

MULTI-AGENCY REVISION AND DEVELOPMENT OF A STANDARDIZED TEMPLATE  
FOR ASSESSING OCCUPATIONAL AND RESIDENTIAL RISKS OF PESTICIDE  
EXPOSURE THROUGH FUMIGATION AND SPRAY DRIFT PATHWAYS

BY

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## ABSTRACT

This report summarizes my experiences as a United States Public Health Service (PHS) environmental scientist working jointly with the Washington, DC based offices of the United States Department of Agriculture (USDA), Food and Drug Administration (FDA), the Office of Environmental Justice (OEJ), the Federal Environmental Justice Interagency Working Group on Environmental Justice (EJ/IWG) and the Environmental Protection Agency's Office of Chemical Safety and Pollution Prevention (EPA/OCSP). This field experience was in partial fulfillment of the requirements of the Master of Public Health Program at Kansas State University. During the summer 2015 semester, I worked alongside representatives from the USDA, FDA, OEJ (EJ/IWG), and EPA establishing occupational and residential fumigant risk assessment template guidelines, while working with the (OEJ) and the (EJ/IWG) concerning new environmental justice laws and protocols as they pertain to predominately minority residential community pesticide exposure concerns.

During this joint governmental agency project, while under the supervision of Bill Smith (US/EPA Health Effects Division), I worked with Jeff Dawson (EPA/OCSP/OEJ) and Spencer Walse (USDA-Agricultural Science Dept.) refining the EPA occupational and residential exposure assessment template while addressing the fumigant exposure and spray drift issues as they pertain to predominately minority communities located in and around fumigation sites (agricultural fields, packing houses and shipping ports). The purposes of this research in Washington, DC included learning about (1) occupational and residential exposure, (2) how to conduct an assessment that deals with pesticides use (in particular, fumigants in soil, on commodities, and in packing material), and (3) indoor pest deterrents. A second objective was to incorporate into the assessment template practical and legally enforceable language for the protection of the general public during spray drift activities.

The results of this project lead to a new occupational and residential risk assessment template that incorporated input from USDA, FDA, OEJ and (EJ/IWG) and directly implemented fumigant modeling and spray drift (pesticide application methods that use high volume spray equipment) calculations and language addressing potential environmental justice issues protecting agricultural and industrial port based communities. This template can now be used for chemical specific risk assessments agency wide.

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## LIST OF ABBREVIATIONS

CDPR	CALIFORNIA DEPARTMENT OF PESTICIDE REGULATION
EPA	ENVIRONMENTAL PROTECTION AGENCY
FDA	FOOD AND DRUG ADMINISTRATION
GIS	GEOGRAPHIC INFORMATION SYSTEM
HED	HEALTH EFFECTS DIVISION
MeBr	METHYL BROMIDE
MTRS	MERIDIAN TOWNSHIP RANGE SECTION
OCR	OFFICE OF CIVIL RIGHTS
OCSP	OFFICE OF CHEMICAL SAFETY AND POLLUTION PREVENTION
OEJ/IWG	ENVIRONMENTAL JUSTICE INTERAGENCY WORKING GROUP
OPP	OFFICE OF PESTICIDES PROGRAM
PHS	PUBLIC HEALTH SERVICE
ORE	OCCUPATIONAL AND RESIDENTIAL EXPOSURE
PUR	PESTICIDE USAGE REPORT
SAP	SCIENCE ADVISORY PANEL
USDA	UNITED STATES DEPARTMENT OF AGRICULTURE

## ACKNOWLEDGMENTS

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## CHAPTER 1 - BACKGROUND INFORMATION

### ENVIRONMENTAL PROTECTION AGENCY

In 1996, the Food Quality Protection Act (FQPA) was passed and increased the Environmental Protection Agency's (EPA) risk assessment requirements and expectations under the Federal Insecticide Fungicide and Rodenticide Act (FIFRA) and the Federal Food, Drug, and Cosmetics Act (FEDCA). The emphasis from this legislation centered on protecting infants and children from acute and aggregated (combined) exposures from all potential pathways. These aggregate exposure pathways consisted of food, drinking water, and residential exposures stemming from dermal and inhalation routes of exposure. The EPA, in response to this legislation, developed science policies<sup>1</sup> that also included an initial set of guidelines called the Standard Operating Procedures<sup>2</sup> or (SOPs) for Residential Exposure Assessments. These SOPs addressed all major potential pesticide exposure possibilities in residential settings such as homes, schools and parks.

In 2009, revisions to the SOPs were made as new data emerged from studies generated by registrants and consumer advocacy groups. Furthermore, new exposure scenarios and their accompanying algorithms were added to reflect new products that emerged on the market. In 2012, revisions were made to accommodate new over-all exposure data stemming from new equipment and product information as well as new analysis of field trial data generated by a pesticide volatilization (sorption and depuration) study sponsored by the United States Department of Agriculture (USDA) and the Food and Drug Administration (FDA). Further revisions were made in 2015, which incorporated pesticide spray drift language concerning legal guidelines for spray drift near residential areas generated by the California Department of Pesticide Regulation (CDPR) and the Office of Environmental Justice/Interagency Working Group (OEJ/IWG).

### EPA: METHYL BROMIDE

In 1987, at the Vienna Convention for the Protection of the Ozone, the Montreal Protocol was enacted. This treaty dealt specifically with ozone depletion and stressed the need for the international community to begin phasing out the production of chemicals that depleted ozone.<sup>3</sup> Among the listed chemicals was methyl bromide (MeBr). By the early 1990's, combined with

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<sup>1</sup> EPA Office of Pesticide Program. (2012). Standard Operating Procedures for Residential Pesticide Assessment. <http://www.epa.gov/oppfead1/trac/science/>

<sup>2</sup> EPA. SOPs for residential and occupational exposures, (2015). <http://www.epa.gov/pesticides/science/residential-exposure-sop.html>

<sup>3</sup> EPA Ozone Layer Protection – Regulatory Programs. The Phase-out of Methyl Bromide. <http://www3.epa.gov/ozone/mbr/>

ozone depleting characteristics, MeBr was found to be primarily toxic to the central nervous system and lungs, while possessing both mutagenic and carcinogenic capabilities. The phase out time line designated in the Montreal Protocol stated that by 2005, one hundred percent of “standard” MeBr uses needed to be halted. The “non-standard” exemptions received “critical use permits” and are currently being used predominantly as soil and commodity fumigants. In the 2013 sorption and depuration study described below, the USDA began seeking alternatives such as phosphine as a MeBr substitute. The theory behind this study is that phosphine, although very toxic, has a higher vapor pressure thus dissipates quicker leaving less residue for exposure. Furthermore, phosphine was classified as a much safer chemical with respect to ozone depletion. In the Title VI “Angelita C complaint” discussed later in this document, MeBr was the chemical mentioned in the complaint, whereas it was and still is the chemical of choice for soil and pest fumigations nationwide.

#### **UNITED STATES DEPARTMENT OF AGRICULTURE**

In 2013, during EPA’s SOP revision, the United States Department of Agriculture (USDA) sponsored a study that analyzed phosphine and methyl bromide.<sup>4</sup> This pesticide volatilization (sorption and depuration) study compared the volatility characteristics and residue levels of phosphine and methyl bromide during and after fumigation treatments of grapes and citrus (oranges, lemons and limes). The purpose of the study was to determine if phosphine left the least amount of residue (sorption) and “off-gassed/dissipated” (i.e. depuration) the quickest post treatment. The reason for the study was to see if phosphine could be used as a methyl bromide alternative. The study results presented new data that was used to help create revised algorithms and unit exposure values for fumigant exposure scenarios used in the 2015 revised risk assessment template. Furthermore, due to the data generated by the study, worker protection standards and food laws concerning packaging and cold food chain storage had to be examined.

#### **FOOD AND DRUG ADMINISTRATION**

The Food and Drug Administration (FDA), as a result of the 2013 USDA-sponsored phosphine and methyl bromide volatility study, was able to issue benchmark residue and tolerance levels for grapes and citrus for both phosphine and MeBr. With these tolerances in place, risk assessments for grapes and citrus could be performed. Furthermore, the data generated could be used as surrogate data for other fumigant exposures, which would help create handler and post-application fumigation algorithms for the 2015 revised risk assessment template.

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<sup>4</sup> Walse, S, (2013). Sorption and Depuration of Phosphine Relative to Methyl Bromide following Post-Harvest Fumigation of Grapes and Citrus. Publication from USDA-Agriculture/Research Science Lab.

## OFFICE OF CHEMICAL SAFETY AND POLLUTION PREVENTION

The Office of Chemical Safety and Pollution Prevention's (OCSPP)<sup>5</sup> purpose consists of protecting people and the environment from potential risks from pesticides and toxic chemicals through government and private sector partnerships and collaboration. OCSPP works to prevent pollution with the goal to reduce waste, save energy and natural resources and to help maintain safety standards in our residential and occupational settings. OCSPP implements aspects of the:

- Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA)
- Federal Food, Drug and Cosmetic Act (FFDCA)
- Toxic Substances Control Act (TSCA)
- Pollution Prevention Act

OCSPP regulates the manufacture and use of all pesticides (including insecticides, herbicides, rodenticides, disinfectants, sanitizers and more) in the United States and along with help from the FDA and USDA, helps establish maximum levels for pesticide residues in food.<sup>6</sup> Furthermore, OCSPP communicates with registrants on issues ranging from worker protection standards (WPS) to un-authorized or misuse of pesticides. Currently, the EPA and individual states can register or license pesticides for use throughout United States. In addition, anyone planning to import pesticides for use in the U.S. must notify the EPA, whereas the EPA receives its authority to register pesticides under the Federal Insecticide, Fungicide, and Rodenticides Act (FIFRA). OCSPP, which includes the Office of Pesticide Program (OPP), works on a wide range of pesticide issues and topics such as:

- New Pesticides and Uses
- Special Local Needs (SLNs) and Emergency Situations
- Re-Registration

My work for OCSPP primarily took place within the OPP.<sup>7</sup> In June of 2012, the Occupational and Residential Science Advisory Panel maintained that the current risk assessment template, written in 2009, was outdated due to newly submitted studies reflecting the Title VI Disparity/MeBr complaint. This study provided new data sets for both occupational and residential fumigation exposure scenarios; therefore, a new risk assessment template that incorporated this new data and fumigant language reflecting this data was needed.

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<sup>5</sup> EPA. Office of Chemical Safety and Pollution Prevention (Last updated October 9, 2015). <http://www2.epa.gov/aboutepa/about-office-chemical-safety-and-pollution-prevention-ocspp>

<sup>6</sup> EPA. Office of Chemical Safety and Pollution Prevention "Food Tolerances," (Last updated October 9, 2015). <http://www2.epa.gov/aboutepa/about-office-chemical-safety-and-pollution-prevention-ocspp>

<sup>7</sup> EPA. "Pesticide Safety," (Last updated October 14, 2015), <http://www.epa.gov/pesticides/>

## OFFICE OF ENVIRONMENTAL JUSTICE/INTERAGENCY WORKING GROUP

The Office of Environmental Justice/Interagency Working Group (OEJ/IWG) was established in 1994. The IWG is comprised of the EPA, the Departments of Justice, Defense, Energy, Labor, Interior, Transportation, Agriculture, Housing and Urban Development, Commerce, and Health and Human Services, the Council on Environmental Quality, the Office of Management and Budget, the Office of Science and Technology Policy, the Domestic Policy Council, and the Council of Economic Advisors.<sup>8</sup> The Office of Environmental Justice is tasked with holding all federal agencies accountable in their compliance to Title VI. The Interagency Working Group (representatives from all government agencies) was set up to respond to all complaints submitted by citizens of the United States. The OEJ states that,

"Title VI of the Civil Rights Act of 1964 is a federal law that prohibits employers from discriminating against employees on the basis of sex, race, color, national origin, and religion. It generally applies to employers with 15 or more employees, including federal, state, and local governments."<sup>9</sup>

In June of 1999, administrative complaint number 16R-99-R9 (hereafter referred to as the Angelita C. complaint) was filed on behalf of children and parents who attend six California public schools (Rio Mesa High School, Pajaro Middle School, MacQuiddy Elementary School, Rio Plaza Elementary School, Ohione Elementary School, and Barton Elementary School), which consist of predominately Hispanic students. The complaint was filed by California Rural Legal Assistance, Inc.; the Center on Race, Poverty & the Environment; the California Rural Legal Assistance Foundation; and the Farm-worker Justice Fund, Inc.

Upon review of the complaint and the supporting data supplied, the EPA began an investigation in May of 2000. The complaint alleged the California Department of Pesticide Regulation (CDPR) discriminated against minority/Hispanic school children in California by re-registering the soil fumigant pesticide methyl bromide (MeBr) without considering the potential health impact on children attending schools near where the soil fumigant is applied, whereas MeBr is extensively used to treat soil in barren fields, nursery soil, and for structural and commodity fumigation. In July of 2000, the EPA notified CDPR of its findings and investigation. Prior to the Angelita C. complaint, beginning in 1995, MeBr use in California was being monitored by CDPR in adherence to the Montreal Protocol ozone guidelines. When CDPR received the Angelita C. complaint in 1999, they contracted ICF Intl. to evaluate and compare CDPR's existing fumigation exposure data, then develop a number of alternative regression

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<sup>8</sup> EPA. "Reducing Risk." (Last updated March 14, 2015).

<http://www.epa.gov/compliance/ej/resources/publications/interagency/fy18-action-agenda.pdf>

<sup>9</sup> EPA. "Civil Rights." (Last updated October 14, 2015). <http://www.epa.gov/civilrights/>

models to estimate daily air exposures at more than 8,000 schools throughout Northern and Central California, including the schools that were noted in the complaint. The models were developed using a similar approach to that of CDPR, by using linear regression methods to derive coefficients which are multiplied by MeBr usage and other factors (“adjusted usage”) to predict daily concentrations.<sup>10</sup> The MeBr air concentrations used for model calibration were monitored by the California Air Resources Board from 1995, prior to the 1999 Title VI complaint, through 2001. The predicted daily concentrations at each school were averaged across designated time periods in various exposure scenarios.<sup>11</sup> Methyl bromide usage data for each meridian/township/range/ section (MTRS) location in California were obtained from CDPR’s Pesticide Usage Report<sup>12</sup> (PUR) records. MTRS usage was allocated using geographic information systems (GIS) to ¼ mile by ¼ mile square grid cells proportionally to the amount of farmland inside a grid cell. Within the model, usage values were adjusted to account for the distance and direction from the receptor to the usage site, days between usage and concentration prediction, temperature, and wind speed in predicting the daily MeBr concentrations. Based on previous daily average concentrations at each public school in the state, 7-, 30-, 42-, 182-, and 365-day average concentrations were estimated using two alternative algorithms.

The first algorithm (“Criterion”) was designed to find the highest K-day averages of MeBr (maximum concentrations in ppb) at each school, where K is either 7, 30, 42, 182 or 365 days. The second algorithm (“Exceedances”) was designed to find the maximum number of K-day averages exceeding selected benchmarks at each school (maximize exceedances). Table 1 below summarizes the algorithmic results for the “maximize concentrations, exceedances” and details the number of affected schools for ten different exposure scenarios. Each of these scenarios were assigned concentration benchmarks (35, 9, 5, 1, 1.3 ppb) established by either the EPA/OPP or Cal EPA/CDPR over different time (days) durations. These benchmarks were identified based on both EPA and California reviews of MeBr toxicity concerns. See Table 1 for details.

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<sup>10</sup> Cohen, J., Rosenbaum, A., & Carr, E. (2011). Model Development for Assessing California Methyl Bromide Ambient Concentrations. Draft report prepared by ICF International. EPA Office of Civil Rights, Washington DC.

<sup>11</sup> Li, L., Johnson, B., & Segawa, R. (2005). Empirical Relationship between Use, Area, and Ambient Air Concentration of Methyl Bromide. *J. Environ. Qual.* 34:403–407.

<sup>12</sup> UCIPM. “Research Tools,” Last updated July 10, 2014, <http://www.ipm.ucdavis.edu/PUSE/overview.html>

<b>Table 1. Details the number for predicted exceedances and affected schools post MeBr usage from various averaging periods and concentration benchmarks.</b>			
<b>Criterion</b>	<b>Exceedances</b>	<b>Affected Schools</b>	<b>Benchmark Source &amp; Type</b>
> 35 ppb in 7 days	4	3	EPA/OPP, Intermediate
> 9 ppb in 42 days	102	44	Cal-EPA/CDPR, Intermediate
> 9 ppb in 30 days	214	69	Cal-EPA/CDPR
> 5 ppb in 30 days	868	145	Cal-EPA/CDPR, Intermediate
> 1 ppb in 42 days	5039	743	Cal-EPA/OEHHA, Intermediate
> 1 ppb in 30 days	7101	929	Cal-EPA/OEHHA, Intermediate
> 1 ppb in 182 days	866	168	EPA/OPP, Long-term
> 1.3 ppb in 365 days	287	91	EPA/OPP, Long-term
> 1.3 ppb 2x in 182 days in same year	162	64	EPA/OPP, Long-term
>1.3 ppb in 30 days (6 x the same year)	29	23	EPA/OPP, Long-term
> 2.6 ppb and > 1.3 ppb in 182 days	33*	21	EPA/OPP, x 2, Long-term
> 2.6 ppb 2x in 182 days in same year	222	71	EPA/OPP x 2, Long-term

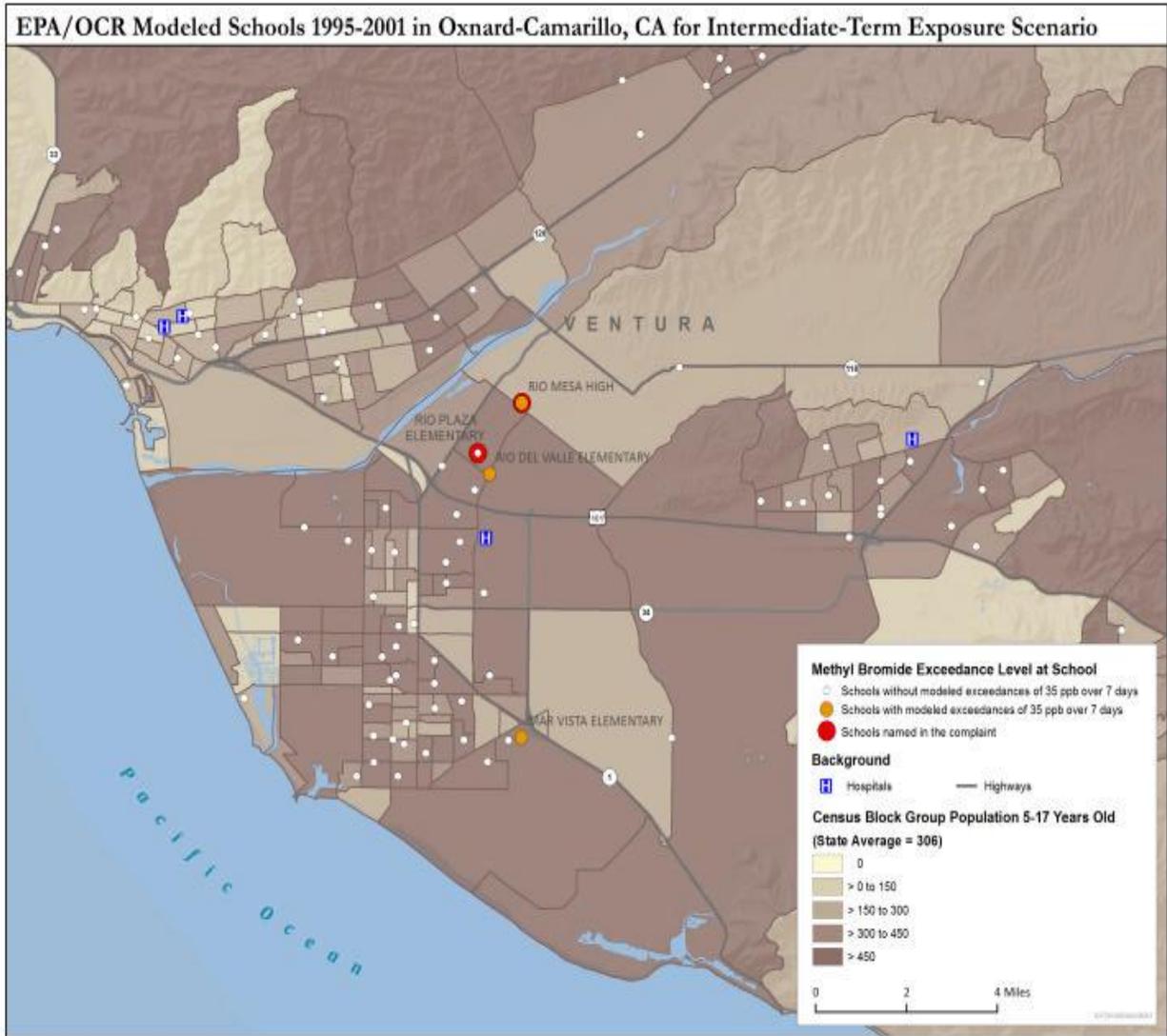
All of these data bases include information about the locations of farmland and various types of land cover, and were merged to create an integrated database covering all of California. (ICF 2011).

Figures 1, 2 and 3 are maps that show the schools monitored for MeBr exposure.<sup>13</sup> Altogether, there were 8,000 schools represented in the study including the schools named in the complaint (Rio Mesa High School, Pajaro Middle School, MacQuiddy Elementary School, Rio Plaza Elementary School, Ohione Elementary School, and Barton Elementary School). The schools that are represented on these maps are the data sites for the exposure data listed in Tables 1 and 2.

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<sup>13</sup> Cal-EPA/CDPR. (2002). Pesticide Use Report Data: User Guide & Documentation Department of Pesticide Regulation, Information Systems Division.  
[http://www.krisweb.com/biblio/cal\\_dpr\\_dpr\\_2002\\_pesticidecdguide.pdf](http://www.krisweb.com/biblio/cal_dpr_dpr_2002_pesticidecdguide.pdf)

(FIG. 1) Overview of Central California - Oxnard - Camarillo geographical area school sites monitored for MeBr concentrations.



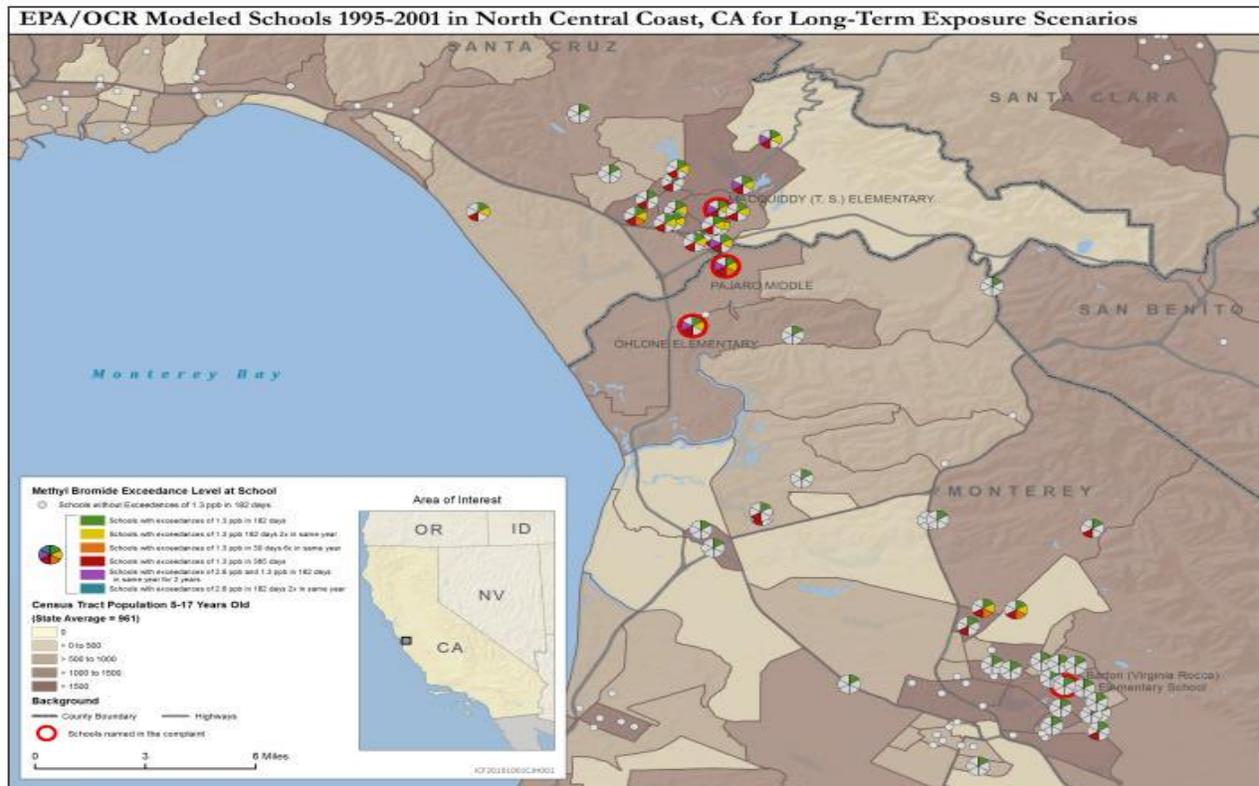
Exceedance Levels at School

White - Schools without modeled exceedances of 35 ppb over 7 days.

Yellow - Schools with modeled exceedances of 35 ppb over 7 days.

Red - Schools that were named in the complaint.

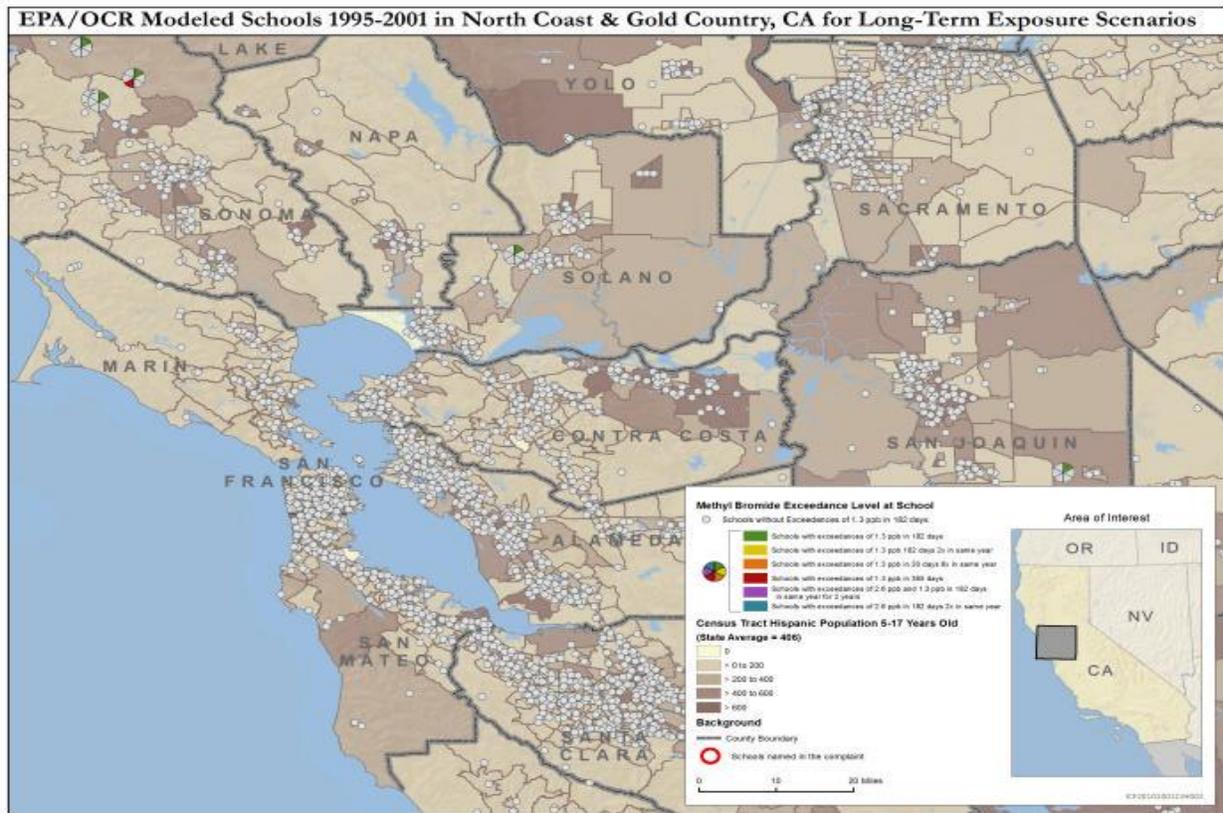
(FIG. 2) Overview of Northern California - Central Coast geographical area school sites monitored for MeBr concentrations.



Exceedance Levels at School

- Green - Schools with modeled exceedances of 1.3 ppb in 182 days.
- Yellow - Schools with modeled exceedances of 1.3 ppb in 182 days two years in a row.
- Orange - Schools with modeled exceedances of 1.3 ppb in 30 days (6x/year).
- Red - Schools with modeled exceedances of 1.3 ppb in 365 days “red”.
- Purple - Schools with modeled exceedances of 2.6 and 1.3 ppb in 3182 days.
- Turquoise - Schools with modeled exceedances of 2.6 ppb in 182 days (2x/year).

(FIG. 3) Overview of Northern California - North Central Coast/ Gold County geographical area school sites monitored for MeBr concentrations.



Exceedance Levels at School

- White - Schools without exceedances of 1.3 - 35 ppb for listed day values.
- Green - Schools with modeled exceedances of 1.3 ppb in 182 days.
- Yellow - Schools with modeled exceedances of 1.3 ppb in 182 days two years in a row.
- Orange - Schools with modeled exceedances of 1.3 ppb in 30 days (6x/year).
- Red - Schools with modeled exceedances of 1.3 ppb in 365 days.
- Purple - Schools with modeled exceedances of 2.6 and 1.3 ppb in 3182 days.
- Turquoise - Schools with modeled exceedances of 2.6 ppb in 182 days (2x/year).

<b>Table 2. Summary of the Exposures for Schools named in the Title VI complaint.</b>						
Criterion	School					
	Rio Mesa HS	Pajaro MS	Mac Quiddy ES	Rio Plaza ES	Ohlone ES	Barton ES
County	Ventura	Monterey	Santa Cruz	Ventura	Monterey	Monterey
<b>Proportion of Students who were Hispanic (1995-2001)</b>	<b>64%</b>	<b>94%</b>	<b>91%</b>	<b>88%</b>	<b>96%</b>	<b>98%</b>
<b>&gt; 35 ppb in 7 days (# in 7 years)</b>	<b>2</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>
> 9 ppb in 42 days (# in 7 years)	12	4	1	3	2	0
> 9 ppb in 30 days (# in 7 years)	15	6	5	8	5	0
> 5 ppb in 30 days (# in 7 years)	19	17	15	15	17	0
> 1 ppb in 42 days(# in 7 years)	25	24	21	26	25	18
> 1 ppb in 30 days(# in 7 years)	35	30	28	33	32	25
<b>&gt; 1.3 ppb in 182 days (# in 7 years)</b>	<b>12</b>	<b>13</b>	<b>11</b>	<b>10</b>	<b>13</b>	<b>3</b>
<b>&gt; 1.3 ppb in 365 days (# of years)</b>	<b>6</b>	<b>6</b>	<b>6</b>	<b>6</b>	<b>7</b>	<b>0</b>
<b>&gt; 1.3 ppb in 182 days, 2x in a year (# of years)</b>	<b>5</b>	<b>6</b>	<b>4</b>	<b>3</b>	<b>6</b>	<b>0</b>
<b>&gt; 1.3 ppb in 30 days, 6x in a year (# of years)</b>	<b>1</b>	<b>1</b>	<b>0</b>	<b>1</b>	<b>0</b>	<b>0</b>
<b>&gt; 2.6 ppb and &gt; 1.3 ppb in 182 days in same year for 2 yrs in a row (# of pairs of consecutive years)</b>	<b>4</b>	<b>3</b>	<b>1</b>	<b>1</b>	<b>3</b>	<b>0</b>
<b>&gt; 2.6 ppb in 182 days, 2x in a year (# of years)</b>	<b>4</b>	<b>0</b>	<b>0</b>	<b>1</b>	<b>0</b>	<b>0</b>

Note: Rows with **bold text** indicate predicted exceedances associated with EPA toxicity benchmarks.

Geographic information about farmland in California was obtained from three sources: the California Department of Conservation, the California Department of Water Resources, and the California Department of Forestry and Fire Protection's Fire and Resource Assessment Program (FRAP). All of these data bases include information about the locations of farmland and various types of land cover, and were merged to create an integrated database covering all of California. (ICF 2011).

These daily values were aggregated to calculate exposure estimates over various averaging periods. These concentration estimates were evaluated in several occupational and residential exposure scenarios, then compared to a concentration benchmark identified by either the US EPA or a Cal-EPA agency (CDPR or OEHHA). Schools with MeBr concentrations above an established benchmark were described as having an “exceedances” for that exposure period. For purposes of this exposure analysis, schools with MeBr exposures above a threshold in an occupational or residential exposure scenario were described as “affected.”

After reviewing the number of predicted exceedances of occupational and residential exposure concentration benchmarks of interest, EPA- OCR determined that a disparity analysis was warranted.<sup>14</sup> Once all of the MeBr concentration data and the ethnicity of the student population for all 8,000 schools was collected, it was noted that due to the location of the schools and their populations being mostly minority (Hispanic), the probability of a Hispanic student being affected was higher than that of a non-Hispanic student by a factor of 18.3 to 1.<sup>15</sup> For every 1 non-minority student affected, 18.3 Hispanic students were affected in the areas of study.

Furthermore, OCR determined that a disparity existed for the Hispanic populations in the areas of study, and that the fumigant methyl-bromide was the contributing factor. Therefore, the spray-drift/fumigation exposure team that I served on for this project was tasked to utilize the study data and input from the USDA, FDA, OEJ and OEJ/IWG. Then to design and implement fumigant modeling and spray drift calculations and language addressing potential environmental justice issues with the goal of drafting a revised Occupational and Residential Exposure Risk Assessment Template protecting agricultural and industrial port-based communities.

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<sup>14</sup> Cal-EPA/CDPR. (2010). Methyl Bromide Regulation Risk Management Decision. Department of Pesticide Regulation.

<sup>15</sup> Cohen, J., Rosenbaum, A., & Carr, E. (2011). Model Development for Assessing California Methyl Bromide Ambient Concentrations. Draft report prepared by ICF International. EPA Office of Civil Rights, Washington DC

## CHAPTER 2 – FIELD EXPERIENCE AND CAPSTONE PROJECT

### ACTIVITIES

During the summer of 2015, I worked mainly with two agency offices within the EPA: the OEJ/IWG and the OCSPP. Within OCSPP, I worked with OPP as well. Furthermore, while working within the EPA, I worked jointly with the USDA and the FDA to analyze field trial data generated by their pesticide volatilization studies, while examining worker protection standards and food law concerning packaging and cold food chain transportation. The underlying goal was to help update the 2012 occupational and residential risk assessment template that was deemed outdated by the Occupational and Residential Advisory Panel due to the newly submitted Title VI studies concerning the use patterns of MeBr in predominately minority (Hispanic) communities. Revisions included instituting new calculation methods as well as updating exposure profiles (residential and occupational) and existing data sets (body weight, fumigation unit exposures, and transfer coefficients) to align with updated exposure protocols designed by Science Advisory Panel (SAP). My work with OEJ/IWG centered on helping to create and implement into the new exposure assessment template, language that incorporated environmental justice concerns for communities located in and around high pesticide (fumigation exposure via spray drift) usage areas such as agricultural fields, commodity packaging facilities and shipping ports/harbors.

In May of 2015, discussions concerning the fumigant exposure section began. Shortly thereafter, our task group designed an Occupational and Residential Exposure (ORE) Roadmap. This roadmap would eventually lead to the current ORE risk assessment used for exposure assessment and characterization.

#### Field Experience Risk Assessment Roadmap:

- 2.1 Occupational Handler.
- 2.2 Occupational Post-Application.
- 2.3 Residential Handler.
- 2.4 Residential Post-Application.
- 2.5 Environmental Justice Spray Drift /Fumigation.

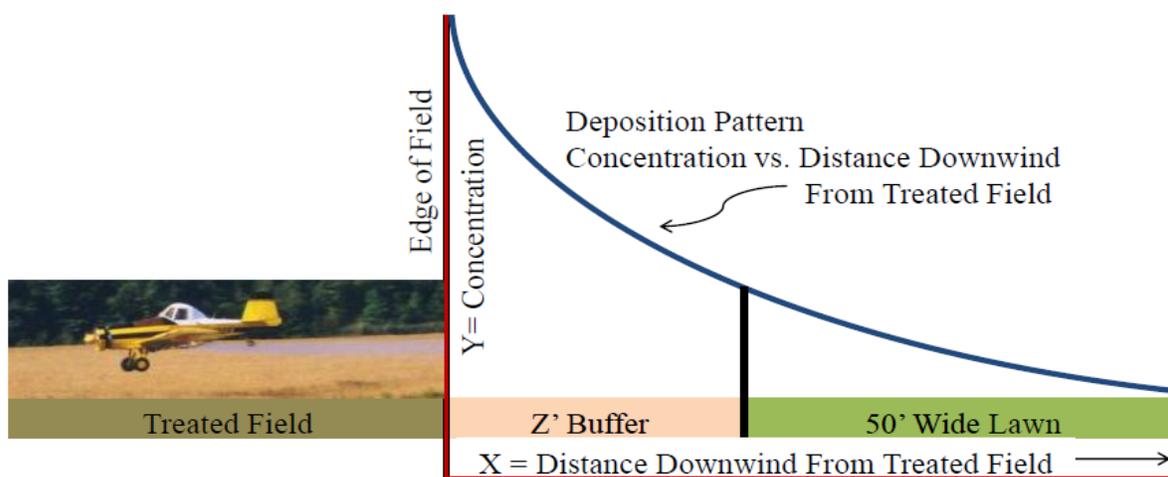
In order to satisfy the spray drift/fumigation criteria of the roadmap (2.5), which lead to the revised boilerplate spray drift and fumigation language inserted into the revised occupational and residential risk assessment, our task group had to develop an understanding of spray drift, its related exposure situations (bystander) and the environmental justice risk dynamics. Information gathered below for the Residential Exposure Assessment Standard Operating Procedures

"Consideration of Spray Drift" <sup>16</sup> served as the starting point for our task force to not only help finish this SOP, but to use this information to help design risk assessment language used for the new occupational and residential exposure risk assessment template.

Preventing all possible spray drift exposure is not possible. Foliar (leaf), and direct fruit applications of sprays are prevalent in many geographical areas and are used for many agricultural crops such as fruit trees. Therefore, the goal was to accumulate enough data from actual on farm exposure scenarios and apply practical science to monitor this activity smartly. Currently, there is a great deal of effort focused within the agricultural engineering and scientific communities to combine safety measures to reduce acute spray drift exposure with the understanding that these application methods are needed within the industry.

Currently, the EPA-OPP, by utilizing different models (SOFEA, Ag DRIFT, and PERFUM)<sup>17</sup> combined with data stemming from newly studied techniques previously designed to evaluate residential turf uses of pesticides, has developed a practical scientific based methodology for estimating potential risks from spray drift. The amount of pesticide residue from an aerial application that accumulates from a drift scenario varies according to the distance from the edge of a treated field to the drift area such as a home or school "lawn". The overall approach taken from the EPA SOP is illustrated below in (Fig. 4). The term "buffer" appears in this example as a 50 feet wide area between the treated field and a home or school "lawn". These "buffers" are explained in more detail below.

(FIG. 4) Spray Drift Profile.



<sup>16</sup> EPA. "SOPs for residential and occupational exposures." (March 2015).

<http://www.epa.gov/pesticides/science/residential-exposure-sop.html>

<sup>17</sup> EPA. "Pesticide Models." (Last updated October 14, 2015).

[http://www.epa.gov/pesticides/science/models\\_db.htm](http://www.epa.gov/pesticides/science/models_db.htm)

Spray drift levels/profiles can be directly impacted by many factors including application equipment<sup>18</sup> (airplane, helicopter, airblast or groundboom) which directly depends on the crop being treated, environmental conditions (wind direction and speed, fog, weather patterns such as rain or temperature and atmospheric stability), and site characteristics (big open field or small field surrounded by homes). For instance, the higher the wind speed the more drift which occurs based on total mass of pesticide moving off-target but changes in wind direction can lower total drift estimates in a specific area downwind because less mass is moving away from a treatment area in one direction. The characteristics of an application site also have relevance. Flat terrain in some ways can cause more drift especially if it has a low surface roughness (i.e., essentially the contour of the area that may be bare soil or field stubble) which impacts how much drift can be trapped as spray plumes move across such areas. Exposures considered for risk assessment purposes occur solely as a result of contact with a surface that has been previously impacted by spray drift such as nearby lawns.

The spray drift task force that I was part of was asked to construct the spray drift boilerplate language and develop the exposure calculations used for the 2015 revised assessment template. See Chapter 2 section 2.5 for details.

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<sup>18</sup> Ministry of Agriculture. “Pesticide Wise.” (Last updated March 18, 2014).  
<http://www.agf.gov.bc.ca/pesticides/>

## REFLECTION

The underlining goal of my field experience program was to work with the EPA, OCSPP, USDA, FDA, OEJ, and the OEJ/IWG to help refine the current occupational and residential risk assessment template. My interaction with these agencies allowed me to analyze, then incorporate new (occupational, residential and fumigation) exposure data. Furthermore, I helped create and implement into the exposure assessment template, language that incorporated environmental justice concerns for communities located in and around high pesticide usage areas such as agricultural fields, commodity packaging facilities and shipping ports/harbors. Through multiple inter-agency FDA meetings, Science Advisory Panel meetings and reviewing multiple studies generated by the FDA, I was able to better understand the role that the FDA plays concerning food and worker safety. Furthermore, I was able to review studies that were directly related to fumigation off-gassing rates which would eventually assist in understanding how to approach fumigation exposure calculations.

My time with the USDA was imperative in that I learned about food pesticide tolerances, food packaging laws, transportation and food chain laws that ensure the safe "field to market" process, and the worker safety protocols especially as fumigants are applied to commodities that are internationally sold and transported. Furthermore, my meetings concerning the fumigant Phosphine and MeBr were extensive and helped me to understand the dynamics of fumigation application techniques, worker safety scenarios and the types of applications that fumigants are used for. My rotation with the OEJ and OEJ/IWG helped me understand the legal aspect of mitigation. While being tasked to formulate language concerning spray drift, analyzing the Title VI complaint and the field studies that accompanied this action, I was able to better understand how to craft language that is protective of not only the individuals involved directly (workers and bystanders), but also for the companies or registrants that produce these products. All in all, my rotation through these agencies consisted of meetings, crop tours to better understand fumigation techniques, congressional briefings concerning that Title VI stakeholder expectations and the field study analysis workshops that helped me to better understand international transportation expectations concerning fumigation protocols proved very valuable.

This experience provided me with the opportunity to further understand and apply the knowledge and skills learned during my time in the MPH Program at Kansas State University. My experience involved mining data in areas such as; epidemiology, pesticide food tolerances, occupational and residential exposure, fumigant bystander exposure and environmental law with the task of bridging these different aspects into an inter-agency pesticide risk assessment. By understanding multiple scientific languages combined with bio-statistics, epidemiology, food law, and many other aspects taught in the MPH program, I was able to navigate the process along with my other task force workmates. Environmental health and epidemiology risk concepts really helped in dealing with the USDA, EPA, and FDA. Bio-statistics was the main tool used in

the studies I reviewed, especially the OEJ spray drift study as it dealt with risk populations and pesticide exposure. Having an understanding of food laws and global trade issues was particularly helpful while dealing with fumigations (gas applied to food) in ship hulls coming from other countries to control mold and burrowing pests. Lastly, the food science/chemistry was beneficial in dealing with the FDA in setting pesticide food tolerances. This experience greatly enhanced my education dealing with multiple government health agency dynamics, protocols, territory responsibilities, and overall public health role. I am grateful to all of the people and agencies that allowed me to participate in this policy making forum.

## CAPSTONE PROJECT

In June of 2015, the EPA decided to update their occupational and residential handler and post-application risk assessments, while incorporating fumigant and spray drift calculation methods and language to address the findings of the Angelita C. complaint filed through the OEJ. The revised occupational and residential exposure template was constructed through the collaborative efforts of the EPA, OCSPP, USDA, FDA, OEJ and EJ/IWG. The following changes were designed with the help of the inter-agency group task force that I was proud to be part of.

### 2.1 OCCUPATIONAL HANDLER

The occupational handler segment of the revised risk assessment takes into consideration new data and worker activity updates, especially with new “fumigant” research and application techniques for emerging fumigation market needs. A series of inputs based on the exposure type (crop, building -then- activity, equipment, time and protection equipment) are detailed below for an exposure assessment overview for the purpose of calculating risk.

- ✚ Handlers: professional applicators who may be exposed while mixing, loading, and/or applying pesticide products to crops, lawns, or indoors.

(FIG. 5) Occupational Handler: Row Crop and Orchard Exposure



Groundboom Application (Row Crops)



Airblast Application (Orchards)



Handheld Equipment (Row Crops)



Chemigation



Aerial

(FIG. 6) Occupational Handler: Fumigation exposure



Residential Areas



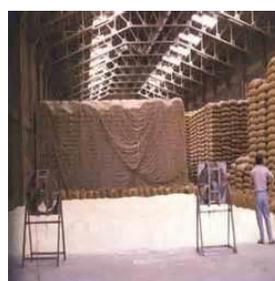
Imported and Exported



Cargo Ship Hulls (a)



Soil Fumigation



Inside Ship Hull (b)

(FIG. 7) Occupational Handler: PPE Examples



Gloves/ Dust/Mist or OV respirators



Coveralls or Closed Systems

### Occupational Handler Inputs

*Three major inputs* were included in the occupational handler algorithm calculations.

- 1) Application rates [pesticide company labels (lbs active ingredient/Acre)],
- 2) Amount of area treated [values taken from data and surveys in (Acres)] which depends on the application technique you are using (airblast, ground equipment, aerial...), and
- 3) Unit Exposures (mg/lbs ai or ug/lb ai): Depends on the formulation of the pesticide (solid or liquid) and PPE worn.

From these inputs, the Occupational Handler exposure and dose can be calculated as follows.

Occupational Handler Algorithms: (see Appendix A for complete details)<sup>19</sup>

- Exposure (mg/day) = Application Rate x Area Treated x Unit Exposure.
- Dose (mg/kg/day) = (Exposure x % inhalation or dermal absorption) / (body weight)

From the dose calculation, the Margin of Exposure (MOE) can be calculated as follows:

- MOE (unit-less) = Point of Departure (PoD – mg/kg/day) / Dose (mg/kg/day)

For the risk conclusion, the MOE is either  $\geq$  or  $\leq$  the Level of concern (LOC)

- The appropriate PoD and LOC information comes from the chemical toxicologist. The exposure duration of the assessed scenario should be compared to and paired with the appropriately matched PoD. See Table 3 for details.

Exposure Scenario	Dose Used in Risk Assessment, UF <sup>1</sup>	FQPA SF and Level of Concern (LOC) for Risk Assessment	Study and Toxicological Effects
Short-Term (1-30 days) and Intermediate-Term Dermal (1 – 6 months) (Occupational)	PoD - NOAEL= 40 mg/kg/day (Dermal absorption rate = 3.0 %) UF <sub>A</sub> = 10X UF <sub>H</sub> = 10X	<b>LOC for MOE = 100</b> (Occupational/Residential)	Prenatal Developmental Toxicity - rabbit  LOAEL = 200 mg/kg/day based on increased mortality, abortions, and decreased maternal body weight gain.
Short-Term (1-30 days) and Intermediate-Term Inhalation (1 - 6 months) (Occupational)	Oral Maternal PoD - NOAEL= 40 mg/kg/day (Inhalation absorption rate = 100%) UF <sub>A</sub> = 10X UF <sub>H</sub> = 10X	<b>LOC for MOE = 100</b> (Occupational/Residential)	Prenatal Developmental Toxicity - rabbit  LOAEL = 200 mg/kg/day based on increased mortality, abortions, and decreased maternal body weight gain.
Incidental Oral Short (1-30 days)- and Intermediate (1-6 months)-Term	(PoD) - NOAEL = 80 mg/kg/day  UF <sub>A</sub> = 10X UF <sub>H</sub> = 10X FQPA SF = 1X	<b>LOC for MOE = 100</b> (Residential)	90-Day oral toxicity – dog.  LOAEL = 400 mg/kg/day based on moderate cortical areas of dilated basophilic tubules in the kidneys and decreased potassium levels.

**Point of Departure (POD)** = A data point or an estimated point that is derived from observed dose-response data and used to mark the beginning of extrapolation to determine risk associated with lower environmentally relevant human exposures. **NOAEL** = no observed adverse effect level. **LOAEL** = lowest observed adverse effect level. **UF** = uncertainty factor. **UF<sub>A</sub>** = extrapolation from animal to human (interspecies). **UF<sub>H</sub>** = potential variation in sensitivity among members of the human population (intra-species). **FQPA SF** = FQPA Safety Factor. **Rfd** = reference dose. **MOE** = margin of exposure. **LOC** = level of concern. **N/A** = not applicable.

<sup>19</sup> EPA. “SOPs for residential and occupational exposures.” (March 2015). <http://www.epa.gov/pesticides/science/residential-exposure-sop.html#sops>

## Occupational Handler Risk Characterization

If the  $MOE \geq LOC$

- “The risk does not exceed HED’s Level of Concern”
- Characterize as based on max label rate and standard assumptions

If the  $MOE < LOC$

- “The risk exceeds HED’s Level of Concern”
- Further risk mitigation and/or characterization may be necessary

### *Risk Mitigation Options:*

- Require gloves or other additional PPE to the standard single layer clothing PPE for these scenarios.
- Lower the application rate
- Limiting the number of acres treated in a day or amount mixed in a day is not a viable/enforceable mitigation option

## 2.2 OCCUPATIONAL POST-APPLICATION

✚ Post-application: professionals who enter previously treated fields, buildings or ship hulls to harvest crops, clean up home, or to load packages commodities that have been previously treated with a pesticide product. Included in the handler post-application algorithm calculations were dislodgeable fraction of residues (DFRs), transferrable residue, transfer coefficients (TCs), time doing the task.

- Exposure varies by type of crop/Agricultural or Commercial/Fumigant and activity being performed.
- Example: Picking, pruning, thinning, and packing strawberries versus grapes and port or commercial fumigations. All different activities and crops have different DFR and TC values.

(FIG. 8) Occupational Post-Application Exposure



Agricultural worker post-application exposure



Commercial (hired worker) post-application exposure

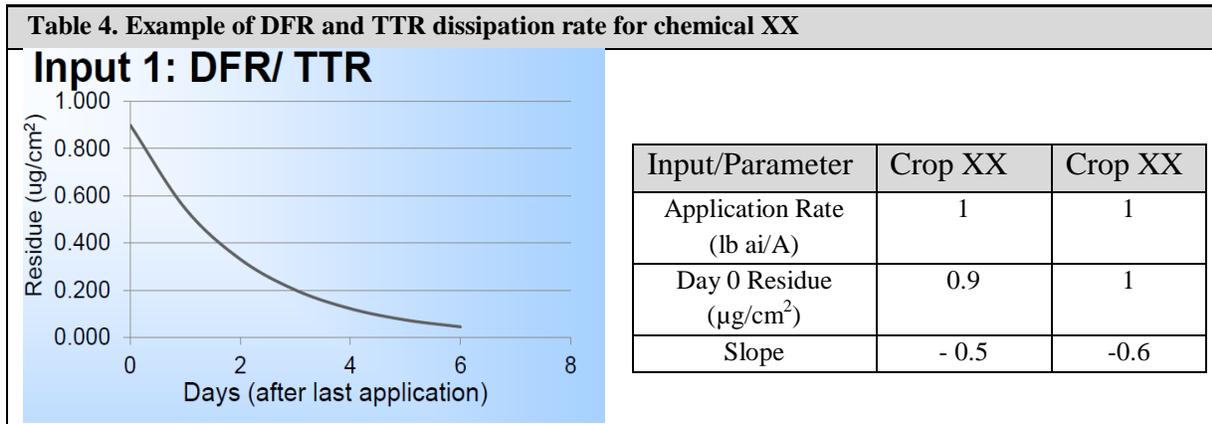


## Occupational Post-Application Inputs

*Four major inputs* were included in the occupational post-application algorithm calculations.

- 1) Dislodgeable Foliar Residue (DFR) or Turf Transferable Residue (TTR):  
Residue on foliage that is available to transfer onto a worker during post-application activity.
  - DFR/TTR ( $\mu\text{g}/\text{cm}^2$ ) is chemical-specific:
    - DFR/TTRs must be generated for each chemical
    - Default values are used when **non** chemical-specific data are available
    - Use the value that represents the day individuals are expected to be in the treated area.
  - Default inputs (non-chemical specific):
    - DFR: 20% of the initial application rate (retained on foliage)
    - TTR: 5% of the initial application rate (retained on treated turf)
    - Dissipation per day: 10%

(FIG. 9) DFR and TTR Dissipation



- 2) Transfer coefficient (TC) ( $\text{cm}^2/\text{hr}$ ).
  - Not chemical-specific
  - Depends on the specific activities and types/growth stage (see above).
  - Example: hand weeding for sugarcane and tree fruit (TC = 70) and (TC = 100) Respectively. “Measure of contact with foliage while performing a specific activity”.
- 3) Exposure Duration (hours/day)
  - 8 hours assumed worked per day for post-application activities
- 4) Inputs:
  - Crop or Commercial Post-Application Activities.

### Occupational Post-Application Algorithms: (see Appendix A for complete details)<sup>20</sup>

- Exposure (mg/day) = DFR or TTR ( $\mu\text{g}/\text{cm}^2$ ) x TC ( $\text{cm}^2/\text{hr}$ ) x Est. Time Duration (hrs./day)
- Dose (mg/kg/day) = (Exposure x % inhalation or dermal absorption) / (body weight)

From the dose calculation, the Margin of Exposure (MOE) can be calculated as follows:

- MOE (unit-less) = Point of Departure (PoD – mg/kg/day) / Dose (mg/kg/day)

For the risk conclusion, the MOE is either  $\geq$  or  $\leq$  the Level of concern (LOC)

### Occupational Post-Application Risk Characterization

- See handler risk characterization section above for details.

#### *Risk Mitigation Options:*

Extend the Re-Entry time interval (time as to which the workers can re-enter the fields or commercial structure) or the Pre-Harvest Interval (time before harvesting activities). These intervals are based on the Worker Protective Standards guidelines (40 CFR 156.208).

#### *Occupational Post-Application Summary:*

Inputs that are entered into the occupational and post-application algorithms are acquired from the pesticide label produced by the registrant (company) desiring to market their product. These input descriptions typically include:

- Are there occupational (professional) uses?  
Applications to crops, lawns, or indoor areas (commercial buildings, residential houses, ship hulls).
- What formulations? (liquid, wettable powder, etc)
- What crops are being assessed?
- Maximum application rate?
- What personal protective equipment (PPE) is required?
- What applications methods/equipment? (Groundboom, Aerial, Chemigation, Handheld, Airblast, or Fumigation)

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<sup>20</sup> EPA. "SOPs for residential and occupational exposures." (March 2015).  
<http://www.epa.gov/pesticides/science/residential-exposure-sop.html#sops>

## 2.3 RESIDENTIAL HANDLER

The residential handler (home owner) segment of the revised risk assessment takes into consideration new residential data updates, especially with new “bed bug” and “fumigant/mosquito/insect repellent” research/application techniques for emerging residential fumigation market needs. A series of inputs based on the exposure type (outdoor or indoor exposure, activity and equipment) are detailed below for a residential exposure assessment overview for the purpose of calculating risk. The risk calculations in section II (residential) are centered on two types of exposure scenarios; residential handlers and post-application:

- ✚ Handlers: homeowner/consumer applicators who may be exposed while mixing, loading, and/or applying pesticide products (non-job related) indoors or outdoors. For residential handler exposure assessments, it is assumed that residents will be wearing shorts, short-sleeved shirts, shoes and socks.

(FIG. 10) Residential Handler Exposure



*Residential Lawn/Turf applications*



*Garden applications*



*Indoor pesticide applications*



*Insect repellent*



*Standard repellent*

### Residential Handler Inputs

*Three major inputs* were included in the residential handler algorithm calculations.

- 1) Application rates [pesticide company labels (lbs. active ingredient/ft<sup>2</sup> or gallon)],
- 2) Amount of area treated [based on the label instructions or default assumptions (e.g., ft<sup>2</sup>/day or gal/day)], and
- 3) Unit Exposures (mg/lbs ai or ug/lb ai): Depends on the formulation of the pesticide (solid or liquid). They can be dermal or inhalation unit exposures.

## Residential Handler Algorithms<sup>21</sup>

The residential algorithms are the same as the occupational section (*see occupational section above or Appendix B*), however they will have different inputs which are specific to residential products.

### Residential Handler Risk Characterization

The residential risk characterization is the same as the occupational, (*see occupational section above for details or Appendix B*), however they will have different inputs which are specific to residential products.

#### *Residential Handler Summary:*

- No tiered approach for PPE in residential handler risk assessments.
- Residential handler assessments are based on the assumption that individuals are wearing shorts, short-sleeved shirts, socks, and shoes.
- Residential handlers are expected to complete all tasks associated with the use of a pesticide product including mixing/loading if needed as well as the application.

## 2.4 RESIDENTIAL POST-APPLICATION

- ✚ Post-application: Exposures that occur after applications in residential settings (e.g., homes, parks, schools, athletic fields, hotels, and others). Adults (i.e., individuals above 18 years of age) and Children (i.e., sentinel populations) are assessed. They also include adult and child (different ages) populations which include a different set of behavior/exposure activities not assessed in occupational or adult scenarios.

(FIG. 11) Residential Post-Application Exposure



Mowing the yard/  
Trimming bushes



Swimming



Gardening



Playing in the yard

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<sup>21</sup> EPA. "SOPs for residential and occupational exposures." (March 2015).  
<http://www.epa.gov/pesticides/science/residential-exposure-sop.html#sops>



*Playing with treated Pets    Playing on treated carpet*

**(FIG. 12) Sentinel Populations Examples**



**Sentinel Population Characteristics**

- Young children (1 < 2 years old) tend to be less mobile which could lead to lower dermal exposures but they tend to exhibit higher rates of mouthing behaviors, which could enhance their overall body burden compared to older children.
- Older children (3+ years) are more mobile, which could increase dermal exposures, but mouthing behaviors tend to be reduced in children of this age

**Major Exposure Scenarios (Incidental Oral)**

- Dermal Exposure
- Inhalation Exposure
- Non-dietary Ingestion Exposure (child only)
- Hand to Mouth (child only)
- Object to Mouth (child only)
- Incidental Soil Ingestion (child only)
- Episodic Granular Ingestion (child only)
- Dust Ingestion

**(FIG. 13) Residential Incidental Oral Exposure**



Non-Dietary Ingestion



Hand to Mouth on Treated Carpet



Dermal Exposure



Object to Mouth on Treated Grass or Carpet

Residential Post-Application Algorithms: (see Appendix B for complete details)<sup>22</sup>

The residential post-application algorithms are the same as the occupational post-application section (see *occupational post-application section above or Appendix A*), however they will have different inputs for child specific behavior (incidental oral) and inhalation exposure which are specific to residential post-application activities. Indoor/outdoor residential dwellings will have different inputs as listed below.

Residential Inhalation Post-Application Exposure inputs:

<b>Table 5. Residential Inhalation Exposure</b>	
Air concentration (C)	Initial concentration and saturation concentration are based on application rate or molecular weight and vapor pressure of the active ingredient (ai).
Inhalation rate (IR)	Arithmetic means based on EFH
Air changes per hour (ACH)	Low end of the range for both indoor and outdoor (more protective).
Air velocity (AV)	Minimum value based on published literature (more protective)
Volume of treated space (V)	Average room or deck size.
Exposure Time (ET)	Arithmetic means for time spent in EFH or best available data.

Residential Non-Dietary Ingestion “incidental oral” Post-Application Exposure inputs:

The non-dietary ingestion exposure is limited to children playing on previously treated are areas

- Hand to Mouth
- Object to Mouth
- Soil Ingestion

<b>Table 6. Residential Non-Dietary Ingestion “Incidental Oral” Exposure</b>	
Surface area of one hand (SAH)	Arithmetic mean.
Saliva extraction factor (SE)	Arithmetic mean.
Fraction of ai on hands (Fai hands)	Average residues from scenario specific studies.
Fraction mouthed (FM)	Arithmetic mean.
Exposure Time (ET)	Arithmetic means for time spent in EFH.
Replenishment Intervals per Hour (N_Replen)	Conservative assumptions based on SHEDS model.
Hand-to-Mouth events per hour (Freq_Replen)	Arithmetic mean.

*Risk Mitigation options:*

- Restrict application rate or prohibit use

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<sup>22</sup> EPA. “SOPs for residential and occupational exposures.” (March 2015). <http://www.epa.gov/pesticides/science/residential-exposure-sop.html#sops>

*Residential Post-Application Summary:*

- In order to calculate residential post-application exposure, exposure activity and age designations need to be distinguished.

## 2.5 ENVIRONMENTAL JUSTICE SPRAY DRIFT/FUMIGATION

### Background

As noted in Chapter 1, administrative complaint number 16R-99-R9 (hereafter referred to as the Angelita C. complaint) was filed in June 1999 on behalf of children and parents who attend six California public schools with a high percentage of Hispanic students. Our task was to analyze the data from the field spray drift study, then construct calculation methods and language that could characterize any and all potential risk due to spray drift. Implemented into the 2015 occupational and residential risk assessment template was language generated in a memorandum titled: Standard Operating Procedures "Consideration of Spray Drift."<sup>23</sup> Spray drift considerations, exposure considerations and calculations addressed in this document were used in the revised template. However, calculations were refined to consider revised unit exposures, worker exposure transfer coefficients, application rates, and body weight changes.

### Spray Drift Exposure Considerations

"Estimated exposures from spray drift are based on the idea that residential areas/neighborhoods, or other public areas routinely accessible/visited to or by the general population such as parks, are near where a pesticide application may occur. Exposures may occur in a variety of ways but for regulatory purposes, as noted above, we focused on compliant application events. In compliant application events no individual should be directly sprayed, given existing product label language and requirements for worker protection, which means direct dermal and inhalation exposures to sprays will not be considered. Exposures considered for risk assessment purposes occur solely as a result of contact with a surface that has been previously impacted by spray drift such as nearby lawns."<sup>24</sup>

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<sup>23, 24</sup> EPA. "SOPs for residential and occupational exposures." (March 2015).  
<http://www.epa.gov/pesticides/science/residential-exposure-sop.html#sops>

## Spray Drift Exposure Scenario Specifics

Deciding which scenarios need to be included in a quantitative spray drift risk assessment is highly dependent upon the details provided on the product label, the pests being controlled, the timing of application, the application equipment used, and whether the pesticide acts in a systemic manner or if it works via contact. Some pesticide labels provide detailed information that describes how spray equipment should be configured for applying the specific product.

Exposure questions taken from pesticide labels that help characterize the use are as follows;

- What crop(s)/pest(s) are treated with the pesticide?
- Pesticide formulation: solid or liquid?
- What types of equipment is used in the application of the pesticide?
- Are applications soil-directed or foliar?
- Do product labels contain specific language related to application parameters such as spray quality (e.g., types of nozzles to be used or the size of droplets that are allowable)?
- Outstanding data?

## Spray Drift Calculation Methods

Initial spray drift calculations are based on the use of the AgDrift model in situations where specific product label application information is not provided. This practice is used as a default method that is later revised when specific data is supplied. The AgDrift model is appropriate for use only when applications are made by aircraft, airblast orchard sprayers, and groundboom sprayers (see Fig 5). The AgDrift model screening options that help calculate specific exposure scenarios include.

- **Groundboom applications** are based on high boom height, very fine to fine spray type using the 90th percentile results.
- **Orchard Airblast applications** for Sparse (Young/Dormant) tree canopies.
- **Aerial applications** are based on aerial option for a fine to medium spray type

## Spray Drift Assessment Language

The new EPA occupational and residential template states,

"Off-target movement of pesticides can occur via many types of pathways and it is governed by a variety of factors. Sprays that are released and do not deposit in the application area end up off-target and can lead to exposures to those it may directly contact. They can also deposit on surfaces where contact with residues can eventually lead to indirect exposures (e.g., children playing on lawns where residues have deposited

next to treated fields). The potential risk estimates from these residues can be calculated using drift modeling onto 50 feet wide lawns coupled with methods employed for residential risk assessments for turf products. The approach to be used for quantitatively incorporating spray drift into risk assessment is based on a premise of compliant applications which, by definition, should not result in direct exposures to individuals because of existing label language and other regulatory requirements intended to prevent them.<sup>25</sup> Direct exposures would include inhalation of the spray plume or being sprayed directly. Rather, the exposures addressed here are thought to occur indirectly through contact with impacted areas, such as residential lawns, when compliant applications are conducted. Given this premise, exposures for children (1 to 2 years old) and adults who have contact with turf where residues are assumed to have deposited via spray drift thus resulting in an indirect exposure are the focus of this analysis analogous to how exposures to turf products are considered in risk assessment."<sup>26</sup>

### Spray Drift Summary

Our task was to analyze the data from the field spray drift study, then construct parameter inputs followed by instituting calculation methods which we accomplished by using the AgDrift model. Furthermore, risk assessment template language was constructed and inserted as a legal notification stating that spray drift occurs and the proper steps have been designed to assess the exposure and characterize potential spray drift risks.

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<sup>25</sup> This approach is consistent with the requirements of the EPA's Worker Protection Standard.

<sup>26</sup> EPA. "SOPs for residential and occupational exposures," March 2015, <http://www.epa.gov/pesticides/science/residential-exposure-sop.html#sops>

## RESULTS

In August of 2015, EPA's Health Effects Division (HED) implemented a revised occupational and residential exposure risk assessment that incorporated the newest data generated from field studies capturing occupational, residential and fumigant spray drift exposure scenarios. This exposure template is to be used while conducting pesticide exposure risk assessments. Through my Field Experience Project, I was able to participate in working with a multiple agency task force with the goal of producing a living document that encompasses the dynamics of these agencies concerning pesticide exposure risk analysis and characterization.

My Capstone Project was to assist in revising the 2009 Occupational and Residential Exposure Assessment by incorporating spray drift and fumigation language legally backed by the OEJ/IWG and the EPA OCR. Secondly, the task group that I worked with was tasked to revise all calculations pertaining to fumigation and standard pesticide exposure scenarios and to formalize the calculation of spray drift exposure using updated study data provided indirectly by the Title VI complaint. In September of 2015, OPP introduced a new revised risk assessment template.

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## APPENDIX A

### (OCCUPATIONAL ALGORITHMS)

#### Occupational Non-cancer Handler Algorithms

Potential daily exposures for occupational handlers are calculated using the following formulas:

$$E = UE * AR * A * 0.001 \text{ mg/ug}$$

where:

- E = exposure (mg ai/day),
- UE = unit exposure ( $\mu\text{g ai/lb ai}$ ),
- AR = maximum application rate according to proposed label (lb ai A or lb ai/gal), and
- A = area treated or amount handled (e.g., A/day, gal/day).

The daily doses are calculated using the following formula:

$$ADD = \frac{E * AF}{BW}$$

where:

- ADD = average daily dose absorbed in a given scenario (mg ai/kg/day),
- E = exposure (mg ai/day),
- AF = absorption factor (dermal and/or inhalation), and
- BW = body weight (kg).

*Margin of Exposure:* Non-cancer risk estimates for each application handler scenario are calculated using a Margin of Exposure (MOE), which is a ratio of the toxicological endpoint to the daily dose of concern. The daily dermal and inhalation dose received by occupational handlers are compared to the appropriate POD (i.e., NOAEL) to assess the risk to occupational handlers for each exposure route. All MOE values are calculated using the following formula:

$$MOE = \frac{POD}{ADD}$$

where:

- MOE = margin of exposure: value used by HED to represent risk estimates (unitless),
- POD = point of departure (mg/kg/day), and
- ADD = average daily dose absorbed in a given scenario (mg ai/kg/day).

## Occupational Non-cancer Post-application Algorithms

Potential daily exposures for occupational post-application workers are calculated using the following formulas:

$$DFR_t = AR * F * (1-D)^t * \left(4.54E8 \frac{ug}{lb}\right) * \left(2.47E-8 \frac{A}{cm^2}\right)$$

where:

- DFR<sub>t</sub> = dislodgeable foliage residue on day "t" (µg/cm<sup>2</sup>),
- AR = application rate (lb ai/acre),
- F = fraction of ai retained on foliage or 25% (unitless),
- D = fraction of residue that dissipates daily or 10% (unitless), and
- t = number of days after application day (days).

$$E = TC * DFR_t * ET * 0.001 \frac{mg}{ug}$$

where:

- E = exposure (mg ai/day),
- TC = transfer coefficient (cm<sup>2</sup>/hr),
- DFR<sub>t</sub> = dislodgeable foliar residue on day "t" (µg/cm<sup>2</sup>), and
- ET = exposure time (hours/day).

The daily doses are calculated using the following formula:

$$ADD = \frac{E * AF}{BW}$$

where:

- ADD = average daily dose absorbed in a given scenario (mg ai/kg/day),
- E = exposure (mg ai/day),
- AF = absorption factor (dermal and/or inhalation), and
- BW = body weight (kg).

*Margin of Exposure:* Non-cancer risk estimates for each scenario are calculated using a Margin of Exposure (MOE), which is a ratio of the toxicological endpoint to the daily dose of concern. The daily dermal dose received by occupational post-application workers is compared to the appropriate POD (i.e., NOAEL) to assess the risk to occupational post-application workers. All MOE values are calculated using the following formula:

$$MOE = \frac{POD}{ADD}$$

where:

- MOE = margin of exposure: value used by HED to represent risk estimates (unitless),
- POD = point of departure (mg/kg/day), and
- ADD = average daily dose absorbed in a given scenario (mg ai/kg/day).

**APPENDIX B**  
**(RESIDENTIAL ALGORITHMS)**

Dermal and Inhalation Handler Exposure Algorithm

Daily dermal and inhalation exposure (mg/day) for residential pesticide handlers, for a given formulation-application method combination, is estimated by multiplying the formulation-application method-specific unit exposure by an estimate of the amount of active ingredient handled in a day, using the equation below:

$$E = UE * AR * A$$

where:

- E = exposure (mg/day);
- UE = unit exposure (mg/lb ai);
- AR = application rate (e.g., lb ai/ft<sup>2</sup>, lb ai/gal); and
- A = area treated or amount handled (e.g., ft<sup>2</sup>/day, gal/day).

**Treated Pets**

Dermal and Inhalation Handler Exposure Algorithm

Daily dermal and inhalation exposure (mg/day) for residential pesticide handlers, for a given formulation-application method combination, is estimated by multiplying the formulation-application method-specific unit exposure by an estimate of the amount of active ingredient handled in a day, using the equation below:

$$E = UE * AR * A$$

where:

- E = exposure (mg/day);
- UE = unit exposure (mg/lb ai);
- AR = application rate (e.g., lb ai/ft<sup>2</sup>, lb ai/gal); and
- A = number of animals treated per day.

## Outdoor Fogging/Misting Systems

### Dermal and Inhalation Handler Exposure Algorithm

Daily dermal and inhalation exposure (mg/day) for residential pesticide handlers is estimated by multiplying a unit exposure appropriate for the formulation and application method by an estimate of the amount of active ingredient handled in a day using the equation below:

$$E = UE * AR$$

where:

E = exposure (mg/day);  
UE = unit exposure (mg/lb ai); and  
AR = application rate (lb ai/day).

The application rate can be calculated as follows:

$$AR = A_{product} * A.I. * CF1 * N$$

where:

AR = application rate (lb ai/ day);  
 $A_{product}$  = amount of product in 1 can (oz or g/can);  
A.I. = percent active ingredient in product (% ai);  
CF1 = weight conversion factor (1 lb/16 oz or 1 lb/454 g); and  
N = number of cans used in one application (cans/day).

Alternatively, if the aerosol can contents are expressed as a volume in milliliters, the application rate for use in the exposure assessment can be calculated as follows:

$$AR = A_{product} * A.I. * CF1 * D_{product} * N$$

where:

AR = application rate (lb ai/ day);  
 $A_{product}$  = amount of product in 1 can (mL/can);  
A.I. = percent active ingredient in product (% ai);  
CF1 = weight conversion factor (1 lb/454 g);  
 $D_{product}$  = density of product (g/mL); and  
N = number of cans used in one day (cans/day).

## Insect Repellents

### Dermal and Inhalation Handler Exposure Algorithm

Daily dermal and inhalation exposure (mg/day) for residential pesticide handlers, for a given formulation-application method combination, is estimated by multiplying the formula-

application method-specific unit exposure by an estimate of the amount of active ingredient handled in a day, using the equation below:

$$E = UE * AR$$

where:

E = exposure (mg/day);  
UE = unit exposure (mg/lb ai);  
AR = application rate (e.g., lb ai/day)

The application rate can be calculated as follows:

$$AR = A.I * W * N$$

where:

AR = application rate per day (lb ai/ day);  
A.I. = % active ingredient in product (by weight);  
W = weight of product unit (e.g., 12 oz aerosol can)  
N = number of product units used per day (e.g. cans/day)

### **Residential Handler Dose Calculations**

Dermal and/or inhalation absorbed doses normalized to body weight are calculated as:

$$D = E * AF / BW$$

where:

D = dose (mg/kg-day);  
E = exposure (mg/day);  
AF = absorption factor (dermal and/or inhalation); and  
BW = body weight (kg).

### **Residential Post-application**

Turf/Physical Activities on Turf

#### Post-application Dermal Exposure Algorithm – Physical Activities on Turf

Exposure resulting from contacting previously treated turf while performing physical activities is calculated as shown below. Residential post-application exposure assessment must include calculation of exposure on the day of application. Therefore, though an assessment can present exposures for any day “t” following the application, it must include “day 0” exposure.

$$E = TTR_t * CF1 * TC * ET$$

where:

- E = exposure (mg/day);
- TTR<sub>t</sub> = turf transferable residue on day t (µg/cm<sup>2</sup>);
- CF1 = weight unit conversion factor (0.001 mg/µg);
- TC = transfer coefficient (cm<sup>2</sup>/hr); and
- ET = exposure time (hr/day).

If chemical-specific TTR data are available, then surface residues from the day of application should be used (assume that individuals could be exposed to residues immediately after application). However, if data are not available, then TTR<sub>t</sub> can be calculated using the following formula:

$$TTR_t = AR * F * (1-FD)_t * CF2 * CF3$$

where:

- TTR<sub>t</sub> = turf transferable residue on day t (µg/cm<sup>2</sup>);
- AR = application rate (lbs ai/ft<sup>2</sup> or lb ai/acre);
- F = fraction of ai as transferable residue following application (unitless);
- FD = fraction of residue that dissipates daily (unitless);
- t = post-application day on which exposure is being assessed;
- CF2 = weight unit conversion factor (4.54 x 10<sup>8</sup> µg/lb); and
- CF3 = area unit conversion factor (1.08 x 10<sup>-3</sup> ft<sup>2</sup>/cm<sup>2</sup> or 2.47 x 10<sup>-8</sup> acre/cm<sup>2</sup>).

Dermal absorbed doses are calculated as:

$$D = \frac{E * AF}{BW}$$

where:

- D = dose (mg/kg-day);
- E = exposure (mg/day);
- AF = absorption factor (dermal); and
- BW = body weight (kg).

Algorithm Notation	Exposure Factor (units)	Point Estimate(s)	
AR	Application rate (mass active ingredient per unit area)	<b>[input]</b>	
F	Fraction of AR as TTR following application (if chemical-specific data is unavailable)	L/WP/WDG	0.01
		Granules	0.002
F <sub>D</sub>	Daily residue dissipation (if chemical-specific data is unavailable) (fraction)	L/WP/WDG	0.1
		Granules	0.1

Table A-X: Turf (Physical Activities) -- Inputs for Residential Post-application Dermal Exposure				
Algorithm Notation	Exposure Factor (units)			Point Estimate(s)
TC	Transfer Coefficient (cm <sup>2</sup> /hr)	L/WP/WDG	Adults	180,000
			Children 1 < 2 years old	49,000
		Granules	Adults	200,000
			Children 1 < 2 years old	54,000
ET	Exposure Time (hours per day)	Adults	1.5	
		Children 1 < 2 years old	1.5	
BW	Body Weight (kg)	Adults	80	
		Children 1 < 2 years old	11	
L/WP/WDG = Liquids/Wettable Powders/Water-dispersible Granules				

### Post-application Hand-to-Mouth Exposure Algorithm– Physical Activities on Turf

Exposure from hand-to-mouth activity is calculated as follows (based on the algorithm utilized in the SHEDS-Multimedia model):

$$E = [HR * (F_M * SA_H) * (ET * N\_Replen) * (1 - (1 - SE)^{(Freq\_HtM/N\_Replen)})]$$

where:

- E = exposure (mg/day);
- HR = hand residue loading (mg/cm<sup>2</sup>);
- FM = fraction hand surface area mouthed / event (fraction/event);
- SAH = typical surface area of one hand (cm<sup>2</sup>);
- ET = exposure time (hr/day);
- N\_Replen = number of replenishment intervals per hour (intervals/hour);
- SE = saliva extraction factor (i.e., mouthing removal efficiency); and
- Freq\_HtM = number of hand-to-mouth contacts events per hour (events/hour).

and

$$HR = \frac{F_{ai\_hands} * DE}{SA_H * 2}$$

where:

- HR = hand residue loading (mg/cm<sup>2</sup>);
- Fai<sub>hands</sub> = fraction ai on hands compared to total surface residue from dermal transfer coefficient study (unitless);
- DE = dermal exposure (mg); and
- SA<sub>H</sub> = typical surface area of one hand (cm<sup>2</sup>).

Dose, normalized to body weight, is calculated as:

$$D = \frac{E}{BW}$$

where:

D = dose (mg/kg-day);  
 E = exposure (mg/day); and  
 BW = body weight (kg).

<b>Table A-X: Turf (Physical Activities) – Inputs for Residential Post-application Hand-to-Mouth Exposure</b>			
<b>Algorithm Notation</b>	<b>Exposure Factor (units)</b>		<b>Point Estimate(s)</b>
Fai <sub>hands</sub>	Fraction of ai on hands from dermal transfer coefficient study (unitless)	Liquid formulations	0.06
		Granular formulations	0.027
DE	Dermal exposure (mg)		Calculated
SA <sub>H</sub>	Typical surface area of one hand (cm <sup>2</sup> ), children 1 < 2 years old		150
AR	Application rate (mass active ingredient per unit area)		<b>[input]</b>
HR	Residue available on the hands (mg/cm <sup>2</sup> )		Calculated via (DE * Fai <sub>hands</sub> )/SA <sub>H</sub>
F <sub>M</sub>	Fraction hand surface area mouthed (fraction/event)		0.127
N_Replen	Replenishment intervals per hour (intervals/hr)		4
ET	Exposure time (hrs/day)		1.5
SE	Saliva extraction factor (unitless)		0.48
Freq_HtM	Hand-to-mouth events per hour (events/hr)		13.9
BW	Body Weight (kg)	Children 1 < 2 years old	11

Post-application Object-to-Mouth Exposure Algorithm– Physical Activities on Turf

Exposure from object-to-mouth activity is calculated as follows (based on the algorithm utilized in SHEDS-Multimedia):

$$E = [OR * CF1 * SAM_O * (ET * N\_Replen) * (1 - (1 - SE_O)^{Freq\_OtM/N\_Replen})]$$

where:

E = exposure (mg/day);  
 OR = chemical residue loading on the object on day “t” (ug/cm<sup>2</sup>);  
 CF1 = weight unit conversion factor (0.001 mg/μg);  
 SAM<sub>O</sub> = area of the object surface that is mouthed (cm<sup>2</sup>/event);  
 ET = exposure time (hr/day);  
 N\_Replen = number of replenishment intervals per hour (intervals/hour);  
 SE<sub>O</sub> = saliva extraction factor (i.e., mouthing removal efficiency); and  
 Freq\_OtM = number of object-to-mouth contact events per hour (events/hour).

and

$$OR = AR * F_o * CF2 * CF3$$

where:

- AR = chemical residue loading on the object ( $\mu\text{g}/\text{cm}^2$ );  
 = application rate (lbs ai/ft<sup>2</sup> or lb ai/acre);  
 F<sub>o</sub> = fraction of residue available on the object (unitless);  
 CF2 = weight unit conversion factor ( $4.54 \times 10^8 \mu\text{g}/\text{lb}$ ); and  
 CF3 = area unit conversion factor ( $1.08 \times 10^{-3} \text{ft}^2/\text{cm}^2$  or  $2.47 \times 10^{-8} \text{acre}/\text{cm}^2$ ).

Dose, normalized to body weight, is calculated as:

$$D = \frac{E}{BW}$$

where:

- D = dose (mg/kg-day);  
 E = exposure (mg/day); and  
 BW = body weight (kg).

<b>Table A-X: Turf (Physical Activities) – Inputs for Residential Post-application Object-to-Mouth Exposure</b>		
<b>Algorithm Notation</b>	<b>Exposure Factor (units)</b>	<b>Point Estimate(s)</b>
AR	Application rate (to turf) (mass active ingredient per unit area)	[input]
F <sub>o</sub>	Fraction of AR as OR following application <sup>1</sup>	0.01
SAM <sub>o</sub>	Surface area of object mouthed (cm <sup>2</sup> /event)	10
N_Replen	Replenishment intervals per hour (intervals/hour)	4
SE <sub>o</sub>	Saliva extraction factor (fraction)	0.48
ET	Exposure time (hours per day)	1.5
Freq_OtM	Object-to-mouth events per hour (events/hr)	8.8
BW	Body Weight (kg)	11
	Children 1 < 2 years old	11

<sup>1</sup>This SOP assumes that all of the residue on the turf could be transferred to the object (e.g., object residue is equal to turf transferable residue).

Post-application Incidental Soil Ingestion Exposure Algorithm– Physical Activities on Turf  
 Exposure from incidental soil ingestion is calculated as follows:

$$E = SRt * SIgR * CF1$$

where:

- E = exposure (mg/day);  
 SRt = soil residue on day "t" ( $\mu\text{g}/\text{g}$ );  
 SIgR = ingestion rate of soil (mg/day); and

CF1 = weight unit conversion factor ( $1 \times 10^{-6}$  g/ $\mu$ g).

and

$$SR_t = AR * FS * (1 - F_D)^t * CF2 * CF3 * CF4$$

where:

- SR<sub>t</sub> = soil residue on day "t" ( $\mu$ g/g);
- AR = application rate (lbs ai/ft<sup>2</sup> or lb ai/acre);
- FS = fraction of ai available in uppermost cm of soil (fraction/cm);
- F<sub>D</sub> = fraction of residue that dissipates daily (unitless);
- T = post-application day on which exposure is being assessed;
- CF2 = weight unit conversion factor ( $4.54 \times 10^8$   $\mu$ g/lb);
- CF3 = area unit conversion factor ( $1.08 \times 10^{-3}$  ft<sup>2</sup>/cm<sup>2</sup> or  $2.47 \times 10^{-8}$  acre/cm<sup>2</sup>); and
- CF4 = soil volume to weight unit conversion factor (0.67 cm<sup>3</sup>/g soil).

Dose, normalized to body weight, are calculated as:

$$D = \frac{E}{BW}$$

where:

- D = dose (mg/kg-day);
- E = exposure (mg/day); and
- BW = body weight (kg).

Table A-X: Turf (Physical Activities) – Inputs for Residential Post-application Incidental Soil Ingestion Exposure			
Algorithm Notation	Exposure Factor (units)		Point Estimate(s)
AR	Application rate (mass active ingredient per unit area)		[input]
FS	Fraction of AR available in uppermost 1 cm of soil (unitless)		1
F <sub>D</sub>	Daily residue dissipation (fraction)		0.1
SIgR	Soil ingestion rate (mg/day)		50
BW	Body weight (kg)	Children 1 < 2 years old	11

Post-application Episodic Granular Ingestion Exposure Algorithm– Physical Activities on Turf  
Exposure from incidental ingestion of pesticide pellets or granules is calculated as follows:

$$E = GIgR * FD * CF1$$

where:

- E = exposure (mg/day);
- GIgR = ingestion rate of dry pesticide formulation (g/day);

FD = fraction of ai in dry formulation (unitless); and  
 CF1 = weight unit conversion factor (1,000 mg/g).

Dose, normalized to body weight, are calculated as:

$$D = \frac{E}{BW}$$

where:

D = dose (mg/kg-day);  
 E = exposure (mg/day); and  
 BW = body weight (kg).

Table A-X: Turf (Physical Activities) – Inputs for Residential Post-application Episodic Granular Ingestion Exposure		
Algorithm Notation	Exposure Factor (units)	Point Estimate(s)
F <sub>D</sub>	Fraction of active ingredient in dry formulation	[input]
AR	Application rate (lbs/A or lbs/1,000 ft <sup>2</sup> )	[input]
GIgR	Granule ingestion rate per day (g/day) <sup>1</sup>	0.3
BW	Body Weight (kg)	Children 1 < 2 years old 11

<sup>1</sup> See discussion below on how this value may be adjusted if product specific information is available.

## Turf/Mowing

### Post-application Dermal Exposure Algorithm – Mowing

Exposure resulting from contacting previously treated turf while mowing is calculated as follows:

$$E = TTR_t * CF1 * TC * ET$$

where:

E = exposure (mg/day);  
 TTR<sub>t</sub> = turf transferable residue on day "t" (µg/cm<sup>2</sup>);  
 CF1 = weight unit conversion factor (0.001 mg/µg);  
 TC = transfer coefficient (cm<sup>2</sup>/hr); and  
 ET = exposure time (hr/day).

and

$$TTR_t = AR * F_{AR} * (1 - F_D)^t * CF2 * CF3$$

where:

TTR<sub>t</sub> = turf transferable residue on day "t" (µg/cm<sup>2</sup>);  
 AR = application rate (lbs ai/ft<sup>2</sup> or lb ai/acre);  
 F<sub>AR</sub> = fraction of ai retained on turf (unitless);  
 F<sub>D</sub> = fraction of residue that dissipates daily (unitless);  
 t = post-application day on which exposure is being assessed;

- CF2 = weight unit conversion factor ( $4.54 \times 10^8 \mu\text{g/lb}$ ); and  
 CF3 = area unit conversion factor ( $1.08 \times 10^{-3} \text{ ft}^2/\text{cm}^2$  or  $2.47 \times 10^{-8} \text{ acre}/\text{cm}^2$ ).

Absorbed dose, normalized to body weight, are calculated as:

$$D = \frac{E * AF}{BW}$$

where:

- D = dose (mg/kg-day);  
 E = exposure (mg/day);  
 AF = absorption factor (dermal); and  
 BW = body weight (kg).

Table A-X: Turf (Mowing) – Inputs for Residential Post-application Dermal Exposure			
Algorithm Notation	Exposure Factor (units)		Point Estimate(s)
AR	Application rate mass active ingredient per unit area		[input]
F <sub>AR</sub>	Fraction of AR as TTR following application	L/WP/WDG	0.01
		Granules	0.002
F <sub>D</sub>	Daily residue dissipation	L/WP/WDG	0.1
		Granules	0.1
TC	Transfer Coefficient (cm <sup>2</sup> /hr)	Adult	5,500
		Children 11 < 16 years old	4,500
ET	Exposure time (hours per day)		1
BW	Body Weight (kg)	Adults	80
		Children 11 < 16 years old	57

L/WP/WDG = liquid/wettable powder/water dispersible granule

## Turf/Golfing

### Post-application Dermal Exposure Algorithm – Golfing

Exposure resulting from contacting previously treated turf while golfing is calculated as follows:

$$E = TTR_t * CF1 * TC * ET$$

where:

- E = exposure (mg/day);  
 TTR<sub>t</sub> = turf transferable residue on day "t" ( $\mu\text{g}/\text{cm}^2$ );  
 CF1 = weight unit conversion factor ( $0.001 \text{ mg}/\mu\text{g}$ );  
 TC = transfer coefficient (cm<sup>2</sup>/hr); and

ET = exposure time (hr/day).

and

$$TTR_t = AR * F * (1 - F_D)^t * CF2 * CF3$$

where:

- TTR<sub>t</sub> = turf transferable residue on day "t" (µg/cm<sup>2</sup>);
- AR = application rate (lbs ai/ft<sup>2</sup> or lb ai/acre);
- F = fraction of ai retained on turf (unitless);
- F<sub>D</sub> = fraction of residue that dissipates daily (unitless);
- t = post-application day on which exposure is being assessed;
- CF2 = weight unit conversion factor (4.54 x 10<sup>8</sup> µg/lb); and
- CF3 = area unit conversion factor (1.08 x 10<sup>-3</sup> ft<sup>2</sup>/cm<sup>2</sup> or 2.47 x 10<sup>-8</sup> acre/cm<sup>2</sup>).

Absorbed dose, normalized to body weight, is calculated as:

$$D = \frac{E * AF}{BW}$$

where:

- D = dose (mg/kg-day);
- E = exposure (mg/day);
- AF = absorption factor (dermal); and
- BW = body weight (kg).

Algorithm Notation	Exposure Factor (units)		Point Estimate(s)
AR	Application rate (mass active ingredient per unit area)		[input]
F	Fraction of AR as TTR following application	L/WP/WDG	0.01
		Granules	0.002
F <sub>D</sub>	Daily residue dissipation	L/WP/WDG	0.1
		Granules	0.1
TC	Transfer Coefficient (cm <sup>2</sup> /hr)	Adult	5,300
		Children 11 < 16 years old	4,400
		Children 6 < 11 years old	2,900
ET	Exposure time (hours per day)	Pesticides used on greens, tees, and fairways	4
		Pesticides used only on greens and tees	1
BW	Body Weight (kg)	Adults	80
		Children 11 < 16 years old	57
		Children 6 < 11 years old	32

NA = not applicable  
L/WP/WDG = liquid/wettable powder/water dispersible granule

## Insect Repellents

### Post-application Dermal Exposure Algorithm

If product-specific information is available, absorbed dose is calculated as:

$$D = AR_P * ET * AppF * SA/BW * F_{Body} * AF$$

where:

- D = dose (mg/kg-day);  
 AR<sub>P</sub> = product-specific application rate (mg ai/cm<sup>2</sup> skin);  
 ET = exposure time (hours/day);  
 AppF = application frequency (applications/hour);  
 SA/BW = total body surface area to body weight ratio (cm<sup>2</sup>/kg);  
 F<sub>Body</sub> = clothing-dependent fraction of body exposed (fraction exposed/application);  
 AF = absorption factor.

If product-specific information is unavailable, absorbed dose is calculated as:

$$D = AR_F * F_{AI} * ET * AppF * SA/BW * F_{Body} * AF$$

where:

- D = dose (mg/kg-day);  
 AR<sub>F</sub> = formulation-specific application rate (mg product/cm<sup>2</sup> skin);  
 F<sub>AI</sub> = product-specific fraction of active ingredient (mg ai/mg product);  
 ET = exposure time (hours/day);  
 AppF = application frequency (applications/hour);  
 SA/BW = total body surface area to body weight ratio (cm<sup>2</sup>/kg);  
 F<sub>Body</sub> = clothing-dependent fraction of body exposed (fraction exposed/application);  
 AF = absorption factor.

<b>Table A-X: Insect Repellents – Inputs for Residential Post-application Dermal Exposure</b>			
<b>Algorithm Notation</b>	<b>Exposure Factor (units)</b>		<b>Point Estimate(s)</b>
AR <sub>F</sub>	Formulation-specific application rate (mg product/cm <sup>2</sup> skin)	Aerosol	1.1
		Pump spray	0.62
		Lotion	2.0
		Towelette	1.1
F <sub>AI</sub>	Amount of active ingredient (%)		<b>[input]</b>
F <sub>Body</sub>	Fraction of body exposed per application (representing shorts for men and shorts/top for women)		0.75
SA/BW	Surface Area to Body Weight Ratio (cm <sup>2</sup> /kg)	Adult	280
		Children 1 < 2 years old	640
ET	Exposure Time (hours/day)	Adult	3.7
		Children 1 < 2 years old	3.5
AppF	Application Frequency (applications/hour)	Traditional	0.25
		With sunscreen	0.5

### Post-application Hand-to-Mouth Exposure Algorithm

Exposure from hand-to-mouth activity is calculated as follows (based on the algorithm utilized in SHEDS-Multimedia):

$$E = [HR * (F_M * SA_H) * (ET * N\_Replen) * (1 - (1 - SE)^{Freq\_HtM/N\_Replen})]$$

where:

- E = exposure (mg/day);
- HR = hand residue loading (mg/cm<sup>2</sup>);
- F<sub>M</sub> = fraction hand surface area mouthed/event (fraction/event);
- SA<sub>H</sub> = typical surface area of one hand (cm<sup>2</sup>);
- ET = exposure time (hours/day);
- N\_Replen = number of replenishment intervals per hour (intervals/hour);
- SE = saliva extraction factor (i.e., mouthing removal efficiency); and
- Freq\_HtM = number of hand-to-mouth contacts events per hour (events/hour).

and

$$HR = AR_F * F_{AI}$$

where:

- HR = hand residue loading (mg/cm<sup>2</sup>);
- AR<sub>F</sub> = formulation-specific application rate (mg ai/cm<sup>2</sup> skin);
- F<sub>AI</sub> = product-specific fraction of active ingredient (mg ai/mg product);

Oral dose, normalized to body weight, are calculated as:

$$D = \frac{E}{BW}$$

where:

- D = dose (mg/kg-day);
- E = exposure (mg/day); and
- BW = body weight (kg).

<b>Algorithm Notation</b>	<b>Exposure Factor (units)</b>	<b>Point Estimate(s)</b>	
AR <sub>F</sub>	Formulation-specific application rate (mg product/cm <sup>2</sup> skin)	Aerosol	1.1
		Pump spray	0.62
		Lotion	2.0
		Towelette	1.1
F <sub>AI</sub>	Amount of active ingredient (%)	<b>[input]</b>	
SA <sub>H</sub>	Typical surface area of one hand (cm <sup>2</sup> ), children 1 < 2 years old	150	
F <sub>M</sub>	Fraction hand surface area mouthed (fraction/event)	0.127	
N_Replen	Replenishment intervals (intervals/hr)	0.25	
ET	Exposure Time	3.5	

Table A-X: Insect Repellents – Inputs for Residential Post-application Hand-to-Mouth Exposure		
	(hours/day)	
SE	Saliva extraction factor (fraction)	0.48
Freq_HtM	Hand-to-mouth events per hour (events/hr)	13.9
BW	Body Weight (kg)	11

### Post-Application Dermal Exposure Algorithm (hard surfaces and carpets)

The algorithm to calculate exposure is as follows:

$$E = TR * TC * ET * CF1$$

where:

- E = exposure (mg/day);  
 TR = indoor surface transferable residue ( $\mu\text{g}/\text{cm}^2$ );  
 TC = transfer coefficient ( $\text{cm}^2/\text{hr}$ );  
 ET = exposure time (hr/day); and  
 CF1 = conversion factor (0.001 mg/ $\mu\text{g}$ ).

If chemical-specific TR data are available, this is preferred and should be used to calculate exposure. However, if chemical-specific TR data are not available, then TR can be calculated using the following formula:

$$TR = DepR * F_{ai}$$

where:

- TR = indoor surface transferable residue ( $\mu\text{g}/\text{cm}^2$ );  
 DepR = deposited residue ( $\mu\text{g}/\text{cm}^2$ ), based on (in order of preference):  
 (1) Chemical-specific residue deposition data ( $\mu\text{g}/\text{cm}^2$ ),  
 (2) Application rate (lb ai/area), or  
 (3) Default residue based on type of application ( $\mu\text{g}/\text{cm}^2$ ); and  
 F<sub>ai</sub> = fraction of ai available for transfer from carpet or hard surface (unitless).

Absorbed dermal dose, normalized to body weight, are calculated as:

$$D = \frac{E * AF}{BW}$$

where:

- D = dose (mg/kg-day);  
 E = exposure (mg/day);  
 AF = absorption factor; and  
 BW = body weight (kg).

Table A-X: Indoor Environments (Hard Surfaces and Carpets) – Inputs for Residential Post-application Dermal Exposure				
Algorithm Notation	Exposure Factor (units)		Point Estimate(s)	
TR	Transferable residue (µg/cm <sup>2</sup> )		(1) Chemical-specific transferable residue data OR (2) Estimated: DepR * F <sub>ai</sub>	
DepR	Deposited residue (µg/cm <sup>2</sup> )		(1) Chemical-specific residue deposition data, (2) Estimated based on application rate, or (3) Estimated based on default residue related to type of application	
F <sub>ai</sub>	Fraction of DepR as TR following application	Carpets	0.06 <sup>a</sup>	
		Hard surfaces	0.08 <sup>a</sup>	
TC	Transfer Coefficient (cm <sup>2</sup> /hr)	Adult	6,800	
		Children 1 < 2 years old	1,800	
ET	Exposure Time (hrs/day)	Adults	Carpets	8
			Hard Surfaces	2
		Children 1 < 2 years old	Carpets	4
			Hard Surfaces	2
BW	Body weight (kg)	Adult	80	
		Children 1 < 2 years old	11	

#### Post-Application Dermal Exposure Algorithm (mattresses)

The algorithm to calculate absorbed dose is as follows:

$$D = DR * \frac{SA}{BW} * F * F_{ai} * PF * AF * CF1$$

where:

- D = Dermal dose (mg/kg-day);
- DR = Deposited residue (mg/cm<sup>2</sup>);
- SA/BW = Surface area / Body Weight Ratio (cm<sup>2</sup>/kg);
- F = Fraction of body that contacts residue;
- CF1 = Conversion factor (mg/µg);
- AF = Absorption factor;
- F<sub>ai</sub> = fraction of ai available for transfer from treated mattress; and
- P = Protection factor to account for the presence of a single layer of fabric (e.g. bed sheet) between the treated material and individual.

Table A-X: Indoor Environments (mattresses) – Inputs for Residential Post-application Dermal Exposure			
Algorithm Notation	Exposure Factor (units)	Point Estimate(s)	
DR	Deposited residue ( $\mu\text{g}/\text{cm}^2$ )	(1) Calculated based on information provided on label OR (2) based on default residue values	
SA/BW	Surface area / Body Weight Ratio ( $\text{cm}^2/\text{kg}$ )	Adult	280
		Children 1 < 2 years old	640
F	Fraction of body that contacts residue	0.5	
F <sub>ai</sub>	Fraction of DR available for transfer	0.06	
PF	Protection Factor	0.5	

### Post-application Hand-to-Mouth Exposure Algorithm

Exposure from hand-to-mouth activity is calculated as follows (based on algorithm utilized in SHEDS-Multimedia):

$$E = \left[ HR * (F_M * SA_H) * (ET * N_{Replen}) * \left( 1 - (1 - SE)^{\frac{Freq_{HtM}}{N_{Replen}}} \right) \right]$$

where:

- E = exposure (mg/day);
- HR = hand residue loading ( $\text{mg}/\text{cm}^2$ );
- F<sub>M</sub> = fraction hand surface area mouthed / event (fraction/event);
- ET = exposure time (hr/day);
- SA<sub>H</sub> = surface area of one hand ( $\text{cm}^2$ );
- N<sub>Replen</sub> = number of replenishment intervals per hour (intervals/hour);
- SE = saliva extraction factor (i.e., mouthing removal efficiency); and
- Freq<sub>HtM</sub> = number of hand-to-mouth contacts events per hour (events/hour).

and

$$HR = \frac{Fai_{hands} * DE}{SA_H * 2}$$

where:

- HR = hand residue loading ( $\text{mg}/\text{cm}^2$ );
- Fai<sub>hands</sub> = fraction ai on hands compared to total surface residue from jazzercise study (unitless);
- DE = dermal exposure (mg); and
- SA<sub>H</sub> = typical surface area of one hand ( $\text{cm}^2$ ).

and

Dose, normalized to body weight, is calculated as:

$$D = \frac{E}{BW}$$

where:

- D = dose (mg/kg-day);  
 E = exposure (mg/day); and  
 BW = body weight (kg).

Table A-X: Indoor Environments – Inputs for Residential Post-application Hand-to-Mouth Exposure				
Algorithm Notation	Exposure Factor (units)		Point Estimate(s)	
Fai <sub>hands</sub>	Fraction of ai on hands from jazzercise study (unitless)		0.15	
DE	Dermal exposure calculated in <i>Section Error! Reference source not found.</i> (mg)		Calculated	
HR	Residue available on the hands (mg/cm <sup>2</sup> )		Calculated	
SA <sub>H</sub>	Surface area of one hand (cm <sup>2</sup> )	Children 1 < 2 years old	150	
AR	Application rate (mass active ingredient per unit area)		[input]	
F <sub>M</sub>	Fraction of hand mouthed per event (fraction/event)		0.13	
N_Replen	Replenishment intervals per hour (intervals/hr)		4	
ET	Exposure time (hours per day)	Children 1 < 2 years old	Carpets	4
			Hard Surfaces	2
SE	Saliva extraction factor (fraction)		0.48	
Freq_HtM	Hand-to-mouth events per hour (events/hr)	Children 1 < 2 years old	20	
BW	Body Weight (kg)	Children 1 < 2 years old	11	

Post-application Object-to-Mouth Exposure Algorithm

Exposure from object-to-mouth activity is calculated as follows (based on algorithm utilized in SHEDS-Multimedia):

$$E = OR * CF1 * SAM_0 * (ET * N\_Replen) * \left( 1 - (1 - SE)^{\frac{Freq\_OtM}{N\_Replen}} \right)$$

where:

- E = exposure (mg/day);
- OR = chemical residue loading on an object ( $\mu\text{g}/\text{cm}^2$ );
- CF1 = weight unit conversion factor (0.001 mg/ $\mu\text{g}$ );
- SAM<sub>O</sub> = area of the object surface that is mouthed ( $\text{cm}^2/\text{event}$ );
- ET = exposure time (hr/day);
- N\_Replen = number of replenishment intervals per hour (intervals/hour);
- SE = saliva extraction factor (i.e., mouthing removal efficiency); and
- Freq\_OtM = number of object-to-mouth contact events per hour (events/hour).

and

$$OR = DepR * F_O$$

where:

- OR = chemical residue loading on the object ( $\mu\text{g}/\text{cm}^2$ );
- DepR = deposited residue ( $\mu\text{g}/\text{cm}^2$ ); and
- F<sub>O</sub> = fraction of residue transferred to an object (unitless).

and

Oral dose, normalized to body weight, is calculated as:

$$D = \frac{E}{BW}$$

where:

- D = dose (mg/kg-day);
- E = exposure (mg/day); and
- BW = body weight (kg).

Table A-X: Indoor Environments – Inputs for Residential Post-application Object-to-Mouth Exposure				
Algorithm Notation	Exposure Factor (units)			Point Estimate(s)
AR	Application rate (mass active ingredient per unit area)			[input]
F <sub>O</sub>	Fraction of residue transferred to an object	Carpets		0.06 <sup>a</sup>
		Hard surfaces		0.08 <sup>a</sup>
SAM <sub>O</sub>	Surface area of object mouthed ( $\text{cm}^2/\text{event}$ )			10
N_Replen	Replenishment intervals per hour (intervals/hour)			4
SE <sub>O</sub>	Saliva extraction factor			0.48
ET	Exposure Time (hours per day)	Children 1 < 2 years old	Carpets	4

Table A-X: Indoor Environments – Inputs for Residential Post-application Object-to-Mouth Exposure			
Algorithm Notation	Exposure Factor (units)		Point Estimate(s)
		Hard Surfaces	2
Freq_OtM	Object-to-mouth events per hour (events/hour)	Children 1 < 2 years old	14
BW	Body Weight (kg)	Children 1 < 2 years old	11

## Treated Pets

### Post-application Dermal Exposure Algorithm

The following method is used to calculate dermal exposures that are attributable to an adult or child contacting a treated companion pet:

$$E = TC * TR * ET$$

where:

- E = exposure (mg/day);
- TC = transfer coefficient (cm<sup>2</sup>/hr);
- TR = transferable residue (mg/cm<sup>2</sup>); and
- ET = exposure time (hours/day).

$$TR = \frac{AR * F_{AR}}{SA}$$

where:

- TR = transferable residue (mg/cm<sup>2</sup>);
- AR = application rate or amount applied to animal (mg);
- F<sub>AR</sub> = fraction of the application rate available as transferable residue; and
- SA = surface area of the pet (cm<sup>2</sup>).

Absorbed dermal dose, normalized to body weight, is calculated as:

$$D = \frac{E * AF}{BW}$$

where:

- D = dose (mg/kg-day);
- E = exposure (mg/day);
- AF = absorption factor (dermal); and
- BW = body weight (kg).

Table A-X: Treated Pets – Inputs for Residential Post-application Dermal Exposure		
Algorithm Notation	Exposure Factor Units	Point Estimates
AR	Application rate (mg)	[input]
SA	Surface Area of Animal (cm <sup>2</sup> )	Small Cat, Dog Cat – 1,500 Dog – 3,000
		Medium Cat, Dog Cat – 2,500 Dog – 7,000
		Large Cat, Dog Cat – 4,000 Dog – 11,000
F <sub>AR</sub>	Fraction of AR Available for Transfer	0.02
TC	Transfer Coefficient – Liquids (cm <sup>2</sup> /hr)	Adult 5,200
		Children 1 < 2 years old 1,400
	Transfer Coefficient – Solids (cm <sup>2</sup> /hr)	Adult 140,000
		Children 1 < 2 years old 38,000
ET	Exposure Time (hours per day)	Adult 0.77
		Children 1 < 2 years old 1.0
BW	Body weight (kg)	Adult 80
		Children 1 < 2 years old 11

#### Post-application Hand-to-Mouth Exposure Algorithm

Exposure from hand-to-mouth activity is calculated as follows (based on algorithm utilized in SHEDS-Multimedia):

$$E = [HR * (F_M * SA_H) * (ET * N\_Replen) * (1 - (1 - SE)^{Freq\_HtM/N\_Replen})]$$

where:

- E = exposure (mg/day);
  - HR = hand residue loading (mg/cm<sup>2</sup>);
  - SA<sub>H</sub> = surface area of one child hand (cm<sup>2</sup>);
  - F<sub>M</sub> = fraction hand surface area mouthed /event (fraction/event);
  - ET = exposure time (hr/day);
  - N\_Replen = number of replenishment intervals per hour (intervals/hour);
  - SE = saliva extraction factor (i.e., mouthing removal efficiency); and
  - Freq\_HtM = number of hand-to-mouth contacts events per hour (events/hour).
- and

$$HR = \frac{E * Fai_{hands}}{2 * SA_H}$$

where:

- HR = hand residue loading (mg/cm<sup>2</sup>);
- E = dermal exposure (mg);
- Fai<sub>hands</sub> = fraction of a.i. on hands compared to total residue from dermal transfer coefficient study (unitless); and
- SA<sub>H</sub> = surface area of one child hand (cm<sup>2</sup>).

Oral dose, normalized to body weight, is calculated as:

$$D = \frac{E}{BW}$$

where:

- D = dose (mg/kg-day);  
 E = exposure (mg/day); and  
 BW = body weight (kg).

<b>Table A-X: Treated Pets – Inputs for Residential Post-application Hand-to-Mouth Exposure</b>			
<b>Algorithm Notation</b>	<b>Exposure Factor (units)</b>		<b>Point Estimate(s)</b>
Fai <sub>hands</sub>	Fraction of a.i. on hands from transfer coefficient studies (unitless)		Solid = 0.37 Liquid = 0.040
F <sub>M</sub>	Fraction hand surface area mouthed /event (fraction/event)		0.13
N_Replen	Replenishment intervals per hour (intervals/hr)		4
ET	Exposure time (hours/day)	Children 1 < 2 years old	1.0
SE	Saliva extraction factor		0.48
Freq_HtM	Hand-to-mouth events per hour (events/hr)	Children 1 < 2 years old	20
SA <sub>H</sub>	Typical surface area of one child hand (cm <sup>2</sup> )	Children 1 < 2 years old	150
BW	Body Weight (kg)	Children 1 < 2 years old	11

## APPENDIX C

### (SPRAY DRIFT CONSIDERATIONS)

There are a significant number of considerations relevant to risk characterization that should be factored into the interpretation of spray drift exposure and risk assessments completed based on this guidance. These include:

- The risk estimates calculated are based on the premise that spray drift occurs in a manner similar to that predicted and that an exposed person is at the locations and exhibits the behaviors represented in the assessment.
- The aerial drift fraction estimates are based on application to bare ground with no crop in the downwind area as well (i.e., these are referred to as a low surface roughness condition and these conditions are known to have higher drift; this is a convention in AgDrift Tier1). It should also be noted that in the drift analyses completed in the assessment, wind vectors were moving from treated areas to the downwind area of the field 100 percent of the time at a constant windspeed of 10 mph which would maximize spray drift levels under the model conditions.
- Spray drift values are based on the general application of the Tier I output values from AgDRIFT and the subsequent higher tier analyses that were completed. There are uncertainties associated with all of these approaches which have been discussed extensively during the activities of the SDTF and the development of the AgDrift model. All of the associated uncertainties apply to the results of this analysis. There are additional analyses that could be completed in order to elicit how sensitive spray drift levels may be to such changes in how applications are made or the conditions during applications (*e.g.*, evaluate impact of alternative aircraft, evaluate nozzle placement, impacts of surface roughness).
- AgDISP (another spray drift model similar to AgDrift) could also be used if further potential refinements are needed in certain circumstances. For example, the effect that a crop canopy may have on the deposition pattern downwind of a treated field following an aerial application could be investigated. However, such an analysis would be limited because: 1) canopy simulations in AgDISP are theoretical in nature; and 2) AgDISP simulations represent uniformly closed canopy structures that are generally not expected for tree crops in an agricultural orchard setting where air movement really occurs through non-homogeneous canopies more common in agriculture.