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Air Concentrations and Inhalation Exposure to Pesticides in the Agricultural Health Pilot Study

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FOREWORD

The mission of the National Exposure Research Laboratory (NERL) is to provide scientific understanding, information and assessment tools that will quantify and reduce the uncertainty in EPA's exposure and risk assessments for environmental stressors. These stressors include chemicals, biologicals, radiation, and changes in climate, land use, and water use. The Laboratory's primary function is to measure, characterize, and predict human and ecological exposure to pollutants. Exposure assessments are integral elements in the risk assessment process used to identify populations and ecological resources at risk. The EPA relies increasingly on the results of quantitative risk assessments to support regulations, particularly of chemicals in the environment. In addition, decisions on research priorities are influenced increasingly by comparative risk assessment analysis. The utility of the risk-based approach, however, depends on accurate exposure information. Thus, the mission of NERL is to enhance the Agency's capability for evaluating exposure of both humans and ecosystems from a holistic perspective.

The National Exposure Research Laboratory focuses on four major research areas: predictive exposure modeling, exposure assessment, monitoring methods, and environmental characterization. Underlying the entire research and technical support program of the NERL is its continuing development of state-of-the-art modeling, monitoring, and quality assurance methods to assure the conduct of defensible exposure assessments with known certainty. The research program supports its traditional clients -- Regional Offices, Regulatory Program Offices, ORD Offices, and Research Committees -- and ORD's Core Research Program in the areas of health risk assessment, ecological risk assessment, and risk reduction.

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ABSTRACT

The incidence of several types of cancers is higher among farmers than in the general population - this despite lower overall mortality. Occupational agents responsible for these excess cancers have not been definitively identified. The Agricultural Health Study seeks to identify and quantify pesticide exposures to farmers, indirect exposures to their families, and to assess health risks. A 6-farm, exposure pilot study implemented a total exposure assessment methodology, i.e., multimedia transport and multi-pathway exposure. Sampling design included air inhalation, oral ingestion, and dermal absorption. This paper reports on the air transport and inhalation exposures monitored during the exposure pilot study. Meteorological data were collected from an on-site three-meter tower. Outdoor air was sampled on the day of the pesticide application event, and indoor air samples were collected on three consecutive days centered on the application day. Personal activity logs, indicating time and location, were maintained by participants during the monitoring period. Of 33 targeted pesticides, 7 were applied on at least one of the participant farms, 11 were detected in the outdoor air near a farm residence, and 17 were detected in farm residence indoor air. Indoor concentrations of applied pesticides were detected on 4 of the 6 farms, however there is limited and conflicting evidence to support an exclusively outdoor air source of indoor concentrations of applied pesticides. Indoor concentrations of non-applied pesticides were more the rule than the exception. On 5 of the 6 pilot-study farms, concentrations of non-applied pesticides were detected in the indoor air sample on at least one day. As expected, the applicator's inhalation exposure to applied pesticides is greater than that of any other family member on the day of application. For spouse and children, the indoor microenvironment contributed to inhalation exposure of pesticides to a far greater extent than did the outdoor-on-farm microenvironment - even on the day of application.

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INTRODUCTION

The incidence of several types of cancers is higher among farmers than in the general population - this despite lower overall mortality. Occupational agents responsible for these excess cancers have not been definitively identified (Baker and Wilkinson, 1990). Retrospective assessments of exposure to any suspected toxin are inadequate in determining environmental cause and health effect relationships. The Agricultural Health Study is the first prospective study to evaluate the role of pesticides in cancer risks to farmers and their families (Alavanja et al., 1996; Alavanja et al., 1993).

The Agricultural Health Study is a collaborative effort of the National Cancer Institute, the U.S. Environmental Protection Agency, and the National Institute of Environmental Health Sciences. The study seeks to identify and quantify pesticide exposures to farmers, and indirect exposures to their families, and to assess long-term health risks.

The exposure assessment efforts included a pre-pilot phase (four farms; completed in 1992), and a pilot phase (6 farms; monitoring completed in 1994). The objective of both the pre-pilot and pilot phases was to test sampling protocols, develop analysis methods, and refine questionnaires. Improved protocols, methods, and questionnaires will be incorporated in the full-scale study, currently planned for 1998 (Camann et al., 1993; Giardino et al., 1993).

A total exposure assessment methodology was incorporated in the design of the study, i.e., multimedia transport and multi-pathway exposure (Wallace, 1987). Thirty-three pesticides were targeted in the pilot studies. Sampling design included air inhalation, oral ingestion, and dermal absorption. Media and cohort monitoring were chronologically centered around farm pesticide application events. Baseline concentrations of pesticides were considered in sampling during a non-application (i.e. control) season, vs. the application period (Kuchibhatla et al., 1994).

This paper reports on the air transport and inhalation exposures monitored during the second phase pilot study. Applicator, spouse, and up to two children participated from four Iowa and two North Carolina farms. The pesticide applicator was instrumented with a personal air sampler during handling, mixing, and loading operations, as well as during application. Pesticide quantity was recorded and chemical formulation was analyzed. Meteorological data were collected from an on-site three-meter tower. An outdoor air sample was collected on the day of the pesticide application event, and indoor air samples were collected on three consecutive days centered on the application day. Baseline indoor concentrations of target pesticides were established with a non-application season sample. Personal activity logs, indicating time and location, were maintained by participants during the monitoring period.

AIR AND INHALATION EXPOSURE MONITORING PROCEDURES

Sampling Strategy

The assessment of direct inhalation exposure of the applicator during application events (handling, mixing, and loading (HML) operations; as well as actual pesticide application) required concurrent sampling of the applicator's breathing zone. Assessment of indirect inhalation exposures, as may be accrued by all family members from breathing indoor or outdoor air contaminated with fugitive pesticides, required sampling of indoor and outdoor air. The pilot study sampled indoor, outdoor, and applicator personal air. Indoor and outdoor samples were 24-hour averages; applicator personal air samples were collected over the duration of the activity of interest - either HML or application (Harding et al., 1993). Non-application season samples of indoor air were collected to provide baseline levels of detected pesticides. All samples were collected with a polyurethane foam (PUF) and quartz pre-filter cartridge and analyzed for the presence of target pesticides (Hsu et al., 1988; Geno et al., 1993). A size-selective impactor at the cartridge inlet removed particles greater than 2.5 micrometers in diameter. Appreciable differences between open-face and $PM_{2.5}$ cartridges are expected only in the proximity of an atomizing source (Camann et al., 1994).

A five-day sampling strategy was chronologically centered on the day of a planned application event, hereafter synonymous with "day 3". The first and fifth days were directed toward setup and disassembly of monitoring equipment. During the second, or pre-application day, an indoor air sample was collected. During the application day, indoor and outdoor air samples were collected, as well as personal air samples from the applicator. During the fourth, or post-application day, an indoor air sample was collected. Participants' activity logs recorded the time, location, and activity of the applicator, spouse, and one or two children, during days 2, 3, and 4.

Participating Farms

Iowa and North Carolina were selected through a competitive procurement contract (Alavanja et al., 1996; Alavanja et al., 1993). Both states have statewide population-based cancer registries. Enrollment solicitation of participants for the full epidemiology study was facilitated through contacts during state licensing of restricted-use pesticide applicators (Nelson et al., 1993). (Full enrollment, circa 1997, is anticipated to include approximately 75,000 adults). All recruited applicators used at least one of the 33 target pesticides on their farm (see Appendix A). From the full study enrollment, four farms in Iowa and two in North Carolina were recruited for participation in the exposure assessment pilot study. The six pilot-study farms were monitored during a total of seven application events (two separate application events were monitored on one of the Iowa farms).

Meteorological Data

Transport of pesticide spray drift during application may correlate with outdoor air concentrations sampled at the residence (Gilbert and Bell, 1988). A three-meter meteorological monitoring tower was installed within 180 m of the farm residence at all six farms. Wind speed, wind direction, temperature, and relative humidity, were automatically measured at 3 meters, with 10-minute averages of each variable being recorded. Meteorological data were collected during the application day. The relative direction of, and distance to an application event with respect to the farm residence was recorded as a schematic drawing.

Applicator Personal Air Sampling

A personal air sampler measured the applicator's exposure to pesticides by inhalation during HML and application activities. A 3.8 L/min air sample was drawn through an inlet tubing positioned within the applicator's breathing zone. (The inlet tubing of the sampling cartridge was clipped to the collar area of the applicator's shirt, and positioned in front of the face. The outlet tubing went to a pump clipped to the hip belt (Kuchibhatla et al., 1996a)). Onset and completion times of HML or application activities were recorded for subsequent exposure and dose calculations, as well as correlation with meteorological measurements.

Indoor and Outdoor Air Sampling

Indoor air samples were collected on days 2, 3, and 4, as well as a non-application season sample. All indoor air samples were single-point, 24-hour average measurements. An outdoor air sample was collected on the application day only. The outdoor air samples were at a fixed location (near, and upwind of the house), and were 24-hour averages. Both indoor and outdoor samples were collected using PUF and quartz pre-filter samplers. These measurements, in conjunction with participant activity logs, provided data for indirect exposure assessment of all family members.

RESULTS AND DISCUSSION

Definitions and Units

Pesticide concentrations are reported in nanograms pollutant per cubic meter of air, or [ng/m^3]. Time is reported in hours, or [h]. The *air pathway exposure,* as used in this report, shall be defined as the calculated product of an individual's time resident within a designated microenvironment, with the concurrent pollutant concentration within that microenvironment. Exposures are given throughout in units of hour nanograms per cubic meter, or h-ng/m^3 .

$$Exposure\left[\frac{h \cdot ng}{m^3}\right] = Concentration\left[\frac{ng}{m^3}\right] \times Time\,[h]$$

Exposure is to be distinguished from *dose*, which seeks to calculate inhaled mass as a product of exposure, breathing rate, and deposition fraction. Breathing rate is usually measured in liters per minute, or [L / min]. The deposition fraction (dimensionless) is assumed to be unity in this report. Dose calculations are reported in nanograms, or ng.

$$Dose\,[ng] = Exposure\left[\frac{h \cdot ng}{m^3}\right] \times Breathing\,Rate\left[\frac{L}{min}\right] \times Deposition\,[-] \times \left[0.06\ \frac{m^3 \cdot min}{L \cdot h}\right]$$

Applied Pesticides

Appendix A lists the 33 AHS target pesticides. Of the 33 pesticides, 7 are herbicides, 21 are insecticides, and 5 are fungicides. Appendix B lists the pesticides that were *applied* on the six study farms. This list contains 7 of the target pesticides - 5 herbicides and 2 insecticides. Additionally, a chemical variant of 2,4-D, namely 2,4-D butoxy ethyl ester, and an insecticide synergist - piperonyl butoxide, were applied.

The Role of Modeling

The contribution of modeling in this study was to estimate potential peak outdoor concentrations under hypothetical near worst case conditions. A scenario consisting of a high pesticide application rate on a field adjacent to, and directly upwind of, the farm residence represents a reasonably worst case configuration. The specific equipment used, the prevailing meteorology,

as well as the toxicity of the pesticide, contribute to an overall assessment. A model will serve to provide estimates of emissions and spacial and temporal distributions of outdoor concentration for hypothetical scenarios for which measurement and analysis are impractical or prohibitively expensive. Model simulations, within their domain of validity, may provide cost-effective alternatives to field measurements. Screening estimates of reasonably worst case scenarios, if found to be well below threshold levels for health effects, may reduce the need for on-site measurements. Reference concentrations for most *pesticides*, however, have not been established.

Model Selection

A physically-based modeling assessment of pesticide dispersion (spray drift, fugitive emission, etc.) requires an understanding of the mechanisms of environmental release and transport, and the engineering, physical, chemical, and meteorological laws that apply. Estimation of both source function (time dependent emission characterization; physical properties of released pesticide [i.e. gas, liquid, aerosol, or powder]) and dispersion parameters are required. The time dependent release of pesticide into the air from a farm implement must be determined in order to estimate subsequent spacial and temporal distribution of the pesticide. The physical state of the pesticide - gaseous, powder, or liquid aerosol - influences removal process such as gravitational settling and deposition. Hence physical properties such as particulate/aerosol size distribution must be estimated (Lewis and Lee, 1976; Johnson, 1994). The kinds of pesticide application implements for which pesticide release is well characterized is limited. Models do exist to estimate release and transport of *aerial* boom sprayers. Modeling efforts in characterizing release and transport from *ground*-based boom sprayers have been reported using generic computational fluid dynamics software (Reichard et al., 1992). However, no self-contained, tailored model exists *per se* that models the unique attributes of ground boom sprayers.

The AgDRIFT model (Teske, 1996; Teske et al., 1994) was initially developed to assess off-target drift deposition rates of water-based *aerial* pesticide applications. It can also calculate plume centerline *concentrations* needed in the assessment of inhalation exposure. The AgDRIFT model provides the user with a hierarchy of modeling sophistication, from screening-level assessments to comprehensive, state-of-the-science simulations. At the model's core is a Lagrangian treatment of dispersion, tracking each nozzle stream of droplets through a flow field. AgDRIFT incorporates source constructs such as nozzle type, flow rates, and drop size distribution. Environmental variables having greatest impact on transport - wind speed, temperature, and relative humidity - are incorporated in AgDRIFT's calculations. AgDRIFT was deemed suitable to simulate *ground* boom sprayer drift, provided several extrinsic source parameters are appropriately assigned. Primarily, boom traverse speed must be reduced to plausible tractor speeds. Normal aircraft-induced wake effects (not present behind tractor booms) were eliminated by reducing the simulated aircraft mass to essentially zero.

Meteorology and Pesticide Transport

Meteorological measurements were taken at all application events except Iowa farm #2, where technical difficulties were encountered. A meteorological instrumentation tower was set up on the farms at locations deemed representative for the characterization of air transport of applied pesticides from field to farm house. Ten minute averages of wind speed, wind direction, temperature, and relative humidity were collected at a height of 3 meters above ground level. Modeling of the dispersion of applied pesticides requires that basic meteorological variables be measured during the application event. Short range transport, typically of the order of 100 meters in the cases observed in this study, takes place in seconds to minutes. Appendix C reports meteorological data (Kuchibhatla et al., 1996b) for Iowa farm #1, Iowa farm #3-first visit, and North Carolina farm #1. In addition to the date, time, and meteorological data, Appendix C reports the application activity in progress concurrent with the meteorological conditions. The application activity is designated as either handling, mixing, loading ("HML" in Appendix C), or as applying ("app"). Since transport of applied pesticides to the farm house is of primary interest, the approximate wind direction that would place the house downwind of the treated field is reported in the column labeled "Target WD". The following column, labeled "Hit", indicates whether the measured wind direction was within $\pm 45°$ of the target wind direction (yes "y" or no "n"). The 24-hour average concentrations (outdoor and indoor) are also reported on the top row.

Selection of Farms to be Modeled

The selection of application events suitable to a physically based model simulation was based on both model capability and data limitations. The model initiative presented here is appropriate in estimation of reasonable worst case conditions; it is not intended that modeled concentrations be compared directly with ambient measurements. Each simulated case adheres to actual pesticide amounts applied and rate of application. However, drop size distribution is treated conservatively (i.e. to yield higher downwind concentrations), and meteorological conditions are a conservative composite of measured variables (wind speed, relative humidity, temperature). Most significant in interpretation of model results is that concentrations are calculated at plume centerline (i.e. assuming wind direction is directly from application field to monitor). Furthermore, all calculations are 1-hour averages, not 24-hour averages as were measured by the outdoor samplers. All application events chosen for modeling were between 1 and 3 hours in duration, so a 1 hour averaging period is a better indication of the peak concentration.

AgDRIFT simulates emission characteristics and dispersion of liquid pesticide from boom sprayers. Application events suitable for modeling were required to have adequate data on pesticide quantity and meteorology; and the application implement was limited to boom sprayers. As Appendix D indicates, four of the seven monitored applications days used ground boom sprayers. Three of these applications were suitable for modeling - Iowa farm #1, Iowa farm #3-first application, and North Carolina farm #1. Iowa farm #2 had no meteorological data, and furthermore the application event was approximately 5 km from the farm house and outdoor receptor. Iowa farm

#3 during the second application visit used a hand sprayer - an uncharacterized source type. The Iowa farm #4 application was a pesticide dusting of cows (no known source characterization), and furthermore was performed inside of a milking parlor, hence not subject to ambient meteorological dispersion. Finally, North Carolina farm # 2 used a hand cranked duster, a source type for which emission characterization is not known.

Specification of Model Parameters and Results of Modeling

The application of the AgDRIFT model to ground boom spraying was accomplished by the appropriate setting of various emission and dispersion variables. The objective of the modeling exercise was to provide conservative assessments of downwind concentrations of applied pesticides for an averaging time typical of application duration. The objective of a conservative (i.e. reasonable worst case) estimate suggests the reporting of plume centerline concentrations. The actual application rate (pounds active ingredient applied per acre and per unit time) was adhered to in the calculations. The drop size distribution was a medium-to-coarse, consistent with a TX-6 nozzle type. Nozzle direction was angled 45° between down and back-facing. The boom height was assumed to be 127 cm (50 in) above the ground, and the crop height was assumed to be 15 cm (6 in). (The choice of the TX-6 nozzle, nozzle angle, as well as the crop and boom height are reasonable worst case insofar as contributing to maximum downwind concentrations.) The model assumes that swath width is 12 m, and that application passes are transverse (at an angle of 90 degrees) to the wind direction. The receptor location was modeled as directly downwind of the center of the application field, corresponding to the average location of a plume centerline. Model simulations were consistent with measured values of wind speed during actual application periods.

In all modeled cases, application events were at least one hour in duration. Model results are reported as time-averaged concentrations during the application, as a function of downwind distance at the field centerline (hence average plume centerline). These average concentrations during the application may be interpreted as peak one-hour concentrations, at plume centerline, as a function of downwind distance. In the interest of comparing measured outdoor 24-hour average concentrations with a modeled reasonable worst case centerline estimate, the modeled estimates of the steady-state concentration have been "averaged down" to 24-hours, by weighting non-application periods with a zero concentration. This "24-hour" version of the model estimate must be interpreted with caution. The frequent detection of non-applied pesticides in outdoor samples suggest that background concentrations are often not zero (Jegier, 1969). Nevertheless, the conservative assumptions built into the simulation conditions should provide a defensible 24-hour estimate of reasonable worst case for comparison with measured values.

Appendix E reports applied pesticide quantitative details (Kuchibhatla et al., 1996a) for each modeled application, including pesticide identification, amount of active ingredient, total volume of liquid mixture applied, the concentration, acreage of application, application rate, duration of the application, and distance to the receptor (i.e. farm house). Additionally, the model estimate of worst case peak concentration at the receptor is reported, as is the "24-hour averaged" model calculation,

and finally the measured 24-hour average concentration. Figures 1 through 5 illustrates modeled peak one-hour concentration, at nominal adult breathing height (1.5 m), as a function of downwind distance.

Iowa farm #1 was configured with a 55 acre application field approximately 100 m to the southeast of the farm house (and outdoor monitor location). Two separate applications of dicamba were monitored during the day. The first application consisted of 500 gallons liquid (2.25 gallons Banvel), applied to 25 acres during approximately 2 hours 15 minutes. The second application consisted of 500 gallons liquid (2.5 gallons Banvel), applied to 30 acres during approximately 1 hour 15 minutes. Winds out of the southeast (135°) would favor transport of pesticide spray toward the monitor. HML activities occurred to the northwest of the house; winds from the northwest (315°) would favor transport of fugitive pesticide emission during HML activities. Iowa farm #1 experienced field-to-outdoor monitor wind directions during two (non-consecutive) 10 minute time intervals during the first application activity (at 9:20 a.m. and at 11:10 a.m.). At no other time did wind direction favor transport of pesticide (either application spray drift or HML fugitive emissions) to the monitor location. The applied pesticide (dicamba) was not detected (i.e., below quantitation limit) in the 24-hour outdoor sample. Model estimate of worst case *peak* concentrations (i.e. during the application, assuming winds toward the monitor), as a function of downwind distance, are shown graphically in figures 1 and 2 (first and second applications, respectively), and reported (see Appendix E) for the 100 m receptor distance as 14400 ng/m^3, and 12650 ng/m^3, respectively. The calculated 24-hour worst case concentration is reported as 2000 ng/m^3.

Iowa farm #3 was configured with a 30 acre application field approximately 100 m to the west of the farm house. Atrazine was applied as 100 lbs. Extrazine in 600 gallons liquid. The duration of the application was approximately 2 hours 15 minutes. Winds out of the west (270°) would favor transport of pesticide spray toward the monitor. HML activities occurred to the north northwest of the house; winds from the north northwest (330°) would favor transport of fugitive pesticide emission during HML activities. Iowa farm #3 did not experience any field-to-monitor wind during the application, nor was wind direction favorable for fugitive emission transport during the HML activity. The applied pesticide (atrazine) was, nevertheless, detected in the 24-hour outdoor sample (9.91 ng/m^3). Model estimate of worst case *peak* concentrations, as a function of downwind distance, are shown graphically in figure 3, and reported in Appendix E for the 100 m distance as 28750 ng/m^3. The calculated 24-hour worst case concentration is reported as 2700 ng/m^3.

North Carolina farm #1 was configured with a 14 acre field approximately 300 m to the north of the farm house. Two separate applications of alachlor were monitored during the day. The first application consisted of 85 gallons liquid (2.5 gallons Bronco), applied to 5.6 acres during approximately 1 hour 10 minutes. The second application consisted of 110 gallons liquid (5 gallons Bronco), applied to 8.3 acres during approximately 2 hours 55 minutes. Winds out of the north (0°) would favor transport of pesticide spray toward the monitor. HML activities occurred to the north of the house as well. (Records did not indicate a distinct separation of HML activity from application activity). North Carolina farm #1 experienced 21 (not consecutive) 10-minute time

intervals (210 minutes total) during the HML/application activities for which wind direction favored field-to-monitor pesticide transport (see Appendix C). The applied pesticide (alachlor) was detected in the 24-hour outdoor sample (265 ng/m^3). Model estimate of worst case *peak* concentrations, as a function of downwind distance, are shown graphically in figures 4 and 5 (first and second applications, respectively), and reported in Appendix E for the 300 m receptor distance as 10900 ng/m^3, and 11100 ng/m^3, respectively. The calculated 24-hour worst case concentration is reported as 1900 ng/m^3.

Interpretation of outdoor monitor concentration must consider wind direction at the time of application. A single point measurement is not representative of all directions. The outdoor monitor at Iowa Farm #1 did not detect dicamba in the 24-hour sample; the model indicated that an average concentration as high as 2000 ng/m^3 could occur at that same distance, under worst case conditions of spraying and meteorology. The outdoor monitor on Iowa Farm #3 (first application visit) measured a 24-hour concentration of 9.91 ng/m^3; the model indicated that an average concentration as high as 2700 ng/m^3 could occur at that same distance, under worst case conditions of spraying and meteorology. The outdoor monitor on North Carolina farm #1 measured a 24-hour concentration of 265 ng/m^3; the model indicated that an average concentration as high as 1900 ng/m^3 could occur at that same distance, under worst case conditions of spraying and meteorology. In these three examples, the measured concentration was, respectively, 0.0%, 0.4%, and 14% of the worst case maximum.

To put these numbers in context, the modeled peak one-hour concentrations at receptor distance, worst case assumptions of spraying and meteorology noted, greatly exceeded the applicators' measured personal air concentration (discussed later). While an applicator's breathing zone (i.e. personal air) during HML and application activity is probably consistently higher in applied pesticide concentration, it may not always exceed concentrations obtained directly downwind of an application.

Time Series of Indoor and Outdoor Pesticide Concentrations

Appendix F presents indoor and outdoor monitored concentrations of all detected pesticides, by farm, for both *control* (non-application) season, and application period (Kuchibhatla et al., 1996b). All reported air concentrations of pesticides are limited to the $PM_{2.5}$ fraction. (Significant differences between the $PM_{2.5}$ fraction and the total are to be expected only in the near vicinity of an atomizing source.) The concentrations are presented in time series format. The indoor air of the farm residence was sampled (24 hour averages) on days 2, 3, and 4 of the application period. The *control* (non-application) season indoor air as well as the outdoor air (24 hour average) for day 3 are reported as well in Appendix F. An asterisk (*) appended to a detected pesticide indicates that this pesticide was applied; a dagger (†) appended to a detected pesticide indicates that this pesticide was found as residue within the applied mixture. Threshold limit values, or TLV, are included for reference where possible (Durham, 1976; Exposure Factors Handbook, 1989). Additionally, Appendix G calculates indoor to outdoor ratios of detected pesticides. (The *mean* indoor

concentration was used for this calculation when detection occurred on multiple days. The ratio was not calculated if only day 2 or day 4 detected an indoor concentration, since the day 3 outdoor concentration was not coincident.)

On Iowa farm #1, control season concentrations of chlorpyrifos, dichloran, heptachlor, metolachlor, and trifluralin were detected in indoor air samples. None were detected during the three-day monitoring period of the application (May 17, 18, and 19, 1994). Dicamba was the only applied pesticide on day 3 of the application period. While dicamba was not detected in the outdoor sample, it was found in the indoor air on day 3 (2.27 ng/m^3), following a non-detect on day 2, and a subsequent non-detect on day 4.

On Iowa farm #2, control season concentrations of chlorpyrifos, metolachlor, and trifluralin were detected in indoor air samples. No pre-application day (day 2) indoor air samples were taken on Iowa farm #2. Day 3 and 4 monitoring (May 9, and 10, 1994) followed the scheduled protocol of measurements. Day 3 pesticide application involved the greatest number of pesticides observed in this study. Applications of atrazine, 2,4-D butoxy ethyl ester, dicamba, and metolachlor were completed over the course of 10 hours. Indoor concentrations of all pesticides detected during control season sampling were again found on application period day 3 and day 4. Chlorpyrifos and trifluralin were detected at similar levels as in the control season (neither were applied), but metolachlor, which was applied, was detected at substantially greater concentration on day 3 and day 4, compared with control season levels (71.9 and 63.0 vs. 15.6 ng/m^3). Metolachlor was also detected in the outdoor sample on day 3, but at substantially lower levels than the mean indoor concentrations. (The ratio of mean indoor concentration of metolachlor to day 3 outdoor concentration was approximately equal to 9; see Appendix G). Atrazine, 2,4-D butoxy ethyl ester, and dicamba, were all applied but none were detected in indoor air samples. Atrazine, alachlor, and trifluralin were detected on the day 3 outdoor sample. Terbufos, which was not applied nor was it found as residue in the applied mixture, was detected in the indoor air samples collected on day 3 and day 4 (52.0 and 49.4 ng/m^3, respectively). Terbufos was not detected in the day 3 outdoor sample, nor was it detected in the indoor air sample collected during the control season.

On Iowa farm #3, control season concentrations of alachlor, chlorpyrifos, metolachlor, and propoxur were detected in indoor air samples. During the "first" visit/application period (May 13, 14, and 15, 1994), atrazine was the only applied pesticide, although metolachlor was residual within the mixture. Outdoor concentrations of atrazine and metolachlor were detected on the application day, but only metolachlor was detected in the indoor air samples (on days 2, 3, and 4). (The ratio of mean indoor concentration of metolachlor to day 3 outdoor concentration was approximately equal to 0.16) Alachlor, chlorpyrifos, and propoxur, which were not applied but were detected indoors during the control season, were again detected during the first application period. Alachlor was detected at similar concentrations every day of the three-day monitoring period as during the control season (6.13, 9.39, 7.03, vs. 13.3 ng/m^3). Alachlor was detected on day 3 in the outdoor air sample as well (18.7 ng/m^3). (The ratio of mean indoor concentration of alachlor to day 3 outdoor concentration was approximately equal to 0.40). Chlorpyrifos was detected at similar concentrations on day 3 as during the control season (0.950 vs. 1.03 ng/m^3), and was detected in the

day 3 outdoor sample (3.44 ng/m^3). Chlorpyrifos was not detected indoors on days 2 or 4. Propoxur was detected at greater concentrations every day of the monitoring period than was detected during the control season (21.5, 27.4, and 19.8 vs. 14.6 ng/m^3). The indoor air samples also detected terbufos (25.0, 41.3, and 26.6 ng/m^3), and very low levels of trifluralin (days 3 and 4). Neither terbufos nor trifluralin were applied, nor were they found present in the indoor air sample taken during the control season. Trifluralin was detected in the outdoor sample taken on day 3, at concentrations higher than were detected indoors.

During Iowa farm #3's "second" visit/application period (June 11, 13, and 14, 1994), 2,4-D, and 2,4-D butoxy ethyl ester were applied, and alachlor was found to be residual within the mixture. Outdoor concentrations of 2,4-D, and 2,4-D butoxy ethyl ester were not detected on day 3, nor were they ever detected in indoor air samples on days 2, 3, or 4, or during the control season sampling. Alachlor was detected in the outdoor sample on day 3 (2.86 ng/m^3), but was detected at higher concentrations in indoor samples on days 2, 3, and 4 (3.67, 5.68, and 4.78 ng/m^3, respectively). The control season indoor sample contained the highest measured concentration (13.3 ng/m^3). As was the case during the first application period, propoxur was detected in the indoor samples every day of the second monitoring period at levels higher than were detected during the control season (23.3, 33.4, and 36.2 ng/m^3, vs. 14.6 ng/m^3), but at concentrations similar to those found during the first application period. Similarly, metolachlor was detected in the indoor samples every day of the second application monitoring period, but again concentrations were lower than in the day 3 outdoor sample. The indoor air samples taken during the second application period also detected terbufos - at lower levels than were found during the first application period, and trifluralin - at similar (low) levels as were found during the first application period. Neither terbufos nor trifluralin were applied, nor were they found present in the indoor air sample taken during the control season. Trifluralin was detected in the outdoor sample taken on day 3, at concentration higher than were detected indoors. (Ratios of mean indoor concentration to day 3 outdoor concentration were computed for the following pesticides: alachlor: 1.64; chlorpyrifos: 1.26; metolachlor: 0.58; propoxur: 34; and trifluralin: 1.06). Chlorothalonil was detected every day on the second monitoring period (5.60, 11.0, and 9.47 ng/m^3). Chlorothalonil was not applied, was not detected in the day 3 outdoor sample, nor was it detected during the first application period or the control season. Atrazine, the only applied pesticide during the first application period, was detected in the outdoor sample on day 3 of the second application period (6.17 ng/m^3), and was detected indoors on day 4 only, at lower concentrations (4.82 ng/m^3) than the outdoor level.

On Iowa farm #4, control season concentrations of α-chlordane, γ-chlordane, chlorpyrifos, diazinon, fonofos, lindane, metolachlor, terbufos, and trifluralin were detected. Control season concentration of lindane (111 ng/m^3) is particularly noteworthy. The applied pesticides during the application period were pyrethrins and piperonyl butoxide. Neither were detected in the 24-hour outdoor sample on day 3, nor were indoor concentrations detected during any of the three-day monitoring period (June 15, 16, and 17). (Note: a deviation from the application/sampling protocol occurred on Iowa farm #4 with applications (presumably pyrethrins and piperonyl butoxide) made on days 2 and 4 (designed non-application days), in addition to day 3.) Of the pesticides detected during the control season, α-chlordane, γ-chlordane, lindane, and metolachlor, were detected each

day of the three-day indoor monitoring - α-chlordane and γ-chlordane were detected at similar (low) concentrations as during the control season; lindane levels were somewhat reduced (71.0, 57.0, and 76.6 ng/m^3, vs. 111. ng/m^3 control season); metolachlor levels were substantially lower (2.80, 2.68, and 3.15 ng/m^3, vs. 9.19 ng/m^3). Chlorpyrifos, also detected during the control season, was detected indoors on day 2 and day 4 only, at consistently low levels. Diazinon, fonofos, terbufos, and trifluralin, detected in indoor air samples during the control season, were not found during any of the three application period monitoring days. Atrazine and heptachlor, which were not detected during the control season indoor air sampling, were detected on day 2 (heptachlor only), and day 3 (atrazine and heptachlor). The only pesticide to be detected in the day 3 outdoor air sample was atrazine, but at lower concentrations than were detected in the indoor sample day 4 (1.94 ng/m^3 outdoor day 3 vs. 21.0 ng/m^3 indoor day 4).

North Carolina farm #1 was not sampled for a control season. Alachlor was the only applied pesticide during the application period (monitored on June 21, 22, and 23, 1994); metolachlor was found residual within the applied pesticide mixture. (Note: a deviation from the application/sampling protocol occurred on North Carolina farm #1 with an application (presumably alachlor) made on day 2 (a designed non-application day), in addition to day 3.) Outdoor concentrations of alachlor were detected on the application day. The 24-hour outdoor concentration of alachlor was 265 ng/m^3. Outdoor concentrations of metolachlor (7.97 ng/m^3), as well as non-applied, non-residual, pesticides were detected (α-chlordane (6.99 ng/m^3), γ-chlordane(7.36 ng/m^3), chlorpyrifos (3.09 ng/m^3), and heptachlor (1.65 ng/m^3)). Concentrations of alachlor were detected in indoor samples on each monitoring day (27.9, 33.2, and 46.3 ng/m^3, respectively). In fact, every pesticide that was detected in the outdoor sample on North Carolina farm #1, was also detected indoors on all three monitoring days. In the cases of alachlor, indoor concentrations were substantially lower than outdoor concentrations. In the case of chlorpyrifos and metolachlor, indoor and outdoor concentrations were comparable. But α-chlordane, γ-chlordane, and heptachlor were found indoors at substantially higher concentrations than were found outdoors. In the case of α-chlordane, mean indoor concentration over the three-day monitoring period was a factor of 21 times greater than the day 3 outdoor sample. In the case of γ-chlordane, the three-day mean indoor concentration was a factor of 26 times greater than the day 3 outdoor sample. And in the case of heptachlor, the three-day mean indoor concentration was a factor of 48 times greater than the day 3 outdoor sample. Two pesticides were detected in indoor samples that were not detected in the outdoor sample - propoxur and trifluralin. Trifluralin was present a very low levels on day 2 only (0.664 ng/m^3), but propoxur was detected each of the three days, at persistently high levels (203, 245, and 239 ng/m^3, respectively).

North Carolina farm #2 was not sampled for a control season. Carbaryl was the only applied pesticide during the application period (monitored on July 27, 28, and 29, 1994). Outdoor concentrations of carbaryl were detected on the application day. The 24-hour outdoor concentration of carbaryl was 93 ng/m^3. Outdoor concentrations of α-chlordane (1.53 ng/m^3) and γ-chlordane (1.75 ng/m^3) were detected as well. Carbaryl was detected in the indoor air samples on each monitoring day (279, 47.9, and 72.4 ng/m^3, respectively). Indeed, as was the case with North Carolina farm #1, every pesticide that was detected in the outdoor sample was also detected in the

indoor sample on all three monitoring days. The three-day mean indoor concentration of carbaryl was a factor of 1.4 times greater than the day 3 outdoor concentration. The three-day mean indoor concentration of α-chlordane was a factor of 70 times greater than the day 3 outdoor concentration. The three-day mean indoor concentration of γ-chlordane was a factor of 84 times greater than the day 3 outdoor concentration. Chlorpyrifos was detected at low levels in the indoor air on each monitoring day (1.69, 1.46, and 3.07 ng/m^3, respectively). Heptachlor was detected in the indoor air on each monitoring day at higher levels (79.3, 90.2, and 73.9 ng/m^3, respectively). Terbufos was detected in the indoor air on day 3 only (47.6 ng/m^3).

Indoor concentrations of an applied or residual pesticide were higher on the application day than conterminous days on Iowa farm #1 (dicamba), Iowa farm #2 (metolachlor), and Iowa farm #3 (alachlor; second application period). However, the cases observed in the pilot study do not strongly support a conclusion that outdoor air (exclusively) is the source of indoor concentrations of applied/residual pesticides. If stated as an hypothesis, " *For applied/residual pesticides, the indoor concentration on day 3 (application day) is not zero if and only if the outdoor concentration on day 3 is not zero*", there are 7 cases for which this hypothesis may be tested. Of the 7, 4 support the hypothesis (metolachlor on Iowa farm #2; metolachlor on Iowa farm #3/first application; alachlor on Iowa farm #3/second application; carbaryl on North Carolina farm #2); and 3 refute the hypothesis (dicamba on Iowa farm #1; atrazine on Iowa farm #2; atrazine on Iowa farm #3/first application). Thus, there is limited and conflicting evidence to support an (exclusively) outdoor air source of indoor concentrations of applied pesticides.

Activity Logs

The time, location, and activity of study participants were recorded by the participants during days 2, 3, and 4. These activity logs were reviewed with respect to participant location (and activity, in the case of HML or application). To assess exposure to detected pesticides, participant location was partitioned by characterized microenvironments (indoors; outdoors on farm; or performing HML/application activity), and time-in-microenvironment was accumulated within 24-hour periods. Activity logs were sufficiently detailed and complete to permit time accounting precision to whole hours. While some participants recorded detail to within 5 minutes, a coarser time resolution was the rule. Furthermore, occasional ambiguities in recorded time-activity precluded ascertaining participant location to resolutions of less than one hour.

Exposure calculations reported in Appendices I, J, K, L, M and O should be regarded as "back of the envelope" estimates only. Limitations in such calculations arise from several simplifying approximations and uncertainties in interpretation. Firstly, the indoor and ambient (outdoor) concentrations reported are 24-hour averages obtained from single sampling locations. This approximation is valid to the extent that respective microenvironment air is well mixed or that sample locations were "representative" of the microenvironment.

Secondly, averaging periods for indoor air measurements were not identical with "midnight

to midnight" activity logs of the participants. The partition of the participant activity day is based on a midnight-to-midnight day. However, the indoor and outdoor air sample "day" did not begin and end at midnight (precise changeover time was not recorded, but was typically early to mid morning). While this does introduce some uncertainties when calculating exposures, the similarity of participant activities between days (autocorrelation), especially with respect to the microenvironment occupied (indoors, outdoors on farm, or performing HML/application) between the hours of midnight and 8 a.m., is similar day-to-day .

Thirdly, the interpretation of activity logs with respect to identification of the (hourly) location of individuals assigned each to one of four microenvironments: "indoors", "outdoors on farm", "engaged in HML/Application activity", or "off the farm". The first three microenvironments were sampled for at least a portion of the monitoring period. (The "off the farm" microenvironment, effectively a placeholder to account for otherwise unassigned hours in the day, was not sampled and did not accrue any pesticide exposure to participants.) The single point sampling of the indoor and outdoor microenvironments necessitates the assumption (for purposes of exposure calculation) of well-mixed pollutant concentration within that microenvironment. Consequently, "indoors" and "outdoors" were designated intentionally as undifferentiated microenvironments, even when participant activity logs permitted a finer resolution of location (e.g., within specific rooms).

With the above limitations noted, some general interpretive remarks may be stated. It is generally true that the spouse spent more hours indoors during the 3-day monitoring period than other participating members of the family (four of seven cases; a child's indoor time lead in the other three). As such, the spouse's exposure to any pesticide via the inhalation pathway and from the indoor microenvironment, usually exceeded that of other family members, and generally greatly exceeded indoor inhalation exposure of the applicator (except in North Carolina #1, where spouse and applicator were comparable). The ratio of spouse indoor inhalation exposure to applicator indoor inhalation exposure ranged from a high of 3.09 (dicamba on Iowa #1) to a low of 0.97 (alachlor on NC #1). Children generally spent slightly less time indoors than the spouse, but again substantially more than the applicator (except at Iowa #3-first application period, and North Carolina #2).

Applicator's Personal Exposure and Inhalation Dose

Applicator exposures represented the preponderance of the applied pesticide inhalation exposure of any family member on any AHS farm on the day of application. Applicators generally used no respiratory protection during HML or application activity. Iowa farm #3 applicator used a dust mask during HML activities; North Carolina farm #2 applicator used a dust mask during application activity. No other respiratory protection was practiced (see Appendix H). Not surprisingly, HML and application activities accounted for nearly all of the applicator's day 3 exposure to the applied pesticide.

All air measurements were limited to the $PM_{2.5}$ fraction. Applicators may have been exposed

to larger-sized aerosols during HML or application activity. Controlled wind tunnel experiments with an atomizing source have estimated, under specific and limited conditions, that the $PM_{2.5}$ cut may represent only 50% of the total air concentration for volatile pesticides (e.g., chlorpyrifos, lindane); 30% of the total for intermediate volatility pesticides (e.g. atrazine, α-chlordane, γ-chlordane); and only 10% of the total for low volatility pesticides (e.g. 2,4-D salt, dicamba, pyrethrins). The conditions under which AHS HML/applied pesticides were vaporized cannot be assumed to be similar to the near-worst case wind tunnel conditions, hence the aerosol size distribution within the applicators breathing zone (and the temporal stability of that distribution) cannot be estimated. All reported air concentrations are the $PM_{2.5}$ fraction, and inhalation exposure/dose calculations are exposures/doses to the PM2.5 fraction.

Appendix I presents applicator exposure from HML/application activity as a percentage of day 3 total exposure. Applicator exposure during HML/application activities accounted for between 80 % (alachlor on North Carolina farm #1) and 100 % (dicamba and 2,4-D butoxy ethyl ester on Iowa farm #2) of applicator day 3 exposure to applied pesticides. A summary of applicators' day 3 HML/application - related dose is given in Appendix J. Most remarkable among these is the NC #2 applicator's carbaryl inhalation dose - 1,932,000 ng.

The exposures accrued by applicators during several of the monitored AHS applications may be put in context by comparison with inhalation exposures catalogued in the Pesticide Handlers Exposure Database (PHED, 1995). PHED contains measured exposure data for workers involved in the handling or application of pesticides in the field. Design and development of PHED was undertaken with the assumption that "exposure to pesticide users is primarily a function of the physical parameters of handling and application...rather than of the chemical properties of the active ingredient". PHED is intended to allow prediction of pesticide exposures based on selection (subsetting) of formulation type, HML procedures, application equipment, or other relevant exposure parameters. PHED contains measured exposure data with associated exposure parameters for approximately 800 records of applicator and activity.

Comparisons between inhalation dose retrieved from PHED with personal air concentrations measured during applicator HML and application activities are provided with several cautions. Firstly, the PHED air concentration data are total concentrations, without aerosol/particulate size cutoff (Keigwin, 1996), whereas the AHS air concentrations are limited to the $PM_{2.5}$ fraction. Secondly, the personal air concentrations are multiplied by the activity time to obtain an exposure estimate. The activity time is known with limited precision. Observed HML vs. application activity within the AHS could not always be differentiated. (PHED distinguishes between HML and application activities). Thirdly, a breathing rate must be applied to the exposure calculation to obtain an inhaled dose. A rate of 25 liters per minute (light to moderate work) is applied in all HML/application dose calculations in this report. (PHED defaults to 25 liters per minute breathing rate in its inhalation dose calculations. No measurements of breathing rates of any applicators were recorded in this pilot, therefore this rate was deemed acceptable for dose calculations derived from applicator personal air exposures). Finally, retrieval of PHED data pertaining to HML activities required specific information regarding the mechanics of the mixing, and the physical state of the

constituents. The complete conditions of mixing during the HML activities were not recorded.

In obtaining valid comparisons with PHED, proper subsetting (data filtering subject to certain selection criteria) must be chosen to limit cases to those comparable to the study conditions. Data classification within PHED treats pesticide handling/mixing/loading separately from pesticide application, consistent with AHS. In the subsetting appropriate for HML activities, PHED data selection criteria included pesticide physical state (liquid or powder formulations), open pour mixing, and data quality limited to the highest 2 of 5 PHED rating categories (Keigwin, 1996). In the subsetting appropriate for application activities, PHED data selection criteria included mixture physical state (liquid), ground boom sprayer, a tractor as the applicator transport vehicle, and data quality limited to the highest 2 of 5 PHED rating categories. The Revelations database driver then selects all appropriate cases. The distribution type is estimated (lognormal, normal, indeterminate), and distribution statistics (geometric mean, mean, median, and number of observations) are calculated. In the subsettings selected for HML activities with either liquid and powder formulations, the distributions were unknown (i.e. did not fit a standard model), so the statistic selected for each calculation of inhalation dose was the median. In the subsetting deemed appropriate for liquid applications with ground boom sprayers, the distribution was lognormal, and the statistic selected in calculation of inhalation dose was the geometric mean.

Appendix K presents approximate inhalation dose comparisons for Iowa farms #1 and #3 (first application period), and North Carolina farm #1. Applicators used a single pesticide in each of these cases, and each was applied with a ground boom sprayer. The Iowa farms recorded distinct HML and application activities; North Carolina farm #1 HML and application could not be differentiated. The calculated inhalation dose (based on personal air concentration measurement (Kuchibhatla et al., 1996b)) delivered to Iowa farm #1 applicator during HML activities was 66 ng dicamba; and during application activities the received dose was 3690 ng dicamba. The combined total HML/application calculated inhalation dose was 3756 ng dicamba. The data retrieved from PHED, subject to the aforementioned selection criteria, reports median dose received during HML activities, scaled to amount of pesticide used, is 41600 ng; geometric mean inhaled dose received during application activities was retrieved from PHED as 3620 ng. The calculated dose for HML activity was incomparably below PHED median reference (on the order of three orders of magnitude). The calculated inhalation dose arising from application activity was, on the other hand, very similar to geometric mean PHED reference level.

The calculated inhalation dose delivered to Iowa farm #3 applicator during HML activities was 211 ng atrazine; and during application activities the received dose was 751 ng atrazine. The combined total HML/application calculated inhalation dose was 962 ng atrazine. The data retrieved from PHED reports median dose received during HML activities, scaled to the amount of pesticide used, is 90400 ng; geometric mean inhaled dose received during application activities was retrieved from PHED as 9046 ng. Comparisons indicate again that HML dose received was markedly below the PHED median (by two orders of magnitude); application dose received was one tenth of PHED geometric mean reference level.

The HML and application of alachlor on North Carolina farm #1 could not be differentiated into distinct HML and application. The combined HML/application was repeated a second time during day 3, and personal air monitors as well as pesticide quantity were documented as separate events. The calculated inhalation dose delivered to North Carolina farm #1 applicator during the first of two combined HML/application activities was 1700 ng alachlor; and during the second combined HML/application the received dose was 11900 ng alachlor. The combined total HML/application calculated inhalation dose was 13600 ng alachlor. The data retrieved from PHED was limited to application-related dose for both events (no HML records were retrieved). PHED reports a geometric mean dose for application as 1900 ng (corresponding to the amount of pesticide used in the first event); geometric mean inhaled dose corresponding to the second application was retrieved from PHED as 3800 ng. The combined total application activity (not inclusive of HML activity) yields a PHED reference inhalation dose of 5700 ng - less than the calculated 13600 ng alachlor received.

In the three cases considered, PHED geometric mean doses associated with the application event was a better indicator of the calculated inhalation dose derived from personal air concentration measurements, than was the PHED median dose associated with HML events an indicator of calculated HML dose received. In fact, the PHED application dose was a fair indicator of total (HML plus application) calculated dose. PHED median HML doses were consistently orders of magnitude greater than the observed dose.

Total Air Pathway Exposure on Application Day

Day 3 of the application period was the most intensively monitored. The applicator was outfitted with a personal air monitor during HML and/or Application activities. Indoor and outdoor samplers were set up to record a 24-hour average. The outdoor sampler was placed near the house, upwind of the prevailing wind direction at the time of setup. Personal, indoor, and outdoor samplers were quartz pre-filter, PUF cartridge 2.5 micron samplers. The personal monitor worn by the applicator contained a personal respiratory air sampling pump. Significant differences between the $PM_{2.5}$ fraction and the total are to be expected only in the near vicinity of an atomizing source. All calculated inhalation exposure calculations are based on the $PM_{2.5}$ fraction.

It is of interest to calculate inhalation exposures of all family members on the application day to assess relative exposure of applicator, spouse, and children. It is also instructive to partition the exposures by microenvironment, to attribute a person's accrued application day exposure to a single predominant microenvironmental exposure, or, as the case may be, to no particular microenvironmental exposure. Appendix L presents application day air pathway exposures, by farm, applied pesticide, family member, and by microenvironment. The data are presented to permit attribution of a family member's exposure to each of the three designated microenvironments (i.e. HML/application activities, outdoors on farm, and indoors). When personal air samples distinguished multiple HML/application activities, separate exposures are calculated. The final column in each table provides the sum of exposures accrued in all microenvironments on the

application day, by family member and applied pesticide.

On Iowa farm #1, monitoring on the application day included two HML/application events. Dicamba was the only applied pesticide for both events. The applicator was engaged in HML/application activities for 3 hours with the first event, and for 2 hours during the second event. The applicator's air exposures during these events were respectively, 442 h-ng/m^3 and 2075 h-ng/m^3. The spouse and children were not involved in the HML/application activities. No outdoor exposures were accrued by any family member as Dicamba was not detected in the 24-hour average outdoor sample. Indoor concentrations of Dicamba were detected, and exposures are reported for each family member. The day 3 total air exposure to dicamba is reported in the last column, as the sum of personal air exposure (applicator only), outdoor air exposure, and indoor air exposure. The applicator's total day 3 exposure to dicamba was 2528 h-ng/m^3, of which nearly all (> 99%) was accrued during HML/application activities. The total (day 3) air exposure of the applicator to the applied pesticide dicamba exceeded other family members by nearly two orders of magnitude. The spouse, child #1, and child #2 exposures to dicamba on the application day were, respectively, 34, 27, and 32 h-ng/m^3.

The largest number of pesticides applied during an application day in this study was observed on Iowa farm #2. Over the course of ten hours, in two HML/application events, the applicator applied atrazine, metolachlor, 2,4-D butoxy ethyl ester, and dicamba. The applicator was exposed to all applied pesticides. Atrazine was detected in the 24-hour outdoor sample, but not in the indoor sample. Metolachlor was detected in the outdoor sample, and at higher levels indoors. The applications of 2,4-D butoxy ethyl ester and dicamba did not result in detectable levels in either the outdoor or indoor sample. The air exposures accumulated for the applicator, spouse, and child are reported in Appendix L. The applicator's day 3 exposure to atrazine (9931 h-ng/m^3) was three orders of magnitude greater than the spouse or child. The applicator's total atrazine exposure on day 3 was almost entirely (>99%) accrued during HML/application activities. The applicator's total day 3 exposure to metolachlor (26924 h-ng/m^3) exceeded that of the spouse or child by more than one order of magnitude. The applicator's total metolachlor exposure on day 3 was predominantly attributable to HML/application activities (97% vs. 3% combined outdoor and indoor exposure). Exposures of 2,4-D butoxy ethyl ester and dicamba were limited to the applicator.

On Iowa farm #3, during the first of two application events, atrazine was the only pesticide applied during a single HML/application event lasting for 4 hours. The applicator accrued virtually all of his day 3 exposure to atrazine during the HML/application activity (640 h-ng/m^3 personal air exposure vs. 680 h-ng/m^3, or 94 % of the day 3 total). Detectable levels of atrazine were found in the 24-hour outdoor sample; atrazine was not detected in the indoor sample.

The second application period on Iowa farm #3 monitored the application of 2,4-D and 2,4-D butoxy ethyl ester. Neither pesticide was detected in the applicator's personal air, 24-hour outdoor air sample, nor day 3 indoor air sample.

On Iowa farm #4, a single 3 hour HML/application event was monitored. The applied

pesticides were pyrethrin and piperonyl butoxide. Neither pesticide was detected in the applicator's personal air, 24-hour outdoor air sample, nor day 3 indoor air.

On North Carolina farm #1, two applications of alachlor were monitored. The first HML/application was 1 hour in duration, resulting in a personal air exposure to the applicator of 1130 h-ng/m^3. The second HML/application event on day 3 was 3 hours in duration, resulting in a personal air exposure to the applicator of 7920 h-ng/m^3. Outdoor and indoor concentrations of alachlor were detected in their respective 24-hour samples. The applicator's total air exposure (day 3) to alachlor was 11337, of which 80% was accrued in application activities. The spouse and child accrued alachlor exposures of 697 and 2320 h-ng/m^3, respectively.

On North Carolina farm #2, a single application event was monitored. Carbaryl was applied in a 2-hour HML/application, resulting in a personal air exposure to the applicator of 1,288,000 h-ng/m^3. Detectable levels of carbaryl were measured in the outdoor and indoor 24-hour samples. The applicator's total air exposure (day 3) to carbaryl was 1,289,000 h-ng/m^3, virtually all (>99%) of which was accrued in application activities. The spouse, child #1, and child #2 accrued carbaryl exposures of 955, 479, and 575 h-ng/m^3, respectively.

Not unexpectedly, the applicator received the preponderance of air pathway exposure during day 3. Appendix M presents spouse and child day 3 total exposures to applied pesticides as a percentage of the applicator's day 3 total exposure. Spouse and child relative air exposures to applied pesticides ranged from 0% of the applicator's air exposure, to a high of 20% of the applicator's air exposure (child exposure to alachlor on North Carolina farm #1).

Indoor Air Exposure and Inhalation Dose

The indoor microenvironment is unique in its contribution to pesticide exposure of *all* study participants via the air pathway. Time-activity logs indicated that all participating family members at all farms spent an average in excess of 8 hours per day indoors, over the three-day period. In all cases except Iowa Farm #4, concentrations of at least one pesticide being applied, or found as residue within the application mixture, were measured indoors during the three-day monitoring period. This is not to infer that the application event *necessarily* served as the source of the indoor concentration. Indoor sources of a pesticide may be present as residue in dust or on surfaces (NOPES, 1990; Lewis et al., 1994; Whitmore et al., 1994). Numerous examples of non-applied, non-ambient (no detectable outdoor concentration), pesticides were found to be present in indoor air samples. Indeed, indoor concentrations of non-applied pesticides were the rule more than the exception. Historical use of such pesticides (Kuchibhatla et al., 1996b) may serve to provide plausible explanation for a detected presence in indoor air - assuming an appropriate vapor pressure. As Appendix N indicates, historical use of chlorpyrifos on Iowa farm #2; terbufos on Iowa farm #3 (first visit); atrazine, metolachlor, and terbufos on Iowa farm #3 (second visit); and atrazine on Iowa farm #4 were indicated by applicator questionnaire. (Vapor pressures of the indoor-detected, non-applied, historically used pesticides are as follows: atrazine: 0.039 mPa; chlorpyrifos: 2.7 mPa;

metolachlor: 4.2 mPa; terbufos: 34.6 mPa; [Pesticide Manual, 1994]). The absence of a confirmed historical use should not be construed as "never" used.

Appendix O presents indoor air exposures and inhalation doses of all indoor detected pesticides - *regardless of their known origin on the farm*, for all participants, by farm, pesticide, and day. All calculated inhalation dose calculations are based on the $PM_{2.5}$ fraction. The three-day exposure sum, as well as a mean daily indoor inhalation dose, is also calculated in the final columns of each table. For ease of reference, the 24-hour indoor concentration of each detected pesticide for each day is reported in the same box with the pesticide name.

A resting breathing rate of 10 liters per minute [L/min] (Cotes et al., 1991; The Exposure Factors Handbook, 1989; Nigg et al., 1990; ACGIH, 1991) is applied to all exposure sums in calculating an inhalation dose. Daily inhalation rates vary by age, and by sex after age 10 (3.1 L/min for infants less than a year old, to 11.8 L/min for 18 year old males). A daily inhalation rate of 10 L/min, applied to indoor air exposures, is a reasonable estimate for adults, but is high for children. Since the ages of the 9 children in the AHS were not always recorded, it is not possible to apply a more age-specific inhalation rate to the children's indoor inhalation dose calculation. (Children participants in the AHS were known to range in age from at least 3 years to as old as 19 years.) The uniform application of 10 L/min daily inhalation rate to all AHS cohorts during indoor activity is seen as yielding appropriate estimates of indoor inhalation dose for adults, and conservative (i.e. high) estimates for the children.

Iowa Farm #1 detected indoor air concentrations of dicamba on day 3. Dicamba was the only applied pesticide on day 3 (2.27 ng/m^3). Mean daily inhaled indoor air dose was calculated to be on the order of nanograms for all family members.

Iowa Farm #2 measured indoor air concentrations of chlorpyrifos, metolachlor, terbufos, and trifluralin - each on days 3 and 4 (no sample was collected on day 2). Of these, only metolachlor was applied on day 3. Atrazine, 2,4-D BOEE, and dicamba were also applied, and 2,4-D was found to be residual within the applied mixture. Calculated mean daily inhaled indoor air dose of metolachlor and terbufos was on the order of hundreds of nanograms for all family members; chlorpyrifos and trifluralin doses were on the order of tens of nanograms for all family members.

Iowa Farm #3 during the first application event measured indoor air concentrations of alachlor (days 2, 3, and 4); chlorpyrifos (day 3); metolachlor (days 2, 3, and 4); propoxur (days 2, 3, and 4); terbufos (days 2, 3, and 4); and trifluralin (days 3 and 4). Atrazine was the only applied pesticide during this (first) application period, but was never detected in indoor air samples. Calculated mean daily inhaled indoor air dose of propoxur and terbufos were on the order of hundreds of nanograms for all family members; alachlor and metolachlor doses were on the order of tens of nanograms; and chlorpyrifos and trifluralin were in the single digit nanogram dose levels for all family members.

Iowa Farm #3 during the second application event measured alachlor (day 2, 3, and 4),

atrazine (day 4), γ-chlordane (day 4), chlorothalonil (days 2, 3, and 4), chlorpyrifos (days 2, 3, and 4), metolachlor (days 2, 3, and 4), propoxur (days 2, 3, and 4), terbufos (days 2, 3, and 4), and trifluralin (days 2, 3, and 4). Only 2,4-D and 2,4-D BOEE were applied (neither were detected), while alachlor was residual in the applied mixture. Calculated mean daily inhaled indoor air doses of propoxur were in the hundreds of nanograms for all family members; alachlor, atrazine, chlorothalonil, chlorpyrifos, metolachlor, propoxur, terbufos, and trifluralin were on the order of tens of nanograms; and γ-chlordane was in single nanograms dose.

Iowa farm #4 measured indoor air concentrations of atrazine (day 4); α-chlordane (days 2, 3, and 4); γ-chlordane (days 2, 3, and 4); chlorpyrifos (days 2 and 4); heptachlor (days 3 and 4); lindane (days 2, 3, and 4); and metolachlor (days 2, 3, and 4). The applied pesticide was pyrethrin, with piperonyl butoxide as a synergist (neither were detected in the indoor air). Calculated mean daily inhaled indoor air doses of lindane were on the order of hundreds of nanograms for all family members; atrazine, α- and γ-chlordane, chlorpyrifos, heptachlor, and metolachlor were on the order of tens of nanogram doses for all family members, with applicator dose being slightly less due to relatively less time spent indoors (approximately 9 hours per day vs. approximately 20 hours per day for spouse and children).

North Carolina farm #1 measured indoor air concentrations of alachlor (days 2, 3, and 4); α-chlordane (days 2, 3, and 4); γ-chlordane (days 2, 3, and 4); chlorpyrifos (days 2, 3, and 4); heptachlor (days 2, 3, and 4); metolachlor (days 2, 3, and 4); propoxur (days 2, 3, and 4); and trifluralin (day 2). Alachlor was the only applied pesticide, with metolachlor found to be residual within the mixture. Calculated mean daily inhaled indoor air doses of α-chlordane, γ-chlordane, and propoxur were on the order of a microgram for *all* family members, comparable to typical applicator inhalation doses during a pesticide application (excluding HML activities). Alachlor and heptachlor mean daily inhaled air doses were on the order of hundreds of nanograms; chlorpyrifos and metolachlor were on the order of tens of nanograms; and trifluralin doses were calculated to be on the order of one nanogram, for all family members.

North Carolina farm #2 measured indoor air concentrations of carbaryl (days 2, 3, and 4); α-chlordane (days 2, 3, and 4); γ-chlordane (days 2, 3, and 4); chlorpyrifos (days 2, 3, and 4); heptachlor (days 2, 3, and 4); and terbufos (day 2). Carbaryl was the only applied pesticide. The spouse on North Carolina farm #2 spent substantially more time indoors than either child or the applicator during the three-day monitoring period. This resulted in the spouse receiving a significantly greater dose of all indoor detected pesticides than other family members (by approximately a factor of 2). Calculated mean daily inhaled indoor air doses of carbaryl, α-chlordane, and heptachlor were on the order of a microgram for the spouse, and on the order of hundreds of nanograms for the applicator and children. Mean daily indoor inhalation doses of γ-chlordane were on the order of a microgram for spouse and child #2, and on the order of hundreds of nanograms for the applicator and child #1. Terbufos doses were on the order of a hundred of nanograms for all family members; chlorpyrifos mean daily indoor inhalation dose was on the order of tens of nanograms for all family members.

SUMMARY AND CONCLUSIONS

Of the 33 targeted pesticides, 7 were applied on at least one of the participant farms, 11 were detected in the outdoor air near a farm residence, and 17 were detected in farm residence indoor air.

The pesticide applicator was usually exposed to the applied pesticide(s) during HML and application activities. An exception was found on Iowa farm #4, where pyrethrins and piperonyl butoxide were applied but their presence in personal air samples was not detected. Inhalation dose during application was comparable with the PHED reference, however inhalation dose received during HML was well below PHED reference. While the applicator's inhalation exposure to applied pesticides occurs almost exclusively during HML/application activities (at least 80%), exposure to non-applied (fugitive) pesticides does occur during time spent outdoors on the farm, and even more so during time spent indoors.

Outdoor concentrations of pesticides applied using a ground boom sprayer were detected (stationary point measurement) at significant concentrations (265 ng/m^3 alachlor, 24-hour average, on North Carolina farm #1) when wind direction favored such transport. The converse is not supported, however, as outdoor concentrations of atrazine were detected on Iowa farm #3 even though wind direction never favored source-to-receptor transport during HML or application activities. Outdoor concentrations of non-applied pesticides were detected on 5 of the 6 farms. The highest 24-hour outdoor concentration of any non-applied pesticide was 26.3 ng/m^3 metolachlor on Iowa farm #3 during the first application period, although metolachlor was found residual within the applied pesticide mixture. The highest 24-hour outdoor concentration of any non-applied, non-residual pesticide was 18.7 ng/m^3 alachlor, also detected on Iowa farm #3 during the first application period.

Indoor concentrations of applied pesticides were detected (stationary point measurement) on 4 of the 6 farms, although one case (metolachlor on Iowa farm #2) confirmed detection during the control season as well. Indoor concentrations of an applied or residual pesticide were higher on the application day than conterminous days on Iowa farm #1 (dicamba), Iowa farm #2 (metolachlor), and Iowa farm #3 (alachlor; second application period). However, the cases observed in the pilot study do not strongly support a conclusion that outdoor air (exclusively) is the source of indoor concentrations of applied/residual pesticides. Indoor concentrations of non-applied pesticides were more the rule than the exception. On 5 of the 6 pilot study farms, concentrations of non-applied pesticides were detected on at least one day. In most cases, applicator/spouse questionnaires relating to historical use of such pesticides could not confirm usage.

The applicator's inhalation exposure to applied pesticides is greater than that of any other family member on the day of application (calculated exposures indicated applicator inhalation exposure to be at least a factor of 5 times greater). This elevated exposure is attributable to HML/application activities. Non-applicator family members can be exposed indirectly to applied (and non-applied) pesticides during time spent indoors or outdoors on the farm. For spouse and children, the indoor microenvironment contributed to inhalation exposure of pesticides to a far

greater extent than did the outdoor-on-farm microenvironment - even on the day of application. On two of six farms, mean daily indoor inhalation dose for a spouse or child was calculated to be on the order of micrograms - comparable to doses received by an applicator during an application (although toxicological response and health risk cannot be presumed to be the same). This importance of the indoor microenvironment to an individual's total inhalation exposure is attributable to several factors. Firstly, the time spent indoors (over the course of 24 hours) exceeded time spent outdoors on the farm. Secondly, pesticide concentrations were generally higher indoors than outdoors (of 20 comparisons that could be made, 14 pesticides had higher 24-hour indoor concentrations; only 6 had higher 24-hour outdoor concentrations). Thirdly, the indoor microenvironment contained a greater number of detected pesticides than outdoors (17 different pesticides were detected in indoor samples; 11 were detected in outdoor samples).

In conclusion, the inhalation pathway does contribute to the total pesticide exposure of applicator and family. Pesticide handling, mixing, loading, and applying present occasion for acute exposure to the applicator. Pesticide application events can substantially increase outdoor concentrations directly downwind - to levels exceeding typical applicator personal air concentration during handling, mixing, and loading. Elevated outdoor pesticide concentrations were not clearly related to indoor concentrations on farms monitored in this study. Participant activity logs indicated substantially more time was spent indoors at the farm residence than outdoors on the farm. Chronic exposure to pesticides found in farm residence indoor air can be comparable, in cumulative inhaled dose, to exposures accrued by applicators during pesticide applications.

RECOMMENDATIONS

The sampling design and protocol for air measurements in the AHS pilot study is fundamentally sound. Data completeness is sufficient to assess inhalation exposure of applicator and family members on the application day. The focus on the HML and application activities as the greatest opportunity for acute inhalation exposure for the applicator is substantiated. Personal air sampling of the applicator during HML and application activities should continue. Applicator personal air concentrations during HML activities were measured to be well below PHED reference averages, and below the personal air samples taken during the application activity. Insofar as these were not expected, future efforts to measure applicator personal air should undergo a procedural quality control review.

The use of size-selective impactors at air sampling cartridge inlets should be reviewed. Pesticide air samples measured in support of exposure assessments should capture the full size distribution of aerosols/particulates that are inhalable.

The outdoor air sample on the application day provides *some* indication of the impact of application activity on the ambient air near the farm house. This enables comparisons between indoor and outdoor air, and provides indication that the source of indoor concentrations of pesticides is not to be found exclusively, or even predominantly, in outdoor air. The *potential* impact of application activity on downwind air concentrations is revealed only by model simulation. Fixed location ambient air sampling would only by chance capture a worst case condition of spraying and meteorology. The potential for significant inhalation exposure to occur in the non-homogeneous, non-isotropic outdoor air -e.g. a cohort located directly downwind of an application event - is unknown. Sampling personal air of spouse and/or children during their outdoor activity on application day would provide such data, but at a cost of increased participant burden. Implementation of a spouse/child personal air sampling protocol during outdoor activity could better utilize on-site meteorology data. In the absence of such a protocol, a nearby weather station may provide representative data to support a model screening assessment of downwind concentrations.

The indoor air samples on the pre-, post-, and application days provided the most useful data in assessing spouse and child chronic inhalation exposure to pesticides. Collection of single-point, 24-hour integrated indoor air samples limits the choice of an indoor inhalation exposure assessment model to one that assumes spatially uniform and constant intra-day pesticide concentrations. Activity log records indicate that the time spent indoors is not random within a 24-hour period, thereby introducing potential bias in exposure calculations that make assumptions of temporal uniformity. Nor is indoor habitation random with respect to location within the house, thereby introducing potential bias in exposure calculations that assume spacial uniformity. Improvement in chronic indoor inhalation exposure assessment for all family members could be aided by implementing a more frequent, shorter duration, sampling protocol - partitioning the day into two or more sampling periods. Improvement in assessment could also be made by implementing multi-point sampling - over-sampling more frequently used rooms. Sampling personal air of applicator, spouse or children during their indoor activity would provide the best assessment data, but again,

at an increased burden to participants.

The collection of control season 24-hour integrated indoor air measurements should continue. Exposure assessments derived from the three-day application period sampling must be confirmed as representative by similar control season sampling to increase confidence that the exposure is indeed "chronic".

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APPENDIX A: AHS TARGET PESTICIDES

AHS TARGET PESTICIDES		
HERBICIDES	**INSECTICIDES**	**FUNGICIDES**
ALACHLOR	ALDICARB	CAPTAN A,B
ATRAZINE	ALDRIN	CHLOROTHALONIL A
2,4-D	CARBARYL	DICLORAN
DACTHAL	CARBOFURAN	FOLPET A,B
DICAMBA	CHLORPYRIFOS	METALAXYL
METOLACHLOR	α-CHLORDANE	
TRIFLURALIN	γ-CHLORDANE	
	DDD	
	DDE	
	DDT	
	DIAZINON	
	DIELDRIN	
	FONOFOS	
	HEPTACHLOR	
	LINDANE	
	MALATHION	
	PERMETHRIN	
	PHORATE	
	PROPOXUR	
	PYRETHRINS	
	TERBUFOS	

APPENDIX B: APPLIED PESTICIDES

APPLIED PESTICIDE LIST		
FARM	**PESTICIDE**	**CLASS**
IA1	DICAMBA	Herbicide
IA2	ATRAZINE	Herbicide
	DICAMBA	Herbicide
	2,4-D BUTOXY ETHYL ESTER	Herbicide
	METOLACHLOR	Herbicide
IA3-First Visit	ATRAZINE	Herbicide
IA3-Second Visit	2,4-D	Herbicide
	2,4-D BUTOXY ETHYL ESTER	Herbicide
IA4	PYRETHRIN	Insecticide
	PIPERONYL BUTOXIDE	Insecticide Synergist
NC1	ALACHLOR	Herbicide
NC2	CARBARYL	Insecticide

APPENDIX C: METEOROLOGY

IA1

Mo	Day	Time	Temp C	RH	WS [m/s]	WD	Activity	Target-WD	HIT	Dicamba Outdoors 24 Hour Ave [ng / m3]	Dicamba Indoors 24 Hour Ave [ng / m3]
5	18	-	-	-	-	-	-	-	-	nd	2.27
5	18	850	15.0	28	1.46	69	hml	315	n		
5	18	900	15.8	27	0.89	29	hml	315	n		
5	18	910	15.3	26	1.66	98	hml	315	n		
5	18	920	16.3	25	1.69	100	app	135	y		
5	18	930	16.0	25	1.70	64	app	135	n		
5	18	940	16.5	25	1.51	355	app	135	n		
5	18	950	16.9	25	1.09	36	app	135	n		
5	18	1000	17.4	24	0.91	61	app	135	n		
5	18	1010	18.0	21	1.12	64	app	135	n		
5	18	1020	18.0	25	1.37	28	app	135	n		
5	18	1030	17.9	22	1.71	74	app	135	n		
5	18	1040	19.0	21	1.01	52	app	135	n		
5	18	1050	18.9	20	1.54	83	app	135	n		
5	18	1100	19.7	21	1.44	334	app	135	n		
5	18	1110	19.8	17	1.59	105	app	135	y		
5	18	1120	20.4	17	1.78	254	app	135	n		
5	18	1130	20.8	14	1.20	80	app	135	n		
5	18	1140	20.8	15	2.01	36	app	135	n		
5	18	1630	25.4	13	1.17	109	hml	315	n		
5	18	1640	25.1	12	1.53	24	hml	315	n		
5	18	1650	25.2	13	1.90	36	hml	315	n		
5	18	1700	25.4	15	1.19	70	app	135	n		
5	18	1710	25.0	13	1.58	65	app	135	n		
5	18	1720	25.4	15	0.94	226	app	135	n		
5	18	1730	25.0	14	1.20	81	app	135	n		
5	18	1740	25.3	15	1.00	13	app	135	n		
5	18	1750	25.3	17	0.74	17	app	135	n		
5	18	1800	25.0	15	0.97	39	app	135	n		
5	18	1810	24.4	15	1.16	88	app	135	n		
5	18	1820	24.4	16	0.95	14	app	135	n		

Mo	Day	Time	Temp C	RH	WS [m/s]	WD	Activity	Target-WD	HIT	Dicamba Outdoors 24 Hour Ave [ng / m3]	Dicamba Indoors 24 Hour Ave [ng / m3]
5	18	1830	24.4	16	0.88	354	app	135	n		
5	18	1840	24.1	15	1.06	86	app	135	n		
5	18	1850	24.1	18	0.69	58	app	135	n		

IA3-First Application Period

Mo	Day	Time	Temp C	RH	WS [m/s]	WD	Activity	Target-WD	HIT	Atrazine Outdoors 24 Hour Ave [ng / m3]	Atrazine Indoors 24 Hour Ave [ng / m3]
5	14	-	-	-	-	-	-	-	-	9.91	nd
5	14	800	15.0	60	4.46	141	hml	330	n		
5	14	810	15.1	61	4.46	152	hml	330	n		
5	14	820	15.1	61	4.23	143	hml	330	n		
5	14	830	15.0	61	4.36	144	hml	330	n		
5	14	850	15.3	62	3.71	142	app	270	n		
5	14	900	14.8	70	3.12	165	app	270	n		
5	14	910	14.7	70	3.68	152	app	270	n		
5	14	920	14.7	68	3.72	170	app	270	n		
5	14	930	14.8	68	3.11	154	app	270	n		
5	14	940	14.8	68	2.90	162	app	270	n		
5	14	950	14.3	76	3.74	167	app	270	n		
5	14	1000	14.0	81	3.35	157	app	270	n		
5	14	1010	13.7	86	3.23	172	app	270	n		
5	14	1020	13.7	86	2.78	170	app	270	n		
5	14	1030	13.8	85	3.31	148	app	270	n		
5	14	1040	14.0	86	3.37	172	app	270	n		
5	14	1050	14.3	85	3.59	159	app	270	n		
5	14	1100	14.1	86	4.04	125	app	270	n		

NC1

Mo	Day	Time	Temp C	RH	WS [m/s]	WD	Activity	Target-WD	HIT	Alachlor Outdoors 24 Hour Ave [ng / m3]	Alachlor Indoors 24 Hour Ave [ng / m3]
6	22	-	-	-	-	-	-	-	-	265	33.2
6	22	900	26.0	78	1.97	318	hml/app	0	y		
6	22	910	26.6	75	1.87	339	hml/app	0	y		
6	22	920	27.0	77	1.69	337	hml/app	0	y		
6	22	930	27.3	72	2.14	352	hml/app	0	y		
6	22	940	28.2	69	1.50	349	hml/app	0	y		
6	22	950	28.1	68	2.07	32	hml/app	0	y		
6	22	1000	28.4	62	2.30	4	hml/app	0	y		
6	22	1010	28.6	58	2.38	17	hml/app	0	y		
6	22	1020	28.8	57	2.57	16	hml/app	0	y		
66	22	1030	29.1	56	2.17	23	hml/app	0	y		
6	22	1040	29.0	58	2.46	59	hml/app	0	n		
6	22	1100	29.5	55	2.57	1	hml/app	0	y		
6	22	1110	29.0	57	2.80	28	hml/app	0	y		
6	22	1120	29.6	54	2.17	19	hml/app	0	y		
6	22	1130	30.0	59	2.36	26	hml/app	0	y		
6	22	1140	30.5	52	1.58	4	hml/app	0	y		
6	22	1150	30.6	55	1.43	65	hml/app	0	n		
6	22	1200	30.0	57	1.77	54	hml/app	0	n		
6	22	1210	30.8	58	1.87	91	hml/app	0	n		
6	22	1220	30.6	57	2.55	79	hml/app	0	n		
6	22	1230	30.3	57	2.66	39	hml/app	0	y		
6	22	1240	30.5	56	1.97	61	hml/app	0	n		
6	22	1250	31.0	55	1.74	64	hml/app	0	n		
6	22	1300	31.3	53	1.78	23	hml/app	0	y		
6	22	1310	31.3	54	2.11	115	hml/app	0	n		
6	22	1320	31.4	53	1.53	1	hml/app	0	y		
6	22	1330	31.4	54	1.92	139	hml/app	0	n		
6	22	1340	31.5	53	1.83	37	hml/app	0	y		
6	22	1350	30.8	58	2.45	14	hml/app	0	y		
6	22	1400	31.0	57	2.10	82	hml/app	0	n		
6	22	1410	31.8	49	2.00	36	hml/app	0	y		

Mo	Day	Time	Temp C	RH	WS [m/s]	WD	Activity	Target-WD	HIT	Alachlor Outdoors 24 Hour Ave [ng / m3]	Alachlor Indoors 24 Hour Ave [ng / m3]
6	22	1420	31.7	50	2.06	76	hml/app	0	n		
6	22	1430	31.4	53	2.20	107	hml/app	0	n		
6	22	1440	31.7	45	2.32	75	hml/app	0	n		
6	22	1450	32.0	44	1.49	169	hml/app	0	n		

APPENDIX D: APPLICATION EQUIPMENT

APPLICATION EQUIPMENT		
FARM	**SPRAY IMPLEMENT**	**VEHICLE**
IA1	Boom Arm	Open-Cab Tractor
IA2	Boom Arm	Closed-Cab Tractor
IA3-First Visit	Boom Arm	Closed-Cab Tractor
IA3-Second Visit	Hand Sprayer	Open-Cab Tractor and All-Terrain-Vehicle
IA4	Hand Sprayer	None
NC1	Boom Arm	Closed-Cab Tractor
NC2	Hand Duster	None

APPENDIX E: APPLICATION PARAMETERS AND MODEL CALCULATIONS

IA1

Ap #	Chem	Quantity A.I.	Tot Vol	Liq Conc	Area	Rate	Duration	Receptor Dist	Model Conc over Duration	Model Conc (worst case) (24 hr ave)	Meas (24 hr)
1	dicamba	2.25gal	500gal	0.0045	25 ac	20 gal/ac	2h15m	100 m	14400 ng/m3	-	-
2	dicamba	2.5gal	500gal	0.005	30 ac	16.7 gal/ac	1h15m	100 m	12650 ng/m3	-	-
										2000 ng/m3	nd ng/m^3

IA3

Ap #	Chem	Quantity A.I.	Tot Vol	Liq Conc	Area	Rate	Duration	Receptor Dist	Model Conc over Duration	Model Conc (worst case) (24 hr ave)	Meas (24 hr)
1	atrazine	100 lbs	600gal	0.167 lbs/gal	30 ac	20 gal/ac	2 h 15 m .	100 m	28750 ng/m3	-	-
										2700 ng/m3	9.91 ng/m^3

NC1

Ap #	Chem	Quantity A.I.	Tot Vol	Liq Conc	Area	Rate	Duration	Receptor Dist	Model Conc over Duration	Model Conc (worst case) (24 hr ave)	Meas (24 hr)
1	alachlor	2.5gal	85gal	0.0294	5.6ac	15.2 gal/ac	1h10m	300m	10900 ng/m3	-	-
2	alachlor	5gal	110gal	0.0455	8.3ac	13.2 gal/ac	2h55m	300m	11100 ng/m3	-	-
										1900 ng/m3	265 ng/m^3

APPENDIX F: TIME SERIES OF INDOOR AND OUTDOOR CONCENTRATIONS

IA1		Control Season	Application Period		
Pesticide [ng/m^3]	**Sample Location**		**Day 2** (May 17)	**Day 3** (May 18)	**Day 4** (May 19)
Atrazine *	Indoor	nd	nd	nd	nd
	Outdoor	nm	nm	nd	nm
Chlorpyrifos	Indoor	1.03	nd	nd	nd
	Outdoor	nm	nm	nd	nm
2,4 - D *	Indoor	nd	nd	nd	nd
	Outdoor	nm	nm	nd	nm
Dicamba *	Indoor	nd	nd	2.27	nd
	Outdoor	nm	nm	nd	nm
Dicloran	Indoor	22.2	nd	nd	nd
	Outdoor	nm	nm	nd	nm
Heptachlor	Indoor	1.27	nd	nd	nd
	Outdoor	nm	nm	nd	nm
Metolachlor *	Indoor	2.00	nd	nd	nd
	Outdoor	nm	nm	nd	nm
Trifluralin	Indoor	1.04	nd	nd	nd
	Outdoor	nm	nm	nd	nm

nm = not measured
nd = not detected
*First Application, Applied compound: 0.193 % Dicamba
Residual compound: 0.00120% Atrazine, 0.00118% Metolochlor, 0.000200% 2,4 - D
*Second Application, Applied compound: 0.245% Dicamba
Residual compound: 0.000177% Atrazine, 0.000413 % Metolachlor, 0.0000564 % 2,4 - D

IA2		Control Season	Application Period		
Pesticide [ng/m^3]	**Sample Location**		**Day 2** (May 8)	**Day 3** (May 9)	**Day 4** (May 10)
Alachlor	Indoor	nd	nm	nd	nd
	Outdoor	nm	nm	3.10	nm
Atrazine *	Indoor	nd	nm	nd	nd
	Outdoor	nm	nm	2.16	nm
Chlorpyrifos	Indoor	2.43	nm	2.38	2.89
	Outdoor	nm	nm	nd	nm
2,4 - D *	Indoor	nd	nm	nd	nd
	Outdoor	nm	nm	nd	nm
2,4 - D boee *	Indoor	nd	nm	nd	nd
	Outdoor	nm	nm	nd	nm
Dicamba *	Indoor	nd	nm	nd	nd
	Outdoor	nm	nm	nd	nm
Dicloran	Indoor	nd	nm	nd	nd
	Outdoor	nm	nm	nd	nm
Heptachlor	Indoor	nd	nm	nd	nd
	Outdoor	nm	nm	nd	nm
Metolachlor *	Indoor	15.6	nm	71.9	63.0
	Outdoor	nm	nm	7.66	nm
Terbufos	Indoor	nd	nm	52.0	49.4
	Outdoor	nm	nm	nd	nm
Trifluralin	Indoor	6.80	nm	7.03	5.60
	Outdoor	nm	nm	1.27	nm

nm = not measured

nd = not detected

*First Application, Applied compounds: 0.115% Atrazine, 0.960% Metolachlor, 0.267% 2,4-D butoxyethyl ester
Residuals: 0.00204% 2,4-D, 0.00238% Dicamba

*Second Application, Applied compounds: 0.304% Atrazine, 1.61% Metolachlor, 0.241% Dicamba
Residuals: 0.00595% 2,4-D butoxyethyl ester, 0.000262% 2,4-D

IA3 - First Visit		Control Season	Application Period		
Pesticide [ng/m^3]	**Sample Location**		**Day 2** (May 13)	**Day 3** (May 14)	**Day 4** (May 15)
Alachlor	Indoor	13.3	6.13	9.39	7.03
	Outdoor	nm	nm	18.7	nm
Atrazine *	Indoor	nd	nd	nd	nd
	Outdoor	nm	nm	9.91	nm
Chlorpyrifos	Indoor	1.03	nd	0.950	nd
	Outdoor	nm	nm	3.44	nm
Fonofos	Indoor	nd	nd	nd	nd
	Outdoor	nm	nm	2.38	nm
Metolachlor *	Indoor	0.834	5.13	4.04	3.22
	Outdoor	nm	nm	26.3	nm
Propoxur	Indoor	14.6	21.5	27.4	19.8
	Outdoor	nm	nm	nd	nm
Terbufos	Indoor	nd	25.0	41.3	26.6
	Outdoor	nm	nm	nd	nm
Trifluralin	Indoor	nd	nd	0.822	0.692
	Outdoor	nm	nm	8.08	nm

nm = not measured
nd = not detected
* Applied compound: 0.295% Atrazine
Residuals: 0.00553% Metolachlor

IA3 - Second Visit		Control Season	Application Period		
Pesticide [ng/m^3]	**Sample Location**		**Day 2** (Jun 11)	**Day 3** (Jun 13)	**Day 4** (Jun 14)
Alachlor *	Indoor	13.3	3.67	5.68	4.78
	Outdoor	nm	nm	2.86	nm
Atrazine	Indoor	nd	nd	nd	4.82
	Outdoor	nm	nm	6.17	nm
γ-Chlordane	Indoor	nd	nd	nd	0.419
	Outdoor	nm	nm	nd	nm
Chlorothalonil	Indoor	nd	5.60	11.0	9.47
	Outdoor	nm	nm	nd	nm
Chlorpyrifos	Indoor	1.03	0.827	1.46	1.65
	Outdoor	nm	nm	1.04	nm
2,4 - D *	Indoor	nd	nd	nd	nd
	Outdoor	nm	nm	nd	nm
2,4 - D boee *	Indoor	nd	nd	nd	nd
	Outdoor	nm	nm	nd	nm
Metolachlor	Indoor	0.834	2.01	3.71	3.24
	Outdoor	nm	nm	5.11	nm
Propoxur	Indoor	14.6	23.3	33.4	36.2
	Outdoor	nm	nm	0.901	nm
Terbufos	Indoor	nd	11.8	11.4	7.11
	Outdoor	nm	nm	nd	nm
Trifluralin	Indoor	nd	3.43	1.27	1.83
	Outdoor	nm	nm	2.05	nm

nm = not measured
nd = not detected
*First Application, Applied compound: 0.0328% 2,4 - D
Residual compound: 0.00403% 2,4 - D butoxyethyl ester, 0.00125 % Alachlor
*Second Application, Applied compound: 0.569% 2,4 - D butoxyethyl ester
Residual compound: 0.120 % 2,4 - D

IA4		Control Season	Application Period		
Pesticide [ng/m^3]	**Sample Location**		**Day 2** (Jun 15)	**Day 3** (Jun 16)	**Day 4** (Jun 17)
Atrazine	Indoor		nd	nd	21.0
	Outdoor	nm	nm	1.94	nm
α-Chlordane	Indoor	1.28	1.41	1.11	1.48
	Outdoor	nm	nm	nd	nm
γ-Chlordane	Indoor	1.70	1.83	1.55	1.85
	Outdoor	nm	nm	nd	nm
Chlorpyrifos	Indoor	2.77	2.40	nd	2.66
	Outdoor	nm	nm	nd	nm
Diazinon	Indoor	7.30	nd	nd	nd
	Outdoor	nm	nm	nd	nm
Fonofos	Indoor	8.77	nd	nd	nd
	Outdoor	nm	nm	nd	nm
Heptachlor	Indoor		nd	1.55	1.87
	Outdoor	nm	nm	nd	nm
Lindane	Indoor	111	71.0	57.0	76.6
	Outdoor	nm	nm	nd	nm
Metolachlor	Indoor	9.19	2.80	2.68	3.15
	Outdoor	nm	nm	nd	nm
Piperonyl Butoxide *	Indoor		nd	nd	nd
	Outdoor	nm	nm	nd	nm
Pyrethrins *	Indoor		nd	nd	nd
	Outdoor	nm	nm	nd	nm
Terbufos	Indoor	15.4	nd	nd	nd
	Outdoor	nm	nm	nd	nm
Trifluralin	Indoor	0.934	nd	nd	nd
	Outdoor	nm	nm	nd	nm

nm = not measured
nd = not detected
* Applied compounds: 0.116% Pyrethrins, 0.109% Piperonyl Butoxide

NC1		Control Season	Application Period		
Pesticide [ng/m^3]	**Sample Location**		**Day 2** (Jun 21)	**Day 3** (Jun 22)	**Day 4** (Jun 23)
Alachlor *	Indoor	nm	27.9	33.2	46.3
	Outdoor	nm	nm	265	nm
α-Chlordane	Indoor	nm	176	152	113
	Outdoor	nm	nm	6.99	nm
γ-Chlordane	Indoor	nm	231	197	145
	Outdoor	nm	nm	7.36	nm
Chlorpyrifos	Indoor	nm	4.51	3.78	3.26
	Outdoor	nm	nm	3.09	nm
Heptachlor	Indoor	nm	89.9	84.9	62.3
	Outdoor	nm	nm	1.65	nm
Metolachlor *	Indoor	nm	11.4	9.76	9.64
	Outdoor	nm	nm	7.97	nm
Propoxur	Indoor	nm	203	245	239
	Outdoor	nm	nm	nd	nm
Trifluralin	Indoor	nm	0.664	nd	nd
	Outdoor	nm	nm	nd	nm

nm = not measured
nd = not detected
*First Application, Applied compounds: 1.13% Alachlor
Residuals: 0.00704% Metolachlor
*Second Application, Applied compound: 0.298% Alachlor
Residuals: 0.000392% Metolachlor

NC2		Control Season	Application Period		
Pesticide [ng/m^3]	**Sample Location**		**Day 2** (Jul 27)	**Day 3** (Jul 28)	**Day 4** (Jul 29)
Carbaryl *	Indoor	nm	279	47.9	72.4
	Outdoor	nm	nm	93.0	nm
α-Chlordane	Indoor	nm	121	97.0	103
	Outdoor	nm	nm	1.53	nm
γ-Chlordane	Indoor	nm	161	133	145
	Outdoor	nm	nm	1.75	nm
Chlorpyrifos	Indoor	nm	1.69	1.46	3.07
	Outdoor	nm	nm	nd	nm
Heptachlor	Indoor	nm	79.3	90.2	73.9
	Outdoor	nm	nm	nd	nm
Malathion	Indoor	nm	nd	nd	nd
	Outdoor	nm	nm	nd	nm
Terbufos	Indoor	nm	nd	47.6	nd
	Outdoor	nm	nm	nd	nm

nm = not measured
nd = not detected
*Applied Compounds: 0.194% Carbaryl
Residuals: None

APPENDIX G: INDOOR TO OUTDOOR CONCENTRATION RATIOS

Ratio Indoor/Outdoor	Farm						
Pesticide	**Iowa #1**	**Iowa #2**	**Iowa #3 (First)**	**Iowa #3 (Second)**	**Iowa #4**	**NC #1**	**NC #2**
Alachlor	-	-	0.40	1.64	-	0.14	-
Carbaryl	-	-	-	-	-	-	1.43
α-Chlordane	-	-	-	-	-	21.0	70.
γ-Chlordane	-	-	-	-	-	26.0	84.
Chlorpyrifos	-	-	0.28	1.26	-	1.25	-
Heptachlor	-	-	-	-	-	48.	-
Metolachlor	-	8.8	0.16	0.58	-	1.29	-
Propoxur	-	-	-	34.	-	-	-
Trifluralin	-	5.0	0.094	1.06	-	-	-

APPENDIX H: APPLICATOR RESPIRATORY PROTECTION

APPLICATOR RESPIRATORY PROTECTION		
FARM	**HML**	**APPLICATION**
IA1	None	None
IA2	None	None
IA3-First	Dust Mask	None
IA3-Second	na	None
IA4	na	None
NC1	na	None
NC2	na	Dust Mask

APPENDIX I: HML/APPLICATION EXPOSURE RELATIVE TO TOTAL

Applicator's Day 3 HML/Application Air Exposure as a % of Day 3 Total Air Exposure							
Applied Pesticide	**Iowa #1**	**Iowa #2**	**Iowa #3 (First)**	**Iowa #3 (Second)**	**Iowa #4**	**NC #1**	**NC #2**
Alachlor	-	-	-	-	-	80 %	-
Atrazine	-	> 99 %	94 %	-	-	-	-
Carbaryl	-	-	-	-	-	-	> 99 %
Dicamba	> 99 %	100 %	-	-	-	-	-
2,4-D	-	-	-	nd	-	-	-
2,4-D BOEE	-	100 %	-	nd	-	-	-
Metolachlor	-	97 %	-	-	-	-	-
Piperonyl Butoxide	-	-	-	-	nd	-	-
Pyrethrin	-	-	-	-	nd	-	-

APPENDIX J: APPLICATOR TOTAL INHALATION DOSE

Applicator's Day 3 Total Received Inhlation Dose of Applied Pesticides							
Applied Pesticide	**Iowa #1**	**Iowa #2**	**Iowa #3 (First)**	**Iowa #3 (Second)**	**Iowa#4**	**NC #1**	**NC #2**
Alachlor						13,600ng	
Atrazine		14,900ng	960 ng				
Carbaryl							1,932,000ng
Dicamba	3760 ng	462ng					
2,4-D				0 ng			
2,4-D BOEE		660ng		0 ng			
Metolachlor		39,200ng					
Piperonyl Butoxide					0 ng		
Pyrethrin					0 ng		

APPENDIX K: APPLICATOR PERSONAL AIR EXPOSURE AND INHALATION DOSE

Iowa #1	Applicator Inhalation Dose Derived from Personal Air Concentration and from PHED				
Pesticide	**Amount [lbs]**	**Personal AirConc [ng/m^3]**	**Duration of Activity [h]**	**Calculated Dose [ng]**	**PHED Dose [ng]**
Dicamba (1st HML)	19	87.5	0.5	66	19779
Dicamba (1st Appl'n)		160	2.5	600	1719
Dicamba (2nd HML)	21	nm	0.5	-	21861
Dicamba (2nd Appl'n)		1030	2.0	3090	1900
Total HML Dose				66	41600
Total Application Dose				3690	3620

Iowa #3 (First)	Applicator Inhalation Dose Derived from Personal Air Concentration and from PHED				
Pesticide	**Amount [lbs]**	**Personal AirConc [ng/m^3]**	**Duration of Activity [h]**	**Calculated Dose [ng]**	**PHED Dose [ng]**
Atrazine (1st HML)	100	210	0.67	211	90400
Atrazine (1st Appl'n)		215	2.33	751	9046

North Carolina #1	Applicator Inhalation Dose Derived from Personal Air Concentration and from PHED				
Pesticide	Amount [lbs]	Personal AirConc [ng/m^3]	Duration of Activity [h]	Calculated Dose [ng]	PHED Dose (Application Only) [ng]
Alachlor (1st HML/Appl'n)	21	1130	1.0	1700	1900
Alachlor (2nd HML/Appl'n)	42	2640	3.0	11900	3800

APPENDIX L: FAMILY TOTAL EXPOSURE TO APPLIED PESTICIDE ON APPLICATION DAY

IA1 Day3

DICAMBA	Time HML/ Appl 1 [h]	Personal Exposure [ng-h/m3]	time HML/ Appl 2 [h]	Personal Exposure [ng-h/m3]	Time Outdoors (on farm) [h]	Outdoor Exposure [ng-h/m3]	Time Indoors (in house) [h]	Indoor Exposure [ng-h/m3]	Total Air Exposure [ng-h/m3]
Applicator	3	442	2	2075	4	nd	5	11	2528
Spouse	0	-	0	-	8	nd	15	34	34
Child1	0	-	0	-	3	nd	12	27	27
Child2	0	-	0	-	7	nd	14	32	32

IA2 Day3

ATRAZINE	Time HML/ Appl 1 [h]	Personal Exposure [ng-h/m3]	time HML/ Appl 2 [h]	Personal Exposure [ng-h/m3]	Time Outdoors (on farm) [h]	Outdoor Exposure [ng-h/m3]	Time Indoors (in house) [h]	Indoor Exposure [ng-h/m3]	Total Air Exposure [ng-h/m3]
Applicator	3	1245	7	8680	3	6.48	11	-	9931
Spouse	0	-	0	-	1	2.16	13	-	2.16
Child1	0	-	0	-	4	8.64	19	-	8.64

IA2 Day3

METOL-ACHLOR	Time HML/ Appl 1 [h]	Personal Exposure [ng-h/m3]	time HML/ Appl 2 [h]	Personal Exposure [ng-h/m3]	Time Outdoors (on farm) [h]	Outdoor Exposure [ng-h/m3]	Time Indoors (in house) [h]	Indoor Exposure [ng-h/m3]	Total Air Exposure [ng-h/m3]
Applicator	3	3150	7	22960	3	23	11	791	26924
Spouse	0	-	0	-	1	8	13	935	943
Child1	0	-	0	-	4	31	19	1366	1397

IA2 Day3

2,4-D BUTOXY-ETHYL ESTER	Time HML/ Appl 1 [h]	Personal Exposure [ng-h/m3]	time HML/ Appl 2 [h]	Personal Exposure [ng-h/m3]	Time Outdoors (on farm) [h]	Outdoor Exposure [ng-h/m3]	Time Indoors (in house) [h]	Indoor Exposure [ng-h/m3]	Total Air Exposure [ng-h/m3]
Applicator	3	-	7	440	3	-	11	-	440
Spouse	0	-	0	-	1	-	13	-	0
Child1	0	-	0	-	4	-	19	-	0

IA2 Day3

DICAMBA	Time HML/ Appl 1 [h]	Personal Exposure [ng-h/m3]	time HML/ Appl 2 [h]	Personal Exposure [ng-h/m3]	Time Outdoors (on farm) [h]	Outdoor Exposure [ng-h/m3]	Time Indoors (in house) [h]	Indoor Exposure [ng-h/m3]	Total Air Exposure [ng-h/m3]
Applicator	3	-	7	308	3	nd	11	-	308
Spouse	0	-	0	-	1	nd	13	-	0
Child1	0	-	0	-	4	nd	19	-	0

IA3-1 Day3

ATRAZINE	Time HML/ Appl 1 [h]	Personal Exposure [ng-h/m3]	time HML/ Appl 2 [h]	Personal Exposure [ng-h/m3]	Time Outdoors (on farm) [h]	Outdoor Exposure [ng-h/m3]	Time Indoors (in house) [h]	Indoor Exposure [ng-h/m3]	Total Air Exposure [ng-h/m3]
Applicator	4	850	na	-	4	40	16	nd	890
Spouse	0	-	na	-	1	10	23	nd	10
Child1	0	-	na	-	3	30	7	nd	30

IA3-2 Day3

2,4-D	Time HML/ Appl 1 [h]	Personal Exposure [ng-h/m3]	time HML/ Appl 2 [h]	Personal Exposure [ng-h/m3]	Time Outdoors (on farm) [h]	Outdoor Exposure [ng-h/m3]	Time Indoors (in house) [h]	Indoor Exposure [ng-h/m3]	Total Air Exposure [ng-h/m3]
Applicator	1	nm	2	nd	5	nd	10	nd	nd
Spouse	0	-	0	-	1	nd	17	nd	nd
Child1	0	-	0	-	3	nd	17	nd	nd

IA3-2 Day3

2,4-D BUTOXY-ETHYL ESTER	Time HML/ Appl 1 [h]	Personal Exposure [ng-h/m3]	time HML/ Appl 2 [h]	Personal Exposure [ng-h/m3]	Time Outdoors (on farm) [h]	Outdoor Exposure [ng-h/m3]	Time Indoors (in house) [h]	Indoor Exposure [ng-h/m3]	Total Air Exposure [ng-h/m3]
Applicator	1	nm	2	nd	5	nd	10	nd	nd
Spouse	0	-	0	-	1	nd	17	nd	nd
Child1	0	-	0	-	3	nd	17	nd	nd

IA4 Day3

PYRETH-RIN	Time HML/ Appl 1 [h]	Personal Exposure [ng-h/m3]	time HML/ Appl 2 [h]	Personal Exposure [ng-h/m3]	Time Outdoors (on farm) [h]	Outdoor Exposure [ng-h/m3]	Time Indoors (in house) [h]	Indoor Exposure [ng-h/m3]	Total Air Exposure [ng-h/m3]
Applicator	3	0	na	-	13	0	8	0	0
Spouse	0	-	na	-	3	0	21	0	0
Child1	0	-	na	-	6	0	18	0	0
Child2	0	-	na	-	9	0	15	0	0

IA4 Day3

PIPER-ONYL BUTOXIDE	Time HML/ Appl 1 [h]	Personal Exposure [ng-h/m3]	time HML/ Appl 2 [h]	Personal Exposure [ng-h/m3]	Time Outdoors (on farm) [h]	Outdoor Exposure [ng-h/m3]	Time Indoors (in house) [h]	Indoor Exposure [ng-h/m3]	Total Air Exposure [ng-h/m3]
Applicator	3	0	na	-	13	0	8	0	0
Spouse	0	-	na	-	3	0	21	0	0
Child1	0	-	na	-	6	0	18	0	0
Child2	0	-	na	-	9	0	15	0	0

NC1 Day3

ALACHLOR	Time HML/ Appl 1 [h]	Personal Exposure [ng-h/m3]	time HML/ Appl 2 [h]	Personal Exposure [ng-h/m3]	Time Outdoors (on farm) [h]	Outdoor Exposure [ng-h/m3]	Time Indoors (in house) [h]	Indoor Exposure [ng-h/m3]	Total Air Exposure [ng-h/m3]
Applicator	1	1130	3	7920	7	1855	13	432	11337
Spouse	0	-	0	-	1	265	13	432	697
Child1	0	-	0	-	7	1855	14	465	2320

NC2 Day3

CARBARYL	Time HML/ Appl 1 [h]	Personal Exposure [ng-h/m3]	time HML/ Appl 2 [h]	Personal Exposure [ng-h/m3]	Time Outdoors (on farm) [h]	Outdoor Exposure [ng-h/m3]	Time Indoors (in house) [h]	Indoor Exposure [ng-h/m3]	Total Air Exposure [ng-h/m3]
Applicator	2	1,288,000	na	-	9	837	13	622.7	1,289,000
Spouse	0	-	na	-	1	93.0	18	862.2	955.2
Child1	0	-	na	-	0	0	10	479.	479.
Child2	0	-	na	-	0	0	12	574.8	574.8

APPENDIX M: SPOUSE AND CHILD EXPOSURE RELATIVE TO APPLICATOR

Total Air Exposure to Applied Pesticide on Day 3: Ratio of Spouse and Children to Applicator								
Pesticide	**Family Member**	**Iowa #1**	**Iowa #2**	**Iowa #3 (First)**	**Iowa #3 (Second)**	**Iowa #4**	**NC #1**	**NC #2**
Alachlor	Spouse	-	-	-	-	-	6 %	-
	Child 1	-	-	-	-	-	20 %	-
	Child 2	-	-	-	-	-	na	-
Atrazine	Spouse	-	< 1 %	1 %	-	-	-	-
	Child 1	-	< 1 %	3 %	-	-	-	-
	Child 2	-	na	na	-	-	-	-
Carbaryl	Spouse	-	-	-	-	-	-	< 1 %
	Child 1	-	-	-	-	-	-	< 1 %
	Child 2	-	-	-	-	-	-	< 1 %
Dicamba	Spouse	1 %	0 %	-	-	-	-	-
	Child 1	1 %	0 %	-	-	-	-	-
	Child 2	1 %	na	-	-	-	-	-
2,4-D BOEE	Spouse	-	0 %	-	-	-	-	-
	Child 1	-	0 %	-	-	-	-	-
	Child 2	-	na	-	-	-	-	-
Metolachlor	Spouse	-	4 %	-	-	-	-	-
	Child 1	-	5 %	-	-	-	-	-
	Child 2	-	na	-	-	-	-	-

na = not applicable

APPENDIX N: INDOOR DETECTION OF NON-APPLIED PESTICIDES

INDOOR DETECTION OF NON-APPLIED PESTICIDES

FARM	PESTICIDE	HISTORICAL USE
IA2	CHLORPYRIFOS (10 May 1994)	05 MAY 1994
	TERBUFOS (10 May 1994)	na
	TRIFLURALIN (10 May 1994)	na
IA3-First Visit	ALACHLOR (15 May 1994)	na
	CHLOPYRIFOS (14 May 1994)	na
	PROPOXUR (15 May 1994)	na
	TERBUFOS (15 May 1994)	10 MAY 1994
	TRIFLURALIN (15 May 1994)	na
IA3-Second Visit	ATRAZINE (14 Jun 1994)	14 MAY 1994
	γ-CHLORDANE (14 Jun 1994)	na
	CHLOROTHALONIL (14 Jun 1994)	na
	CHLORPYRIFOS (14 Jun 1994)	na
	METOLACHLOR (14 Jun 1994)	14 MAY 1994
	PROPOXUR (14 Jun 1994)	na
	TERBUFOS (14 Jun 1994)	10 MAY 1994
	TRIFLURALIN (14 Jun 1994)	na
IA4	ATRAZINE (17 Jun 1994)	11 JUNE 1994
	α-CHLORDANE (17 Jun 1994)	na
	γ-CHLORDANE (17 Jun 1994)	na
	CHLORPYRIFOS (17 Jun 1994)	na
	HEPTACHLOR (17 Jun 1994)	na
	LINDANE (17 Jun 1994)	na
	METOLACHLOR (17 Jun 1994)	na
NC1	α-CHLORDANE (23 Jun 1994)	na
	γ-CHLORDANE (23 Jun 1994)	na
	CHLORPYRIFOS (23 Jun 1994)	na
	HEPTACHLOR (23 Jun 1994)	na
	PROPOXUR (23 Jun 1994)	na
	TRIFLURALIN (21 Jun 1994)	na
NC2	α-CHLORDANE (29 Jul 1994)	na
	γ-CHLORDANE (29 Jul 1994)	na
	CHLORPYRIFOS (29 Jul 1994)	na
	HEPTACHLOR (29 Jul 1994)	na
	TERBUFOS (28 Jul 1994)	na

APPENDIX O: INDOOR AIR EXPOSURES AND INHALATION DOSES

IA1	Indoor Air Exposures and Inhalation Doses								
Pesticide [ng/m^3]	**Family Member**	**Day 2** (May 17)		**Day 3** (May 18)		**Day 4** (May 19)		**Expos Sum**	**Mean Dose**
*** applied † residual**		Time **[h]**	Expos **[h-ng/m^3]**	Time **[h]**	Expos **[h-ng/m^3]**	Time **[h]**	Expos **[h-ng/m^3]**	**[h-ng/m^3]**	**[ng/d]**
Atrazine †	Applicator	9	-	5	-	13	-	-	-
Day 2: nd	Spouse	17	-	15	-	19	-	-	-
Day 3: nd	Child1	13	-	12	-	12	-	-	-
Day 4: nd	Child2	18	-	14	-	22	-	-	-
2,4 - D †	Applicator	9	-	5	-	13	-	-	-
Day 2: nd	Spouse	17	-	15	-	19	-	-	-
Day 3: nd	Child1	13	-	12	-	12	-	-	-
Day 4: nd	Child2	18	-	14	-	22	-	-	-
Dicamba *	Applicator	9	-	5	11	13	-	11	2
Day 2: nd	Spouse	17	-	15	34	19	-	34	7
Day 3: **2.27**	Child1	13	-	12	27	12	-	27	5
Day 4: nd	Child2	18	-	14	32	22	-	32	6
Metolachlor †	Applicator	9	-	5	-	13	-	-	-
Day 2: nd	Spouse	17	-	15	-	19	-	-	-
Day 3: nd	Child1	13	-	12	-	12	-	-	-
Day 4: nd	Child2	18	-	14	-	22	-	-	-

IA2	Indoor Air Exposures and Inhalation Doses								
Pesticide [ng/m^3]	**Family Member**	**Day 2** (May 8)		**Day 3** (May 9)		**Day 4** (May 10)		**Expos Sum**	**Mean Dose**
*** applied † residual**		Time [h]	Expos [h-ng/m^3]	Time [h]	Expos [h-ng/m^3]	Time [h]	Expos [h-ng/m^3]	[h-ng/m^3]	[ng/d]
Atrazine *	Applicator	na	-	11	-	11	-	-	-
Day 2: nm	Spouse	na	-	13	-	18	-	-	-
Day 3: nd									
Day 4: nd	Child1	na	-	19	-	13	-	-	-
Chlorpyrifos	Applicator	na	-	11	26	11	32	58	17
Day 2: nm	Spouse	na	-	13	31	18	52	83	25
Day 3: 2.38									
Day 4: 2.89	Child1	na	-	19	45	13	38	83	25
2,4-D †	Applicator	na	-	11	-	11	-	-	-
Day 2: nm	Spouse	na	-	13	-	18	-	-	-
Day 3: nd									
Day 4: nd	Child1	na	-	19	-	13	-	-	-
2,4-D boce *	Applicator	na	-	11	-	11	-	-	-
Day 2: nm	Spouse	na	-	13	-	18	-	-	-
Day 3: nd									
Day 4: nd	Child1	na	-	19	-	13	-	-	-
Dicamba*	Applicator	na	-	11	-	11	-	-	-
Day 2: nm	Spouse	na	-	13	-	18	-	-	-
Day 3: nd									
Day 4: nd	Child1	na	-	19	-	13	-	-	-
Metolachlor *	Applicator	na	-	11	791	11	693	1484	445
Day 2: nm	Spouse	na	-	13	935	18	1134	2069	621
Day 3: 71.9									
Day 4: 63.0	Child1	na	-	19	1366	13	819	2185	656
Turbufos	Applicator	na	-	11	572	11	543	1115	334
Day 2: nm	Spouse	na	-	13	676	18	889	1565	470
Day 3: 52.0									
Day 4: 49.4	Child1	na	-	19	988	13	642	1630	489
Trifluralin	Applicator	na	-	11	77	11	62	139	42
Day 2: nm	Spouse	na	-	13	91	18	101	192	58
Day 3: 7.03									
Day 4: 5.60	Child1	na	-	19	134	13	73	207	62

IA3-First	Indoor Air Exposures and Inhalation Doses								
Pesticide [ng/m^3]	**Family Member**	**Day 2** (May 13)		**Day 3** (May 14)		**Day 4** (May 15)		**Expos Sum**	**Mean Dose**
*** applied † residual**		Time **[h]**	Expos **[h-ng/m^3]**	Time **[h]**	Expos **[h-ng/m^3]**	Time **[h]**	Expos **[h-ng/m^3]**	**[h-ng/m^3]**	**[ng/d]**
Alachlor	Applicator	10	61	16	150	16	112	323	13
Day 2: **6.13**	Spouse	15	92	23	216	17	120	428	86
Day 3: **9.39** Day 4: **7.03**	Child1	5	31	7	66	17	120	217	43
Atrazine *	Applicator	10	-	16	-	16	-	-	-
Day 2: nd	Spouse	15	-	23	-	17	-	-	-
Day 3: nd Day 4: nd	Child1	5	-	7	-	17	-	-	-
Chlorpyrifos	Applicator	10	-	16	15	16	-	15	3
Day 2: nd	Spouse	15	-	23	22	17	-	22	4
Day 3: **0.950** Day 4: nd	Child1	5	-	7	7	17	-	7	1
Metolachlor †	Applicator	10	51	16	65	16	52	168	34
Day 2: **5.13**	Spouse	15	77	23	93	17	55	225	45
Day 3: **4.04** Day 4: **3.22**	Child1	5	26	7	28	17	55	109	22
Propoxur	Applicator	10	215	16	438	16	317	970	194
Day 2: **21.5**	Spouse	15	322	23	630	17	337	1289	258
Day 3: **27.4** Day 4: **19.8**	Child1	5	108	7	192	17	337	637	127
Terbufos	Applicator	10	250	16	661	16	426	1337	267
Day 2: **25.0**	Spouse	15	375	23	950	17	452	1777	355
Day 3: **41.3** Day 4: **26.6**	Child1	5	125	7	289	17	452	866	173
Trifluralin	Applicator	10	-	16	13	16	11	24	5
Day 2: nd	Spouse	15	-	23	19	17	12	31	6
Day 3: **0.822** Day 4: **0.692**	Child1	5	-	7	6	17	12	18	4

IA3-Second	Indoor Air Exposures and Inhalation Doses								
Pesticide [ng/m^3] * applied † residual	Family Member	Day 2 (Jun 11)		Day 3 (Jun 13)		Day 4 (Jun 14)		Expos Sum	Mean Dose
		Time [h]	Expos [h-ng/m^3]	Time [h]	Expos [h-ng/m^3]	Time [h]	Expos [h-ng/m^3]	[h-ng/m^3]	[ng/d]
Alachlor †	Applicator	17	62	10	57	11	53	172	34
Day 2: 3.67	Spouse	16	59	17	97	14	67	223	45
Day 3: 5.68	Child1	16	59	17	97	12	57	213	43
Day 4: 4.78									
Atrazine	Applicator	17	-	10	-	11	53	53	11
Day 2: nd	Spouse	16	-	17	-	14	67	67	13
Day 3: nd	Child1	16	-	17	-	12	58	58	12
Day 4: 4.82									
γ-Chlordane	Applicator	17	-	10	-	11	4.6	4.6	1
Day 2: nd	Spouse	16	-	17	-	14	5.9	5.9	1
Day 3: nd	Child1	16	-	17	-	12	5.0	5.0	1
Day 4: 0.419									
Chloro-thalonil	Applicator	17	95	10	110	11	104	309	62
Day 2: 5.60	Spouse	16	90	17	187	14	133	410	82
Day 3: 11.0	Child1	16	90	17	187	12	114	391	78
Day 4: 9.47									
Chlorpyrifos	Applicator	17	14	10	15	11	18	47	9
Day 2: 0.827	Spouse	16	13	17	25	14	23	61	12
Day 3: 1.46	Child1	16	13	17	25	12	20	58	12
Day 4: 1.65									
2,4 - D *	Applicator	17	-	10	-	11	-	-	-
Day 2: nd	Spouse	16	-	17	-	14	-	-	-
Day 3: nd	Child1	16	-	17	-	12	-	-	-
Day 4: nd									
2,4 - D boee *	Applicator	17	-	10	-	11	-	-	-
Day 2: nd	Spouse	16	-	17	-	14	-	-	-
Day 3: nd	Child1	16	-	17	-	12	-	-	-
Day 4: nd									
Metolachlor	Applicator	17	34	10	37	11	36	107	21
Day 2: 2.01	Spouse	16	32	17	63	14	45	140	28
Day 3: 3.71	Child1	16	32	17	63	12	39	134	27
Day 4: 3.24									
Propoxur	Applicator	17	396	10	334	11	398	1128	226
Day 2: 23.3	Spouse	16	373	17	568	14	507	1448	290
Day 3: 33.4	Child1	16	373	17	568	12	434	1375	275
Day 4: 36.2									

IA3-Second (cont)	**Indoor Air Exposures and Inhalation Doses**								
Pesticide [ng/m^3]	**Family Member**	**Day 2** (Jun 11)		**Day 3** (Jun 13)		**Day 4** (Jun 14)		**Expos Sum**	**Mean Dose**
*** applied † residual**		Time **[h]**	Expos **[h-ng/m^3]**	Time **[h]**	Expos **[h-ng/m^3]**	Time **[h]**	Expos **[h-ng/m^3]**	**[h-ng/m^3]**	**[ng/d]**
Terbufos	Applicator	17	201	10	114	11	78	393	79
Day 2: **11.8** Day 3: **11.4** Day 4: **7.11**	Spouse	16	189	17	194	14	100	483	97
	Child1	16	189	17	194	12	85	468	94
Trifluralin	Applicator	17	58	10	13	11	20	91	18
Day 2: **3.43** Day 3: **1.27** Day 4: **1.83**	Spouse	16	55	17	22	14	26	103	21
	Child1	16	55	17	22	12	22	99	20

IA4	Indoor Air Exposures and Inhalation Doses									
Pesticide [ng/m^3]	**Family Member**	**Day 2 (Jun 15)**		**Day 3 (Jun 16)**		**Day 4 (Jun 17)**		**Expos Sum**	**Mean Dose**
*** applied † residual**		Time [h]	Expos [h-ng/m^3]	Time [h]	Expos [h-ng/m^3]	Time [h]	Expos [h-ng/m^3]	[h-ng/m^3]	[ng/d]
Atrazine	Applicator	9	-	8	-	9	189	189	38
Day 2: nd Day 3: nd Day 4: 21.0	Spouse	20	-	21	-	18	378	378	76
	Child1	21	-	18	-	20	420	420	84
	Child2	23	-	15	-	20	420	420	84
α-Chlordane	Applicator	9	13	8	9	9	13	35	7
Day 2: 1.41 Day 3: 1.11 Day 4: 1.48	Spouse	20	28	21	23	18	27	78	16
	Child1	21	30	18	20	20	30	80	16
	Child2	23	32	15	17	20	30	79	16
γ-Chlordane	Applicator	9	16	8	12	9	17	45	9
Day 2: 1.83 Day 3: 1.55 Day 4: 1.85	Spouse	20	37	21	33	18	33	103	21
	Child1	21	38	18	28	20	37	103	21
	Child2	23	42	15	23	20	37	102	20
Chlorpyrifos	Applicator	9	22	8	-	9	24	46	9
Day 2: 2.40 Day 3: nd Day 4: 2.66	Spouse	20	48	21	-	18	48	96	19
	Child1	21	50	18	-	20	53	103	21
	Child2	23	55	15	-	20	53	108	22
Heptachlor	Applicator	9	-	8	12	9	17	29	6
Day 2: nd Day 3: 1.55 Day 4: 1.87	Spouse	20	-	21	33	18	34	67	13
	Child1	21	-	18	28	20	37	65	13
	Child2	23	-	15	23	20	37	60	12
Lindane	Applicator	9	639	8	456	9	689	1784	357
Day 2: 71.0 Day 3: 57.0 Day 4: 76.6	Spouse	20	1420	21	1197	18	1379	3996	799
	Child1	21	1491	18	1026	20	1532	4049	810
	Child2	23	1633	15	855	20	1532	4020	804
Metolachlor	Applicator	9	25	8	21	9	28	74	15
Day 2: 2.80 Day 3: 2.68 Day 4: 3.15	Spouse	20	56	21	56	18	57	169	34
	Child1	21	59	18	48	20	63	170	34
	Child2	23	64	15	40	20	63	167	33

IA4 (cont)	Indoor Air Exposures and Inhalation Doses								
Pesticide [ng/m^3] * applied † residual	**Family Member**	**Day 2** (Jun 15)		**Day 3** (Jun 16)		**Day 4** (Jun 17)		**Expos Sum**	**Mean Dose**
		Time **[h]**	Expos **[h-ng/m^3]**	Time **[h]**	Expos **[h-ng/m^3]**	Time **[h]**	Expos **[h-ng/m^3]**	**[h-ng/m^3]**	**[ng/d]**
Piperonyl Butoxide * Day 2: nd Day 3: nd Day 4: nd	Applicator	9	-	8	-	9	-	-	-
	Spouse	20	-	21	-	18	-	-	-
	Child1	21	-	18	-	20	-	-	-
	Child2	23	-	15	-	20	-	-	-
Pyrethrins * Day 2: nd Day 3: nd Day 4: nd	Applicator	9	-	8	-	9	-	-	-
	Spouse	20	-	21	-	18	-	-	-
	Child1	21	-	18	-	20	-	-	-
	Child2	23	-	15	-	20	-	-	-

NC1	Indoor Air Exposures and Inhalation Doses								
Pesticide [ng/m^3]	**Family Member**	**Day 2** (Jun 21)		**Day 3** (Jun 22)		**Day 4** (Jun 23)		**Expos Sum**	**Mean Dose**
*** applied † residual**		Time [h]	Expos [h-ng/m^3]	Time [h]	Expos [h-ng/m^3]	Time [h]	Expos [h-ng/m^3]	[h-ng/m^3]	[ng/d]
Alachlor *	Applicator	13	363	13	432	13	602	1397	279
Day 2: 27.9 Day 3: 33.2 Day 4: 46.3	Spouse	13	363	13	432	12	556	1351	270
	Child1	11	307	14	465	16	741	1513	303
α-Chlordane	Applicator	13	2288	13	1976	13	1469	5733	1147
Day 2: 176 Day 3: 152 Day 4: 113	Spouse	13	2288	13	1976	12	1356	5620	1124
	Child1	11	1936	14	2128	16	1808	5872	1174
γ-Chlordane	Applicator	13	3003	13	2561	13	1885	7449	1490
Day 2: 231 Day 3: 197 Day 4: 145	Spouse	13	3003	13	2561	12	1740	7304	1461
	Child1	11	2541	14	2758	16	2320	7619	1524
Chlorpyrifos	Applicator	13	59	13	49	13	42	150	30
Day 2: 4.51 Day 3: 3.78 Day 4: 3.26	Spouse	13	59	13	49	12	39	147	29
	Child1	11	50	14	53	16	52	155	31
Heptachlor	Applicator	13	1169	13	1104	13	810	3083	617
Day 2: 89.9 Day 3: 84.9 Day 4: 62.3	Spouse	13	1169	13	1104	12	748	3021	604
	Child1	11	989	14	1189	16	997	3175	635
Metolachlor †	Applicator	13	148	13	127	13	125	400	80
Day 2: 11.4 Day 3: 9.76 Day 4: 9.64	Spouse	13	148	13	127	12	116	391	78
	Child1	11	125	14	137	16	154	416	83
Propoxur	Applicator	13	2639	13	3185	13	3107	8931	1786
Day 2: 203 Day 3: 245 Day 4: 239	Spouse	13	2639	13	3185	12	2868	8692	1738
	Child1	11	2233	14	3430	16	3824	9487	1897
Trifluralin	Applicator	13	9	13	-	13	-	9	2
Day 2: 0.664 Day 3: nd Day 4: nd	Spouse	13	9	13	-	12	-	9	2
	Child1	11	7	14	-	16	-	7	1

NC2	Indoor Air Exposures and Inhalation Doses								
Pesticide [ng/m^3]	**Family Member**	**Day 2** (Jul 27)		**Day 3** (Jul 28)		**Day 4** (Jul 29)		**Expos Sum**	**Mean Dose**
*** applied † residual**		Time **[h]**	Expos **[h-ng/m^3]**	Time **[h]**	Expos **[h-ng/m^3]**	Time **[h]**	Expos **[h-ng/m^3]**	**[h-ng/m^3]**	**[ng/d]**
Carbaryl *	Applicator	11	3069	13	623	9	652	4344	869
Day 2: **279**	Spouse	24	6696	18	862	20	1448	9006	1801
Day 3: **47.9**	Child1	7	1953	10	479	11	796	3228	646
Day 4: **72.4**	Child2	11	3069	12	575	17	1231	4875	975
α-Chlordane	Applicator	11	1331	13	1261	9	927	3519	704
Day 2: **121**	Spouse	24	2904	18	1746	20	2060	6710	1342
Day 3: **97.0**	Child1	7	847	10	970	11	1133	2950	590
Day 4: **103**	Child2	11	1331	12	1164	17	1751	4246	849
γ-Chlordane	Applicator	11	1771	13	1729	9	1305	4805	961
Day 2: **161**	Spouse	24	3864	18	2397	20	2900	9161	1832
Day 3: **133**	Child1	7	1127	10	1330	11	1595	4052	810
Day 4: **145**	Child2	11	1771	12	1596	17	2465	5832	1166
Chlorpyrifos	Applicator	11	19	13	19	9	28	66	13
Day 2: **1.69**	Spouse	24	41	18	26	20	61	128	26
Day 3: **1.46**	Child1	7	12	10	15	11	34	61	12
Day 4: **3.07**	Child2	11	19	12	18	17	52	89	18
Heptachlor	Applicator	11	872	13	1173	9	665	2710	542
Day 2: **79.3**	Spouse	24	1903	18	1624	20	1478	5005	1001
Day 3: **90.2**	Child1	7	555	10	902	11	813	2270	454
Day 4: **73.9**	Child2	11	872	12	1082	17	1256	3210	642
Terbufos	Applicator	11	-	13	619	9	-	619	124
Day 2: nd	Spouse	24	-	18	857	20	-	857	171
Day 3: **47.6**	Child1	7	-	10	476	11	-	476	95
Day 4: nd	Child2	11	-	12	571	17	-	571	114

FIGURES

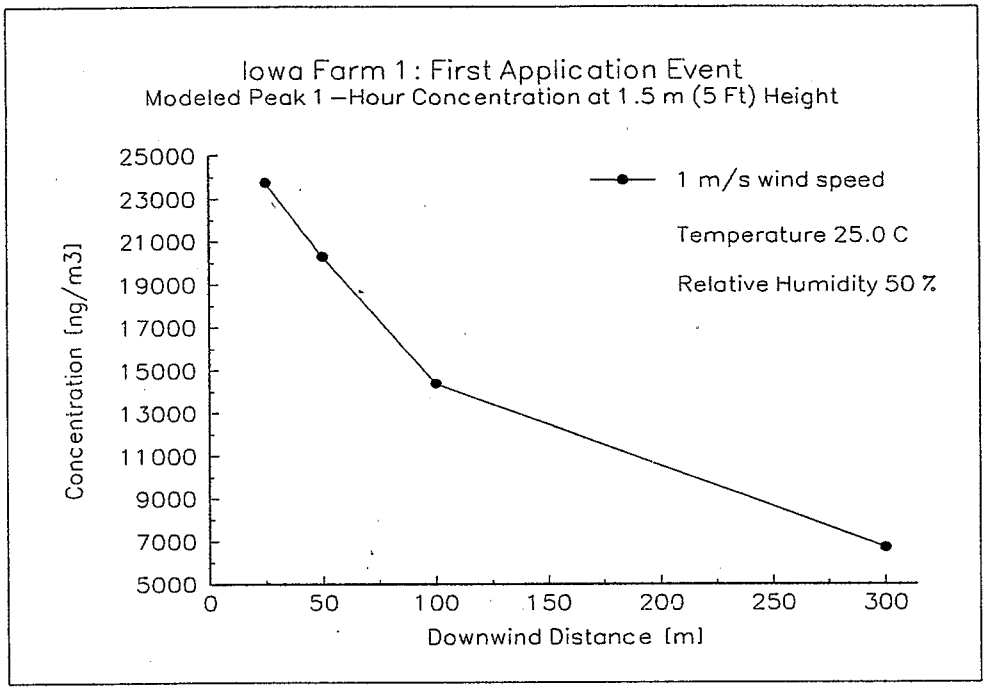

Figure 1

Modeled concentration profile for Iowa farm #1, first application event. Peak 1-hour concentration of dicamba at the 1.5 m height is plotted against downwind distance. Dicamba application rate (per acre and per unit hour) was simulated as actually recorded; other parameters of boom sprayer emission, meteorology, and receptor location (i.e. centerline), were estimated as reasonable worst case.

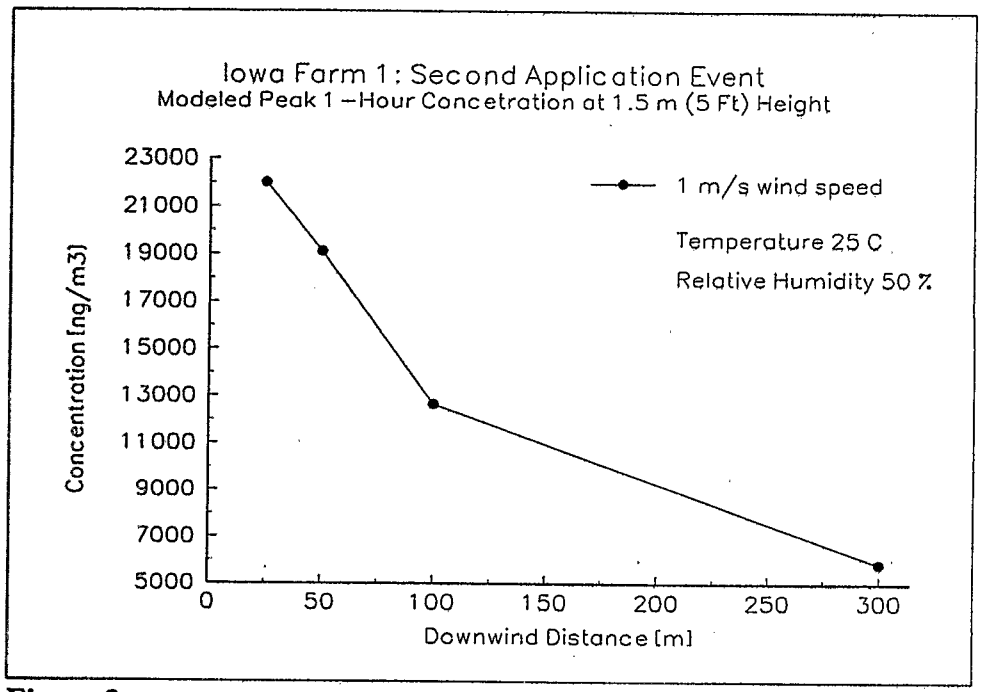

Figure 2

Modeled concentration profile for Iowa farm #1, second application event. Peak 1-hour concentration of dicamba at the 1.5 m height is plotted against downwind distance. Dicamba application rate (per acre and per unit hour) was simulated as actually recorded; other parameters of boom sprayer emission, meteorology, and receptor location (i.e. centerline), were estimated as reasonable worst case.

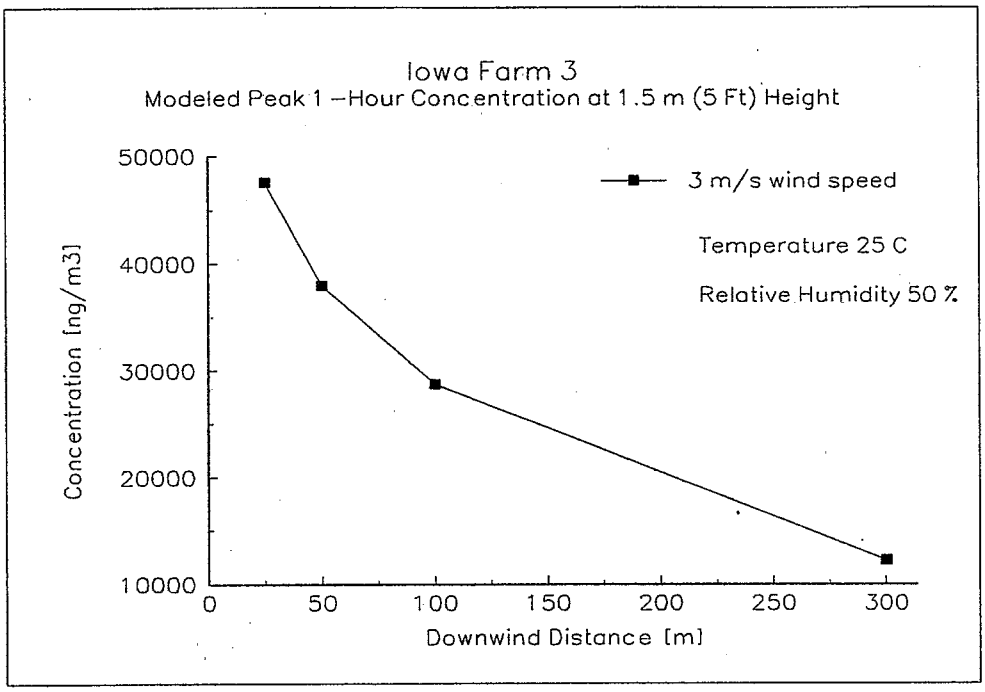

Figure 3

Modeled concentration profile for Iowa farm #3, first application period. Peak 1-hour concentration of atrazine at the 1.5 m height is plotted against downwind distance. Atrazine application rate (per acre and per unit hour) was simulated as actually recorded; other parameters of boom sprayer emission, meteorology, and receptor location (i.e. centerline), were estimated as reasonable worst case.

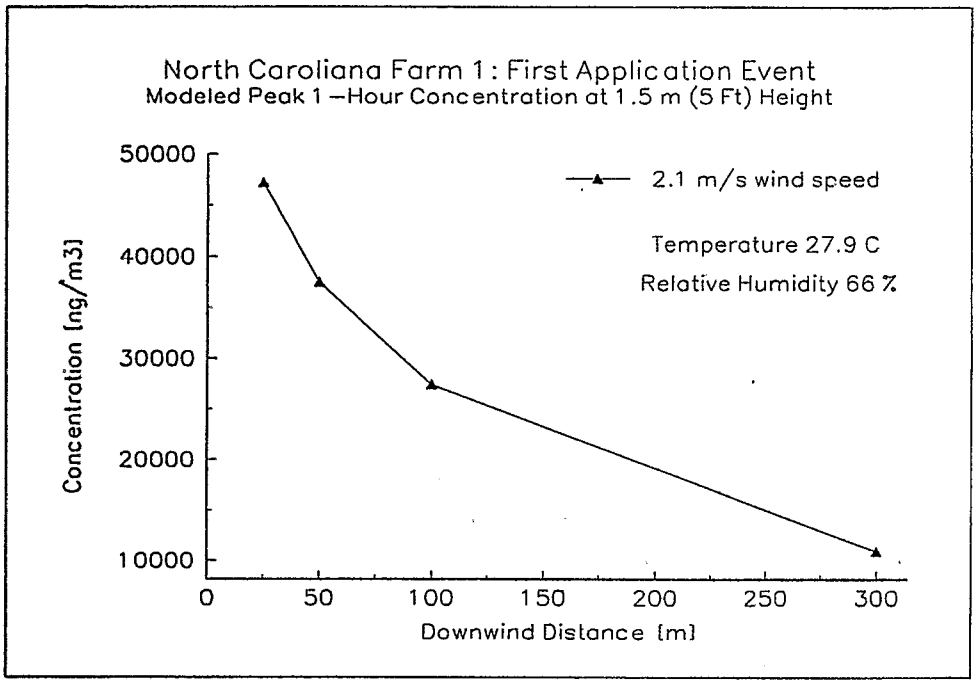

Figure 4

Modeled concentration profile for North Carolina farm #1, first application event. Peak 1-hour concentration of alachlor at the 1.5 m height is plotted against downwind distance. Alachlor application rate (per acre and per unit hour) was simulated as actually recorded; other parameters of boom sprayer emission, meteorology, and receptor location (i.e. centerline), were estimated as reasonable worst case.

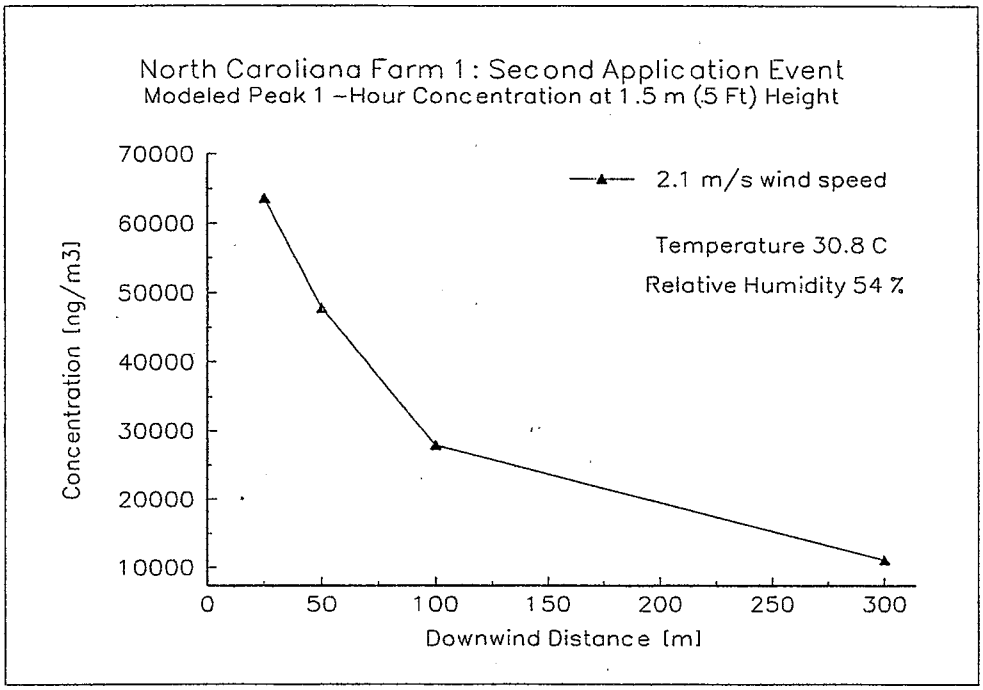

Figure 5

Modeled concentration profile for North Carolina farm #1, second application event. Peak 1-hour concentration of alachlor at the 1.5 m height is plotted against downwind distance. Alachlor application rate (per acre and per unit hour) was simulated as actually recorded; other parameters of boom sprayer emission, meteorology, and receptor location (i.e. centerline), were estimated as reasonable worst case.

KEYWORDS

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