	95	58	0.09
Presence of pet (cat or dog) that spends time both indoors and outdoors	34	20	33	42	32	0.43
Distance of the home from crop fields < 0.5 miles						
Launder worker's clothes separate from rest of the family	79	60	100	68	-	0.31
Change work clothes inside the home	100	93	67	100	-	0.04
Change work shoes inside the home	69	68	67	72	-	1.0

1. Results with different letter have a statistically significant difference.

application (Table 3.3). There were fewer days between atrazine application and dust sampling in the farm – self apply group.

More farmers – self apply and farm – no atrazine wore a long-sleeved shirt during pesticide handling (Table 3.4). Commercial applicators and farmers – self apply were much more likely to wear long pants during pesticide application than farmers – other application and farm – no atrazine. All of the commercial applicators used tractors with enclosed cabs, air conditioning, and filters for the cabs (most charcoal) to apply pesticides. Only 58% of the farmers – self apply had a fully enclosed cab on their tractor.

Table 3.3 Mean atrazine handling and interim days by job category.

Atrazine Handling	Commercial Applicator	Farm – self apply	Farm – other application	p-value
Days handling atrazine	9.9[a]	3.3[b]	2.2[b]	<0.001
Pounds of atrazine handled	4743[c]	862[d]	745[d]	<0.001
Acres applied with atrazine	3008[e]	320[f]	237[f]	<0.001
Days between last atrazine handling and dust sampling	4.5[gh]	2.2[h]	7.5[g]	0.075

1. N for each cell varies due to missing data on some participants.

Table 3.4 Percent of pesticide applicators using clothing, personal protective equipment, and application equipment during pesticide application and handling.

Personal Protective Equipment	**Commercial Applicator (n=29)**	**Farm – Other Application (n=30)**	**Farm – No Atrazine (n=3)**	**Farm – Self Apply (n=19)**	**p-value[1]**
Long shirt	21	17	67	53	0.01
Long pants	97	33	67	89	<0.001
Respirator	0	0	0	0	-
Chemical Protective Clothing	4	0	0	11	0.27
Rubber Boots	7	10	0	21	0.52
Goggles	3	13	33	11	0.21
Gloves	28	37	0	84	<0.001
Fully enclosed cab on tractor used for pesticide application	100	17	100	58	<0.001

1. p-value was calculated using Fisher's exact test.
2. Values are given as percentage of workers using clothing or PPE during pesticide application and handling.

Dust Analysis

A total of 359 dust samples were taken from 100 homes during the atrazine application season. 89% of the homes were sampled in their entryway, 76% in the living room or play room, 73 % in the master bedroom (or area where applicator changes out of work clothes), 57% in the kitchen, 38% in children's bedrooms, and 26% in the laundry room. The kitchen location had two and a half times the amount of atrazine concentration (ng/g) as the entryway and master bedroom (Table 3.5). However, this data is misleading because there were no kitchen samples collected for the farm – no atrazine and non-farm control groups; the two household types with the lowest overall atrazine dust concentrations. The common areas of the homes and where the applicator changes clothes were the most contaminated with atrazine dust, while the children's bedrooms and the laundry room had significantly lower levels (Table 3.5).

Commercial applicators had almost three times as much atrazine in their homes as farmers – self apply (Table 3.5). A two-sample t-test showed a p-value of 0.11 for this difference. The difference in chemical loading between these two groups was not significant either, but commercial applicators still had more than twice as much loading as farmers – self apply (Table 3.6). Farmers – no atrazine and farmers – other application had similar household means for both contamination and chemical loading. The non-farm control population was significantly lower than all other groups, but atrazine traces were still detectable in 53% of the homes.

Table 3.5 Geometric mean atrazine dust concentration (ng/g) by location and job classification during pesticide application season.

Location	Commercial Applicator (GSD)	Farm – Self Apply (GSD)	Farm – Other Application (GSD)	Farm – No Atrazine (GSD)	Non-Farm Control (GSD)	Location Average (GSD)
Kitchen	1758 (4.5)	1901 (7.8)	309 (10.2)	NA	NA	968 (8)[x]
Entryway	3269 (3.7)	857 (12.1)	351 (7.7)	98 (1.0)	4.3 (6.6)	383 (19)[xy]
Master Bedroom	2457 (5.6)	1062 (6.4)	109 (10.4)	219 (n=1)	0.75 (1.0)	383 (18)[xy]
Living Room	1719 (5.5)	327 (14.6)	160 (16.0)	52 (2.8)	1.8 (5.3)	274 (20)[y]
Child Bedroom	NA	115 (4.4)	7.9 (12.3)	9.9 (9.9)	3.1 (9.2)	9 (12)[z]
Laundry Room	NA	1329 (7.0)	8.3 (11.0)	163 (1.4)	0.96 (2.7)	7 (21)[z]
Household Average	2270 (4)[a]	787 (6)[a]	107 (11)[b]	102 (2)[b]	2 (4)[c]	

1. Column and row averages with the same letter are not statistically different (p=0.05).
2. Sample sizes for each cell are not equal.

Table 3.6 Geometric mean atrazine loading (ng/cm^2) by location and job classification during pesticide application season.

Location	Commercial Applicator (GSD)	Farm – Self Apply (GSD)	Farm – Other Application (GSD)	Farm – No Atrazine (GSD)	Non-Farm Control (GSD)	Location Average (GSD)
Kitchen	2.683 (7)	1.167 (16)	0.173 (13)	0.054 (4)	0.001 (20)	0.252[x] (11.9)
Entryway	0.176 (10)	0.095 (19)	0.018 (8)	0.008 (5)	0.000 (8)	0.257[x] (37.5)
Master Bedroom	0.442 (8)	0.140 (11)	0.023 (5)	0.003	0.000 (5)	0.065[y] (18.0)
Living Room	0.465 (6)	0.252 (18)	0.110 (18)	NA	NA	0.037[y] (19.8)
Child Bedroom	NA	0.011 (3)	0.001 (14)	0.005 (10)	0.000 (12)	0.001[z] (13.0)
Laundry Room	NA	0.060 (13)	0.001 (15)	0.015 (19)	0.000 (13)	0.0004[z] (40.6)
Household Average	0.575[a] (4.5)	0.259[a] (7.5)	0.031[b] (8.3)	0.012[b] (4.5)	0.0004[c] (7.0)	NA

1. Column and row averages with the same letter are not statistically different (p=0.05).
2. Sample sizes for each cell are not equal.

An analysis of household atrazine contamination during winter months using only data from the studies by Lozier and Golla (Table. 3.7) showed that for both contamination (ng/g) and chemical loading (ng/cm^2), commercial applicators were significantly higher than farmers – self apply, who were significantly higher than farmers – other application. Approximately six months after the application season, commercial applicators and farmers – self apply still had higher atrazine levels than households of farmers – no atrazine and farmers – other application during the planting season.

Table 3.7 Average household atrazine dust concentration and chemical loading during winter months; approximately 6 months after atrazine application season.

Job Classification (n)	Household Geometric Mean (GSD) – ng/g	Household Geometric Mean (GSD) – ng/cm^2
Commercial Applicator (29)	443[a] (3)	0.095[x] (5.5)
Farm – Self Apply (10)	108[b] (7)	0.016[y] (13.9)
Farm – Other Application (21)	18[c] (6)	0.0035[z] (8.8)

1. Results with the same letter are not statistically different from each other ($p > 0.05$).
2. For this analysis only participants from Golla's and Lozier's studies were used because they were collected on a similar schedule (approximately 6 months later) while Curwin collected a second round of dust samples approximately 5 weeks after the first round of sampling.

Univariate Analysis

The age of the pesticide applicator had a significantly negative association with household mean contamination and chemical loading (Table 3.8). The older the applicator, the lower the atrazine levels in the home. There is a negative association (non-significant) of the number of interim days between atrazine handling and atrazine concentrations. There is a highly significant positive association between the number of days atrazine handled, the pounds of atrazine handled, and the amount of acres applied with atrazine, with the average atrazine household concentration (Table 3.8). These three atrazine handling variables are highly correlated ($p < 0.0001$ for all pairs). Figure 3.1

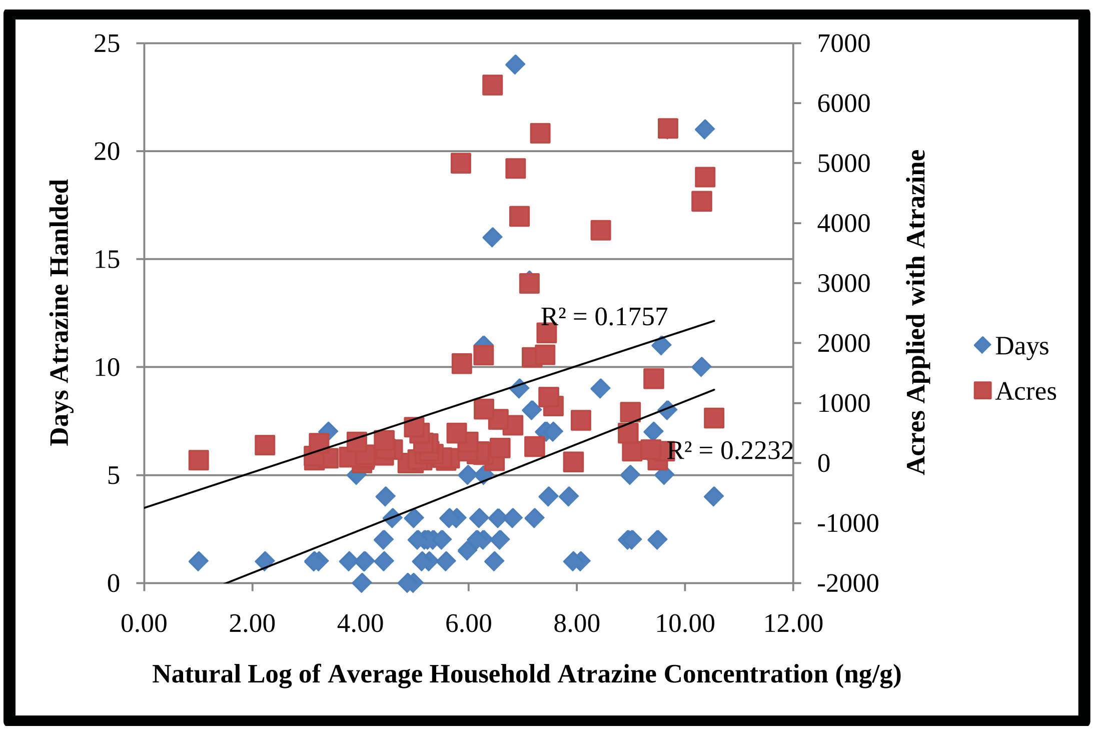
shows the scatter plots and best fit lines for the regression analysis of days atrazine handled and acres applied with atrazine.

Table 3.8 Regression analysis to assess the association between atrazine handling variables, floor cleaning, age of applicator, house variables and atrazine concentration and chemical loading in households.

	N	Household dust mean (natural log of ng/g)			Household chemical loading mean (natural log of ng/cm^2)		
		β	R^2	p-value	β	R^2	p-value
Age of the home	98	-0.0084	0.0124	0.27	-0.002	0.0005	0.83
Years lived in home	98	0.022	0.0101	0.32	0.017	0.005	0.47
Age of pesticide applicator	59	-0.0369	0.0756	0.035	-0.05	0.13	0.004
Days between atrazine handling and dust collection	44	-0.1118	0.0474	0.1556	-0.118	0.0664	0.0912
Days handling atrazine	71	0.225	0.2232	<0.0001	0.2414	0.268	<0.0001
Pounds atrazine handled[1]	70	0.0003	0.1673	0.0004	0.0003	0.1580	0.0007
Acres atrazine applied to	71	0.0006	0.1757	0.0003	0.0006	0.200	<0.0001
Times clean floor each month	99	-0.101	0.003	0.57	-0.134	0.005	0.48

1. Based on data from Golla and Lozier studies only.

Figure 3.1 Regression scatter plot for number of days that atrazine was handled, and number of acres applied with atrazine, versus the average household atrazine concentration during atrazine application season.



The associations between various categorical variables and the mean household atrazine concentration are presented in Table 3.9. Wearing long pants, using chemical protective clothing, changing work clothes inside, and having an enclosed cab on the tractor used for application all had a highly significant association with increased atrazine concentration. Participants that had at least one doormat inside one of the house's entrances had significantly higher atrazine levels than households that had no doormats. Households that had applied lawn pesticides in the last year, and that had consumed food from their garden in the last month, had higher household means (not significant). Households with a dog or a pet (cat or dog) also had higher levels, although not significant. Houses less than half-mile from cropland had higher (not significant) atrazine levels than houses greater than half-mile from cropland.

Table 3.9 Atrazine concentrations (ng/g) by response for categorical variables.

	Household Geometric Mean ng/g (GSD) <n>		p-value
	Yes	No	
House has at least one doormat	239 (19) <83>	44 (26) <16>	0.04
Pesticide used in home in the last year	415 (17) <39>	106 (21) <60>	0.03
Lawn pesticide used within last year	373 (16) <39>	114 (23) <60>	0.06
Family consumed food from garden in last month	454 (14) <19>	116 (18) <52>	0.08
Household has dog	275 (15) <63>	88 (34) <36>	0.07
Household has pet (dog or cat)	227 (18) <77>	83 (35) <22>	0.17
Wearing long pants during atrazine handling	886 (8) <56>	150 (12) <24>	0.001
Using chemical protective clothing during handling	6355 (3) <3>	470 (10) <79>	0.05
Tractor has a fully enclosed cab	1235 (6) <32>	133 (12) <43>	<0.0001
Change work clothes inside[1]	619 (9) <75>	14 (15) <3>	0.004
Distance from house to crops < ½ mile	229 (18) <81>	64 (39) <18>	0.11
Change work shoes inside	548 (9) <53>	469 (14) <24>	0.79

Discussion

The results from this study show that the major risk factor for in-home atrazine contamination is atrazine handling: more days, acres, and pounds of atrazine handled by pesticide applicators increase atrazine contamination in their homes. This holds true for both concentration (ng/g) and chemical loading (ng/cm^2). Consequently, because commercial pesticide applicators handled significantly larger quantities of atrazine, they have much higher levels of atrazine in their home.

Based on correlation between atrazine application and urinary atrazine mercapturate levels, Bakke et al (2009) concluded that the amount of atrazine applied likely provides a valid surrogate of atrazine exposure in epidemiologic studies. Similarly, the amount of atrazine applied by agricultural workers (farmers and commercial pesticide applicators) can likely serve as a valid surrogate for in-home levels of atrazine (Bakke et al, 2009). The results from the present study support the idea that the number of days atrazine handled, pounds applied, or acres applied with atrazine can all serve as surrogates for in-home levels of atrazine.

The public health implications for these findings are significant. In 2008 there were approximately 13.3 million acres of corn planted in Iowa (Iowa Agricultural Statistics, 2009). Assuming 60% coverage, atrazine was applied to approximately 8 million acres of corn in Iowa that year. There are approximately 5,700 commercial pesticide applicators in Iowa and there are more than 52,000 Iowa farms that produce corn (USDA, 2002). Family members of both types of households are at elevated risk for in-home atrazine exposure. This study shows that commercial applicators represent a younger population in society. They are likely to have younger families than farmers so women in their childbearing years and young children in the homes are potentially exposed to significantly higher levels of atrazine, and likely other pesticides. Exposure in the womb and in the first years of life can increase the risk of disease.

Golla (2007) reported that farmers who applied atrazine to their own land had higher in-home atrazine levels than farmers who did not apply atrazine to their own land during both the planting and non-planting season. This association persisted in this study. Inside homes, the areas where the pesticide applicator spends time (common areas and master bedroom) had the highest atrazine levels. Children's bedrooms and the laundry room had the lowest levels. This, and the fact that commercial applicators have the highest atrazine levels in their home, supports the theory that take-home exposure is a more significant source of pesticide contamination in the home than environmental drift. Hiring out pesticide application to commercial applicators appears to be an effective way to decrease the amount of pesticide contamination in farm homes. However, this practice merely shifts the risk of exposure from the farm home to the home of the person who does apply pesticides.

Regression analysis found a significant negative association between age of the pesticide applicator and atrazine levels. However, recall that farmers are significantly older than commercial applicators. Therefore, it is likely that the reason younger participants have higher levels of atrazine in their homes is not due to their age (or lack of experience). Rather, this association is probably due to the fact that younger applicators in this study were likely to handle atrazine on more days and in greater quantities than older applicators.

Despite using tractors with fully enclosed cabs, commercial applicators have significantly higher atrazine levels in their home. While an enclosed cab may be useful for preventing inhalation exposure during application, it is not effective in preventing the surface contamination of workers' clothing and skin, leading to take-home exposure pathway.

Changing work clothes inside is significantly associated with higher household concentrations. However, only three participants changed their work clothes outside. Two of these participants were farm – other application, and the third was farm – no atrazine. So it is possible that the lower levels of atrazine in their homes are a function of them not handling atrazine, rather than changing their work clothes outside. A sample with more commercial and farm applicators that change their work clothes outside of the home is needed to evaluate the effect that changing clothes outside the home has on in-home atrazine contamination.

Wearing long pants, using chemical protective clothing, and having a fully enclosed cab were significantly associated with elevated levels of atrazine in the homes. However, these variables were associated with being a commercial applicator and likely reflect the greater amount of pesticide handling by applicators. Higher atrazine levels in homes that have at least one doormat could be due to the possibility that the doormat serves as a reservoir for pesticides. These reservoirs could allow pesticides to be tracked further into the home throughout the year if they are not routinely washed.

In this study there is very little difference in the average household atrazine concentration of participants that changed their work shoes inside compared to those who changed their work shoes outside of the home. One of the important findings of Chapter

2 was that changing your shoes outside the home was associated with lower household average atrazine levels during atrazine application season. Golla (2007) reported the opposite trend: during the atrazine application season, among farmers that apply their own atrazine, those who changed work shoes outside the home had significantly higher average household atrazine levels (p=0.04) than farmers who changed their work shoes inside the home. There was a similar yet not significant (p=0.09) trend among farmers who hired out their atrazine application. In the present study, combining the data caused both associations to be cancelled out. So is there a real association?

As seen in this study, atrazine usage frequently confounded associations with in-home atrazine dust concentrations. Data from Golla's study was analyzed to see if this was the case. Participants that changed their shoes inside handled atrazine about the same number of days (3.2) as those that change them outside (3.1). However, farmers that changed their shoes outside applied atrazine to 563 acres compared to 241 acres (p=0.0009) for those changed their shoes inside. Similarly, farmers who changed their shoes outside applied 1513 pounds of atrazine while those who changed shoes inside applied 629 pounds (p=0.0006). This evidence further supports the fact that it is atrazine usage that is the principal determinant for in-home levels and that it is possible that where the pesticide applicator removes work shoes is less important of a factor than where they change their work clothes.

One of the strengths of this study is that it combined data from three very similar pilot studies. The larger sample size allowed for the verification of associations that had been identified in previous studies. It also made it possible to statistically analyze in-home atrazine contamination and chemical loading between different household types, rather than simply comparing means between studies.

One of the weaknesses of this study is the misclassification that could have taken place while combining and standardizing the data. Golla and Curwin were involved in cleaning and sorting the data to help avoid these misclassifications. Another weakness is that the laboratory analysis of the dust samples for Golla and Lozier were corrected by recovery analysis while the samples from Curwin's study were not. This could have caused misclassification in the atrazine concentrations. The average recovery percentage in the analysis of dust samples from Lozier's study was 82%. This means that the dust concentrations from Lozier's study were increased by 22% on average when they were corrected for recovery. The dust samples from Golla's study were also corrected by recovery. This means that the dust concentrations were systematically increased for all 29 commercial pesticide applicators and for the 32 farm families from Golla's study. This differential misclassification likely exaggerated the difference between the commercial pesticide applicators and the other homes since all of the dust samples from the commercial pesticide applicator households were, on average, corrected up, while the dust samples from only 61% (32 of 52) of the farm homes were corrected, and none of the dust samples from the non-farm homes were corrected. However, it is unlikely that the adjustment of the dust concentrations for these homes caused Type I errors.

Conclusion

This study has demonstrated that the most important determinant for in-home atrazine dust contamination is the amount of atrazine handled by the pesticide applicator living in the home. The number of days handling atrazine, pounds of atrazine handled, and acres applied with atrazine, are the best indicators for predicting atrazine levels in the home. Because commercial pesticide applicators handle more atrazine than farmers, they have more atrazine in their homes. While enclosed tractor cabs and enclosed pesticide mixing devices may reduce exposure to pesticides, they do not bring exposure levels down to that of a farmer.

Commercial applicators may be easier to regulate than farmers because there are fewer of them and the majority of them operate through companies. Regulations should be developed to target these companies to reduce the exposure of the highest risk pesticide applicators at work, and interrupting the take-home pathway to reduce the exposure risk of their families. Requiring commercial applicator companies to provide an area to change clothes at work and onsite laundry service could greatly reduce the amount of pesticides carried home by the worker. The major difficulty that this type of regulation would face is the fact that commercial pesticide applicators work long hours during application season. They often finish work in the field at dark and head straight home. Requiring them to return to work to change clothes is unrealistic. Therefore, these regulations need to be paired with education about occupational exposure to pesticides and the risk that the take-home exposure route poses to their families.

Regulating farmers could be more difficult because there are many thousands more of them and they are an extremely autonomous population. Reducing exposure through engineering and design methods may be more successful than efforts to change behaviors. However, educating farmers regarding the importance of changing pesticide application clothes outside the home, or in a designated area of the garage, barn, or mud room, should be part of a comprehensive intervention to reduce take-home exposures.

CHAPTER 4

HONDURAS CORN PRODUCTION PRACTICES AND PERSONAL AIR SAMPLING DURING ATRAZINE APPLICATION

Abstract

The use of herbicides in agricultural production in developing countries has increased drastically over the last 20 years. Many studies have assessed exposure to acutely toxic pesticides, but there has been less chronic exposure assessment of herbicides like atrazine.

Farm workers and farmers who apply atrazine (n=29) were recruited to participate in this study. Personal air samples were collected during atrazine application from 26 of the 29 participants to assess inhalation exposure. Application techniques were observed during sampling and a survey was completed in the home with the pesticide applicator and his family.

Fifteen of the 26 participants sampled used backpack sprayers to apply atrazine and 11 used a tractor and boom. On average, the backpack sprayers applied 884 grams of atrazine to 2.4 acres. This compared to 13,805 grams of atrazine applied to 24.4 acres by those using tractor and boom. Despite applying about fifteen times as much atrazine during sampling, the tractor/boom participants only had slightly higher inhalation exposure (11.5 $\mu g/m^3$) than participants using backpack sprayers (9.0 $\mu g/m^3$). This difference was not statistically significant. Within the group of backpack sprayers, those that used a conical spray nozzle had significantly higher inhalation exposure (11.54 $\mu g/m^3$) than applicators using a curtain nozzle (5.98 $\mu g/m^3$; $p = 0.04$). Applicators that

rode on the boom or the back of the tractor and monitored the nozzles had almost double the inhalation exposure (15.0 $\mu g/m^3$) of the tractor drivers (8.0 $\mu g/m^3$; $p = 0.097$). These associations were not significant but sample sizes were small.

Since tractor/boom application equipment decreases the number of days and number of people required to apply pesticides, it also decreases overall occupational exposure. Monitoring nozzles on booms from a distance rather than on the back of a tractor or boom may decrease or eliminate inhalation exposure. Use of curtain nozzles for herbicide application among backpack sprayers may reduce their inhalation exposure.

Introduction

According to the Pan American Health organization (PAHO, 2002), from 1994 to 2000 the quantity of pesticides imported into the Central American isthmus increased steadily from 34 to 45 million kilograms. This was due to increased herbicide use throughout Central America (PAHO, 2002). In 1992, little or no triazine derivates were imported into Central America. However, by 1998, nearly 600,000 kilograms of triazine derivates were being imported into the Central American isthmus annually (Galvao et al, 2002).

Overall, studies of pesticide exposure and related health effects in Central America have focused on highly toxic pesticides and acute pesticide poisonings, while few have assessed chronic exposure and inhalation exposure during application. Also, most research on health effects of pesticides has taken place in Costa Rica and Nicaragua and little is known about the rest of Central America (Wesseling et al, 2001). Dowling et al (2005) and Rodríguez et al (2006) used urine samples from farmers and family members to assess exposure to the insecticide chlorpyrifos in Nicaragua among small-scale farmers and banana plantation workers. Dermal exposure to chlorpyrifos and methamidophos of 32 farmers in Nicaragua using motorized or manual backpack sprayers was assessed using a fluorescent tracer (Aragón et al, 2006). Pesticide deposition was most frequently observed on the front and back of hands (>87%), the front side of the left forearm (75%), and the back of the trunk (75%). In this study, concerns were raised about drift of pesticide clouds and inhalation exposure, but personal air sampling during pesticide application was not done.

Steinberg et al (1989) used serum pesticide concentrations to assess exposure differences between members of farming cooperatives and a control population because of concern about aerial spraying of pesticides. Keifer et al (1996) studied pesticide drift and environmental exposure among general populations not involved in pesticide application in Nicaragua where aerial application was common. Mean cholinesterase activity levels were significantly lower (indicating more exposure) for residents living near cotton fields than for the control community. The exposure group also reported more chronic and acute symptoms. No exposure studies have focused on the widely used herbicide atrazine in Central America (Wesseling et al, 2005).

There are typically two agricultural seasons in Honduras and these seasons vary by region, crop, and land. The first one is called Primera and for corn production usually runs from May to October. Approximately 80% of the corn in Honduras is produced during this season (personal communication, Aug. 13, 2008). The second corn production season, Postrera, runs from November to March, producing about 20% of the total corn, and yield is approximately 30% lower due to poorer weather conditions.

In 2007, approximately 95,000 acres of corn were planted in the department of Olancho, Honduras (personal communication, Aug. 13, 2008). According to staff at the Regional Secretary of Agriculture and Livestock (SAG – from its initials in Spanish), corn producers in Olancho typically apply 0.9 – 1.3 pounds of atrazine per acre (personal communication, Aug. 13, 2008); atrazine is the most commonly used corn herbicide and this is the application rate recommended by SAG technicians in the field. However, it is possible that farmers are not diluting the pesticide correctly and are applying either a hyper-concentrated solution or a hypo-concentrated solution.

In the commercial pesticide applicator study done in Iowa and discussed in Chapter 2, all of the commercial applicators worked with enclosed cabs and kept the windows closed at all times. Frequently, pesticides were mixed in enclosed systems with little direct contact. Commercial applicators reported that they were only exposed to pesticides when a nozzle clogged on their sprayer or when they were mixing pesticides in the shop. Consequently, it is believed that the primary route of exposure for these applicators was dermal. In Honduras conversely, with the extensive use of backpack sprayers and very few tractors with enclosed cabs, it is likely that dermal and inhalation are both significant routes of exposure. This study aims to quantify the inhalation exposure of Honduran farmers and farm workers to atrazine during the application process. The study identified determinants of inhalation exposure among pesticide applicators and offered strategies to reduce exposures via the inhalation route. While atrazine is the central focus of this study, atrazine can be used as a surrogate for other pesticides routinely applied using the same application methods.

Materials and Methods

This study took place in the department of Olancho, Honduras during the first agricultural season (Primera) from May – July 2009. The study population was a convenience sample. The pesticide applicators were recruited using nine agro-chemical vendors in Juticalpa and staff of the regional Secretary of Agriculture and Livestock (SAG) office, also located in Juticalpa. People who purchased atrazine products from one of the nine agro-chemical vendors were compiled into lists and this was used as a recruitment mechanism. In addition to the lists from the atrazine vendors, a SAG agronomist helped identify areas where corn was produced on a large scale and introduced study personnel to corn farmers in the region. To be eligible for the study, the pesticide applicator had to plan to apply atrazine during the Primera agricultural season. The participant could be either a landowner/corn producer or a hired farm-worker. For logistical reasons, the study population came from approximately a 30-mile radius around Juticalpa, the departmental capital.

Once a participant was enrolled in the study, a field surveyor accompanied the participant on the day that atrazine was applied. Atrazine application methods were observed and a personal inhalation sample was collected. Each participant was equipped with an OSHA Versatile Sampler (OVS-2) sorbent tubes (SKC, Eighty Four, PA) containing XAD-2 resin with an 11 mm quartz fiber filter and polyurethane foam (PUF) (Figure 4.1). A personal sampling pump, calibrated to 1 liter per minute, was attached to the sampling tube and the belt of the applicator. Field observation notes were taken regarding the amount of atrazine applied, number of acres sprayed with atrazine, equipment used, type of spray nozzle used, and clothing worn. Field blanks were collected for quality control purposes. Samples were transported from the field in coolers with ice packs and transferred to a refrigerator for storage. Samples were shipped to Battelle Northwest Laboratory in Columbus, Ohio for analysis.

Figure 4.1 Study participant equipped with OSHA Versatile Sampler (OVS-2) sorbent tubes.

The individual sections of the OVS-2 tube were removed and placed into separate test tubes. The glass fiber filter was included with the front sorbent section of the tube. The foam plugs that separated the sections were discarded. The individual sections were then chemically desorbed using 2 mL of acetonitrile. The samples were capped and placed on a mechanical shaker for 30 minutes. After desorption, the samples were transferred to auto-sampler vials and analyzed by high performance liquid chromatography. Three field blanks were tested and atrazine was not detected in them. Three sets of laboratory control spike (LCSILCSD) pairs were prepared and analyzed with this subsequence. The recoveries were all within the default limits of 80% to 120%. The average recovery was 89.69%. The sample results and blind spikes were recovery-corrected with the average recovery of the LCS pairs. Two blind spikes were prepared and analyzed in replicate with this subsequence. The recoveries were all within the default limits of 80% to 120%. The replicate analyses were all within the 20% relative percent difference limit. The results were reported in micrograms (μg) per sample. The limit of detection (LOD) was 0.1 μg/sample and results that were reported as less than the LOD were give the value 0.05 μg/sample (LOD/2).

A questionnaire was completed with the pesticide applicator and his family during a different visit to the participant's home. The questionnaire contained questions related to pesticides used, quantities used, frequency used, which members of the household worked directly with the pesticides, the type of spray equipment used to apply pesticides, personal protective equipment used, the laundering practices of work clothes, and other general information about the house and agricultural practices (Appendix B).

Data Analysis

Time-weighted averages (TWA) were calculated for each sample using the average of the before and after flow rates and the total minutes during which each sample was taken. Descriptive summary statistics were used to describe the central tendency and variance of each variable measured. Simple linear regression and analysis of variance (ANOVA) were used to determine if atrazine handling and other personal practices influenced the levels of atrazine found in personal air samples. All statistical analyses were performed using SAS system software, version 9.2 (SAS Institute, Inc., Cary, NC). All significance testing was performed at the 0.05 level of significance.

Results

Twenty-nine pesticide applicators and their families filled out the in-home questionnaire. All of the pesticide applicators that participated in the study were male with an average age of 37.6 years (s.d. = 11.6). The average body mass index (BMI) of the applicator was 24.6 with a range from 19.6 – 35.4. The average years of formal education that the pesticide applicator had received was 5.2 (s.d. = 4.3) and 62% of the pesticide applicators reported that they could read and write.

The average age of the pesticide applicators' spouses was 34.3 years (s.d. = 10.7). The average BMI for the applicators' spouses was 29.5 (s.d. = 8.3). The homes that the participants lived in had an average age of 22 years (range: 3-80 years). On average, the participants and their families had lived in the homes for 11.6 years (s.d. = 11.2 years).

Household Information

Of the 29 participants, 7 (24%) said that they had used some type of pesticide at home in the month previous to the interview; 5 (17%) reported fumigation for mosquitoes either done themselves or by the municipality, and 2 (7%) had applied an herbicide to their yard. Also, 12 (41%) reported using an insecticide in the last year: 10 for mosquito control and 2 used a can of Raid™.

Only one participant reported keeping a garden to produce vegetables. One reported eating from their garden and another reported consuming coconuts from their trees. Twenty-one (72%) of the participant families had dogs in the home, but only 7 of them said that their children played with the dogs. Only 9 (31%) of the families had cats and 4 of them said their children played with the cats.

Farming Practices

Manual backpack sprayers were used by 17 (59%) of the participants to apply atrazine and other pesticides while 12 (41%) applied pesticides using a tractor and boom (Figure 4.2). Five of the participants who applied with tractor/boom worked as tractor drivers, five were placed on the side of the boom observing the nozzles and raising and lowering the boom arms, and two observed boom nozzles from the edge of the corn field. Among the participants that used backpack sprayers, ten used conical nozzles to apply atrazine while five used curtain nozzles. Two backpack sprayers were not observed in the field and no air sample was taken, so nozzle type was not recorded.

Figure 4.2 Left: Atrazine application to corn using backpack sprayers. Right: Atrazine application to corn using tractor and boom.

Sixteen participants reported traveling by bicycle from home to the field where they applied pesticides, 8 travelled by their boss's car or tractor, 6 by personal car, 4 walked, and one rode a motorcycle. Some participants reported multiple methods of getting to work and were counted more than once.

Not all of the participants were corn farmers. Many of them worked as hired hands for corn producers carrying out a variety of duties, one of which was pesticide application. This employment was typically on an "as needed" basis. However, some of the participants were fulltime employees of corn producers and received weekly pay regardless of their work hours and duties. Many of the hired pesticide applicators did not own their own land and therefore did not have land where they could produce corn. However, many of these workers were often loaned a small piece of land (approximately 1.5 – 3 acres) by their employer or other community member where they could produce corn. Sometimes this land was lower quality or in a flood plain so corn production was more difficult, the yield was lower, and sometimes there was no yield at all due to flooding. Occasionally the worker was even given corn seed to plant on that land. The corn produced from this land was almost exclusively used for subsistence.

Only 2 of the participants reported having access to a well on or near their corn field. These wells were 13 and 14 meters deep. Another 2 corn fields had access to surface water in the form of small streams, and the remaining 25 (86%) had to haul water on trucks or tractors to the corn field for pesticide mixing.

All but two of the applicators reported buying their pesticides from a licensed vendor and 21 (72%) said that the vendor "always" explained how to use the pesticide product, while 5 (18%) reported they "sometimes" received explanations. All of the pesticide products they purchased had labels. Despite the high percentage of pesticide applicators who received instructions, and the presence of a label, only 18 (62%) reported following these instructions. However, this data is misrepresentative because some participants thought the question referred to using appropriate personal protective equipment while others thought it referred to pesticide dilutions.

Table 4.1 General farming data compared between backpack sprayers and tractor/boom applicators.

Variable	Backpack Sprayers (n=15)	Tractor/Boom Applicators (n=11)	p-value
Years living in current town	33.8	23.5	0.09
Age (years)	38.2	36.6	0.71
Years of Formal Education	3.2	8.0	0.002
Years Farming Corn	16.2	12.9	0.53
Acres of Corn Planted Last Year	2.9	70.5	0.02
Corn Yield Last Year (bushels/acre)	61.1	85	0.38
Corn Used for Household Consumption (bushels)	30.3	33.1	0.84
Corn Sold (bushels)	248	10,547	0.05
Price of Corn Sold (dollars/bushel)	$2.84	$2.38	0.48
Number of years that you have been applying pesticides to your corn	12.5	12.9	0.92
Acres of corn planted during Primera	1.7	54.8	0.004
Acres of corn planted during Postrera	0.4	4.7	0.11
Daily work duration when working in corn field (hours)	5.6	9.4	0.0002

1. This data is based on the 26 participants from whom personal air samples were collected during atrazine application.

In general, women were not very involved in agricultural field work: one participant reported working with a female and 8 (28%) reported that someone under the age of 18 worked with them. Seventy-eight percent of the participants' spouses said that they worked exclusively as housewives. One spouse ran a general store from her home, another sold treats, a third raised pigs and chickens, and another reported that she worked in the field. One reported being a nurse and another reported being a student. Six spouses (21%) reported being involved in agricultural grain production. All six of them reported spreading fertilizer, 3 worked clearing fields with machetes, 2 harvested corn manually, one stripped corn kernels after harvest, one hauled water to the field for her husband to mix pesticides, another brought food to her husband when he was in the field, and one reported applying the insecticide terbufos. Two spouses also reported buying pesticides for their husbands.

Twenty-three (79%) of the pesticide applicators report having another job: 12 do other general farm work like machete clearing and mending fences, 3 are truck drivers, 2 work in construction, and one reported doing each of the following: raising livestock, slaughtering animals, window making, student, and mechanic. Only three (10%) thought that their other jobs involve contact with pesticides: fixing pumps and backpack sprayers, hauling corn and beans, using other types of pesticides to control ticks and other pests, and pesticides used in red bean production.

Pesticide Use and Application

The number of times a pesticide was applied was almost entirely dictated by field conditions. For the most part, corn producers would only apply a pesticide if the target pest was observed. It was rare that they would follow a recommended application schedule in order to prevent pests or weeds from emerging. Anecdotal data suggests this was for economic reasons because many of the participants in this study commented that they did not want to spend money on a pesticide that they did not truly need.

Overall, herbicides were used more frequently than insecticides, and fungicides were not reported as being used by any participants. Atrazine (100%), glyphosate (71%), paraquat (64%), and nicosulfuron (43%) were the most widely used herbicides reported. Insecticides were used much less frequently: lambda-cyhalothroin (32%), cipermetrina

(25%), and carbosulfan (21%). Three of the most widely used insecticides (carbosulfan, carbofuran, and thiodicarb) are used to cure the corn seed before planting (Table 4.2).

About a third of the participants reported checking the direction of the wind before beginning application. However, this practice had no effect on the application method. Atrazine and other pesticides were always applied with the direction of the corn rows. They would never stop spraying in one direction due to the wind. It would be too inefficient for backpack sprayers who would double the distance they walk, and for tractors that would consume twice as much gas. Backpack sprayers reported lowering the height of the spray apparatus when they were spraying into the wind in an effort to reduce spray from getting on their clothing or in their face.

The equipment used to apply atrazine and other pesticides was relatively new (Table 4.3). The booms were slightly older than the backpack sprayers and most of the booms were purchased second-hand in the United States and then brought to Honduras. Backpack sprayers were readily available in Juticalpa and Catacamas, nearby cities. Eleven of 15 backpack sprayers reported cleaning their equipment after applying pesticides and 100% of the boom applicators said that they clean their equipment after each use. Some of the backpack sprayers stated that they do not clean or rinse out their tanks if they were going to spray the same pesticide(s) the next day. All of them reported cleaning their equipment when they switch to a different pesticide, or when they stored it for a long period of time.

Table 4.2 Pesticides used and application methods in agricultural setting in Olancho, Honduras.

Active Ingredient	Class[1]	Number of participants using product	Application Method[2]			Re-Entry Period After Application					Average number of times applied per season
			Backpack Sprayer	Tractor & Boom	Hand[3]	Immediate	1 hour	2-6 hours	Next Day	Longer	
2,4-D	H	9	8	1	0	2				7	1.4
Atrazine	H	28	23	12	0	4	1		3	18	1.1
Profenofos	I	1	1	0	0				1		1
Terbufos	I	1	0	0	1				1		1
Carbofuran	I	4	0	0	4	NA					1
Carbosulfan	I	6	0	0	6	NA					1
Cipermetrina	I	7	6	4	0	4	1		0	2	1.3
Clomazone	H	1	1	1	0		1				1
Deltamethrin	I	1	1	0	0				1		1
Deltamethrin + triazophos	I	4	4	1	0	1				3	1
Glufosinate Ammonium	H	2	2	1	0					2	1
Glyphosate	H	20	15	13	0	6	1		3	10	1.4
Imidaclorprid	I	1	0	0	0						1
Lambda-cyhalothroin	I	9	8	5	0	5			2	2	1.25
Metamidofos	I	2	1	2	0					2	1.5
Nicosulfuron	H	12	10	3	0				3	9	1
Paraquat	H	18	16	3	0	3		1	3	8	1.5
Pendimethalin	H	2	0	2	0					2	1
Picloram + 2,4-D	H	3	2	2	0	3					1
Thiodicarb	I	4	0	0	4	NA					1

1. For class; H = herbicide, I = insecticide
2. Application methods do not always add up to "number of participants using product" because some participants reported using multiple application methods for the same pesticide.
3. The insecticides that are applied by hand are used to cure seed before planting and are mixed onto the corn seed.

Table 4.3 Age of pesticide application equipment and how it performs in the field.

	Backpack Sprayer	Boom Sprayer
Equipment Age		
1-2 years	1	1
2-5 years	11	6
6-10 years	1	2
> 10 years	3	2
Equipment malfunctions in the field		
Yes	9	8
No	8	4
Equipment fails completely during pesticide application		
Always	1	0
Sometimes	13	7
Never	3	4

When asked who mixed and loaded pesticides, and who actually applied pesticides, 90% of the participants reported that they do both of these tasks in the field. There were never any extra mixed pesticides that were brought home. If there was still mixed pesticide product in the equipment when they finished applying to a certain field, they double-applied until they ran out of pesticides. Rarely was there extra bulk or dry product after a day of pesticide application because they calculated how much they needed each day and only brought that amount to the field.

Thirteen (45%) of the participants reported using pesticides for non-agricultural purposes: 10 reported using them for killing weeds in their yard and 3 said that they used pesticides for controlling insects or mice in their home. Eleven (38%) reported that they stored pesticides somewhere in their home and three (10%) of those eleven stated that they have stored pesticides in a bedroom. Backpack sprayers were much more likely to litter pesticide packaging at the point of use than boom applicators ($p=0.04$), while boom applicators were much more likely to burn pesticide packages ($p< 0.001$).

All of the participants reported that they will continue to use pesticides in corn production despite the fact that all of them answered yes to the question, "Do you think that working with pesticides is hazardous to your health?" They reported knowing that pesticides are dangerous chemicals; they had seen other people get poisoned or heard stories, and the labels of the products explain how dangerous they are. When asked why they will continue to use pesticides in corn production, the most common answer was that it is necessary to control the weeds and pests (76%). One participant summarized, "nowadays there are many pests and they are difficult to treat without pesticides." The remaining 24% said that pesticide application is their job; it is how they support their family. For example, "when farmers are hiring people to apply pesticides I get work – it is my job."

Personal Protective Equipment and Hygiene Practices

Hygiene practices did not differ significantly between the backpack sprayer and boom sprayer groups (Table 4.4). Twenty-four (83%) of the participants reported changing their clothes immediately if they became contaminated with pesticides. However, workers never had extra clothes in the field and were often more than 30 minutes away from home during pesticide application. Therefore, the responses to this question seem to refer to changing their clothes when they returned home after they had completed pesticide application that day. Twenty participants reported that a pesticide spill never occurred, and 4 reported it only occurred one time. One worker reported that this occurred 12 times; every time that he worked applying pesticides on a boom. He stated that his clothes were extremely contaminated and damp when he arrived home after a day of applying pesticides.

Table 4.4 Hygiene practices after and during pesticide application compared by applicator type.

Hygiene Practice	Backpack Sprayers (n=17)	Boom Sprayer (n=12)	p-value
Bathe before continuing with other farm work	15	9	0.62
Change into clean clothes	16	11	1.0
Change clothes immediately if contaminated with pesticide	15	9	0.62
Wash your clothes separate from the rest of family	11	7	1.0
Wash your hands before eating	16	12	1.0
Wash your hands before smoking[1]	5	4	1.0
Wash your hands before urinating	3	5	0.23
Remove your shoes before entering your house	11	8	1.0
Uses pesticide application clothes more than once	8	4	0.70

1. 13 participants smoke.

Seventeen (59%) of the pesticide applicators used their work clothes only once before washing them. Of the 12 that reused their work clothes, all of them reused their work pants while only 4 reported reusing their shirts. The clothes items that are not washed every time they are used are washed as needed. All of the worker's clothes were dried by hanging; 93% outside and 7% inside.

Participants were asked a series of questions regarding the frequency of use of clothing and personal protective equipment during pesticide mixing, loading, and application. For each item they could answer one of the following: always, usually, sometimes, or, never. All participants reported that they always wear long pants for these duties. All of the participants reported never using any of the following: respirator, chemical protective clothing, cloth apron, and disposable gloves. Similarly, all participants except for one reported using the following "never:" rubber apron, goggles, clothe or leather gloves, and rubber gloves. Backpack sprayers were significantly more likely to wear long-sleeved shirts and rubber boots (Table 4.5).

Table 4.5 Frequency of use of clothing and personal protective equipment during pesticide application.

Clothing	Backpack Sprayer (n=17)	Boom Sprayer (n=12)	p-value
Long Shirt			
Always	12	2	0.02
Usually	1	4	
Sometimes	2	4	
Never	2	2	
Rubber Boots			
Always	15	1	< 0.0001
Usually	2	0	
Sometimes	0	4	
Never	0	7	

Fifteen (88%) backpack sprayers changed out of their work shoes outside of their house, compared to 8 (67%) tractor and boom applicators (p=0.20). Seven of the 23 pesticide applicators who removed their shoes outside reported bringing their shoes inside after removing them. However, this was usually done after the shoes (typically rubber boots) had been thoroughly washed in the outdoor washbasin.

Health Outcomes

Seventeen (59%) of the 29 pesticide applicators reported that either they or someone they knew had been poisoned with pesticides. There was no statistical difference between backpack sprayers and tractor/boom applicators (Table 4.6). When asked details about how the pesticide poisoning occurred, a wide variety of cases were described. Of these 17 cases, the most common cause of the poisoning was exposure during pesticide application (6). Three different pesticide applicators attributed the poisoning to exposure caused by not using gloves while curing corn seed before or during planting. Three others reported that someone had mistaken mixed pesticides in a reused, 2-liter soda bottle for water and ingested pesticides. Two said that it happened during mixing/loading pesticides and another two thought the cause was eating or smoking in the field without washing hands. Lastly, there was one report of aerial pesticide application and someone on the ground getting doused with pesticides. Here is one account, "about 8 years ago corn seed had to be cured and they were planting the corn. [The farmer's] helper was touching the [treated] corn seed too much without gloves and he experienced headaches and vomiting."

There were 16 responses about how the person who was poisoned with pesticides was treated. Ten reported that the person was taken to a hospital or private clinic, 5 said that the person was given milk to drink, and one said that nothing was done; they simply waited for the symptoms to pass. While many of the pesticide poisoned people visited the hospital, none of them were hospitalized.

When asked where they would seek treatment in the case of an accidental poisoning, all participants responded they would seek medical attention in a hospital or health center. Zero participants responded that they would seek treatment at a traditional healer and none indicated that they would use home remedies. They preferred to seek treatment at a hospital or health center because generally they trust hospitals more, hospital staff is better trained and more equipped than traditional healers, treatment is better, they would receive faster attention and treatment, and hospitals have doctors. One answer was, "if it is a serious poisoning then the hospital, but if I just have some minor symptoms then I tell my wife to buy some milk and I drink it warm or hot."

Table 4.6 Responses to the question, "in the last 12 months have you had any of the following symptoms while applying pesticides or after applying pesticides to your field?"

Variable	Backpack Sprayer (n=17)	Boom Sprayer (n=12)	Total Responding Yes (%)	p-value
You or someone you know every had a pesticide poisoning	11	6	17 (59%)	0.47
Headache or Dizziness	7	7	14 (48%)	0.46
Nausea or Vomiting	1	0	1 (3%)	1.0
Eye Irritation	8	8	16 (55%)	0.45
Eye Tearing	7	6	13 (45%)	0.72
Tightness in Chest	5	2	7 (24%)	0.66
Difficulty Breathing	4	2	6 (21%)	1.0
Difficulty Walking	2	1	3 (10%)	1.0
Blurred or Double Vision	6	3	9 (31%)	0.69
Drooling	1	2	3 (10%)	0.55
Twitching of Arms or Legs	9	6	15 (52%)	1.0
Fainted	0	0	0	NA
Convulsions	1	0	1 (3%)	1.0
Skin Irritation	12	6	18 (62%)	0.44

Field Observations & Personal Air Samples

During the in-home surveys the backpack sprayers reported that they used long-sleeved shirts more often than tractor/boom applicators. However, this was not observed during the field observations. Backpack sprayers reported wearing rubber boots "always" more often than boom sprayers. The information given in the questionnaire regarding wearing rubber boots coincided with the observations during the field visits (Table 4.7).

Table 4.7 Observed clothing in the field during atrazine application

Pesticide Application Clothing	Backpack Sprayer (n=15)	Boom Sprayer (n=7)	p-value
Footwear			
Rubber Boots	12	1	0.007
Other Boots or Shoes	3	6	
Leg Wear			
Pants	15	6	0.32
Coveralls	0	1	
Shirt			
Short Sleeve	10	4	1.0
Long Sleeve	5	3	
Head Wear			
Wide brim hat	4	1	1.0
Other[2]	11	6	

1. n=22 due to missing data points; backpack sprayer = 15, tractor/boom = 7.
2. One of the 17 participants labeled as "other" for head wear was observed with no hat during atrazine application. This person was a boom operator and sat on the tractor wheel cover of a tractor with a roof for shade so he had some protection from the sun. The other 16 participants were observed wearing baseball caps.

Twenty-six personal air samples were taken from the 29 participants while they applied atrazine. All of the field blanks were below the analytical limit of detection. There were 15 participants who applied atrazine with a backpack sprayer and 11 that applied with a tractor/boom. Of the 15 using backpack sprayers, 10 were observed using conical nozzles for application, while the other 5 used curtain nozzles. One of the backpack sprayer participants did not spray atrazine the day of the sampling but was in the same field as other study participants who applied atrazine, so he was included in the analysis. Five of the participants on the tractor/boom were tractor drivers, another five were observers who rode on the back of the tractor or on the boom. One of the participants observed the tractor/boom application from the edge of the field and was not included in the analysis.

Atrazine was always mixed in the field while some other pesticides were mixed before going to the field. In some cases other pesticides were added to the tank and applied simultaneously with atrazine. Water was most often hauled to the field from far away. There were a few fields where water was available nearby in the form of a small stream. Atrazine was mixed with water in a 5-gallon bucket to dissolve it and then added to either the backpack sprayer tank or boom tank (Figure 4.3). No one used gloves when pesticide mixing was observed. All mixers except one were observed using a stick to mix the atrazine solution in a 5-gallon bucket; the other used his hand. When the atrazine solution was added to the boom tank and then water was added to fill the rest of the tank and dilute the solution, large amounts of foam were produced. Many participants were seen removing this foam with their bare hands (Figure 4.3).

Figure 4.3 Top left: A sardine can was the unit of measurement for atrazine mixing for backpack sprayers. Top right: Mixing atrazine in a 5-gallon bucket for tractor/boom application. Bottom: Applicator removing foam formed from atrazine solution with his bare hand; water hauled to field in pickup truck; a 14 year-old boy hauled the water in the truck and helped mix atrazine

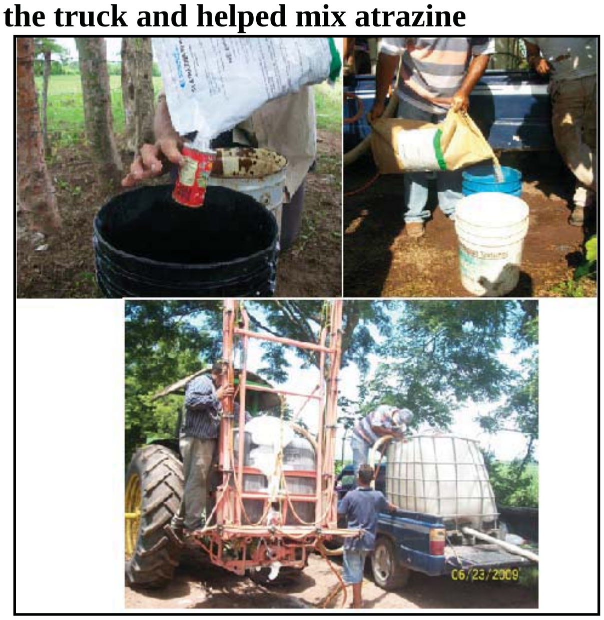


Table 4.8 compares atrazine handling and inhalation exposure between backpack sprayers and tractor/boom applicators. During sampling the backpack sprayers applied atrazine to about one tenth the number of acres, applied less than 10% of atrazine by weight, and applied about 35% less atrazine per acre than tractor/boom applicators. Despite using only 1/15 of atrazine by weight, backpack sprayers had almost the same amount of potential air exposure as tractor/boom applicators (p=0.30).

Table 4.8 Personal air sampling done during atrazine application to corn fields.

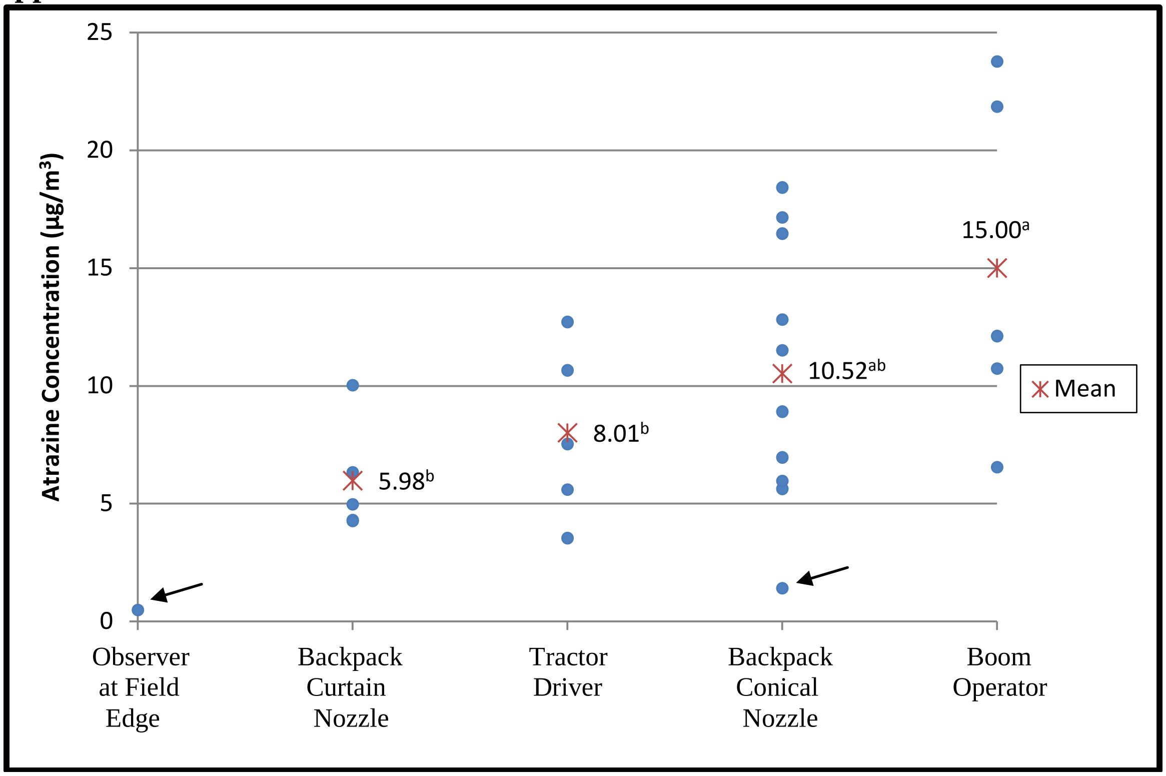
Variable	Central Tendency	Backpack Sprayers (n=15)	Tractor/Boom Applicators (n=10)	p-value
Acres applied during air sampling	Mean S.D. (Range)	2.4 0.76 (1.4-3.4)	24.4 15.5 (5.2-48.2)	<0.0001
Atrazine applied during air sampling (grams)	Mean S.D. (Range)	884 420 (0-1,606)	13,805 10,173 (2,850-30,000)	<0.0001
Pounds of atrazine applied per acre	Mean S.D. (Range)	0.926 0.33 (0.64-1.49)	1.29 0.52 (0.88-2.10)	0.047
Mean atrazine exposure ($\mu g/m^3$)	Mean S.D. (Range)	9.0 5.2 (1.4-18.4)	11.5 6.7 (3.5-23.8)	0.30

While there was not a large difference between backpack sprayers and tractor/boom applicators, there were associations within each group that provide insight into potential inhalation exposure (Figure 4.4). Among backpack sprayers, those who applied atrazine with a conical nozzle had almost twice as much exposure (mean=10.52 $\mu g/m^3$) compared to applicators using curtain nozzles (mean=5.98 $\mu g/m^3$; p = 0.115). The lowest time-weighted average (TWA) for backpack sprayers with conical nozzles was 1.41$\mu g/m^3$. This participant did not actually apply atrazine but was in the field with four other atrazine applying participants. When this participant is removed from the analysis, the average TWA for backpack sprayers that used conical nozzle increased to 11.54 µg/m^3, which is significantly higher than curtain nozzle backpack sprayers ($p=0.04$). Within the group of applicators who used tractor/boom, workers that were either on the boom or on the back of the tractor had almost double (mean=15.0 µg/m^3) the exposure of the tractor drivers (mean=8.0 µg/m^3; $p = 0.097$).

Boom operators were the highest risk group because they worked in close proximity to pesticide application booms where large quantities of pesticides were sprayed. Efforts to reduce their exposure are needed the most. Despite driving a tractor that pulled a boom that applied on average 15 times more atrazine, tractor drivers had less inhalation exposure than backpack sprayers using conical nozzles. It appears that pesticide applicators that used a backpack sprayer with a curtain nozzle had the lowest risk for inhalation exposure. The boom observer that stayed at the edge of the field was the only sample that was below the limit of detection.

Lastly, regression analysis showed that there was no significant association between personal air sampling atrazine concentrations and atrazine handling variables such as acres applied with atrazine, pounds of atrazine applied, and number of tanks of atrazine applied.

Figure 4.4 Personal air sampling atrazine concentrations by category of pesticide application.



1. Mean atrazine concentrations with the same letter are not significantly different at p=0.05.

Discussion

This study shows that in Honduras, the inhalation exposure risk for atrazine applicators depended more on how atrazine was applied than the quantity of atrazine applied. Atrazine handling variables were not associated with time-weighted average inhalation exposures, but nozzle type for backpack sprayers, and job duties for tractor/boom applicators did affect exposure levels.

Curtain nozzles spray pesticide mixtures in droplets in a 2-dimensional curtain and are designed to help create a film over the entire soil surface. According to an agronomist that worked with the regional SAG office in Juticalpa, curtain nozzles are recommended for herbicide application because they are more effective at creating a film of herbicide over the entire ground surface. Conical nozzles spray pesticide mixtures in a cone-shaped, 3-dimensional form and are not recommended for herbicide application. They create more of a pesticide mist and are designed for targeted spraying which is more ideal for insecticides and fungicides. Despite these recommendations, two-thirds of the backpack sprayer participants were observed using a conical nozzle to apply atrazine. During field observations, pesticide applicators with conical nozzles were seen swinging their arm and spray apparatus back and forth in order to create the desired herbicide film. This appears to cause the inhalation, and likely the dermal, exposure to be greater for these applicators. Backpack sprayers using curtain nozzles were observed holding their spray apparatus and nozzle steady at a fixed height in order to get the best results.

It is recommended that the boom operator observe the boom spraying apparatus from a distance whenever conditions allow. One of the boom monitors observed the atrazine application from the edge of the corn field rather than mounted on the boom or the back of the tractor. While this was only one participant, his time-weighted average exposure level was below the analytical limit of detection and much lower than all other participants. Intuition indicates that removing the worker from the boom area is the most effective way to reduce inhalation exposure. However, observing from a distance is not always possible. The one participant that did observe from the side of the corn field observed application to a field where the corn had not germinated. Also, Prowl, a herbicide with a yellow color, was mixed with atrazine. These two factors made it easier to observe from a distance because corn plants were not blocking his line of sight and the yellow color made seeing a malfunctioning nozzle easier. Other tractor and boom applications that were observed required that the worker be mounted on the boom for one of two reasons: 1) the corn plant was too tall and a malfunctioning nozzle could not be spotted from a distance; or, 2) the boom arms needed to be manually raised frequently to turn the tractor or due to obstacles in the field. Therefore, when a worker must be mounted on the boom, it is recommended that the worker use long pants and long shirts at all times, and also use a handkerchief or mask to reduce inhalation exposure.

Backpack spraying will continue to be a very large part of pesticide application in Honduras for many years due to the high cost of tractor/boom application and terrain. Therefore, it is necessary that backpack sprayers use the correct nozzle for the pesticide being sprayed. However, workers sometimes do not own their own backpack sprayer and cannot control which kind of nozzle is in place. Nor do they have enough money to purchase the recommended nozzle for each pesticide application. Nozzles are typically only available at agronomy stores in larger towns or cities that can be up to two hours away by bus. The Secretary of Agriculture and Livestock operates many agricultural extension programs to education farmers and provide seeds. A new program to educate about proper nozzle usage and provide nozzles to pesticide applicators may greatly decrease inhalation (and likely dermal) exposure to hazardous pesticide. Using the correct nozzle would also increase the pesticide efficiency and probably the yield.

It is interesting that chapters 2 and 3 demonstrated that atrazine handling is the most important risk factor for predicting in-home atrazine dust concentrations. The more atrazine handled, the more gets on the worker’s clothes and person, and more atrazine gets taken home. However, this study’s findings indicate that direct inhalation exposure of atrazine, at least in Honduras, depends more on application methods rather than the quantity of atrazine handled.

Aragón et al (2001) reported that the educational level of independent farmers in the Northern Pacific Plain of Nicaragua is not higher than primary school and their illiteracy rate is 40.3%. This is similar to the participants in this study whose average formal education was 5.2 years and 38% self-reported that they cannot read or write. Similar to Honduras, Nicaragua imports basic grains to meet the demand for domestic consumption (Aragón et al, 2001).

There are similarities and differences between the study done by Aragón et al (2001) in Nicaragua and this study. In both studies, pesticides were mostly purchased in retail chemical stores, pesticide applicators were observed repairing backpack sprayers and touching the nozzles with their bare hands (Figure 4.5). Similarly, farmers in Nicaragua and Honduras stated that they were aware of the risks involved with pesticide exposure, but that is not demonstrated by their practices. The sentiment that pesticides are a necessary ingredient to successful farming was prominent in both studies. Aragón reports that pesticides are stored in one-room homes, sometimes under the family bed, and empty pesticide containers are used to store water or food in homes. This was not the case in Honduras, were pesticides were rarely stored in the homes and containers were never used for water or food storage. This could be due to the fact that plastic-ware is now widely available in Central America and may not have been 10-11 years ago in Nicaragua when Aragón's study was carried out. Also, in Honduras, rubber boots were worn frequently while they were worn rarely in Nicaragua (Aragón et al, 2001).

Figure 4.5 Dismantling and repairing the nozzle of a backpack sprayer that had become clogged because of debris in the water.

According to Cantor & Young-Holt (2002), a survey published in 1982 in Central America found that 64% of farmers used no protection when applying pesticides. While "no protection" was not defined, mask, rubber gloves, rubber boots, rubber apron, and a waterproof hat or helmet were mentioned. In the current study, 55% of the participants always wore rubber boots when applying pesticides and only 24% reported that they never wear rubber boots. It appears that wearing rubber boots during pesticide application has increased in the last 30 years. This is a significant improvement of protection against pesticide exposure due to the fact that backpack sprayers walk through the area they just sprayed.

Gramoxone (paraquat) was reportedly used by 94% of farming households in Santa Barbara, Honduras (Cantor & Young-Holt, 2002). This compares to only 62% in the current study. In Santa Barbara, 16.7% of the participating families reused pesticide containers to store water compared to none in this study. This could be attributed to education and outreach efforts as well as the fact that most pesticide containers today are plastic bags instead of large plastic jugs.

Backpack sprayers were more likely to use rubber boots and take their shoes off outside when they return home from applying pesticides. While there was more potential for them to bring pesticides home on their boots, they may have actually brought less into the home because their boots were usually washed outside in the washbasin before being brought inside. While this could reduce pesticide contamination in the home, it could greatly increase the exposure of the person who washes the boots; most often the spouse or daughter.

A study assessing exposure to herbicides among pesticide applicators along electric power transmission line right-of-ways observed that using hand-held application equipment is more liable to result in exposure than other application methods (Libich et al., 1984). The present study showed that using backpack sprayers did not increase inhalation exposure to atrazine in agricultural herbicide application in Honduras. However, despite using much less product, backpack sprayers were exposed to almost the same amount of atrazine via inhalation and most likely have an increased risk for dermal exposure due to their proximity to the pesticide mist during application. Some boom operators also reported their clothes being soaked in pesticide after applying all day, indicating high risk for dermal exposure. There also appears to be an increased risk for dermal exposure during atrazine mixing.

Atrazine may serve as a surrogate for other pesticides. For example, work practice and hygienic factors found to be associated with atrazine in inhalation samples are likely to also be associated with exposure to other similarly handled and applied pesticides. Therefore, interventions developed from the results of this study to control risk factors of exposure to atrazine could also control exposure to other pesticides.

Wesseling et al (2001) recommend that strategies to control pesticide exposure should focus on eliminating or reducing the use of pesticides rather than training and supplying personal protective equipment. This is consistent with findings in Aragón et al (2001) and this study, which showed that despite knowledge of the risks of pesticide exposure, pesticide applicators rarely change their behaviors. However, this study shows that there are differences in exposure depending on equipment used and as long as pesticides are part of agriculture, training applicators to use appropriate equipment may reduce exposure.

Conclusion

Boom pesticide applicators were not at an increased risk for inhalation exposure of atrazine compared to backpack sprayers. However, workers who rode on the boom or the back of the tractor had increased risk of inhalation exposure compared to the tractor drivers and backpack sprayers who used curtain nozzles. Backpack sprayers who used recommended curtain nozzles to apply atrazine had a significantly lower inhalation exposure compared to backpack sprayers who applied atrazine with conical nozzles, and boom operators.

The recent introduction of boom application has reduced pesticide exposure to applicators because they can apply more and are further removed from the spraying apparatus. However, boom operators have the highest risk for inhalation exposure (and likely dermal exposure) and interventions should target this population accordingly. Tractor/boom technologies are only available to wealthier farmers in Honduras. The working poor who apply pesticides are disproportionally exposed to greater quantities of pesticides due to the continued use of backpack sprayers and the fact that it takes more man-hours to spray the same number of acres with a backpack sprayer than with a tractor and boom.

CHAPTER 5

CONCLUSION

The studies presented in this dissertation have provided valuable information regarding in-home atrazine levels in Iowa homes and inhalation exposure to atrazine during application in Honduras and other developing countries where similar application methods are employed. The findings have population based public health implications and also point in the direction of needed follow-up research.

High levels of atrazine contamination in the homes of commercial pesticide applicators, and the distribution pattern of atrazine throughout the home, indicated that the pesticide take-home pathway among this population is prevalent. Atrazine persisted in the homes of commercial applicators at least six months and only reduced by a factor of five between sampling visits. In Golla's study of farm homes the levels reduced by a factor of 10 over the same period.

Among commercial applicators, changing out of work shoes outside of the home had a protective effect against high atrazine levels in the home. This association is actually opposite in the study of farm homes by Golla (2007). When this determinant was analyzed in the study that combined three data sets, the opposite trends cancelled out and there was no association. Further analysis discovered that 'pounds' and 'acres' were significantly associated with where the applicator was removing work shoes. This finding provided further evidence that atrazine usage is the key determinant and also brings to light the debate about if shoes or clothes carried more pesticides on them. This evidence suggests that shoes may not be as important, indicating that clothes could be a larger carrier.

A study to evaluate the effectiveness of an intervention encouraging commercial applicators to change work clothes and shoes at work is a good idea but would be difficult to implement. During pesticide application season farmers and commercial applicators alike work long and hard hours. When fields are planted dictate when certain pesticides need to be applied and field conditions determine when they can apply pesticides. They often work 12-14 hour days finishing when it is dark and late. It is unlikely that commercial applicators would be willing to travel back to their shop to change the work clothes and shoes, and then go home. They are exhausted and usually go straight home from the field. Farmers might be more willing to change outside in their barn or garage because it does not make them get home any later. Holding focus groups with commercial applicators to determine what interventions could be effective is an essential step before any intervention study is carried out.

Combining data from three studies helped clarify and reiterate just how important atrazine usage is as a determinant. Increased atrazine usage is the reason that commercial applicators have significantly higher levels of atrazine in their home. Nearly all other variables that appeared to have associations with household contamination were explained by atrazine usage when looked at closely.

Farmers that do not apply atrazine to their own crops have lower contamination in their home. Hiring out pesticide application appears to be an effective way for farmers to reduce potential personal and family exposure. However, by doing this they merely transfer the take-home exposure issue to different, albeit fewer, homes.

An alternative hypothesis before the commercial pesticide applicator field study began was that despite using more atrazine product, commercial applicators would have similar or lower in-home levels due to safer work practices. These studies showed that commercial applicators used only enclosed cabs with filtered air-conditioning while many farmers were using tractors with open, or no cabs. Also, anecdotal evidence from commercial applicators suggested that many of their companies use computerized instruments for mixing pesticide orders to reduce contact with pesticides. This alternative hypothesis was proven wrong.

Findings from the field study done in Honduras provide trends for pesticide usage and exposure and specific findings about occupational exposure in developing country agricultural settings. Findings indicate that in Honduras, using pesticide containers for storing food and water rarely occurred. This is likely due to the way many pesticides are packaged and the ubiquitous nature of plastic water bottles in Honduras. Many more pesticide applicators are wearing rubber boots than earlier studies in Central America indicated. This study reported about a third less people using paraquat compared to another study done in Honduras and published in 2002. The other study was done in western Honduras so this could be a regional effect or a temporal one. Since 2002 the availability of less toxic, yet effective herbicides has increased.

The equipment used to apply atrazine in Honduras is less associated with inhalation exposure than type of nozzle used among backpack sprayers and job duties among tractor/boom applicators. Consequently, backpack sprayers need to be educated about which nozzle is appropriate for which pesticide so that inhalation exposure can be decreased. For the most part these are poor farm workers and therefore the provision of appropriate nozzles, and not just education about nozzle selection, is necessary. Workers who ride on the boom or the back of the tractor should be targeted by educational campaigns that stress what clothes to wear while applying pesticides and what inexpensive personal protective equipment could be effective in reducing exposure. The Honduran Secretary of Health and the Secretary of Agriculture and Livestock have a common interest in protecting the health of farmers and farm workers and should collaborate in these efforts.

Study Strengths

One of the strengths of the commercial pesticide applicator study is that is used a protocol that had been implemented in two previous studies. The survey was modified to improve the data gathered from participants. The usage variable for the number of pounds of atrazine handled was improved by using the percent of active ingredient obtained from the Iowa Department of Agriculture and Land Stewardship online pesticide registration database. Also, the study filled a gap by addressing a population that had the potential to be the highest risk population.

Replication of the sampling protocol during both atrazine application season and six months later in the winter months validated the findings from Golla (2007). Recruitment for the Iowa commercial pesticide applicator study was carried out in a systematic, randomized approach and this helped recruit a sample population from 16 different counties, making the findings more generalizable.

Combining the raw datasets from three studies that essentially used the same protocol created a larger database to work with. The process went well beyond a meta-analysis and three small pilot studies morphed into a study with 100 households and more than 350 dust samples. This process allowed questionable variables from the pilot studies to be verified or nullified.

The field study in Honduras collected personal air samples during atrazine application. Articles on personal air samples taken during pesticide application in developing countries could not be found. Even though dermal exposure is thought to be the more critical route for pesticide application, the findings shed light on an important part of exposure assessment.

Study Limitations

One of the weaknesses of the field study carried out in Iowa was that it was done during the summer of 2008 when much of eastern Iowa flooded. Field conditions were very different from ‘typical’ years and commercial applicators were even busier than usual. This resulted in many refusals to participate in the study. Also, it is estimated that as much as 8% of the corn crop was lost that year due to the floods. However, most of the atrazine application happened before the flood so commercial applicators still applied atrazine. In fact, some of the corn was replanted so it is possible that they applied more atrazine than they would have in a normal year.

Both the Iowa and Honduras studies were small pilot studies with very limited funding. As a result, comprehensive sampling was not done. Urine samples were collected in both studies but analysis was not expedited due to the analysis being done in-kind. A second round of urine sampling was planned for Honduras but this did not happen due to the lack of funding to pay for the samples that would have been collected. It was planned to sample water that each household consumes in order to determine if family members were being exposed to atrazine through their water. The atrazine analysis kit was brought to Honduras but the laboratory in Honduras did not have the correct plate reader to be able to perform this analysis.

Recommendations

When considering policy or outreach interventions it is crucial to consider your target audience. Private farmers are very different from commercial pesticide applicators and interventions aimed at these two groups would have to be tailored to each population. In general, commercial applications companies and applicators should be easier to regulate with policy than farmers.

Future research should include further exploration of the difference between atrazine concentration and atrazine loading in dust samples collected in homes. Specifically, is one or the other more predictive of atrazine metabolites in the urine of children? The question about which metric is more correlated to urine metabolites (if either is correlated at all) is more important to young children who spend more time on the floor and have increased hand-to-mouth activity,

When possible, the worker who observes the nozzles on the boom should make an effort to get as far away from the boom as possible. Many workers were observed standing on the boom and this resulted in a two-fold increase in inhalation exposure for these workers compared to tractor drivers. Sitting on the tractor would help but the best option would be to observe from the edge of the field or walk along with the tractor, trying to stay upwind and in the part of the field that has not been sprayed.

Backpack sprayers and their employers should make efforts to use the recommended nozzle for the pesticide they are applying for increased pesticide effectiveness and possible reduced inhalation exposure. Also, disposable latex gloves in the field could be an important piece of personal protective equipment so that when nozzles need maintenance, there is a barrier between the applicator's hands and the pesticide/nozzle. Too many researchers from developed countries want to educate pesticide applicators and provided PPE and claim success. It is essential that any intervention that is implemented is evaluated to see if it is having the desired effect.

The increased availability of tractors and boom applicators in Honduras is decreasing overall exposure. Exposure per time unit is the same between backpack sprayers and tractor/boom operators. However, tractor/boom operators can apply to more acres in less time and also with less people. The financial barriers to using a tractor are significant and the introduction of developed world farming technologies like transgenic seed corn and mechanized planting, pesticide application, and harvesting will only increase the disparities between wealthy and poor farmers.

APPENDIX A

COMMERCIAL PESTICIDE APPLICATOR EXPOSURE STUDY

PARTICIPANT INTERVIEW

Participant Interview

Part I. Parental or Guardian Information (to be asked to each parent or guardian)

Name: ____

Home ID #: ________________ Subject ID #: ________________

Date: ______/______/______(Month/ Day/Year) Interviewer: ______________

What is the applicator's date of birth? ____/ ____/ ____ (Month Day Year) Age_____

What is the spouses date of birth? ____ /____/____ (Month Day Year) Age _____

What is the applicators height?__________ Weight?__________

What is the spouse's height? __________ Weight?__________

Interviewer: Please note the sex of the applicator and the spouse:

Applicator: Male____ Female____ Spouse: Male____ Female____

Spouse Work Questions:

What is the current job of the spouse?_________________________________

Does the spouse carry out any farm related work? Yes____ No____

(i.e. any work directly involved in farm production)

If yes, please describe ____

____

____

Does the spouse do any work that involves handling pesticides? Yes____ No____

If yes, please describe ____

____

____

Applicator Work Questions:

Which months of the year does the applicator work applying pesticides?

____

Does the applicator have other jobs during the year? Yes____ No____

If yes, what jobs are those? ____

Do any of those jobs involve contact with pesticides? Yes____ No____

If yes, which jobs involve contact with pesticides? _________________________

____

Does the applicator carry out any farm related work?

Yes____ No____ (i.e. any work directly involved in farm production)

If so please describe ____

____

____

Some of the questions we will be asking you relate to commercial pesticide application while others relate to care of the home and the children. In order to minimize the burden of asking questions to both members in the family, we would like you to designate a primary respondent for each of these areas. This of course should be the person who you feel is most knowledgeable.

Commercial pesticide application: Myself____ Spouse:____

Home and child care: Myself____ Spouse:____

Part II. Information About Children

Part A.

How many children are living in your home?_____________________

List their names and ages:

Name	Age	Sex	Birth date	Wight (lbs)	Height (ft, in)

Section B (To be filled out for each child participating in the study).

Child 1

Name of child: ____

Subject ID #: ________________

On a typical spring or summer day, how many hours does the child spend:

Indoors?____________ Outdoors?____________

When indoors, where does he/she play most often?

Bedroom ____ Living/family room____ Kitchen____ Laundry area____

Play room (if any)____ Other__________________________________

How much time does he/she spend in the:

Bedroom: None____ 1-4 hrs ____ 5-8 hrs____ 9-12 hrs ____ More than 12 hrs____

Living/family room: None____ 1-4 hrs ____ 5-8 hrs____ 9-12 hrs ____

More than 12 hrs____

Kitchen: None____ 1-4 hrs ____ 5-8 hrs____ 9-12 hrs ____ More than 12 hrs____

Laundry area: None____ 1-4 hrs ____ 5-8 hrs____ 9-12 hrs ____

More than 12 hrs____

Play room (if any): None____ 1-4 hrs ____ 5-8 hrs____ 9-12 hrs ____

More than 12 hrs____

When outdoors, where does he/she play most often?____________________________

How many hours are spent here on an average day?___________

Does the child play in crop fields? Yes______ No_______

Is the child involved in any farm chores? Yes______ No______

If yes, please describe:____

____

____

Does the child handle or apply pesticides? Yes______ No_______

If yes, what does your child wear when handling pesticides?____________________

____

____

If yes, where does your child change out of work clothes? ______________________

____

____

Does the child live with you all of the time? Yes_____ No______

If not how many days since pesticide applications began has he/she resided elsewhere?

____

Does your child go to school? Yes_____ No______

If yes, how many hours/day? _____________

If yes, how many days per week? _______________

Is school still in session? Yes______ No_______

If no, when did the school year end?_____________

If yes, how many days has your child been at school since pesticide applications began? _____________

Does your child attend daycare or go to a private home for childcare on a regular basis? Yes_____ No______

If yes, how many hours per day?____________

If yes, how many days per week?____________

Is it a private residence or commercial daycare facility? ______________________

Has he/she done this since pesticide applications began? Yes______ No______

If yes, how many days has your child been at daycare since pesticide applications began? _____________

Child 2

Name of child: ____

Subject ID #: ________________

On a typical spring or summer day, how many hours does the child spend:

Indoors?____________ Outdoors?____________

When indoors, where does he/she play most often?

Bedroom ____ Living/family room____ Kitchen____ Laundry area____

Play room (if any)____ Other__________________________________

How much time does he/she spend in the:

Bedroom: None____ 1-4 hrs ____ 5-8 hrs____ 9-12 hrs ____ More than 12 hrs____

Living/family room: None____ 1-4 hrs ____ 5-8 hrs____ 9-12 hrs ____

More than 12 hrs____

Kitchen: None____ 1-4 hrs ____ 5-8 hrs____ 9-12 hrs ____ More than 12 hrs____

Laundry area: None____ 1-4 hrs ____ 5-8 hrs____ 9-12 hrs ____

More than 12 hrs____

Play room (if any): None____ 1-4 hrs ____ 5-8 hrs____ 9-12 hrs ____

More than 12 hrs____

When outdoors, where does he/she play most often?___________________________

How many hours are spent here on an average day?___________

Does the child play in crop fields? Yes______ No_______

Is the child involved in any farm chores? Yes______ No______

If yes, please describe:____

____

____

Does the child handle or apply pesticides? Yes______ No_______

If yes, what does your child wear when handling pesticides?____________________

____

____

If yes, where does your child change out of work clothes? ______________________

____

____

Does the child live with you all of the time? Yes_____ No______

If not how many days since pesticide applications began has he/she resided elsewhere?

____

Does your child go to school? Yes_____ No______

If yes, how many hours/day? _____________

If yes, how many days per week? _______________

Is school still in session? Yes______ No_______

If no, when did the school year end?_____________

If yes, how many days has your child been at school since pesticide applications began? _____________

Does your child attend daycare or go to a private home for childcare on a regular basis?

Yes_____ No______

If yes, how many hours per day?____________

If yes, how many days per week?____________

Is it a private residence or commercial daycare facility? ______________________

Has he/she done this since pesticide applications began? Yes______ No______

If yes, how many days has your child been at daycare since pesticide applications began? ______________

Part III. Household Information (to be asked to the parents or guardians)

What year did you move into this home? _____________

What year was this home constructed? _____________

How close is this home to crop fields? _____________

Do you have a door mat for your outside doors? Yes_____ No______

If yes, record which doors: Front door ____ Back door _____ Garage door ____

Other door (specify) ____

Home Pesticide/Insecticide Questions

Have insecticides been applied in this home in the last month:

Professionally? Yes ____ No ____ Don't know ____

Personally? Yes ____ No ____ Don't know ____

If yes which insecticide(s) were used? ____

____

Have insecticides been applied in this home in the last 12 month:

Professionally? Yes ____ No ____ Don't know ____

Personally? Yes ____ No ____ Don't know ____

If yes which insecticide(s) were used? ____

____

Has your lawn been treated with pesticides (insecticides, herbicides, or fungicides) in the last month:

Professionally? Yes ____ No ____ Don't know ____

Personally? Yes ____ No ____ Don't know ____

If yes which pesticide(s) were used? ____

____

Has your lawn been treated with pesticides (insecticides, herbicides, or fungicides) in the last 12 months:

Professionally? Yes ____ No ____ Don't know ____

Personally? Yes ____ No ____ Don't know ____

If yes which pesticide(s) were used? ______________________________________

____

Do you have a garden? Yes____ No_____

If yes, has your garden been sprayed with pesticides (insecticides, herbicides, or fungicides) in the last month:

Professionally? Yes ____ No ____ Don't know ____

Personally? Yes ____ No ____ Don't know ____

If yes, which pesticide(s) were used ____

____

Has your garden been sprayed with pesticides (insecticides, herbicides, or fungicides) in the last 12 months:

Professionally? Yes ____ No ____ Don’t know ____

Personally? Yes ____ No ____ Don’t know ____

If yes which pesticide(s) were used? ____

____

Do you consume food from the garden? Yes_______ No__________

If yes, have you consumed food from the garden in the last month? Yes___ No___

Floor Cleaning Questions

How often do you mop or vacuum your floors in the family room/living room?

Less than once a month____ Once a month____ Twice a month____

Once a week____ More than once a week____

How often do you mop or vacuum your floors in the entryway?

Less than once a month____ Once a month____ Twice a month____

Once a week____ More than once a week____

How often do you mop or vacuum your floors in the kitchen?

Less than once a month____ Once a month____ Twice a month____

Once a week____ More than once a week____

How often do you mop or vacuum your floors in the laundry room/pesticide applicator changing area?

Less than once a month____ Once a month____ Twice a month____

Once a week____ More than once a week____

Pesticide Applicator Clothes Questions

Where does the applicator change out of their work clothes?

____

If the applicator changes outside the home, do they bring your work clothes in the home?

Yes______ No_______

Where does the applicator change out their work shoes?

____

If the applicator changes their shoes outside the home, do they bring their work shoes into the home? Yes______ No______

Are the work clothes of the applicator laundered separately from the rest of your family's clothes? Yes ____ No ____

If yes, is a separate washer and dryer used for the work clothes? Yes____ No____

Are all of the applicator's work clothes washed every day that the applicator wears them? (Including jackets, cloth gloves and cloth coveralls) Yes___ No___

If no, which clothes are not washed every time? _____________________________

When are those clothes washed?

End of the week___ End of the season___ As needed____ Never____

What temperature are the applicator's clothes washed in?

Cold___ Hot___ Warm___

How are the applicator's clothes dried?

Hung outside___ Dried in a dryer___ Hung inside___

Pet Questions

Do you have a dog? Yes_____ No_____

If yes: Does your dog spend time both indoors and outdoors? Yes____ No____

Do your children play with the dog? Yes_____ No_____

Do you have a cat? Yes_____ No_____

If yes: Does your cat spend time both indoors and outdoors? Yes____ No____

Do your children play with the cat? Yes_____ No_____

Part. IV Pesticide Application Information

(To be asked to the person living in the household who is the commercial applicator)

When was the last time you applied atrazine? _____________________

When you apply atrazine, who mixes and loads the atrazine?

Yourself____ Other worker____

When you apply atrazine, who applies the pesticide?

Yourself____ Other worker____

What kind of application equipment do you use?

Aerial____ Groundboom____ Other (please describe)______________________

____

How many times this year have you had a pesticide containing atrazine spill or splash on yourself such that you had to change clothes?_______________________________

Cab Questions

Do you have a closed (ie. completely closed with air conditioning) or open cab?

Yes_____ No _____

If yes, how often do you drive with the window open in the cab? ________________

If yes, is there a filter on the air intake for the air conditioning?

Yes_____ No_____ Don't know______

If yes, when was the last time the filter was changed? _______________________

Personal Protective Equipment/Clothes Questions

How often do you wear the following clothes and protective equipment when mixing, loading pesticides?

long pants: Always____ Usually____ Sometimes____ Never____

long shirt: Always____ Usually____ Sometimes____ Never____

respirator: Always____ Usually____ Sometimes____ Never____

If any answer but never, how often do you change the cartridge?

Every Time____ Every Day____ Once a week____ As needed____

End of Season____

chemical protective clothing (eg. tyvek, PVC):

Always____ Usually____ Sometimes____ Never____

If any answer but never, how often do you replace the chemical protective clothing?

Every Time____ Every Day____ Once a week____ As needed____

End of Season____

rubber boots: Always____ Usually____ Sometimes____ Never____

rubber apron: Always____ Usually____ Sometimes____ Never____

cloth apron: Always____ Usually____ Sometimes____ Never____

goggles: Always____ Usually____ Sometimes____ Never____

disposable gloves: Always____ Usually____ Sometimes____ Never____ cloth or leather gloves: Always____ Usually____ Sometimes____ Never____

If any answer but never, how often do you replace the gloves?

Every Time____ Every Day____ Once a week____ As needed____

End of Season____

rubber gloves: Always____ Usually____ Sometimes____ Never____

If any answer but never, how often do you replace the gloves?

Every Time____ Every Day____ Once a week____ As needed____

End of Season____

What protective equipment or clothing do you wear when applying pesticides?

long pants: Always____ Usually____ Sometimes____ Never____

long shirt: Always____ Usually____ Sometimes____ Never____

respirator: Always____ Usually____ Sometimes____ Never____

If any answer but never, how often do you change the cartridge?

Every Time____ Every Day____ Once a week____ As needed____

End of Season____

chemical protective clothing (eg. tyvek, PVC):

Always____ Usually____ Sometimes____ Never____

If any answer but never, how often do you replace the chemical protective clothing?

Every Time____ Every Day____ Once a week____ As needed____

End of Season____

rubber boots: Always____ Usually____ Sometimes____ Never____

rubber apron: Always____ Usually____ Sometimes____ Never____

cloth apron: Always____ Usually____ Sometimes____ Never____

goggles: Always____ Usually____ Sometimes____ Never____

disposable gloves: Always____ Usually____ Sometimes____ Never____

cloth or leather gloves: Always____ Usually____ Sometimes____ Never____

If any answer but never, how often do you replace the gloves?

Every Time____ Every Day____ Once a week____ As needed____

End of Season____

rubber gloves: Always____ Usually____ Sometimes____ Never____

If any answer but never, how often do you replace the gloves?

Every Time____ Every Day____ Once a week____ As needed____

End of Season____

Transportation Questions

How do you travel from your work site (fields) to home?_________________________

Is the car/truck driven to from work site and home the same car/truck used for family transportation? Yes______ No_______

Do your kids spend any time in this vehicle? Yes______ No_______

If yes, approximately how many hours/week would they spend in this vehicle?____

APPENDIX B

CORN FARMER HEALTH AND SAFETY QUESTIONNAIRE (CFHSQ)

NOTES:

1. This questionnaire is to be administered to the farmer or farm worker that is the principal participant in the study (i.e. the person that we will take urine samples from).

SECTION 1:

FARM OPERATOR AND FARM CHARACTERISTICS

This section of the questionnaire gathers information on the principal farm operator, other persons working on the farm, and the overall characteristics of the farm operation.

1. NAME:____

(Complete first names and last names)

2. ADDRESS: Community_______________________ Municipality: ______________________________

Department__________________________________

3. How long have you lived in this town? ___________________Years

4. Gender Age _______ (years) Date of birth _____ _____ _____

- ❑ Male Day Month Year
- ❑ Female

5. Can you read and write? Yes □ No □

6. What is your level of formal education? How many years of school did you complete?

____

7. For how many years have you farmed corn? __________________________ years

8. In the last year, how many manzanas of corn did you cultivate and how many quintales of corn did each manzana produce?

Area planted ___________ manzanas Yield ______________ quintales/manzana

9. From your corn production in the last year, how much was consumed by your family and how much did you sell?

Consumed __________ quintales Sold at market ___________ quintales

10. What was the sale price of those quintales? ____________ Lempiras per quintal

11. How far away do you live from your field where you plant corn? ________ (meters) _________ (kilometers)

12. Do you have well(s) in or very near (i.e. less than 10 meters) from your farm?

- ❑ Yes
- ❑ No

13. How deep is/are the well(s)? ________________________ (meters)

14. What do you use the water from the wells for? **(Check the box or boxes that apply)**

- ❑ Watering crops
- ❑ Drinking
- ❑ Bathing
- ❑ Domestics including clothes washing
- ❑ Pesticide mixing
- ❑ None of the above

SECTION 2: CULTURAL PRACTICES IN CORN FIELDS

This section intends to gather information on the farm work practices and the workers that perform them

15. Do you do physical work on the farm?

- ❑ Yes
- ❑ No

16. Circle the months in which you work on your farm

January	April	July	October
February	May	August	November
March	June	September	December

17. How many manzanas of corn do you typically farm during the Primera?
_____________________ manzanas

18. How many manzanas of corn do you typically farm during the Postrera?
_____________________ manzanas

19. On average, how many **hours per day** do you spend doing farm work for corn production (i.e. from land clearing to harvest)?
____________________________________(Hours/Day)

20. **<u>This question is to identify the people that work on your farm</u>**

a. Please indicate in the space below the names of the other persons who regularly live or work in your

farm. Persons listed here should include:

- family members who live in the same or a separate residence on the farm (this is regardless of if they work there or not).
- other family members who do not live on the farm, but work on your farm.
- hired workers who regularly live or work on your farm.
- any other persons, such as friends, relatives or roomers who do/don't live on the farm, but do work on the farm.

b. The person's address (write "**same**" unless different from yours)

c. The person's relationship to the principal operator

1 –spouse,

2 –child,

3 –parent,

4 –other relative by blood or marriage,

5 –non-relative

(CIRCLE THE APPROPRIATE NUMBER (1 TO 5) IN SUB-SECTION "C" BELOW TO INDICATE THE RELATIONSHIP TO THE PRINCIPAL OPERATOR)

d. "Work status" means that the person participates in the physical operation of the farm, as opposed to domestic chores or just living there **(CIRCLE ONE)**

e. Are they paid in any monetary form or unpaid from the farm income? **(CIRCLE ONE)**

f. Sex **(CIRCLE ONE)**

g. Age **(ESPECIALLY IF THE PERSON IS OVER 18 YEAR OR UNDER THE AGE OF 6 YEARS)**

(CIRCLE APPROPRIATE ANSWERS FOR QUESTIONS c TO f)

	A) Name	B) Address – If different from principal operator	C) Relationship to principal operator	D) Work Status	E) Pay Status	F) Gender	G) Age
A.			1 2 3 4 5	S N	Pagado No Pagado	M F	
B.			1 2 3 4 5	S N	Pagado No Pagado	M F	
C.			1 2 3 4 5	S N	Pagado No Pagado	M F	
D.			1 2 3 4 5	S N	Pagado No Pagado	M F	
E.			1 2 3 4 5	S N	Pagado No Pagado	M F	

SECTON 3: PESTICIDE APPLICATIONS

21. Pesticide Handling & Use. **(Fill in the blank columns and Check the box or boxes that apply)**

#	Trade name of Pesticide	Technical Name of Pesticide	Application Method	Type of PPE used during Mixing, Loading & Applying	Re-Entry Period
i			Hand-held sprayer □ Backpack sprayer/ knapsack □ Mist-blower/fogger on tractor/veh. □ Mist-blower/fogger on aero plane □ Other ____________________ (Specify)	Chemically resistant overalls □ Chemically resistant boots/shoes □ Cartridge respirator, gas mask □ Full face shield □ Gloves □ Other ____________________ (Specify)	Immediately after □ 1 hour later □ 2-6hrs later □ Next day □ Longer □

For Each of the Pesticides Listed Above, State:

22. How many times per production cycle was each pesticide applied and what was the application schedule in the most recent production cycle? (**For example: daily, weekly, bi-weekly, monthly etc.)**

1. ____
2. ____
3. ____
4. ____
5. ____
6. _______________________________________

23. How long does it take to complete an application with each pesticide; mix, load and apply it? (**Estimate the average time it takes each time you mix in minutes and/or hours**)

1. ____
2. ____
3. ____
4. ____
5. ____
6. ____

24. How many applications were needed to complete the required applications in the entire production cycle? **(For example; the number of days that you applied each pesticide to crops during the entire length of the last farming season [primera]**)

1. ____
2. ____
3. ____
4. ____
5. ____
6. ____

25. Where did you usually get the pesticides?

- ❑ From licensed vendor
- ❑ From agric. agency/extension worker
- ❑ From the market
- ❑ From the streets

- ❑ Other (Specify)____
  ____

26. Do the pesticides have a label, pamphlet, or instructions about how to use them properly?

- ❑ Yes
- ❑ No

27. Did your supplier or vendor explain how to properly use the pesticides?

- ❑ Yes (GO TO QUESTION 28)
- ❑ Sometimes (GO TO QUESTION 28)
- ❑ Never (GO TO QUESTION 29)

28. Did you follow the explanations/directions?

- ❑ Yes
- ❑ No

29. Why or why not?
(**Explain**)____
____

30. On the days of pesticide application, did you mix, load and operate the spraying equipment yourself (- i.e

alone)?

- ❑ Yes (GO TO QUESTION 33)
- ❑ No (GO TO QUESTION 31)
- ❑ Worked together with help (GO TO QUESTION 31)

31. Who did or worked with you? **(Check only the box or boxes that apply)**

- ❑ Son(s)/Daughter(s)
- ❑ Wife
- ❑ Other relative(s)
- ❑ Friend(s)
- ❑ Hired worker(s)

32. If your help was female(s), was/were she/ they pregnant at the time? **(Check only the box that applies)**

- ❑ Yes- all were
- ❑ Yes- some were
- ❑ No- none was

33. If you are female, were you pregnant at the time?

- ❑ Yes
- ❑ No

34. Was any of your help less than 18 years of age?

- ❑ Yes
- ❑ No

35. Did you or your help check the wind direction before applying pesticides?

- ❑ Yes
- ❑ No

36. Why or why not?
(**Explain**)____

37. Did you or your help apply pesticides? **(Check the box that applies)**

- ❑ With the wind direction
- ❑ Against the wind direction

38. Why or why not?
(**Explain**)____

39. On which of the following days were you most likely to apply pesticides? **(Check only the box or boxes that apply)**

- ❑ Clear sunny day
- ❑ Partly cloudy day
- ❑ Very cloudy day

- Rainy day
- Foggy day
- Windy day
- Other (Specify)____ ________________

40. What are your reasons for choosing such day(s)?
(**Explain**)____

41. What sorts of pests do you normally control with pesticides on the farm? **(Circle the letter to all those that apply)**

a. Insects
b. Worms
c. Arachnids (e.g. Spiders)
d. Weeds
e. Fungi
f. Bacteria
g. Viruses
h. Yeasts
i. Birds
j. Rodents
k. Protozoans
l. Raccoons
m. Other (Specify)_____________________________

42. Did you use pesticides for something else other than controlling pests or weeds on the farm?

- Yes (GO TO QUESTION 43)
- No (GO TO QUESTION 44)

43. For what?
(**Explain**)____ __________

44. Why not?
(**Explain**)____ __________

45. Do you store pesticides at home—(i.e. in dwelling houses)?

- Yes
- No

46. Why (and in what part of the house) or why not?
(**Explain**)____

SECTION 4:

APPLICATION EQUIPMENT

This section of the questionnaire gathers information on the state of the equipment used to apply pesticides to crops on the farm.

47. How old is the sprayer/equipment you use to apply pesticides? **(Check only the box that applies)**

- ❑ Less than a year old
- ❑ 1-2 years old
- ❑ 2-5 years old
- ❑ 6-10 years old
- ❑ More than 10 years old

48. Does the sprayer/equipment spill, splash, drip or leak when in use?

- ❑ Yes (GO TO QUESTION 49)
- ❑ No (GO TO QUESTION 50)

49. When it does, what do you do?
(**Explain**)____

50. Does the sprayer/equipment completely break down during application? **(Check only the box that applies)**

- ❑ Always (GO TO QUESTION 51)
- ❑ Sometimes (GO TO QUESTION 51)
- ❑ Never (GO TO QUESTION 52)

51. When it does what do you do?
(Explain)____

SECTION 5:

PESTICIDE: POST-APPLICATION PRACTICES

This section of the questionnaire gathers information on what is done after a pesticide application process is concluded.

52. After working with pesticides and other agro-chemicals, do you or your help usually?

i. Bathe or shower before continuing with other farm work?....................... Yes □ No □
ii. Change into clean washed clothes?... Yes □ No □
iii. Change clothes immediately if contaminated?...................................... Yes □ No □

iv. Wash clothes separately from those of other family members?............ Yes □ No □

v. Wash hands before eating?... Yes □ No □

vi. Wash hands before smoking or using snuff?.. Yes □ No □

vii. Wash hands before urinating?.. Yes □ No □

viii. Take work shoes/boots off before entering their homes?................... Yes □ No □

53. After an application process, what do you do with the sprayer/equipment? Where is the sprayer/equipment stored?
(**Explain**)____
____

54. What did you do with left over pesticide(s)?
(Explain)____

55. How did you normally dispose of your empty pesticide containers? **(Check the box or boxes that apply)**

- ❑ Gather and burn
- ❑ Gather and bury
- ❑ Throw away indiscriminately
- ❑ Throw them away with other trash
- ❑ Use to store water or food
- ❑ Sell them
- ❑ Other
  (Specify)____
  ____

56. How often did young children play or work in the farm just after a pesticide application event? **(Check the**

box or boxes that apply)

- ❑ Most of the time
- ❑ Sometimes
- ❑ Rarely to almost never
- ❑ Don't know

57. How often were the children's hands washed before eating? **(Check the box that applies)**

- ❑ Most of the time
- ❑ Sometimes
- ❑ Rarely to almost never
- ❑ Don't know

58. Did you (or your help) usually wear the same work clothes you used to mix or apply pesticides two or more

days without washing them?

- ❑ Yes
- ❑ No

59. Were agricultural pesticides ever stored (even temporarily) in a sleeping or bedroom?

- ❑ Yes (GO TO QUESTION 60)
- ❑ No (GO TO QUESTION 61)

60. Where were they stored?
(**EXPLAIN**)____

61. How far is your home from the nearest farm where pesticide(s) was/ were applied? **(Probe, estimate and Check the**

box that applies)

- No pesticides applied on farm
- Less than 50 meters
- 50-100 meters
- 100-199 meters
- 200M–1 Kilometer
- More than 1 Km.

SECTION 6:

HEALTH IN RELATION TO PESTICIDE HANDLING

This section of the questionnaire gathers information about the farmers' health in relation to using pesticides.

During the last 12 months did you have any of the following symptoms while or after working (-i .e. mixing or applying) with pesticides on your farm?

62. Headaches or dizziness?.. Yes □ No □
63. Nausea or vomiting?.. Yes □ No □
64. Eye irritation?.. Yes □ No □
65. Eye tearing?... Yes □ No □
66. Tightness or discomfort in the chest?... Yes □ No □
67. Difficulty in breathing?.. Yes □ No □
68. Difficulty walking?.. Yes □ No □
69. Blurred or double vision?... Yes □ No □
70. Drooling?.. Yes □ No □
71. Twitching, jerking or involuntary movements of arms or legs?............. Yes □ No □
72. Faint?.. Yes □ No □
73. Convulsions, seizures or fits?.. Yes □ No □
74. Skin irritation?.. Yes □ No □

75. Have you or anyone that you know been poisoned by pesticides?

- ❑ Yes (GO TO QUESTION 76)
- ❑ No (GO TO QUESTION 77)

76. How did it happen and what did you or him/her do to treat it? (**Explain)**
____

77. During the last 12 months has there been an incident where you (or your help) had to make emergency visit to

the hospital or health center during or just after working with pesticides on the farm?

- ❑ Yes (GO TO QUESTION 78)
- ❑ No (GO TO QUESTION 80)

78. Was that person hospitalized (-i.e. admitted)?

- ❑ Yes (GO TO QUESTION 79)
- ❑ No (GO TO QUESTION 80)

79. How long were you/they hospitalized? **(Check only the box that applies)**

- ❑ One day or more
- ❑ One week or more
- ❑ One month or more

80. In the case of an accidental pesticide poisoning occurring on the farm, where would you prefer to seek

treatment?

- ❑ Hospital or health center
- ❑ Traditional healer
- ❑ Use home remedies
- ❑ Other (Specify)____

81. Why? (**Give the reasons**)____

82. What do you consider the hardest work in corn production (preparing the land – burning or cutting; planting, harvesting, etc.)? (**Explain**)____

83. How long have you been using pesticides on your corn farm? (**Estimate in years and/or months**)________

84. Will you continue using pesticides on your corn farm?

- ❑ Yes
- ❑ No

85. Why or why not? (**Give reasons**)____

86. Do you think that working with pesticide is hazardous to health?

- ❑ Yes
- ❑ No

87. Why or why not? (**Give your reasons**)____

88. **<u>FOR MALES ONLY.</u>** How many children have you fathered? (You need to use discretion when asking this question. You might have to ask it in private, when the farmer's spouse is not present, in hopes of getting a true response. Remind the farmer that this question, and all questions for that matter, is in strict confidence and that he can trust you. Be sure to ask the question about children with the current wife and those outside of the marriage)___________________

Additional Information

Part I. Information about the Parents/Guardians

89. What is the spouse's date of birth? ____ /____/____ (Month Day Year) Age _____

90. What is the applicators height?__________ Weight?__________

91. What is the spouse's height? __________ Weight?__________

Spouse Work Questions:

92. What is the current job of the spouse?_________________________________

93. Does the spouse carry out any work related to agricultural production? Yes____ No____

If yes, please describe ____

____

94. Does the spouse do any work that involves handling pesticides? Yes____ No____

If yes, please describe _______________________

____

Applicator Work Questions:

95. Does the applicator have other jobs during the year? Yes____ No____

If yes, what jobs are those?
____

96. Do any of those jobs involve contact with pesticides? Yes____ No____

If yes, which jobs involve contact with pesticides?
____

Part II. Information About Children

Section A.

97. How many children are living in your home? _____________________

List their name, heights, and weights:

	Nombre	Peso (libras)	Estatura (metros)
1			
2			
3			
4			
5			
6			
7			
8			
9			

Section B (To be filled out for each child participating in the study).

Child 1

98. Name of child: ____

99. Subject ID #: _____________

100. On a typical spring or summer day, how many hours does the child spend:

Indoors?__________ Outdoors?__________

101. How much time does he/she spend in the: (make one check mark for each row)

	Amount of Time				
Room	**None**	**1-4 hours**	**5-8 hours**	**9-12 hours**	**More than 12 hours**
Bedroom					
Living Room					
Kitchen					
Laundry Room					
Play Room (if any)					

102. When outdoors, where does he/she play most often?___________________________

103. How many hours are spent here on an average day?___________

104. Is the child involved in any farm chores? Yes______ No______

If the answer is yes, please describe what work the child does:_-
____
____
____
____
____

105. Does the child handle or apply pesticides? Yes______ No_______

If yes, what does your child wear when handling pesticides?____

If yes, where does your child change out of work clothes?
____

106. Does the child live with you all of the time? Yes_____ No______

107. Does your child go to school? Yes_____ No______

If yes, how many hours/day? _____________

If yes, how many days per week? _______________

108. Is school still in session? Yes______ No_______

109. Does your child attend daycare or go to a private home for childcare on a regular basis? Yes_____ No______

If yes, how many hours per day?____________

If yes, how many days per week?____________

110. Is it a private residence or commercial daycare facility? ______________________

111. Has he/she gone therer since pesticide applications began? Yes______ No______

If yes, how many days has your child been at daycare since pesticide applications began? _____________

Child 2

112. Name of child: ____

113. Subject ID #: ________________

114. On a typical spring or summer day, how many hours does the child spend:

Indoors?____________ Outdoors?____________

115. How much time does he/she spend in the: (make one check mark for each row)

	Amount of Time				
Room	**None**	**1-4 hours**	**5-8 hours**	**9-12 hours**	**More than 12 hours**
Bedroom					
Living Room					
Kitchen					
Laundry Room					
Play Room (if any)					

116. When outdoors, where does he/she play most often?___________________________

117. How many hours are spent here on an average day?___________

118. Is the child involved in any farm chores? Yes______ No______

If the answer is yes, please describe what work the child does:_______________________________________

____

119. Does the child handle or apply pesticides? Yes______ No_______

If yes, what does your child wear when handling pesticides?____

If yes, where does your child change out of work clothes?
____

120. Does the child live with you all of the time? Yes_____ No______

121. Does your child go to school? Yes_____ No______

If yes, how many hours/day? _____________

If yes, how many days per week? _______________

122. Is school still in session? Yes______ No_______

123. Does your child attend daycare or go to a private home for childcare on a regular basis? Yes_____ No______

If yes, how many hours per day?____________

If yes, how many days per week?____________

124. Is it a private residence or commercial daycare facility? ______________________

125. Has he/she gone there since pesticide applications began? Yes______ No______

If yes, how many days has your child been at daycare since pesticide applications began? _____________

Part III. Household Information (to be asked to the parents or guardians)

126. What year did you move into this home? ____________

127. What year was this home constructed? ____________

128. Do you have a door mat for your outside doors? Yes_____ No______

If yes, record which doors: Front door ____ Back door _____ Garage door ____

Other door (specify) ____

Home Pesticide/Insecticide Questions

129. Have insecticides been applied in this home in the last month:

Personally? Yes ____ No ____ Don't know ____

If yes which insecticide(s) were used? ______________________________

130. Have insecticides been applied in this home in the last 12 month:

Personally? Yes ____ No ____ Don't know ____

If yes which insecticide(s) were used?

____

____

131. Do you have a garden? Yes____ No_____

132. If yes, has your garden been sprayed with pesticides (insecticides, herbicides, or fungicides) in the last month:

Personally? Yes ____ No ____ Don't know ____

If yes, which pesticide(s) were used

____
____

133. Has your garden been sprayed with pesticides (insecticides, herbicides, or fungicides) in the last 12 months:

Personally? Yes ____ No ____ Don't know ____

If yes which pesticide(s) were used?

____

134. Do you consume food from the garden? Yes_______ No__________

If yes, have you consumed food from the garden in the last month? Yes___ No___

Floor Cleaning Questions

135. How often do you mop or vacuum your floors in the family room/living room?

Once a month____ Twice a month____ Once a week _____

Once a day ______ More than once a day____

136. How often do you mop or vacuum your floors in the entryway?

Once a month____ Twice a month____ Once a week _____

Once a day ______ More than once a day____

137. How often do you mop or vacuum your floors in the kitchen?

Once a month____ Twice a month____ Once a week _____

Once a day ______ More than once a day____

138. How often do you mop or vacuum your floors in the laundry room/pesticide applicator changing area?

Once a month____ Twice a month____ Once a week _____

Once a day ______ More than once a day____

Pesticide Applicator Clothes Questions

139. Where does the applicator change out of their work clothes?

____

140. If the applicator changes outside the home, do they bring your work clothes in the home?

Yes______ No_______

141. Where does the applicator change out their work shoes?

____

142. If the applicator changes their shoes outside the home, do they bring their work shoes into the home? Yes______ No______

143. Are all of the applicator's work clothes washed every day that the applicator wears them? (Including jackets, cloth gloves and cloth coveralls) Yes___ No___

144. If no, which clothes are not washed every time? ____________________________

145. When are those clothes washed?

End of the week___ End of the season___ As needed____ Never____

146. How are the applicator's clothes dried?

Hung outside___ Dried in a dryer___ Hung inside___

Pet Questions

147. Do you have a dog? Yes_____ No_____

148. If yes: Does your dog spend time: inside ____ outside ____ or both ____ ?

149. Do your children play with the dog? Yes_____ No_____

150. Do you have a cat? Yes_____ No_____

151. If yes: Does your cat spend time: inside ____ outside ____ or both ____ ?

152. Do your children play with the cat? Yes_____ No_____

Part. IV Pesticide Application Information

(To be asked to the person living in the household who is the commercial applicator)

153. When was the last time you applied atrazine? ____________________

154. When you apply atrazine, who mixes and loads the atrazine?

Yourself____ Other worker____

155. When you apply atrazine, who applies the pesticide?

Yourself____ Other worker____

156. How many times in this agricultural season have you had a pesticide containing atrazine spill or splash on yourself such that you had to change clothes?________________________________

Cab Questions

157. Do you have a closed (ie. completely closed with air conditioning) or open cab?

Closed _____ Open _____

158. If closed, how often do you drive with the window open in the cab? ________________

159. If closed, is there a filter on the air intake for the air conditioning?

Yes_____ No_____ Don't know______

160. If yes, when was the last time the filter was changed? ________________________

Personal Protective Equipment/Clothes Questions

How often do you wear the following clothes and protective equipment when mixing or applying pesticides?

161. long pants: Always____ Usually____ Sometimes____ Never____

162. long shirt: Always____ Usually____ Sometimes____ Never____

163. respirator: Always____ Usually____ Sometimes____ Never____

164. If any answer but never, how often do you change the cartridge?

Every Time____ Every Day____ Once a week____

As needed____ End of Season____

165. chemical protective clothing (eg. tyvek, PVC):

Always____ Usually____ Sometimes____ Never____

166. If any answer but never, how often do you replace the chemical protective clothing?

Every Time____ Every Day____ Once a week____

As needed____ End of Season____

167. rubber boots: Always____ Usually____ Sometimes____ Never____

168. rubber apron: Always____ Usually____ Sometimes____ Never____

169. cloth apron: Always____ Usually____ Sometimes____ Never____

170. goggles: Always____ Usually____ Sometimes____ Never____

171. disposable gloves: Always____ Usually____ Sometimes____ Never____

172. cloth or leather gloves: Always____ Usually____ Sometimes____ Never____

173. If any answer but never, how often do you replace the gloves?

Every Time____ Every Day____ Once a week____

As needed____ End of Season____

174. rubber gloves: Always____ Usually____ Sometimes____ Never____

175. If any answer but never, how often do you replace the gloves?

Every Time____ Every Day____ Once a week____

As needed____ End of Season____

Transportation Questions

176. How do you travel from your work site (fields) to home?________________________

177. Is the car/truck driven to from work site and home the same car/truck used for family transportation?

Yes______ No_______

178. Do your kids spend any time in this vehicle? Yes______ No_______

179. If yes, approximately how many hours/week would they spend in this vehicle?____

THANK YOU FOR YOUR TIME!!!

INTERVIWER RESPONSIBILITIES

NOTE: 1. It is the responsibility of the interviewer to check that all questions are completely answered.

2. This questionnaire is not considered complete if any question is left unmarked/answered.

3. Sign this section only after thoroughly checking that all questions and sections are completely marked/answered.

4. This questionnaire will not be accepted if the information requested below is not supplied.

Respondent ID # ______________________ Name of Interviewer_______________________________

Date of Interview____/____/____ Time Interview Started____________ Time Interview Ended____________

dd mm aaaa

Signature of Interviewer____ Date___________________

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